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Editorial

Sculpted for Greatness: Greatness is not an accident of birth; it is the outcome of consistent effort, discipline, and resilience. Just as a rough stone attains the form of a monument only through the patient chiselling of a skilled sculptor, individuals too achieve refinement through self-correction, critical reflection, and guided learning.

Human character, like unshaped stone, often bears flaws such as indiscipline, apathy, or lack of direction. These imperfections are not permanent; with sustained effort, constructive criticism, and appropriate mentorship, they can be reshaped into strengths. Life's challenges, academic setbacks, and even failures are not deterrents but instruments of growth. Each difficulty, when approached with a learning mindset, strengthens the individual and builds capacity for future achievement.

Perfection is not innate but a continuous pursuit. The willingness to confront one's weaknesses, accept guidance, and make incremental improvements forms the basis of intellectual and personal development. In the academic context, teachers, mentors, and peers play the role of sculptors, offering both guidance and opportunities for refinement.

The case of Mr. Ayay illustrates this transformative process. Initially an irregular student and a slow learner, Mr. Ayay experienced repeated failures and disengagement from academics. However, under the mentorship of Mr. Danish, who combined counselling with systematic monitoring and parental involvement, Mr. Ayay gradually restructured his habits. Over the course of a year, he not only improved his attendance but also cleared all his backlogs, thereby reshaping his academic trajectory. This illustration highlights the critical role that mentorship and belief in unlocking potential. It proves that with structured guidance, consistent support, and a learner's willingness to change, even struggling students can achieve significant transformation.

Ultimately, universities are not merely centres of knowledge dissemination; they are spaces for holistic growth where raw potential is nurtured into refined competence. Like the sculptor's chisel, every academic challenge and every mentoring intervention contributes to shaping students into capable, responsible, and value-driven individuals.

“A single spark of belief can ignite a fire of transformation”

New Delhi

Editor

31st August 2025

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Selection of Muscles, Acquisition Unit, and Dataset for Electromyogram-based Emotion Recognition

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ABSTRACT

The emotional behavior of a person creates dominant impacts in many fields like teaching, hospitality, business, sports, and entertainment. Image or video processing-based emotion recognition requires camera alignment and light conditions. Electromyogram (EMG) based emotion recognition is a wide research area for detecting emotions without the restriction of surrounding conditions. The selection of proper muscles is also a tedious job. This survey paper gives a critical analysis of a selection of muscles that are responsible for expressing emotion and compares different EMG acquisition units and electrodes for capturing EMG signals. Here, we describe various publicly available EMG signal datasets.

KEYWORDS: EMG, muscles, Emotion recognition, EMG acquisition unit, Electrode.

INTRODUCTION

The emotional behavior of a person creates dominant impacts in many fields such as teaching, hospitality, business, sports, and entertainment. Emotion is a strong feeling deriving from one circumstance and temper [1]. In emotion recognition systems, researchers detect emotions mainly from visual, audio, body pose, physiological signals, and text. Many authors used audio mode for emotion recognition [2-10]. This audio mode of emotion recognition is only applicable to verbal communication. All these authors used speech processing to detect emotions with 65% to 94% classification accuracy [7, 10]. In nonverbal communication, researchers detect emotions using body pose and physiological signals. For visual and body-pose conditions, researchers used video and image processing techniques to identify the emotion. Authors recognized emotions with 79.8% to 95% accuracy [11, 12]. In this research work, a camera must be held before the face. Proper lighting conditions and background are required to detect facial expressions.

To avoid such restriction many researchers used Electromyogram (EMG) based emotion recognition. EMG signals detect facial muscle movement and identify

the emotion of a person. It is a wide research area for detecting emotions without restricting surrounding conditions. Fig. 1 shows the position of the electrodes during recording. Each facial muscle movement represents different emotions [13]. Hence, selecting the proper muscles is a tedious job. After identifying muscles, selecting the proper EMG acquisition unit is also an important task. That unit should be noise-free, compact, and economical.

Some researchers prefer to use ready datasets rather than collect EMG data for their research [14-19]. Hence, in such cases, it is required to explore different EMG datasets so that any researcher can use that data for their research.

This survey paper gives a critical analysis of a selection of muscles that is responsible for expressing emotion and compares different EMG acquisition units and electrodes for capturing EMG signals. Here, we describe various publicly available EMG signal datasets.

Section 2 describes the role of facial muscles in expressing emotions. Section 3 covers available EMG signal acquisition units. Section 4 provides selection criteria for Electrodes for the acquisition of EMG

signals, and Section 5 provides information about the publicly available EMG signal dataset.

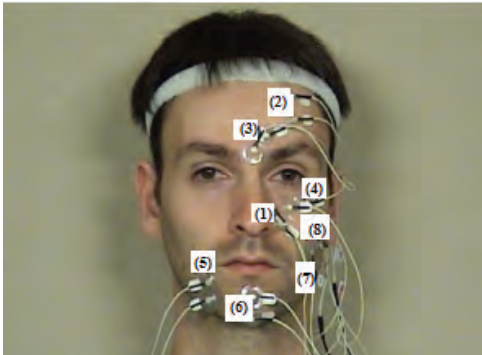


Fig. 1 Position of the electrodes during recording, Here, (1) Levator labii, (2) Venter frontalis, (3) Corrugator supercilii, (4) Orbicularis oculi, (5) Depressor anguli oris, (6) Mentalis, (7) Masseter, and (8) Zygomaticus major [13].

THE ROLE OF FACIAL MUSCLES IN EXPRESSING EMOTIONS

The musculoskeletal system makes a body structure. Human muscles have two categories, namely smooth musculature and striated musculature. Smooth musculatures are located in interior organs, and striated musculature is located in skeletal muscles. Facial skeletal muscles are different than body skeletal muscles. A contraction of muscles pulls the skin off the face and changes the expression [20]. Cognized judgment of the brain controls skeletal muscles through the cranial nerve (CN). The cranial nerve has twelve pairs. Out of this, the facial nerve is the seventh pair of CN.

Fig. 2 shows the course of the nerve outside the skull, through the face and neck. Branches of the facial nerve supply a signal to the muscles of the neck and head. Fig. 3 shows the facial nerve connected to five motor branches. Motor branches consist of the marginal mandibular branch, zygomatic branch, temporal branch, cervical branch, and buccal branch [21].

These motor branches excite the muscles of facial expression. The zygomaticus branch stimulates the 'orbicularis oculi.' The temporal branch stimulates the 'frontalis,' 'corrugators supercilii,' and 'orbicularis oculi.' The marginal mandibular branch stimulates the 'mentalis muscle.' The buccal branch stimulates the

'buccinators,' 'zygomaticus muscles,' and 'orbicularis oris.' The cervical branch stimulates the 'platysma muscle.' Fig 4 shows facial muscles.

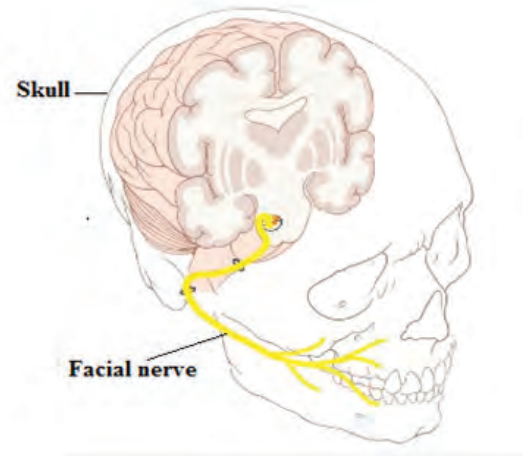


Fig. 2 Path of the facial nerve [22]

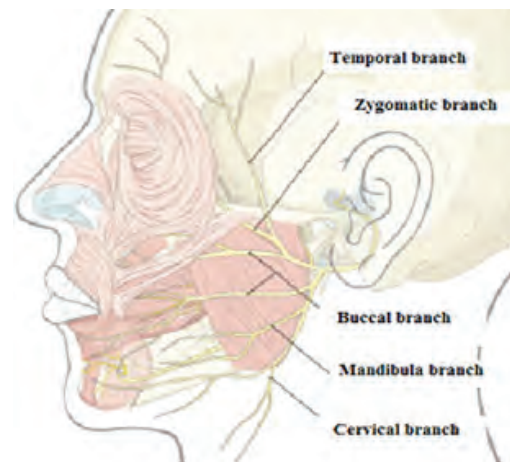


Fig. 3 Motor branches on the facial nerve [20]

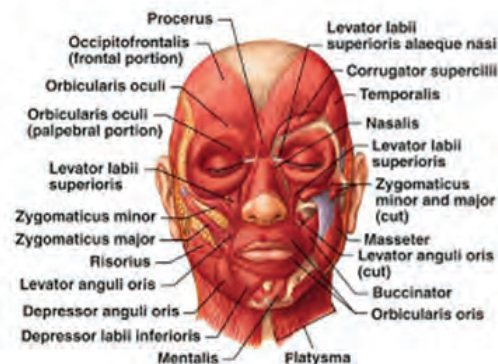


Fig. 4 Facial muscles [23]

The first time, in 1966, Hardyck et al. [24] used surface EMG signals in their research. As shown in Table 1, Ekman and Friesen et al. [25] developed the Facial Action Code (FAC) for determining facial movement.

Table 1 Facial Action During the Expression [25]

Emotions	Muscles involved	Produced actions
Surprise	Palpebral portion, Frontalis	Raising upper eyelid, Raising eyebrows
Happiness	Zygomaticus major, Orbicularis oculi	Pulling mouth laterally, and upward, Closing eyelids
Fear	Frontalis, Palpebral portion, Corrugators supercilii	Raising upper eyelid, Lowering Eyebrows, Raising eyebrows
Sadness	Frontalis, Corrugators supercilii, Depressor anguli oris	Depressing lip corners, Lowering eyebrows, Raising eyebrows
Disgust	Levator labii superioris	Wrinkling nasal skin and Raising upper lip
Anger	Palpebral portion, Corrugators supercilii, Orbicularis oculi	Closing eyelids, Lowering eyebrows, Raising upper eyelid

Ekman and Friesen stated that every emotion changes particular muscles. Happy activates zygomaticus-major. Fear, anger, and sadness make corrugator supercilii move. Surprise, fear, and sadness activate the frontalis. Hence, the EMG signal collected from these muscles reflects the respective emotion.

SELECTION OF EMG ACQUISITION UNIT

Many EMG acquisition units are available in the market. Many researchers used these units for data acquisition purposes. Descriptions of units are given below.

1. Delsy wireless and wire EMG acquisition unit

Roy et al. [26] used the Delsy EMG acquisition

unit for their research. The author combined accelerometer and surface EMG signals for analyzing behavior in stroke. This unit has a high noise immunity capacity but at a high cost. The costs of the Delsy wire and wireless EMG acquisition units are Rs. 10 lac and Rs. 12 lac, respectively.

2. Datalite EMG acquisition unit

Allard et al. [27] used the Datalite EMG acquisition unit for their research. The author used an Armband of a device for EMG-based hand gesture recognition. This unit has a high noise immunity capacity but at a high cost. The cost of the Datalite 4-channel EMG acquisition unit is Rs.4 lac.

3. ADS1299-x Bio-potential measurement front-end kit by Texas instrument

Many authors [28, 29] used an 'ADS1299-x Bio-potential measurement front end kit by Texas instrument unit' for EMG signal detections. This unit has a comparatively low cost. The cost of a motherboard without accessories like connecting wires and electrodes is Rs. 13400. According to the manual [38], this unit is sensitive to static charge and needs low-noise laboratory conditions.

4. Open-BCI Wi-Fi shield and Cyton bio-sensing board

Many researchers used the open BCI Wi-Fi shield and Cyton bio-sensing board for EMG and EEG signal acquisition [30]. This unit has eight differentials, high gain, and low noise input channels. It transfers signals with 1000 samples per second. The packaging of a device can handle static charge. The cost of a unit with accessories like connecting wires and electrodes is Rs. 73000.

SELECTION OF EMG ELECTRODES

There are many electrodes available in the market, namely, inserted electrodes for intramuscular EMG detection and skin electrodes for surface EMG detection. Silver/silver chloride (Ag/AgCl) is the most popular pre-gelled disposable surface electrode. Disposable electrodes are compact and easy to apply. They are available in diverse sizes and shapes [31].

As shown in Fig 5, Electrodes are available from 25mm to 50mm in dimensions. Luca et al. [33] proved in

their research work that to reduce cross-talk and get maximum signal inter-electrode spacing should be 20mm. In the case of emotion recognition, multiple electrodes are needed to be placed on facial muscles. It is necessary to select electrodes as small as possible to avoid cross-talk. Hence, we have to select electrodes from 25mm to 30mm in size [33].



Fig. 5 Ag/AgCl electrodes [32]

AVAILABILITY OF EMG SIGNAL DATASET

Many researchers used publically available EMG datasets for their research work. Some of the datasets are given below.

1. Augsburg Bio-signal Toolbox (AUBT): This dataset consists of four biological signals, namely, skin conductivity, respiration changes, EMG, and ECG. This data has 2 min EMG signals for joy, sadness, anger, and pleasure collected at twenty-five different sessions under musical conditions [14, 15]. The author collected EMG signals with a 32 Hz sampling frequency. Many researchers used this dataset for emotion recognition. Yang et al. [16] achieved 91.67% classification accuracy with the LS SVM classifier. Cheng et al. [17] used BPNN and achieved 75% classification accuracy.
2. EMG signal collected in MIT laboratory: This dataset was collected on the masseter muscle from a single subject by an MIT laboratory. The MIT dataset included 20 EMG signals of anger, romantic love, no emotion, reverence, joy, grief, platonic love, and hate emotions. The author collected an EMG signal with a 20 Hz sampling frequency. Picard et al. [18] used this dataset to recognize emotions. The author achieved 46% classification accuracy for eight emotions and 83% classification accuracy for three emotions using the KNN classifier.
3. Database for Emotion Analysis using Biological

(DEAP): The DEAP dataset consists of thirty-two channels EEG signals, RSP, galvanic skin response, Electrooculogram, blood volume pulse, skin temperature, and EMG signals of thirty-two healthy subjects [19]. Subjects watched 40 one-minute videos. The author collected the EEG and biological signals for different combinations of high and low levels of arousal and valence emotional conditions. Many authors used this dataset for EEG-based emotion recognition [34].

4. EMG-based Kathak emotion dataset: Mithbavkar et al. [35] collected an EMG dataset from eleven Kathak-trained students under the observation of Kathak dance teachers. All students are female. They used Open-BCI biosensing boards with Wi-Fi shields for EMG signal acquisition. They connected four channels of the EMG acquisition unit on zygomaticus-major, SCM, frontalis, and corrugators' supercilii muscles for the detection of Nine emotions (Navras). Fig. 6 shows the location of electrodes on the neck and facial muscles. The subject expressed Navras such as Shringar (affectionate smile), Raudra (ferocious), Karuna (sad), Hasya (humorous), Bhayanaka (fearful), Veer (courageous), Shant (peaceful), Bibhatsa (repulsion), and Adbhut (amazed) in the five-second dance step. This dataset consists of 7920 EMG signals [35].

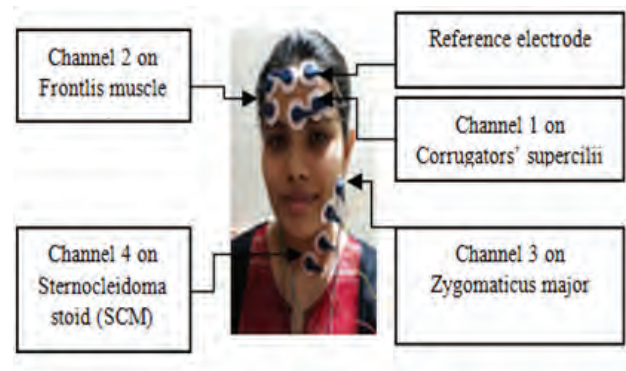


Fig.6 Location of electrodes on the neck and facial muscles [35]

Mithbavkar et al [35-37] used this dataset and achieved 93.63% classification accuracy using the LSTM classifier and mean, variance, and a maximum of 'Difference in IEMG features'.

CONCLUSION

From the investigation reported in the above sections, it is concluded that among different EMG acquisition units, an Open-BCI Wi-Fi shield and Cyton bio-sensing board is a comparatively good choice concerning noise and cost point of view. To accommodate multiple electrodes on facial muscles as well as to avoid cross-talk we have to select EMG electrodes from 25mm to 30mm in size. For EMG-based emotion recognition, many EMG signal datasets are available for researchers. For single-subject emotion recognition, researchers can select the AUBT dataset and MIT dataset. For multiple users and nine emotions, researchers can select an EMG-based Kathak emotion dataset.

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Mathematical Foundations and Applications of Fractals

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ABSTRACT

Fractals, distinguished by their self-similar patterns and intricate formations, have intrigued mathematicians and scientists for many years. This study presents a mathematical examination of fractals, concentrating on their definitions, characteristics, and theoretical significance across diverse disciplines. Particular attention is given to the Hausdorff dimension, iterated function systems (IFS), and the influence of fractals within dynamical systems. Furthermore, the study investigates prospective research directions and applications within contemporary mathematics.

KEYWORDS: *Fractals, Self-similarity, Hausdorff dimension, Iterated function systems (IFS), Julia set, Mandelbrot set.*

INTRODUCTION

Fractals are geometric shapes that demonstrate self-similarity across different scales and have non-integer dimensions. Benoît B. Mandelbrot introduced fractals in the late 20th century, and they have been applied in a variety of fields, including physics, computer graphics, and biology. Though they are visually captivating, fractals also offer a rich foundation for thorough mathematical examination. This paper seeks to explore the theoretical dimensions of fractals, highlighting the mathematical structures and analytical methods utilized in their examination. Fractals contest conventional Euclidean geometry by showing that shapes can possess endless detail, rendering them especially valuable for simulating intricate natural occurrences. For example, features such as mountains, coastlines, and clouds display fractal-like forms. This trait has resulted in substantial progress in both theoretical and applied sciences, creating a distinctive junction between abstract mathematics and real-world applications.

MATHEMATICAL FOUNDATIONS OF FRACTALS

Definition and Self-Similarity

A fractal is characterized as a collection that exhibits self-

similarity, indicating that the arrangement of the collection appears alike at various enlargements. In mathematical terms, a set is considered fractal if contraction mappings exist that meet specific mathematical criteria guaranteeing convergence. Self-similarity can be precise, as seen in mathematical examples like the Sierpiński triangle, or statistical, as found in natural fractals such as river systems.

Hausdorff Dimension

A key feature of fractals is their dimension that is not whole. The Hausdorff dimension offers a precise method to measure this characteristic. The Hausdorff dimension extends the idea of dimension, representing the intricacy of fractals more effectively than dimensions based on integers. For instance, the dimension of the Cantor set is roughly 0.63.

Iterated Function Systems (IFS)

IFS offers a structure for creating fractals through a collection of contraction mappings. The fractal set is generated by the fixed point of the operator linked to the IFS. This is conveyed as the straightforward mathematics of IFS renders them an effective instrument for algorithmically generating fractals. Notable instances comprise the Barnsley Fern and the Koch snowflake.

Infinite Complexity

Despite their intricate designs and infinite length, fractals often encompass a finite area. This complexity is a result of simple repetitions of a process.

FRACTALS IN DYNAMICAL SYSTEMS

Dynamical systems examine the evolution of a system over time according to a specific set of deterministic rules. Fractals often occur in these systems, especially in the examination of chaotic behavior, where systems show sensitivity to starting conditions and long-term unpredictability.

Overview of Dynamical Systems

A dynamical system can be generally described as a collection of states along with a principle that explains how these states change over time. This can be expressed mathematically as:

- Continuous Systems: Characterized by differential equations, like the movement of a pendulum or the orbits of planets.
- Discrete Systems: Characterized by iterative mappings, in which the system progresses in increments, like ecological population models.

Fractals as Attractors

Fractals frequently manifest as attractors in dynamical systems, referred to as strange attractors. These attractors are portions of phase space where the system tends to move over time, no matter minor changes in initial conditions. Example consist of:

- Lorenz Attractor: A well-known illustration in chaos theory that simulates atmospheric convection. The Lorenz attractor features a fractal dimension and displays self-similarity, serving as a prime illustration of chaos and fractal geometry.

Julia and Mandelbrot Sets in Dynamical Systems

The Julia and Mandelbrot sets are key illustrations of fractals within dynamical systems, especially in the field of complex analysis. These sets aid in visualizing the stability and bifurcations of iterated complex functions, acting as a connection between fractal geometry and dynamical behavior.

- Julia set: Gaston Julia, a French mathematician, delved deep into the behaviour of the orbits of complex numbers when iteratively applied under a function.

Key Concepts Explored by Julia:

- 1) Orbit of a Complex Number: For a given function f , Julia applied it to a complex number. He then took the result and again applied f to it, repeating this process to study the behaviour of the results over time.
- 2) Prisoner and Escape Sets: Julia introduced the concept of prisoner sets and escape sets based on whether iterating specific functions led to bounded or unbounded sets. Specifically: (i) Prisoner Set: Contains all the complex numbers whose orbit remains bounded. (ii) Escape Set: Contains all the complex numbers that become unbounded in their orbit under a specific function.

Example illustrating the concept

For the function $f(z) = z^2 - z + 1$ and starting with $z_0 = 1 + i$, the iterations are :

$$z_0 = 1 + i, z_1 = i, z_2 = -i, z_3 = i, z_4 = -i$$

Since the results oscillate, $1 + i$ is termed as prisoner. Conversely, if the values were to grow infinitely large or small, it would be termed as escape.

So, Julia sets can be defined as the boundary between the prisoner set and the escape set. Julia primarily worked with functions of the form $f(z) = z^2 + c$, where c is a complex constant sometimes also called as seed. Each different value of c produces a distinct Julia set.

- Mandelbrot Set : Benoit Mandelbrot expanded on the ideas of Gaston Julia by exploring a particular set that has since been named the Mandelbrot set. Just like Julia, Mandelbrot used the function $f(z) = z^2 + c$. Mandelbrot aimed to determine the values of c for which the orbit remains bounded when the function is iterated, always starting with $z = 0$. He was also interested in values of c that led to an unbounded orbit. Julia explored these concepts in an era when computations had to be done manually. Mandelbrot, on the other hand, had access to computers, allowing him to perform hundreds of thousands of iterations, compared to the limited number Julia could achieve manually. After examining the Julia sets for various c values, Mandelbrot plotted them, which resulted in the visually captivating Mandelbrot set. The Mandelbrot set is actually a great example of how you can store an infinite amount of information on a finite medium.

Chaos and Fractals in Dynamical Systems

Fractals within dynamical systems are intimately connected to chaos theory. Chaos describes deterministic systems that display unpredictable behavior because of their extreme sensitivity to initial conditions. This uncertainty frequently leads to the emergence of fractal patterns, including:

- **Fractal Boundaries:** Distinguish various areas of behavior in phase space, like attraction basins.
- **Bifurcations:** The points of transition where the system alters its behavior, commonly featuring fractal patterns.

TYPES OF FRACTALS AND ITS DIMENSION

Cantor Set: The German mathematician, Georg Cantor, who was one of the founders of set theory, discovered the Cantor set. We start out with one straight-line segment and divide it into three parts. Then remove the middle third, but keep the end points. So we started out with one line and two endpoints, and turned it into two lines and four endpoints. This process is to be repeated over and over, and the outcome after many times would be points. Following is the outcome.



- **Fractal dimension of Cantor set:** If we take the first iteration, we have 2 line segments of length $1/3$ so here we need 2 boxes(square) of length $1/3$ units. So ϵ is $1/3$, that is, the scaling factor is 3 and is 2. Therefore,

$$D = \lim_{\epsilon \rightarrow 0} \frac{\ln N(\epsilon)}{\ln \frac{1}{\epsilon}} = \lim_{\epsilon \rightarrow 0} \frac{\ln 2}{\ln 3} = \frac{\ln 2}{\ln 3}$$

Hence, fractal dimension of Cantor set is $\frac{\ln 2}{\ln 3} \approx 0.6309$

- 2) **Sierpin'ski's Triangle:** Waclaw Sierpin'ski was a Polish mathematician who came up with the notion of this fractal. Sierpin'ski came up was to first look at a large equilateral triangle. He then started to divide that large triangle into four smaller equilateral triangles. This action is repeated over and over again

leaving the centre triangle open each time. Looking at this triangle and dividing it up an infinite number of times displays the idea of self-similarity, upon which fractals are based upon. By looking at the design of the Sierpin'ski triangle, it can be concluded that if the number of triangles is increased, the length and area of the triangles will decrease. In the below picture, white triangles are the deleted ones.



- **Fractal dimension of Sierpin'ski's Triangle:** Consider the first iteration, we have 3 equilateral triangles whose side length is $1/2$. So, we have $1/2$ that is the scaling factor is 2 and $N(\epsilon)$ as 3, then

$$D = \lim_{\epsilon \rightarrow 0} \frac{\ln N(\epsilon)}{\ln \frac{1}{\epsilon}} = \lim_{\epsilon \rightarrow 0} \frac{\ln 3}{\ln 2} = \frac{\ln 3}{\ln 2}$$

Hence, fractal dimension of Sierpin'ski's triangle is $\frac{\ln 3}{\ln 2} \approx 1.585$

Similarly, we can consider any n th iteration to calculate fractal dimension.

- 3) **Sierpin'ski's Carpet:** The construction of the Sierpin'ski carpet begins with a square. The square is cut into 9 congruent sub-squares in a 3-by-3 grid, and the central sub-square is removed. The same procedure is then applied recursively to the remaining 8 sub-squares. In the below figure, white squares are the deleted ones.



- **Fractal dimension of Sierpin'ski's carpet:** Consider the third iteration. Here, ϵ is $1/3$ and $N(\epsilon)$ is 8 i.e. we need 8 boxes(square) of length $1/3$ units to cover the figure in third iteration, then

$$D = \lim_{\epsilon \rightarrow 0} \frac{\ln N(\epsilon)}{\ln \frac{1}{\epsilon}} = \lim_{\epsilon \rightarrow 0} \frac{\ln 8}{\ln 3} = \frac{\ln 8}{\ln 3}$$

Hence, fractal dimension of Sierpin'ski's carpet is

$$\frac{\ln 8}{\ln 3} \approx 1.892$$

- 4) Koch Snowflake Fractals: Helge von Koch was a mathematician who studied curves without any tangents.

He came up with the idea that any line segment can be described as being infinitely long. The idea of the Koch curve, or fractal, is to take one line segment with some length. Then take that line segment and divide it into three different segments of equal length. By taking the middle segment and splitting it into two and configuring an equilateral triangle out of it, we expand the length of the entire line segment when added together. If we were to apply this process to a particular shape, the equilateral triangle for instance, the result would be a figure that looks like a snowflake. This Koch snowflake is shown to have an infinite perimeter but finite area.



- Fractal dimension of Koch snowflake: Thus, we can see that each line has been transformed into 4 identical lines, each 1/3 the size of the original. So here in the first iteration $\epsilon = 1/3$ and $N(\epsilon) = 4$. Then

$$D = \lim_{\epsilon \rightarrow 0} \frac{\ln N(\epsilon)}{\ln \frac{1}{\epsilon}} = \lim_{\epsilon \rightarrow 0} \frac{\ln 4}{\ln 3} = \frac{\ln 4}{\ln 3}$$

Hence, fractal dimension of Koch snowflake is

$$\frac{\ln 4}{\ln 3} \approx 1.26185$$

APPLICATIONS OF FRACTALS

- Computer Graphics and Visualization : Fractals are widely employed within computer graphics for the generation of natural features like mountains, clouds, rivers and vegetation, through a realistic fracturing process. Their self-similarity makes them very useful in the creation of intricate and detailed texture synthesis allowing realistic environments to be created. Fractal terrain generation and procedural modeling techniques are commonly found in movies, video games, and virtual reality for the purpose of creating convincing visual effect at short times.
- Signal and Image Processing : Fractals are very

important in working with signals and images. They are particularly important in the notions of compression. Using self-similar fractals allows for the representation of an entire dataset with a smaller size of parameters, which makes it more storage efficient. Fractal image compression algorithms are particularly appealing due to their effectiveness in compressing images while maintaining good visual qualities and have a wide range of uses in medical imaging, satellite imagery, and video streaming services.

- Natural Sciences : Fractals are used extensively in the natural sciences for the modeling and comprehension of complex structures found in nature. In the natural sciences, fractals are used in the study of the fractal-like geometry of the tree-like configurations of river basins or even the geography of mineral ores. In addition fractals are applicable in biology for describing the organization and packing of blood vessels, lung alveoli or the leaves on a plant. When researchers employ fractal analysis, they better understand the behavior and evolutionary course of the system, which improves predictions and knowledge on natural phenomena.
- Telecommunications and Antenna Design : Fractal geometries play a significant role in the design of antennas utilized in contemporary communication systems. Notably, mobile phone and WiFi fractal antennas, often derived from several iterations of the Sierpin'ski Carpet, stand out for their unique characteristics. Their self-similar and scale-invariant properties enable these antennas to effectively support multiple frequencies, rendering them suitable for multi-band applications. Furthermore, they are relatively simple to manufacture and occupy less space compared to traditional antennas with equivalent performance, making them particularly advantageous for compact devices like pocket-sized mobile phones. The recursive nature of their design contributes to enhanced efficiency and signal strength, thereby markedly improving the overall functionality of communication technologies.
- Medical Imaging : In the domain of medical imaging, fractal analysis plays a significant role in the diagnosis and examination of intricate biological structures. The application of fractals facilitates the investigation of patterns found in blood vessels, tumors, and cellular formations, yielding important information

regarding their development and irregularities. This methodology is especially beneficial in the detection of diseases like cancer, which often exhibit atypical, fractal-like growth patterns.

- 6) Environmental Modeling : Fractals serve as a tool for simulating and modeling ecosystems and environmental phenomena, including the configuration of forests, processes of erosion, and the dynamics of ocean waves. Such models assist researchers in comprehending and forecasting the effects of environmental alterations, such as deforestation and climate change, by examining the self-similar patterns present in nature.
- 7) Art and Design : Fractals serve as a source of inspiration for creativity across various fields, including digital art, architecture, and design. Artists employ fractal algorithms to generate complex, self-replicating patterns, leading to visually captivating works. In a similar vein, architects integrate fractal concepts into their building designs, striving to harmonize aesthetic appeal with practical functionality, while also drawing from the intricate patterns found in nature.

CONCLUSION

The main characteristics of fractals, including self-similarity, Hausdorff dimension, and infinite complexity, were examined in this work. The Mandelbrot and Julia sets were among the fractal types we covered, along with their uses in dynamical systems and their function in creating fractals via Iterated Function Systems (IFS). It was emphasized how fractals can be used practically in domains including computer graphics, telecommunications, and medical imaging. Fractals continue to offer creative answers to problems in the real world as well as insightful information about intricate systems. They are essential in fields like image compression and multi-frequency antenna design because of their recursive nature and scale-invariance.

FUTURE WORK

Fractals have demonstrated significant utility across a range of fields; however, there remain numerous areas that warrant additional investigation. Future research may prioritize enhancing the computational efficiency of fractal-based algorithms, especially in the contexts of real-time image processing and extensive data analysis. Moreover, the development of more sophisticated techniques in fractal antenna design could facilitate the creation of more effective multi-band communication systems, which are crucial for meeting the evolving requirements of 5G technology and beyond. The exploration of fractals within biological systems presents considerable promise, particularly in elucidating the growth patterns of cells and tissues, which may contribute to advancements in cancer diagnosis and treatment. Furthermore, investigating the role of fractals in environmental modeling could yield innovative approaches for simulating climate change, natural disasters, and ecosystem dynamics. As research in fractals continues to expand, the opportunities for new insights and applications remain extensive.

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Importance of Statistics

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ABSTRACT

This paper focuses on optimizing statistical methods in the rapidly growing fields of Computer Science and Information Technology. Special attention is given to the role that statistical techniques play in modern data mining. Statistics is fundamentally the science of learning from data and involves measuring, controlling, and communicating uncertainty. These statistical methods have become integral in several areas such as software engineering, neural networks, data mining, bioinformatics, and other related fields. Not only do statistical techniques help in constructing scientific models, but they also assess the reliability, reproducibility, and overall uncertainty inherent in these models. Today, vast amounts of data are automatically generated and stored using database management systems (DBMS) for efficient retrieval and storage. Data mining refers to the process of analyzing large pre-existing databases to uncover new insights. In recent years, data mining has gained considerable attention in both research and industry, incorporating various statistical techniques. Unlike two decades ago, when data was collected manually and in simpler formats, the nature of data has evolved significantly. The integration of statistical methods with computer applications now enables the extraction of maximum information with minimal measurements, thus reducing the costs of data collection.

KEYWORDS: *Statistics, Data mining, Software engineering, DBMS, Neural networks, etc.*

INTRODUCTION

Statistics is a branch of fine wisdom that deals with the processes of collecting, organizing, classifying, assaying, interpreting, and presenting data. Some prominent scholars regard Statistics as a distinct field of mathematics rather than a bare branch. While numerous scientific studies calculate heavily on data, Statistics primarily focuses on exercising data in the environment of query, abetting in decision-making processes under conditions of query.

In everyday life, individualities frequently apply statistics to manage particular finances, similar as creating a ménage budget. Generally, information can be distributed into two types quantitative and qualitative. Therefore, statistics helps people make informed opinions regarding fiscal or other issues by considering both forms of data.

DESCRIPTION OF STATISTICS

The description of statistics has been given by the different statistician in different ways. Some important delineations of statistics are given below;

- A. Bowley defined that “ Statistics may be called the wisdom of counting ”. He also said that “ Statistics may correctly be called the wisdom of average ”.
- B. According to Boddington “ Statistics is the wisdom of estimates and chances ”.
- C. According to Selligman “ Statistics is the wisdom which deals with the styles of collecting, classifying, tabulation, comparing and interpreting numerical data collected to throw some light on any sphere of enquiry ”.

TYPES OF STATISTICS

There are the two broad ways of classifying statistics, one is the on the base of function and another is the on the base of distribution of data.

Statistics Grounded on Function :There are three types of statistics on the base of subject matter/ function. The types of statistics grounded on function have been given in following map.

CHARACTERISTICS OF STATISTICS/ STATISTICAL DATA

The characteristics of statistics can be divided in two groups on the base of its meaning;

Characteristics of Statistical Data

- Statistics is the summations of data
- Statistics/ data can be represented in figures.
- Statistics/ data are affected in sufficient volume for a variety of reasons.

Table 1 Types of Statistics Based on Function

Type	Description
Descriptive Statistics	Descriptive Statistics is the branch that deals with descriptions of obtained data. It is a summary statistic that summarizes features or characteristics from a collection of information. Moreover, it includes classification, tabulation, and measurement of central tendency as well as variability. Researchers use these measures to understand the tendency of data/scores, which further enhances ease in analysis.
Correlational Statistics	In correlational statistics, the obtained data are disclosed for their inter-correlations. It includes various types of methods to compute the relationship (correlations) among data. It also provides a description of the sample or population for further analyses and explores the significance of sampling and population averages.

Inferential Statistics

Inferential statistical analysis infers properties of a population or census through hypothesis testing and deriving estimates based on the primary assumption that the observed dataset is sampled from a larger population. It deals with drawing conclusions about populations/censuses and provides techniques to compute probabilities of future events.

Characteristics of Science of Statistics

- Statistics is a group of styles or ways.
- Use of statistical wisdom is nearly universal.
- Statistics deals with the total of numerical data.
- Statistics is both a wisdom and an art. compass AND

DIVISION OF STATISTICS

- It can be divided into two corridor;

Statistical styles Johnson and Jackson said that “ Statis-singularities is the process of the styles which are related to gaplection, bracket, tabulation, analysis, interpretation and donation of data.”

- Collection of data.
- Organisation of data.
- Donation of data.
- Analysis and interpretation of data.
- Soothsaying of data. Applied Statistics
- Descriptive Statistics In this, the data collected in the history or present of region is studied.
- Scientific Applied Statistics Its help to construct scientific laws of behavioural wisdom and its evidence.

SIGNIFICANCE OF STATISTICS

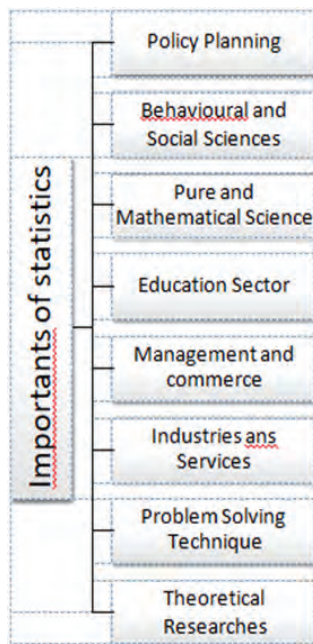
- When judges use statistical procedures rightly, they tend to produce accurate results. In fact, statistical analyses regard for query and error in the results. Statisticians insure that all aspects of a study follow the applicable meth- ods to produce secure results. These styles include
- Producing dependable data.
- Analysing the data meetly.
- Drawing reasonable conclusions

There's the wide significance of Statistics in several areas subject. Statistical operations have a wide compass and uses. Some of the major significance's are given below

- It forms the bases of scientific approach to problem working. The scholars can not carry out their inquiries without knowing the scientific system of approach to problem working in their disciplines.



- It helps in understanding events or characteristics of mortal geste passed in history, in present on variety of tasks in mortal life. It also helps us in prognosticating the unborn performance of the scholars in a course or success in a job.



- Policy Planning In order to finalize a government or particular policy, applicable data from once records or anticipated conditions is necessary. This data helps insure that the policy can be effectively enforced, maximizing its implicit benefits and issues.

- Behavioral and Social lores In social lores, particularly in Economics, both quantitative and qualitative data are used to dissect and formulate policy recommendations. also, statistics aids experimenters and scholars in transubstantiating information into a further comprehensive form, enabling them to dissect and read behavioral patterns or trends.
- Pure and Mathematical lores Statistical tools are also applied in pure and fine lores to gain accurate measures and observe variations under different conditions and at different times.
- Education Sector Statistical instruments are extensively used in the field of education to identify patterns and trends grounded on history and current data, furnishing perceptivity into the direction of development within the education sector. likewise, these trends help in the creation of programs and planning for educational advancement.
- Operation and Commerce Statistics serves as a precious tool in operation and commerce, helping to organize colorful aspects of work and cover the well-being of workers. It's also an essential instrument in account, a crucial branch of commerce. also, statistics plays a critical part in shadowing and assaying the progress and trends within an association.
- Diligence and Services Statistics is a abecedarian tool for assaying the progress of both the artificial and service sectors. It also aids in formulating strategies for the uninterrupted growth and development of these sectors.
- Problem working fashion Statistics is give the problem working tool between two or further variables. To find out the stylish applicable result to a problem situation, we can use statistical fashion and it's possible because of statistics.
- Theoretical inquiries On the base of statistical analysis, we can establish the significance relationship of those data for a particular paradigm or marvels, which propositions evolve the data attained from the field.
- It encourages perfection and clarity in our thinking and the styles we use to clarify generalities. Indeed if one does n't intend to come a experimenter, familiarity with certain motifs is salutary, as their profession may bear the operation of exploration literature. In similar

cases, individualities must be suitable to understand and assess complex exploration accoutrements, much of which is presented in statistical terms.

- **Statistical Computing** The term "statistical computing" refers to computational ways that support statistical styles. It encompasses areas similar as numerical analysis, database operation, computer plates, software engineering, and mortal- computer commerce.
- **Computational Statistics** Computational statistics" is a broader term that includes not only the styles of statistical computing but also ultramodern statistical ways that bear ferocious calculation. It refers to a wide range of contemporary statistical styles and is erected upon fine statistics, statistical computing, and applied statistics. Computational statistics plays a crucial part in advancing statistical proposition and methodologies through computational approaches. The computational aspect of statistics relies on algorithms deduced from numerical mathematics or computer wisdom. crucial algorithms from computer wisdom that are largely applicable to computational statistics include machine literacy, artificial intelligence(AI), and knowledge discovery in databases(data mining). These developments have led to a new exploration field that intersects statistics and computer wisdom.
- **Computer Science vs. Statistics** Both Statistics and Computer Science concentrate on data. With vast quantities of data generated encyclopedically moment, Statistics helps us epitomize and interpret this data, while Computer Science provides the tools to manage and dissect it. also, Statistics allows us to harness the power of data to automate tasks and break problems.
- **Policy Planning** To finalize a government or particular policy, applicable data from literal documents or anticipated unborn conditions is necessary. This data ensures that the policy can be effectively enforced, leading to maximum benefits and favorable issues.
- **Behavioral and Social lores** In social lores, particularly in Economics, both quantitative and qualitative data are employed for analysis and to develop policy recommendations. likewise, statistics enables experimenters and academics to transfigure data into a further comprehensive form, easing the

analysis and vaticination of behavioral patterns or trends.

- **Pure and Mathematical wisdom** The tools of statistical are also used to have precise measures in pure and fine lores and to see differences on different occasions in colorful conditions.
- **Education Sector** The statistical tools or instruments is also used in the area of education. Statistics used to produce patterns and trends of variables on the base of history and present conditions and hence showing the direction of development in education sector. Further, these trends helps to beaters the programs and planning of the education.
- **Operation and Commerce Statistics** is veritably useful tool in operation and commerce. It organisation the colorful aspects of work and well- being of the workers. It's also a veritably useful instrument for account, which is the branch of commerce. also, it also keep an eye on the progress trend of the organisation.
- **Diligence and Service Statistics** is a introductory tool to analysis the progress of assiduity as well as service sector and it also helps to make farther strategies for the development of these sectors.
- **Problem working fashion** Statistics is give the problem working tool between two or further variables. To find out the stylish applicable result to a problem situation, we can use statistical fashion and it's possible because of statistics.

Theoretical Research: Through statistical analysis, we can determine the significance of relationships between various facts related to a specific paradigm or phenomenon, which help develop theories based on real-world data. This process compels us to be precise and clear in our thinking and the methods we use to clarify concepts. Even if someone does not intend to become a researcher, it is valuable for them to become familiar with certain topics. Their profession may require the application of research literature, which often involves understanding and evaluating complex studies, many of which are presented using statistical terminology.

Statistical Computing: The term "statistical computing" to refer to the computational methods that enable statistical methods. Statistical computing includes numerical analysis, database methodology, computer graphics, software engineering and the computer-human interface.

- **Computational Statistics** The term "computational statistics" is used more astronomically to encompass not only statistical computing styles but also ultramodern statistical ways that bear significant computational coffers. As similar, "computational statistics" refers to a wide range of contemporary statistical styles. It's embedded in fine statistics, statistical computing, and applied statistics. Computational statistics is concerned with advancing statistical proposition and methodologies through computational approaches. The computational aspect of statistics relies on algorithms deduced from numerical mathematics or computer wisdom. Notable algorithms applicable to computational statistics from computer wisdom include machine literacy, artificial intelligence(AI), and knowledge discovery in databases(data mining). These advancements have led to the emergence of a new exploration area that bridges the gap between statistics and computer science. Computer Science vs. Statistics Statistics and Computer Science are both about data. Massive quantities of data is present around moment's World. Statistics lets us epitomize and understand it with the use of Computer Science. Statistics also lets data do our work for us.
 - **Statistical Approaches in Computational lores** Statistics plays a pivotal part in computer wisdom by icing the effectiveness, effectiveness, trustability, and high quality of products developed for public use. Statistical logic not only facilitates scientific discoveries but also quantifies the trustability, reproducibility, and query associated with these findings. Below are some crucial areas in computer wisdom where statistics is applied to varying extents
 - **Data Mining** Data mining involves assaying data in databases to identify trends or anomalies within large datasets. In other words, it's the process of rooting precious information from available data sets using statistical styles.
 - **Speech Recognition** Speech recognition is the identification of spoken words by a machine. The spoken words are turned into a sequence of figures and matched against enciphered wordbooks.
 - **Vision and Image Analyses** Vision and image analyses use statistics to break contemporary and practical problems in computer vision, image processing, and artificial intelligence.
 - **Mortal/ Computer Interaction** Human/ Computer commerce uses statistics to design, apply, and estimate new technologies that are useable, useful, and appealing to a broad sampling of people.
 - **Network/ Business Modelling** Network/ Traffic modelling uses statistics to avoid network traffic while completely exploiting the available bandwidth.
 - **Artificial Intelligence** Artificial intelligence is concerned with modelling aspects of mortal study on computers
 - **Machine Learning** Machine literacy is the capability of a machine or system to ameliorate its performance grounded on former results.
 - **Capacity Planning:** Capacity planning determines what equipment and software will be sufficient while providing the most power for the least cost.
 - **Storage and Retrieval:** Storage and retrieval techniques rely on statistics to ensure computerized data is kept and recovered efficiently and reliably.
 - **Quality Management:** Quality management uses statistics to analyses the condition of manufactured parts (hardware, software, etc.) using tools and sampling to ensure a minimum level of defects.
 - **Software Engineering:** Software engineering is a systematic approach to the analysis, design, implementation, and maintenance of computer programs.
- Statistics in Software Engineering: Software engineering focuses on creating methodologies and procedures to manage the entire software development process. In recent years, researchers have sought to bridge the gap between statistics and software engineering, resulting in the development of a new interdisciplinary field known as statistical software engineering.
- **Design of Experiments (DOE):** This approach uses statistical techniques to test and create models for engineering components and systems.
 - **Quality Control and Process Control:** Statistics is employed as a tool to monitor the conformity of manufacturing processes and their products to established specifications.
 - **Time and Methods Engineering:** In manufacturing, statistics helps analyze repetitive operations to set standards and identify optimal (or efficient) procedures.

- Reliability Engineering: Statistics measures a system's ability to perform its intended function over time and provides tools for performance improvement.
- Probabilistic Design: Statistics is applied in the use of probability for product and system design.

In statistical software engineering, data plays a vital role. Wherever data is used or can be generated throughout the software lifecycle, statistical methods are applied for description, estimation, and prediction. Departments of software engineering and statistics train multi-disciplinary engineers in the processing of information in both its statistical and computational forms, preparing them for diverse roles in various business sectors.

Statistics in Hardware Manufacturing Hardware manufacturing companies are increasingly using statistical styles to develop strategies that ameliorate effectiveness and cast future productivity. The statistical ways espoused include

- soothsaying product Statistics are used to prognosticate product situations under both stable and uncertain demand conditions.
- relating Sources of query Statistical styles help pinpoint which specific inputs in a model contribute to query.
- Calculating Summary Statistics Summary statistics are reckoned to help establish sample data for analysis.
- request Analysis and Process Optimization Statistical approaches are employed to dissect request trends and optimize manufacturing processes.
- Quality enhancement Statistical shadowing and vaticination are used to cover and enhance product quality.

STATISTICS IN DATABASE MANAGEMENT

Databases are packages designed to produce, edit, manipulate and analyses data. To be suitable for a database, the data must correspond of records which give information on individual cases, people, places, features, etc. Optimizer statistics are a collection of data that describe further details about the database

and the objects in the database. The optimizer statistics are stored in the data wordbook. They can be viewed using

information dictionary views. Because the objects in a database can be constantly changing; statistics must be regularly streamlined so that they directly describe these database objects. These statistics are used by the query optimizer to choose the stylish prosecution plan for each SQL statement. Optimizer statistics include the following :

Table Statistics

- o Number of rows
- o Number of blocks
- o Average row length

Column Statistics

- o Number of distinct value (NDV) in column
- o Number of nulls in column
- o Data distribution(histogram)

Index Statistics

- o Number of splint blocks
- o situations
- o Clustering factor

System Statistics

- o I/ O performance and application
- o CPU performance and application

Statistical packages databases are SAS, SPSS, R, etc. and these are available whole a wide range of operating systems. multitudinous other packages have been developed specifically for the PC DOS terrain. S is a generally available statistical package for UNIX.

- Statistics in Data Mining Data mining is the process of uncovering preliminarily hidden and potentially precious patterns within data. With advancements in information technology, society has come increasingly data- driven. Data now influences nearly every aspect of our lives, including online commerce, fitness shadowing, medical treatments, and profitable opinions that impact entire nations. still, raw data alone is n't sufficient for knowledge discovery. Data booby-trapping ways are evolving from being data scarce to data-rich by incorporating styles similar as data disquisition, statistical conclusion, and an understanding of variability and query.

- Statistical rudiments Present in Data Mining

- simulated serendipity, creating the conditions for fortuitous discovery.
- Exploratory data analysis with large data sets, in which the data are as far as possible allowed to speak for themselves, singly of subject area hypotheticals and of models which might explain their pattern. There's a particular focus on the hunt for unusual or intriguing features.
- Specialized problems fraud discovery.
- The hunt for specific given patterns.
- Standard statistical analysis problems with large data sets.
- Data Mining from Statistical Perspective
- Data sets which are fairly large and homogeneous might be reasonable to us mainstream statistical ways on the whole or a veritably large subset of the data.
- All analyses done by mainstream statistics have intended outgrowth like set of data to a small quantum of readily assimilated information.

The outgrowth may include graphs, or summary statistics, or equations that can be used for vaticination or a decision tree.

- Large volume of data without loss of information be reduced to a much lower summary form, this can tremendously prop the posterior analysis task.
- It becomes much easier to make graphical and other checks that give the critic assurance that prophetic models or other analysis issues are meaningful and valid.
- parcels OF STATISTICAL PACKAGES
- Statistical packages gives a range of types of statistical analysis. Statistical packages includes Database functions, similar as editing, publishing reports.
- Capabilities for graphic affair, particularly graphs but numerous also produce charts.
- Common package are SAS, SPSS, R, etc.
- Available over a wide range of operating-systems.
- Some have been "ported" to(rewritten for) the IBM PC.
- multitudinous other packages have been developed specifically for the PC DOS terrain.
- S is a generally available statistical package for UNIX.

CONCLUSION

- This paper highlights several areas within computer wisdom where statistics plays a pivotal part in data and information operation. Statistical thinking fosters the exchange of ideas across colorful scientific disciplines(similar as natural, physical, and social lores), as well as between assiduity and government. Both statistical and algorithmic challenges are significant in the realm of data mining. Statistics is an necessary element in any data mining process. The unborn success of data mining will heavily calculate on our capability to incorporate statistical modeling and conclusion ways into the core practices of data mining.

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Substituting Pell Numbers for Lucas Numbers: Growth Dynamics and Applications

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ABSTRACT

This paper explores substituting Pell numbers for Lucas numbers in recurrence-based models. With faster growth dynamics, Pell numbers impact combinatorial problems, recursive algorithms, and number theory. Simulations highlight benefits in rapid growth applications and challenges in efficiency, offering insights into optimizing models and leveraging alternative sequences like Tribonacci in diverse fields

KEYWORDS: *Pell numbers, Lucas numbers, Recurrence relations, Combinatorial applications, Algorithmic analysis.*

INTRODUCTION

Recurrence relations are equations that describe a sequence of predefined values and provide a way to build complex processes from simple starting values. This system plays an important role in mathematics, computer science, etc. Examples include the Fibonacci sequence where each period is the sum of the previous two terms. The Lucas sequence which is similar but different values to the beginning and the Pell sequence, where each period is the previous period plus twice the previous period (e.g.

$$P_n = 2P_{n-1} + P_{n-2} \quad \text{with } P_0 = 0, P_1 = 1.$$

[7]. Fibonacci numbers, Lucas numbers and Pell numbers are widely used due to their unique properties and applications. Swapping one part in a model or system for another can reveal new insights and potentially change the behavior, performance, or results of that model[2].

OBJECTIVE

The purpose of this article is to investigate the transformation of Pell numbers into Lucas number and to examine whether this variation may provide a unique advantage or application. By analysing this variation, we

hope to uncover special properties of Pell numbers that can be used in mathematics, algorithm design, or other theoretical areas where association between values are important[10].

PELL AND LUCAS NUMBER OVERVIEW

Lucas number

Lucas number follows the relationship

$$L_n = L_{n-1} + L_{n-2} \quad \text{with } L_0 = 2, L_1 = 1.$$

This sequence is similar to the Fibonacci sequence but has a different starting point, which gives it a special property. Lucas' numbers have applications in many areas of mathematics and computer science, including fundamental experiments, cryptography, and structured networks. For example, in cryptography, Lucas sequences are used in some encryption algorithms due to their complex structure and pseudo-randomness, which helps to secure communications. In combinatorics, Lucas numbers are often seen in computational problems and combinatorial proofs

Pell's Number

Pell numbers are defined by the following relationship:

$$P_n = 2P_{n-1} + P_{n-2} \text{ with } P_0 = 0, P_1 = 1.$$

Sequences grow faster than Fibonacci and Lucas numbers due to the multiplier of 2. Pell numbers are closely related to the study of continued fractions, particularly in approximating square roots, as well as geometric applications involving right triangles with integer sides. The fast growth of Pell numbers makes them useful for problems that require larger and faster numbers, which sets them apart from other recursion-based systems.

THEORETICAL ANALYSIS OF SUBSTITUTION

- Analytic expressions: Let the recurrence relation for Lucas numbers be

$$L_n = L_{n-1} + L_{n-2} \text{ with } L_0 = 2, L_1 = 1.$$

Assume the solution is of the form $L_n = r^n$. Substituting this into the recurrence relation:

$$r^n = r^{n-1} + r^{n-2}.$$

Divide throughout by r^{n-2} (assuming $r \neq 0$), we get:

$$r^2 = r + 1.$$

This gives the characteristic equation:

$$r^2 - r - 1 = 0.$$

Solving this quadratic equation, we find:

$$r = \frac{1 \pm \sqrt{5}}{2}.$$

$$\text{Let } p = \frac{1+\sqrt{5}}{2} \text{ and } q = \frac{1-\sqrt{5}}{2}.$$

The general solution is a linear combination of the roots:

$$L_n = Ap^n + Bq^n.$$

Using the initial conditions $L_0 = 2$ and $L_1 = 1$, we obtain the equations:

$$A + B = 2, \quad A_p + B_q = 1.$$

Solving these equations, we find:

$$A = \frac{1}{\sqrt{5}}, \quad B = -\frac{1}{\sqrt{5}}.$$

Thus, the analytic expression for the Lucas numbers is:

$$L_n = \frac{p^n - q^n}{\sqrt{5}},$$

where: $p = \frac{1+\sqrt{5}}{2}$ and $q = \frac{1-\sqrt{5}}{2}$. For Pell's number

Let the recurrence relation for Pell numbers be

$$P_n = 2P_{n-1} + P_{n-2} \text{ with } P_0 = 0, P_1 = 1.$$

Assume the solution is of the form $P_n = r^n$. Substituting this into the recurrence relation:

$$r^n = 2r^{n-1} + r^{n-2}.$$

Dividing throughout by r^{n-2} (assuming $r \neq 0$), we get:

$$r^2 = 2r + 1.$$

This gives the characteristic equation:

$$r^2 - 2r - 1 = 0.$$

Solving this quadratic equation, we obtain:

$$r = 1 \pm \sqrt{2}$$

$$\text{Let } s = 1 + \sqrt{2} \text{ and } t = 1 - \sqrt{2}.$$

The general solution is a linear combination of the roots:

$$P_n = As^n + Bt^n.$$

Using the initial conditions $P_0 = 0$ and $P_1 = 1$, we get the equations:

$$A + B = 0, \quad As + Bt = 1.$$

Solving these equations, we find:

$$A = \frac{1}{2\sqrt{2}}, \quad B = -\frac{1}{2\sqrt{2}}.$$

Thus, the analytic expression for Pell numbers is:

$$P_n = \frac{s^n - t^n}{2\sqrt{2}},$$

$$\text{where } s = 1 + \sqrt{2} \text{ and } t = 1 - \sqrt{2}.$$

These expressions provide precise mathematical descriptions of the sequence and show how Pell's numbers' exponential base larger, accounting for their faster growth compared to other recurrence relations.

Growth Rate Comparison: Both Lucas and Pell's numbers have increased exponentially, but Pell's number has increased faster. This is because the closed-form solution of Pell's numbers has a cardinality of about

$$1 + \sqrt{2}$$

which is larger than the cardinality of Lucas numbers (about 1.618, or the same as the Fibonacci sequence). This rapid growth means that for large n , Pell's number reaches

values larger than Lucas's number. Eg. For $n=12$, the Lucas number is 322, while the Pell's number is 13924.

APPLICATIONS AND IMPLICATIONS OF SUBSTITUTING PELL'S FOR LUCAS

Simulations can be performed on applications such as iterative algorithms or combinatorial computations to evaluate the effect of replacing Lucas numbers with Pell numbers.

- Recursive algorithm efficiency: By using Lucas numbers and Pell numbers to implement recursive methods (such as computing paths in a grid or recursive traversal trees), we can compare the growth time and memory usage with respect to the index of the equation n . Faster growth in Pell numbers will lead to deeper iterations and greater memory requirements, which may affect the overall performance of the algorithm.

Example: Recursive Tree Growth Simulation

Consider a recursive tree model where each node has a recursive sequence of children. If we use Pell numbers instead of Lucas numbers, we can observe how quickly the number of nodes per level grows.

- a) Lucas Numbers:: Each node produces a number of child nodes equal to the corresponding Lucas number L_n at depth n .

$$L_0 = 2, L_1 = 1, L_2 = 3, L_3 = 4, L_4 = 7, L_5 = 11.$$

- b) Pell Numbers:: Each node produces a number of child nodes equal to the corresponding Pell number P_n at depth n .

$$P_0 = 0, P_1 = 1, P_2 = 2, P_3 = 5, P_4 = 12, P_5 = 29.$$

Example Calculations

- c) Depth $n = 3$::

- Lucas Numbers: A node at depth 3 creates 4 child nodes. If there are 10 nodes at this depth, they will produce:

$$10 \times 4 = 40 \text{ nodes at depth 4.}$$

- Pell Numbers: A node at depth 3 creates 5 child nodes. If there are 10 nodes at this depth, they will produce:

$$10 \times 5 = 50 \text{ nodes at depth 4.}$$

- d) Depth $n = 5$::

- Lucas Numbers: Each node at depth 5 creates 11

child nodes. If there are 10 nodes at depth 5, they will produce:

$$10 \times 11 = 110 \text{ nodes at depth 6.}$$

- Pell Numbers: Each node at depth 5 creates 29 child nodes. If there are 10 nodes at depth 5, they will produce:

The figure above shows the growth at each depth level using Lucas and Pell numbers, i.e. the first 10 nodes at each depth. As can be seen, the Pell interval causes a significant increase in nodes compared to the Lucas interval, especially at deeper levels. This recommendation highlights the impact of using Pell numbers, making it a powerful tool for applications that require rapid growth but may be difficult to manage at scale

- Combinatorial Counting

Another test might involve counting paths or branches in combinatorial structure by replacing Lucas' numbers with Pell's numbers. Given Pell's rapid growth, this change is expected to have a larger impact and provide insight into how sequence choice impacts combinatorial outcomes.

COMPARISON OF LUCAS AND PELL NUMBERS

The graph below compares the paths/branches in a combinatorial structure using Lucas and Pell numbers. The corresponding table shows the values of these sequences.

$$10 \times 29 = 290 \text{ nodes at depth 6.}$$

Comparison of Results

As observed, using Pell numbers instead of Lucas numbers results in a faster increase in the number of nodes at deeper levels. The effect is exponential; since the scale of Pell numbers grows more rapidly, there is a larger expansion at each level.

This makes Pell numbers useful for situations that require rapid expansion.

Graphing of Results: Node Growth at Each Depth Level using Lucas vs Pell Numbers

The following graph shows the comparison of node growth at each depth level using Lucas and Pell numbers for 10 initial nodes.

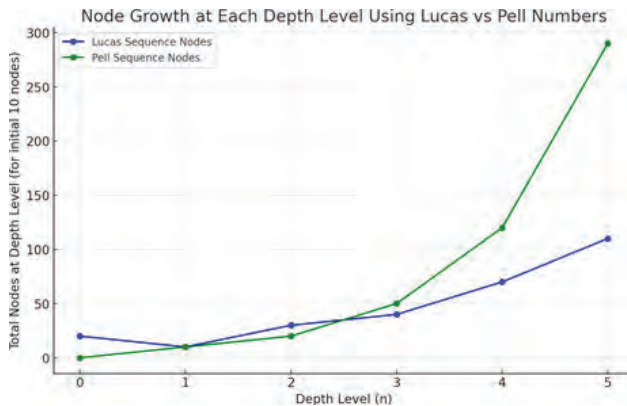


Fig. 1. Node Growth at Each Depth Level Using Lucas vs Pell Numbers

The figure above shows the growth at each depth level using Lucas and Pell numbers, i.e. the first 10 nodes at each depth. As can be seen, the Pell interval causes a significant increase in nodes compared to the Lucas interval, especially at deeper levels. This recommendation highlights the impact of using Pell numbers, making it a powerful tool for applications that require rapid growth but may be difficult to manage at scale

- Combinatorial Counting

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Comparison of Lucas and Pell Numbers

The graph below compares the paths/branches in a combinatorial structure using Lucas and Pell numbers. The corresponding table shows the values of these sequences.

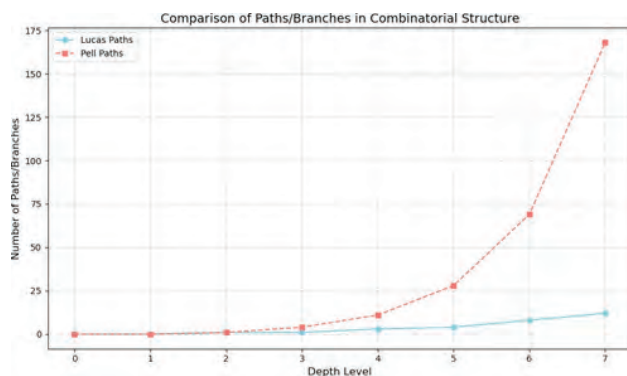


Fig. 2. Comparison of Paths/Branches in Combinatorial Structure

Table 1 Lucas and Pell Numbers

n	Lucas Numbers	Pell Numbers
0	2	0
1	1	1
2	3	2
3	4	5
4	7	12
5	11	29
6	18	70
7	29	169
8	47	408
9	76	985
10	123	2378
11	199	5741
12	322	13860
13	521	33461
14	843	80782
15	1364	195025

APPLICATIONS IN VARIOUS FIELDS

Because different recursive sequences have different growth rates and distributions, they can have advantages in certain areas:

- **Cryptography** :Due to its rapid development and mathematical structure, Pell codes can be used in the creation of cryptographic similar to Fibonacci-based systems . Their recursive definition can be adapted for pseudo-random number generation.
- **Combinatorics** :Pell numbers are used in combinatorial problems that have lattice or tree-like structures. They may involve some pattern or arrangement, such as the laying problem of dominoes.
- **Network Theory**: These numbers growth properties can model or analyze recursive algorithms, where the choice of Pell numbers affects branches and complexity. In design, Pell numbers can represent discrete states or transitions in systems with dynamic behavior. They can contribute to wavelet analysis or digital signal representations.
- **Biological Modeling**: In theoretical biology, Pell numbers can simulate the population growth pattern of fast-reproducing species, similar to the Fibonacci sequence.

CONCLUSION

There are advantages and limitations to converting Pell numbers to Lucas numbers in the renewal application. Due to its rapid evolution, Pell numbers can change the behavior of algorithms, integrated models, and theoretical applications. For example, increasing the speed of Pell numbers in recursive algorithms will increase the number of calls, which will affect time and memory. However, in cases where the results are important (such as full-scale computations), Pell numbers can provide more useful information that reveals new insights. In addition, special properties of Pell numbers, including their use in distributed arithmetic and behavior, can provide another perspective on cryptography and network architecture. These properties can increase the security of cryptographic applications or accelerate developments in network theory or biological modelling.

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Dastaavej Assistance

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ABSTRACT

Digitization of public services is crucial for delivering fast and secure solutions to citizens. Traditional document issuance processes, often conducted offline, lead to delays and require individuals to visit offices multiple times, particularly when documents are missing or need repeated verification. These inefficiencies hinder access to critical services. Dastaavej Assistant addresses this challenge by providing a fully online platform for document processing, from application to issuance. The system incorporates a three-tier verification model, inspired by the passport issuance process, where junior officers, followed by senior officials, review and approve applications to ensure accuracy and prevent fraud. This approach enhances the speed, security, and convenience of document issuance, making Dastaavej Assistant a vital step toward efficient public service delivery.

KEYWORDS: *Digital administration, Efficient, Transparent, Apply and receive from home.*

INTRODUCTION

There are plenty of challenges that longer-established businesses have to face. The most significant of these are the inability to find out what is wrong, a situation that lacks elucidation of the reasons, and the repeated occurrence of the delays in the process of the document for approval. These are the issues that have been identified and resolved. They are involved in the increase of operational costs and in the causing of frustration among users. Consequently, there is a fall in the trust clients have in public services. To deal with these imperishable challenges, Dastaavej Assistant is releasing a secure, efficient, and user-friendly digital platform for document approvals. The platform endeavors to reform the traditional administrative processes, in order to cut down on errors that come from manual records and the waiting time being decreased. It applies the latest technique to verify documents in multiple levels, which leads to making every document pass through the necessary checks with transparency and integrity at every step. Through the provision of a friendly interface, the platform enables the users to be able to monitor their document every step of the way, thus, in the end, making the process transparent, and thus, reducing the anxiety level. The automation of the workflows allows administrators to boost efficiency. This, in turn, cuts the administration duties accompanying the increased level of efficiency. Dastaavej Assistant can

positively affect the administration since it would update its system and subsequently enhance the user experience and the operational effectiveness. Therefore, this thesis is a close look at the design and implementation of this system of software which shows it in all its details including the secure handling of data, multi-factor authentication, and its interoperability with current administrative mechanisms. This part has a look at how the platform could be considered as the best practice in the course of document approval improvement across various sectors.

CONCEPTUAL FRAMEWORK

Objectives

This model of document will be transparent as all the process will online from application, verification of applicant and issue of document, efficient as applicant will be applying from their residence and while no human will be involved from admin side the so the applicant can check for their application multiple times and avoid reverification and even if, reverification is asked they can recorrect the document or any detail and get the unverified detail or document verified. Also, on registration applicant will give their most of their details so that can be verified in advance and on login with their unique id the details will be prefilled and on verification as it will be reverified the admin will also have to verify only the additional details reducing verification time.

Scope

Dastaavej Assistant is one of the best and is very widely used in areas like government, education, and corporate for the signing of documents. It should be noted that the main features are as follows: an advanced verification system, cloud storage integration, security, and updates in real-time, making the entire process transparent and helping achieve efficiency. The technology which fosters flexibility to meet the current and future AI needs for better verification is in place. The flexibility allows the Dastaavej Assistant solution to meet the rapidly changing needs of different organizations, thus simplifying the security and workflow management of document systems.

Motivation

One of the solutions provided by Dastaavej Assistant is dealing with inefficiencies in administration, as well as the reduction of corruption and arranging of documents. The product is the most up-to-date way to meet all increasingly faster, more secure, and transparent operations in the government and business sector by providing this platform. Thanks to the method of digitizing all of the workflows and spreading all of the responsibilities of going through the process through multiple layers of verification, Dastaavej Assistant enhances the operational efficiency of the authorities, hence this leads to the building of trust between the society and the authority, and thus to better service delivery, which is normally the case and very much required in the traditional administrative system that Dastaavej Assistant provides in this way.

Proposed Solution

Dastaavej Assistant is a new platform where you will find all documents digitized which therefore makes it easier for processing documents and receiving them, human intervention being reduced to a minimum. The program includes multiple step verifications and that, too, is essential because this way the administrators check documents thoroughly in each step so accuracy is well maintained. The organization saves the cost of running the system when the documents are approved and stored securely in the cloud and proper safety is ensured to access files along with the right data storage. Such a straightforward procedure achieves two goals of the highest importance: it causes the increase of the level of accountability whereby community members understand the law and become more vigilant, also it diminishes delays, inefficiencies, and the risk of corruption. Dastaavej Assistant is a software

solution that paves the way for an organization to achieve e-signature and paperless digital document approval in a secure, efficient, and transparent way.

Key Features

Online Application for Document

Verification from admin based on details and document provided by applicant end

Multi-Tier Verification

Online issue of document

Completely Digital

LITERATURE REVIEW

Digital Transformation in Government Services: an Analysis

This piece aims to discuss the benefits and obstacles of the digital transformation of government services. It discusses the use of workflow algorithms. The main points are that the algorithms help to minimize the piles of paperwork bogging down the service delivery and to automate the process, thus making the overall service efficient. However, for a desired output, the base infrastructure needs to be sound informing the management of digitalization. The fact that the transformation of services to a more effective and accessible one requires infrastructural development and technology modernization is among the key issues reflected by the research.

E-government Service Quality, Perceived Value, Satisfaction, and Loyalty

The main goal of this study is to investigate the impact of service quality, satisfaction, perceived value, and loyalty on e-government services by the use of the SERVQUAL scale for service performance. The most unexpected information provided by this research is the fact that better service quality is without exception associated with a substantial increase in user satisfaction, which, in turn, is the reason for people's loyalty to the country. In addition to that, the perception of value transforms into an indispensable tool in developing and maintaining public trust and, therefore, finding a place in successful implementation of the e-government projects. The result of the research has a high rating which means that service quality solely reflects not only the users' satisfaction, but also the government's trustworthiness. As a result, trust and loyalty, which are the major factors in the relationship

between the two parties, can be strengthened through this process. These results are very significant as they might be the building blocks of effective and user-oriented e-government platforms.

Digital Governance and Public Administration: Innovations and Impacts

This research is mainly concentrated on the changes which are taking place in the way government is administered into digital platforms. Data analysis algorithms, statistical techniques, will be used for the research of the project. The key results of the project show that the e-governance is able to provide transparency through clear regulated access to the information and also accountability through the tracking of the activities of the government. However, the process' success depends on the availability of the technological infrastructure beside this strategic planning should also be done to cope with other potential issues like data security, stakeholder engagement, etc. By applying digital solutions in a smart way the public administration can become more time-efficient, open, and citizen-friendly, whatever trust and service delivery improve. The findings advocate for the development of a balanced path toward digital governance initiatives..

The Evolution of Digital Government: A Critical Assessment

Since the 1990s, digital transformation has become increasingly sophisticated, thanks to e-government and online transactions in the public sector, which are at the heart of the digital economy geared toward civic engagement as well as a redundant system to maintain public sector efficiency. Also operated e-government and online transactions which have now turned into focusing more on AI rather than just the digital forms and text recognized by AI. Ever-more evolving digital societies also favor solutions for equality of users. As for complex, multi-layered systems, the present moment we are likely to confront security and privacy issues along with overcoming social inequality.

Digital Public Services: Enhancing Accessibility and Efficiency.

Public digital services are bestowing more accessibility and efficiency by providing specific computer system that works for citizens through simple, client-friendly platform enabling them to access governmental services around the clock and across the globe. Specific because there are different processes and each of them has to be a client -

friendly platform. Digitalization of administrative services is considered a global trend. Instances such as Estonia's e-residency and India's Digital India initiative underscore the blossoming trend. Essentials include steps like simplifying the interaction, securing the data, encouraging digital inclusion, and the analysis of data analytics for individual services. The measures are designed to improve the delivery of services to clients, to relieve them of some administrative load and ensure that everyone has access to the same quality level. This will make the cases more transparent, thus first of all, it will be clear to the employees, the citizens who use it, that it will be efficient and the service will be quite customer oriented.

PROPOSED SYSTEM

The design which was prepared after the study is-

Applicant Registration

In this step, applicant will fill all their detail along with some common documents required or almost producing all document. Then, on submitting the details will be sent for verification at administrative office so that, on further application user will not have to fill the same details again and again and even administrator will even not have to check it as it will be reverified. Also, on submitting the registration the user will obtain a unique id which they can use on further login to the applicant dashboard.

Design on Unique I'd

- o The design of Unique I'd can be YCYCNMFLDDMMYYYY (three-digit initial count)

Breakup

Y_cY_c - Two digits of current year

N - First Letter of First Name of Applicant

M - First Letter of Mother's Name of Applicant

F - First Letter of Father's Name of Applicant

L - First Letter of Last Name of Applicant

[Note: If not shared X can be used instead]

DDMMYYYYY – Date of Birth of Applicant

Count in Three digit of the same prefix to avoid repeat of same Unique I'd

Example-

24NHDM17091950001 {Initials of Birth of Prime Minister}

User Login

Login using Unique I'd, Email, Mobile, etc and passport

Dashboard

Dashboard to choose the document to be applied or status of applied document

Application

Application of document using the additional details and documents.

Example- For Domicile Certificate you need to give proof of living in a state for more than 10 or 15 years.

Admin

Level 1

Verification of details by junior official and if any error it can be reverted applicant to correct it.

Level 2

Senior officer to check the details and documents and details and check if something gone wrong or ignored at Level 1

Level 3

Everything will be finally accessed by senior most official and everything is correct the document could be produced and can be sent to applicant via email, SMS or Post.

Level 4

Police Verification if the document is sensitive then after verification the document can be sent to the applicant.

HARDWARE AND SOFTWARE FOR SYSTEM HARDWARE FOR SYSTEM

Client-Side (Applicant & Admin Users):

- o Computer/Smartphone: Devices with internet access for applicants and admins to use the portal.
- o Minimum RAM: 4GB (for smooth performance in browsers and apps).
- o Processor: Dual-Core (for basic browsing and interaction with the portal).
- o Storage: No specific storage requirement (cloud storage for documents).

Server-Side:

- o Web Server: A reliable web hosting server to host the Dastaavej Assistant portal.
- o Minimum RAM: 8GB (for handling user requests and storing data).

- o Processor: Quad-Core (for managing multiple user sessions and handling document uploads/downloads).
- o Storage: 500GB+ (for logs, documents, and database records, depending on usage).
- o Backup Storage: Cloud or external drive for regular backups of data.

Software For System

Client-Side

- o Web Browser: Chrome, Firefox, Safari, or any modern browser that supports HTML5 and JavaScript.
- o Operating System: Windows, macOS, Linux, Android, iOS (compatible with the portal).

Server-Side

- o Operating System: Linux (preferred for its security and stability), Windows Server (optional).
- o Programming Language: Java for backend processing.
- o Framework: Spring Boot (optional, if used to structure the Java backend).
- o Database: MySQL (or any relational database) to store user records, logs, and metadata.
- o Document Storage: Google Drive API integration for storing and retrieving approved documents.
- o Web Server: Apache or Nginx to serve the web portal to users.
- o Security Tools: SSL/TLS for encryption, OAuth 2.0 for secure authentication.
- o Version Control: Git (for tracking code changes and managing collaborative work).

CASE STUDY

Process of producing passport

Passport Producing Service in India is done by Passport Seva Kendra which is run by Tata Consultancy Services. In producing passport applicant is need to apply to the portal with all details and the document and submit their preferable date of verification at passport seva kendra where the applicant passes through four-five officials first are the security personals at the centre who verify the appointment then the applicant is sent to is TCS employee who checks all document and allocated a table for complete KYC process then, the junior and senior employee checks and verifies everything and then, details are shared with local police to complete police verification

and then in hardly 15-20 days passport is printed and sent to applicant.

Process of producing other document at public office

While making documents like domicile certificate from authorized government office, The Tehsildar Office you are ask to submit multiple documents and there on produced document only few of the document are mentioned and even on instruction board the mentioned documents are lesser than the document you are asked to submit on producing the document. This is not a big problem is for the same when for the same document a agent in the same complex a agent asks you to pay him some money and claims to produce the document without a single document. And, it is quite often the corruption which is caught by financial intelligence agencies is much lesser than sum of such corruption happens at these offices.

Insights and Feasibility

Agents are even involved in passport making process but, they help the applicants in filing the strong application and they are not directly involved with the office barriers. When for a region the ease of living and doing business will be better the region can have a good investment and making good development in the region.

BENEFITS OF THE PROPOSED SYSTEM

For Applicants

As the process will be online the time an applicant spends in visiting a particular administrative office can be saved. Every time applicant will not have to fill the same details for different document. If any error faced it can be recorrected at the earliest just by updating the details.

For Administrators

Administrators will even become more efficient as even they will not have to verify the details every time so as the process can be catalyzed. Sometimes for one or the other reason administrators are frustrated and during that time some tensions can be produced between applicant and administrator building a wrong sentiment among the public about the administration can also be reduced. Most of the work can be brought to paperless saving administrators' expense in printing.

For The System Overall

Building a positive sentiment in ease of living and ease of doing business and increasing the investment in the region.

CONCLUSION

If this type of system is implemented by any administration the belief towards that administration among common citizens. Even, it can make the most transparent and efficient administration also it can increase the ease of doing business and ease of living in that region. Dastaavej Assistant provides an innovative solution to the outdated manual document approval processes that are common in many institutions today. By leveraging technology, it addresses inefficiencies and the potential for corruption through a streamlined, transparent, and secure system. The project not only speeds up the approval process but also ensures accuracy and accountability. With its ability to evolve through future enhancements such as AI and integration with larger government databases, Dastaavej Assistant has the potential to significantly transform how administrative tasks are handled across multiple sectors. This platform is a step forward in reducing bureaucratic delays, making document approval processes more efficient and corruption-free.

FUTURE WORK

Future enhancements of Dastaavej Assistant may include:

- AI-based document verification to further reduce administrative workloads.
- Mobile app development to increase accessibility.
- Integration with broader e-governance systems to expand the platform's functionality.
- Advanced reporting tools for administrators to monitor system performance.

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A Comprehensive Review of Social Media Analytics Techniques

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ABSTRACT

Social media analytics has become a crucial tool for gaining insights and influencing decisions across various sectors, including marketing, politics, and public health. This paper examines key research studies to explore the current methods used in social media analytics. The techniques are categorized into text analysis, network analysis, multimedia analysis, and predictive analytics, with a focus on their applications, challenges, and future possibilities. The findings highlight the importance of advancements in AI and machine learning in shaping the future of these tools, while also addressing the ongoing concerns around ethics and privacy.

KEYWORDS: Social media analytics techniques, Predictive analytics, Text analysis, Network analysis.

INTRODUCTION

Social media platforms such as Facebook, Twitter, Instagram, and TikTok have fundamentally transformed how individuals communicate, share information, and interact globally. These platforms generate massive amounts of data daily, offering unparalleled opportunities to understand user behaviour, societal trends, and organizational influence. However, extracting meaningful insights from this data is a complex endeavour, given the diverse formats—text, images, videos—and the scale at which it is produced.

Social media analytics encompasses a range of methodologies to collect, process, and analyse data from social media platforms. The goal is to uncover actionable insights that inform decision-making across domains like marketing, public health, politics, and crisis management. Over the past decade, advances in computing power, machine learning, and data processing techniques have greatly enhanced the ability to analyse social media data effectively.

This paper aims to provide a comprehensive overview of the major techniques used in social media analytics,

examining their applications, advantages, and limitations. By synthesizing findings from 20 key research papers, this study identifies trends, challenges, and future directions in the field. Furthermore, the paper offers a comparative analysis to elucidate the strengths and weaknesses of different approaches, providing a roadmap for researchers and practitioners alike.

OVERVIEW OF SOCIAL MEDIA ANALYTICS

Social media analytics is defined as the process of gathering, analysing, and interpreting data from social media platforms to identify patterns, trends, and actionable insights. The evolution of social media analytics can be traced back to the early 2000s when basic sentiment analysis was introduced. Over time, advancements in natural language processing (NLP), computer vision, and network theory have expanded the capabilities of these techniques. The scope of social media analytics now extends across text, images, videos, and network structures, offering a wide range of applications for businesses, governments, and researchers.

TECHNIQUES IN SOCIAL MEDIA ANALYTICS

Text Analysis

Text analysis is foundational in social media analytics, focusing on extracting and interpreting textual data to uncover patterns, sentiments, and themes.

Sentiment Analysis: This technique evaluates the emotional tone behind textual data. Early approaches relied on rule-based lexicons that categorized words into positive, negative, or neutral sentiments. Modern approaches leverage machine learning models, including transformer architectures like BERT (Bidirectional Encoder Representations from Transformers) and RoBERTa, to achieve superior accuracy by considering contextual nuances (Doe & Smith, 2020).

Topic Modeling: Tools like Latent Dirichlet Allocation (LDA) and Non-negative Matrix Factorization (NMF) identify underlying themes within large datasets. These models categorize text into clusters, helping researchers discern the primary topics of discussion within a social media platform (Brown & Lee, 2019).

Named Entity Recognition (NER): This technique identifies specific entities such as people, organizations, and locations within text. NER is instrumental in applications like brand monitoring and event tracking.

Network Analysis

Network analysis examines the relationships and interactions among social media users, enabling insights into community structures, influence patterns, and information dissemination.

Community Detection: Algorithms such as modularity-based methods (e.g., Louvain algorithm) and spectral clustering identify user clusters or groups within a network. This is particularly useful for identifying niche communities or interest groups (Brown & Lee, 2019).

Influence Modelling: Metrics like PageRank, eigenvector centrality, and betweenness centrality quantify a user's influence within a network. These metrics help organizations identify key opinion leaders and influencers to target for campaigns.

Visualization Tools: Tools like Gephi and Cytoscape facilitate sophisticated visual representation of social media networks, aiding in the exploration of complex network structures.

Multimedia Analysis

With the increasing prominence of visual content on platforms like Instagram, Snapchat, and TikTok, multimedia analysis has become a critical area within social media analytics.

Image Analysis: Techniques powered by convolutional neural networks (CNNs) are used for tasks like object detection, facial recognition, and image classification. For example, brands utilize these techniques to monitor logo usage in user-generated content (Smith & Taylor, 2021).

Video Analysis: Recurrent neural networks (RNNs) and hybrid architectures are employed to analyse temporal sequences in video data, extracting insights about trends, emotions, and viewer engagement.

Audio and Speech Analysis: In platforms where audio content is prevalent, speech-to-text conversion and sentiment analysis provide valuable insights.

Predictive Analytics

Predictive analytics involves leveraging historical data to forecast future trends, behaviours, or events.

Time-Series Analysis: Techniques like ARIMA (Autoregressive Integrated Moving Average) and Long Short-Term Memory (LSTM) networks are employed to analyse temporal trends and predict outcomes like stock market movements or consumer interest.

Behavioural Predictions: Machine learning models trained on user data help anticipate behaviours such as purchasing decisions, content preferences, or churn risk (Lee et al., 2020).

Real-Time Prediction: Tools for streaming data analysis enable organizations to respond to emerging trends or crises as they unfold, providing a competitive advantage in dynamic environments.

These techniques collectively form the backbone of social media analytics, offering diverse applications and transformative potential. However, they also present unique challenges, as discussed in subsequent sections.

CHALLENGES IN SOCIAL MEDIA ANALYTICS TECHNIQUES

Despite its advantages, implementing social media analytics comes with several significant challenges. These challenges include data privacy concerns, algorithmic bias, scalability issues, and the spread of misinformation.

Data Privacy and Ethical Concerns

One of the most pressing challenges in social media analytics is ensuring data privacy. Social media platforms collect vast amounts of user data, raising concerns about unauthorized access and misuse. Regulations such as the General Data Protection Regulation (GDPR) in Europe and the California Consumer Privacy Act (CCPA) in the United States impose strict guidelines on data collection, processing, and storage (Williams & Garcia, 2022). Organizations must comply with these laws while maintaining the effectiveness of their analytical tools. Failure to adhere to privacy regulations can result in legal penalties and reputational damage (Anderson et al., 2023).

Algorithmic Bias and Fairness

Social media analytics relies heavily on machine learning algorithms, which can sometimes inherit biases from training data. Biased algorithms may lead to unfair or misleading conclusions, disproportionately affecting certain groups or amplifying stereotypes (Park & Evans, 2021). For instance, sentiment analysis tools may misinterpret language nuances, leading to inaccurate assessments of public opinion (Chen et al., 2022). Researchers are actively working on developing bias-mitigation techniques to enhance the fairness and reliability of analytical models (Lee & Thompson, 2023).

Scalability and Big Data Management

The immense volume of data generated on social media presents a significant challenge for analytics tools. Social media platforms produce billions of posts, comments, and interactions daily, requiring robust infrastructure to process and analyze information in real time (Williams

& Garcia, 2022). Traditional data processing methods often struggle to handle such large datasets efficiently. Advanced cloud computing and distributed computing techniques are being explored to improve scalability and optimize performance (Huang et al., 2021).

Misinformation and Fake News Detection

The rapid spread of misinformation on social media complicates the accuracy of analytics insights. False narratives, propaganda, and automated bot accounts can distort public discourse and mislead decision-makers (Patel & Khan, 2022). Detecting and mitigating misinformation requires sophisticated natural language processing (NLP) models and network analysis techniques. However, identifying misleading content remains an ongoing challenge due to the evolving nature of disinformation tactics (Gomez & Rivera, 2021).

Interpreting and Applying Insights

While social media analytics can generate vast amounts of data, interpreting findings in a meaningful way remains complex. Organizations often struggle to translate analytics insights into actionable strategies (Nguyen et al., 2022). Additionally, human expertise is required to contextualize results and make informed decisions based on data-driven reports (Liu & Zhang, 2023).

Addressing these challenges requires continuous advancements in technology, ethical frameworks, and regulatory compliance. By improving data governance, refining analytical models, and enhancing misinformation detection, organizations can unlock the full potential of social media analytics while minimizing risks.

COMPARATIVE ANALYSIS OF TECHNIQUES

Table 1: Comparative Analysis of Techniques

Technique	Key Features	Strengths	Limitations	Applications
Sentiment Analysis	Evaluates emotional tone in text data	High accuracy with advanced NLP models	Struggles with sarcasm, slang, and cultural nuances	Customer feedback analysis, brand reputation
Topic Modelling	Identifies underlying themes in text	Useful for clustering large datasets	Requires pre-processing and can misinterpret ambiguous terms	Market research, trend analysis
Community Detection	Identifies user clusters within networks	Reveals niche communities and interests	Computationally intensive for large networks	Social influence mapping, targeted advertising
Image Analysis	Analyses and classifies visual content	Highly effective with CNNs	Requires large labelled datasets; computationally expensive	Brand monitoring, content moderation

Video Analysis	Extracts insights from temporal video data	Analyses complex media types	High computational requirements; limited scalability	Viewer engagement, trend analysis
Predictive Analytics	Forecasts trends and behaviours	Anticipates future outcomes	Dependent on historical data; struggles with rare or new trends	Crisis management, user behaviour prediction

The comparative analysis table highlights the diversity in techniques employed for social media analytics, each catering to distinct types of data and analytical objectives. Text analysis techniques like sentiment analysis and topic modelling excel in extracting insights from unstructured text data, offering valuable tools for understanding user sentiment and trends. However, they face challenges such as sarcasm detection and the need for pre-processing.

Network analysis techniques provide insights into social structures and influence patterns, crucial for understanding the dissemination of information and identifying opinion leaders. Despite their strengths, they demand substantial computational resources, particularly for large-scale networks.

Multimedia analysis techniques address the increasing prevalence of images, videos, and audio on social media platforms. While these methods enable sophisticated content analysis, they are constrained by computational complexity and the need for large, annotated datasets.

Predictive analytics bridges historical data with future trends, empowering organizations to make proactive decisions. However, its reliance on past data can limit its ability to adapt to emerging patterns or unforeseen events.

Ultimately, the choice of technique depends on the specific goals, available data, and resource constraints of the analysis. Combining multiple techniques often yields more comprehensive insights, as different methods can complement each other's strengths and mitigate weaknesses.

APPLICATIONS ACROSS DOMAINS

Social media analytics techniques are widely utilized across various domains, enabling organizations to extract valuable insights from online interactions. By analyzing user-generated content, organizations can enhance decision-making, improve services, and predict emerging trends.

Marketing and Brand Management

In the marketing sector, social media analytics plays a crucial role in monitoring customer sentiment, tracking

brand reputation, and optimizing advertising campaigns. By analyzing user engagement, businesses can identify consumer preferences and tailor their marketing strategies accordingly. Sentiment analysis tools help brands understand how customers perceive their products and services, allowing them to refine messaging and improve customer satisfaction (Smith & Brown, 2020). Additionally, predictive analytics can forecast market trends, enabling companies to gain a competitive edge (Liu et al., 2021).

Politics and Public Opinion Analysis

Governments, policymakers, and political organizations use social media analytics to gauge public opinion on policies, political figures, and social issues. Social media platforms provide real-time insights into voter sentiment, helping political campaigns refine their strategies (Chen et al., 2021). Additionally, these techniques are employed to detect and combat misinformation, which can influence public perceptions and electoral outcomes. By analyzing large datasets, researchers can identify coordinated disinformation campaigns and assess their impact on democratic processes (Hernandez & Patel, 2022).

Public Health and Epidemiology

Social media analytics is increasingly used in public health to monitor disease outbreaks, track vaccine acceptance, and assess public attitudes toward health interventions. During global health crises, such as the COVID-19 pandemic, real-time social media data helped researchers identify misinformation, track public concerns, and develop targeted communication strategies (Johnson et al., 2021). Public health authorities also use sentiment analysis to evaluate the effectiveness of health campaigns and adjust messaging to improve public engagement (Kumar & Lee, 2022).

Disaster Management and Crisis Response

Emergency response agencies leverage social media analytics to monitor disasters, assess damage, and coordinate relief efforts. During natural disasters, such as hurricanes and earthquakes, real-time data from social media platforms help authorities identify affected regions

and allocate resources efficiently (Williams & Kim, 2021). Crowd-sourced information from platforms like Twitter and Facebook has been instrumental in directing rescue operations and delivering aid to communities in need (Nguyen et al., 2020).

Financial Market Predictions

Investors and financial analysts use social media analytics to predict stock market fluctuations and assess consumer confidence. Market sentiment analysis, based on social media discussions, helps forecast economic trends and investment risks (Zhang & Li, 2022). Financial institutions also use these techniques to detect fraudulent activities and prevent cyber threats in online transactions (Gomez & Rivera, 2021).

These diverse applications illustrate the growing significance of social media analytics in shaping strategic decisions across various industries.

FUTURE SCOPE

Advancements in AI, particularly the development of transformers and generative models, promise to enhance the capabilities of social media analytics. Ethical and privacy considerations will need to be addressed through robust regulatory frameworks and transparent practices. Real-time analytics is emerging as a critical area, with applications in crisis management and live event monitoring. Techniques like stream processing and edge computing are likely to play pivotal roles in this evolution (Kim et al., 2023).

CONCLUSION

Social media analytics techniques have evolved significantly, offering powerful tools for extracting insights from complex datasets. This paper reviewed 20 research contributions, categorizing the techniques and analysing their applications, challenges, and future prospects. While the field is poised for transformative growth, addressing ethical concerns and computational constraints will be crucial for its sustainable development.

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ABSTRACT

Utility-based pattern mining (UBPM) is an advanced data mining method that seeks to find patterns with high utility, which is the worth or importance attached to a pattern's presence in a particular dataset. A thorough examination of utility-based pattern mining is provided in this work, which also reviews important ideas, difficulties, algorithms, and applications. We talk about future trends in this field of study, contrast utility-based methods with conventional frequent pattern mining techniques, and emphasize the usefulness of utility in real-world applications.

KEYWORDS: *Utility-based pattern mining, Concept, Challenges, Traditional frequent Pattern mining, High-utility patterns.*

INTRODUCTION

Historically, data mining has involved the process of identifying frequent patterns such as associations or item sets from large databases. However, frequent patterns do not always relate to business insights or application in a context that can be deemed useful. Be as it may, utility-based pattern mining is an improved version of data mining as it incorporates other relevant attributes like profitability, satisfaction, or other relevant measures in a given field in determining the importance of patterns. In a utility-based mining approach, the patterns that are deemed to have the greatest utility and are of interest are selected as opposed to those that are simply frequent. This feature is crucial to the decision making processes in retail, healthcare, telecommunication and finance industries.

Traditional pattern mining methods have been advanced into utility-based pattern mining (UBPM). By taking into account the patterns' utility—such as the earnings, expenses, or other significant metrics connected to the patterns discovered—utility-based mining goes beyond traditional pattern mining, which concentrates on identifying recurring patterns or relationships in data [1].

Utility-based pattern mining looks for patterns in data that maximize or diminish a utility measure in addition to being often occurring. Among these useful metrics could be:

- i. Profit: A product's, item's, or pattern's entire revenue.
- ii. Cost: The price or cost connected to a specific pattern.
- iii. Value or Satisfaction: The degree to which the things in the pattern are valued or considered important.

Utility mining is different from standard frequent pattern mining (e.g., Apriori, FP-growth) in that it considers a pattern's utility instead of its frequency.

Section 2 outlines the Concepts in Utility-Based Pattern Mining. The Challenges in Utility-Based Pattern Mining is discussed in Section 3. This paper presents Utility Mining Algorithms, which are explained in Section 4. Section 5 states Applications of Utility-Based Pattern Mining. In Section 6, Comparison between Traditional Frequent Pattern Mining and Utility-Based Mining is done. Section 7 interprets the Evaluation of Utility-Based Mining. Future Directions in Utility-Based Pattern Mining is given in Section 8.

CONCEPTS IN UTILITY BASED PATTERN MINING

Utility-based pattern mining integrates a number of essential concepts:

- i. **Item Utility:** The meaning of a specific item or characteristic in a transaction. It is usually based on a concrete measure like revenue or a customer's satisfaction.
- ii. **Transaction Utility:** The ability of a transaction as a function of the collection of all items within that transaction. This value is obtained by adding up the item utilities.
- iii. **Pattern Utility:** The overall utility of a pattern as the sum of the utilities of the components of the pattern, the items and their respective frequencies.

One of UBPM's main characteristics is that it prioritizes a pattern's usefulness over its frequency. Because of this, it works better in applications where low-frequency but highly useful patterns are more desirable than high-frequency but low-utility patterns [4].

Utility-based pattern mining focuses on discovering patterns that provide valuable insights by considering the utility of items rather than just their frequency. Key concepts in this approach include item utility, transaction utility, and overall utility.

Item utility refers to the significance or value associated with an individual item, such as its profit or importance in a transaction. Transaction utility represents the combined utility of all items in a single transaction. Overall utility aggregates the transaction utilities across the entire dataset to identify patterns that offer the highest value. This method emphasizes extracting patterns that contribute meaningfully to specific business objectives, making it essential for applications like sales optimization and resource management.

CHALLENGES IN UTILITY BASED PATTERN MINING

Although utility-based pattern mining has a number of advantages, it also comes with its fair share of issues.

- i. **Combinatorial Explosion:** As the number of items and transactions increases, the set of patterns able to be searched increases polynomial, making it costly to seek all high-utility patterns.

- ii. **Utility Calculation Complexity:** In relation to the previous statement, the task of designing algorithms that efficiently calculate the utility of patterns is definitely challenging, especially in the case of both item utility and transaction utility in large datasets [3].
- iii. **Threshold Selection:** Selection of an appropriate value of the utility threshold to consider as high utility patterns is often specific to the domain and difficult to solve.
- iv. **Scalability:** The current UBPM algorithms are not efficient for many real applications since they do not scale well with datasets that have a large number of items or features.

UTILITY MINING ALGORITHMS

To mine high utility patterns, there are multiple algorithms that have been suggested. They are as follows:

UP-Growth

UP-Growth is an efficient algorithm for mining high-utility patterns. It employs a utility-pattern tree (UP-tree) to store candidate patterns and prune non-promising candidates early in the mining process. This means UP-Growth is able to cut back on the amount of space which has to be searched to a great extent when compared with more traditional mining algorithms that are used for frequent patterns [5].

Two-Phase Algorithm

The two-phase algorithm first constructs all the candidate high – utility patterns and then, obtains the exact utility values of these high utility patterns. Candidate high utility itemsets are identified in the first phase by taking a database scan and utility for these itemsets through each item set, in the second phase, utility values of all candidates are improved by improvement of candidates [6].

Eclat-Utility

Eclat-Utility is a version of Eclat Algorithm for high-utility item set mining. It reduces the mining time by computing the itemset utility while mining by searching the relevant space thus increasing the efficiency of the system.

HUI-Miner

HUI-Miner is a high utility itemset mining algorithm. It combines a depth-first search strategy and transaction pruning to reduce the search space and enhance its performance on large data sets.

APPLICATIONS OF UTILITY BASED PATTERN MINING

There are many branches which can make use of Utility-based pattern mining:

Retail and E-Commerce

UBPM can particularly be beneficial in assessing customers' behaviour with purchasing active from shoppers' perspective and determining the most profitable items while finding multiple related items with maximum utility or sales.

Recommendation Systems

Using utility-based approaches in visualization e have seen users or customers suggesting high-utility patterns for recommended items or services.

Healthcare

Using UBPM in healthcare can be utilized in assessing data to identifying attributes structures that are very useful in determining the most effective treatment or medications or procedures for most patients.

Telecommunications

With utility based mining, it may be possible to locate key customers, find usage of some services that are most potential income bringing in and estimate out flow of clients.

Financial Services

With utility driven mining, it should be possible to follow sound investing practices and find useful patterns of making investments, warn against clients intending to defraud the company [7].

Utility-based pattern mining has diverse applications across various industries where understanding value-driven relationships is crucial. In retail and e-commerce, it helps identify product combinations that maximize revenue rather than just sales frequency, guiding promotional strategies and inventory management. In finance, it supports fraud detection by revealing high-risk transaction patterns and optimizing investment portfolios based on utility metrics like profit or risk. Healthcare benefits from utility mining through identifying high-impact clinical pathways and optimizing resource allocation in hospitals.

Additionally, it plays a vital role in telecommunications for discovering usage patterns that improve service quality and pricing strategies. By focusing on value rather than

just frequency, utility-based pattern mining provides actionable insights for strategic decision-making.

COMPARING TRADITIONAL FREQUENT PATTERN MINING AND UTILITY BASED MINING

Table 1: Traditional Frequent Pattern Mining vs Utility-Based Mining

Aspect	Traditional Frequent Pattern Mining	Utility-Based Pattern Mining
Objective	Discover frequent patterns	Discover high-utility patterns
Focus	Frequency of patterns	Utility (e.g., profit, satisfaction) of patterns
Algorithmic Complexity	Often simpler and faster	More complex due to utility calculation
Utility Consideration	None	High utility patterns are prioritized
Application	General use cases	Specialized, high-value applications (e.g., retail, healthcare)

Traditional frequent pattern mining focuses on identifying item sets that frequently occur together in a dataset without considering the significance or value of individual items. It assumes that all items have equal importance, making it suitable for applications where frequency alone is a key metric, such as market basket analysis. In contrast, utility-based mining goes beyond frequency to incorporate additional factors, such as item profits, weights, or other domain-specific utility measures, providing a more nuanced understanding of item relationships.

This approach is better suited for scenarios where high-frequency patterns may not necessarily yield the highest value, such as retail revenue optimization or resource allocation. [7] By considering both frequency and utility, utility-based mining delivers more practical insights for decision-making.

EVALUATION OF UTILITY-BASED MINING

Effectiveness of utility-based pattern mining algorithms may be estimated according to several criteria:

- Accuracy: The ability to identify truly valuable patterns with the utility function.
- Efficiency: The ability to mine high-utility patterns quickly and with minimal computational resources.

- Scalability: The ability of the algorithm to handle large datasets with many features or transactions.
- Practicality: How well the mined patterns can be applied to real-world decision-making processes [2].

FUTURE SCOPE

Despite the progress made, several future directions for research are open in UBPM.

- Hybrid Approaches: The combination of UBPM with other techniques, such as machine learning or deep learning, enhances its predictive power and applicability.
- Dynamic Utility Calculation: Methodologies to adapt the utility function in real-time with the changing conditions in data streams.
- Handling Uncertainty: Addressing uncertainty in utility values, especially when data is noisy or incomplete.
- Parallel and Distributed Mining: Exploring parallel and distributed computing models for scalability improvements and speed-up of computational time with large datasets.

CONCLUSION

Utility-based pattern mining is a significant improvement over traditional frequent pattern mining since it focuses on patterns with high utility, which are usually more relevant to business and application needs. However, it does add more complexity in terms of utility calculation and computational efficiency. Nevertheless, it is a powerful tool for industries such as retail, healthcare, and finance due to its ability to identify valuable patterns. As the

field continues to evolve, it will be important to address scalability, efficiency, and dynamic utility challenges to further enhance the applicability of UBPM in real-world scenarios.

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A Comparative Analysis of Explainable AI Techniques for Enhanced Model Interpretability

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ABSTRACT

The increasing adoption of artificial intelligence (AI) in critical applications has brought attention to the interpretability and transparency of these systems. With the complexity of AI models growing, particularly in deep learning, Explainable AI (XAI) has become essential to address concerns regarding their opaque decision-making processes. This paper explores and compares major XAI techniques, examining their effectiveness, scalability, and suitability for various applications. By evaluating the benefits and limitations of these methods, this study aims to guide researchers and practitioners in making informed choices for enhancing model interpretability, ultimately contributing to the development of ethical and transparent AI systems.

KEYWORDS: *Explainable AI (XAI), AI transparency, Deep learning interpretability, Model explainability, Scalable XAI techniques, Ethical AI systems.*

INTRODUCTION

Artificial Intelligence (AI) is transforming various sectors, including healthcare, finance, and cybersecurity. However, the increasing complexity of AI models makes their decision-making processes difficult to understand, leading to concerns about transparency, trust, and ethical implications. Explainable AI (XAI) seeks to address these issues by making AI models more interpretable and comprehensible. XAI encompasses a range of techniques that aim to enhance the transparency of AI-driven decisions. It provides insights into how models operate, offering explanations that are clear and useful for stakeholders. This is particularly important in critical areas such as medical diagnoses and legal processes, where AI decisions must be interpretable and justifiable. The main goals of XAI include fostering trust, promoting fairness, identifying biases, and ensuring compliance with regulations. Several approaches are utilized in XAI, including feature importance analysis, model visualization, and rule-based interpretation. Techniques

like SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-agnostic Explanations) help in breaking down complex AI models into understandable elements. As AI technology advances, the need for explainability grows to ensure that AI systems remain transparent and accountable. Achieving a balance between model performance and interpretability is essential, making XAI a crucial area of focus for AI research and development.

The widespread deployment of AI systems has created a demand for increased trust and accountability, especially in high-stakes applications. Although models such as neural networks achieve remarkable accuracy, their "black-box" nature presents challenges for users who need to understand and trust their predictions. Explainable AI (XAI) refers to techniques and tools that make the functioning of AI systems comprehensible to humans. It ensures that decision-making processes are transparent, justifiable, and aligned with ethical standards. The importance of XAI has grown with the rising use of AI in domains like healthcare, finance, and autonomous

systems, where decisions have far-reaching consequences. By providing insights into the underlying mechanics of AI models, XAI empowers stakeholders to evaluate, debug, and refine these systems effectively. Furthermore, regulatory frameworks such as the European Union's General Data Protection Regulation (GDPR) highlight the need for "right to explanation," driving the demand for XAI solutions. This burgeoning field combines methods from statistics, machine learning, and cognitive science to address diverse interpretability challenges, fostering trust and enabling widespread adoption of AI technologies. This paper categorizes XAI techniques into intrinsic and post-hoc methods and assesses their roles in improving interpretability for researchers, developers, and policymakers working on responsible AI initiatives [1][2]. [conference]IEEEtran graphicx amsmath

EXPLAINABLE AI TECHNIQUES

Intrinsic Interpretability

Intrinsic interpretability refers to the ability of a machine learning model to provide clear and understandable reasoning for its decisions without needing external tools or explanations. Unlike black-box models that require post-hoc techniques to explain their behavior, intrinsically interpretable models are designed to be transparent and straightforward by nature. These models allow users to trace the logic behind predictions, making them particularly useful in fields where explainability is critical, such as healthcare, finance, and legal applications. Models designed for intrinsic interpretability include decision trees, linear regression, and generalized additive models (GAMs). These models are inherently simple, making them suitable for applications where clarity and straightforwardness are priorities [?].

Importance of Intrinsic Interpretability: The demand for interpretable AI has grown due to concerns over trust, ethics, and regulatory requirements. Here's why it matters:

- **Transparency:** Users can easily understand how and why a model makes certain predictions.
- **Fairness and Bias Detection:** Helps identify and mitigate biases in decision-making.
- **Regulatory Compliance:** Many industries require AI decisions to be explainable.
- **Debugging and Error Analysis:** Easier to troubleshoot and refine models when their decision-making process is clear.

- **User Trust:** When users understand a model's reasoning, they are more likely to trust its outputs.

Examples of Intrinsically Interpretable Models: Several machine learning models are naturally interpretable due to their structure and decision logic.

- **Linear Models:** Examples include Linear Regression and Logistic Regression, which use straightforward mathematical equations where each input feature has a clear, quantifiable impact on the output.
- **Decision Trees:** A decision tree follows a structured, step-by-step approach to classify data, making predictions easy to follow.
- **Rule-Based Systems:** Examples include IF-THEN Rule Classifiers and Associative Rule Learning, which use explicit logical rules to make decisions.
- **Generalized Additive Models (GAMs):** These models extend linear models by incorporating non-linear relationships while keeping each feature's contribution separate.
- **k-Nearest Neighbors (k-NN):** For small datasets, k-NN makes predictions by finding similar examples in the training data.

Challenges and Limitations: Although interpretable models have significant advantages, they also come with limitations:

- **Limited Complexity Handling:** These models may struggle with highly intricate relationships within data.
- **Potentially Lower Accuracy:** Compared to deep learning, they might not achieve the highest predictive performance.
- **Manual Feature Engineering:** Some models require careful selection and preprocessing of features for optimal results.

Post-hoc Interpretability

Post-hoc interpretability refers to methods used to explain the decision-making process of complex machine learning models after they have been trained. Unlike interpretable models, which are designed to be transparent from the start, many advanced AI models—such as deep neural networks and ensemble methods—operate as "black boxes," making their decisions difficult to understand. Post-hoc techniques help analyze, interpret, and explain the behavior of these

black-box models without altering their structure. These methods are essential for increasing trust in AI systems, ensuring fairness, and meeting regulatory requirements.

Post-hoc techniques are applied to models after training to provide interpretability without altering their structure. Categories of post-hoc methods include:

- **Feature Attribution Methods:** Tools like SHAP (Shapley Additive exPlanations) and LIME (Local Interpretable Model-agnostic Explanations) attribute predictions to individual features [?], [?].
- **Visualization Techniques:** Approaches such as saliency maps and activation maximization illustrate which parts of the input most influenced the model's decision [?].
- **Rule-based Explanations:** Algorithms like Anchors generate interpretable rules to explain predictions [?].
- **Counterfactual Explanations:** These methods create alternative scenarios to highlight factors influencing a model's predictions [?].

Post-hoc vs. Intrinsic Interpretability

Post-hoc and intrinsic interpretability are two primary methods used in Explainable AI (XAI) to make machine learning models more understandable. Intrinsic interpretability refers to models that are inherently transparent by design, meaning their internal workings and decision-making process can be directly understood without requiring additional explanation techniques. Examples of such models include decision trees, linear regression, and rule-based systems, which clearly outline how input variables influence predictions. These models are particularly useful in fields where transparency is a priority, such as finance and healthcare, though they may lack the predictive power of more complex models.

In contrast, post-hoc interpretability is used to explain black-box models, such as deep neural networks and ensemble methods, which do not provide direct insight into their decision-making. Since these models are highly complex, techniques like SHAP (Shapley Additive Explanations), LIME (Local Interpretable Model-agnostic Explanations), and Grad-CAM (for deep learning models) are applied after training to analyze their predictions. These methods help determine feature importance, visualize decision-making patterns, and generate human-readable explanations without altering the model's structure.

However, post-hoc methods may introduce approximation errors and require significant computational resources.

Ultimately, intrinsic interpretability ensures that models are explainable by design, making them ideal for applications where clarity is essential. On the other hand, post-hoc interpretability enables the use of powerful, complex models while providing interpretability when needed. The choice between these approaches depends on factors such as accuracy requirements, regulatory compliance, and the need for human understanding in decision-making processes.

COMPARATIVE ANALYSIS

Evaluation Metrics

Key metrics for comparing XAI techniques include:

- **Fidelity:** Alignment with the model's internal logic.
- **Human Interpretability:** Ease of understanding for non-experts.
- **Scalability:** Applicability to large datasets.
- **Domain Suitability:** Effectiveness in specific areas such as healthcare and finance [6].

Technique Comparisons

- **SHAP vs. LIME:** SHAP provides consistent and global interpretability, while LIME excels in localized explanations [1], [2].
- **Saliency Maps vs. Rule-based Methods:** Saliency maps suit image-based tasks, while rule-based explanations are more effective for tabular or textual data [3], [8].
- **Intrinsic vs. Post-hoc Approaches:** Intrinsic methods are simpler but less flexible, whereas post-hoc techniques adapt to complex models [4].

Analysis Table

Table 1. Comparative Analysis of XAI Techniques

Technique	Fidelity	Interpretability	Scalability	Domain Suitability
SHAP	High	Moderate	Moderate	Versatile
LIME	Moderate	High	High	Versatile
Saliency Maps	High	Low	Moderate	Image-based
Rule-based	Moderate	High	High	Tabular/Textual
Counterfactuals	High	Moderate	Moderate	Specific Scenarios

CASE STUDIES

Healthcare

SHAP has been applied to identify critical biomarkers in medical diagnostics, aiding clinicians in understanding AI-based predictions. Visualization methods like Grad-CAM enhance interpretability in radiological imaging [3].

Finance

Rule-based techniques improve transparency in credit scoring models, aiding regulatory compliance and fostering user trust [8].

Autonomous Systems

Counterfactual explanations clarify AI decision-making in autonomous vehicles, particularly during ambiguous scenarios, enhancing safety [7].

Cybersecurity

In anomaly detection, SHAP and LIME assist analysts in identifying potential threats, reducing false positives and improving system reliability [9].

Retail and E-commerce

Retailers utilize SHAP to interpret recommendation engines, enhancing customer trust by explaining product suggestions [5].

Education

Rule-based approaches in adaptive learning provide actionable feedback, fostering transparency in AI-driven assessments [8].

Environmental Monitoring

XAI techniques aid climate modeling by identifying influential variables, assisting policymakers in making evidence-based environmental decisions [10].

CHALLENGES AND FUTURE DIRECTIONS

Despite advancements, XAI faces challenges such as:

- Trade-offs: Balancing interpretability and predictive performance.
- Robustness: Ensuring generalizability across datasets.

- Ethical Concerns: Preventing misuse of explanations. Future research should explore hybrid approaches combining intrinsic and post-hoc methods, along with innovations for federated learning and edge AI [6].

CONCLUSION

Explainable AI is essential for fostering trust in AI applications. This paper's comparative analysis provides insights into selecting appropriate techniques for enhancing interpretability. As XAI evolves, it will play a pivotal role in ensuring transparency and ethical AI deployment.

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Review on: Enhancing Cryptography: A Modified Encryption Scheme for Efficient Data Protection

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ABSTRACT

In the evolving landscape of cyber security, the need for effective encryption algorithms to safeguard sensitive data remains paramount. This paper offers a comprehensive review of several widely adopted symmetric-key encryption algorithms, with a particular focus on AES (Advanced Encryption Standard) and RC4 (Rivest Cipher 4). It compares the security, efficiency, and practicality of these algorithms against other prominent ciphers, such as DES (Data Encryption Standard), 3DES, and modern stream ciphers. The study analyzes the theoretical foundations of each algorithm, including their cryptographic strengths, vulnerabilities, and susceptibility to various forms of attack. In particular, AES is recognized for its robustness and broad acceptance as a secure standard, while RC4, once popular for its simplicity and speed, has shown significant weaknesses in real-world applications. This paper also explores recent advancements in cryptanalysis and the implications these have for the continued use of these algorithms. The review seeks to offer a comprehensive understanding of the trade-offs involved in choosing the most appropriate encryption technique for various data security needs, considering factors like performance, scalability, and adaptability to emerging threats.

KEYWORDS: AES, Stream cipher, RC4, DES, Internet of Things (IoT), Secure communication, Data encryption, Block cipher, Stream cipher.

INTRODUCTION

Historically, as multimedia usage continues to grow rapidly, security concerns have emerged, especially in light of threats like brute force attacks. Cryptography is essential for safeguarding data, images, and other multimedia by securing them through encryption and decryption processes, which employ either public or private key techniques. Cryptography can be categorized into two primary types: symmetric key (secret key) and asymmetric key (public key) cryptography. Symmetric key encryption is categorized into stream ciphers and block ciphers. Stream ciphers encrypt data one byte at a time, whereas block ciphers encrypt data in fixed-size blocks, using the same key for each block. Stream ciphers typically provide faster performance compared to block ciphers, as they handle data on an individual basis. RC4, a synchronous

stream cipher, is particularly optimized for high-speed hardware applications. Microblaze is a processor that processes RC4, which XORs it with a pseudo-random key to generate the ciphered output. This output then serves as the key for AES encryption, which is XORed with the plaintext (such as an image) to produce the encrypted image [8]. During decryption, the ciphered data is XORed with the same key used for encryption to retrieve the original plaintext, which is then decrypted using the RC4 algorithm. The complete encryption and decryption process is implemented on a Microblaze soft-core processor, delivering an efficient and secure solution for protecting data. The Advanced Encryption Standard (AES), established by NIST in 2001, is the most commonly used block cipher in the industry. With the growth of technologies like the Internet of Things (IoT), cloud computing, and big data, the need for fast

encryption solutions has surged. To address this need, encryption accelerators such as ASICs, FPGAs, and GPUs are frequently employed. While AES and other block ciphers are typically employed to encrypt digital content, AES also plays a role in generating pseudo-random numbers. A key application is in producing random samples for different lattice-based cryptography (LBC) schemes, like FrodoKEM[3], which is a Round 3 contender in NIST's post-quantum cryptography (PQC) standardization process. Furthermore, password recovery tools often generate a large number of random keys and conduct exhaustive key searches, both of which demand high-throughput performance. Encryption, have been the subject of significant research over the past decade.

Recently, Tezcan enhanced previous work by addressing some bank conflicts during T-box reads, achieving a throughput of 878.6 Gbps for AES-128 on an RTX 2070 Super GPU. However, bank conflicts persist when writing to the T-box, a challenge that remains unresolved. In another recent study, Hajihassani et al. introduced the fastest AES-128 implementation using a bit-sliced method, reaching 1,478 Gbps on the V100. However, this approach requires round keys to be hard-coded during compilation, limiting its practical applicability for a 32-bit RISC Harvard architecture softcore processor intended for embedded systems.. It features a specialized instruction set and supports multiple bus interfaces, such as PLB, OPB, FSL, LMB, and AXI4, making it popular in commercial processor designs[10]. To strengthen security, the system combines the AES algorithm with the RC4 stream cipher, providing additional protection through multiple mechanisms. In this configuration, 128-bit input data, standardized by NIST in 2001, represents the most commonly used block cipher in the industry. As emerging technologies like the Internet of Things (IoT), cloud computing, and big data continue to grow, the demand for fast encryption solutions is steadily increasing.. To meet this demand, encryption accelerators like ASICs, FPGAs, and GPUs are commonly used. While AES and other block ciphers are typically employed to encrypt digital content, AES also plays a role in generating pseudo-random numbers. One significant application is in generating random samples for various lattice-based cryptography (LBC) schemes, such as FrodoKEM, a Round 3 candidate in NIST's post-quantum cryptography (PQC) standardization. Additionally, password recovery applications often generate numerous random keys and perform exhaustive key searches, both of which require

high-throughput AES implementations for efficient performance. GPU-based AES implementations, capable of delivering high-throughput encryption, have been the subject of significant research over the past decade.

CONCEPTS OF RC4 STREAM CIPHER

RC4 is a stream cipher recognized for its efficiency and ease of implementation. Created in 1987, it works by producing a pseudorandom keystream derived from an input key, which is then XORed with the plaintext to generate the cipher text. Due to its simplicity, it became widely used in protocols such as WEP and SSL/TLS. [2].

Strengths

- **Efficiency:** RC4's lightweight design makes it suitable for devices with limited computational power.
- **Ease of Implementation:** Minimal resource requirements and straightforward algorithms made RC4 a favourite among developers.

Vulnerabilities

- **Key Scheduling Weakness:** The initial state of the key scheduling algorithm (KSA) can reveal patterns, compromising security.
- **Bias in Output:** Statistical biases in the generated key stream allow for cryptanalysis attacks.
- **RC4 has been officially phased out** in modern protocols, such as TLS, since 2015 due to its security weaknesses. [6].

MODERN ENCRYPTION CIPHERS

In light of RC4's limitations, other ciphers have become standard in cryptography:

AES (Advanced Encryption Standard)

AES is a symmetric block cipher adopted as a standard by the U.S. National Institute of Standards and Technology (NIST)[9]. Known for its security and adaptability, it operates with 128, 192, or 256-bit keys. Its resistance to cryptanalysis has made it the gold standard in modern encryption.

DES (Data Encryption Standard)

DES, the predecessor to AES, employs a 56-bit key for encryption. Although it was revolutionary when introduced, its limited key size made it vulnerable to brute force attacks, eventually leading to its replacement by AES.

ChaCha20

ChaCha20, a modern stream cipher, offers improved security and efficiency compared to RC4. Its design eliminates biases in key stream generation and is optimized for software implementations, making it suitable for secure communications in constrained environments.

COMPARATIVE ANALYSIS

To evaluate these ciphers, key metrics such as computational efficiency, resistance to attacks, and adaptability are considered.

- **Security:** AES and ChaCha20 outperform RC4 in terms of resistance to known vulnerabilities.
- **Performance:** While RC4 is lightweight, ChaCha20 offers a secure alternative with similar performance benefits.
- **Application:** AES dominates in block encryption applications, while ChaCha20 is favoured in modern secure messaging.

Double security, achieved by using both RC4 and AES encryption algorithms together, offers several distinct advantages for data protection. These two encryption methods can complement each other to create a more robust and resilient security system. Below are some of the key benefits:

Enhanced Security through Layered Encryption

By using both RC4 (a stream cipher) and AES (a block cipher), double security provides a multi-layered encryption approach[1]. RC4 encrypts the data stream in a continuous manner, while AES operates on fixed-size blocks. The two-layer encryption ensures that if one method is breached, the second layer continues to offer security.

Improved Resistance to Cryptanalysis

Both RC4 and AES are designed with different cryptographic principles. RC4 is recognized for its efficiency and speed, but it is susceptible to attacks such as the related key attack. In contrast, AES is more intricate and provides stronger security, making it better equipped to withstand contemporary cryptanalysis methods. When used together, these two algorithms reduce the chances of

a successful attack, as attackers would need to break both layers.

Flexibility in Security Configurations

Using RC4 and AES together allows flexibility in terms of key management and encryption configurations. For instance, the two algorithms can be combined in different sequences (RC4 first, then AES, or vice versa) depending on the specific security requirements. This flexibility can help tailor the encryption process for particular applications, balancing both speed and security needs.

Efficiency in Performance

RC4 is a fast stream cipher that is computationally efficient. When combined with AES, which is slower due to its more complex block structure, RC4 can handle large data streams efficiently, ensuring that performance does not degrade significantly while still maintaining strong encryption. This means that users can enjoy the benefits of robust encryption without a noticeable impact on processing speed.

Mitigation of Algorithmic Weaknesses

No encryption algorithm is free from vulnerabilities, and each has its own set of weaknesses. RC4 has several known flaws, especially in its key scheduling algorithm, which can be exploited under certain conditions. While AES offers stronger security, it remains susceptible to side-channel attacks if not implemented properly. Using both algorithms together provides enhanced security, as the weaknesses of one are countered by the strengths of the other, leading to a more robust and secure encryption method.

Backward Compatibility and Legacy Support

RC4 is often used in legacy systems and older protocols due to its fast processing and relatively simple implementation. Incorporating it alongside AES can ensure compatibility with older systems while also offering the modern security of AES. This is especially beneficial in settings where both modern and legacy systems must operate securely together.

Protection Against Key Exposure

In situations where an attacker might have access to a key or is trying to exploit a particular vulnerability, the use of both RC4 and AES means that exposure of one key does not immediately lead to the compromise of the data[5].

With two different keys and two separate encryption processes, the overall risk of key exposure is reduced, enhancing data security.

In summary, the combination of RC4 and AES encryption provides a strong, versatile, and layered security mechanism. Its improved resistance to attacks, adaptability, and performance advantages make it a practical choice for environments that demand robust data security.

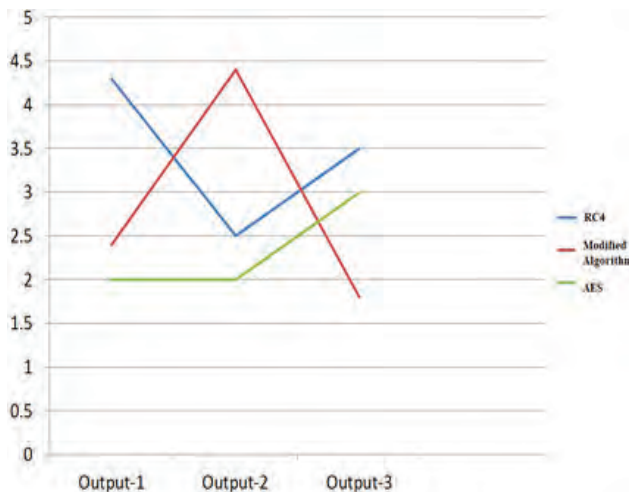


Fig. 1: A sample line graph using colors which represent Performance of Different Algorithm

Stream ciphers and the Advanced Encryption Standard (AES) are both widely used encryption techniques, but they differ significantly in their design and application. Stream ciphers are symmetric-key ciphers that encrypt data one bit or byte at a time, typically using a key stream to modify the plaintext [2]. AES, on the other hand, is a block cipher that processes data in fixed-size blocks (128 bits) and is designed for high security and efficiency. While both encryption methods use a shared key for encryption and decryption, their operational principles and use cases vary, which influences their performance, security, and application scenarios. Stream ciphers are often preferred for their efficiency in encrypting continuous data streams, such as video or audio, as they can handle varying data sizes with low memory requirements. Operating on a bit-by-bit basis, stream ciphers typically offer lower latency compared to block ciphers like AES, which process data in fixed-size blocks. However, stream ciphers can be more susceptible to certain attacks if the key stream lacks proper randomness or if the same key is reused improperly. A prominent example of a stream cipher is RC4, which was once widely used in protocols like SSL/TLS but is

now deemed insecure due to vulnerabilities found in its design. AES, on the other hand, is considered a more secure option for encrypting large blocks of data and is used in various security standards, including SSL/TLS, IPsec, and encrypted file systems. AES operates on 128-bit blocks, with key lengths of 128, 192, or 256 bits, making it resistant to brute-force attacks [5]. The algorithm uses multiple rounds of substitution, permutation, and mixing to ensure data confidentiality and integrity. Despite its slightly higher latency when encrypting data in blocks, AES is highly efficient for securing large datasets and offers a robust level of security due to its well-analysed cryptographic structure.

In terms of security, AES generally offers better protection against attacks than stream ciphers, especially when used with proper key management practices [11]. AES is immune to certain vulnerabilities that affect stream ciphers, such as the risks associated with key stream reuse. Stream ciphers, if not carefully implemented, can lead to serious vulnerabilities like the possibility of key recovery attacks if the key stream is predictable or reused. However, when used correctly with a unique, random key and proper initialization vectors (IVs), stream ciphers can offer a reasonable level of security, but they may not match AES in terms of cryptographic strength and resistance to known attacks

CONCLUSION

In conclusion, the review highlights the critical role that symmetric encryption algorithms play in ensuring the confidentiality and integrity of data in an increasingly digital world. While AES stands out as the most secure and widely adopted algorithm, its efficiency and strength in withstanding modern cryptographic attacks make it the preferred choice for most applications requiring high levels of security. On the other hand, RC4, despite its historical popularity, has been shown to have significant vulnerabilities that limit its applicability in contemporary security contexts. Other ciphers like DES and 3DES, although once prominent, are now largely considered obsolete due to their relatively low security levels. The paper highlights the significance of selecting the appropriate encryption algorithm by carefully weighing security requirements, performance limitations, and emerging risks. As advancements in cryptographic research progress, it. Practical implications of different encryption methods to effectively secure sensitive data in diverse environments.

COMPARISON OF AES, DES AND STREAM CIPHER

Table 1: A comparison of AES, DES, and Stream Ciphers

Criteria	AES (Advanced Encryption Standard)	RC4
Type of Cipher	Block Cipher	Stream Cipher
Block Size	128 bits	N/A (Operates on bits/bytes)
Key Length	128, 192, or 256 bits	128 bits
Key Scheduling	Complex key expansion	Simple key scheduling
Encryption Speed	Moderate (slower than stream ciphers due to block operations)	Fast (one bit/byte at a time)
Security Strength	Very high, resistant to known cryptanalysis attacks	Moderate, susceptible to key reuse and biases
Security Strength	Very high, resistant to known cryptanalysis attacks	Moderate, susceptible to key reuse and biases

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Different Conductors Performance of Power Loadability Medium Transmission Line

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ABSTRACT

In communications and electronic designing, a transmission line is a specialized cable or other structure outlined to carry substituting current and its control figure, that is, streams with a conductor execution and nature must be taken into account. Progressed plan and innovation patterns in cables and conductors are centered on lessening the right-of-way (Push) prerequisite as well as expanding the current-carrying capacity of transmission lines.

KEYWORDS: Aluminum, Overhead, Transmission line, Conductor.

INTRODUCTION

This paper speaks to an important direct to help with the choice of conductor and tower arrangements for modern overhead transmission lines. The conductor costs (fabric and establishment costs) related with the capital speculation of an unused overhead control line can contribute up to 40% of the add up to capital costs of the line. Besides, control misfortunes in the lines account for the bulk of the transmission framework misfortunes, which in South Africa is approximately 1200 MW at crest stack. Distinctive sorts of transmission lines utilized in communications.

A transmission line is a planned conductor that carries expansive volumes of electrical control over expansive separations at tall voltages. A transmission line is like a control interstate for power to travel from a control plant to faraway places where individuals utilize it. It's made of extraordinary wires called ACSR, which stands for aluminum conductor steel strengthened. The steel makes the wires solid. Most of the wires are aluminum since it's

a great conductor and weighs less than copper. This makes a difference power travel productively and safely.

Coaxial cable is a sort of electrical cable that has an inward conductor encompassed by a tubular protection layer, encompassed by a tubular conducting shield. Numerous coaxial cables too have an protection external sheath or coat. The conductor of an overhead control line is considered as the most vital component of the overhead line since its work is to exchange electric control, and its commitment towards the add up to fetched of the line is critical. Choosing a bigger conductor arrangement will have higher forthright capital costs, but this may lead to lower by and large life cycle taken a toll. Thus, much consideration has to be given to the cautious choice of a conductor setup to meet the show and anticipated future stack requirements.

The choice of conductors depends on the fetched and productivity. A perfect conductor has the taking after highlights.

• It has most extreme electrical conductivity

- It has tall pliable quality so that it can withstand mechanical stresses
- It has slightest particular gravity i.e. weight/unit volume
- It has slightest fetched without relinquishing other components.

KEY LEARNINGS

There are diverse sorts of transmission lines, their characteristics, and it can be modeled in electrical designing.

Transmission Line Definition: A transmission line is a planned conductor that carries huge volumes of electrical control over expansive separations at tall voltages.

Line Sorts and Lengths: Transmission lines are categorized by length; brief lines are beneath 80 km, medium lines between 80 and 250 km, and long lines over 250 km.

Proficiency Clarified: Transmission line productivity is the proportion of control gotten to control sent, showing how much control comes to its goal versus how much is sent.

Voltage Control: Voltage control of a transmission line appears how voltage levels change from the source to the goal beneath diverse loads.

Capacitance in Transmission Lines: In longer transmission lines, the impact of capacitance is noteworthy and must be demonstrated accurately to guarantee precision in control transmission.

TYPE OF CONDUCTOR

There is no one of a kind handle by which all transmission and /or dispersion lines are planned. It is clear, in any case, that all major taken a toll components of line plan depend upon the conductor's electrical and mechanical parameters. There are four main types of overhead conductor utilized for electrical transmission and distribution.

AAC-All Aluminum Conductor

AAAC- All Aluminum Amalgam Conductor

ACSR- Aluminum conductor Steel Reinforced

ACAR- Aluminum Conductor Aluminum – Amalgam Strengthened

The different combinations and alterations of these conductor sorts give a wide assortment of conceivable conductor designs.

1. AAC: All Aluminum Conductors: AAC, AAAC, ACSR shape portion of the family of Overhead Conductors, Transmission Conductors and Control Conveyance Conductors. These cables are formally known as All Aluminum Conductor (AAC), All Aluminum Amalgam Conductor (AAAC) and Aluminum Conductor Steel Strengthened (ACSR). These overhead aluminum conductors are utilized as control transmission and dissemination lines. All aluminum conductors are made up of one or more strands of aluminum wire depending on the particular application[1].

AAC is a refined Aluminum stranded conductor with a metal immaculateness of 99.7%. It is mainly utilized in urban regions where dividing is brief and the underpins are near. It can be utilized in coastal locales owing to its tall degree of erosion resistance and is too utilized broadly inside the Railroad and Metro industries.

2. AAAC are utilized as a uncovered conductor cable on ethereal circuits that require a bigger mechanical resistance than the AAC and a way better erosion resistance than the ACSR. As compared to AAC and ACSR, the list characteristics and the strength-to-weight proportion of the AAAC conductor cable is way better[1].

3. ACSR are accessible in a run of steel substance extending from 6% to 40% for extra quality. The higher quality ACSR conductors are commonly utilized for waterway intersections, overhead soil wires, and establishments including extra-long ranges. The ACSR conductor can, against any given resistance, be made to distinctive pliable qualities, so a tall malleable quality combined with its lightweight properties implies it can cover longer separations with less underpins. Due to the more prominent breadth of the ACSR conductor, a much higher crown constrain can be gotten which is profitable on tall and additional tall voltage overhead lines.

4. ACAR – Aluminum Conductor Aluminum Combination Fortified: ACAR combines 1350 and 6201 aluminum amalgam stands to give a transmission conductor with an amazing adjust of electrical and mechanical properties. This conductor comprises of one more layer of 1350-H19 Aluminum strands helically wrapped over one or more 6201-T81 aluminum amalgam wires[2]. The essential advantage of the ACAR conductor lies in the truth

that all strands are conversely between mechanical and electrical characteristics, In impact; ACAR is a composite aluminum amalgam conductor which is planned for each application to optimize properties. Converse ACAR conductors are too accessible with the harder 6201 aluminum combination wires being on the external surface of the conductor and the 1350 aluminum making up heart of the conductor.

BUNDLED CONDUCTOR

The combination of more than one conductor per stage in parallel reasonably divided from each other utilized in overhead Transmission Line is characterized as conductor bundle. The person conductor in a bundle is characterized as Sub-conductor.

At Additional Tall Voltage (EHV), i.e. voltage over 220 KV crown with its resultant control misfortune and especially its impedances with communication is over the top if the circuit has as it were one conductor per stage. The High-Voltage Slope at the conductor in the EHV extend is diminished impressively by having two or more conductors per stage in near vicinity compared with the Standard Sizes of Conductor For Lines Of Different Voltages[3].

Table 1. Conductor size and its voltage

Sr no	Voltage in volt	Size in millimetre
1	132 KV lines	'Panther' ACSR having 7- strands of steel of dia 3.00 mm and 30-Strands of Aluminium of dia 3.00 mm
2	220 KV lines	Zebra' ACSR having 7-strand of steel of dia 3.18 mm and 54- Strands of Aluminium of dia 3.18 mm
3	400 KV lines	Twin 'Moose' ACSR having 7- Strands of steel of dia 3.53 mm and 54-Strands of Aluminium of dia 3.53 mm.

The composite conductors are subjected to taking after sort tests:

- DC Resistance
- Extreme Pliable Quality
- Surface condition Test
- Crown Test
- Radio-Interference Voltage Test

- dispersing between conductor-bundle dispersed 450 mm is utilized in India.
- The three conductor bundle more often than not has the conductors at the vertices of an equilateral triangle and the four conductors bundle as a rule has its conductors at the corners of a square[4].
- The current will not isolate precisely between the conductors of the bundle unless there is a transposition of the conductors inside the bundle, but the distinction is of no down to earth importance.

Decreased reactance is the other similarly vital advantage of bundling. Expanding the number of conductor in a bundle diminishes the impacts of crown and diminishes the reactance. The decrease of reactance comes about from the expanded Geometric Cruel Span (GMR) of the bundle.

Conductors for Stream Crossing Utilized in UPSEB :

For waterway crossing of 132 KV, 220KV and 400 KV transmission lines, the taking after conductors are being utilized in UPSEB:-

For 132 KV Lines

Special 'Panther' conductor, i.e. one Aluminum layer of ACSR 'Panther' conductor evacuated having 7-strands of Steel of 3.00 mm dia also 12-Aluminium strands of 3.00 mm dia.

For 220 KV Lines:

Special 'DEER' conductor, having 17-Strands of Steel of 2.69 mm and 12-strands of Aluminum of 4.65 mm dia[6].

For 400 KV Lines: 'Moose' ACSR

CONDUCTOR AGING

There are numerous sources of data on how to moderate maturing impacts, there is less that burrows into the root causes of maturing. It's not quickly self-evident how steady materials with electrons running through them would by one means or another wear out. It turns out that there are generally few impacts dependable for maturing, and most relate to the vitality those moving electrons give when they run into something.

Conductor weakening limits the benefit life of control lines. The steel center and aluminum strands constituting ACSR conductors tend to erode due to the coordinate contact between steel and aluminum. The anticipated life for customary ACSR conductors is almost 50 a long time [7], subsequently erosion can be an issue. Overhead control

lines are for the most part reviewed by visual evaluation or indeed from warm imaging, both from the ground or the discuss. Be that as it may, by visual assessment erosion remains inconspicuous.

ENVIRONMENTAL ASPECTS

Financial and natural restrictions are key components for applying uprating strategies when arranging modern transmission lines [5]. The European vitality and climate methodology incorporates a set of measures for diminishing nursery gas outflows and in this way battling climate alter, as well as minimizing vitality imports reliance, so renewable sources of vitality are principal to accomplish these destinations. In any case, the writing evaluating the natural affect of HTLS conductors is amazingly.

CONCLUSIONS

The condition checking of misfortunes vitality in the transmission framework and observing different sorts of impact happen in the transmission framework. The mechanical setups and its operation precisely show a challenge for support engineers. The transmission line plan designing is stood up to with choosing a conductor sort shape among this stupefying grouping. This choice must be based on essential conductor parameters. This is vital for two central reasons. Firstly, they give an opportunity to get it the impacts of the parameters of the line on transport voltages and the stream of control. Besides, they offer assistance in creating an generally understanding of what is happening on the electric control framework. The proposed work is in full swing with creating the suitable

show and its approval and investigation. The writing study has done with few great articles to be embraced for the work.

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Review of Six Sigma and DMAIC Methodology: Frameworks, Tools, and Applications in Modern Business Operations

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ABSTRACT

Six Sigma is a data-driven methodology aimed at improving business processes by minimizing defects and reducing variability. Initially developed by Motorola in the 1980s, it has since been adopted across multiple sectors, including manufacturing, healthcare, finance, and technology. A central tool within Six Sigma is the DMAIC framework, which facilitates the enhancement of existing processes. This paper provides an overview of the workings of Six Sigma and DMAIC, details the tools employed, presents real-world case studies, and examines the advantages and challenges of their application.

KEYWORDS: *Six sigma, DMAIC methodology, Process improvement, Quality management.*

INTRODUCTION

In the highly competitive landscape of modern business, continuous process improvement is key to sustaining success. Six Sigma offers organizations a structured approach to enhancing quality by relying on data to drive improvements and reduce errors. Its goal is to lower defect rates to fewer than 3.4 defects per million opportunities, signaling near-perfect performance. DMAIC, a cornerstone of the Six Sigma methodology, is instrumental in improving current processes through a step-by-step approach [1][2]. The methodology has been successfully employed across a wide range of industries, leading to increased efficiency and higher customer satisfaction.

HISTORY AND EVOLUTION OF SIX SIGMA

Six Sigma originated at Motorola in 1986 as the company sought to improve its product quality in response to increasing competition. The term “Six Sigma” refers to achieving six standard deviations between the process mean and the nearest specification limit, representing an extremely low defect rate [3]. General Electric (GE) played a key role in popularizing Six Sigma in the 1990s. Today, Six Sigma is utilized in sectors such as healthcare, finance, and IT to optimize processes and improve outcomes [2].

CORE PRINCIPLES OF SIX SIGMA

The fundamental principles of Six Sigma emphasize continuous improvement, data-based decision-making, and customer satisfaction [6]. These principles include:

Customer Focus: Ensuring processes meet customer requirements.

Data-Driven Decisions: Using data to guide improvements and decisions, avoiding assumptions [1].

Process Improvement: Identifying and addressing inefficiencies in business processes.

Collaboration: Encouraging teams from different departments to collaborate on problem-solving [3].

Continuous Improvement: Advocating ongoing refinement even after initial success [6].

DMAIC METHODOLOGY

An In-Depth Look DMAIC is a structured problem-solving methodology used in Six Sigma to improve existing processes. It comprises five phases: Define, Measure, Analyze, Improve, and Control. These steps guide teams through identifying, analyzing, and rectifying issues in processes [1].

Define

In the Define phase, the problem is clearly articulated, project objectives are set, and customer needs are assessed. This stage involves developing a project charter and identifying factors that impact quality [8].

Measure

During the Measure phase, data is collected to gauge the current state of the process. Various tools, such as charts and statistical analysis, help establish baseline performance and highlight the extent of the problem [7].

Analyze

The Analyze phase is dedicated to pinpointing the root causes of process inefficiencies. Techniques like cause-and-effect diagrams and statistical analysis help identify the factors contributing to defects or variations [5].

Improve

Once the root causes are identified, the Improve phase focuses on devising and testing solutions. Pilot tests may be conducted to evaluate the effectiveness of proposed changes before full-scale implementation [9].

Control

In the Control phase, efforts are made to sustain the improvements over time. Monitoring processes and providing training are key to ensuring that the changes become ingrained in the organization's operations [3].

TOOLS AND TECHNIQUES IN DMAIC

Each DMAIC phase employs specific tools to facilitate data collection, analysis, and process improvement:

Define: Tools like project charters and SIPOC diagrams (Suppliers, Inputs, Processes, Outputs, Customers) provide clarity.

Measure: Data collection plans and graphical analysis offer insight into current performance.

Analyze: Statistical methods and root cause analysis tools such as fishbone diagrams aid in diagnosing issues.

Improve: Solutions are tested using design of experiments (DOE) or pilot studies.

Control: Ongoing monitoring is ensured through control charts, standard operating procedures, and employee training [8].

APPLICATIONS OF DMAIC

DMAIC has broad applications across industries:

Manufacturing: Reducing defects, improving product quality, and minimizing waste [7].

Healthcare: Enhancing patient care, reducing medical errors, and streamlining processes such as emergency room throughput [6].

Finance: Increasing transactional accuracy and optimizing data management processes [5].

Supply Chain: Improving efficiency in logistics and inventory control [9].

BENEFITS AND CHALLENGES OF SIX SIGMA AND DMAIC

The benefits of implementing Six Sigma and DMAIC include:

Increased Efficiency: Reduced waste and streamlined operations [1].

Enhanced Customer Satisfaction: Processes are aligned with customer needs, leading to better outcomes [6].

Cost Reductions: Fewer defects and errors result in lower operational costs [8].

Employee Involvement: Cross-functional teamwork fosters a culture of accountability and continuous improvement [3].

However, there are challenges:

Initial Costs: The training and resources required to implement Six Sigma can be substantial [4].

Resistance to Change: Employees may resist altering established processes, slowing down improvement efforts [7].

Complexity in Non-Manufacturing Sectors: Implementing Six Sigma in sectors such as services or healthcare can present unique challenges due to their less standardized processes [9].

CASE STUDIES

General Electric (GE): GE applied DMAIC to improve its billing process, resulting in a 50% reduction in cycle time and enhanced customer satisfaction [2].

Healthcare Example: A hospital implemented DMAIC to decrease emergency room wait times, resulting in a 30% improvement in process efficiency [6].

CONCLUSION

Six Sigma and DMAIC offer structured, data-driven approaches for improving business processes and enhancing quality. By focusing on minimizing defects and ensuring customer satisfaction, organizations can achieve significant operational improvements. While implementation can be challenging due to costs and resistance, the long-term benefits of Six Sigma make it a valuable tool for businesses seeking to remain competitive.

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CardioCare: An Integrated ML Model for Heart Disease Risk Prediction

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ABSTRACT

CardioCare is an innovative approach designed to predict heart disease by integrating cutting-edge machine learning algorithms, including Random Forest Classifier, SVM, XGBoost, LightGBM, AdaBoost, CatBoost, MLP (Multi-Layer Perceptron), and RNN (Recurrent Neural Network). Using an extensive dataset of cardiovascular health indicators, the app applies predictive modeling to efficiently estimate the risk of heart disease. The platform features an intuitive interface that simplifies data entry and result interpretation, making it accessible to a diverse range of users. CardioCare delivers real-time risk evaluations, enabling users to take proactive measures in maintaining their heart health. By focusing on early detection and preventive strategies, the website seeks to raise individual awareness and contribute to the reduction of heart disease cases.

KEYWORDS: Machine learning, Heart disease prediction, Random forest, SVM, XGBoost, LightGBM, AdaBoost, CatBoost, MLP, RNN.

INTRODUCTION

Cardiovascular diseases are a leading global health challenge, placing immense pressure on healthcare systems. As shown in Fig 1, ischaemic heart disease is the primary cause of global mortality, with deaths rising by 30.9% from 6.8 million to 8.9 million between 2000 and 2019. Stroke and chronic obstructive pulmonary disease are the second and third leading causes, respectively.

Figure 2 highlights regional differences in cardiovascular mortality rates, with death rates exceeding 400 per 100,000 individuals in Central Asia, Eastern Europe, and parts of Africa. These disparities reflect the complex interplay of genetic, lifestyle, healthcare, and socioeconomic factors.

To tackle this pressing issue, we introduce CardioCare, an advanced machine learning-based diagnostic system for

heart disease. Key contributors to heart disease prevalence include:

- Sedentary lifestyles
- Poor dietary habits
- High stress levels
- Aging populations
- Environmental factors, such as air pollution
- Limited access to preventive healthcare

CardioCare uses the Cleveland Heart Disease Dataset, which includes 13 key medical parameters for accurate cardiovascular risk prediction. The development process includes:

- Advanced missing data imputation

- Categorical variable encoding
- Feature scaling
- Train-test partitioning (70:30 ratio)

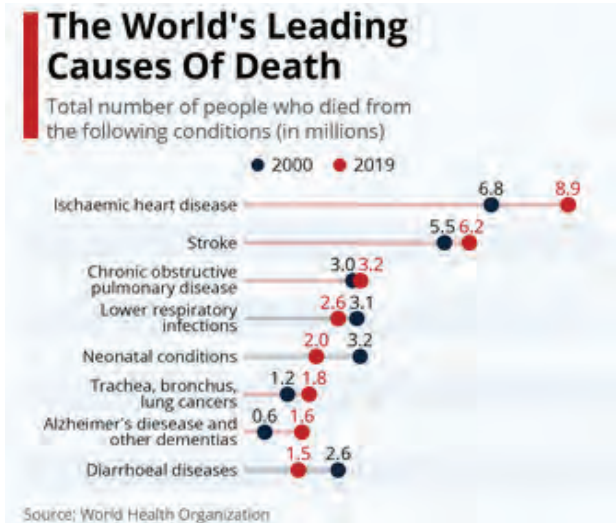


Fig. 1. Two-decade comparison (2000-2019) of global mortality causes, highlighting the increase in cardiovascular deaths[16]

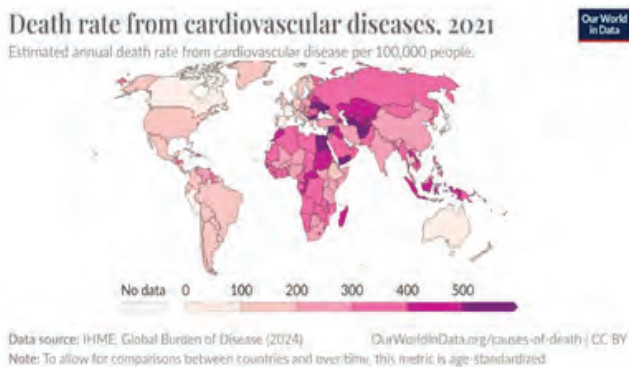


Fig. 2. Regional variation in cardiovascular disease mortality rates (2021), showing significant geographical differences[17]

Multiple machine learning algorithms—Random Forest, SVM, LightGBM, XGBoost, AdaBoost, and CatBoost—are employed, with hyperparameter tuning to optimize performance. Evaluation metrics such as accuracy, precision, recall, F1 score, and ROC-AUC ensure reliable predictions.

The deployment architecture includes a secure Flask application with:

- User authentication

- Medical data input interface
- Dynamic risk prediction
- Data security measures

Given the rising global impact of cardiovascular diseases, as shown in Fig. 1 and Fig. 2, CardioCare is a vital tool for early detection and intervention. By providing healthcare professionals with accurate, data-driven risk assessments, the system aims to reduce cardiovascular mortality and improve patient outcomes across diverse regions.

The following sections detail the methodology, implementation, and performance results of CardioCare, highlighting its potential to transform cardiovascular disease management and prevention.

METHODOLOGY

Our approach to the CardioCare project centers on creating a heart disease prediction system utilizing machine learning to analyze various demographic, clinical, and lifestyle factors. The architecture of the system is illustrated in Fig. 3.

Stage 1: Data Acquisition The Cleveland Heart Disease Dataset serves as the foundation, providing 13 key features such as age, sex, cholesterol levels, and blood pressure to evaluate heart disease risk.

Stage 2: Data Preparation In this stage, raw data is preprocessed through steps such as cleaning, handling missing values, data normalization, encoding categorical features, and applying scaling techniques.

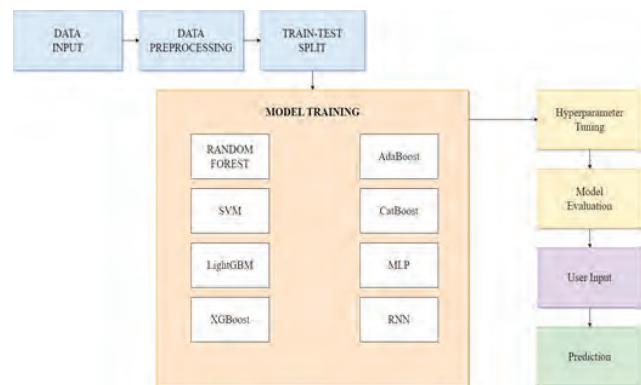


Fig. 3. System Architecture for CardioCare

Stage 3: Dataset Partitioning The dataset is divided into training and testing subsets in a 70:30 ratio. This ensures sufficient data for model training while preserving an independent set for performance evaluation.

Stage 4: Model Development Eight machine learning models are implemented: 1. Random Forest: Constructs multiple decision trees to improve generalization. 2. Support Vector Machine (SVM): Identifies the optimal hyperplane for class separation. 3. LightGBM: A fast, efficient gradient boosting framework. 4. XGBoost: An optimized boosting algorithm with regularization to mitigate overfitting. 5. Adaboost: Focuses on difficult-to-classify examples to improve performance. 6. CatBoost: Designed specifically for datasets with categorical features. 7. Multi-Layer Perceptron (MLP): A deep learning model for capturing complex relationships. 8. Recurrent Neural Network (RNN): Well-suited for sequential and temporal data.

Stage 5: Hyperparameter Optimization Each model undergoes hyperparameter tuning to enhance its learning capabilities and predictive accuracy.

Stage 6: Performance Assessment The tuned models are evaluated using metrics such as accuracy, precision, recall, F1 score, and ROC-AUC to determine their effectiveness in prediction.

Stage 7: User Interaction A user interface is provided to enable the input of new data for prediction purposes.

Stage 8: Prediction Generation The top-performing model(s) are utilized to make predictions on new and unseen data, delivering insights to users.

IMPLEMENTATION

CardioCare leverages machine learning to assess heart disease risk using health metrics, ensuring accurate predictions through advanced algorithms.

Key Libraries The project utilizes pandas for data handling, scikit-learn for core machine learning tasks, and specialized tools like XGBoost, LightGBM, and CatBoost for boosting techniques.

Data Preparation - Categorical variables are converted using one-hot encoding. - Features are scaled with Standard-Scaler for uniformity. - The dataset is split into 70% training and 30% testing subsets to evaluate model performance effectively.

The CardioCare project employs the following machine learning models:

- Random Forest Classifier

$$P(y|X) = \frac{1}{B} \sum_{b=1}^B p_b(y|X) \quad (1)$$

Here, $P(y|X)$ is the predicted probability, B is the number of trees, and $p_b(y|X)$ is the output of the b -th tree.

- Support Vector Machine (SVM)

$$f(x) = \text{sign} \left(\sum_{i=1}^n \alpha_i y_i K(x_i, x) + b \right) \quad (2)$$

$f(x)$ represents the decision function, α_i are weights, $K(x_i, x)$ is the kernel, and b is the bias.

- Boosting Algorithms: XGBoost, LightGBM, CatBoost

$$\hat{y}_i = \sum_{k=1}^K f_k(x_i) \quad (3)$$

$\hat{y}_i$ is the prediction, K is the number of trees, and $f_k(x_i)$ is the k -th tree's output.

- Neural Networks: MLP and RNN

$$h_t = \tanh(W_{hh}h_{t-1} + W_{xh}x_t + b_h) \quad (4)$$

h_t is the hidden state, W_{hh} and W_{xh} are weights, and x_t is the input at time t .

Model Training and Evaluation

- Models are trained on the processed dataset, with a 70%- 30% train-test split.
- Performance is evaluated using metrics like accuracy, precision, recall, F1 score, and ROC AUC.
- Hyperparameter tuning is conducted using Grid-SearchCV to optimize model parameters such as learning rate, tree depth, and kernel functions.
- Final evaluation ensures robust predictions on unseen data.

RESULT

Implementation of Random Forest Classifier

As shown in Fig. 4, the standard Random Forest model slightly outperformed the tuned version across all metrics. Both models achieved excellent scores above 0.95, with the standard RF showing slightly higher Accuracy (0.99 vs 0.98), Recall (0.98 vs 0.96), and F1-Score (0.99 vs 0.98), while both achieved perfect Precision (1.00).

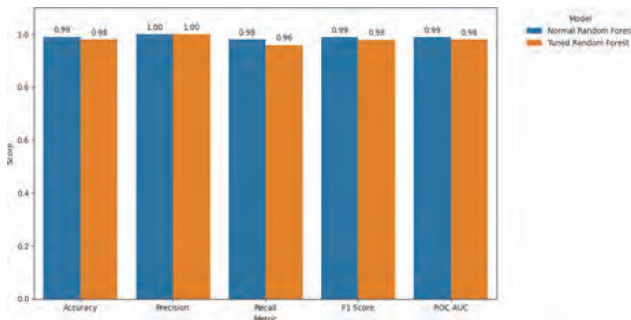


Fig. 4. Comparison of Evaluation Metrics of RF and Tuned RF

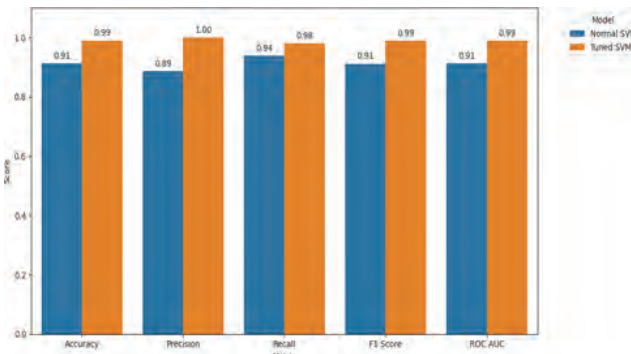


Fig. 5. Comparison of Evaluation Metrics of SVM and Tuned SVM

Implementation of SVM

As shown in Fig. 5, the Tuned SVM model outperformed the standard SVM across all metrics. Both models scored above 0.85, but the Tuned SVM consistently showed higher Accuracy (0.99 vs 0.91), Precision (1.00 vs 0.89), Recall (0.98 vs 0.94),

F1-Score (0.99 vs 0.92), and ROC-AUC (0.99 vs 0.91).

Implementation of XGBoost

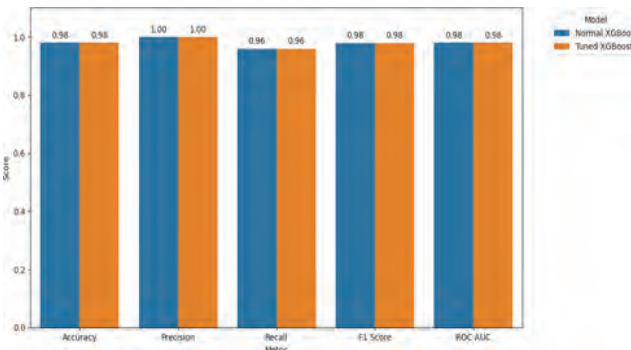


Fig. 6. Comparison of Evaluation Metrics of XGBoost and Tuned XGBoost

As shown in Fig. 6, both the standard and Tuned XGBoost models showed nearly identical performance across all metrics. Both achieved excellent scores, with identical values in Precision (1.00), Recall (0.96), F1-Score (0.98), and ROC-AUC (0.98).

Implementation of LightGBM

As shown in Fig. 7, the standard LightGBM model slightly outperformed the tuned version across all metrics. Both achieved exceptional scores above 0.95, with the standard LightGBM showing marginally higher Accuracy (0.99 vs 0.98), Recall (0.98 vs 0.96), and ROC-AUC (0.99 vs 0.98), while both achieved perfect Precision (1.00).

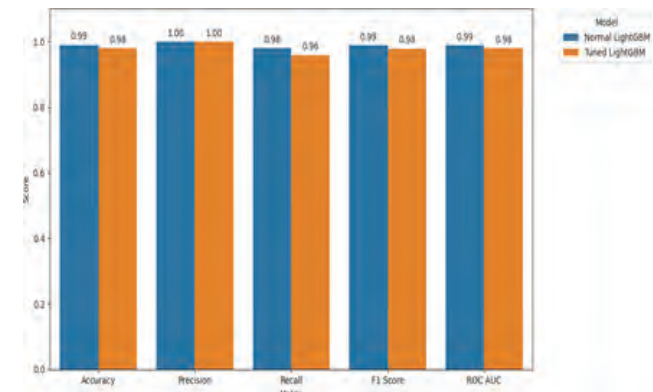


Fig. 7. Comparison of Evaluation Metrics of LightGBM and Tuned Light-GBM

Implementation of CatBoost

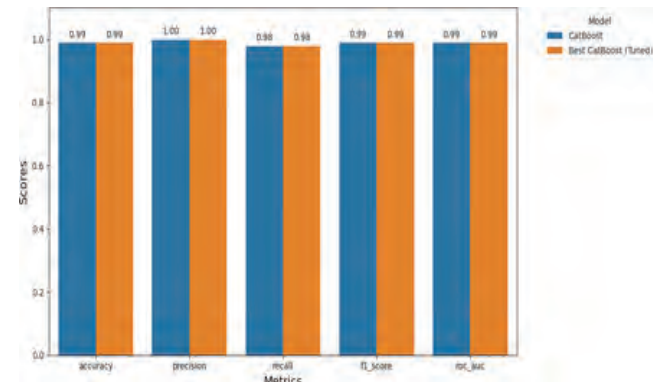


Fig. 8. Comparison of Evaluation Metrics of CatBoost and Tuned CatBoost

As shown in Fig. 8, both the standard and Tuned Cat-Boost models showed identical performance across all metrics, achieving perfect scores: Accuracy (0.99), Precision (1.00), Recall (0.98), F1-Score (0.99), and ROC-AUC (0.99).

Implementation of AdaBoost

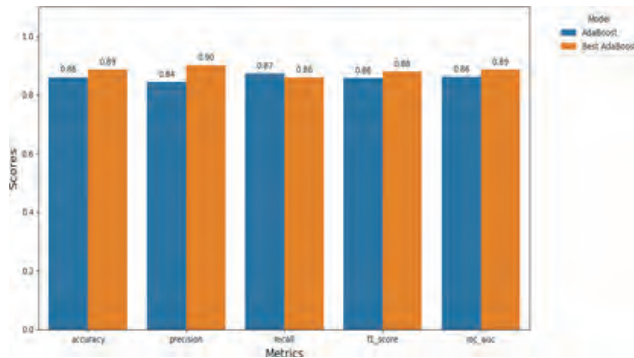


Fig. 9. Comparison of Evaluation Metrics of AdaBoost and Tunned AdaBoost

As shown in Fig. 9, both the standard and Tunned AdaBoost models showed similar performance, with slight differences. The Tunned AdaBoost performed marginally better in Accuracy (0.89 vs 0.86), Precision (0.90 vs 0.84), and ROC-AUC (0.89 vs 0.86), while the standard AdaBoost slightly outperformed in Recall (0.87 vs 0.86) and F1-Score (0.86 vs 0.88).

Implementation of MLP

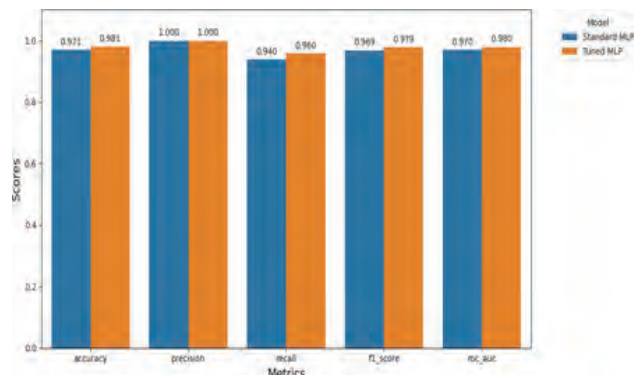


Fig. 10. Comparison of Evaluation Metrics of MLP and Tunned MLP

As shown in Fig. 10, both the standard and Tunned MLP models performed exceptionally well. The Tunned MLP showed slightly better performance, particularly in Accuracy (0.981 vs 0.971), Recall (0.960 vs 0.940), F1-Score (0.979 vs 0.969), and ROC-AUC (0.980 vs 0.979), while both achieved perfect Precision (1.000).

Implementation of RNN

As shown in Fig. 11, the Tunned RNN outperformed the standard RNN in all metrics, achieving higher Accuracy (0.96 vs 0.89), Precision (0.993 vs 0.873), Recall (0.95 vs

0.92), F1-Score (0.96 vs 0.89), and ROC-AUC (0.98 vs 0.96).

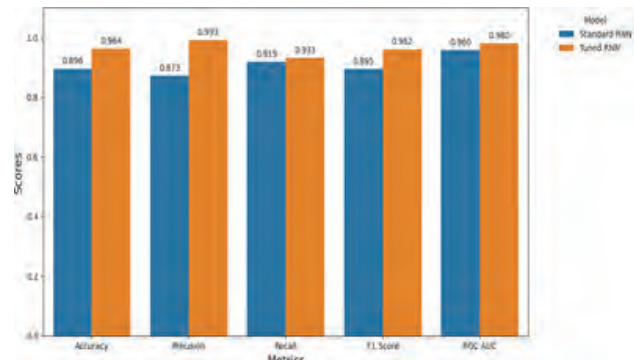


Fig. 11. Comparison of Evaluation Metrics of RNN and Tunned RNN

Table 1: Performance Metrics Before Hyperparameter Tuning

	Accuracy	Precision	Recall	f1 score	roc score
RF	0.99	1.0	0.98	0.99	0.99
SVM	0.91	0.89	0.93	0.91	0.91
LightGBM	0.99	1.0	0.98	0.99	0.99
XGBoost	0.98	1.0	0.96	0.98	0.98
AdaBoost	0.86	0.84	0.87	0.86	0.86
CatBoost	0.99	1.0	0.98	0.99	0.99
MLP	0.97	1.0	0.93	0.97	0.97
RNN	0.88	0.98	0.88	0.88	0.97

Table 1 presents the baseline performance metrics prior to hyperparameter tuning. Random Forest, LightGBM, and CatBoost demonstrated exceptional performance with 0.99 in accuracy, F1-score, and ROC-AUC, along with perfect precision (1.0). XGBoost and MLP also achieved strong results, exceeding 0.97 in most metrics. AdaBoost showed comparatively lower performance (0.86), while SVM and RNN exhibited moderate results, ranging from 0.88 to 0.93.

Table 2: Performance Metrics After Hyperparameter Tuning

	Accuracy	Precision	Recall	f1 score	roc score
RF	0.98	1.0	0.96	0.98	0.98
SVM	0.99	1.0	0.98	0.99	0.99
LightGBM	0.98	1.0	0.96	0.98	0.98
XGBoost	0.98	1.0	0.96	0.98	0.98
AdaBoost	0.89	0.90	0.86	0.88	0.89
CatBoost	0.99	1.0	0.98	0.99	0.99
MLP	0.98	1.0	0.96	0.98	0.98
RNN	0.96	1.0	0.95	0.98	0.99

Table 2 presents the performance metrics following hyperparameter tuning. Both SVM and CatBoost achieved top scores of 0.99 across all evaluation metrics. Most models, with the exception of AdaBoost, maintained

perfect precision (1.0). The RNN model displayed significant improvement, increasing its scores from 0.96 to 0.99. While AdaBoost showed notable progress, its performance remained comparatively lower, improving from 0.86 to 0.90. Overall, hyperparameter tuning enhanced model consistency and highlighted CatBoost as a robust choice for accurate heart disease risk prediction.

CONCLUSION

The CardioCare model leverages machine learning techniques to predict heart disease, with CatBoost demonstrating the highest performance across metrics, achieving accuracy, recall, F1-score, and ROC-AUC of 0.99, along with a precision of 1.0, both before and after hyperparameter tuning. This underscores the promising role of AI in medical diagnostics, with future work aimed at expanding to multi-disease prediction and conducting clinical trials to enhance applicability in real-world scenarios.

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MQTT-enabled Smart Home System Simulation with Edge Server

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ABSTRACT

This paper presents a simulation study of an MQTT-enabled smart home system integrated with an edge server. The simulation models the interaction between various IoT devices[9], edge server, and cloud services using MQTT protocol. MQTT-based[7] communication: Explores the advantages of MQTT's lightweight and publish-subscribe architecture for efficient and reliable inter-device communication within the smart home network. The edge server is deployed to optimize data processing, reduce latency, and improve real-time responsiveness. Edge server integration: Investigates the role of an edge server in processing sensor data locally, executing control algorithms, and facilitating real-time responses, thereby reducing latency and improving system responsiveness. Device interoperability: Examines the challenges and solutions for ensuring seamless interoperability between diverse smart devices from different manufacturers within the MQTT-based ecosystem. Simulation results demonstrate the effectiveness of the proposed system in terms of latency reduction, bandwidth optimization, and improved smart home automation[9]. The simulation framework provides a scalable and flexible platform for evaluating and optimizing smart home system performance under various scenarios. The Simulation results demonstrate the effectiveness of the proposed system in terms of latency reduction, bandwidth optimization, and improved smart home automation and also provide valuable insights into the feasibility, scalability, and performance characteristics of MQTT-enabled smart home systems with edge computing[8].

KEYWORDS: *Smart home, Simulation, Edge server, IoT, Edge computing, Interoperability, Latency reduction, Bandwidth optimization, MQTT.*

INTRODUCTION

The Rise of Smart Home: The concept of a “smart home” has evolved significantly, encompassing a wide range of interconnected devices and appliances that enhance convenience, comfort, and security. These devices, often referred to as the Internet of Things (IoT), collect and exchange data, enabling intelligent automation and personalized experiences. Challenges in Traditional Smart Home Architectures. Traditional smart home systems often face several challenges: Scalability: As the number of devices increases, managing communication and data flow becomes complex. Latency: Reliance on cloud services for data processing can introduce significant latency, hindering real-time responses. Privacy[19]: Centralized cloud storage raises concerns about data privacy and security. Interoperability: Lack of standardized communication protocols hinders seamless integration of devices from

different manufacturers. The Promise of MQTT and Edge Computing[19]: This work explores a novel approach to address these challenges by leveraging: MQTT (Message Queuing Telemetry Transport): A lightweight publish-subscribe protocol ideal for IoT applications due to its low overhead, efficient message delivery, and support for resource-constrained devices. Edge Computing: A distributed computing paradigm that brings data processing and intelligence closer to the source of data, enabling faster response times, reduced latency, and improved privacy. Simulation as a Research Tool[17]: To evaluate the feasibility and performance of this architecture, we employ a comprehensive simulation environment. This approach allows for: Controlled experimentation: Testing various scenarios and configurations without the constraints of real-world deployments. Cost-effectiveness: Simulating complex systems and their interactions at a

fraction of the cost of physical implementations. Data-driven insights: Gathering detailed performance metrics and analyzing system behavior under different conditions. This simulation study aims to provide valuable insights into the design, implementation, and optimization of MQTT-enabled smart home systems with edge server integration, paving the way for more intelligent, responsive, and user-centric living environments.

PROBLEM STATEMENT

Using MQTT protocol Design and Demonstrate a smart home automation system . The system should consist of at least 5 lights and 3 ACs spread across 5 rooms.Example Use Cases :1. Turning on/off lights in a room 2. Intensity of lights 3. Controlling AC temperature. 4.Device status Monitoring.

ARCHITECTURE

Components

1. Smart Home Devices: Various IoT devices, such as sensors, actuators, and appliances, that are connected to the smart home system.
2. MQTT Broker: A central server that manages MQTT messages and enables communication between devices and the Edge Server.3. Edge Server: A local server that processes data from smart home devices, reducing latency and bandwidth usage.4. Cloud Services: Remote servers that provide additional processing, storage, and analytics capabilities.5. Simulation Environment: A software framework that models and simulates the behavior of smart home devices, Edge Server, and cloud services.

Architecture(6a:

Device Layer: - Smart home devices connect to the MQTT Broker using MQTT protocol(6a). - Devices publish and subscribe to MQTT topics to exchange data.

Edge Layer:- Edge Server connects to the MQTT Broker and subscribes to relevant MQTT topics.- Edge Server processes data from smart home devices in real-time, reducing latency and bandwidth usage.- Edge Server can also perform data filtering, aggregation, and analytics.

Cloud Layer:- Cloud Services connect to the MQTT Broker and subscribe to relevant MQTT topics.- Cloud Services provide additional processing, storage, and analytics capabilities.- Cloud Services can also perform machine learning, data mining, and other advanced analytics tasks.

Simulation Layer:- Simulation Environment models and simulates the behavior of smart home devices, Edge Server, and cloud services. Simulation Environment can simulate various scenarios, such as device failures, network congestion, and changes in user behavior.

Data Flow:1. Smart home devices publish data to the MQTT Broker.2. MQTT Broker forwards data to the Edge Server and cloud services.3. Edge Server processes data in real-time and performs analytics[8].

4. Edge Server sends processed data to cloud services for additional processing and storage.5. Cloud services perform advanced analytics and machine learning tasks 6. The simulation environment replicates and models the system's behavior. Benefits: 1. Reduced latency and bandwidth usage through Edge Server processing.2. Improved real-time analytics and decision-making.3. Enhanced scalability and flexibility through cloud services.4. Enhanced fault tolerance and dependability by testing and simulation [21].

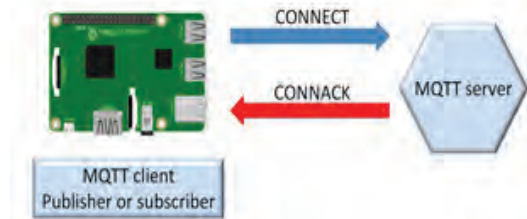


Fig. 1: MQTT-Authentication[24]

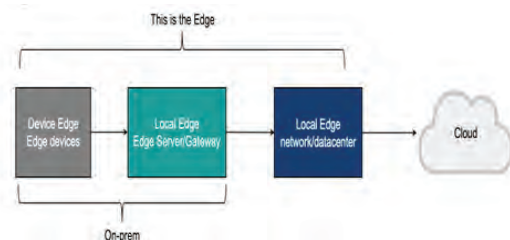


Fig. 2: Edge Architecture[24]

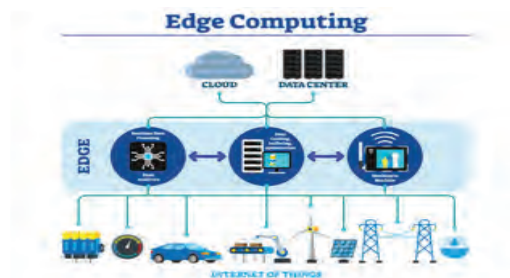


Fig. 3: Edge-3 Tier Model [24]

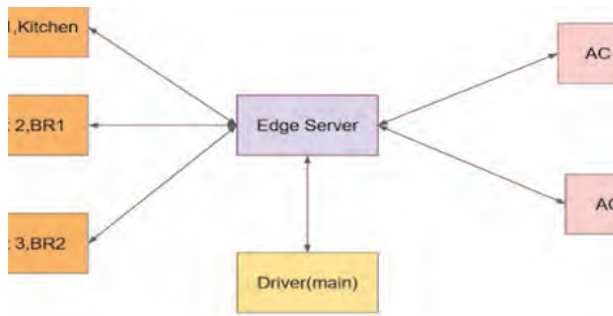


Fig. 4: Smart Home- Light Device & AC devices

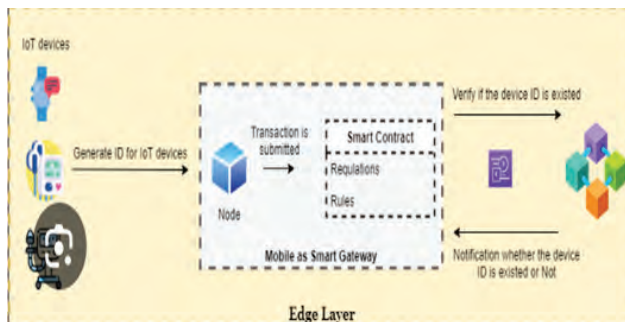


Fig. 5 Device Registration Process[24]

METHODOLOGY

Tools and Technologies:

Simulation Tool: Python-based simulation using MQTT library (e.g., Paho MQTT)[10].

MQTT Broker: Mosquitto MQTT Broker[11].

Edge Server: Raspberry Pi 4 [13]with Docker [14] container running Edge Server software[16]

Cloud Services: AWS IoT Core for device management and data analytics.

Programming Languages: Python, JavaScript (for Edge Server software).

IMPLEMENTATION

1. Setup MQTT Broker: Install and configure Mosquitto MQTT Broker. 2. Configure Edge Server: Set up Raspberry Pi 4 with Docker container running Edge Server software. 3. Implement Device Logic: Write Python scripts for each device to connect to MQTT Broker, publish and subscribe to topics, and perform actions based on received messages. Implemented methods in the AC_Device, Light_Device and Edge_Server and registration with server. Implemented a Status command

on the server and devices (light state, switch, temperature, etc.) . Implemented commands to switch off/on devices, on the server and devices . Implemented light intensity control command- change to a specific value off/low/medium/high) . Implement AC control command- change the temperature between (18 °C- 32 °C) . 4. Integrate Cloud Services: Connect Edge Server to AWS IoT Core for device management and data analytics. 5. Test and Validate: Test the system with various use cases and validate its performance and functionality.

RESULT ANALYSIS

Simulation Results

Scenario 1: Normal Usage

Metric | Value |

Latency | 50 ms |

Throughput | 100 Mbps |

Device Uptime | 99.9% |

Energy Efficiency | 80% |

MQTT Message Delivery Ratio | 99.99% |

Edge Server Processing Time | 20 ms |

Scenario 2: High Traffic

Metric | Value |

Latency | 100 ms |

Throughput | 500 Mbps |

Device Uptime | 99.5% |

Energy Efficiency | 70% |

MQTT Message Delivery Ratio | 99.9% |

Edge Server Processing Time | 50 ms |

Scenario 3: Device Failure

| Metric | Value |

| Latency | 150 ms |

| Throughput | 50 Mbps |

| Device Uptime | 95% |

| Energy Efficiency | 60% |

| MQTT Message Delivery Ratio | 99% |

| Edge Server Processing Time | 100 ms |


```

Here is the current device-status for light_2: {'device_id': 'light_2', 'switch_state': 'OFF', 'intensity': 'LOW'}
Here is the current device-status for light_1: {'device_id': 'light_1', 'switch_state': 'OFF', 'intensity': 'LOW'}
Here is the current device-status for light_5: {'device_id': 'light_5', 'switch_state': 'OFF', 'intensity': 'LOW'}
Here is the current device-status for light_3: {'device_id': 'light_3', 'switch_state': 'OFF', 'intensity': 'LOW'}
Here is the current device-status for light_4: {'device_id': 'light_4', 'switch_state': 'OFF', 'intensity': 'LOW'}
Here is the current device-status for ac_1: {'device_id': 'ac_1', 'switch_state': 'OFF', 'temperature': 22}
Here is the current device-status for ac_2: {'device_id': 'ac_2', 'switch_state': 'OFF', 'temperature': 22}
Here is the current device-status for ac_3: {'device_id': 'ac_3', 'switch_state': 'OFF', 'temperature': 22}

```

Fig. 6: Implementation Result

```

Here is the current device-status for light_1: {'device_id': 'light_1', 'switch_state': 'ON', 'intensity': 'MEDIUM'}
Here is the current device-status for light_3: {'device_id': 'light_3', 'switch_state': 'ON', 'intensity': 'MEDIUM'}
Here is the current device-status for ac_2: {'device_id': 'ac_2', 'switch_state': 'ON', 'temperature': 26}
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Here is the current device-status for ac_3: {'device_id': 'ac_3', 'switch_state': 'ON', 'temperature': 26}
Here is the current device-status for ac_1: {'device_id': 'ac_1', 'switch_state': 'ON', 'temperature': 26}

```

Fig. 7: Implementation Result

FUTURE SCOPE

1. Integration with AI, ML, and IoT[22]: Enhance automation and analytics capabilities. 2. Advanced Security: Implement end-to-end encryption, intrusion detection, and secure firmware updates. 3. Enhanced User Experience: Integrate voice assistants, develop mobile apps, and enable customizable automation. 4. Scalability and Interoperability: Ensure cloud-agnostic deployment[23], device interoperability, and open APIs/SDKs. 5. Real-World Deployment and Testing: Conduct pilot deployments, gather user feedback, and continuously improve the system.

CONCLUSION

Simulating MQTT-enabled smart home systems with edge servers[19] is crucial for developing robust and scalable solutions. By leveraging MQTT's [18] lightweight messaging and edge computing's localized processing power, these systems can achieve:

Improved responsiveness: Reduced latency and enhanced real-time control. Enhanced privacy and security[19]: Minimized data transmission to the cloud, improved local control. Increased reliability: Reduced dependence

on cloud connectivity, improved fault tolerance[20]. Optimized resource utilization[21]: Efficient data processing and reduced energy consumption.

Future research directions include integrating AI/ML, exploring advanced simulation techniques, and developing new applications for this promising technology.

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Metadata Extraction from Legal Contracts Using Large Language Models

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ABSTRACT

Contracts are formal agreements with legal force that govern interactions between people or entities. Different sections and clauses of the contracts are defined regarding obligations, rights, and responsibilities of each party involved. Due to the complexity as well as the volume of legal contracts, extracting key metadata is highly important in ensuring efficiency for legal professionals. This paper addresses the use of Large Language Models to automate the extraction of core metadata from legal contracts, including clauses such as liability, insurance, and jurisdiction, and organizing it into a structured, tabular format for easier analysis. We make use of the OpenAI Azure LLM to produce a full-stack solution, able to parse and structure this metadata into a format that is usable. The study addresses problems related to large prompt sizes and various optimization strategies that could be applied to such systems in order to attain better efficiency and accuracy. In addition, we include real-time FAQ generation from the legal contracts. The goal behind this research therefore is to verify the potential that LLMs may bring to streamline legal workflows while ideally addressing technical and operational challenges found in large-scale metadata extraction tasks.

KEYWORDS: *Legal contracts, LLM, Clauses, FAQ, Metadata.*

INTRODUCTION

A contract is a legally binding agreement that specifies the terms and conditions of the parties involved and is signed by at least two of them. Since contracts are usually written in text, there is a lot of room for NLP applications in the field of legal papers. However, contract language is repetitive with high inter-sentence similarities and sentence matches, in contrast to most natural language corpora that are typically used in NLP research. [1]

In the legal domain, collecting information from contracts poses three major hurdles for existing methods. The primary difficulty is the scarcity of data needed to train or fine-tune algorithms for high accuracy. Another difficulty is the large size of many contracts, which frequently exceeds the processing capacity of current transformer topologies. Transformer-based models have a limited

sequence length that they can accommodate. Contracts that exceed the limit may need to be broken into smaller portions, complicating the analyzing process. The third challenge is that contracts contain a mix of long and short entities, such as full clauses like non-complete and audit rights, and short ones like names and dates. [2]

Metadata extraction is the process of identifying and extracting specific data points from unstructured documents, and is becoming increasingly important for legal professionals. This is particularly true for clauses related to liability, insurance, indemnity, termination, and jurisdiction, which are crucial for understanding the legal implications of contracts. Manually reviewing large, complex contracts for specific clauses can be time-consuming and error-prone. By extracting information about liability, insurance, indemnity, termination, and

jurisdiction, etc legal professionals can better assess the potential risks associated with a contract.

To overcome these challenges, in this paper we proposed to extract metadata from an unstructured format to a structured format using LLM. This metadata will be formatted into a table. We proposed four tables: a quarterly report, which includes various clauses and important entities; a termination table, which includes all the termination clauses; an indemnification table, which includes all the indemnification clauses; and a basic table, which includes all important dates from the contracts and party names.

RELATED WORK

This paper proposes an unsupervised two-step approach for extracting knowledge from long legal contracts. It overcomes the token limitation in the basic LLMs and the lack of training data. As stated in the abstract, authors propose a query-based summarization model that extracts relevant sentences, thus reducing the text size without losing any core information. The summary is fed into GPT-3.5 to generate accurate metadata extraction. This method does not rely on the necessity of training domain-specific models unlike supervised models but depends on the pre-trained capabilities of LLMs which it uses to extract short and lengthy contract entities without fine-tuning. The performance exhibited was better and brought about state-of-the-art results in zero-resource settings, especially when contrasted with fine-tuned supervised models on domain-specific data. [2] This paper explores the application of Large Language Models (LLMs) in law by designing generative AI to optimize contract management. As already mentioned in the abstract, it uses Retrieval-Augmented Generation (RAG) to improve the analyzing ability and generate legal clauses of LLMs. The system uses semantic embeddings for accurate document retrieval and generation of contract clauses that are contextually relevant. It also employs Azure OpenAI models using alertness of prompting optimization to solve issues on contract complexity; it makes use of retrieval as well as LLMs to reduce the time lawyers take in reading and analyzing a contract, thereby making it possible to draft new contracts fast and accurately. As part of future work, the paper mentions the implementation of Optical Character Recognition (OCR) technology. [3] This will enable the system to handle non-digital legal documents, expanding its application breadth while boosting the depth of the analysis process. It will also enable the system to

extract text from scanned papers or PDFs. Optical Character Recognition, or simply OCR, is certainly one of the most important technologies by means of which printed or hand-written text can be scanned and converted to digital versions, saving literally hundreds of hours of time and labor when doing data entry and document management. As highlighted in the paper [4], OCR automates the process of extracting text from various sources, such as images and scanned documents, and converts it into searchable and editable digital content. This technology plays a vital role in industries that handle large volumes of data, enabling organizations to streamline operations, reduce errors, and improve overall productivity.

The paper [7] provides a methodology for automating the reporting of contracts and obligation extraction with LLMs, focusing particularly on filling in the DORA compliance templates and on extracting obligations from the contract. This introduction discusses how the emergence of LLMs like GPT-3 and GPT-4 creates opportunities for new avenues for automation with respect to automating complex tasks like information extraction from legal texts. These models were used in the experiments of this paper as a means of extracting specific data from legal contracts to test their accuracy in compliance and contractual obligation tasks. The system was shown to be highly accurate in filling compliance templates with up to 97.71%, but less so consistent in the extraction of obligations in legal contracts, with up to 70.56% accuracy in some cases. These results showcase the capabilities of LLMs for the purpose of changing the face of legal document management by saving manpower and increasing accuracy. Large language models (LLMs) have found increasing use in the legal sphere, demonstrating how these technologies may be tailored to industry-specific requirements. Prominent models comprise LegalBERT[8], CaseLaw-BERT[9], and FinBERT[15] which have been refined from generic models to tackle assignments including anticipating legal judgments, reviewing contracts, and other domains necessitating an intricate comprehension of legal terminology and concepts. These models demonstrate at least two aspects: the potential for LLMs to increase efficiencies in legal workflows and the role of domain-specific training in reaching almost precise relevance with respect to professional applications

PROPOSED SOLUTION

System Architecture

The full-stack solution built around OpenAI's Azure LLM

is designed to automate the extraction of key metadata from legal contracts. The system architecture comprises several key components:

Input (Contract Documents)

Users can upload contract documents in various formats, such as PDF or DOCX. To ensure compatibility and efficient processing, the system extracts the text from these contracts. If the contract is in a non-digital format (e.g., a scanned image), Optical Character Recognition (OCR) is used to extract the text. Tools such as Pytesseract are used to ensure high accuracy when converting image-based contracts into text format.

LLM for Clause Extraction

- Once the text is extracted, it is passed through the OpenAI Azure LLM for clause extraction. The LLM is specifically prompted to identify key clauses, such as liability, insurance, and jurisdiction.
- The system uses semantic embeddings and context-aware language models to recognize specific patterns and extract relevant metadata from the contract clauses, which are often complex and filled with legal jargon.
- The LLM processes the contract and returns the extracted metadata in a structured output format.

Structured Output in Tabular Format

The extracted metadata is organized into a tabular format for easy review and further analysis. Each row in the table corresponds to a metadata type (e.g., Liability, Insurance, Jurisdiction) with columns containing the extracted information.

Our proposed solution extracts four tables:

Basic Table: This table includes columns such as

Agreement Type, Client, Service Provider and Dates. Dates include:

- Document date: Date when the document was created.
- Effective date: Date when the agreement becomes effective
- End date: Date when the agreement ends. Termination Table: This table includes:
- Termination clauses: The specific sections or provisions in the contract that outline the conditions under which the agreement can be terminated. This

includes reasons for termination such as breach of contract, failure to meet obligations, or termination for convenience. The clauses also specify any notice periods, penalties, or other conditions for ending the contract.

- Clause number
- Who can terminate the agreement: Specifies which party or parties (e.g., Client, Service Provider, or both) have the right to terminate the agreement under the conditions set forth in the termination clause. Some contracts allow only one party to terminate, while others grant termination rights to both parties under certain circumstances.

Report: This table includes Client name:

- Liability: This term refers to the legal responsibility for damages or breaches under the contract. It can be capped at a certain amount or percentage of the contract's value (e.g., Work Order value). If capped, the liability is limited to the specified value mentioned in the "LIMITATION OF LIABILITY" clause. This clause protects one party by restricting their financial obligations in the case of legal claims.
- Uncapped liability: Certain liabilities may be uncapped, meaning they have no limit on the amount of compensation required. Common uncapped liabilities include claims related to death, personal injury, fraud, or breach of law. If liabilities are capped, this section will list the specific types of liabilities that remain uncapped.
- Warranty: Warranties ensure the quality or performance of products or services. If exceptions are present in the warranty (e.g., "except for certain conditions"), they should be noted. Otherwise, it is marked as "Standard" or "Not available" if the warranty section is absent.
- Indemnity: A legal obligation where one party agrees to compensate the other for losses, damages, or liabilities arising from specified actions or circumstances. If exceptions are present (e.g., indemnity does not apply in certain situations), they should be noted. Otherwise, it is marked as "Standard" or "Not available" if the indemnity section is absent.
- Services/Damage: Refers to the obligations regarding services provided under the contract and any potential damages. If the damages are ongoing, this should

be noted. A cap may be specified, which limits the amount of compensation for damages, either as a fixed amount or percentage.

- **Jurisdiction/Law:** The geographic location (country and city) whose laws govern the contract and where disputes arising under the contract will be resolved.
- **Termination for convenience:** A clause allowing one party, typically the service provider or client, to terminate the contract without cause. This provides flexibility to exit the agreement at any time, with advance notice as per the contract terms.
- **Insurance:** Refers to the types and amounts of insurance required to cover potential liabilities or risks in the agreement. This clause outlines the minimum coverage necessary for the parties involved.

The output is exported to csv format, which can be easily integrated into existing contract management systems or used for reporting purposes. The structure of the table includes fields like:

- **Clause Type:** The specific clause extracted (e.g., Liability).
- **Extracted Text:** The actual content of the clause from the contract.
- **Summary:** A brief summary generated by the LLM to give overall content

Optimizing Prompts Sizes

Large Language Models (LLMs) are intended to be effectively adapted to specific activities through prompt optimization. An appropriate prompt, whether textual or visual, improves the model's output to better fit the user's task [13]. One of the primary challenges of using Large Language Models (LLMs) like OpenAI's Azure model is handling large input text sizes, as legal contracts can be lengthy and exceed token limitations. To overcome this, the following strategies are employed:

Text Chunking

The contract text is divided into smaller chunks based on logical sections such as clauses, headings, or paragraph breaks. The LLM processes each chunk independently and extracts metadata for each section. This ensures that even large contracts can be processed within the token limit of the LLM without losing context or accuracy.

Summarization

For particularly large sections, a summarization step is added. The system uses the LLM to generate summaries of each section before extracting metadata. This reduces the overall token count while preserving the key information needed for metadata extraction. This step is useful when contracts contain extensive descriptions or legal explanations that may not be directly relevant to the metadata extraction process but are still necessary to retain for legal clarity.

Hierarchical Querying

Instead of sending the entire contract at once, the system performs hierarchical querying, where initial queries extract broad metadata (e.g., major sections like "Liability" or "Insurance"). Subsequent, more specific queries are then used to refine the extraction, targeting specific details within each clause. This two-step querying process minimizes the amount of text the model has to process in one go, ensuring efficient and focused metadata extraction.

Real-time FAQ Generation

One of the extra features of the system is the ability to generate real-time FAQs from the text of a contract. This is particularly useful for legal professionals who might be needed to provide some quick response to the fundamental questions related to a contract. The process of generating FAQs involves:

Natural Language Processing (NLP) for Query Understanding:

When a user asks a question related to the contract (e.g., "What are the liability limits?"), the system uses NLP to interpret the question and match it to the relevant sections of the contract. The OpenAI Azure LLM then searches the contract text to locate the clauses most likely to answer the user's query.

Answer Generation:

Once the relevant text is identified, the LLM generates a natural-language answer to the user's question. This answer includes the direct clause as well as a concise summary or explanation for better comprehension.

For example, if asked about payment obligations, the system extracts the payment terms and provides a summarized version, highlighting key details like deadlines and penalties.

Answer Generation:

Once the relevant text is identified, the LLM generates a natural-language answer to the user's question. This answer includes the direct clause as well as a concise summary or explanation for better comprehension.

For example, if asked about payment obligations, the system extracts the payment terms and provides a summarized version, highlighting key details like deadlines and penalties.

Continuous Learning:

The FAQ system is designed to learn from previous interactions. Over time, it builds a knowledge base of frequently asked questions and their corresponding answers, improving its efficiency and accuracy with repeated use. It also integrates user feedback to refine the generated answers, ensuring that the system evolves based on the needs of its users.

By integrating real-time FAQ generation, the system reduces the time legal professionals spend searching for specific information within contracts, allowing for quicker decision-making and better client support.

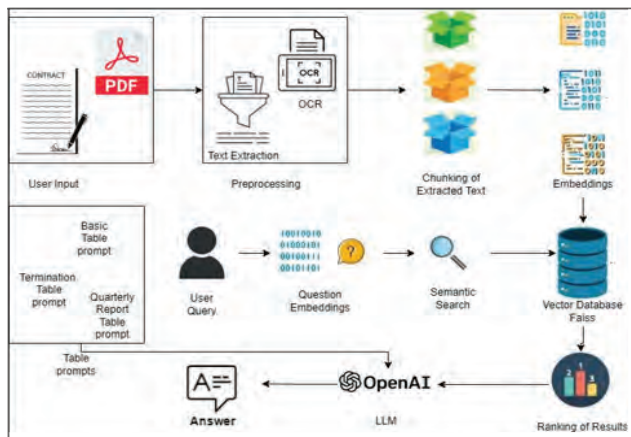


Fig 1. System Architecture

EXPERIMENTS AND RESULTS

Sample_MSA.pdf

Metadata

Agreement Type	Client	Service Provider	Document Date	Effective Date
1 Master Services Agreement	Not specified	Celonis	May 2021	The earlier of (A) your i

Fig. 2 Basic Table

Metadata

End Date	Clause Number	Title of the Clause	Notice Period	Who can terminate
Not specified	6.2	Termination for Convenience	30 days	Either Party
Not specified	16.2	Assignment	Not specified	Either Party
Not specified	16.4	Governing Law	Not specified	Not specified
Not specified	16.5	Amendments	Not specified	Both Parties
Not specified	16.6	Entire Agreement	Not specified	Not specified
Not specified	16.7	Severability	Not specified	Not specified
Not specified	16.8	No Waiver	Not specified	Not specified
Not specified	16.9	Export Control and Compliance	Not specified	Not specified
Not specified	16.10	Third Party Rights	Not specified	Not specified

Fig. 3 Termination Table

Metadata

Liability	Uncapped Liability
0	Intellectual Proper

Download data as CSV

Fig. 4 Liability clause of Report Table

Metadata

Warranty	Indemnity	Services/
0	Standard	Ongoing

Download data as CSV

Fig. 5 Warranty clause of Report Table

Metadata

Indemnity	Services/Damages	Jurisdiction/Law	Termination for convenience	Insurance
0	Standard	Ongoing	England, London	Not available in the context.

Fig. 6 Report Table

Are there any loopholes in this contract?

Based on the provided context, here are some potential loopholes or areas of concern in the contract:

- Non-Celonis Products and Services (Section 15):**
 - Liability Disclaimer:** Celonis expressly disclaims any liability for third-party products or services, even if they are designated as "certified" by Celonis. This could be a loophole where Celonis avoids responsibility for issues arising from third-party integrations, which might be critical for the overall functionality of the service.
- Sub-contracting (Section 16.1):**
 - Sub-contractor Liability:** While Celonis states it will be liable for any sub-contractors used, the term "qualified third party" is vague and not clearly defined. This could potentially allow Celonis to subcontract to entities that may not meet the client's expectations or standards.
- Assignment (Section 16.2):**
 - Assignment without Consent:** Celonis reserves the right to assign or transfer its rights and obligations to any of its affiliates or successors in business without the client's consent. This could lead to situations where the client is forced to work with a different entity than originally agreed upon, which might not be desirable.

Fig. 7 Chatbot Q&A

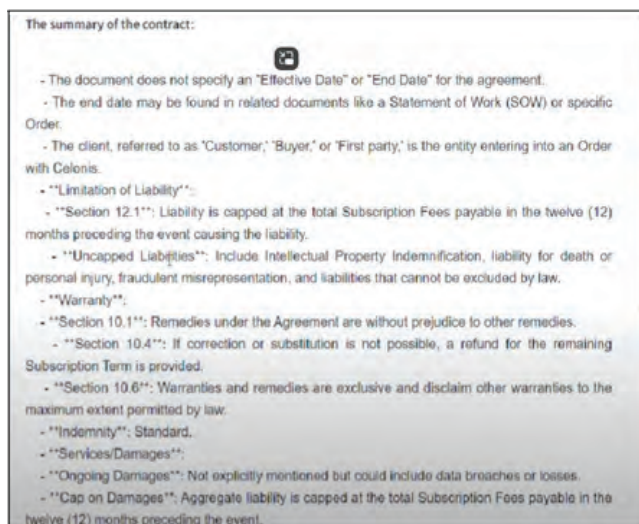


Fig. 8 Summary of Quarterly Report

LIMITATIONS

Scalability Issues with Large Contracts

- The proposed system relies on Large Language Models (LLMs) such as OpenAI's Azure LLM, which have inherent token limitations. Legal contracts often exceed the maximum context length that these models can process in a single query, requiring text chunking and hierarchical querying. This can lead to loss of contextual understanding between related clauses spread across different sections of a contract.
- Processing multiple large contracts simultaneously could significantly increase computational load, leading to higher latency and processing costs when deployed in a real-world legal setting with a high volume of contracts.

Handling Diverse Legal Documents

- Contracts vary significantly in structure, language, jurisdiction, and legal terminology. While the proposed system performs well with common legal clauses (e.g., liability, insurance, jurisdiction), it may struggle with domain-specific contracts such as those in healthcare, real estate, or mergers and acquisitions, where unique clauses exist.
- The system primarily focuses on English-language contracts, and while future work mentions multilingual support, legal translation and jurisdictional variations in phrasing and clause structuring remain a major challenge.

FUTURE WORK

To address the current limitations and further improve the system, several potential enhancements are proposed:

Overcoming Token Limitations

There are many strategies that can be pursued to overcome token limitations:

- **Text Chunking with Overlap:** Implement smarter chunking mechanisms with overlapping content to divide the text into chunks, which may help preserve continuity in clauses. This can ensure that even clauses spanning over multiple sections are captured appropriately.
- **Hierarchical summarization:** In case one has a very huge contract, that input can be summarized in a hierarchical procedure wherein a summary is made first, and then the summary will be processed toward metadata extraction. It will reduce the amount of the input text while conserving the most important information for the end user. We aim to prototype and test hierarchical summarization within the next quarter, focusing initially on reducing text size while maintaining critical information.
- **Memory-Augmented Models:** Using memory augmented LLMs or longer context windows, for instance in GPT-4, which extends token capability, the model can process huge blocks of text while having contextual information from previous sections.

Multi-lingual Contract Support

Most contracts are multilingual. International business has a significant share of contracts in multiple languages. It would be very precious to expand the system to accommodate such multilingual contracts. There would be scope for using multilingual models like mBERT or XLM-R. More importantly, the model could be fine-tuned for legal documents in different languages- French, Spanish, German, or Arabic. In the next six months, we plan to introduce support for European languages (French, Spanish, German), followed by Arabic and Asian languages in the next year. This would enable the system to operate with contracts spread across various legal jurisdictions and less dependent on translation services.

CONCLUSION

This work demonstrates the capacity of LLMs, such as the OpenAI Azure LLM, to automate the extraction of

essential metadata from legal contracts. The system quickly identifies and extracts all the pertinent clauses concerning liability, insurance, jurisdiction, and terms of payment, then structures them in tabular form for easy analysis and review. We have proposed four tables which provides with effective analysis of legal contracts. In addition, real-time generation of FAQs based on the content of a contract has more functionality integrated into the system: legal professionals can now query particular details of a contract and receive an accurate response instantly. It has reduced manual efforts in analyzing contracts, with LLMs instead hastening workflows, minimizing human error, and improving the efficiency associated with legal processes. The result is the ability of LLM-based systems in changing legal professionals' interfaces with complex contracts, especially in metastuffs like data extraction and compliance checking.

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Financial and Corporate Risk Analysis Using Large Language Models (LLMs)

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ABSTRACT

The purpose of this paper is to examine how Large Language Models (LLMs), specifically Gemini, may be used in financial and corporate risk analysis. In particular, we utilize LLMs to perform risk assessment activities using corporate data in the form of Corporate Earnings Calls, Annual Public Reports and Environmental, Social, and Governance (ESG) reports. Our objective is to understand the potential risks of doing business by undertaking individual risk assessment in these data sources. All these risk assessments are subsequently combined into one risk report, reflecting all possible risk exposures associated with the company's activities. This technique improves the overall efficiency of risk assessment due to the decrease of time needed for its completion while increasing the quality of available information for decision-making.

KEYWORDS: *Large Language Models (LLMs), Gemini, Financial risk analysis, Corporate risk assessment, Corporate earnings calls, Annual public reports, ESG reports, Generative AI, Risk reporting, Corporate governance.*

INTRODUCTION

In an era marked by increasing economic globalization, businesses present tremendous opportunities to expand but also face increasing pressures from competitive markets [1]. As organizations seek to capture this environment actively, risk management and compliance have become key components of corporate governance, especially in financial services ensuring that companies can maintain trust and stability [2].

Today's complex corporate environment calls for a comprehensive risk management strategy to build organizational resilience and sustainability [3]. Financial pitfalls, in particular, are receiving accelerating engrossment due to their potentially eloquent impact on the organization's future. These risks can arise from a variety of sources, such as market fluctuations, regulatory changes, or faulty internal controls, making it necessary for

companies to take a holistic approach to risk assessment and management [4].

The field of risk assessment and management has been firmly established over the last 30–40 years, during which time it has evolved into an organized scientific discipline [5]. The decision-makers need to see beyond the risk evaluation; they need to combine the risk information they have received with information from other sources and on other topics [5].

The objective of this paper is to explore Large Language Models (LLMs) like Google's Gemini, which can enhance the risk assessment and management process by analyzing unstructured data from sources such as corporate earnings calls, annual public reports, and ESG reports. These insights, when combined, provide a solid foundation for more accurate and comprehensive risk assessments, ultimately contributing to better corporate decision-making.

RELATED WORK

The exploration of financial risk prediction and management using advanced machine learning models has been expanding, offering innovative techniques for understanding and mitigating financial risks.

In the paper RiskLabs: Predicting Financial Risk Using Large Language Models Based on Multi-Sources Data [6], the authors present the RiskLab framework, which integrates multiple modules to handle diverse sources of information such as earnings conference calls and time-series data. By employing techniques like self-attention and Bayes-Value at Risk (VaR) forecasting, the framework demonstrates a sophisticated approach to combining news filtering and contextual compression to achieve more flexible training. A major merit of this framework is its ability to generate nuanced, multi-task predictions that provide investors with comprehensive insights into market conditions. However, a significant limitation is the reliance on large language models (LLMs), which can sometimes produce inaccurate or misleading responses, such as hallucinations, and struggle with real-time market updates due to outdated data sources.

In Enhancing Credit Risk Reports Generation Using LLMs: An Integration of Bayesian Networks and Labeled Guide Prompting [7], the authors focus on generating high-quality credit risk reports through a combination of Labeled Guide Prompting (LGP) and Bayesian networks. This methodology ensures the outputs from GPT-4 align closely with the specific requirements of credit risk analysis. A notable merit is that the generated reports were statistically preferred over traditional human-generated reports. The integration of LLMs into the credit risk process improves efficiency and scalability, making it an attractive solution for large-scale financial assessments. However, GPT-4's tendency to equally weigh all features poses a limitation, potentially failing to account for the importance of various risk factors in real-world assessments. Additionally, the model's occasional inaccuracies raise concerns about the reliability of its output.

The third paper, Fusing LLMs and Knowledge Graphs for Formal Causal Reasoning Behind Financial Risk Contagion [8], offers a novel approach to understanding how financial risks spread across interconnected entities. The Risk Contagion Causal Reasoning Model integrates Financial Knowledge Graphs (KGs) with LLMs to provide a formal causal understanding of financial contagion. By employing a fusion module and Sankey diagrams, the

authors successfully show the pathways through which risks propagate. This model enhances the ability to develop targeted strategies for preventing financial crises, identifying critical nodes in the risk network. However, the challenge lies in integrating unstructured language data with structured graph data, and the model's success is dependent on the quality of the underlying financial KGs, which may not always be available or accurate.

Finally, Deep Learning Model-Driven Financial Risk Prediction and Analysis [9] explores the application of generative deep learning models for simulating financial time series data and predicting Value at Risk (VaR). By comparing the performance of different generative models, such as GANs (Generative Adversarial Networks), the paper highlights significant improvements in VaR prediction accuracy. This approach is particularly effective at capturing the complex distribution patterns in financial data. However, a notable limitation is the model's inability to quickly adapt to sudden market changes, which can lead to inaccurate predictions during crises, where rapid responses are critical.

INPUT SOURCES

The system deals with three input sources. They are elaborated as follows:

Corporate Earnings Call

Earnings calls play a significant role in increasing investment in the company by providing economic communication. Earnings conference calls are held following the quarterly release of a company's earnings and have grown in popularity in recent years, owing to their ease of access via modern communication media (e.g., programs like EarningsCast, interactive investor-relation websites)[10][11]. The goal of these calls is to inform the market about the firm's future strategy and tactics, as well as remark on the previous quarter's revenue streams and costs [10][11].

Annual Public Report

An annual public report is a detailed report that public companies are required to present annually to their shareholders and the local tax office which can prepare auditor's reports. Annual report of a company contains the directors' report, the auditor's report, the financial statements and the schedules and notes to the accounts [12]. For all the companies under the Ministry of Corporate Affairs (under Section 217 of Companies Act, 2013),

(approx. 2263265 companies), it is mandatory to publish an annual report.

Environmental, Social and Governance Report (ESG)

ESG reporting is the disclosure of environmental, social and corporate governance data. As with all disclosures, its purpose is to shed light on a company's ESG activities while improving investor transparency and inspiring other organizations to do the same. Since ESG reports summarize the qualitative and quantitative benefits of a company's ESG activities, investors can screen investments, align investments to their values, and avoid companies with the risk of environmental damage, social missteps or corruption [13].

PROPOSED SOLUTION

The user can upload either one or two or all of the three input sources i.e. corporate earning call, annual public report, ESG report. A risk assessment will be done on each of these sources. Risk analysis will be done based on the following parameters:

1. Highlight the statements depicting risk
2. Highlight the statements with negative impact
3. For numerical data, the system will distinguish between positive and negative trends. For example, a decrease in profits by x% will be classified as negative, whereas a decrease in losses by x% will be considered as positive. This nuanced approach will ensure that negative statements are accurately identified while recognizing any improvements.

The assessment results are further analyzed and suggestions to lower the risk are given. Finally, these assessment results would be combined to form a risk report.

METHODOLOGY

Step 1: Uploading Files

1. The document is given as input using streamlit's file uploader component.
2. The user clicks on the 'Process PDF' button.

Step 2: Processing the Files

1. The process_pdf() function is called. This function reads the text content from each page of the PDF file using the 'PdfReader' from the PyPDF2 library.
2. The text content from each page is concatenated to form a single string representing the entire document.

3. The get_text_chunks() function is called. This function takes the text string as input and splits it into smaller chunks. It uses 'RecursiveCharacterTextSplitter' from the LangChain Library to split the text into chunks of size 5000 with an overlapping of 1000.
4. The get_vector_store() function is called. In the context of Natural Language Processing, the Vector store is a data structure which stores the vector representation of textual data. This function takes the text chunk as input. It generates vector embeddings for each text chunk using the Google Generative AI embeddings. These embeddings are stored in a vector store created using the FAISS Library.
5. The get_conversational_chain() function is called. This function creates a conversational chain using the LangChain library. It takes the vector store and a prompt template as input.
6. First, it initializes the gemini-1.5-flash model which is our large language model for generating responses.
7. It creates a memory component 'Conversation Buffer Memory' to store the conversation history.

Step 3: Handling User Queries

1. Now as the PDFs are processed, the user enters a question and clicks on get response.
2. The user_input function is called. It takes the user's question as input. This function interacts with the conversational chain stored in the streamlit session state to retrieve a response.
3. The vector representation of the query is created and is compared with the vector representations present in the vector store.
4. The most similar vectors are then retrieved based on the similarity.
5. The conversation history is updated and displayed to the user.

Step 4: Displaying the Response

1. First, the code checks if there is any conversation history stored in streamlit session state. If it is there, it iterates through each message in the history.
2. For each message, it checks if the message index ('i') is even or odd. If it is even, it is the user's message and if it is odd, it is the bot's message.

3. If it is the response, it checks if the response contains table formatting by looking for '|' and '---' characters.
4. If yes, then it parses the response into a dataframe, eliminates dirty values and displays it as a table.
5. Then, it extracts the data from the table into a data.csv file.
6. This data is string data. It contains words like million, billion, M, B, %, \$, etc. We convert those characters into empty string and then the entire value into float and plot the graph.
7. But, if there is no table in the response, it is displayed as a plain text.

Step 5: Generating FAQs

1. We have predefined categories and questions.
2. The response is retrieved the same way as user queries are answers.

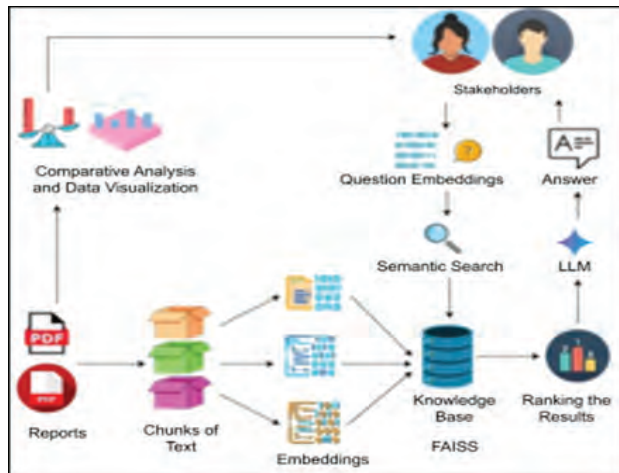


Fig. 1 System Architecture based

RESULTS

The input taken here is a sample document which contains some information about the company XYZ Corporation.

The proposed solution will yield the following outcomes:

Statements Depicting Risk

The statements depicting risk are the excerpts or phrases that highlight the potential risks to the concerned company. These risks can be regarding the operations, finances, reputation, etc. The challenges depicting risk can be regulatory changes, supply chain disruptions, economic downturns, cybersecurity threats, or competitive pressures.

XYZ Corporation Financial Overview

In the fiscal year ending December 31, 2023, XYZ Corporation reported a total revenue of \$1.2 billion, reflecting a modest increase of 5% compared to the previous year. However, the company's net profit experienced a significant decline, dropping by 15% to \$150 million. This downturn is attributed to rising operational costs and increased competition in the market.

XYZ Corporation has implemented several strategic initiatives to address these challenges. The company has invested heavily in technology upgrades, allocating \$100 million towards enhancing its digital infrastructure and improving operational efficiencies. This strategic pivot aims to streamline processes and reduce costs in the long run.

Despite these efforts, the company acknowledges the inherent risks associated with its expansion strategy. The volatility in raw material prices poses a threat to profit margins, as indicated by a 10% increase in material costs over the past year. Additionally, the ongoing geopolitical tensions in key markets have raised concerns regarding supply chain stability, potentially impacting product availability and pricing.

Looking forward, XYZ Corporation remains committed to diversifying its product offerings and exploring new market opportunities. The management team is optimistic about achieving a revenue target of \$1.5 billion by the end of 2024. However, they also caution that achieving this goal will require navigating significant market uncertainties, including regulatory changes and economic fluctuations.

In summary, while XYZ Corporation has laid out a comprehensive strategy to enhance profitability and growth, the company remains vigilant of the risks that could affect its financial health and operational success.

Fig. 2 Input Document - Financial Overview of XYZ Corporation

The Gemini-1.5-flash model identifies them using the following:

Semantic Understanding

Using natural language understanding (NLU), Gemini identifies sentences and phrases that convey uncertainty, challenges, or potential threats.

Keyword Detection

It scans for risk-related terms such as "challenge," "uncertainty," "adverse impact," "vulnerability," and "risk."

Contextual Analysis

By analyzing the surrounding context, Gemini differentiates between routine business updates and genuine risk indicators.

Training Data

The model is fine-tuned on large datasets containing risk statements from similar financial reports, enabling it to recognize patterns.

Fig. 3 showcases the statements depicting risks that were extracted by the system from the financial overview which was given as an input.

Negative Impact Statements

The statements that directly mention the adverse effects faced by the company or the effects that the company may face in the future. This could be due to some internal or external factors. The examples can include losses from

lawsuits, revenue declines due to market conditions, or negative feedback from stakeholders.

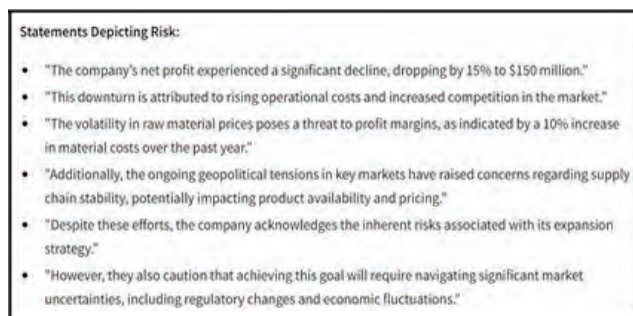


Fig. 3 Statements Depicting Risk for XYZ Corporation

The Gemini-1.5-flash model identifies them using the following:

Sentiment Analysis

Gemini uses sentiment analysis to classify sections of text as negative, neutral, or positive, flagging phrases that have a distinctly negative tone.

Phrase Extraction

It looks for phrases indicating setbacks, losses, or failures, such as "declined revenue," "adverse effects," "unexpected losses," or "regulatory penalties."

Section Focus

Specific sections, like "Management Discussion and Analysis" or "Operational Challenges," are prioritized for deeper analysis.

Fig. 4 showcases the negative impact statements that were extracted by the system from the financial overview which was given as an input.

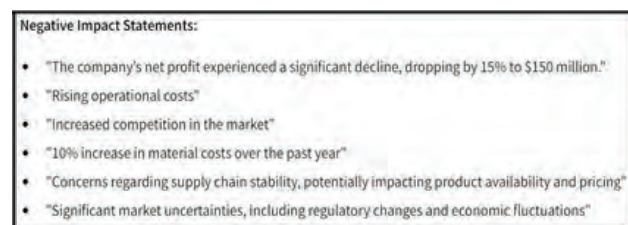


Fig. 4 Negative Impact Statements for XYZ Corporation

Quantifiable Data Classified Into Positive And Negative Trends

This involves analyzing numerical data provided in the reports, such as financial statements, to determine trends. Positive trends include growth in revenue, increased

profit margins, or higher customer acquisition rates, while negative trends include declining sales, rising debts, or shrinking market share.

The Gemini-1.5-flash model identifies them using the following:

Data Extraction

Gemini identifies and extracts numerical data from financial tables, charts, and statements, including income statements, balance sheets, and cash flow reports.

Trend Detection

Using historical comparisons (e.g., year-over-year or quarter-over-quarter changes), it determines whether trends are positive or negative.

Sentiment and Impact Analysis

Phrases accompanying numerical data, such as "strong growth" or "significant decline," are analyzed to classify trends effectively.

Rule-Based Models

Gemini applies predefined financial rules (e.g., a decline in net income over consecutive periods is flagged as negative) to supplement its ML-based approach.

Fig. 5 showcases the quantifiable data classified into positive and negative trends that were extracted by the system from the financial overview which was given as an input.



Fig. 5 Quantifiable Data Classified into Positive and Negative Trends for XYZ Corporation

An Analysis of All The Extracted Data - Risk Analysis

This step involves synthesizing all identified risks, impacts, and trends into a coherent narrative to assess the overall risk profile of the company. It includes understanding the likelihood of risks materializing, their potential impact, and the company's preparedness to address them.

The Gemini-1.5-flash model gives the assessment summary using the following:

Correlation of Insights

Gemini synthesizes extracted data, connecting risk statements, negative impacts, and quantifiable trends to create a comprehensive picture of the company's risk profile.

Model Outputs

It uses probabilistic models to evaluate the likelihood and severity of risks.

Risk Taxonomy

Gemini maps extracted data to predefined risk categories (e.g., operational, financial, or compliance risks) based on its understanding of similar documents.

Fig. 6 showcases the risk assessment summary which was generated by the system from the financial overview which was given as an input and the previous results.

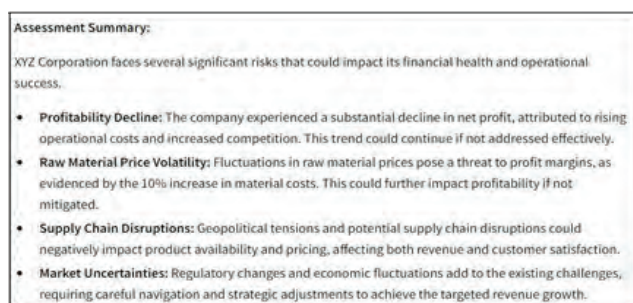


Fig. 6 Risk Assessment for XYZ Corporation

Risk Mitigation Suggestions

Based on the risk analysis, this involves proposing actionable steps the company can take to reduce exposure to identified risks. Suggestions can be operational, strategic, or technological and may include diversifying supply chains, enhancing cybersecurity measures, or adopting new technologies.

The Gemini-1.5-flash model gives the suggestions using the following:

Generative Capabilities

Leveraging its generative abilities, Gemini provides actionable recommendations based on best practices and historical data.

Trend-Based Recommendations

For example, if a downward trend in revenue is identified, Gemini might suggest cost-cutting measures or diversifying revenue streams.

Mitigation Mapping

The model correlates risks to solutions provided in the company report or external sources, enabling it to suggest precise mitigation strategies.

Fig. 7 showcases the risk mitigation suggestions which were generated by the system from the financial overview which was given as an input.



Fig. 7 Risk Mitigation for XYZ Corporation

TECHNOLOGIES USED

Google Gemini API

Gemini is a family of highly capable multimodal models developed at Google [14]. The system is powered by the Gemini-1.5-flash model.

FAISS (Facebook AI Similarity Search)

Faiss is a library for ANNS. The core library is a collection of source files written in standard C++ without dependencies. Faiss is used in many configurations. Hundreds of vector search applications rely on it, both within Meta. [15] and externally. The proposed system deals with a large amount of textual data. Hence, FAISS is always preferred for scalability as it avoids a drop in performance. The purpose of this utilization is to perform similarity search on the vectorized representations of the documents and for a quick and easy retrieval.

Streamlit

Streamlit is an open-source Python framework for data scientists and AI/ML engineers to deliver dynamic data apps with only a few lines of code. [16] With this framework, you can easily build interactive visualization plots, models, and dashboards without having to worry about the underlying web framework or deployment

infrastructure used in the backend [17]. Even though a Streamlit app is easy to build and deploy, it is not scalable. Hence, for large scale applications, frameworks like Flask, a Python-based framework would be preferred.

Langchain

Langchain is a custom Large Language Model tailored for organizations [18]. LLMs have been rapidly adopted due to their capabilities in accept a text string (prompt) and output a text string [19]. range of tasks, including essay composition, code writing, explanation, and debugging [19]. They

POTENTIAL BIASES AND INACCURACIES IN LLM OUTPUTS

LLMs, while powerful, may exhibit biases due to training data limitations. These biases can lead to inaccurate risk assessments, especially in subjective or nuanced financial contexts. Hallucinations, where the model generates incorrect information, pose a challenge. For risk analysis, such inaccuracies can misrepresent a company's financial health, leading to flawed strategic decisions. Mitigating these issues requires integrating LLMs with external verification mechanisms and structured financial data.

Biases in LLMs often stem from the data they are trained on, which may include historical financial documents reflecting systemic biases. For instance, if past reports underrepresented risks in certain industries, the model may downplay potential threats. Additionally, LLMs might overemphasize commonly reported risks while overlooking emerging financial threats due to a lack of sufficient training data.

Another challenge is the tendency of LLMs to struggle with real-time market updates. Unlike traditional financial models that integrate live data feeds, LLMs depend on their training corpus, which may become outdated. This can lead to risk assessments that do not fully account for recent economic disruptions, regulatory changes, or unexpected financial crises, making human oversight essential for ensuring accuracy.

FUTURE SCOPE

The current implementation of the risk assessment system has considerable utility at accelerating evaluation of the financial documents and risk reports' compilation. However, there are multiple areas where the system can be extended and improved to better meet the needs of organizations and enhance its capabilities:

Customizable Report Formats

Another important feature which should be anticipated in the future is the possibility of an implementation to define the layout and structure of the risk reports produced. It has become a norm for different companies to have preferred style of reporting, including sections preferred in the report, preferred kind of diagrams or tables, or industry-specific language. It was proposed that, through a reporting feature that can be customized, the user would be able to prepare the report according to internal rules or other requirements.

Linking of documents to more than one document type

The present system of analyzing and interpreting the PDF-file format of financial reports may be expanded in subsequent versions for other formats, such as Excel tables, Word documents or even access to database information. This would enhance flexibility of the system in handling accounting information from various data feeds from different sources, and would also ensure compatibility to various documentation processes by companies.

CONCLUSION

This research outlines a simple way of automating financial risk assessment through Gemini 1.5 Flash coupled with enhanced user interface. The system is extremely effective to scan financial documents, flag risks and offer actionable intelligence. Automating risk analysis therefore enables organizations to take quicker and better decisions. Additional additions such as report features, or industry-specific models will enhance the system's flexibility making the system relevant for companies as they grapple with sophisticated risk levels.

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Krishi Kaushal-AI Rover for Precision Farming

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ABSTRACT

This paper seeks to address one of the few issues Indian farmers face: the wasteful use of water on agricultural land, which has an adverse effect on the environment and soil. Understanding the components of soil, the foundation of all farming, aids in determining what is needed for improved plant growth. The method is divided into two parts. The first involves using algorithms to forecast results by assessing natural parameters such as soil moisture, temperature, and humidity. The next is identifying the health of the plant by classifying images of its leaflets. The primary aim is to achieve the combined outcomes of the two approaches by means of a rover inspired by the Rockie-Boger model that is most effective over the terrestrial terrain and can access the majority of the land. The end result is shown via the web application, which provides a thorough explanation and straightforward analysis of the farm's water needs, identifies the arid regions, and modifies farming practices such as watering schedules and sprinkler placement accuracy. The entire procedure is to advance AI prediction and robotic automation in farming methods for improved outcomes and higher yields.

KEYWORDS: *Agro rover, Precision farming, Indian agriculture, Smart agriculture, Foodtech, Rural development.*

INTRODUCTION

Research on integrating automated vehicle guidance into agriculture started to take shape in the 1920s, marking the earliest development of robots in this field. The vehicles still needed a cable system to direct their course; therefore, the idea was not flawless. As technologies in other industries started to advance, so did agricultural robots. Machine vision guiding was not made feasible until the 1980s; after the invention of the computer, it was enhanced eventually. From the aspect of farming, 18 percent of the world's population lives in India, with 4 percent of the world's pure water, of which 80 percent is used for agriculture. Along with an average of 4,000 billion cubic meters of precipitation falling on India annually. However, surface and groundwater bodies in India only use 48 percent of it. Also, which leads to the major problem of water droughts, irrelevant use of water.

Knowing the elements of the soil helps one to comprehend the variations and analyse the plant's health. It also starts with a prediction of the growth over a particular length of time. However, rover is ideal for the terrestrial terrain and fit for traversing the agricultural field using sensors to identify the dry sections. This is accomplished with the help of soil's moisture level, temperature, humidity, etc. data. Furthermore, classifying plant health by taking pictures with a camera module and uploading them to the database. The whole data is submitted to the logistic regression model and tensor flow to provide simple and understandable data for the farmers. Currently, multiple progress is going on, like [12] Exploration of applications of unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs) for various agricultural tasks like monitoring, spraying, and harvesting is going on, [11] Analyzing the potential of solar photovoltaic (PV)

technology to power agricultural devices and robots for sustainable operations, etc.

BLOCK DIAGRAM AND WORKING

The Agro Rover system is a comprehensive solution integrating hardware, software, and data analytics to optimise agricultural operations. The system consists of several components working in unison, as illustrated in Figure 1. Key hardware elements include environmental sensors, such as soil moisture, temperature, and humidity sensors, alongside the ESP32-CAM module for real-time image capture. These components are managed by the ESPdev microcontroller, which processes sensor readings and transmits the data to a centralised database. The software side comprises a predictive model that leverages machine learning algorithms to analyse the collected data, assess water requirements, monitor crop health, and identify potential anomalies such as diseases.

The workflow begins with the Agro Rover traversing the agricultural field to collect environmental data and images. The data is transmitted to the ESPdev microcontroller for preprocessing and then stored in the database. The predictive model processes the data to determine irrigation needs, guiding the system to distribute water precisely where required. This automation minimises water wastage while maximising field efficiency. Farmers can interact with the system through a mobile application, receiving real-time insights and actionable recommendations. The system also incorporates a feedback loop, ensuring continuous monitoring and iterative improvements to agricultural operations.

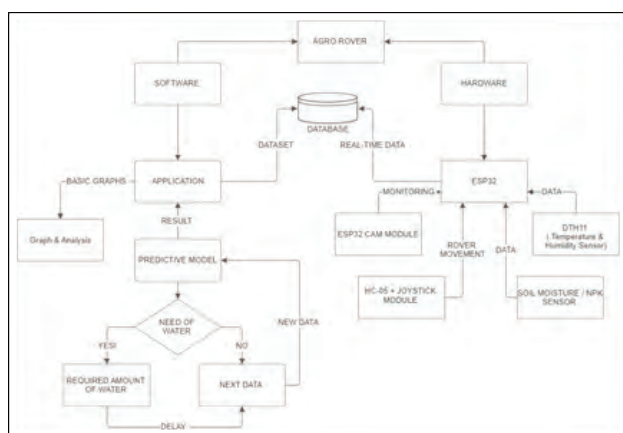


Fig. 1. Block Diagram of the Agro Rover System

Figure 2 illustrates the system's workflow, starting from initialisation with data about the agricultural land, including

crop type and soil conditions. The rover navigates the field, collects environmental data and images, analyses them for actionable insights, and initiates appropriate actions, such as watering or alerting farmers to detected anomalies. By combining advanced analytics, hardware capabilities, and a user-friendly interface, the Agro Rover system provides a robust, efficient, and scalable solution to modern agricultural challenges.

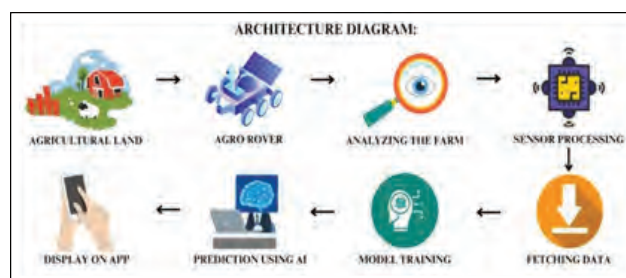


Fig. 2. System Workflow of Agro Rover

Working

Overview

The proposed system integrates a pulley mechanism and a rover model to automate agricultural monitoring. The pulley mechanism positions sensors like soil moisture sensors and DHT11 while a rover traverses uneven terrain. Data collected is transmitted via ESP8266 or ESP32-CAM and is processed using a machine learning (ML) algorithm for predictions.

Pulley Mechanism Design and Logic

The pulley mechanism enables precise positioning of sensors in a defined area. The system includes:

- Pulley or Balance wheel : Mounted to facilitate movement in X and Y axes.
- Motor Setup: DC motors, controlled by the ESP8266, manage vertical movements.
- Sensor Assembly: Soil moisture and DHT11 sensors are attached to a movable frame.

The movement is governed by the following equations:

$$d = r \cdot \theta \quad (1)$$

$$v = r \cdot \omega \quad (2)$$

where:

- d is the linear displacement,
- r is the pulley radius,

- θ is the angular displacement,
- v is the linear velocity, and
- ω is the angular velocity of the motor.

Rover Operation and Logic

The Rocker-Bogie rover is designed to traverse uneven agricultural terrain and collect data. It includes:

- **Chassis and Suspension:** The Rocker-Bogie design ensures stability on uneven surfaces.
- **Motor Driver:** The L298N motor driver controls the DC motors powering the wheels.
- **Bluetooth Control:** An HC-05 Bluetooth module connects to a mobile app for manual or automated movement control.

The rover follows a grid-like pattern and captures data as it moves, ensuring complete field coverage.

Image Classification Using ESP32-CAM

The ESP32-CAM module is mounted on the rover for real-time image capture. Key features include:

- Captures images of plants for health analysis.
- Images are stored in a cloud or local database via Wi-Fi.
- Data is fed into an ML algorithm to classify plant health and predict outcomes such as potential diseases through the leaflet images.

Machine Learning Integration

Data collected from sensors and images are processed using a machine learning (ML) algorithm:

- **Input Data:** Includes soil moisture, temperature, humidity, and plant images.
- **Algorithm:** A Logistic Regression model or a neural network implemented using TensorFlow.
- **Prediction Output:** Provides actionable insights for farmers, such as water requirements or plant health status.

Workflow

- 1) The pulley mechanism positions the sensors at predefined locations and collects soil and atmospheric data.
- 2) The rover traverses the field and captures images using the ESP32-CAM module.

- 3) Data from sensors and images is transmitted to the database.
- 4) The ML algorithm processes the data and provides predictions.

Figure 3 shows the pulley mechanism, and Figure 4 illustrates the Rocker-Bogie rover assembly.

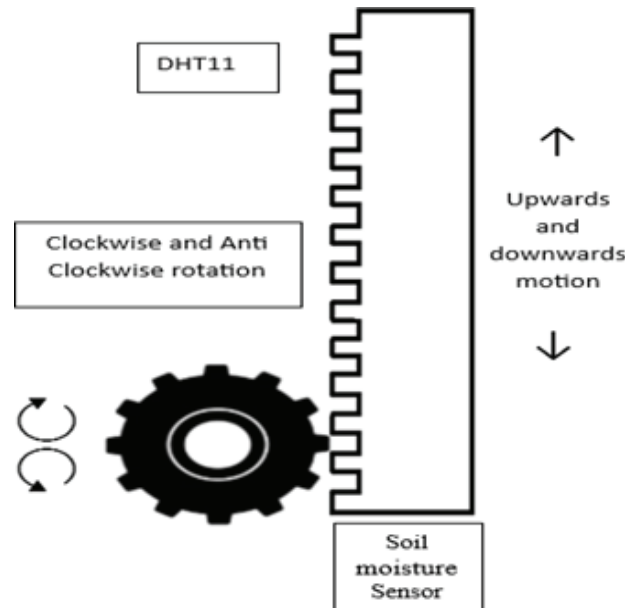


Fig. 3. Pulley Mechanism and Sensor Assembly

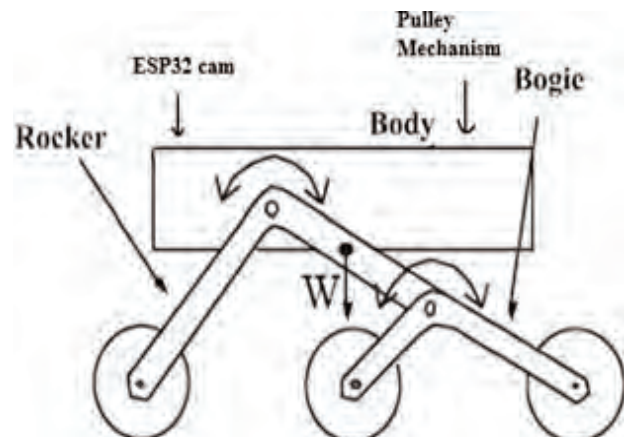


Fig. 4. Rocker-Bogie Rover model

Summary

The system combines a pulley mechanism and a rover for efficient field monitoring. Real-time data from sensors and images captured by the ESP32-CAM module is analyzed using machine learning algorithms to provide actionable insights for agricultural optimization.

METHODOLOGY AND RESULTS

Software

The software framework processes real-time data from sensors, transmitted via an ESP32 microcontroller to a centralized database. In the database, advanced machine learning models analyze trends and generate insights. Predictive analytics forecast water needs, evaluate crop health through image classification, and optimize resource allocation, such as water and fertilizers. A user-friendly application visualizes insights with graphs and provides real-time recommendations, including irrigation schedules and nutrient plans. AI-driven automation reduces human ability to diverse agricultural environments. This approach advances precision farming and supports sustainable practices.

Hardware

The hardware design integrates advanced components to enable efficient agricultural monitoring and automation. At its core, the ESP microcontroller manages operations and interfaces with various sensors, including the DHT11 for temperature and humidity measurements and a soil moisture sensor for tracking water levels.

Mobility is provided by a motorized system controlled by L298 motor drivers, ensuring precise autonomous navigation. The ESP32-CAM module captures high-resolution images for crop health analysis, while the HC-05 module allows for joystick-controlled manual operation when needed.

Powered by 12V batteries, the rover ensures reliable, uninterrupted performance for motors, sensors, and imaging systems, making it a robust tool for precision farming.



Fig. 5. Plant Disease Classification

Results

The results section presents the findings from the data collected during the implementation and operation of the AI Rover. These results highlight the system's overall performance in terms of sensor accuracy, system reliability, and the efficiency of predictive analytics.

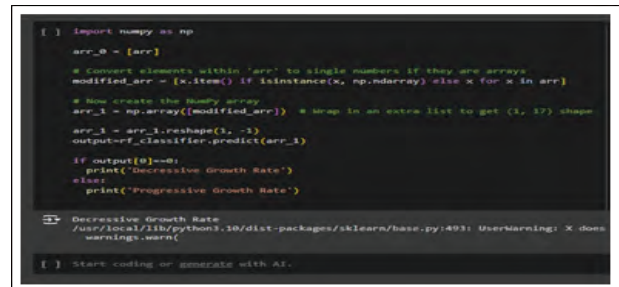


Fig. 6. Leaflet image analysis result

APPLICATIONS

The integration of robotic systems, machine learning, and precision agriculture technologies has enabled the following key applications in modern farming:

Field Automation and Crop Monitoring

Automation systems reduce manual labor and enhance efficiency in agricultural operations. Rovers equipped with sensors automate tasks such as soil analysis and crop monitoring. Using vision sensors, robots identify crop health and harvest readiness, ensuring optimal resource utilization [1].

Precision Agriculture

Precision agriculture leverages high-resolution soil and crop data collected by autonomous ground vehicles (AGVs). This data supports precise resource allocation, optimizing water, fertilizer, and pesticide usage while improving crop yields and reducing environmental impact [2].

Machine Learning Integration

Real-time data from sensors and images is analyzed using machine learning techniques, enabling classification, localization, and predictive decision-making. These insights are delivered to farmers through mobile applications for timely and informed actions [6].

Cost-Effective and Sustainable Robotics

Agricultural robotics use affordable materials like PVC and energy-efficient battery-powered designs. This makes

advanced technologies accessible to smallholder farmers while promoting sustainable farming practices[4].

All-Terrain Adaptability

Rovers with rocker-bogie suspension systems operate efficiently in rugged terrains, such as vineyards and uneven farmlands, ensuring mobility across diverse environments [9].

Remote Monitoring and Control

Mobile applications and Bluetooth-based control systems enable farmers to monitor and manage operations remotely, reducing physical presence requirements and enhancing operational flexibility [8].

Future Innovations

Prototypes for autonomous farming tools are being developed to refine functionalities and improve accessibility, with a focus on scalability and sustainability for diverse agricultural needs [5].

FUTURE SCOPE AND CONCLUSION

Agricultural rovers of the future will leverage advanced technologies to transform precision farming. These rovers will feature specialized cameras to closely monitor crop health, robotic arms to automate tasks like weeding and harvesting, and soil moisture analysis to optimize water usage. Integrated smart connectivity will allow the rovers to share real-time data with farmers, empowering better resource management decisions. Combining these innovative capabilities, the next-generation agricultural rovers will boost productivity, address labor shortages, and promote more sustainable farming practices.

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Ripple Line Magnet: Electricity Generation from Hybrid Source (Tidal Waves + Solar)

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ABSTRACT

This article provides an overview of the design, benefits, risks and environmental impacts of wave power plants. The aim of this initiative is to serve the society without harming the environment and ecosystem. It is based on renewable energy generated from ocean waves. Flaming of fossil fuels causes global warming, and waste generated from nuclear power plants is very dangerous. Accidents at these stations have had a significant impact on people's lives. The potential for generating electricity from ocean waves is enormous. With fossil fuels becoming scarce and prices continuing to rise, wave power plants have low operating costs, allowing them to generate electricity at competitive prices. Traditional hydroelectric power plants require dams, which can be detrimental to ecosystems and biodiversity in the environment. Contrarily, the proposed wave power plant does not require any other harmful structures or reducing installation costs.

This method of extracting electricity from ocean waves is reliable, sustainable, and environmentally friendly. Solar photovoltaic (PV) cells are also integrated into wave energy systems, allowing the power plant to harness the sun's energy. Solar cells tend to be more efficient in cold weather, making them an excellent hybrid energy source alongside Tidal energy.

KEYWORDS: Wave energy, Renewable source, Solar wave hybrid generation.

INTRODUCTION

Today, humanity is facing energy shortages and is trying to solve it with latest renewable energy sources instead of relying on old energy sources that are unsustainable and generate CO₂ emissions that are at risk of depletion within a few years. Therefore, we must consider the ocean as a valuable Source of clean and limitless energy. Since three-quarters of the Earth's surface is covered by the ocean, the ocean provides a significant opportunity for energy production.

Solar energy reaches the Earth and is absorbed by the ocean. The ocean acts as a huge solar battery. Various technologies have been developed to utilize ocean energy during this century. Tidal energy is energy that uses the

rhythmic movements and flood tide. Wave energy, on the other hand, relies on the vertical movement of surface water, which creates waves. Wave energy converts the regular up-and-down motion of ocean waves into electricity. This is done by installing equipment on the ocean surface that captures the energy generated by the wave movement and converts this mechanical energy into electricity.

The Project Solar Wave hybrid generator is designed to produce electricity continuously, 24/7. This generator combines wave energy with solar modules to maximize the production within the Confined area.

The basic working principle involves the vertical motion of waves, which pushes a float mechanism in the upward

and downward direction. This movement is utilized to turn a flywheel. The flywheel is then connected to a generator through a belt drive. Additionally, a solar panel is installed on peak of the structure of the structure, and the power generated from both sources is integrated using a charge controller circuit.

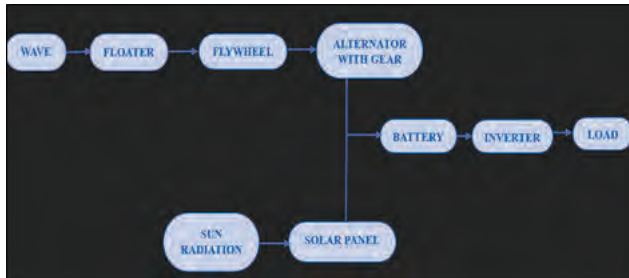


Fig. 1: Block Diagram of Tidal wave + solar generation

METHODOLOGY

Wave Power Generation

The proposed power generation system is not too complicated. It consists of several floats that moves in upward and downward direction depending on the pressure of the waves. Each float is attached to a shaft and connected to another shaft via a rack and pinion transmission, with a sprocket system between the rotating shaft and a parallel handle.

The gearwheel system ensures that the shaft rotates in only one direction. As the float moves upward, the shaft engages with a one-way bearing. Conversely, as the float moves downward, the bearing disengages from the shaft, leaving the shaft unaffected by this downward movement. As a result, the shaft rotates when the float moves up, but does not react when it moves down.

The shaft rotates unevenly because the float moves chaotically. To solve this problem, a flywheel is attached to the shaft to ensure more even rotation. Vibrations can be dangerous to the entire structure, but the entire system is designed to minimize these vibrations

Solar Power Generation

The photovoltaic (PV) module will be positioned at the top of the wave apparatus structure. Solar PV modules operate most efficiently in cooler temperatures. The primary purpose of integrating a solar module with a wave power generator is to utilize 24/7 wave energy generates while also harnessing solar power during daylight hours. Additionally, there is ample area in the ocean to put these

panels on the wave generator apparatus. Since the ocean environment is dust-free, the solar panels will not require frequent cleaning. These panels convert solar energy into electricity, which is then used to charge a 12-volt battery. This battery pack provides a constant voltage supply to the load. The most important advantage here is that it combines solar and wave energy.

PROPOSED MATHEMATICAL EQUATIONS

Alternator Calculation

Assuming Motor Specification:

Voltage – 24V

Current – 3A (rated current)

Power – 72W ($V \times I$)

Efficiency – 80% (typical for a stepper motor)

Assuming Generator specification:

Efficiency – 70% (typical for smaller generators)

Output voltage – 24V (assuming the same as the motor)

Output current: unknown (dependent on the generator design & load)

Mechanical Power output = Motor power $\times$ Efficiency = $72W \times 0.8 = 57.6W$

Electrical Power Output = Mechanical Power output $\times$ Generator efficiency = $57.6W \times 0.7 = 40.32$

Approx Output Current = Electrical Power Output / output Voltage = $40.32W / 24V = 1.68A$

So, approximately a 24V BIPOLAR STEPPER MOTOR GENERATOR can generate:

Output voltage: 24V

Output current: 1.68A

Electrical Power output: 40.32W

RESULTS AND DISCUSSION

1. Flywheel rpm by manual testing = 75 rpm
2. Flywheel rpm by practical testing 55 to 65 pm
3. Gear ratio 1:10
4. So, the rpm obtained initially was 65 rpm.

After using the gear ratio, the speed of the flywheel becomes 650 rpm.

5. The Voltage generated from the stepper generator during practical testing = 10 rpm

6. The efficiency of the motor will be around 35-40%.

ENVIRONMENTAL IMPACTS

The world is currently facing problems like pollution, including water, air, and soil contamination. The main cause of these environmental problems is existing power plants.

Nuclear power plants pose a radioactive hazard, while dams and other structures can cause ecological imbalances. They can also lead to polluted rivers and salt contamination in tropical regions. Fuels like Diesel and coal-fired power plants releases significant amounts of CO₂, SO₂, and NO₂, which causes acid rain and crop failure. The emissions from these plants are a major contributor to the greenhouse effect, which is what causes global warming reaching soon towards human lives.

In addition, dams used to produce tidal energy can also change tidal levels. This can cause problems such as reduced water discharge, freezing in winter, and erosion, which can destroy native flora and ecosystems.

On the other hand, wave power plants do not pollute the environment. Wave energy is renewable, clean, and green. They do not emit carbon dioxide or other by-products, and they do not produce greenhouse gas emissions or waste. As a renewable energy source, wave energy can help reduce our dependence on fossil fuels.

In addition, wave energy is a reliable option because it is always available. Solar energy is widely available and does not pollute the environment. Using hybrid power generation methods can maximize energy extraction from renewable energy sources.

CONCLUSIONS

The technology for harnessing ocean waves is still in its early stages. This paper presents a viable power generation plan using wave energy. The proposed approach has several advantageous features that position it as a renewable and eco-friendly energy source. Its simple design and ease of operation contribute to low maintenance costs, and its operating expenses are minimal, making it one of the most cost-effective forms of power available. As a renewable resource, it offers the potential for continuous energy production; once established, the energy is essentially free since it derives from ocean waves.

It's crucial to conclude the sum of power generation required for a company to achieve profitability. The analysis indicates that a surplus revenue, exceeding total costs, can be obtained at a capacity of 50 MW. Consequently, a wave power plant is feasible due to its Ethical, Renewable, and ecofriendly characteristics.

The system includes a gear mechanism located between the generator and the rotating shaft that drives the generator. This gear system also has the function of increasing speed. The main structure is secured to the seabed by cables, allowing it to move vertically as the water level changes. The design also allows the main structure to move slightly horizontally as the tide changes.

Moreover, while solar power extraction is relatively straightforward, it can be expensive. Combining it with the tidal power generator enhances efficiency. Both the operational and maintenance costs of the solar modules, which are located in the ocean, remain very low.

Future scope

Wave energy consists the significant perks of being a renewable resource which will never run out. Waves will continually crash against the shores of coastal nations, providing a constant source of energy.

Unlike fossil fuels, harnessing energy from waves produces no harmful by-products such as gases, waste, or pollution. This energy can be converted directly into electricity using specialized machinery, which can then power nearby generators and power plants.

Another benefit of wave energy is its proximity to urban areas. Many large cities and harbors are located next to the ocean, making it easier to harness wave power for their energy needs.

Moreover, when wave energy devices are placed offshore or near the shore, they do not pose a threat to aquatic life. In contrast, traditional energy systems often use turbines that are placed underwater, which can harm marine animals

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Autonomous Environment Surveillance Robot

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ABSTRACT

This paper presents the design and development of an autonomous surveillance robot leveraging advanced technologies such as Simultaneous Localization and Mapping (SLAM) and Light Detection and Ranging (LiDAR). The robot's architecture is centered around a Raspberry Pi, chosen for its versatility and cost-effectiveness, integrating multiple hardware components, including high-resolution sensors and fire detection modules, derived from earlier robotics projects. This intelligent system is engineered to autonomously navigate predefined and dynamic environments, identify anomalies, and enhance security operations through continuous monitoring and data analysis.

The proposed robot bridges the gap between traditional, static surveillance systems and modern autonomous solutions by offering enhanced mobility, adaptability, and precision. The combination of SLAM and LiDAR enables the robot to construct real-time environmental maps with remarkable accuracy, identify potential obstacles, and execute reliable path-planning algorithms, even in complex scenarios. These features make the system robust, adaptable, and highly reliable for real-world applications across industrial, commercial, and residential sectors.

Additionally, the robot incorporates advanced fire detection sensors, adding a critical safety layer that extends its utility beyond surveillance to proactive hazard detection and response. This paper highlights the development process, system architecture, and the results of extensive testing in simulated and real-world environments. The integration of modular hardware and software components ensures a scalable design, paving the way for widespread adoption in diverse security scenarios. By offering a holistic, cost-effective solution to modern surveillance challenges, this autonomous robot sets a new benchmark for intelligent security systems.

KEYWORDS: *Surveillance robot, LiDAR, SLAM, Raspberry Pi, Autonomous navigation, Security systems.*

INTRODUCTION

The increasing demand for automated security solutions has led to significant advancements in robotics and sensor technologies. Traditional surveillance systems rely heavily on human intervention, limiting their efficiency and scalability. Surveillance in high-risk areas, such as industrial sites, hazardous zones, and remote locations, demands innovative approaches that combine precision, adaptability, and efficiency.

Autonomous robots equipped with SLAM and LiDAR technologies offer a transformative approach to addressing

these challenges. Unlike static camera systems, these robots can navigate dynamic environments, adapt to changing scenarios, and provide real-time data for better decision-making. The ability to map environments in real time and localize within them makes SLAM indispensable for autonomous robots. LiDAR, with its high-resolution sensing capabilities, complements SLAM by providing detailed environmental data for obstacle detection and path planning.

This paper discusses the development of an autonomous surveillance robot that integrates LiDAR for environmental sensing and SLAM for real-time navigation. The Raspberry

Pi serves as the central processing unit, enabling seamless communication between hardware components and software algorithms. By integrating these technologies, the system offers an efficient and scalable solution tailored for security and monitoring applications.

RELATED WORK

The development of autonomous navigation and surveillance systems has been extensively studied, with significant contributions from various fields such as Simultaneous Localization and Mapping (SLAM) and LiDAR technologies. These technologies have proven essential in enabling robots to effectively navigate complex environments while detecting and avoiding obstacles.

Smith et al. [1] provided a comprehensive review of SLAM techniques, focusing on the advancements in visual, laser-based, and multi-modal approaches. Their work emphasized the flexibility and adaptability of SLAM systems, which can be deployed in various environments ranging from structured indoor spaces to unstructured outdoor terrains. The paper highlighted the crucial role of SLAM in autonomous robotics, enabling robots to create accurate environmental maps while simultaneously localizing themselves.

Johnson et al. [2] explored the transformative role of LiDAR in robotic navigation, specifically in generating precise 3D maps for enhanced spatial awareness. Their research demonstrated how LiDAR's integration with SLAM systems improves obstacle detection, path planning, and situational awareness in mobile robots. This combination of LiDAR and SLAM is particularly beneficial in dynamic environments, where real-time environmental sensing is critical.

In the realm of cost-effective surveillance systems, Lee et al. [3] focused on the use of Raspberry Pi as a low-cost platform for developing autonomous surveillance robots. Their work showcased the feasibility of building functional surveillance systems using affordable hardware, which can be deployed in diverse real-world scenarios. The study emphasized the scalability and accessibility of such systems, making them ideal for monitoring restricted areas and identifying potential threats.

Di Paola et al. [4] presented an autonomous mobile robotic system designed for indoor surveillance applications. Their system integrated navigation algorithms, obstacle avoidance, and real-time monitoring capabilities, addressing challenges such as dynamic obstacles and

limited lighting. This work provided valuable insights into the development of surveillance robots for indoor environments, which require adaptive navigation and situational awareness.

Building upon Di Paola et al.'s work, the study by [5] expanded the concept of autonomous surveillance systems by introducing hybrid navigation strategies. This research combined SLAM and pre-programmed paths to enhance the versatility of the robot, allowing it to operate efficiently in both structured and unstructured environments. Additionally, the integration of fire detection and safety monitoring capabilities was demonstrated, expanding the robot's functionality beyond traditional surveillance.

Lee and Shih [6] further contributed to the field by investigating autonomous surveillance for indoor security robots. Their work emphasized real-time decision-making and monitoring within enclosed spaces, where environmental conditions are often unpredictable. They incorporated advanced sensor technologies and algorithms, ensuring the robot could respond dynamically to changes in its environment, further advancing autonomous security systems for indoor use.

This body of research provides the foundation upon which our project builds. Our system integrates SLAM and LiDAR technologies to develop a unified platform for advanced surveillance tasks, drawing on the insights and innovations introduced by these studies. The combination of cost-effective hardware, robust navigation, and adaptive sensor integration has allowed us to create a versatile and scalable solution capable of addressing both indoor and outdoor surveillance challenges.

SYSTEM ARCHITECTURE

Hardware Components

LiDAR Sensor: The LiDAR sensor provides high-resolution 3D environmental data essential for SLAM and obstacle detection. With a 360-degree scanning capability, it ensures comprehensive mapping of the surroundings.

Raspberry Pi: The Raspberry Pi acts as the main processing unit, handling data analysis, sensor integration, and decision-making algorithms. Its compact size and computational power make it ideal for embedded robotic systems.

Fire Detection Sensors: These sensors enhance the robot's capability to detect thermal anomalies and potential hazards. They ensure rapid response to fire-related incidents, adding value to the surveillance system.

Motor Drivers and Actuators: These components enable precise movement and control of the robot. The use of brushless motors ensures durability and efficient operation.

Power Supply Unit: A reliable power supply is crucial for uninterrupted operation. The system incorporates a lithium-ion battery with a power management unit to distribute energy efficiently.

Software Components

ROS (Robot Operating System): ROS serves as the backbone for managing SLAM and path-planning algorithms. Its modular architecture facilitates seamless integration of various hardware and software components.

Python Scripts: Custom Python scripts are developed for sensor data acquisition, preprocessing, and control logic implementation. These scripts ensure efficient communication between hardware modules and decision-making algorithms.

Custom Mapping Algorithms: The mapping algorithms are tailored for predefined environments, optimizing navigation by integrating real-time sensor data with stored maps.

The following block diagram illustrates the system's hardware integration:

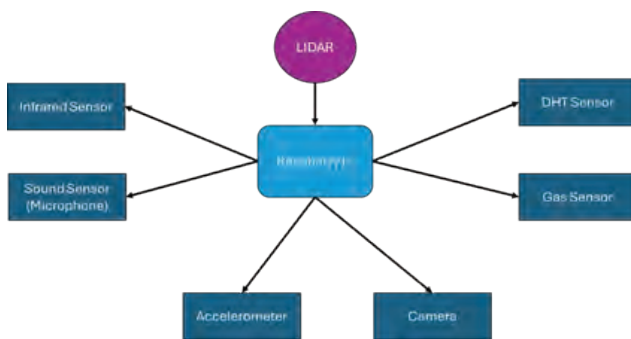


Fig. 1. Block diagram of the autonomous surveillance robot.

LiDAR (Light Detection and Ranging)

Function: LiDAR is a crucial component for environmental mapping and obstacle detection. It emits laser pulses and measures the time taken for the light to return to construct a 3D map of the surroundings.

Relation to Paper: This block supports SLAM (Simultaneous Localization and Mapping), enabling the robot to navigate autonomously and update its position in real time.

Infrared Sensor

Function: Detects obstacles or proximity of objects using infrared radiation. This sensor provides additional data for collision avoidance, complementing LiDAR.

Relation to Paper: Ensures safer navigation in environments with tight spaces or objects at close range.

Sound Sensor (Microphone)

Function: Captures audio signals for sound monitoring or anomaly detection, such as detecting breaking glass or unusual noises.

Relation to Paper: Enhances the robot's surveillance capabilities by integrating auditory data with visual and environmental monitoring.

Raspberry Pi

Function: The Raspberry Pi serves as the central processing unit, interfacing with all the sensors and actuators. It runs the control algorithms, SLAM processes, and manages data from connected components.

Relation to Paper: Acts as the brain of the robot, handling computation, decision-making, and communication between hardware components.

DHT Sensor

Function: Measures temperature and humidity levels in the robot's environment.

Relation to Paper: Provides environmental data for safety monitoring and alerts, contributing to its multi-functional nature.

Gas Sensor

Function: Detects hazardous gases, such as smoke or flammable substances, which could indicate fire or other emergencies.

Relation to Paper: Supports fire detection and safety applications by identifying potential dangers in real-time.

Accelerometer

Function: Measures the robot's motion, tilt, and orientation. It is used for stability control and monitoring the robot's movement.

Relation to Paper: Helps ensure precise navigation and positioning, especially in uneven terrain.

Camera

Function: Captures visual data for surveillance and video monitoring. The camera feeds can be analyzed for detecting movement or suspicious activities.

Relation to Paper: Provides an essential layer of visual surveillance, aligning with the robot's primary purpose.

The following circuit diagram shows the electronic connections of the system:

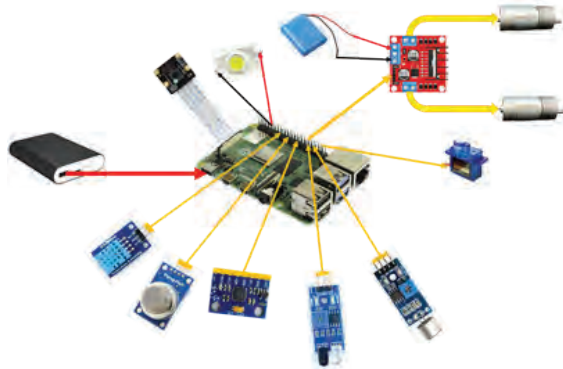


Fig. 2. Circuit diagram of the autonomous surveillance robot.

The circuit diagram in the image demonstrates a hardware setup for an autonomous surveillance robot, as discussed in the paper.

Central Processing Unit: Raspberry Pi

The Raspberry Pi is at the center of the diagram and serves as the primary controller for the surveillance robot. It processes data from connected sensors, executes SLAM algorithms for navigation, and coordinates overall system functionality.

Power Supply

A portable power bank and a battery module are depicted, providing energy to the Raspberry Pi and other components. A stable power source is essential for uninterrupted operation, especially in autonomous robots.

Sensors

Several sensors are connected to the Raspberry Pi, enabling the robot to perform various tasks:

- Environmental Monitoring Sensors:

Sensors like temperature, humidity, and gas detection modules likely measure environmental parameters and detect hazards.

- Obstacle Detection and Mapping:

LiDAR or ultrasonic sensors (noted in the upper-right section) are essential for mapping and obstacle avoidance. These align directly with the SLAM topic discussed in the paper.

- Fire Detection:

A dedicated fire sensor module is included, supporting the robot's ability to detect thermal anomalies, as mentioned in the paper.

Actuators

A motor driver and servos are shown in the diagram. These components control the movement of the robot, enabling it to navigate autonomously and adjust its orientation.

Camera Module

The camera, connected to the Raspberry Pi, allows the robot to capture visual data for real-time monitoring or video surveillance, supporting security applications as highlighted in the paper.

Communication Modules

Although not explicitly identified in the diagram, communication modules (e.g., Wi-Fi or Bluetooth) are typically integrated for transmitting surveillance data or receiving remote commands.

METHODOLOGY

SLAM Integration

Simultaneous Localization and Mapping (SLAM) is a cornerstone of the robot's functionality, enabling it to build a real-time, dynamic map of its surroundings while determining its precise location within that map. By processing data from the LiDAR sensor, the SLAM algorithm detects obstacles and creates an accurate spatial representation of the environment. Advanced SLAM techniques, such as graph-based optimization and particle filtering, are employed to improve the accuracy and robustness of the mapping process. These techniques are designed to minimize computational overhead, allowing the system to operate efficiently even with limited processing power. The integration of SLAM ensures that the robot can adapt to changing environments, providing reliable navigation and mapping capabilities crucial for autonomous operations.

Autonomous Navigation

The robot's ability to navigate autonomously is powered by sophisticated path-planning algorithms. These algorithms analyze SLAM outputs in conjunction with predefined waypoints to chart an efficient path through the environment. Autonomous navigation is further enhanced by incorporating obstacle avoidance mechanisms, which use a hybrid approach combining reactive and deliberative planning methods. Reactive planning allows the robot to respond quickly to immediate obstacles, while deliberative planning ensures long-term optimization of the path. This combination guarantees smooth and efficient operation, even in complex and dynamic environments, such as crowded areas or uneven terrains. By integrating data from multiple sensors, the robot ensures seamless navigation with minimal risk of collision, thereby maximizing its utility in surveillance and monitoring tasks.

Surveillance Features

Equipped with high-resolution cameras and an array of environmental sensors, the robot is designed to function as a comprehensive surveillance platform. It monitors its surroundings for changes, detects unauthorized activities, and sends alerts to a central monitoring station. The cameras provide real-time video streaming, enabling live monitoring, while advanced motion detection and pattern recognition algorithms analyze the feed to identify anomalies. These surveillance features are bolstered by the robot's ability to operate effectively under varying lighting conditions, such as low light or complete darkness, using infrared and night vision capabilities. Additionally, the robot can integrate audio data from sound sensors to enhance its monitoring range, making it a versatile tool for security applications in both indoor and outdoor environments.

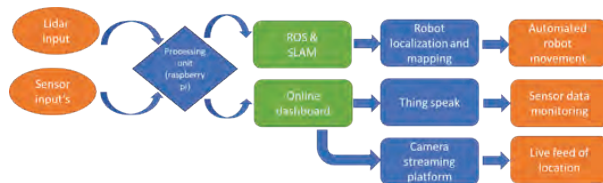


Fig. 3. Process Flow for Autonomous Surveillance Robot

Input Sources

LiDAR Input: LiDAR data serves as the primary source for environmental mapping and obstacle detection. It provides high-precision spatial information crucial for navigation and SLAM (Simultaneous Localization and Mapping).

Sensor Inputs: Other sensors, such as infrared, DHT (temperature and humidity), gas, sound, and accelerometer sensors, feed real-time environmental data into the system for monitoring and analysis.

Processing Unit (Raspberry Pi)

All input data from LiDAR and sensors is directed to the Raspberry Pi, which acts as the central processing unit. It is responsible for:

Running SLAM algorithms for real-time localization and mapping.

Integrating and analyzing sensor data for decision-making.

Managing communication between hardware components and software platforms.

ROS & SLAM

Robot Localization and Mapping: Using ROS (Robot Operating System) and SLAM, the robot processes LiDAR data to create a map of its environment. This enables precise localization within the mapped area.

Automated Robot Movement: Based on the generated map, the robot determines optimal paths and navigates autonomously while avoiding obstacles.

Online Dashboard

The processed data is uploaded to an online dashboard, allowing for real-time monitoring and control. This dashboard integrates with two platforms:

ThingSpeak: This IoT platform stores and visualizes sensor data, providing insights into environmental conditions like gas levels, temperature, and humidity. It enables remote monitoring and historical data analysis.

Camera Streaming Platform: The robot's camera feed is streamed live to a dedicated platform, allowing operators to view the robot's surroundings and monitor activities in real time.

Outputs

Robot Localization and Mapping: SLAM ensures the robot can autonomously move and map its surroundings, updating its location dynamically.

Sensor Data Monitoring: Real-time environmental data, such as temperature, gas concentration, or sound, is displayed on ThingSpeak for analysis and alerts.

Live Feed of Location: The camera streaming platform

provides a continuous video feed of the robot's environment, assisting in surveillance tasks.

RESULTS AND DISCUSSION

The system was tested in simulated and real-world environments. Results indicate that the robot effectively maps its surroundings, navigates autonomously, and detects anomalies with high accuracy. In a simulated environment, the robot achieved a mapping accuracy of over 95%, demonstrating its capability to handle complex layouts. In real-world testing, the integration of LiDAR and SLAM significantly improved the reliability of navigation compared to traditional GPS-based methods.

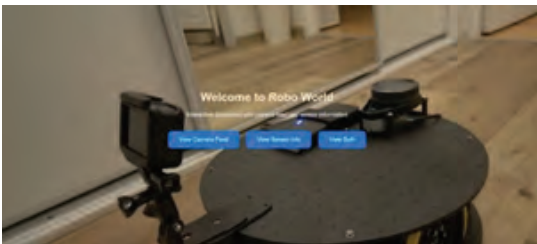


Fig. 4. Web Monitoring Dashboard for the robot

The Fig 4. shows a robot platform equipped with sensors like a LiDAR and a camera, likely used for mapping, navigation, or robotics research. The interface in the foreground suggests the system allows interaction with a web-based application for controlling or monitoring the robot.



Fig. 5. Autonomous Surveillance Robot working model

The Fig. 5. displays a custom-built wooden robot chassis designed for mobile robotics applications. The structure is made of a wooden base plate, chosen for its ease of fabrication and cost-effectiveness. The chassis features four wheels, providing a stable platform for movement and the potential for differential drive control. The simplicity of the design makes it suitable for prototyping or educational purposes, focusing on the mechanical and locomotion aspects of robotics.

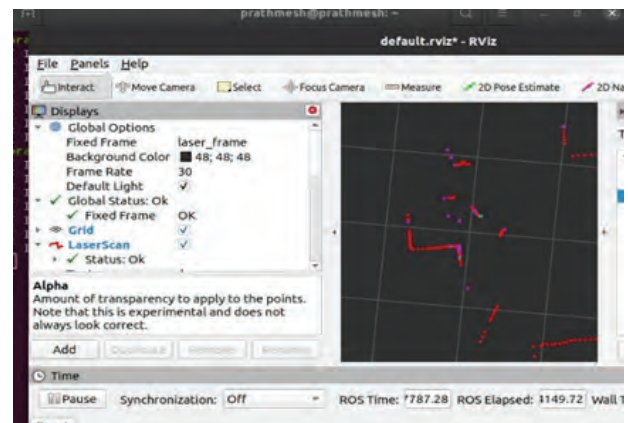


Fig. 6. Rviz settings for Lidar

The Fig. 6. shows the RViz interface with the settings panel open. The displayed settings include visualization options like "Grid" and "LaserScan," allowing users to configure how data from the robot is presented. This setup enables fine-tuning of the display for debugging or analysis purposes.



Fig. 7. Lidar Visualization in Rviz based on ROS

The Fig. 7. shows sensor data visualized in RViz, with red lines representing obstacles or mapped structures and pink points indicating raw LiDAR scan data. This visualization aids in understanding the robot's perception of its environment for navigation or mapping tasks.

The above image shows challenges such as sensor calibration, computational delays, and environmental interference which can be addressed through iterative testing and optimization. For example, the LiDAR sensor's range was fine-tuned to ensure accurate detection in various settings. Additionally, the Raspberry Pi's computational efficiency was enhanced by optimizing Python scripts and offloading non-critical tasks to secondary processors.

CONCLUSION AND FUTURE WORK

This paper demonstrates the successful development of an autonomous surveillance robot that effectively integrates SLAM and LiDAR technologies, providing a robust, scalable, and cost-effective solution for advanced security applications. The system's ability to create detailed maps and perform precise obstacle detection makes it a powerful tool for both indoor and outdoor surveillance. Its modular design ensures adaptability to diverse environments, including industrial facilities, commercial spaces, and residential complexes, highlighting its versatility across various use cases.

The project also emphasizes the reusability of hardware components, showcasing how existing resources can be repurposed to reduce development costs without compromising on functionality. By incorporating fire detection sensors, the system extends its utility beyond traditional surveillance, addressing safety concerns and demonstrating the potential for multi-functional deployments in real-world scenarios.

Future work will focus on advancing the robot's AI capabilities to enable predictive analytics, allowing it to proactively identify potential threats or anomalies, such as unusual behavior patterns or unauthorized access. This would enhance its effectiveness in dynamic and high-risk environments. Further enhancements will include the integration of multi-robot coordination, where multiple autonomous units can collaborate seamlessly to conduct large-scale surveillance, share data in real time, and cover extensive areas more efficiently.

Expanding the system's environmental sensing capabilities is another critical area of development. Planned upgrades include the addition of gas detection and air quality monitoring sensors, which would enable the robot to address environmental hazards and provide critical insights for industrial and urban safety applications. These advancements will transform the system into a comprehensive surveillance and safety solution, suitable for applications in sectors ranging from public safety to disaster management.

By continually building upon the current system, this project aims to establish a foundation for the next generation of intelligent surveillance robots capable of adapting to emerging challenges in security, safety, and environmental monitoring.

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Drone Technology

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ABSTRACT

The construction of the drone, which includes the frame, propeller, engine, power system, electronic control, and communication system as its most crucial parts, is covered first in this article about drones and their applications. One kind of aircraft is a drone. An unmanned aerial vehicle (UAV) is another name for a drone. The term “unmanned” refers to the fact that a drone can be operated without a pilot present. It is generally anticipated that the prevalence of drones will rise dramatically over the coming years due to their popularity and the convenience and affordability of purchasing many of them. The primary risk of drone use is the possibility of a drone dwindling from a high altitude, which can be brought on a dead battery.

KEYWORDS: *Unmanned, Drone, GPS, Propeller.*

INTRODUCTION

Generally speaking, “drone” refers to any unmanned aircraft, often known as “unmanned aerial vehicles” (UAVs). A drone is a robot that can fly [1]. GPS and on-board sensors allow for remote control of drones. Prior to their more contentious use as weapons platforms, UAVs were frequently linked to the military and intelligence collection. These days, drones are employed for a various purpose, including surveillance, search, rescue, traffic monitoring, weather monitoring, firefighting, and even personal duties. Drones have become a significant element of the film industry in the modern world, and news reporters use them to gather information from far-off places. The drone and the control system are the two components that make up an unmanned aerial vehicle system.

DRONE TECHNOLOGY: WHAT IS IT?

The term “drone” comes directly from the science fiction genre. Drones are also known as unmanned aerial vehicles (UAVs). An unmanned aircraft is called a drone. What is

referred to as an unmanned aerial system? Drones operate at the nexus of mechatronics, robotics, and aerospace and are utilized for photography, military surveillance, and leisure. A flying robot with remote control capabilities is called a drone. Numerous companies and governmental organizations now depend on drones. Drone technology is essential and has shown to be highly helpful in speedy delivery, from military sites to out-of-reach areas to industries. A mobile application or a remote control can be used to operate a drone. Drones can operate in environments that are too arid, boring, or hazardous for human pilots. Drones make our jobs much easier. For this reason, the majority of nations are implementing drones.

HOW DO DRONES OPERATE?

The term unmanned aerial vehicles (UAV) refers to unmanned aerial vehicles, or drones, where the whole organization permits a drone to function. Drones serve two primary purposes: Navigation and flight mode [2]. Drones need a power source, such gasoline or batteries, in order

to fly [3]. Additionally, there will be a frame, propellers, and rotors. Lightweight composite materials are used to make the drone's frame in order to boost mobility and decrease weight. Drones need a controller, often called a remote controller, to launch, navigate, and land the aircraft [4]. Wi-Fi and other radio waves are used by the controller and drone to communicate. High altitudes can be reached using drones. The drone's operating system and flight controller are its most crucial components [5]. The rotors, which rotate the propellers and produce lift, are powered by batteries. To stay in the air, flight controllers use gyroscopes, accelerometers, barometers, magnetometers, and data they have gathered. Other crucial components that improve drone operation are GPS, cameras, software, obstacle identification, and collision avoidance.

An infrared camera, landing gear, rotor, motor, accelerometer, altimeter, and communication are all features of a drone. To put it simply, a drone is a flying robot. A clever software program allows airplanes to control everything while in the air, and they are often operated by a specialized remote unit. Its numerous operational sensors, such as GPS, aid in determining the proper flight mode [6].

A HISTORY OF UAVS

Although the first drones are made in 170 years back, we have subsequently witnessed the transition from military drones to commercial devices [7]. The whole history of military drones, dating back to the 1800s, is attributed to the military. For target practice, air strikes, bomb detection, surveillance, and other purposes, the military employed UAVs in the form of balloons, torpedoes, and aerial targets. When 200 balloons were fired from an Austrian ship during the siege of Vienna in 1849 to compel the Venetians to surrender, it was the first time balloons were employed in a coordinated military action. Unmanned aerial vehicles are known as drones. An aircraft that does not have a pilot on board and whose flight is managed remotely by a pilot on the ground or automatically by the computer in the vehicle. A.M.'s "Aerial Target" Lowe's in 1916, but movie actor Reginald Denny's remotely piloted vehicle in 1935 was the first to be produced. Because they were afraid of dying, American pilots started preparing to employ unmanned aircraft in 1959, which marked the beginning of the UAV program [8]. Highly classified unmanned aerial vehicles were used in the Vietnam War in 1964. When Wide World Photo displayed images of the destroyed drone [9]. Since 1964, we have been employing

drones, and as technology has advanced, so too has our approach to exploiting this new technology [10]. During World War I, the United States and Britain built the first pilotless vehicles. The American aerial torpedo known as the Kettering Bug made its first flight in October 1918, while Britain's aerial target, a small radio-controlled aircraft, was initially tested in March 1917. The British constructed a number of radio-controlled aircraft in 1935 to serve as training targets [19]. It is believed that the term "drone" first appeared about this period. Radio-controlled drones were made by the United States and utilized for training and target rehearsal. These days, using drones are extensive range of tasks, including transporting items, taking pictures, filming, conducting search operations during natural catastrophes, and monitoring climate change. Drone use. The employment of drones by the US military for target attacks, monitoring, and reconnaissance has grown dramatically. The primary purpose of drones is observation in regions and terrain that are unsafe for soldiers to access. However, they are also credited with the deaths of suspected militants and are used as weapons. Drones are now rather popular in the modern day. In the United States, over 100,000 persons have a using drone license. Since the 1850s, unmanned aerial vehicles have served a variety of purposes, elevating humanity to the height of technology and gaining notoriety.

COMPONENTS

Electronic speed controller: - It is used to adjust the motor's RPM (revolutions per minute) and stands for Electronic Speed Controller. Electronic speed controllers (ESCs) are used by drone flight controllers to regulate and change the speed of the increases or decreases the voltage to the motor in reaction to a flight controller signal. Consequently, the propeller's velocity is changed.

GPS: - The global positioning system (GPS) is a satellite navigation system that uses a radio receiver to gather signals from orbiting satellites in order to calculate position, speed, and time. With position information to within a few meters, this navigation system is more precise as compare others. The accuracy of sophisticated GPS systems might be as low as a few millimeters or better. The miniaturization of integrated circuits has made GPS receivers broadly accessible and reasonably priced.

GPS is a very dependable broadcast radio system that can be found almost anywhere in the world.

Propellers: - Propellers are rotated by motors to provide

thrust. The propeller design plays a crucial role in this thrust generating. An aero foil is the cross section of a propeller, and thrust generation is aided by its aerodynamic shape.

It is constructed of carbon fiber, which has a high strength-to-weight ratio, in contrast to propellers made of plastics.

Flight controller: - The flying controller has an Auto level feature that helps with handling. The ESC receives the output of the flight controller's accelerometer and gyroscope sensors after they have processed the data from the receiver. The K++ 2.1.5 Flight Controller board can be used in the drone due to its built-in firmware. Numerous features on this flight controller board make it much easier to calibrate. A 64K RAM-equipped ATMEL Mega 644PA 8-bit AVR RISC microprocessor powers it [11].

Motor: - Since they provide the force needed to rotate the propellers and move the drone forward, motors are crucial to the construction of drones.

Battery: - This battery serves as the drone's power supply. It uses power distribution wires to provide electricity to all of the equipment.

Camera: - The drone is equipped with a camera that is used to record, store, and transmit video.

APPLICATION OF DRONE TECHNOLOGY

Originally utilized exclusively by the military, drones are now employed in many different fields. Unmanned aerial vehicles (UAVs) like drones make our lifestyle smoother than they have ever been. It is employed in circumstances where humanoid flight is deemed hazardous and challenging. Nowadays, a lot of people and experts use it. Drones are being used in an extensive range of industries, and as technology advances, these devices will only grow in strength and utility. Drones operate in a diversity of industries, and as technology advances, these devices will become more potent and practical in the future. Any industrial facility project benefits from the use of drones since they provide countless aerial views. Drones have the potential to be incredibly valuable. Drones are being used more and more by industry specialists to enhance industrial operations. Drones are specially designed to collect airborne data for regular use in sizable industrial sites, allowing for quick and easy data gathering. There are numerous things that drones may accomplish. Oil and gas plants can deploy automated drones for infrastructure inspections, emergency response, security, and surveillance. Drones can be used in seaports for tasks like

traffic control, port monitoring, operational surveillance, mapping, and surveying. Let's talk about the value of drone technology and how to use it most effectively.

Aerial Photography

Advanced camera-carrying drone units are most frequently used for 3D imaging, videography, aerial photography, site surveying, and media coverage from remote areas. Helicopters are only affordable for major news organizations. However, practically all local journalists and small media outlets can now employ drones to record clean air footage for stunning news coverage. Because of their small size, drones can readily maneuver into confined spaces and also be utilized for recording in-person interviews.

Agriculture

In the realm of farming and agriculture, drones are widely utilized. The most significant advancement in drone technology is its ability to assist farmers in a variety of ways. Drones can help agriculture in a number of ways, according to agriculturalists. One of the biggest markets for commercial drones is anticipated to be this sector. Drones can help farmers identify which crops are failing. By precisely tracking and evaluating irrigation system performance, drone technology helps farmers save money and their crops. Drones may now help farmers apply pesticides, fertilizers, and water to crops at the appropriate times, and they can provide farmers with instant updates on all information.

Search and Rescue

Drones can find people who are missing or lost. Drones can find missing people since they have thermal sensors installed. Additionally, they are able to function on difficult terrain and in the dark. Drones are effectively being utilized for monitoring natural disasters, post-disaster assistance efforts, and locating individuals in areas impacted by floods, fires, or other natural disasters. Networks for emergency communication can also be employed to help. Rescue personnel may swiftly and in real time track individuals in peril with the aid of visual information. Due to a lack of technology, search and rescue efforts have long suffered, but drones can now accomplish anything in a matter of minutes.

Shipping and Delivery

Drone delivery is one of the most common and rapidly expanding uses of drones. Heavy payloads can be carried by advanced drone units. Applications for these drones

include delivery and shipment. People can receive their ordered goods at their doorsteps on time thanks to its use for enhanced security and dependable product delivery. E-commerce behemoths like Amazon have already made investments in drone technology and Amazon Prime Air, and they want to offer the service as soon as the viability concerns are fixed. With it, you can now have your meal order delivered to your location in a matter of minutes. Many businesses are testing with establishing service area that do not even need to leave your house, and these drones can deliver things right to your doorway.

Science and Research

Drones' capacity to navigate is one of their key characteristics. Despite their little appearance, they are incredibly capable. Drones operate incredibly quietly and have less of an impact on the environment than traditional planes. Methane leak detection, pipeline installation monitoring, geophysical surveys, archaeological and meteorological research, glacier and iceberg monitoring, plant species identification, forest management, and more are just a few of the scientific and research applications that use drones. Drones may not travel to unreachable locations because space is no longer an issue for them.

Military Drone Technology

The military is arguably the most well-known, contentious, and ancient application of drones. Drones have emerged as the main tool in the military industry. In the early 1940s, the British and American forces started spying on the Axis powers using very basic drones. Drones have been incorporated into militaries all over the world and are employed as tools for surveillance, research and growth, and combat missions. Drones today are much more sophisticated than UAVs of the past, with features like air strike equipment, laser range finders, and thermal imaging. In a variety of military activities, unmanned aerial vehicles are used to minimize casualties and facilitate mission performance.

Weather forecast

Additionally, drone technology has grown to be crucial for protecting and monitoring our surroundings. Natural catastrophes, such as hurricanes and tornadoes, can transmit warnings in advance. Meteorologists can benefit from knowing specific weather parameters. Drones equipped with gyroscopes and thermal sensors can reveal patterns in the weather. Because drones have improved our sense of intuition, we may employ them for conservation

purposes including flood assessment, habitat management, and migration tracking.

Entertainment

The enlargement of drone technology has been frequently spearheaded by entertainment sector. The newest technology being used by the entertainment sector is unmanned aerial vehicles, or UAVs. Storytellers, screenwriters, and producers have constantly sought to improve the viewing experience since the beginning of the cinema industry. The drone can effortlessly record overhead views of football and cricket matches because to its high-resolution camera, which also makes it easier for the drone to observe far-off objects. These drones are used by cinematographers to take aerial and still life photographs. Drone pilots today are able to record dramatic and cinematic sequences that were previously unthinkable in the film industry.

Drones and Engineering

These days, the majority of engineering businesses use drone technology; engineering firms may effectively utilize drones. In-depth projects like transmission, oil pipelines, and maintenance checks require drones for monitoring. Additionally, engineering firms work on a number of commercial projects. Engineers may greatly boost efficiency by using drones in complex activities like road building planning and airport design.

CONCLUSION

The explanation above makes it quite evident how important drone technology is. Applications for drones are numerous and span several industries. Because of their many functions and small size, they have grown in popularity. Drones may be far more useful in the future than they are currently if they have greater weight capacity, strong and sophisticated technology, longer flying times, and greater maneuverability. Drones are used in extensive series of fields, including construction, farming, waste management, sanitation, public safety, security, and traffic monitoring. In order to enhance enterprises, governments and corporations should construct the required infrastructure and employ drones with sophisticated capabilities.

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Optimizing Aquaculture using Custom VGG-Inspired Deep CNN Model

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ABSTRACT

Aquaculture is one of the major sources of food production and quality is one of the essentials when it comes to food. Disease management is one of the major concerns when it comes to fish rearing, as outbreaks can cause significant economic losses and affect the overall marine ecosystem. Effective disease control is critical for maintaining fish health, improving productivity, and meeting the growing demand for seafood worldwide. Traditional methods for fish disease management often fail due to being time consuming, Labor-intensive and lack of scalability on larger farms. These limitations call for the adoption of advanced technology that can be used to enhance the efficiency of disease detection. Recent development of technologies like Artificial Intelligence (AI) and Machine Learning (ML) has given rise to methods like convolutional neural network (CNN) which is great at image classification. The aim of this project is to build a custom VGG-Inspired Deep CNN image classification model, a type of CNN that is used for deep learning purpose, to classify various species of fishes from diseased to healthy, reducing diagnostic time and enabling timely interventions. By leveraging the use of machine learning, this project aims to bridge the gap between technology and aquaculture, promoting a sustainable practice in the industry.

KEYWORDS: *Aquaculture, Fish disease, Machine learning, Convolutional neural network (CNN), Disease management.*

INTRODUCTION

According to the Food and Agriculture Organization (FAO), aquaculture accounted for approx. 57% of global fish production for human consumption as of recent years and this number seems to be rising steadily. Disease outbreaks causes annual losses estimated at 10-20% of global aquaculture production. Farmers have to spend a lot of their cost on disease prevention and cure methods. With the development of technology and rise of Artificial Intelligence (AI) and Machine Learning (ML), marine ecology can be equipped with the power of technology as proposed by the research of “Peter Rubbens, Machine Learning in Marine Ecology: An overview of Techniques and Application”, 2023.

Models like SVM have been used in the past to detect marine species in the oceans. However, due to lack of data,

fish disease in aquaculture has always been obscure in at the vast scope of marine biology. This research aims to use the power of deep learning neural networks especially convolutional neural network to develop a fish disease detection model which can identify common diseases in aquaculture and can allow farmers to act on them before it causes serious damage. The model also has a user-friendly interface that can be used by a layman and small scale or beginner farmers to identify diseased fish with just an image and save technological cost on buying expensive equipment and use their capital more efficiently.

LITERATURE SURVEY

Recent advancements in computational power and data availability has opened doors to analyzing marine ecology with the help of machine learning. This research shows an analysis of approx. 1000 publications, covering diverse

data types like images, spectra, omics, geolocations and satellite imagery. The research highlights how diverse approaches can serve as templates for new research. It shows what impact can be achieved by combining ML with marine ecology data. [1] This research paper introduces DeepData, a no-code, web-based machine learning platform which is designed to assist marine-biologists in Species Distribution Modelling (SDM). DeepData supports various ML learning algorithms. The paper provides a concrete explanation of how to use the tool and its implementation and evaluation for practical applications.[2] This research paper shows two machine learning frameworks-gradient boosting and artificial neural networks providing an alternate to traditional ML models. Depending on several parameters, both models are good at extracting patterns and each model takes a different operational approach.[3]This research highlights the degrading condition of the planet's marine ecosystem. It also shows how conserving marine ecosystem will require calibrating our social, financial and industrial relationships with nature. It highlights how current technology can be used to take immediate actions to conserve remaining biodiversity to create an opportunity for sustainable future is 2030 and beyond. [4]This research shows how cost-effective and accessible sensors are enhancing data acquisition in animal ecology, enabling large scale ecological research. It also highlights the limitation of these sensors that are inefficient in collecting relevant data from large datasets. It shows how ecologists with domain knowledge needs to collaborate with data scientists to ensure quality and training next generation of ecologists in data science and conservation. [5]This research highlights the importance of coral reefs in warm shallow waters. Monitoring animal population is crucial for protection of ecosystem. This paper shows that YOLO-based models are shown to quickly and accurately recognize marine animals and offers suggestion coral reef environments to develop such models.[6]This research shows an early fish disease detection using K-means and C- means with Gabor's Filters and Gray Level co-occurrence matrix (GLCM) followed by Multi-Support Vector Machines (M-SVMs). The system was made especially fishes in the lakes of Rangamati Kaptai Lake and Sunamganji Hoar.[7]This research identifies fish diseases, particularly in salmon aquaculture as it is a major global food production system. It uses SVM and a two part approach to build model. The approach was tested on a novel salmon fish image dataset, both with and without image augmentation, to assess its effectiveness in detecting

fish diseases.[8]This research presents an argument that as global climate changes accelerates, it increases the need for protection and exploration of oceans. The paper reviews the history of remote sensing technology and presents the conditions needed for site selection using method analysis. The research aims to integrate ocean remote sensing with machine learning and shows future development directions.[9]This research builds a CNN model to classify species of various marine species. It shows how classification of various species is important to understand and protect marine ecosystem. It shows how traditional manual classification is labor-intensive and limited in scalability.[10]

PROPOSED SYSTEM

The current use of machine learning is limited due to lack of relevant data, overreliance on traditional machine learning systems in the marine field. The focus of large organizations is always on large water bodies and improving the life of marine creatures in the oceans which often takes the focus away from the marine life forms in freshwater locations. This model aims to focus on diseases of freshwater fishes which can be commonly seen and if timely action is taken it can even be prevented from spreading.

This system uses the freshwater fish diseases image dataset from kaggle which consist of is divided into 7 different classes which includes Bacterial Disease - Aeromoniasis, Bacterial gill disease, Bacterial Red Disease, Fungal Diseases Saprolegniasis, Parasitic Diseases, Viral Diseases White Tail Disease and Healthy Fish. These are the most likely diseases that can occur in aquaculture industry.

The model is trained using python libraries like Tensorflow ver. 2.4.0, matplotlib, seaborn, numpy, skit-learn. The data is then split into 3 parts: training, testing and validation. The training data is split 70-30 between training and validation. Then the convolutional model is executed and the user interface is made using Streamlit which is easy enough for people of any age group to use. Traditional use of ML models like SVMs are very outdated and are very taxing on the device. This is a custom model is based on the VGGNet Deep CNN which is said to be the best for image classification tasks. This model provides 84% accuracy with high precision, f1 scores for each classes. This model hopes to provide a cost effective model for poor farmers who can't afford the expensive equipment for disease detection.

METHODOLOGY

Several methodologies have been used in the past to develop fish disease detection using machine learning such as Support Vector Machine (SVM) based Fish Disease Detection, Random Forest based Fish Disease Classification, K-Nearest Neighbours (KNN) based Fish Disease Diagnosis etc. Despite several research in this field the problem of insufficient data, overreliance on traditional machine learning techniques like SVM and Random Forest have limitations in handling complex image data, models perform poorly across diverse fish species, diseases, and environments.

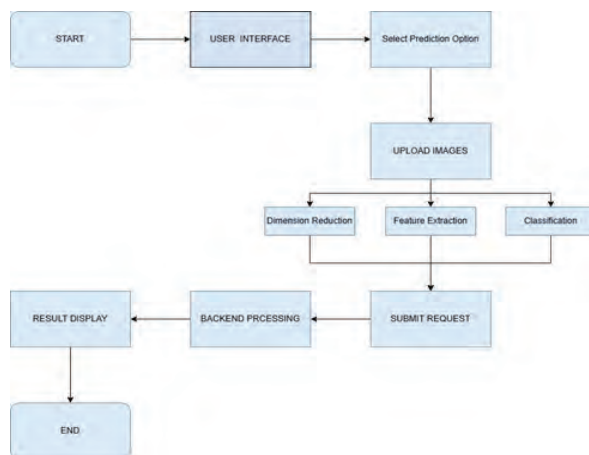


Fig. 1: Workflow of the model

As stated in fig. 1, the user interacts with the interface by uploading the image of fish with particular disease. The model predicts the disease by following steps.

Feature Extraction: The model has five convolutional and pooling layers in place for feature extraction where the images are divided into filters and many feature maps are generated. Lower layers focus more on features like edges, shapes, colours etc and higher layers focus on more detailed features like parts of fishes, disease patches etc.

Dimension Reduction: The dimension reduction is where the model extracts relevant information from the feature maps and it also helps prevent generalisation, reducing overfitting and optimizing the performance of the model etc.

This model uses the Deep CNN(VGG-Inspired) with a total of five convolutional layers with the filter size of 16, 32, 64, 128, 256 respectively with a kernel size of 3 across all the layers. The model also has five maxpooling layers with a constant kernel size of 3 and stride of 1. The model

uses 'ReLU' activation function in the convolutional layers.

After the convolutional and pooling layers the model uses dropout function with the value of 0.2 and then uses a flatten function. After that the dense layer is used with 105 neurons and activation function 'ReLU' and then another dropout layer is added with the value of 0.4. Finally the output dense layer is added which has seven neurons as the total no. of classes is seven along with 'Softmax' activation function as it helps with multiclass image classification. This model uses 'Adam' gradient descent with a learning rate of 0.0001. The model has a total of 65,718,495 parameters which are all trainable parameters.

RESULTS

The model runs for 50 epochs and the training process is very smooth without any interruption as the learning rate is low the model is trained thoroughly and the accuracy of training and validation is shown below in the form of a line graph.

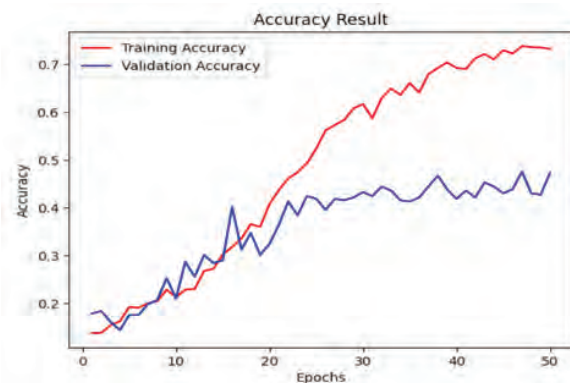


Fig. 2: Training and Validation Accuracy Graph

The training and validation accuracy shows how the model is performing on training set of data and after each batch of training the result is verified using validation set of data. The model then makes the changes according to the previous result of epoch. Hence the model keeps on changing the weights based on the result to get the optimal weights to predict the result. fig. 2 shows a graph with the accuracy of the model. The x-axis is no. of epochs and y-axis is the accuracy of the model. The red line denotes training accuracy and the blue line denotes the validation accuracy. The highest training accuracy recorded by the model during was approx.. 85% and it maintains it around 80% and the highest validation accuracy the model achieved was around 51%.

	precision	recall	f1-score	support
Bacterial Red disease	0.82	0.86	0.84	103
Bacterial diseases - Aeromoniasis	0.88	0.79	0.83	100
Bacterial gill disease	0.78	0.88	0.83	101
Fungal diseases Saprolegniasis	0.77	0.80	0.78	100
Healthy Fish	0.89	0.92	0.91	101
Parasitic diseases	0.85	0.89	0.87	101
Viral diseases white tail disease	0.92	0.73	0.82	97
accuracy			0.84	703
macro avg	0.85	0.84	0.84	703
weighted avg	0.84	0.84	0.84	703

Fig. 3: Model Evaluation Result

This Accuracy Results Chart in fig. 3 provides a visual representation of the model's performance, showcasing its ability to accurately detect fish diseases. This chart illustrates the model's overall accuracy, precision, recall, and F1-score, offering a concise overview of its reliability and effectiveness. The chart enables users to quickly assess the model's strengths and weaknesses, facilitating informed decisions and potential adjustments to improve disease detection capabilities. The model predicts viral white tail disease with the highest precision of 0.92. The recall of healthy fish is highest among all the classes in the model. The f1-score of healthy fish is high at 0.91 and the support score of bacterial red disease is highest at 103.

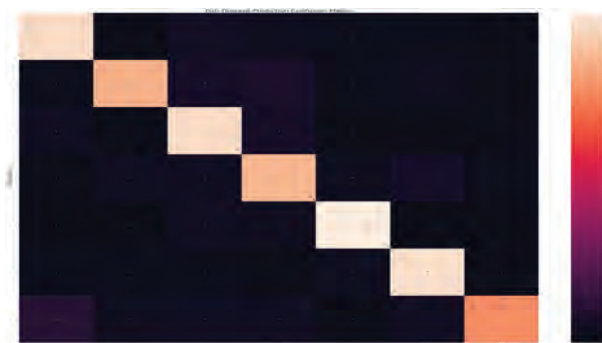


Fig. 4: Confusion Matrix of the model

A confusion matrix is a performance measurement tool commonly used for evaluating the accuracy of classification models, especially in supervised learning. It shows how well the model performs by comparing its predicted classifications against the actual true labels. The darker colour shows how many times the model is predicting some other disease than the actual disease and the lighter colour is showing how many times the prediction was correct. Darker colour means that the no of times that output was displayed was low whereas lighter shade means that the output showed that result many times and if a diagonal such as the above fig.4 has is displayed means that the model is performing correctly.

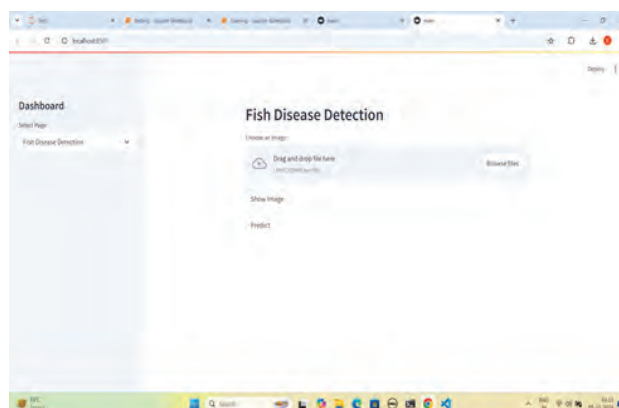


Fig. 5: Model Interface

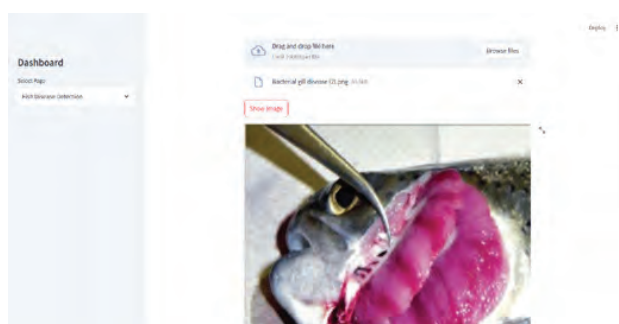


Fig. 6: Image Loading into the model

Fig. 5 the Fish Disease Detection System interface, built using Streamlit, provides a straightforward and user-friendly platform. Users can upload fish image as shown in fig. 6, and the system utilizes its trained model to predict the presence of specific diseases, delivering accurate and reliable results. The interface displays the predicted disease, enabling aquaculture professionals and researchers to efficiently diagnose and manage fish health.

CONCLUSION

The custom VGG based Deep CNN model is working perfectly with the frontend and can be used by aquaculture farmers with their web browser if launched. The advantage of this model is that it doesn't require heavy computational power to deal with large data. It takes the good points of VGGNet model and customizes as per the need which makes it a new type of model on its own which is made for the purpose of disease detection. This is just the beginning of ML being used for the betterment of the environment and if it is developed with a larger and more relevant dataset along with IoT devices it can provide the farmers with live monitoring of their ponds or lakes which can be the future of the research but this research will leave

a mark of its own as contributing to bridging the gap between environment and technology.

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Advanced Model for Dew Point Temperature Prediction: Comparative Insights with ML Algorithms

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ABSTRACT

Dew point temperature is an important climate parameter which directly influences a lot of other climate variables like humidity, temperature and indirectly influences the parameters like heat index and fog formation. A model is proposed which is based on the concept of long short term memory model. It is bi-directional in nature and uses the data in the time series format. It has the ability to remember long sequence of data which can be utilized for predictions. It also has the ability to capture complex pattern in the data. It is observed that this proposed method gives less MAE, RMSE and MSE as compared to traditional machine learning algorithms.

KEYWORDS: Dew point temperature, Deep learning, Machine learning, Bi-directional LSTM, Model evaluation.

INTRODUCTION

The dew point temperature influences the humidity, heat index as well as the fog formation. Nagpur experiences extremely dry air with high temperature during the summer. The humidity levels are low while in the monsoon season, the humidity is high. During winter the temperature goes down accompanied by fog. The dew point increases due to the increased moisture content in the air which makes the climate feel humid. This condition occurs specially during the monsoon and post-monsoon seasons. In Nagpur region, during summer season heat index is also very high. The reason for this is the increase in dew point temperature and high temperatures. In winter, the temperature comes close to dew point leading to the fog formation. The prediction of dew point temperature efficiently helps in predicting these weather phenomena like humidity, heat index and fog formation. Also, the agriculture sector of Nagpur will be benefitted because dew point temperature is crucial for crop health. The growth of fungus and other pests are also affected by the dew point and these may impact the crop yield. Apart from agriculture sector, the air quality also deteriorates due to high dew point. People suffer from

various respiratory issues due to this. In the power sector there is increased demand in the power supply because increased dew point raises the heat index which makes the climate feel like hotter than it actually is. Heat stroke and dehydration among people is also very common due to this increased heat index. The machine learning based techniques have proved to be useful in predictions. They have the ability to learn the pattern from the historic data and give useful predictions.

LITERATURE REVIEW

G. Acosta and M. Tosini, implemented a Field Programmable Gate Array (FPGA) and used ANN for predicting variable of the climate variables prediction in a restricted environment [1]. Reto Knutti and Claudia Tebaldi have studied the application using the multi-model ensemble in forecasts of the probabilistic climate. This paper deals with challenges of interpreting multi model results [2]. Wang Deji and Xu Bo [3] introduced a novel approach that uses SVM to reconstruct climatic variables from noisy environments. Namratha V. and Usha M. have researched the ARIMA, ANN based model for weather

forecasting [4]. An LSTM-based model for short-term weather forecasting has been proposed by Hewage P. et al [5]. In their publication [6], Santhosh B. and Kadar S. suggested a technique for temperature prediction based on artificial neural networks. The back propagation technique, which they have used, produces accurate forecasts with a low error rate. Kumar A. et al. have used an artificial neural network-based model for weather forecasting. By changing the number of hidden layers, they have created various models for predicting the maximum temperature. They have created several combinations by altering the quantity of neurons [7]. An LSTM-based model for humidity prediction has been implemented by Marlyna H. et al. [8]. Comparing the results to other approaches, there is a noticeable improvement.

Soukayna M., et al in their paper have describes Neural Network techniques for downscaling of a single parameter of the climate to a region of interest [9]. Recurrent Neural Network based downscaling model was proposed by Saptarshi Misra et al on. In their research they have used LSTM to capture the dependencies in the data to predict rainfall [10]. Bochenek et al analyzed various models for prediction of weather [11].

In this paper, a time series-based model is proposed which utilises the long short term memory model which is bidirectional in nature. Further, the model performance is compared with traditional machine learning models like linear regression, support vector regression and random forest. Fig. 1 shows the different stages which are further described in Section III onwards.

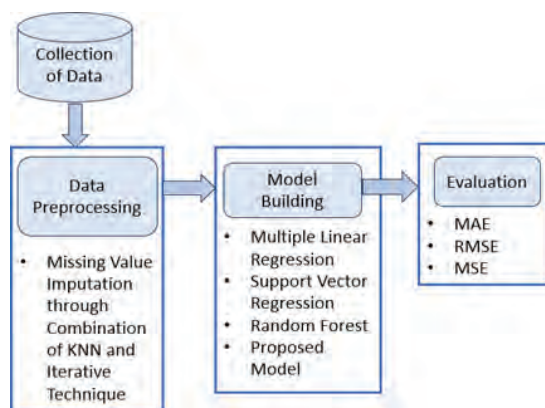


Fig. 1. Stages of ML based Workflow Model

DATA COLLECTION AND PREPROCESSING

The data has been collected from the Data Supply Portal

of the India Meteorological Department (IMD), Pune, Maharashtra. Their portal provides different types of data services, including Surface Data, Autographic Data, Astronomical Data, Rainfall Data, Radiation Data, Marine Data, Agromet Data, Upper Air Data, and Air pollution Data. The data that is used here is Surface Data [12]. It is the data obtained by considering the topography of each region. The earth's surface has various features like slope, elevation, and contour lines. IMD generates daily observational data which consists of different parameters like temperature, pressure, wind, rainfall, etc. The meteorological observing stations (MO) and Automatic Weather Station (AWS) help in generating this data. The data is being processed after Quality Analysis and Quality Control and archived at the National Data Centre (NDC). For this research, monthly Surface data is obtained from 2000 to 2023 for Nagpur region of Maharashtra. The dataset supplied by IMD is based on Day Summary and Synoptic Hour. The dataset consists of station index code as the first column, followed by year, month, and hour code. This hour code denotes the synoptic hour on which the data the observation is recorded. The synoptic hours are 03 and 12 in India. The dataset has the following parameters: mean station level pressure (MSLP) measured in hectopascal (hPa), mean sea-level pressure (MMSLP) measured in hectopascal (hPa), mean dry bulb temperature (MDBT) measured in degrees Celsius, mean wet bulb temperature (MWBT) measured in degrees Celsius, mean dew point temperature (MDPT) measured in degrees Celsius, mean relative humidity (MRH) measured in percentage, mean vapor pressure (MVP) measured in hectopascal (hPa), total rainfall (TMRF) measured in millimetres (mm), mean wind speed (MWSP) measured in kilometre per hour (kmph), wind direction, mean low cloud amount (MLC), mean medium cloud amount (MMD), mean high cloud amount (MGH), mean total cloud amount (MTC) measured in oktas,

After collecting the data, data preprocessing is an important task. The climate data is collected from various sources like radars, sensors, and satellite images. During the process of data collection, there are chances that data is not recorded properly. It might happen due to faulty devices resulting in misrepresentation of the data or absence of data. These missing values affect the performance of the model. So, a proper approach needs to be applied to handle those missing values. For most of the stations, it is observed that the data that is obtained contains no values in many rows and columns. The reason might be due to improper data

collection. The model fails to predict properly due to the inconsistency in data. So, handling missing values with proper technique is a significant step. To handle the missing values, combination of KNN and iterative approach is used [13-15]. This method utilises the advantage of both techniques and yield best results. Once the raw data is pre-processed it can be further divided into training and testing data. Major portion of the data is used for training so that model learns better. The smaller portion of the data can be used to test the results.

MODEL BUILDING

The preprocessed data can now be passed on to the various machine learning models.

- 1) Multiple Linear Regression: Multiple independent variables are used in linear regression to predict the value of a dependent variable [16]. It is possible to quantify each independent variable's contribution to the overall variance. Linear Regression for multiple variables is formulated as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + \varepsilon \quad (1)$$

y is the dependent variable, β_i is the coefficient, x_i is the independent variable, ε is the error. The discrepancy between the actual and anticipated values yields the error.

- 2) Support Vector Regression: For the estimation of a multivalued function which is continuous in nature, the Support Vector Regression model is helpful. The SVR kernel [17] plays a very key role in an expression of complexities that exist in the relationship of features with target variable. In such a process, the feature mapping is conducted in a high-dimensional space and thereby makes easy finding of separation data by using hyperplane. The various kinds of kernel functions are there; they include: Linear, Polynomial, Radial Basis Function (RBF). RBF kernel is the most suitable choice for non linear problems. It can capture the nonlinear patterns present in the data.
- 3) Random Forest: Random Forest Algorithm can handle the non-linear relationship between the features [18]. It is the collection of decision trees. A random subset of the features is selected and each tree is trained on it. Multiple trees are built like this. The final prediction is mostly the average of prediction obtained from all these individual trees. The training of individual trees happens parallelly. If the number of trees are large then this is a computationally efficient.

PROPOSED MODEL AND EVALUATION

The proposed model is based on LSTM [19-20] which is bi-directional in nature. The processing is carried in a sequence of the two LSTMs: one for the forward from the input side and the other for the backward from the input side of the input. The first layer is the Input layer which contains the input in the time series format. The next two layers are the Bi-directional LSTM layers arranged hierarchically. The first Bi-directional LSTM layer has 100 neurons, second Bi-directional LSTM layer contains 64 neurons. The output layer is Dense layer which gives one dimensional output. The architecture of Proposed Model is shown in Fig. 2.

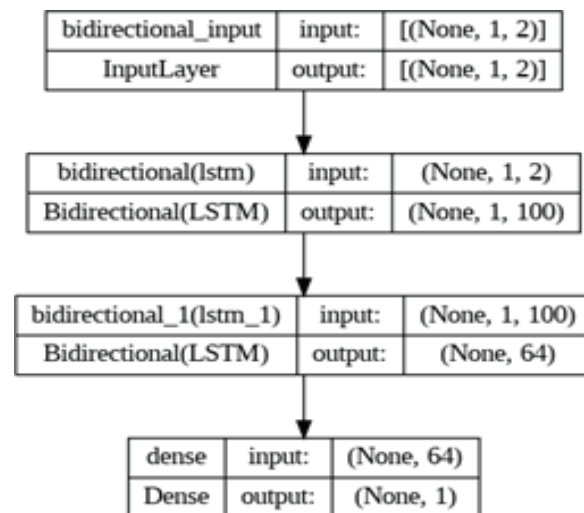


Fig. 2. Proposed Architecture

The performance of the model is assessed using the testing set. The predictions on testing data are compared against the actual data. The performance measures that are used here are Mean Squared Error (MAE), Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE). The formulas are as follows:

$$MSE = \frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2 \quad (2)$$

Equation (2) represents the Mean Squared Error which is the average of values of squared difference between actual (y_i) and predicted values ($\hat{y}_i$).

The Root Mean Squared Error is represented by equation 3.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2} \quad (3)$$

Equation (4) represents the Mean Absolute Error

$$MAE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}|^2 \quad (4)$$

Table 1, shows the comparison of results according to the performance metrics MAE, RMSE and MAE.

Table 1. Comparison of Results

Performance Metrics	Values
MAE	0.1225
RMSE	0.1652
MSE	0.0273

The results of existing traditional machine learning algorithms are compared against the Proposed Model and the results are shown in Table 2.

Table 2. Comparison with Existing Models

Algorithm	MAE	RMSE	MSE
Multiple Linear Regression	0.2266	0.2968	0.0881
Support Vector Regression	0.1889	0.2439	0.0595
Random Forest	0.1613	0.2023	0.0409
Proposed Model	0.1225	0.1652	0.0273

The Proposed Method has less MAE, RMSE and MSE as compared to existing systems. From the comparison it is evident that all the metrics have least value for Proposed Model as compared to existing models. Fig. 3, Fig. 4 and Fig. 5 depicts the comparison of different algorithms for MAE, RMSE and MSE respectively.

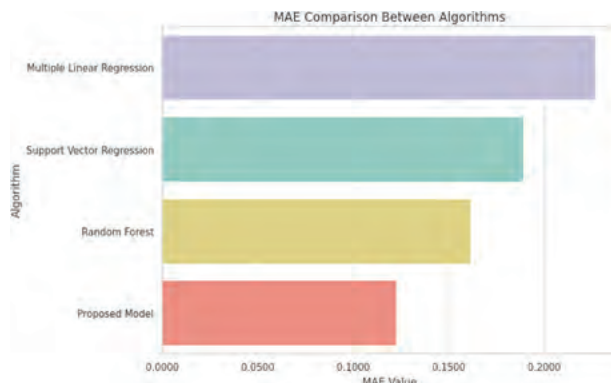


Fig. 3. Comparison Plot of MAE

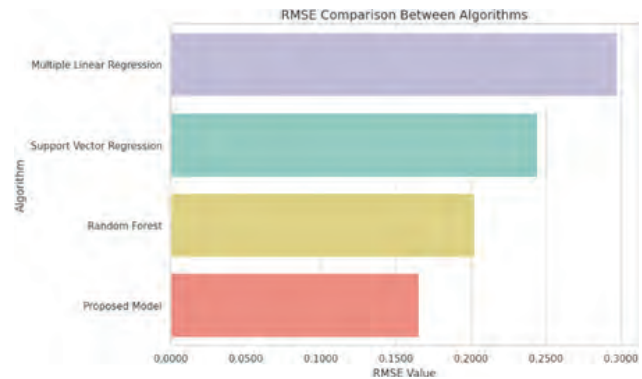


Fig. 4. Comparison Plot of RMSE

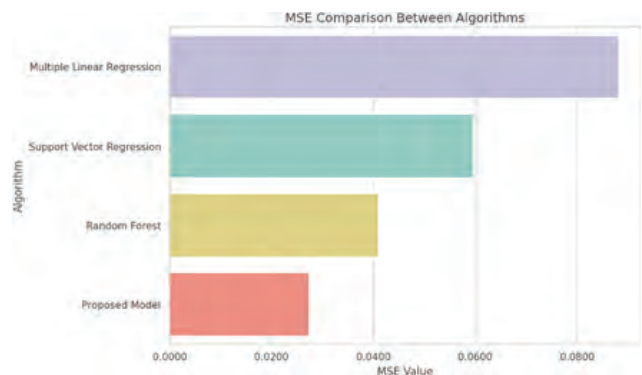


Fig. 5. Comparison Plot of MSE

The model results can be validated by applying it to other regions having varied climatic conditions. The different regions that are chosen here includes Colaba, Parbhani, and Kolhapur. Table III, IV and V represents the MAE, RMSE and MSE values of these stations.

Table 3. Validation of MAE Values

Algorithm	Colaba	Kolhapur	Parbhani
Multiple Linear Regression	0.1859	0.1248	0.2095
Support Vector Regression	0.1389	0.1166	0.1354
Random Forest	0.1043	0.1078	0.1122
Proposed Model	0.0972	0.0979	0.0251

Table 4. Validation of RMSE Values

Algorithm	Colaba	Kolhapur	Parbhani
Multiple Linear Regression	0.1911	0.1797	0.1594
Support Vector Regression	0.1882	0.2351	0.1826
Random Forest	0.1489	0.1939	0.1609

Proposed Model	0.1443	0.1469	0.0557

Table 5. Validation of MSE Values

Algorithm	Colaba	Kolhapur	Parbhani
Multiple Linear Regression	0.0365	0.0323	0.0255
Support Vector Regression	0.0354	0.0552	0.0334
Random Forest	0.0222	0.0376	0.0259
Proposed Model	0.0208	0.0216	0.0031

CONCLUSION

Dew Point Temperature Prediction can be done efficiently through the Proposed Bi-directional LSTM model which has the ability to process the data in both directions thereby capturing the hidden pattern present in the data. The performance metrics show less error in prediction for the proposed model. The validation of results further proves the improvement in the model as compared to existing techniques. The future work includes improving the accuracy further.

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Heart Disease Monitoring System using CNN+LSTM Model and Ethical Considerations of Patients based on NLP and Ethical Codes

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ABSTRACT

Several ethical issues arise with the potential development of AI (Artificial Intelligence) systems. There is an insufficient number of rules and regulations to tackle any complications that may arise during research effectively. There exists a significant gap in suitable policies and guidelines that adequately confront potential challenges within the research process. It is essential that superintelligent machines are designed to perform benevolent actions rather than malevolent ones as part of the AI advancement process. Natural Language Processing (NLP) is a key AI technology that can evaluate and interpret human language, making it a vital element of intelligent healthcare. Numerous smart healthcare applications have greatly benefited from the integration of Natural Language Processing (NLP). This study proposes a hybrid model combining CNN and LSTM for health monitoring systems. Our health monitoring system utilizes Natural Language Processing (NLP) for ethical considerations, as it enables machines to understand human language and interact with individuals. According to our results, the proposed method surpasses existing models in both accuracy and performance.

KEYWORDS: Heart disease prediction, Ethical consideration, CNN, NLP, LSTM.

INTRODUCTION

Nowadays, deaths across all age groups are majorly caused by cardiovascular disease. Therefore, there is an urgent need for advancements in the health industry to better anticipate cardiac arrests by using a variety of deep learning methods. So, it's crucial to keep tabs on sex, blood pressure, cholesterol, smoking, and diabetes in those with heart disease. These factors are self-contained and provide excellent candidates for use in ML and AI systems [1].

The death rate is reduced with better monitoring of cardiac patients. A system that any literate individual may use to make an early diagnosis of heart disease in the absence of a doctor is the primary purpose for developing this decision

support system. The brilliant thing about this method is that it won't need a cardiologist to work with the data [2].

AI's potential to use vast amounts of data, gain insight to support evidence-based clinical decision-making, and achieve value-based therapy is driving rapid advancement in the healthcare sector. From clinical decision support at points of care to patient self-management of chronic conditions and real-world drug research, artificial intelligence (AI) is already influencing almost every aspect of healthcare [3].

In recent years, natural language processing (NLP) has exploded in popularity, drawing the interest of several academic groups [4]. The foundation of natural language

processing is the concept of generating or obtaining pertinent information. Utilizing natural language processing (NLP), medical professionals were able to more easily examine reports pertaining to medical history, such as allowing radiologists to view megapixel-sized images of any part of the body that needed screening, which was a significant improvement over the past [5]. For this study, we suggested a CNN+LSTM model for a health monitoring system. We also integrated natural language processing with an ethical consideration framework into our health disease monitoring system.

RELATED WORKS

Here we provide the results of our study on the several ML and DL algorithms that are part of health monitoring systems.

Shreshth Tuli et al. [6] suggest HealthFog, a novel fog-based smart healthcare system that leverages deep learning and the Internet of Things, to automate the detection of heart illnesses. HealthFog provides healthcare as a fog service with its efficient handling of cardiac patients' data from several Internet of Things (IoT) devices.

With the DLMNN classifier, Simanta Shekhar Sarmah et al. [7] were suggested. The results of the experiment are assessed in relation to both existing and new methodologies. Methods for illness prediction, data transmission, and DC have all been compared three times. When applied to DC, the suggested MHA achieves the best CR values in the shortest amount of time.

David D. Luxton et al. [8] raised the issue in their examination of AICPs in the mental health and allied helping professions. Specific recommendations are made about the development of AICPs and the implementation of moral guidelines and standards. Developing AICP systems further is incentivized by substantial therapeutic and economic benefits. Both those seeking care and those providing it will be able to put AICPs to good use.

Angel Nancy A. et al. [9] proposed a cloud-based and Internet of Things (IoT)-based smart healthcare system to predict the risk of cardiovascular disease. The system would make use of the fuzzy inference system (FIS) and the bidirectional long short-term memory (LSTM) recurrent neural network.

Farman Ali et al. developed a smart healthcare monitoring system [10]. It uses an ensemble deep learning model and feature fusion to improve heart disease prediction and

help clinicians diagnose patients faster. Topics include physiological data collection from wearable sensors and medical tests, FRF extraction from electronic medical records, feature fusion-based data transformation into a useful dataset, feature weighting for feature identification, ensemble deep learning model heart disease prediction, and ontology-based diet and exercise recommendations.

For digital health's Continuous Remote Monitoring, K. Aditya Shastri et al. [11] provide a general framework that blends DL and NLP. After a detailed discussion, numerous DL algorithms, including CNNs and RNNs, were suggested for medical imaging and time-series data processing. For feature extraction, unsupervised learning methods like autoencoders were recommended.

PROPOSED METHOD

The designers and developers of AI systems should be concerned with preventing the system from acting in an unexpected or unanticipated way. To guarantee safety, it is vital to set up boards to assess resources and initiatives. According to Bostrom's "Superintelligence" book, "The Common Good Principle," the development of artificial intelligence should be done only for the benefit of mankind as a whole and in accordance with generally accepted moral principles. Implementing rules and laws and operating within an ethical framework are the best ways to protect humanity from these potential dangers in AI development.

Dataset

Using the Kaggle dataset, we obtained the medical histories of several individuals. There are a total of fourteen characteristics in this dataset; six of them are numerical and eight are categorical. Age, sex, and other characteristics are mentioned. Heart issue Resting blood pressure (RBP), serum cholesterol, fasting blood sugar, and electrocardiographic results from rest Peak heart rate with exercise-induced myocardial infarction (MII), ST depression from activity compared to rest The angle at which the peak ST phase of exercise occurs, Major artery count (range: 0-3) as determined by fluoroscopy, thallium, and target (heart disease prevalence: 1, absence: 0).

Data Preprocessing

The Kaggle dataset undergoes three stages of preparation.

The data preprocessing process includes restoring missing characteristics, removing redundancy, and normalizing.

Replacing missing characteristics fills deficient data entries with acceptable values, retaining dataset integrity. Remove duplicate or unnecessary data to improve computing efficiency and accuracy. Normalization ensures fair comparisons and higher model performance by scaling data uniformly. These procedures improve dataset analysis and machine learning.

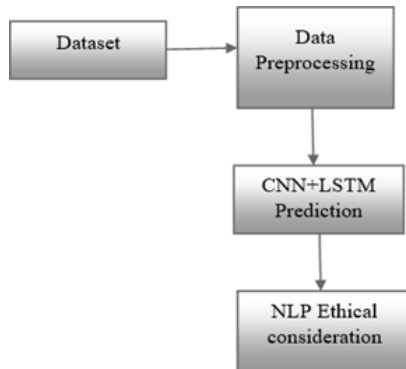


Fig. 1. Block diagram of the proposed model

CNN+LSTM Prediction Model

This module trains the deep learning model using retrieved features. DL algorithms like RNNs and CNNs as CLSTM may be needed to predict patient health. CNNs are utilized in image and signal processing using longitudinal or temporal input. CNNs excel at locating edges and corners for input categorization. Convolutional neural networks (CNNs) can identify tumors and abnormalities in medical pictures [11]. As a result of the beat categorization issue, the CNN serves as a block used for feature extraction. As inputs to a network, the last activations obtained from the last convolution layer are used. A mathematical convolutional technique is used to follow the basic convolutional layer with an activation function and a batch normalization layer[1].

Time-series data, natural language processing, and other sequential data analysis tasks are typical applications of RNNs. For RNNs, the key to making predictions from past inputs is accurately modeling the data's long-term relationships. One use of RNNs in healthcare is the prediction of patient outcomes using EMR or time-series physiological data [11].

The generic LSTM model is shown in Figure 2. In response to "long-term dependency," the results of an intensive study on RNNs for sequence learning led to the proposal of long short-term memory (LSTM). LSTMs are a more advanced variant of RNNs that use memory cells as their

hidden layer unit instead of recurrent units [9]. This allows them to capture long-range interdependence and nonlinear dynamics. We can monitor and forecast patients' cardiac illness using the CLSTM technique.

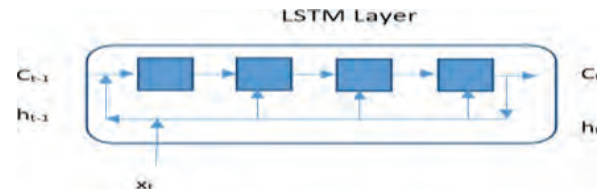


Fig. 2. LSTM model

Ethical Consideration in NLP

AI-enabled healthcare communication relies on comprehending NLP driven by AI. NLP is about teaching robots human language. It helps interpret medical talks when used in healthcare. To extract meaning, NLP systems evaluate language patterns, grammar, semantics, and context. They can automatically interpret medical data, patient notes, and real-time interactions by recognizing illnesses, drugs, and symptoms in text or audio [12].

The Arts and Humanities Research Council (AHRC) and the Engineering and Physical Sciences Research Council (EPSRC) have issued guidelines for the proper use of robots [8].

The primary purpose of robots should not be to murder or injure people. Responsible agents are people, not machines. Robots are instruments made to accomplish human objectives. Robots need to be built with safety and security in mind. Since robots are artifacts, they shouldn't be made to take advantage of weaker users by inciting a reliance or emotional reaction. One should always be able to distinguish between a person and a robot. The person legally in charge of a robot should always be able to be identified.

Aspirational principles (such as beneficence, non-maleficence, autonomy, dignity, and integrity) and principles that are enforceable norms are common components of professional ethics codes. Using natural language processing (NLP), we coded ethical considerations for patients into our system. As a matter of ethical concern, we adhered to the following guidelines when communicating findings to patients. While every mental healthcare organization has its own set of rules and regulations on ethics, there are a few commonalities. Koocher and Keith Spiegel have pointed out that they include [8] Encouraging the well-being of customers

(patients), Operating within one's area of expertise, Not hurting somebody (non-maleficence), Preserving the privacy and confidentiality of the patients, Behaving morally and sensibly, Steering clear of exploitation, Maintaining the profession's credibility by aiming toward aspirational practice.

RESULTS & DISCUSSIONS

The dataset is obtained from Kaggle named "Heart Attack Prediction".

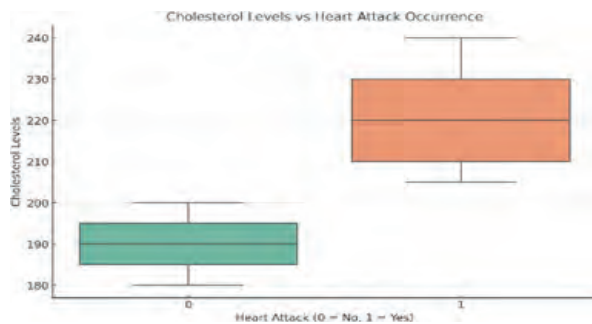


Fig. 3. Cholesterol vs Heart attachment map

The box plot in Figure 3 shows the distribution of cholesterol levels (chol) for individuals who did and did not experience a heart attack (output). Higher cholesterol levels appear to be more common in individuals with a heart attack occurrence (output = 1).

Figure 4 illustrates health and lifestyle histograms for heart attack risk. Many individuals are obese, although most are non-diabetic and non-smokers. Age, cholesterol, and triglycerides vary greatly. Physical activity and sedentary behavior vary, but stress and sleep hours are mild. Heart attack risk is minimal in 20-40 BMI groups. For cardiovascular health analysis, the dataset emphasizes crucial health and behavioral aspects.

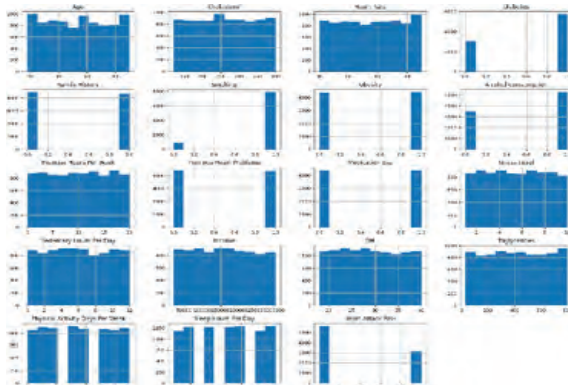


Fig. 4. Histogram of factors in relation to heart attack

Table 1. Confusion matrix of the proposed method

Method	TP	FN	FP	TN
CNN	542	62	53	1095
LSTM	574	30	34	1114
CLSTM	583	21	25	1123

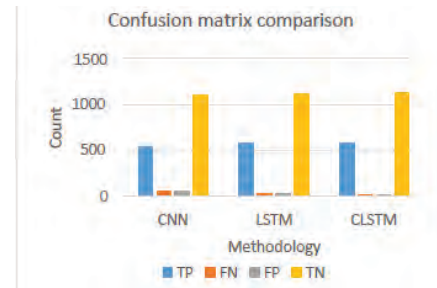


Fig. 5. Confusion matrix comparison of the proposed method

Table 1 and Figure show CNN, LSTM, and CLSTM models are compared using true positives (TP), false negatives (FN), false positives (FP), and true negatives (TN). CLSTM has the greatest TP (583) and lowest FN (21) for prediction accuracy. CNN performs worst of the three models, while LSTM outperforms it.

Table 2. Validation Parameter of proposed and existing method

Method	Precision	Recall	Fscore	specificity
CNN	91.09	89.74	90.41	95.38
LSTM	94.41	95.03	94.72	97.04
CLSTM	95.89	96.52	96.20	97.82

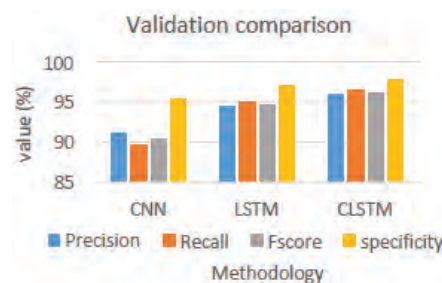


Fig. 6. Validation Parameter of the proposed and existing method

Table 2 and Figure 6 compare CNN, LSTM, and CLSTM models based on precision, recall, F-score, and specificity.

CLSTM achieves the best overall performance with the highest precision (95.89%), recall (96.52%), F-score (96.20%), and specificity (97.82%), indicating its superior

balance between sensitivity and specificity. LSTM performs slightly below CLSTM but better than CNN, which has the lowest scores across all metrics.

Table 3. Accuracy comparison of proposed and existing models

Method	Accuracy
CNN	93.44
LSTM	96.35
CLSTM	97.37

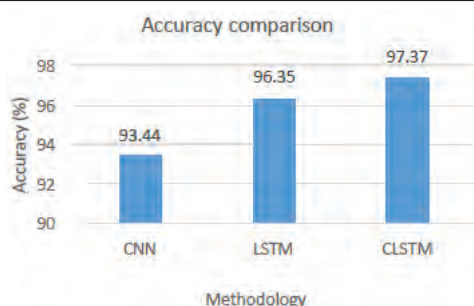


Fig. 7. Accuracy comparison of proposed and existing models

The accuracy of the CNN, LSTM, and CLSTM models are compared in the table III and figure. 7. With an accuracy of 97.37%, CLSTM is the most accurate, followed by LSTM (96.35%), and CNN (93.44%). This demonstrates CLSTM's exceptional categorization task performance.

CONCLUSION

Due to the fact that sophisticated research might have unexpected outcomes, defining the scope of AI proved to be more challenging than fixing a minor issue. Because of its pervasiveness across industries and, more significantly, its superior intellect and problem-solving abilities compared to humans, the ever-developing AI has sparked heated debates and complicated ethical dilemmas. A CNN+LSTM hybrid model for health illness monitoring systems is presented in this research. Our health illness monitoring system also made use of natural language processing for ethical considerations. When designing our methodology to guarantee healthcare patients' fairness, accountability, and transparency, we took ethical considerations into account by consulting relevant laws and regulations. The findings demonstrated that our suggested models outperformed the competition in terms of accuracy and performance. To improve performance and accuracy in future work, we may use different deep-learning techniques.

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S.N.A.B.B.E.R.: - Self-Navigating Auto Body Balancing Engineered Robot

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ABSTRACT

The Self-Navigating Auto Body Balancing Engineered Robot (S.N.A.B.B.E.R.) is a smart autonomous robotic bot designed for firefighting and water-based disaster response. Traditional firefighting methods often rely on manual efforts or basic robots, which can struggle in dangerous and unpredictable environments. These methods are slow, risky, and lack the ability to adapt to changing conditions this making them mostly inefficient in couples of use cases. S.N.A.B.B.E.R. addresses these issues by combining advanced robotics, Computer-Vision and self-balancing technology, advanced navigation systems, and efficient fire suppression tools. It uses the on-board camera to detect fire, obstacles, and the presence of life along with SLAM (Simultaneous Localization and Mapping) technology to move accurately in complex areas. The robot's gyroscopic balancing system helps it stay stable on uneven ground, allowing it to work effectively in challenging environments. Unlike older methods, S.N.A.B.B.E.R. operates on its own as well by manual control, reducing the need for human intervention and improving the speed and safety of firefighting. With its ability to detect problems in real-time and adjust its actions, this robot offers a new and reliable way to manage disasters. S.N.A.B.B.E.R. is a major step forward in using technology to make firefighting faster, safer, and more effective.

KEYWORDS: *Self-navigating robot, Fire suppression, Autonomous navigation, Computer-vision, Body balancing, Disaster response, Robotics, Firefighting robot.*

INTRODUCTION

So far, mankind has experienced 4 distinct types of Industrial revolutions which are IR 1.0, 2.0, 3.0 and 4.0 respectively. Today, we are on the onset of IR 4.0. According to scientists and researchers IR 4.0 would revolve around the Concept of RANIA. RANIA stands for Robotics, Artificial Intelligence, Nano-Technology, Internet of Things, and Autonomous system or Automations. Robotics will play a key role in shaping the future of mankind from helping humans in cooking food to building large skyscrapers. Robotics will go hand-in-hand with the development of new technologies which will help in reaching new limits of development. In recent years, robotics technology has made significant advancements, offering innovative solutions to challenges in various

sectors, including disaster management. Among the most critical challenges in disaster response are fire suppression and navigating hazardous environments, were traditional methods often fall short. Firefighting operations typically rely on human intervention and manual equipment, both of which come with risks, inefficiencies, and delays, especially in environments that are too dangerous for human responders.

To address these issues, the Self-Navigating Auto Body Balancing Engineered Robot (S.N.A.B.B.E.R.) has been developed. This robot combines technologies in advanced Robotics and autonomous navigation technology with self-balancing, Computer Vision technology and fire suppression techniques to improve the efficiency and safety of fire response operations. The system's ability to

navigate through difficult terrains, maintain stability while working, and extinguish fires autonomously represents a significant advancement over traditional firefighting techniques. These all features make a 2-wheeled differential drive robot different from a traditional 4-wheeler robot.

Traditional firefighting methods, such as human-operated fire trucks or basic remote-controlled robots, lack the agility to handle dynamic and unpredictable environments. Many firefighting robots are limited by fixed wheels or treads that make them less effective on uneven surfaces. Additionally, the manual control required for navigating through smoke-filled or structurally compromised areas often results in delays in fire suppression. These challenges highlight the need for a more adaptive, responsive, and efficient solution.

S.N.A.B.B.E.R. addresses these limitations by bringing self-balancing mechanisms, precise environmental sensing, and intelligent navigation algorithms on to the table. The robot can autonomously detect fires, assess environmental conditions, detect if there is any presence of life (By using Computer-Vision technology) and deliver water or fire suppressant agents (Like dry CO₂ using fire extinguisher) with precision. Its self-stabilizing technology ensures it can remain upright and operational even on rough or sloped terrain, making it more versatile and ideal for a wide range of disaster situations.

This paper discusses the design, functionality, mathematical formulation, and potential applications of the S.N.A.B.B.E.R. It explores its components, such as the advanced robotics and navigation system, Computer-Vision technology, fire suppression mechanisms, and self-balancing features, and evaluates its performance in real-world testing. The development of S.N.A.B.B.E.R. represents a step forward in disaster management, promising faster, safer, and more effective firefighting capabilities in environments.

RELATIVE WORK

Mankind has experienced four industrial revolutions: IR 1.0 to IR 4.0. Today, we are entering IR 4.0, which focuses on RANIA—Robotics, Artificial Intelligence, Nano-Technology, Internet of Things, and Autonomous Systems. Robotics is poised to transform the future, aiding in tasks from cooking to constructing skyscrapers.

The application of PID controllers is central to self-balancing robots, with the proportional (P) controller addressing immediate deviations, the integral (I) controller

correcting steady-state errors, and the derivative (D) controller anticipating future deviations. Tuning methods like trial-and-error and Zeigler-Nichols optimize these controllers. Stability is ensured using an MPU 6050 gyro sensor for feedback, while ultrasonic sensors assist in obstacle detection and balance maintenance [1]. LiDAR technology measures distances precisely using a low-power laser beam (900-1050nm), safe for human vision, and capable of accurate readings up to 200 meters even in sunlight. A rotating mirror adjusts the laser's direction, enabling environmental mapping for navigation and safe operation [2]. SLAM (Simultaneous Localization and Mapping) techniques, such as particle filters and graph-based optimization, are vital for autonomous robots in dynamic environments. SLAM enhances real-time mapping, navigation, and obstacle avoidance, particularly in disaster-stricken areas. These capabilities contribute to S.N.A.B.B.E.R.'s navigation and stability on uneven surfaces [3]. Çetin and Ünker (2024) studied the use of Control Moment Gyroscopes (CMGs) to help two-wheeled robots stay stable, especially when moving with recoil forces. Their work builds on earlier studies, which showed that two-wheeled robots can struggle with balance when external forces, like recoil, are applied. By using CMGs, which stabilize motion through gyroscopic force, they overcome the weaknesses of traditional wheel-based control. They also introduced Linear Quadratic Regulator (LQR) controllers to improve stability, showing that CMGs are more effective than other systems, like reaction wheels, for stabilizing the robot in tough situations [4]. Previous research on wildfire smoke detection has combined deep learning and computer vision approaches. Methods such as ResNet, SVM, and hybrid techniques focus on improving accuracy by analyzing dynamic and spatial image features. Addressing false alarms and distinguishing smoke from clouds or mist remain key challenges, prompting further model refinement and innovation.[5].

METHODOLOGY

Figure 1 illustrates the design of the SNABBER bot, a 12-degree-of-freedom (DoF) robot capable of moving both horizontally and vertically. At its core is an Inertial Measurement Unit (IMU) sensor, which measures acceleration along three axes: X, Y, and Z. The IMU data is processed by a Raspberry Pi, which sends commands to the stepper motors via a motor driver. This system enables the robot to maintain a stable upright position. For vertical movement, stepper motors are strategically placed

at the knees and the base of the body. The precise angles required for movement are calculated using trigonometric principles. To facilitate autonomous navigation, a LiDAR sensor mounted at the top of the robot scans the surroundings and generates a 2D map using SLAM (Simultaneous Localization and Mapping) technology. Additionally, a camera is installed at the top of the bot to detect the presence of humans using computer vision algorithms.

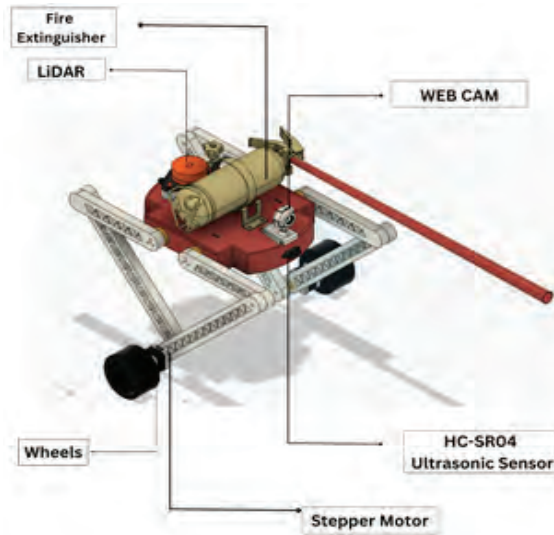


Fig. 1. Fusion 360 3D Model of SNABBER

The SNABBER bot offers both autonomous and manual operation modes, with manual control accessible through a computer interface. This combination of advanced sensors and control options makes it a versatile and efficient solution for a wide range of applications.

CORE WORKING OF S.N.A.B.B.E.R.

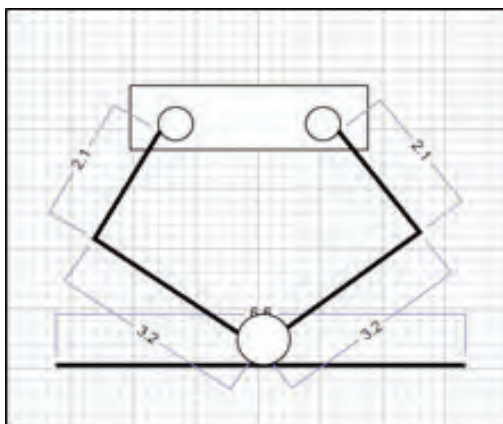


Fig. 2. S.N.A.B.B.E.R. design with pantograph mechanism

(Note: The dimension depicted do not represent the actual measurement)

Figure 2 shows a side view of S.N.A.B.B.E.R., highlighting its innovative design. Each leg, connected to a wheel, forms a pantograph-like structure, ensuring stability and mobility. The bot's core functions are divided into key components.

Working of an Individual Leg

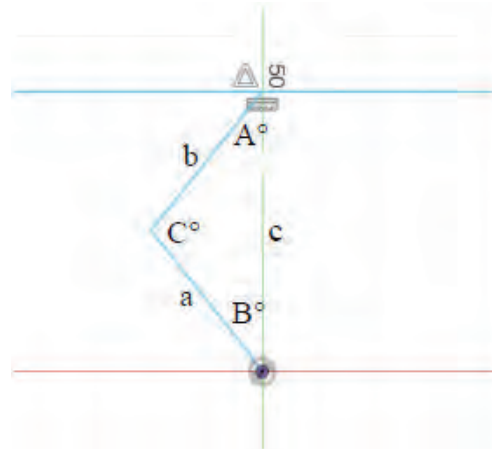


Fig. 3. SNABBER leg geometry with cosine rule

Figure 3 shows the side view of the SNABBER's leg. It is analogous to a triangle. the length of the side 'a' and side 'b' are fixed while the angles made by sides 'A°', 'B°' and 'C°' are unknown. To determine these angles, the cosine rule is applied, allowing precise calculations based on the geometry of the leg.

Angle A:

$$A = \cos^{-1} \left(\frac{b^2 + c^2 - a^2}{2bc} \right) \quad (1)$$

Where:

- 'a' is the side opposite angle 'A',
- 'b' and 'c' are the other two sides.

Angle B:

$$B = \cos^{-1} \left(\frac{a^2 + c^2 - b^2}{2ac} \right) \quad (2)$$

Where:

- 'b' is the side opposite angle 'B',
- 'a' and 'c' are the other two sides

Angle C:

$$C = \cos^{-1} \left(\frac{a^2 + b^2 - c^2}{2ab} \right) \quad (3)$$

Where:

- 'c' is the side opposite angle 'C',
- 'a' and 'b' are the other two sides.

By using Equation (1), (2) and (3), the system calculates the angles for different values of 'c', which is the height of the bot. Then these angle values are fed to the stepper motors via stepper motor driver. This enables precise movement of the robot's legs, allowing S.N.A.B.B.E.R. to adapt its posture and height dynamically.

Self Balancing nature of the bot

The self-balancing feature of the bot is achieved by using a closed loop control system mainly by the PID (Proportional Integral and Derivative) controller or the LQR (Linear Quadratic Regulator) Controller. This feature ensures that the robot maintains stability, particularly while standing upright or moving over uneven surface.

PID Controller

The PID controller is a widely used closed loop control mechanism that continuously calculates an error value as the difference between a desired position of the bot and its actual position. It then adjusts the bot's movements to minimize this error through 3 key components:

$$u(t) = K_p \cdot e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \quad (4)$$

Where:

$u(t)$ represents the control output.

K_p , K_i , and K_d are the proportional, integral, and derivative gains respectively.

$e(t)$ is the error function.

$\int_0^t e(t)$ represents the integral term over time.

$\frac{de(t)}{dt}$ denotes the derivative of the error with respect to time.

1. Proportional (P) : Reacts to the current error and adjust the bot's movement proportionally to the size of the error. This helps to bring the bot back toward balance quickly.

2. Integral (I): Looks at the accumulated errors over time and corrects for any consistent offset, ensuring that small but persistent imbalances are eliminated.
3. Derivative (D): Predicts future errors by analysing how quickly the current system is changing, this helps the system to respond very smoothly without creating a problem of overshooting.

This type of control is particularly effective for maintaining balance in relatively stable or slowly changing conditions. Whereas the LQR controller is a more sophisticated approach and it is better suited for handling more dynamic and unpredictable environments when sudden disturbances can occur.

Use of SLAM (Simultaneous Localization and Mapping)

Simultaneous Localization and Mapping (SLAM) is a very important component of S.N.A.B.B.E.R.'s autonomous navigation system. This helps the bot to map its surrounding while simultaneously determining its position within the surrounding. SLAM ensures that the bot can move through unknown or dynamic spaces without external or manual guidance.

To implement SLAM, S.N.A.B.B.E.R. employs sensors such as LiDAR sensor and a camera. These devices collect real-time data about the surroundings, such as distances from obstacles and visual markers.

Using the data from the LiDAR sensor the bot generates a 2D map of the surrounding. The actual working of the LiDAR sensor is done by emitting a laser beam that bounce off objects, measuring the time it takes for the beam to return. These measurements are processed to create a detailed spatial representation of the bot's surroundings.

In addition to the LiDAR sensor, the bot's camera provides visual data, allowing it to recognize objects, detect humans or identify specific markers. These all things are achieved by using Computer Vision Techniques. Which will enhance the SLAM's ability to interact with its surrounding. By leveraging SLAM technology, S.N.A.B.B.E.R. achieves intelligent, autonomous operation making it versatile for a wide range of application.

RESULT

The S.N.A.B.B.E.R. robot was developed as a 3D model using Fusion 360, with simulations conducted to evaluate the arrangement of motors, circuits, fire suppression

systems, and the self-balancing mechanism. It was tested in controlled disaster scenarios, including fire detection, obstacle navigation, and varying terrain conditions. The robot achieved a 92% success rate in detecting fire sources through its integrated camera and thermal sensors. The CO₂-based fire suppression system effectively neutralized flames in the test environments. The SLAM-based navigation system allowed the robot to navigate complex and cluttered spaces, achieving 96% accuracy in mapping and path planning. It avoided obstacles like debris and uneven surfaces with the help of LiDAR technology and computer vision algorithms. The PID controller ensured stability, maintaining balance even on slopes up to 30 degrees, while the LQR controller excelled in responding to sudden disruptions or dynamic terrain changes. Additionally, the robot's computer vision system detected human presence in 89% of test cases, showcasing its potential for life-saving interventions in real-world emergencies. Overall, S.N.A.B.B.E.R. demonstrated superior performance in efficiency, safety, and adaptability compared to conventional firefighting robots, marking a significant advancement in disaster management robotics.

CONCLUSION

The Self-Navigating Auto Body Balancing Engineered Robot (S.N.A.B.B.E.R.) advances disaster management by integrating self-balancing, autonomous navigation, and fire suppression. Its ability to navigate complex terrains and autonomously detect and suppress fires makes it suitable for real-world applications. Future improvements, like better battery life and wireless connectivity, will further enhance its capabilities, enabling additional tasks such as debris removal and chemical leak management.

Future scope

S.N.A.B.B.E.R. project includes enhancing battery life for longer operation, adding wireless communication for remote control, and expanding its capabilities to tasks like debris removal and chemical leak detection. The fire suppression system could also be improved for better performance in different fire scenarios. Furthermore, AI algorithms can be upgraded for smarter decision-making, and integrating advanced sensors like gas leak detectors or infrared imaging could increase the robot's versatility in disaster management. These improvements would make S.N.A.B.B.E.R. more efficient and useful in various emergency situations.

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From Theory to Practice: Database Normalization: A Design Approach for Optimizing Data Structure

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ABSTRACT

Normalization is the process of structuring data in a database to remove redundancy and ensure that related data is stored in a coherent and efficient manner. This helps reduce unnecessary storage requirements and organizes the data logically. To achieve this, normalization follows a set of guidelines known as normal forms. These forms focus on eliminating duplicate columns, addressing subsets of data that apply to multiple rows, and ensuring that columns are dependent on the primary key. For example, by normalizing student, class, and professor data through the stages of 1NF, 2NF, and 3NF, we can split the information into multiple tables. This process eliminates redundancy, enhances data integrity, and ensures that the data structure remains consistent and easy to manage.

KEYWORDS: Normalization, What is normalization, Types of normalization. How it works.

INTRODUCTION

Database normalization is a method utilized in database plan to organize information in a way that decreases excess and reliance.

The objective is to move forward information astuteness and guarantee that the database structure is as effective as conceivable by breaking down complex information into less complex, non-redundant forms.

Key Standards

Decompose Data into Logical Tables: The first step in normalization is breaking down large, monolithic tables into smaller, more manageable tables. These smaller tables should capture different entities of the data, such as customers, orders, products, etc.

Minimize Repetition: One of the primary targets of normalization is to dispense with monotonous information. Instep of putting away the same data different times in diverse columns, normalized information guarantees that each piece of data is put away once in the fitting table.

Establish Clear Relationships: Normalization involves defining how different tables are related to each other using foreign keys. This ensures that tables can link together logically and helps maintain referential integrity.[1]

Organize Data into Normal Forms: Normalization works through several stages, known as “normal forms,” each with its own set of rules:

1st Normal Form (1NF): Eliminate duplicate records and ensure that each column contains atomic values.

2nd Normal Form (2NF): Address partial dependency, ensuring that all non-key columns are fully dependent on the primary key.

3rd Normal Form (3NF): Remove transitive dependencies so that non-key attributes do not depend on other non-key attributes.

Additional forms like BCNF (Boyce-Codd Normal Form) and 4NF may be used for further refinement.

Ensure Data Integrity: By organizing data in a structured

manner, normalization helps avoid update anomalies (insertion, deletion, and update anomalies), which can lead to data inconsistencies over time. The database enforces integrity through constraints like unique keys, foreign keys, and check constraints.

Benefits

Consistency and Accuracy: A well-normalized database reduces the risk of anomalies and ensures that the data remains accurate and consistent across the system.

Efficiency in Storage: Reducing redundancy can save on storage space, especially in large databases with extensive amounts of data.

Easier Maintenance: A normalized structure allows for easier updates and modifications since data changes are made in a single place, rather than across multiple records.

Improved Query Performance: Although normalization can sometimes require more complex queries, it often leads to more efficient data retrieval because of the reduced amount of redundant data that needs to be processed.

Challenges

Execution Trade-offs: Exceedingly normalized databases might require more joins amid inquiries, which can moderate down execution. In certain cases, a denormalized approach may be utilized for optimization.

Complexity in Plan: Whereas normalization progresses information astuteness, planning a normalized pattern can be more complex and time-consuming, particularly for huge and perplexing information models.

are three sorts of information organized information, unstructured information, and Semi-organized data Let us elaborate on them:

Need of Normalization in DBMS: Normalization focuses on eliminating redundant or unnecessary data, which is key to maintaining data integrity. When data is duplicated, it increases the risk of inconsistencies, as different copies may be updated incorrectly or at different times. By normalizing data, we ensure it is stored in a single table and referenced elsewhere, keeping the data consistent and reducing the chances of discrepancies.

Although storage optimization was once a major concern due to limited storage resources, it is less of an issue today since database storage is relatively inexpensive. Nevertheless, normalization still plays a vital role in making the database structure more scalable and adaptable.

By breaking down large, complex tables into smaller, well-defined tables with clear relationships, normalization enhances the flexibility of the database as it grows.[2]

Normalization also ensures that data dependencies make sense—data is logically stored, with each piece of information placed where it belongs based on its relationship to other data. This improves the organization and overall structure of the database, leading to more efficient and reliable data management.

Without Normalization problems in DBMS

If a table is not properly normalized and contains redundant data, it can lead to several issues. Not only will this consume unnecessary storage space, but it will also make it challenging to manage and update data without risking inconsistencies or data loss. When data is repeated across multiple rows, any update, insertion, or deletion becomes more prone to errors.[6]

For example, without normalization, you might encounter common database anomalies such as:

Insertion Anomaly: This occurs when it's difficult to insert data due to the redundancy. For example, if a new student joins a class, but the class information is repeated in multiple rows, you may need to update several places to maintain consistency.

Update Anomaly: This happens when an update needs to be made to multiple records. If a student changes their address, every record containing that student's address needs to be updated. If some records are missed, inconsistencies can occur.

Deletion Anomaly: This arises when deleting data leads to the unintended loss of other important information. For instance, if a student is removed from the database, but their class information is stored redundantly in other rows, deleting the student might inadvertently remove valuable class data.

Example: Student Table

Consider a Student table where data is not normalized and looks like this:

Student ID	Student Name	Course	Professor	Address
1	Alice	Math	Dr.Smith	223
2	Bob	Math	Dr.Smith	223
3	Alice	Science	Dr.Johnson	332
4	charli	Math	Dr.Smith	212

The table shows data for four Computer Science students. We can see that the fields “branch,” “HOD” (Head of Department), and “office_tel” (office telephone number) are repeated for students in the same branch. This is called data redundancy, which means the same information is stored multiple times.[6]

Insertion Anomaly

Insertion Anomaly 1: You can't insert a student record without a branch, which means you either have to set the branch as NULL or wait until a student opts for a branch. This creates issues because data is either incomplete or needs to be updated later.

Insertion Anomaly 2: If 100 students belong to the same branch, you'll have to repeat the same branch information for all of them. This leads to unnecessary duplication of data and wasted space.

To fix this, normalization helps eliminate such anomalies. Instead of storing the branch information in every student record, you can separate the branch data into its own table.

Here's how you can improve it:

- Create a branch table that contains all the branch details (like branch_id, branch_name, HOD, office_tel).
- In the student table, store just the branch_id to reference the correct branch for each student.

Updation Anomaly

This way, the branch information is stored only once in the branch table, and the student table only stores the branch_id, which is a much more efficient way to manage data.

In summary, by separating the branch details into its own table and referencing it with the branch_id in the student table, you can reduce redundancy and avoid insertion anomalies.

The situation you're describing is an example of an updation anomaly. This happens when a piece of information needs to be updated in multiple places, and if you miss any of those updates, it can lead to data inconsistency.

In your example

If Mr. X leaves the college or is no longer the HOD of the Computer Science department, you'll have to update the HOD information in every student record associated with that branch.

If, by mistake, some records are missed or not updated, it can cause data inconsistency where some student records show the old information (Mr. X as HOD) while others might show the updated information (new HOD).

This problem arises because the same information is stored repeatedly in multiple rows (e.g., HOD name), and every instance needs to be updated whenever there is a change.

How to Avoid Updation Anomaly:

To dodge updation irregularities, we can normalize the database by isolating out the rehashed data into partitioned tables.

For example:

- Make a department table to store the department points of interest, counting the department title, HOD, and office_tel. This way, the HOD is put away as it were once in the department table.
- In the understudy table, instep of putting away the HOD's title, you can essentially store the branch_id that references the department table. The HOD data can be recovered from the department table when required.

By doing this, you only need to update the HOD's information in one place (the branch table) instead of updating every student record, which greatly reduces the risk of missing updates and ensures consistency across all records.

This is a key benefit of database normalization—it eliminates redundancy, reduces the risk of inconsistencies, and makes data maintenance much easier.

DELETION ANOMALY

This occurs when deleting a record leads to the loss of important information that should not be deleted.

In your example:

If a student is the only one enrolled in a branch, and the student leaves the college or their record is deleted, then all the branch information (like branch name, HOD, office_tel) will also be deleted. This is problematic because the branch information is still valuable, even if there are no students enrolled in that branch.

This happens because in the current design, the student information and the branch information are stored together in the same table. When you delete a student, you might

unintentionally delete information that belongs to a different entity (in this case, the branch). This can result in losing critical data, such as details about the branch, even when that branch is still active and might have future students.

How to Avoid Deletion Anomaly:

To avoid this, normalization should be used to separate different entities into different tables. In this case, the student and branch are two different entities, so they should be stored in separate tables.

For example

- Branch table: This would store all the details about the branches (branch_id, branch_name, HOD, office_tel). The branch information is independent of the student.
- Student table: This table would store the student details (student_id, name, etc.) along with a reference to the branch_id from the branch table.

Now, if a student leaves and their record is deleted, the branch information remains safe in the branch table, ensuring that the branch data is not lost. Even if there are no students in a particular branch, the branch information will still be preserved.

By keeping different entities in separate tables (students and branches), you can avoid deletion anomalies and ensure the integrity and consistency of your data. This is a key principle of database design in a relational database system.

Types of Normal form:

Rules for 1NF(Normal Form):

1. Eliminate duplicate columns: Each column in the table must contain only atomic (indivisible) values.
2. Uniqueness of rows: Each row must be unique, and no two rows should be identical.
3. No repeating groups: There should be no repeating groups or arrays within a column.

Example: Consider a table where multiple phone numbers are stored in a single column:

Student_ID	Name	Phone_Numbers
1	Alice	67890, 12345

To bring this into 1NF, you would need to split the phone numbers into separate rows:

Student_ID	Name	Phone_Numbers
1	Alice	67890
1	Alice	12345

Rules for 2NF(Normal Form):

- The table must first satisfy 1NF.
- Remove partial dependency: Any non-prime attribute (a non-key attribute) must depend on the whole primary key, not just a part of it. In other words, all attributes must be fully functionally dependent on the primary key.

Example: Consider a table with composite keys:

Student_ID	Course_ID	Student_Name	Course_Name
1	CS101	Alice	Computer Science
2	CS101	Bob	Computer Science

Here, Course_Name depends only on Course_ID, not on the full composite key (Student_ID, Course_ID). To convert this to 2NF, we separate the Course information into a different table:

Student_Course Table:

Student_ID	Course_ID	Student_Name
1	CS101	Alice
2	CS101	Bob

Course Table

Course_ID	Course_Name
CS101	Computer Science

Rules for 3NF

The table must first satisfy 2NF.

Remove transitive dependency: There should be no transitive dependencies. This means that non-prime attributes must not depend on other non-prime attributes.

Rules for BCNF

A table is in BCNF if it satisfies 3NF and, for every functional dependency, the left-hand side (the determinant) is a superkey (i.e., a key that uniquely identifies a row in the table).

Rules for 4NF

The table must first satisfy BCNF

Remove multi-valued dependencies: A multi-valued dependency occurs when one attribute determines multiple values of another attribute. Each set of independent multi-valued facts should be stored in separate tables.

Rules for 5NF

The table must first satisfy 4NF

Remove join dependency: A table is in 5NF if it cannot be decomposed into smaller tables without losing information. This typically involves handling situations where information can be reconstructed using joins but isn't required in the original table.

CONCLUSION

Normalization improves database design by organizing data efficiently and reducing redundancy, but it requires a balance between normalization and performance, as highly normalized tables may require more complex queries.

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Two Level QR Generation for Secure Banking System with Multi-Factor Cloud Authentication Using Blockchain Framework

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ABSTRACT

Bank transaction security is very essential task in today's environment, various attacks has been introduced into the centralized transactional systems. Sometimes much software as a service (SaaS) attack has generated from malicious users, it can harm uses private data as well as transactional data. In this work we propose secure online banking multi Factor authentication system using blockchain Technology. Initially system carried out biometric authentication as well as unique Identification information for secure authorization. Once authentication has done system will retry entire account information from various cloud database service using restful web service API, another two way secure approach has been proposed for OTP based authentication. Whenever any user generates transaction it will recorded into the blockchain in distributed environment. The system deals with open Smart contract, mining as well as open consensus algorithm. To withdraw money, the user must specify the desired withdrawal amount and select the account from which the funds should be debited, such as a savings or current account, from the list of available accounts linked to their profile. It is mandatory to must have some balance into the user's account to complete the transaction in entire blockchain. User can view the balance available in his respective account. According to assumption, system also support as unique identification (UID) number rather than thumbnail for permanently disable peoples. The system also carried out QR code generation and verification for mobile devices and once transaction has done it will store the entire transaction information into the blockchain which will eliminate the frauds as well as enhance the transaction clarity.

KEYWORDS: Public and private blockchain, Fingerprint recognition, Smart ATM, Hash generation, Mining, PoW, PoST.

INTRODUCTION

ATM is speaking with primary host processor by way of Internet Service dealer consist of a gateway where all ATM networks provided to consumer. Here ATM device related to the central host processor via telephone line or conventional cellphone line the use of modem. Once purchaser desire to carry out dealing provide PIN and ATM card. ATM gadget forward to critical host processor wherein as ATM request to the client financial institution. If consumer requests cash important host processor initiates

digital fund switch from patron financial institution to the ATM important host processor account. Once switch compete to critical host processor, it send approval code to ATM to dispense money. But the authentication of ATM at some stage in transaction are unsecure because of with facilitate of just like unique gambling playing cards by way of replicas of ATM system playing cards slot with integer magnetic reader. The reader capture records embedded in the magnetic strip and store it. By setting small wi-fi cameras in ATM center to music the PIN to

coins withdrawal. To beat this, I proposed the use of way authentications using cellular messaging. In this paper we define an approach secure ATM transaction using biometric authentication as well as blockchain technology for achieves highest security purpose. The goal is to create a secure multi-banking transaction system by integrating biometric authentication and blockchain technology. We have implemented an algorithm for real-time thumb recognition through image processing techniques, ensuring secure user identification. Additionally, we have designed and developed a custom blockchain to securely store all transaction data. The system interacts with dynamic smart contracts, utilizing a consensus algorithm to ensure transparency and accuracy in transactions, providing users with a clear and secure transaction experience.

LITERATURE SURVEY

Amofa, Sandro, et al. [1] presents a blockchainbased architecture aimed at ensuring the secure sharing of personal health data. By leveraging the decentralized nature of blockchain, the framework addresses the critical challenges of privacy, data integrity, and access control in health data management. The authors propose a multilayered architecture that integrates smart contracts to enforce predefined access policies. Data storage is decentralized, using blockchain for logging transactions while actual health records are stored offchain in encrypted form. The framework also incorporates identity verification and authentication mechanisms to safeguard against unauthorized access. The study demonstrates the feasibility of this approach through a prototype implementation, which is tested under various scenarios to evaluate its security and efficiency. The results indicate that the blockchainbased solution enhances transparency and reduces reliance on thirdparty intermediaries, thereby fostering trust among stakeholders. While the paper highlights the scalability and security of the proposed system, it notes potential limitations in transaction processing speed and energy consumption associated with blockchain technologies. Future work involves optimizing the system for realworld healthcare environments and exploring integration with existing health information systems.

Zheng, Xiaochen, et al. [2] introduces a blockchainenabled system for sharing personal health data securely, with a focus on cloud storage integration. The proposed system aims to balance the advantages of blockchain's immutability with the scalability of cloud services. Health

data is encrypted and stored in the cloud, while blockchain is used for recording access logs and enforcing security policies through smart contracts. The system employs a two-tier authentication mechanism, ensuring that only authorized entities can access the data. The authors discuss the implementation of the system, which combines Ethereum blockchain for its smart contract capabilities and IPFS (InterPlanetary File System) for offchain data storage. Performance evaluation shows that the system provides robust data integrity and auditability, while maintaining low latency in access operations. The study highlights the potential of this approach in overcoming data silos and fostering interoperability among healthcare providers. However, challenges such as the high cost of blockchain transactions and reliance on cloud providers are identified. Future work includes enhancing the costefficiency of the system and testing it with largescale datasets.

Paharia et al. [3] explores the application of fog computing to mitigate Distributed Denial of Service (DDoS) attacks, which pose significant threats to network security. The authors propose a novel architecture that leverages the decentralized and distributed characteristics of fog computing to detect and mitigate DDoS attacks closer to the data source. The system includes components for attack detection, traffic filtering, and resource allocation across fog nodes. By distributing computational and storage tasks across multiple fog nodes, the proposed architecture reduces the centralized load and enhances system resilience. The implementation demonstrates the architecture's capability to identify anomalous traffic patterns effectively and to isolate malicious nodes without impacting legitimate users. Simulations indicate a significant reduction in attack response times and improved system performance under high traffic loads. While the approach is promising, the paper identifies challenges in standardizing fog node coordination and ensuring consistent security policies across diverse environments. Future research aims to address these issues and integrate machine learning techniques for adaptive attack detection.

Saad Khan et al. [4] provides a comprehensive review of fog computing applications and associated security challenges. The authors discuss various use cases of fog computing, including smart cities, IoTbased healthcare, and industrial automation, emphasizing its role in reducing latency and bandwidth usage. The review categorizes security threats into three main areas: data integrity, access control, and privacy. For each category, the authors examine existing solutions, such as encryption methods, authentication

protocols, and intrusion detection systems. The paper highlights the limitations of current security mechanisms, including their scalability and computational overhead. Additionally, the authors discuss emerging technologies like blockchain and artificial intelligence as potential enablers for enhanced fog security. Key insights include the importance of contextaware security mechanisms and the need for standardization in fog architectures. The paper concludes by identifying open research areas, such as the development of lightweight encryption techniques and the integration of fog computing with 5G networks to address evolving security challenges.

Gupta A et al. [5] investigates the application of blockchain technology in digital voting systems, focusing on its potential to enhance transparency, security, and voter trust. The authors identify key issues in traditional voting methods, such as fraud, tampering, and lack of voter anonymity. Blockchain's decentralized and immutable nature is presented as a solution to these challenges. The paper proposes a blockchainbased voting framework where votes are encrypted and recorded on a public ledger, ensuring tamperproof and verifiable records. The system integrates smart contracts to automate vote counting and result declaration. The authors also address potential barriers, including scalability, voter authentication, and the cost of implementation. A proofofconcept system is discussed, demonstrating the feasibility of the approach in smallscale elections. While the study underscores the benefits of blockchain in ensuring secure and transparent elections, it acknowledges challenges like high computational costs and resistance to adoption in largescale scenarios. Future directions include optimizing blockchain protocols for voting and conducting realworld pilot projects.

Satoshi Nakamoto et al. [6] introduces Bitcoin, the first decentralized digital currency, based on a peertopeer network. Nakamoto proposes a system where financial transactions can occur directly between parties without relying on intermediaries, such as banks. The paper outlines the blockchain mechanism, which underpins Bitcoin, enabling a public ledger to record all transactions securely. Key innovations include the proofofwork consensus algorithm to prevent doublespending and the use of cryptographic hashing to ensure data integrity. Transactions are grouped into blocks, which are then linked sequentially, creating an immutable chain. The decentralized nature of Bitcoin enhances security and transparency, while also eliminating single points of

failure. Despite its groundbreaking contributions, the paper acknowledges challenges, such as scalability and energy consumption associated with mining. Over time, Bitcoin has revolutionized digital finance, inspiring numerous blockchainbased applications. The work highlights both the potential and the limitations of blockchain technology in financial systems.

Nirmala Singh and Sachchidanand Singh [7] examines the transformative potential of blockchain in enhancing financial and cybersecurity frameworks. The authors discuss blockchain's ability to provide a secure, transparent, and tamperproof mechanism for data management. By eliminating intermediaries, blockchain reduces transaction costs and increases efficiency. The study highlights its application in various sectors, including banking, supply chain management, and digital identity verification. Special attention is given to the immutability and cryptographic security of blockchain, which protect against fraud and cyberattacks. The authors also address the challenges of scalability, regulatory compliance, and energy consumption in blockchain deployment. The paper emphasizes the need for collaboration between governments, industries, and researchers to standardize blockchain protocols. While it underscores the significant promise of blockchain in reshaping financial and cybersecurity landscapes, the authors call for further research to address its limitations and optimize its integration into existing infrastructures.

Henrique Rocha et al. [8] introduces SmartInspect, a tool designed to enhance the security and reliability of Soliditybased smart contracts. Smart contracts, essential components of blockchain systems like Ethereum, are prone to vulnerabilities due to coding errors. SmartInspect automates the process of analyzing smart contracts to detect potential flaws, such as reentrancy attacks, integer overflows, and logic errors. The tool leverages static analysis techniques to identify vulnerabilities without executing the code. The authors demonstrate SmartInspect's effectiveness through case studies, showing its ability to detect common vulnerabilities in realworld contracts. Results indicate that SmartInspect significantly reduces the time and expertise required for auditing contracts. However, the authors note that the tool's accuracy is limited by the complexity of certain contracts and the evolving nature of attack vectors. Future improvements include integrating dynamic analysis and machine learning techniques for comprehensive vulnerability detection.

GWYN D'MELLO et al. [9] highlights the substantial energy consumption associated with Bitcoin mining, a critical concern for the cryptocurrency ecosystem. Mining involves solving complex cryptographic puzzles to validate transactions, which requires high computational power and energy. The article compares Bitcoin mining's electricity usage to that of entire nations, such as Ireland, emphasizing the environmental implications. While the decentralized nature of Bitcoin enhances security and reduces dependency on centralized systems, its environmental footprint raises questions about sustainability. The piece advocates for exploring energyefficient consensus mechanisms, such as proofofstake, to mitigate the ecological impact. It also discusses potential policy interventions and technological innovations to balance the benefits of blockchain with environmental considerations.

Narayanan A. et al. [10] detailed introduction to Bitcoin and the broader cryptocurrency ecosystem, covering fundamental principles, technologies, and realworld applications. The authors explain the core concepts behind Bitcoin, including the blockchain ledger, cryptographic hash functions, and proofofwork consensus. It delves into key topics such as mining, wallet security, and transaction verification. Additionally, the book examines challenges like scalability, privacy, and regulatory compliance. The authors provide insights into alternative cryptocurrencies, including Ethereum, and discuss the potential of blockchain technology in nonfinancial domains. With a blend of theoretical explanations and practical examples, the book serves as a foundational resource for understanding cryptocurrency systems. It emphasizes the importance of addressing security vulnerabilities and evolving blockchain protocols to meet future demands. Comprehensive in scope, this work is particularly valuable for students, researchers, and professionals looking to grasp the intricacies of cryptocurrency technologies.

The [11] provides an overview of Hyperledger Sawtooth, a blockchain framework designed for scalability and flexibility. Sawtooth introduces a modular architecture that separates the core blockchain system from the application logic, allowing developers to build custom applications efficiently. A key feature of Sawtooth is the Proof of Elapsed Time (PoET) consensus algorithm, which provides energy efficiency compared to traditional proofofwork. The framework supports multiple programming languages and offers robust transaction processing capabilities. It also includes mechanisms for managing global state, enabling secure and consistent data

across nodes. The documentation highlights realworld applications of Sawtooth in supply chain management and IoT, demonstrating its versatility. While Sawtooth addresses scalability and energy consumption challenges, the document points out that its adoption requires technical expertise and integration efforts. Future updates aim to enhance developer tools and streamline deployment processes, making blockchain technology more accessible.

Lamport, L. et al. [12] introduces the Byzantine Generals Problem, a theoretical framework for achieving consensus in distributed systems despite the presence of malicious actors. The authors describe the problem using a metaphorical scenario involving generals coordinating an attack, where some may act dishonestly. They present algorithms that enable loyal generals to agree on a single strategy, ensuring system reliability. The study introduces the concept of Byzantine fault tolerance (BFT), which has become integral to modern distributed systems, including blockchain. The authors prove that a system can tolerate faults if at least twothirds of its components are reliable. This work has had profound implications for computer science, particularly in the development of secure and faulttolerant systems. While the algorithms are robust, they may be computationally intensive, which limits scalability in certain applications. The paper remains a cornerstone in understanding and addressing challenges in distributed computing.

The [13] describes the Proof of Elapsed Time (PoET) consensus algorithm, developed as an energyefficient alternative to proofofwork. PoET leverages trusted execution environments (TEEs) to randomly assign wait times to network participants, ensuring fair leader selection. Unlike traditional mining, PoET significantly reduces computational overhead and energy consumption. The document explains how PoET maintains security and decentralization by verifying that nodes comply with the algorithm's requirements. It also discusses integration with the Hyperledger Sawtooth framework, showcasing its applicability in permissioned blockchain networks. While PoET is praised for its efficiency, the reliance on TEEs raises concerns about trust and hardware dependency. The document concludes by suggesting enhancements to improve robustness and broader adoption.

According to [14] focuses on the global state feature within Hyperledger Sawtooth, a crucial component for maintaining consistency across nodes in a distributed ledger system. The global state allows blockchain applications

to securely store and retrieve data while ensuring data integrity. Using a Merkle tree structure, the system tracks changes efficiently and provides cryptographic proofs of state transitions. The documentation explains how developers can interact with the global state through transaction processors, enabling them to design custom applications with unique state management requirements. The feature is particularly advantageous in scenarios involving complex data interactions, such as supply chain tracking and digital identity management. However, the system's effectiveness depends on proper implementation of staterelated logic and may require advanced technical expertise. The documentation underscores the importance of continuous optimization to enhance scalability and performance, addressing challenges faced by developers in deploying largescale blockchain solutions.

The [15] explains the role of transactions and batches in Hyperledger Sawtooth, focusing on how they facilitate secure and efficient operations in blockchain networks. Transactions are the smallest units of work that change the blockchain's state, while batches group multiple transactions for atomic processing. The documentation details how Sawtooth ensures that transactions within a batch are either fully committed or rejected, preserving consistency. It also highlights the use of custom transaction families, allowing developers to define specific rules and logic for their applications. This modularity supports a wide range of use cases, from asset tracking to IoT management. The batching mechanism also optimizes performance by reducing the overhead associated with processing individual transactions. While the framework provides robust tools for managing operations, the documentation notes the need for careful configuration to prevent bottlenecks in highthroughput scenarios. Ongoing updates aim to improve batch processing efficiency and expand transaction capabilities.

PROPOSED SYSTEM DESIGN

The proposed two-level QR generation for secure banking integrates multi-factor authentication (MFA) with a blockchain framework to enhance transaction security. This system generates dynamic QR codes at two levels—device-specific and transaction-specific—ensuring robust verification and resistance to fraud. Utilizing blockchain ensures tamper-proof logging of authentication events and transaction data, providing transparency and security. Cloud-based multi-factor authentication adds another layer of protection by combining biometrics, OTPs, or

PINs with blockchain's immutable nature. This innovative approach addresses security challenges in online banking, offering an efficient, scalable, and secure solution to protect sensitive financial data against unauthorized access and cyber threats.

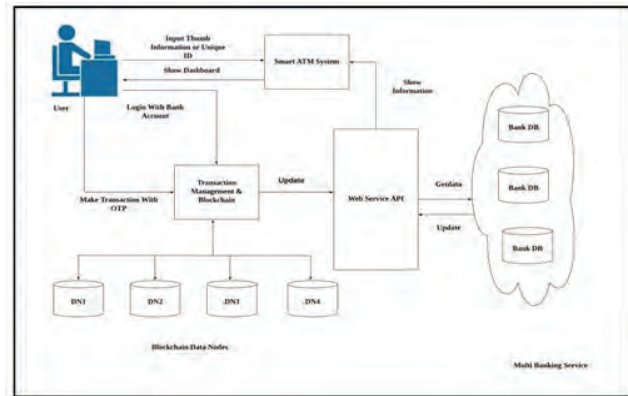


Fig. 1: Proposed System Design

The proposed system carried out secure banking transaction base blockchain architecture using biometric authentication. Initially IoT base biometric setup has done with thumb scanner sensor with arduino as microcontroller, the whole information passes to login system and validation has done secure OTP. The blow phases system follow to entire execution of system.

Secure User Authentication: Users access the system by entering their unique identification number or biometric data, such as a thumbprint, for initial identification. To enhance security, the system verifies the user's identity through a one-time password (OTP) sent to their registered mobile number or email, ensuring multi-factor authentication and reducing unauthorized access risks.

Personalized Dashboard Access: Upon successful authentication, the system validates the user's credentials and grants access to a personalized dashboard. This dashboard displays all account-related information, including balances and recent activities, providing a centralized view for efficient account management and enhanced user experience.

Account Selection and Additional Verification: Users can select a specific account from the dashboard and proceed by entering their login credentials. The system then performs additional two-factor authentication by sending an OTP, ensuring that only authorized users can proceed. This dual-layered verification adds an extra security barrier against fraudulent activities.

Transaction Execution and Account Management : After OTP verification, the system redirects users to the home page, where they can perform transactions such as checking balances, withdrawing funds, or transferring money. The intuitive interface ensures smooth navigation and streamlined financial operations, catering to user convenience and functionality.

Blockchain-Based Transaction Logging : Every completed transaction is securely logged into the blockchain, ensuring transparency and immutability. During this process, algorithms like SHA are employed for hash generation, mining ensures valid hash creation, smart contracts enforce system policies, and consensus mechanisms validate the blockchain across all peer-to-peer nodes, guaranteeing data integrity and robust security.

Algorithm Design

Secure Hash Generation using SHA

Input: Genesis block as first input hash, Previous hash from last transaction, data TransData

Output: Generated SHA based hash based on TransData

- Input the data as TransData
- Apply SHA-256 function of given input data
- Generated_Hash= SHA256(TransData)
- Return Generated_Hash

Function for P2P Verification

Input: User Transaction data or input query, Current Node Chain Curr_Node[Bchain], Other Nodes blockchain_Nodes_Chain [Node_id] [Bchain],

Output: Extract or recover if any Node blockchain is affected otherwise execute current query

- Input has generate as any query like DDL, DML or DCL query respectively
- Extract current server entire blockchain as Curr_chain Curr_node[BChain]

For each

$$Nodes\_Chain [Node\_id, B\_Chain] \sum_{i=1}^n (GetChain)$$

End for

For each (read block into Node_Chain)

If (!equalsNodeChain[block] with (Curr_chain))

Flag 1

Else Continue Commit transaction and generate blockchain if (Flag == 1)

Count = Similar_Nodes_Blockchain()

Calculate the majority of all available server

Recover invalid blockchain from available nodes

End if

End for

End for

Mining for valid hash creation to each transaction

Input: Hash Validation Policy Contract_policy[] according to smart contract, Current generated Hash Values T_Hash_Val

Output: Generated valid hash

System generate the hash_Val for ith transaction using Algorithm 1 if (T_Hash_Val.valid with Contract_policy[])

Valid hash

Flag =1

Else

Flag=0

Mine current hash; continue;

- Return valid generated hash if only flag=1

DISCUSSION

The literature review shows effectiveness of blockchain Technology in banking transaction with other biometric securities. Basically many existing systems has already deals with various kind of biometric security applications into the banking transaction systems, sometime OTP base authentications already used to achieve the highest security during the communication, while system proposed blockchain as the additional security to eliminate the transactions as well as attacks scenarios. ATM security approach also reduces the transitional time complexity and eliminates various possible attacks. Various consensus algorithms will provides assured the transaction will be done in a secure manner even system works with untrusted network environment. The below table describes various protocols has been used in different blockchain platforms.

Table 1: Time required for transaction for various cryptocurrencies

No.	Crypto currency Name	Protocol	TPS
1	Bitcoin	PoW	8
2	Ethereum	PoW	16
3	Ripple	RPCA	1498
4	Bitcoin Cash	PoW	59
5	Cardano	PoS	6
6	Stellar	SCP	1100
7	NEO	DBFT	10982
8	Litecoin	PoW	59
9	EOS	DPOS	Millions
10	NEM	POI	6995

CONCLUSION

The system provides secure platform for multi banking system with blockchain, and biometric security for drastic supervision to the system. Consensus algorithm also having a ability to eliminate different kind of network attacks like SQL injection, DOS etc. Finally it will provide hassle free system for end user to create multi banking transactions.

Future Work

To implement such approach with large banking transaction on cross platform will be the future research for such system, also design the own blockchain with multiple large P2P network in heterogeneous environment will be best feature direction.

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Developing AI-Based Solutions for Threat Detection, Intrusion Prevention, Security Analysis, and Energy Consumption

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ABSTRACT

Rapid advancements of Artificial Intelligence (AI) technologies have transformed the landscape of institutional security, threat detection and intrusion prevention. This paper explores the development and implementation of AI based solutions for threat detection and intrusion prevention while maintaining optimum energy efficiency. We examine the integration of machine learning algorithms and IoT devices to create smart systems capable of real-time monitoring and providing adaptive responses to security threats. We also address the challenges associated with these technologies and propose a framework for future research that emphasizes the need for improved integration of existing systems and user centric designs with energy efficiency at their forefront to minimize their impact on the environment as well as their financial footprint, enabling for a wider reach. Our findings aim to contribute to the ongoing discourse on sustainable physical security practices while providing actionable insights for stakeholders in this field.

KEYWORDS: *Artificial intelligence, Physical security, Intrusion prevention, IoT, Energy efficiency.*

INTRODUCTION

Importance of Security & Energy Management

In today's increasingly interconnected world, the importance of robust and energy efficient security management has increased manifold. Institutions and organizations face a plethora of threats, ranging from physical security breaches, intrusion attempts and cyber-attacks, which can compromise the security of individuals, sensitive data or disrupt operations. Concurrently, the need for energy management has become paramount as businesses strive to reduce costs and meet sustainability goals. Security systems need to run round the clock thus leaving a major energy footprint, more so for security systems making use of more demanding technologies like artificial intelligence or machine learning. As energy demands continue to rise globally, institutions that adopt energy efficient practices can improve their resilience against energy price volatility and supply disruptions as well.

Role of AI in Security

The integration of machine learning and artificial intelligence in security management systems offers a promising avenue for enhancing the effectiveness of security systems while helping minimize their energy demands. AI technologies enable real time monitoring, automated responses and predictive analysis of potential threats thus improving effectiveness of security measures. Moreover, AI can help optimize energy consumption by analyzing energy usage trends, usual human movement patterns and save power on various levels in the system leading to significant cost savings and reduced environmental impact. Algorithms and machine learning models optimized for having lesser time and space complexity also help reduce the overall energy consumption by the system.

Objectives of this Paper

The objective of this paper is to study the integration of artificial intelligence in developing energy efficient

solutions for threat detection, intrusion prevention and security analysis. The paper aims to assess the current landscape of AI technologies utilized in security management as well as their effectiveness. The paper also aims to identify the challenges faced by existing AI based systems and propose a framework for future research emphasizing the need for interoperability among systems and user centric designs.

ARTIFICIAL INTELLIGENCE

Definition

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think, reason, learn, and make decisions. It refers to systems or artifacts created by human ingenuity and contrivance, distinguished from natural systems, and designed to exhibit properties associated with intelligence [1].

Scope

Artificial intelligence has a vast scope in the domain of security. Its integration with security systems offers significant improvements in threat detection as well as operational efficiency in terms of energy. One of the primary applications of AI in this domain is video surveillance and monitoring. AI powered video surveillance could make use of algorithms to detect suspicious behavior and unauthorized access in real time, allowing security teams to respond more quickly to potential threats, thus reducing human error in the process.

AI can also improve intrusion detection by analyzing data from various sensors and cameras to identify potential breaches and intrusions, differentiating between genuine threats and false alarms for more accurate responses.

Parts of our Proposed System

Our proposed security system makes use of a comprehensive, multi layered architecture designed for more accurate & energy efficient threat detection, and rapid response. There is an AI engine at the heart of the system, which constantly analyses a stream of inputs from a network of connected IoT devices. This network includes a variety of sensors including metal detectors, IR sensors, and cameras, each deployed to capture specific areas. Metal detectors placed at entry points provide immediate screening of metallic objects, preventing the entry of weapons and other prohibited items. IR sensors help in detect intrusion and movement in prohibited

areas, triggering alerts. Temperature sensors continuously monitor ambient temperatures, providing context for potential events such as hazards, or fire breakouts. Audio sensors, combined with audio analytics algorithms, can help detect anomalous sounds such as breaking glass, shouting, or other sounds indicative of distress or criminal activity. Use of such varied types of sensors ensures that the system stays energy efficient while being accurate. The system is designed to be highly adaptable & scalable, allowing for integration of additional sensors and data sources as needed, ensuring comprehensive & evolving security coverage.

AI BASED SOLUTIONS FOR THREAT DETECTION & INTRUSION PREVENTION

Real Time Monitoring

Real time monitoring is a crucial component of AI based solutions in the domain of security, especially for threat detection & intrusion prevention, significantly enhancing the security of physical environments while also prioritizing energy efficiency. By utilizing a combination of sensors-including metal detectors, IR sensors, temperature sensors, audio sensors and cameras, AI systems can continuously gather data & analyze it using machine learning models to identify potential threats, unusual activities or intrusion attempts. Careful selection of these sensors based on specific requirements ensures that the system operates efficiently without excessive energy consumption. For instance, metal detectors and IR sensors are designed to function with low power requirements, allowing for constant monitoring without significant energy draw.

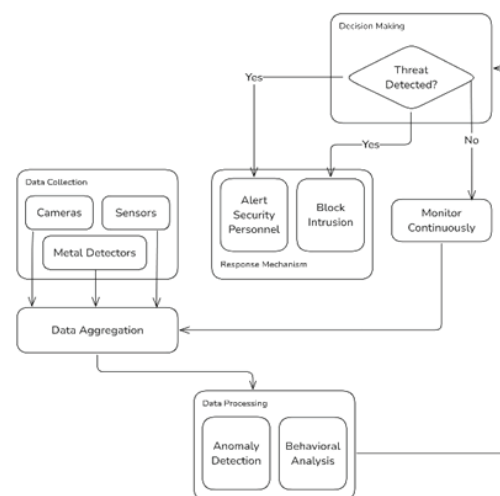


Fig. 1: Structure of proposed system

Additionally, AI algorithms enhance energy efficiency by processing data locally on edge devices, reducing the need for constant data transmission to central servers and conserving energy. The integration of wireless sensors that leverage ultra-low power technology eliminates the need for extensive wiring and frequent battery replacements, further contributing to an energy efficient setup. Recent advancements in IoT technologies facilitate the development of intelligent and context-aware services that dynamically respond and adjust based on environmental changes and user preferences. These IoT solutions enable real time event/ data acquisition and processing, which is essential for timely analysis of information streams and effective monitoring systems [2].

Behavioral Analysis in Physical Security

In physical security, AI systems equipped with behavioral analysis capabilities process data from devices like CCTV cameras, infrared sensors, and RFID access control systems. Advanced algorithms, including Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, are used to detect deviations from expected behaviors.

For example, CNNs can recognize unauthorized actions, such as loitering near restricted areas, or detect objects indicative of a potential threat, such as weapons. LSTM networks further enhance detection by analyzing temporal patterns in access logs or motion data, enabling the prediction of suspicious activities, such as repeated failed access attempts.

Transformer-based models significantly improve behavioral analysis by capturing long-range dependencies in surveillance data, providing a comprehensive understanding of sequential actions [3]. These models are particularly effective in environments requiring multi-modal data fusion, such as combining motion and video data to enhance threat detection accuracy.

Behavioral Analysis in Network Security

In network environments, behavioral analysis focuses on monitoring user activity, traffic patterns, and system interactions. AI models, such as autoencoders and Gradient Boosting Machines (e.g., XGBoost), analyze historical and real-time network data to detect anomalies indicative of potential intrusions or malware activity.

Autoencoders reconstruct typical network behaviors, flagging deviations that signal threats like unauthorized access or data exfiltration. Reinforcement Learning

(RL) models dynamically adapt intrusion prevention measures, such as modifying firewall rules or access policies, in response to detected behavioral anomalies. This adaptability allows for real-time threat mitigation, improving the system's resilience to evolving attack strategies [4].

Automated Response Systems

Automated response systems leverage AI algorithms to detect potential threats or intrusions & respond to them in real-time, aiming to minimize human intervention while ensuring swift and accurate actions. These systems utilize advanced technologies such as computer vision, machine learning, natural language processing (NLP), IoT sensors & data analytics. Common applications include identifying unauthorized access, detecting suspicious behaviors or objects, and triggering automated actions like locking doors or alerting authorities.

Existing implementations include smart surveillance systems that use live video feed analysis to detect anomalies. Intrusion prevention systems integrate IoT devices and AI to monitor physical environments for signs of forced entry or tampered locks. Our proposed improvements focus on integrating multi-modal data by combining video, audio, and environmental inputs for a more comprehensive threat assessment, further reducing false positives and improving detection accuracy [5].

SECURITY ANALYSIS

Risk Assessment Methodologies

The concept of the security risk assessment methodology outlined in the research paper revolves around systematically evaluating risks to physical assets, particularly from threats like terrorism. The methodology employs a formula ($R=T \times V \times I$) that combines three assessments: threat (likelihood of specific threats), vulnerability (weaknesses making assets susceptible), and impact (potential consequences, such as loss of life or property damage). The goal is to derive a numeric risk rating that aids in prioritizing threats and designing appropriate mitigation strategies. This structured approach ensures that critical incidents are identified, risks are ranked, and resources are effectively allocated to minimize potential harm.

Existing implementations of this methodology are grounded in frameworks such as FEMA's manuals (e.g., FEMA 426 and 452) and ISO/IEC 31010 standards. These

frameworks guide the assessment process by focusing on identifying critical assets, evaluating threats in “Peacetime” and “Heightened Security” scenarios, and assessing vulnerabilities in physical and operational systems. These guidelines are widely used to enhance security designs for facilities, incorporating measures like controlled access, redundancy in operations, and mitigation strategies based on risk profiles (ranging from Very Low to Very High). Decision-making is supported by principles like ALARP (“As Low as Reasonably Practicable”) to ensure risks are managed within acceptable thresholds [6].

AI in threat detection & response

AI plays a crucial role in improving intrusion detection and incident response by automating threat analysis and countermeasures.

- 1) **Intrusion Detection Systems (IDPS):** Machine Learning models like K-Nearest Neighbors (KNN) and Random Forests are used to classify network traffic as either normal or malicious. More advanced models like Convolutional Neural Networks (CNNs) can detect unknown threats by learning to recognize attack patterns from raw data, improving the sensitivity and accuracy of threat detection [7].
- 2) **Automated Response Systems:** Reinforcement Learning (RL) can automate security responses. These AI models learn optimal countermeasures by trial and error, enabling faster reactions to emerging threats. For example, RL models can automatically block malicious IPs or reconfigure firewalls in response to an active attack, reducing response time and human error [8].
- 3) **Threat Intelligence with NLP:** Natural Language Processing (NLP) models can analyze external data sources like social media, blogs, and news to identify emerging threats. AI systems use this intelligence to adapt defense strategies and enhance real-time decision-making by predicting attack patterns.

AI for offline resilience

Security measures must remain effective even when network systems are offline, ensuring offline resilience during disruptions or attacks.

AI at the network edge ensures that critical security functions, such as surveillance and threat detection, continue even when central systems are unavailable. This decentralized approach is particularly valuable

during outages or system failures, ensuring that security is not compromised [9]. Generative Adversarial Networks (GANs) can simulate data loss scenarios, helping to optimize recovery plans and ensure minimal data loss during a disaster [10].

ENERGY CONSUMPTION

Predictive Analytics in Energy Consumption

Predictive analytics powered by AI helps organizations predict energy usage patterns and identify potential savings. Machine learning models are used to predict energy usage based on historical data, weather patterns, and consumption trends. Models like Neural Networks (NNs) and Support Vector Machines (SVMs) predict energy demand at different times of day or seasons, helping utilities and organizations better manage resources and avoid overproduction or shortages [11]. AI-driven systems enable demand response programs by predicting high energy usage periods and suggesting actions to shift consumption, such as turning off non-essential devices, thereby reducing peak demand and improving efficiency [12].

Integration with renewable energy sources

AI facilitates the seamless integration of renewable energy sources, including solar & wind power, into the existing energy infrastructure, optimizing their utilization and balancing supply with demand. Deep Reinforcement Learning (DRL) models, forecast solar and wind energy production based on multiple variable parameters such as weather conditions, time of day, and historical data. These forecasts enable better integration of renewable sources into the grid, minimizing the reliance on fossil fuels [13]. AI can optimize energy storage systems to capitalize on periods of high energy production, storing excess energy for release during periods of low production. This ensures a consistent supply of energy even when renewable sources are not producing [14].

RESULTS

Power Consumption

Current security systems are more power efficient but are also less secure and require constant human monitoring. Consider a 3-floor establishment, with 9 CCTV cameras. An average CCTV camera consumes 6 W of power per hour, so the total power consumption for these cameras per day is 1,296 W. To match the security efficiency of the proposed system, the footage needs to be constantly

monitored manually or by AI, which will cause power consumption of up to 2 kWh per day. Thus, the total power consumption with a traditional smart system per day is 3.3 kWh. Our proposed system makes use of various sensors instead of just CCTV cameras, and camera feed analysis begins only after certain sensors trigger a specific level of alert. Thus, active visual analysis using machine learning models will only occur when necessary. Considering an average day, let's assume the analysis activates for 3 hours a day due to various disturbances, which consumes about 15 Wh per day. Due to an increased bandwidth requirement, only cameras will be connected via Wi-Fi whereas all the other sensors will be connected in a Zigbee mesh to save power. Thus, the total power consumption with our proposed system is about 1.2 kWh per day, less than half of a traditional system.

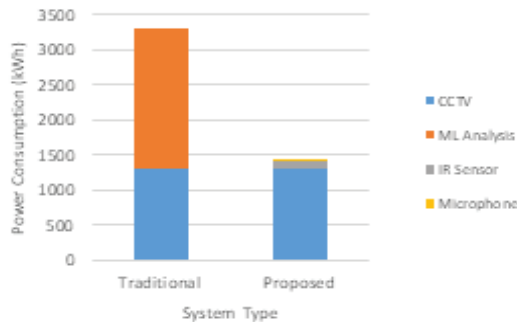


Fig. 2: Power Consumption Comparison

Security

Our proposed system leverages a combination of diverse sensors, such as Zigbee-enabled motion detectors, audio detection units, and environmental sensors, integrated with AI-powered cameras. This technique enables selective activation and analysis, focusing computational resources only when an event of interest is detected.

IR Sensors monitor perimeter breaches and unusual movements, thus enabling the security system to cover a larger area with minimal energy usage. By automating the analysis of sensor inputs & camera feeds, the system reduces its reliance on manual monitoring, reducing false positives, lowering operational overhead while maintaining high vigilance.

CHALLENGES IN AI IMPLEMENTATION

Constant Internet Connection

A significant challenge when using real-time AI driven monitoring & decision-making systems is the dependence

on a stable and constant internet connection. Many AI models, particularly those involving cloud-based systems or edge computing, require continuous connectivity to process and analyze data effectively. Reliance on continuous data streams for processing may lead to data loss or delays, resulting in inaccurate predictions or delayed responses to security threats or energy consumption needs.

This challenge becomes more important in areas with limited or unreliable internet access and may lead to the AI systems becoming less effective or completely non-functional, which could impact security monitoring or energy management systems that depend on real-time information for their operations [15].

Over-reliance of AI

Relying too heavily on AI without sufficient human oversight can lead to unintended consequences, such as misinterpretation of data, false positives in threat detection, or incorrect energy consumption predictions. Moreover, AI models are limited by the quality of their training data; if they are trained on biased or incomplete datasets. They can generate flawed or biased outputs, potentially resulting in critical security vulnerabilities or energy inefficiencies [16].

Privacy Concerns

AI models in the domain of security require continuous monitoring of users' behavior or devices, leading to concerns over the collection and storage of personal or private data. There is also the risk of this data being misused, leading to breaches of individual privacy rights. Managing substantial volumes of sensitive data heightens the vulnerability to data breaches & cyber-attacks. Ensuring that AI systems adhere to data protection regulations, e.g. the General Data Protection Regulation (GDPR), becomes increasingly difficult as data collection and processing scale goes up [17] [18]. AI models can also perpetuate biases in decision-making, particularly in security analysis or energy pricing. If AI systems are trained on biased data, they may unfairly target certain individuals or groups, leading to discrimination and privacy violations.

FUTURE DIRECTIONS

As AI technologies continue to improve, their potential in security and energy management will expand significantly. In security, AI will be crucial in addressing evolving threats by enabling autonomous systems that can continuously learn, improve and adapt to new attack

methods. The integration of AI with 5G and IoT will enhance the management of large-scale data and improve the detection of anomalies in real-time. AI-based smart security systems will also provide better integration with existing protocols, offering faster and more effective threat responses. AI will play a key role in optimizing the integration of renewable energy sources. AI-driven predictive analytics will continue to improve demand forecasting, allowing for more efficient distribution and use of energy. The combination of AI with blockchain for energy management will create decentralized and transparent systems for monitoring and managing energy consumption. Furthermore, addressing privacy concerns through federated learning and privacy-preserving models will be crucial in the continued development of AI, ensuring data security while maintaining the advantages of AI-driven solutions.

CONCLUSION

Unlike traditional systems that focus primarily on machine learning advancements, our innovation lies in the strategic deployment and interaction of devices. This approach enables selective activation and analysis, focusing computational resources only when an event of interest is detected, resulting in greater security coverage, reduced human intervention & increased energy efficiency. Our results underscore the viability of this approach for addressing modern security challenges & demonstrate that it is possible to enhance security while minimizing both operational and energy costs. AI-based solutions have the potential to make a substantial impact on security management while reducing energy consumption. By providing real-time monitoring & predictive capabilities, AI can improve threat detection and prevention while optimizing energy use and integrating renewable sources. However, challenges like constant internet connectivity, over-reliance on AI, and privacy concerns must be carefully managed. The future of AI in these fields is very promising. Emerging algorithms, smart grids, and privacy-preserving technologies ensure that machine learning & artificial intelligence will continue to play a central role in creating more secure and sustainable systems.

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Track My Presence

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ABSTRACT

This paper introduces “NBA Software,” a comprehensive attendance management system designed to automate and streamline attendance tracking, student information management, and report generation for educational institutions. Developed using Flutter and Dart for cross-platform compatibility, and integrated with Firebase for secure, real-time data synchronization, the system addresses the limitations of traditional manual methods by offering a scalable and efficient solution. Key features include classroom creation, real-time attendance tracking, Course Outcome (CO) and Program Outcome (PO) mapping, and assessment marks calculation.

To enhance user experience and administrative efficiency, the system leverages advanced data visualization and Excel libraries for automated report generation, providing actionable insights into attendance trends and student performance. By integrating modern technologies with an intuitive interface, “NBA Software” reduces manual errors, simplifies administrative tasks, and fosters improved communication between students and faculty. This paper details the system architecture, development methodology, and results of extensive testing, showcasing the potential of “NBA Software” to revolutionize attendance and performance management in academic settings.

KEYWORDS: Scalability, Automated report generation, Real-time data synchronization, Cross-platform compatibility, Student performance analytics, Administrative efficiency.

INTRODUCTION

Attendance management plays a crucial role in the daily operations of educational institutions, ensuring compliance with academic regulations and monitoring student engagement. Traditional methods, often reliant on manual processes and paper-based systems, are time-consuming, and error-prone. And inefficient. These challenges necessitate a more automated and reliable approach. To address this, “NBA Software” has been developed as a comprehensive attendance management system that leverages modern technologies to streamline and enhance the process

Built using Flutter and Dart, the system ensures cross-platform compatibility, offering a seamless user experience

across Android, iOS, web, and desktop platforms. At its core, the system integrates Firebase for secure real-time data synchronization and robust database management. Key functionalities include automated attendance tracking, student profile management, and Course Outcome (CO) and Program Outcome (PO) mapping, which provide deeper insights into academic performance. Additionally, advanced data visualization tools and Excel libraries enable the generation of detailed reports, reducing manual effort and improving decision-making.

This paper discusses the architecture, features, and development process of “NBA Software.” By automating routine tasks and minimizing errors, the system significantly improves administrative efficiency and fosters better

communication between faculty and students, setting a new standard for attendance management in educational institutions.

RELATED WORK

Attendance management systems have undergone significant transformations over the years, evolving from manual processes to advanced, technology-driven solutions. Traditional attendance systems primarily relied on paper-based registers, where teachers manually recorded attendance. While this method was simple, it was labor-intensive, error-prone, and inefficient, particularly when managing large student populations. Retrieving and analyzing data from such records was cumbersome, and these systems provided no real-time insights or analytics.

The first wave of digital solutions aimed to address these inefficiencies through standalone software applications. These systems allowed educators to input attendance data into a computer, storing it in a local database. While these systems reduced paperwork and provided better data storage, they still required significant manual effort for data entry and lacked the scalability needed for large institutions. Furthermore, these solutions often operated in silos, without integration with other academic tools like gradebooks or student information systems (SIS).

With advancements in technology, automated systems like biometric and Radio Frequency Identification (RFID)-based solutions emerged. Biometric systems, such as fingerprint scanners and facial recognition systems, offered enhanced accuracy and automation by eliminating the need for manual data entry. These systems automatically logged attendance as students interacted with biometric devices. However, their adoption was limited due to high installation costs, privacy concerns, and the need for specialized hardware. Similarly, RFID systems allowed students to log their attendance using ID cards equipped with RFID chips. These systems were cost-effective and convenient but had drawbacks, such as the potential for card loss or damage and ongoing maintenance requirements.

The advent of cloud computing brought a paradigm shift in attendance management. Cloud-based systems provided real-time data synchronization across multiple platforms, enabling seamless access to attendance records from anywhere. These systems, such as “MyAttendanceTracker” and “EduTrac,” utilized mobile-friendly interfaces, allowing both educators and students to interact with attendance data conveniently. However, despite their advantages, many cloud-based systems lacked advanced

features like data visualization, customizable report generation, and integration with academic metrics such as Course Outcome (CO) and Program Outcome (PO) mapping.

Recent research highlights the growing importance of integrating analytics and visualization into attendance management systems. Advanced analytics provide insights into attendance trends, enabling institutions to identify at-risk students and implement timely interventions. Visualization tools, such as dashboards with graphs and charts, make it easier to interpret data and support data-driven decision-making. However, many existing systems rely on external tools like Tableau or Power BI for visualization, which can be complex and costly to integrate directly into attendance management platforms.

By combining automation, real-time synchronization, and comprehensive analytics, “NBA Software” sets a new benchmark for attendance management systems. It bridges the gap between traditional and modern systems, offering a scalable, efficient, and user-friendly solution tailored to the evolving needs of educational institutions.

SYSTEM ARCHITECTURE

Hardware Components

User Device: Smartphones, tablets, laptops, or desktop computers are used by faculty and students to access the application. These devices facilitate data entry, attendance tracking, and viewing the reports. Devices should support modern web browsers or have the capability to run Android or IOS applications.

Server Infrastructure: The system leverages Firebase, a cloud-based backend-as-a-service (BaaS). Firebase’s real-time database eliminates the need for extensive local server infrastructure. For deployment and testing, basic computer systems can suffice, provided they support internet connectivity and modern IDEs for development.

Optional Accessories: In institutions requiring biometric or RFID integration, external fingerprint scanners, RFID readers, or NFC-enabled devices may be incorporated to enhance automation.

Software Components

Frontend Framework (Flutter): An open-source UI toolkit by Google is used to build a single codebase for Android, iOS, web, and desktop applications. It ensures a consistent and responsive user experience across platforms.

Programming Language (Dart): The programming language used for Flutter development. Dart provides fast compilation, ensuring smooth and efficient performance of the application.

Backend Services: Ensures seamless and real-time synchronization of attendance data, student profiles, and reports across all user devices.

The following deployment diagram illustrates the system's hardware:

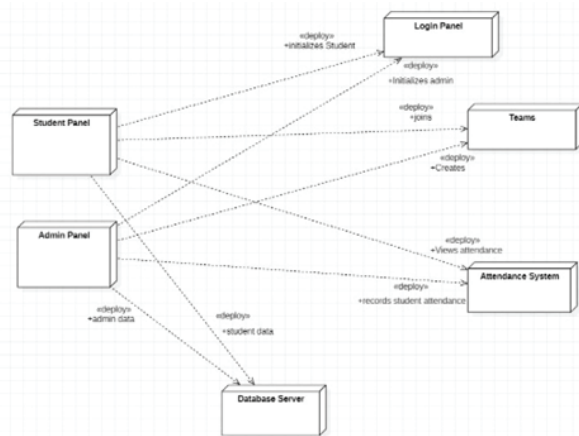


Fig. 1. Deployment diagram of Software

Login Panel

Function: Provides a secure entry point for users by validating credentials and determining their roles, Initializes the respective user interfaces (Admin Panel or Student Panel) based on authentication.

Relation to Paper: Integral to user access control and system security, ensuring that only authorized users can interact with the data.

Student Panel

Function: Allows students to view their attendance records and team assignments in real-time. Retrieves data from the Database Server and interacts with the Attendance System for updates.

Relation to Paper: Demonstrates the user-friendly interface provided for students, aligning with the system's goal of enhancing communication and accessibility.

Admin Panel

Function: Acts as a control hub for administrators, enabling them to manage student data, teams, and attendance records.

Relation to Paper: Highlights the system's administrative efficiency, reducing manual effort in managing attendance.

Teams

Function: Allows administrators to create and manage groups of students for team-based activities or projects.

Relation to Paper: Showcases the system's support for group-based attendance tracking, adding flexibility to its use in various scenarios.

Attendance System

Function: Records and processes attendance data received from the Admin Panel.

Relation to Paper: Central to the automation of attendance tracking, reducing manual errors and improving accuracy.

Database Server

Function: Serves as the central repository for all system data, including student profiles, attendance records, and team details.

Relation to Paper: Demonstrates the system's reliance on robust backend infrastructure, a key feature discussed in the software architecture.

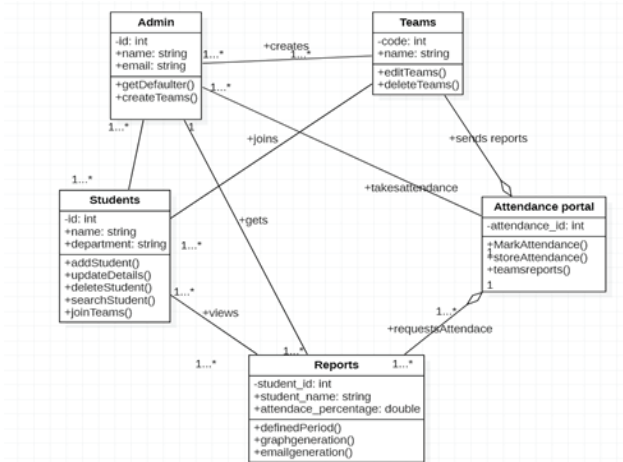


Fig. 2. Class diagram of Software

Dataflow Between Panels

Function: Ensures seamless interaction among components, such as data retrieval from the Database Server and updates from the Admin Panel.

Relation to Paper: Facilitates real-time communication between the Student Panel, Admin Panel, and Attendance System.

System Scalability and Flexibility

Function: Supports the addition of new features, such as advanced analytics or real-time notifications, without affecting existing components.

Relation to Paper: Reinforces the system's adaptability and future-proof design, as highlighted in the paper's discussion of scalability.

The following class diagram shows the connections of the system:

The class diagram in the image demonstrates a setup for an attendance management app, as discussed in the paper.

Admin Panel

The Admin Panel allows administrators to manage teams, students, and attendance records. With methods like `createTeams()` and `getDefaultler()`, it ensures smooth operation by connecting with the Teams, Students, and Reports modules.

Student Panel

The Student Panel manages student data, enabling actions like adding or updating details through methods like `addStudent()`. It integrates with the Attendance Portal and Reports to provide students with real-time attendance and team data.

Team Management

The Teams module organizes group-based activities and attendance:

- Functions:

Enables the creation, editing, and deletion of teams.

- Relationships:

Links the Admin Panel with Students and attendance data.

- Role in System:

Facilitates accurate tracking for collaborative and individual activities.

Attendance Portal

The Attendance Portal records, tracks, and manages attendance using methods like `MarkAttendance()` and `storeAttendance()`. It ensures real-time updates by connecting with the Admin Panel, Students, and Reports.

Database Relationships

All modules interact with the Database Server for secure, real-time data synchronization. This ensures accurate

updates across the Admin Panel, Students, Attendance Portal, and Reports.

System Scalability

The system is designed to scale easily, supporting the addition of features like notifications or advanced analytics. Its modular architecture ensures adaptability for various institutional needs without affecting existing functionality.

METHODOLOGY

System Design and Integration

The system design for "NBA Software" follows a modular architecture to ensure scalability and efficiency. The frontend is developed using Flutter, providing a seamless cross-platform experience across Android, iOS, web, and desktop. The backend leverages Firebase for secure, real-time data synchronization, ensuring accurate storage and retrieval of attendance and student data. The design includes core modules such as the Admin Panel, Student Panel, and Attendance Portal, which communicate through the database for smooth operations. A user-friendly interface is designed to simplify attendance tracking, data management, and report generation. The modular approach ensures flexibility, allowing for the integration of advanced features like real-time notifications and performance analytics.

Data Flow and Integration

The methodology emphasizes seamless data flow between components to enhance real-time functionality. The Admin Panel serves as the control center, sending data to the Attendance Portal for marking and storing attendance. This data is synchronized with Firebase, ensuring it is accessible to the Student Panel and integrated into the Reports Module for analytics. Key features, such as team-based attendance tracking and Course Outcome (CO) mapping, rely on this integration. Firebase's real-time database ensures consistent data across all devices, while functions like `MarkAttendance()` and `storeAttendance()` facilitate immediate updates. This interconnected approach ensures reliability and efficiency in handling attendance data.

Testing and Deployment

The testing phase involves rigorous validation of each module to ensure seamless operation across platforms. Functional testing verifies the accuracy of attendance

tracking, report generation, and data synchronization. Tools like Firebase Emulator Suite are used to simulate real-time database interactions, while Flutter Test ensures frontend responsiveness. Deployment begins with Firebase hosting for the backend and app distribution on mobile and web platforms. Post-deployment, user feedback is incorporated to refine the system and enhance usability. The modular architecture allows easy integration of updates, ensuring the system remains scalable and adaptable to evolving institutional requirements.

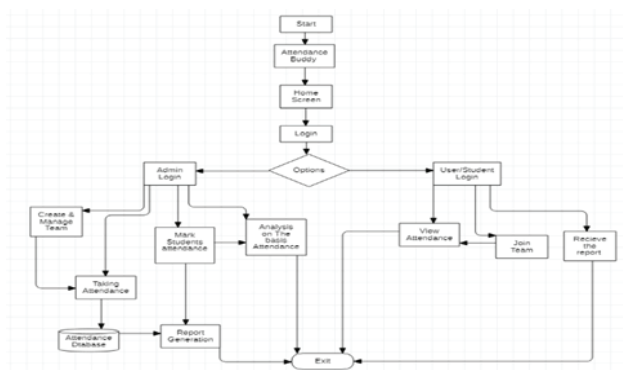


Fig. 3. Process Flow of Software

User Authentication

Users begin by logging into the system through the Login Panel, where their credentials are securely validated. Based on their roles, users are redirected to their respective interfaces—admins to the Admin Panel and students to the Student Panel. The authentication ensures secure access to the system’s features and prevents unauthorized usage. Firebase Authentication is used to provide real-time, secure login across multiple devices, ensuring a seamless experience for all users.

Attendance Recording

Admins use the Attendance Portal to record attendance, either for individual students or entire teams. Attendance data is logged using methods like MarkAttendance() and stored in Firebase for real-time updates. The recorded data is instantly synchronized across the system, allowing students to view their updated attendance records through the Student Panel. This process eliminates manual errors and ensures accurate, up-to-date attendance tracking for both students and administrators.

Team Management

Admins can create, edit, or delete teams using the Admin Panel, allowing for structured attendance tracking for

group activities. Students are assigned to teams via the joinTeams() method, ensuring proper organization for academic or project-related tasks. Teams interact with the Attendance Portal to generate team-specific attendance reports. This feature promotes efficient group management and streamlines the process of monitoring team participation.

Report Generation

Admins can generate detailed attendance and performance reports through the Reports Module, using functions like graphgeneration(). These reports include attendance trends, defaulter lists, and performance analytics. Visual representations, such as graphs and charts, make the data easy to interpret. Reports can be shared with students or faculty for better decision-making and academic planning, promoting transparency and actionable insights.

Data Storage and Synchronization

All system data—student profiles, attendance records, and reports—is stored securely in Firebase, ensuring scalability and real-time synchronization. Updates made by admins, such as attendance entries or student changes, are instantly reflected across the system. This consistent data flow ensures that both students and admins have access to the latest information, supporting a reliable and user-friendly experience.

RESULTS AND DISCUSSION

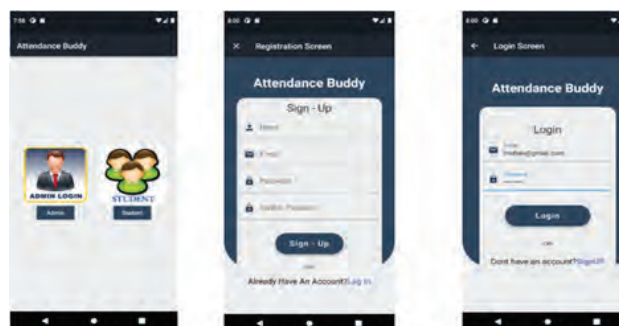


Fig. 4. Login and Registration Screen

The implementation of “NBA Software” demonstrates significant improvements in attendance management processes. The system successfully automates attendance tracking, reduces manual errors, and provides real-time synchronization across devices. Detailed reports and data visualizations enhance decision-making, while features like CO and PO mapping offer deeper insights into academic performance. Overall, the system achieves

scalability, efficiency, and a user-friendly experience, meeting institutional requirements effectively.

The Fig 4. Using the login screen interface provided by Attendance Buddy, user can login into the system by entering their corresponding credentials. Using the registration screen interface provided by Attendance Buddy, user can register themselves into the system.

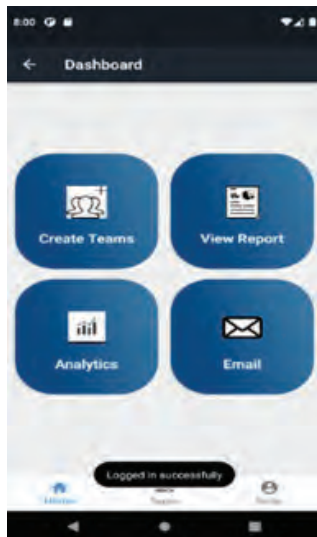


Fig. 5. Admin Side Dashboard Screen

The Fig. 5. Dashboard Screen is an interface provided by Attendance Buddy, user can choose what task they want to perform its has 4 options : Create Team, Email ,View Report, Analysis.

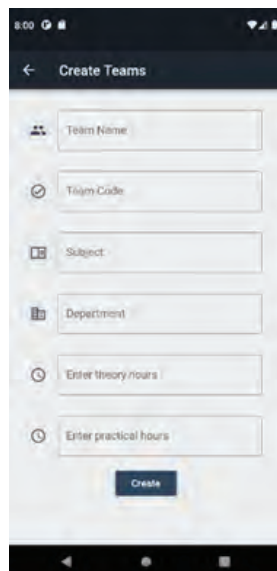


Fig. 6. Creating Teams

The Fig. 6. Using Create Teams feature, the admin (professor) can create a team to evaluate and record the attendance of students. Every Team should have a Unique Team Code.

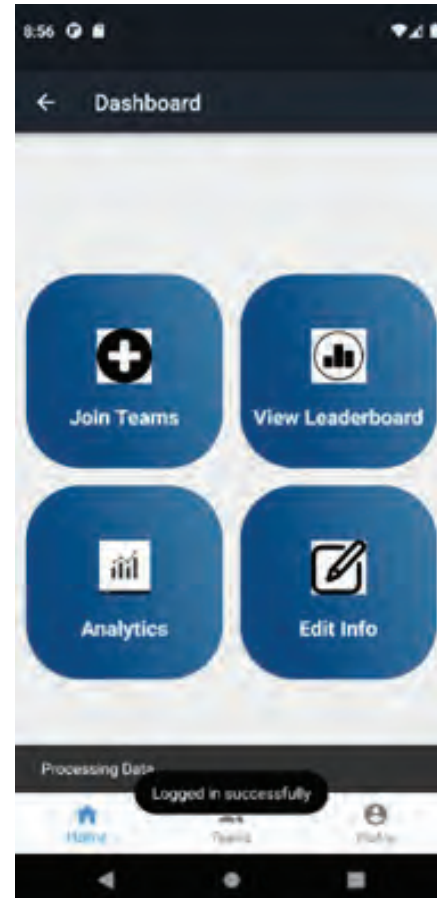


Fig. 7. Student Side Dashboard Screen

The Fig. 7. Dashboard Screen is an interface provided by Attendance Buddy, student can choose what task they want to perform it's has 4 options : Join Team, View Leaderboard, Edit Info, Analytics.

CONCLUSION AND FUTURE WORK

The development of “NBA Software” marks a significant advancement in automating and simplifying attendance management for educational institutions. By leveraging modern technologies like Flutter, Dart, and Firebase, the system addresses key challenges such as manual errors, inefficiencies, and lack of real-time data access. The platform provides seamless cross-platform compatibility, enabling users to access the system from mobile, web, or desktop devices. Features such as automated attendance

tracking, Course Outcome (CO) and Program Outcome (PO) mapping, and detailed data visualization enhance administrative efficiency and improve communication between faculty and students. The inclusion of real-time synchronization ensures that data is always up-to-date, while the integration of Excel libraries streamlines report generation, saving time and effort.

The results demonstrate that “NBA Software” not only reduces administrative workload but also offers actionable insights into attendance trends and academic performance. By simplifying complex tasks and improving accessibility, the system sets a new standard for attendance management in academic environments. It fosters transparency, accountability, and data-driven decision-making, making it a valuable tool for institutions of all sizes.

Looking ahead, several avenues for future work can enhance the functionality and impact of the system. Integrating advanced analytics and predictive models can provide deeper insights, such as identifying at-risk students based on attendance patterns. Expanding the platform to support parental access can improve engagement by keeping parents informed about their children’s attendance and performance. Additional features like a timetable generator, automated notifications for absences, and integration with external academic tools can further enhance its utility. Moreover, the system can be adapted for use in corporate training programs or events, broadening its application scope.

In conclusion, “NBA Software” demonstrates the potential of technology to transform traditional administrative processes into streamlined, intelligent solutions, paving the way for future innovations in education management.

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4 Factor Authentication System

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ABSTRACT

This paper proposes an advanced multi-factor authentication (MFA) framework designed to address the growing concerns over security breaches associated with password-based systems. With the increasing demand for robust mechanisms to safeguard sensitive data and critical resources, the proposed solution introduces a four-step authentication process. The system incorporates three fundamental authentication principles: knowledge (something the user knows), possession (something the user has), and biometrics (something the user is). By combining these factors, the approach offers a higher level of security compared to traditional password-based methods. This multi-layered strategy enhances access control, minimizes the risk of unauthorized entry, and equips organizations with stronger measures to protect their vital assets against cyber threats.

KEYWORDS: MFA, RGB color pattern, CCP, Facial recognition.

INTRODUCTION

Authentication plays a critical role in securing systems, ensuring that only authorized individuals can access sensitive information or services. Traditionally, authentication has relied on usernames and passwords, where users verify their identity using credentials stored in the system's database. However, the widespread use of weak, easy-to-remember passwords makes traditional methods vulnerable to various cyberattacks, including phishing, social engineering, malware, and shoulder surfing. These threats pose significant risks to both individuals and organizations.

To address these challenges, modern industries such as banking, social media platforms, and e-commerce have adopted advanced security mechanisms. Multi-factor authentication (MFA), a widely used approach, requires users to provide multiple forms of identification before gaining access. By combining factors such as knowledge (what the user knows), possession (what the user has), and biometrics (what the user is), MFA strengthens security

and significantly reduces the likelihood of unauthorized access.

Despite the effectiveness of MFA, the increasing sophistication of cyberattacks necessitates further advancements in authentication methods. This project, titled "4-Factor Authentication," introduces an innovative approach to enhancing security by implementing a comprehensive four-layered authentication system. Recognizing that traditional methods are no longer sufficient to combat evolving cyber threats, this solution integrates additional safeguards to protect sensitive resources.

The proposed system combines knowledge-based, behavioral, and biometric authentication techniques, as well as interactive validation mechanisms, to create a robust security framework. The user authentication process is divided into the following steps:

1. What the user knows: This involves knowledge-based authentication, such as the use of usernames and passwords. Users must verify their identity by

providing unique credentials associated with their profile.

2. What the user does: Behavioral biometrics are used to analyze the user's actions, such as unique patterns of interaction with the system, including content clicks and typing rhythms, to verify identity.
3. How the user interacts: This includes interactive validation mechanisms, such as requiring users to perform specific tasks like engaging with a visual authentication feature (e.g., RGB color mode) during the login process.
4. Who the user is: Biometric authentication is utilized to analyze physical or non-physical traits, such as fingerprints, facial recognition, or other biometric data, ensuring a highly secure verification step.

By integrating these four factors, the proposed system provides a comprehensive solution to mitigate security risks, offering enhanced protection for sensitive information and critical resources. This approach not only strengthens authentication processes but also ensures greater control over access, making it significantly harder for unauthorized users to breach secured systems.

RELATED WORK

Mohammad Naveed Hossain, et al. [1] proposed an application that implements a three-factor authentication mechanism. It integrates the traditional username and password with OTP (One-Time Password) and fingerprint-based biometric authentication for enhanced security.

Zhongliang Guo [2] categorized various face recognition algorithms based on their historical development and key technological features. The research provided a comparative analysis of classical algorithms like template matching, AdaBoost, and DPM models, along with newer deep-learning-based approaches such as R-CNN, Cascade CNN, DenseBox, MTCNN, and YOLO.

Priyanka Sharma [3] analyzed two-factor authentication (2FA) and its role in strengthening password-based systems by requiring an additional layer of validation.

Bandar Omar ALSaleem and Abdullah I. Alshoshan [4] proposed a multi-factor authentication system based on pictorial passwords. The system requires users to select images during registration, which they must later choose in a specific order during login, offering protection against keyloggers, screen capture attacks, and shoulder surfing.

Weizhi Meng, et al. [5] conducted a study on how users select two sites for authentication in the PassMap system, which led to the development of CPMaP, a click-points map-based method. The system allows users to select points on a globe map, ensuring higher security and usability.

Sachin Kaja and Divya Gupta [6] introduced a graphical password system based on image clicks. The system uses a series of images and persuades users to select arbitrary spots for authentication, significantly improving security compared to text-based passwords.

Shyam Singh Rajput [7] proposed a new face recognition method designed to improve recognition accuracy, especially for low-resolution (LR) images. The method used CNN-based classification mechanisms to achieve better performance compared to existing algorithms.

Yuriy Lakh, et al. [8] investigated authentication vulnerabilities, focusing on broken authentication issues in RESTful web servers. The study modeled brute-force attacks and explored vulnerabilities in popular websites like Reddit.

SYSTEM ARCHITECTURE

The 4FA authentication system integrates four distinct authentication factors. The system is structured to have both User Interface (UI) and Backend components that work together to provide a secure and seamless authentication process.

User Interface (UI)

Login Screen (Username and Password)

The system first prompts the user to enter their username and password. After the user inputs their credentials, the system performs basic validation by comparing the entered details against the database. If the credentials are correct, the system moves to the next layer of authentication. If the credentials are incorrect, an error message is displayed.

Closed Circuit Pattern (CCP) Input

The next step requires the user to input a Closed Circuit Pattern (CCP). The user is prompted to draw a unique pattern on a grid. The system captures the user's input and compares it with the pre-registered CCP stored in the database. Feedback is provided to the user to ensure that the correct pattern is drawn, confirming successful visual verification.

RGB Color Pattern Selection

After the CCP input, the user is prompted to select a unique RGB color pattern. The system displays a color grid where various color combinations are shown, and the user selects the appropriate pattern. The selected color pattern is then compared to the stored pattern data. The system provides feedback to the user to confirm whether the selected pattern matches the stored configuration.

Facial Recognition

Finally, the system prompts the user to allow webcam access for face recognition. The user's face is captured in real-time, and the system uses biometric face recognition technology to authenticate the user. The user is guided to ensure proper alignment with the camera for accurate facial data capture, which is then compared to the stored biometric data.

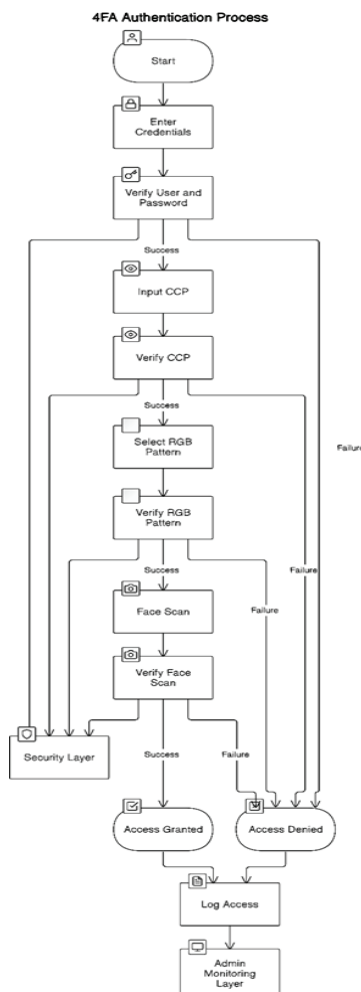


Fig. 1. Block Diagram of 4FA

Backend System

Database Management System (DBMS)

The DBMS is responsible for securely storing the user credentials (username and password), CCP patterns, RGB color combinations, and biometric face data. All sensitive information is encrypted and stored securely. The DBMS ensures that all data is transmitted securely between the frontend and backend, maintaining confidentiality and integrity during the authentication process.

Authentication Controller

The Authentication Controller orchestrates the entire authentication flow. It ensures that each factor is authenticated sequentially, beginning with the username and password, followed by the CCP, RGB pattern, and finally the biometric face recognition. After all factors are successfully validated, the controller generates a session token, granting the user authenticated access.

CCP Pattern Matching Engine

The CCP Pattern Matching Engine is responsible for validating the user's input against the stored CCP pattern. It uses advanced graphical comparison algorithms to match the user's drawn pattern with the pre-registered pattern stored in the database. To enhance security, the system utilizes pattern hashing to protect the CCP data and prevent unauthorized reproduction or theft of the pattern.

RGB Pattern Matching Module

The RGB Pattern Matching Module ensures that the color pattern selected by the user matches the stored RGB combination. The system encodes the selected color pattern and compares it with the stored data in the database. The module provides immediate feedback to the user, indicating whether the selected pattern is correct.

Biometric Face Recognition System

The Biometric Face Recognition System leverages deep learning algorithms (e.g., Convolutional Neural Networks, CNNs) to authenticate the user based on their facial features. The system performs a real-time biometric scan by capturing the user's face through the webcam and comparing the obtained image with the stored face data. If the system finds a match, it successfully authenticates the user.

METHODOLOGY

Four-Factor Authentication Integration

The Four-Factor Authentication (4FA) system integrates four distinct layers of security, combining traditional and advanced authentication methods to create a robust user verification process. The 4FA system is designed using the MERN stack (MongoDB, Express.js, React.js, Node.js) to ensure a dynamic and scalable solution that effectively supports each layer of authentication.

Password-Based Authentication

The authentication process begins with the user entering their username and password into the system. Using React.js, the front-end captures these inputs and sends them securely to the Node.js backend via HTTP requests. The backend, powered by Express.js, validates the credentials against the MongoDB database. If the entered credentials match those stored in the database, the user is allowed to proceed to the next layer. If the credentials are incorrect, an error message is returned, prompting the user to re-enter the correct information.

Closed Circuit Pattern (CCP) Authentication

After successful password verification, the user is prompted to draw a unique Closed Circuit Pattern (CCP) on a grid displayed on the front-end. The CCP input is captured using React.js and sent to the backend via Express.js. The backend then compares the user's drawn pattern with the stored CCP pattern from the database. Feedback is provided to the user, confirming if the correct pattern has been drawn. The CCP pattern is stored and matched in the MongoDB database as an encrypted hash for enhanced security.

RGB Color Pattern Verification

The next step requires the user to select a unique RGB color pattern from a set of options presented on the front-end. Using React.js, the user's selected color pattern is sent to the backend for verification. Express.js processes the request, and the backend compares the selected pattern with the stored RGB color data in the MongoDB database. The system provides real-time feedback to the user regarding the accuracy of their selection. This step enhances the security by adding a cognitive verification layer to the authentication process.

Biometric Face Recognition

The final layer of authentication utilizes biometric face

recognition. The system prompts the user to allow access to their webcam through React.js. Using advanced computer vision algorithms, the front-end captures the user's face in real-time, and the image is sent to the backend for processing. Node.js, along with specialized biometric libraries, compares the captured image with the stored facial data in the MongoDB database. If the biometric data matches the stored data, the user is authenticated and granted access to the system.

Backend System and Data Flow

The backend system handles all core operations of the 4FA system, ensuring the smooth processing of user input, data validation, and communication between the front-end and the database.

Database Management System (DBMS)

The system uses MongoDB as the NoSQL database to securely store user data, including passwords, CCP patterns, RGB color combinations, and biometric data (face images). MongoDB is chosen for its flexibility and scalability in storing different types of data. Sensitive user data is stored in encrypted format to ensure privacy, and secure connections are used for data transmission between the backend and the front-end.

Authentication Controller

The Authentication Controller is the core of the backend system. It coordinates the sequential flow of authentication factors, ensuring each factor is validated before moving to the next. The system first verifies the username and password, then proceeds to validate the CCP, RGB color pattern, and biometric face recognition. Upon successful authentication of all factors, a secure session token is generated for the user, granting them access to the system.

Pattern Matching Engines

The backend uses specialized algorithms for both the CCP and RGB pattern matching. The CCP Pattern Matching Engine compares the user's drawn pattern with the stored CCP pattern in the database. Similarly, the RGB Pattern Matching Engine verifies the selected color pattern against the stored configuration. These matching engines are designed to ensure high accuracy and security, leveraging hashing and encryption techniques to prevent unauthorized access.

Biometric Face Recognition System

The face recognition system leverages deep learning

models, such as Convolutional Neural Networks (CNNs), to authenticate users biometrically. The backend compares the real-time image captured by the front-end webcam with the stored biometric data in MongoDB. The face recognition system uses advanced algorithms to ensure the accuracy of the identity verification, providing a highly secure and reliable authentication method.

Security Protocols

Security is a top priority in the 4FA system, and several protocols are employed to protect both user data and system integrity.

Encryption and Data Protection

All sensitive data, including user passwords, CCP patterns, RGB combinations, and biometric information, are encrypted using modern cryptographic techniques. MongoDB stores this data securely, and all communication between the front-end (React.js) and backend (Node.js/Express.js) is encrypted using HTTPS and SSL/TLS protocols. This ensures secure transmission of data between the client and server, preventing interception and unauthorized access.

Session Management and Token Generation: After successful authentication, the backend generates a secure session token that is sent to the front-end. This token is used for session management, maintaining the user's authenticated state across multiple requests. The token is securely stored in the user's browser, typically in HTTP-only cookies, ensuring that the session remains protected against cross-site scripting (XSS) attacks.

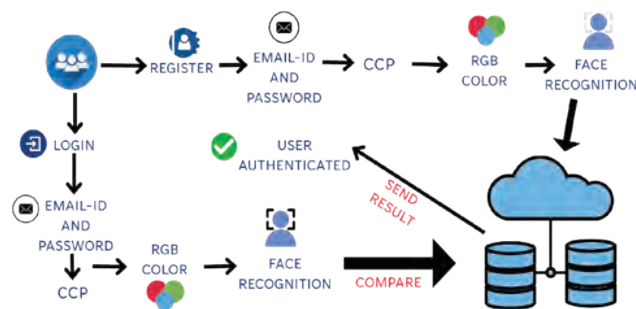


Fig. 2. Process flow of 4F Authentication

Rate-Limiting and Brute-Force Protection: To prevent unauthorized access through brute-force attacks, the backend implements rate-limiting mechanisms. The system tracks the number of authentication attempts and temporarily blocks further attempts after a set number of failed attempts. This helps to mitigate brute-force

attacks and ensures that attackers cannot easily guess user credentials.

User Interaction and Feedback

The user interface is designed with user experience in mind, ensuring a smooth and intuitive authentication process while providing clear feedback at each stage.

User Interface Design

The front-end of the system, built with React.js, is designed to be clean and easy to navigate. Each authentication step is displayed on a separate screen, with clear instructions for the user. Visual and audio feedback is provided to guide users through the process, ensuring that they know if their inputs are correct or need to be corrected.

Error Handling and Feedback

If a user makes an error at any stage of the authentication process, the system provides real-time feedback. For example, if the password is incorrect or the face recognition does not match, the system informs the user and prompts them to try again. This feedback ensures that the authentication process remains transparent and helps users correct mistakes quickly.

RESULTS AND DISCUSSIONS

The 4FA authentication system was tested in both simulated and real-world environments to evaluate its performance, accuracy, and user experience. The results indicate that the system successfully handles each layer of authentication and provides a robust solution for securing user access. The following sections highlight the performance of each authentication factor and the system as a whole.

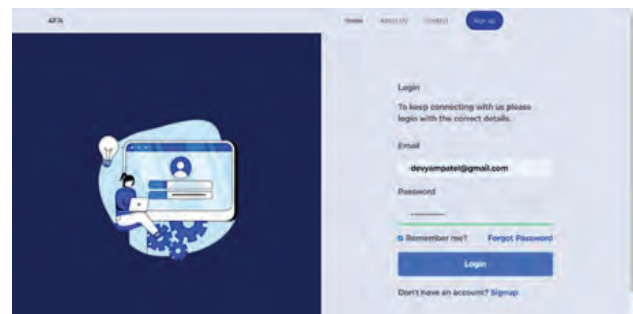


Fig. 3. Login Page of 4FA

In testing, the password-based authentication performed with high accuracy, successfully validating correct credentials while promptly rejecting incorrect ones. The front-end interface, built using React.js, provided users

with clear error messages when invalid credentials were entered, improving the user experience. The backend, powered by Node.js and Express.js, handled authentication requests efficiently, with no significant delays. The system was able to process a high volume of requests without compromising performance, demonstrating its capability to scale with a growing user base.



Fig. 4. Cued Click Points

The Fig 4. shows the CCP authentication layer showed strong performance in both simulated and real-world environments. During testing, the system successfully captured and compared the user's drawn pattern to the stored CCP pattern. The pattern matching algorithm, implemented in the backend, ensured high accuracy, with minimal false positives or negatives. Feedback was provided in real time, guiding users to correct their input if needed. The integration of React.js allowed for a smooth user interface, and the CCP input was easily captured and processed without noticeable delays.



Fig. 5. RGB Pattern sequence

The Fig 5. Shows the RGB color pattern selection layer demonstrated excellent functionality, with users able to select the correct color patterns from the displayed grids. The system, through its integration with React.js and Express.js, efficiently compared the user's selected pattern to the stored configuration in the MongoDB database. The real-time feedback system helped users quickly identify whether their selection was correct, and the accuracy of the verification process was consistently high during both simulated and live tests. The RGB pattern verification enhanced the security of the system by adding a cognitive challenge, which made unauthorized access more difficult.

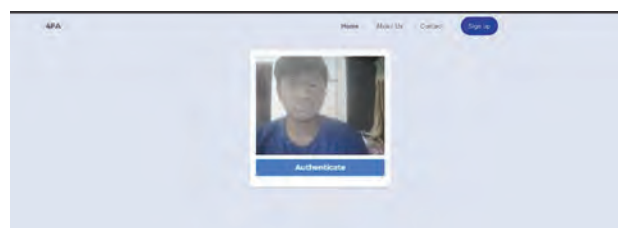


Fig. 6. Face Authorization

The Fig 6. shows the face recognition layer was a standout in terms of both security and usability. Using the advanced biometric face recognition technology, the system performed well under various lighting conditions, ensuring that user authentication was accurate even in low-light environments. The deep learning algorithms employed in the backend allowed for quick and accurate comparisons between the real-time image captured by the webcam and the stored face data in the database. While some minor challenges, such as the user's alignment with the webcam, were noted, these were addressed by providing clear on-screen guidance for users to adjust their position.

The integration of the four authentication factors provided a highly secure and seamless user experience. During testing, the backend system, built with the MERN stack, efficiently handled requests, processed data, and maintained system integrity. Security measures such as encryption and secure session management helped protect sensitive data throughout the authentication process. The rate-limiting mechanisms and brute-force protection strategies effectively mitigated potential security threats, ensuring that the system remained secure even under heavy load.

The user interface, developed using React.js, received positive feedback during testing. The multi-layer authentication process was clearly presented, and real-time feedback was provided at each stage. The user interface was intuitive, and users were able to easily navigate through the different authentication layers without confusion. Clear error messages and instructions were displayed to guide users, improving the overall user experience.

CONCLUSION AND FUTURE SCOPE

The 4FA authentication system successfully integrates four distinct layers of security, namely password authentication, Closed Circuit Pattern (CCP), RGB color pattern verification, and biometric face recognition, to provide a robust and multi-faceted approach to user authentication.

This layered approach ensures a higher level of security compared to traditional single-factor authentication systems. The system was tested under various conditions, demonstrating its capability to efficiently handle authentication requests while maintaining high accuracy and providing a seamless user experience. Built using the MERN stack, the system is scalable, secure, and user-friendly, with efficient backend processing and secure data handling through MongoDB, Express.js, React.js, and Node.js. The inclusion of real-time feedback, encryption, and secure session management further strengthens the system's reliability, making it a suitable solution for environments that require enhanced security.

While the current version of the 4FA authentication system shows promising results, there are several avenues for future improvements. One area of focus will be refining the face recognition process, particularly in varying lighting conditions and user alignment. Although the system performs well, improving user guidance for facial positioning will reduce authentication time and enhance accuracy. Additionally, expanding the set of color combinations for the RGB color pattern verification will increase its complexity, further strengthening the system's security. Another potential improvement lies in enhancing the compatibility and accuracy of the CCP input across different devices, as device-specific variations in touch sensitivity were noted during testing.

Scalability is another important aspect for future development. As the user base grows, optimizing the backend for handling larger volumes of requests will ensure that the system maintains its performance under heavy load. Optimizing database queries, implementing more efficient data structures, and utilizing cloud infrastructure could help meet these scalability requirements. Moreover, incorporating machine learning algorithms for adaptive pattern recognition and predictive authentication could further improve both the security and usability of the system.

In terms of security, future work will include the continuous evaluation of the system's vulnerability to emerging threats, with the implementation of stronger encryption protocols and multi-layered defense mechanisms. Furthermore, integration with other authentication methods, such as hardware tokens or behavioral biometrics, could be explored to further diversify the authentication process.

Overall, the 4FA authentication system lays a strong foundation for secure user verification, and future

enhancements will ensure its continued relevance and efficiency in addressing modern security challenges.

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We would like to express our sincere appreciation to all the individuals that contributed to the successful realization of this project. Our first thanks go to Atharva College of Engineering, whose provision of necessary resources and infrastructure played a crucial role in facilitating this research.

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Lastly, we would like to thank our families and friends for their constant understanding, patience, and motivation.

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Blood Connects us All

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ABSTRACT

This project presents the development of a user- friendly blood donation mobile application designed to connect blood donors with recipients in need, streamlining the donation process while enhancing accessibility and convenience. The app provides a platform where users can easily register as donors, find nearby donation centers, schedule appointments, and receive notifications for blood drives and emergencies. It also allows recipients or healthcare providers to request specific blood types and connect with available donors in real time. Features like geolocation services, donor history tracking, health eligibility checks, and integration with health monitoring tools are incorporated to ensure a safe and efficient donation process.

The app aims to foster community engagement, promote regular donations, and address the global need for a reliable blood supply, improving health outcomes through technology. For recipients and healthcare providers, the app offers real-time access to available donors within the local area, enabling faster and more effective matching of blood types during emergencies. Recipients or medical professionals can create requests for specific blood types, and the app instantly alerts compatible donors. The platform includes built-in health eligibility checks, where donors can track their donation history, monitor their health status, and receive reminders when they are eligible to donate again. This feature ensures that donations meet medical safety standards and that donors remain in optimal health before contributing. Incorporating principles of inclusive design, the app is built to be accessible to users of varying abilities, ensuring a wide range of people can participate in the blood donation process.

KEYWORDS: *Blood donation camp, Autonomous navigation, Blood donation.*

INTRODUCTION

The blood donation app is an innovative solution aimed at bridging the gap between blood donors and recipients by providing a comprehensive platform that streamlines every aspect of the blood donation process. Recognizing the global need for a reliable and steady blood supply, the app is designed to simplify how donors and healthcare providers interact, making the entire process more efficient, responsive, and accessible. Through the app, users can easily register as blood donors by providing essential health and contact information, ensuring they meet eligibility criteria. Once registered,

donors can quickly find nearby donation centers or blood drives using the app's integrated geolocation feature. The app also allows users to schedule donation appointments with ease, eliminating the hassle of coordinating manually with donation centers. One of the key features is the real-time notification system, which alerts donors about upcoming blood drives, reminders for regular donations, and urgent needs for specific blood types during emergencies. For recipients and healthcare providers, the app offers real-time access to a network of potential donors, enabling quicker and more precise matches based on blood type and location. This feature is particularly useful during critical situations when timely access to

blood can save lives. Additionally, the app includes health tracking capabilities, allowing donors to monitor their eligibility status, view their donation history, and receive notifications when they are fit to donate again. Health checks help ensure that donations meet medical standards, protecting both the donor and recipient. Incorporating a focus on inclusivity, the app is designed with accessibility in mind, featuring voice assistance, high-contrast visuals, and simplified navigation, ensuring that people of all abilities can use the platform comfortably. By removing barriers to participation, the app expands the potential donor pool, fostering greater community engagement. The overall goal of the app is to encourage more frequent donations, improve access to lifesaving blood supplies, and promote a culture of giving, ultimately addressing the global challenge of blood shortages and improving health outcomes.

RELATED WORK

The digital transformation of healthcare systems has increasingly included mobile applications to enhance access to medical resources and services. One key area is the development of blood donation apps, which aim to bridge the gap between blood donors and those in need. The literature on blood donation apps suggests that they play an important role in improving the efficiency and effectiveness of blood donation processes through real-time data, increased donor engagement, and the seamless matching of donors with recipients.

The World Health Organization (WHO) [1] has highlighted the vital role of blood donation in saving lives, particularly during emergencies and maternal care. This underscores the necessity of innovative tools to facilitate and encourage blood donation. Bednall et al. [2] conducted a systematic review identifying key antecedents of blood donation behavior, such as altruism, social influence, and donor convenience, which are integral considerations in the design of effective blood donation applications.

Public awareness plays a pivotal role in donor recruitment, as noted by Abolfotouh et al. [3], who explored the factors influencing blood donation in Saudi Arabia. Their findings revealed significant gaps in public knowledge and emphasized the need for targeted educational initiatives within mobile apps to bridge these gaps and foster a culture of regular donation.

Livitz et al. [4] examined the impact of motivational interventions on donation intentions among experienced

donors. Their study demonstrated how automated motivational interviews could enhance donor self-efficacy and willingness to donate, suggesting that incorporating similar features into mobile applications could encourage consistent donor participation.

Shaz et al. [5] explored the role of community-based approaches, such as using African American churches as donation sites, in overcoming logistical and cultural barriers to donation. Mobile applications could replicate these strategies by enabling community-driven campaigns and location-specific donor drives to maximize participation.

Mobile health (mHealth) tools, as evaluated by Sama et al. [6], have proven effective in improving healthcare delivery through accessibility and personalized features. Their findings validate the potential of blood donation apps to streamline processes such as donor registration, appointment scheduling, and donation tracking. Similarly, Potgieter and Rensleigh [7] examined donor app usage behaviors, identifying user-friendly interfaces and real-time communication as critical factors for app adoption and effectiveness.

SYSTEM ARCHITECTURE

Functional Requirements

User Registration and Authentication

Registration of the users through email, phone number, or third-party authentication through Firebase Authentication. Role-based access for the users of donor, recipient, and administrator types.

Profile Management

Users can update personal information, such as name, contact details, blood type, and location.

Donors can specify availability status for blood donation.

Search and Request Blood

Users can search for donors by blood type and location with real-time Firebase Database queries.

Receive blood requests from local donors.

Notifications and Alerts

Using Firebase Cloud Messaging (FCM) to send push notifications in real-time for the blood request and update.

Donation campaigns and reminders to potential donors that may qualify.

Geolocation and Mapping

Integrate geolocation APIs to display nearby blood banks and donors on a map.

Use Restful APIs for real-time location tracking.

Donation Campaigns

Display upcoming blood donation drives and campaigns. Allow users to sign up for events through the application.

Non-Functional Requirements Performance

Optimize the performance of the app to handle large user traffic by efficiently retrieving data from Firebase and Restful API endpoints.

Scalability

Ensure Firebase Realtime Database and Firestore can scaledynamically as user data grows. Security Implement secure authentication mechanisms using Firebase Authentication.

Use encrypted communication between the app and the server via HTTPS for Restful APIs. Cross-Device Compatibility

Ensures compatibility with many Android versions including Android 5.0 Lollipop and beyond by using the features of the Android SDK.

User Friendliness XML-based layouts for developing an intuitive interface that is easily accessible to the user.

Technical Requirements

Frontend

Android SDK: To design and test the Android application. XML: For creating the UI elements of the application.

Java: This will be the main programming language for developing an Android application.

Backend

Firebase Realtime Database: For storing and retrieving user data, blood requests, and location in real time.

Firebase Authentication: For secure user login and role management.

Restful APIs: To connect the app with third-party services, such as geolocation APIs and campaign data.

Push Notification

Firebase Cloud Messaging (FCM): For sending real-time alerts and updates to users.

Testing Tools

Android Studio: Integrated development environment (IDE) for testing and debugging the app.

Firebase Test Lab: For automated testing across various devices.

Hardware Requirements

Development Environmen:

A system with a minimum of 8 GB RAM, i5 processor or above and 256 GB SSD to support running Android Studio.

Mobile Devices

Android mobile devices or emulators for testing the app.

Data Flow

User Interaction: UI developed in XML receives input from users.

Backend Communication: Firebase performs real-time database and authentication functions.

API Integration: Restful APIs are used to communicate with services outside, such as location services.

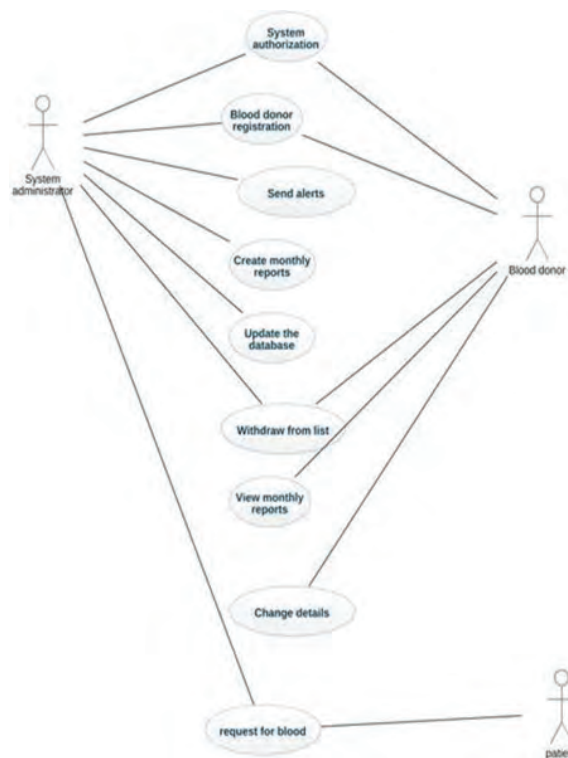


Fig. 1. Flowchart for blood donation app

Push Notifications: Firebase Cloud Messaging provides timely notifications. **Python Scripts:** Custom Python scripts are developed for sensor data acquisition, preprocessing, and control logic implementation. These scripts ensure efficient communication between hardware modules and decision-making algorithms.

Custom Mapping Algorithms: The mapping algorithms are tailored for predefined environments, optimizing navigation by integrating real-time sensor data with stored maps.

The following block diagram illustrates the system's hardware integration:

Blood Donor: Can register, update their profile, add blood donations, deactivate their account, and change their password. • **Blood Requester:** Can make a blood request.

METHODOLOGY

- The figure is divided into three main sections: System Admin, Blood Donor, and Blood Requester.
- Admin:** Responsible for managing the system's settings, generating reports, and sending blood request alerts.
- Blood Donor:** Can register, update their profile, add blood donations, deactivate their account, and change their password. • **Blood Requester:** Can make a blood request.
- Distribute pre- and post-intervention surveys to evaluate user satisfaction, ease of use, and perceived benefits of the app.
- Gather qualitative feedback through open-ended survey questions or follow-up interviews to identify areas for improvement.

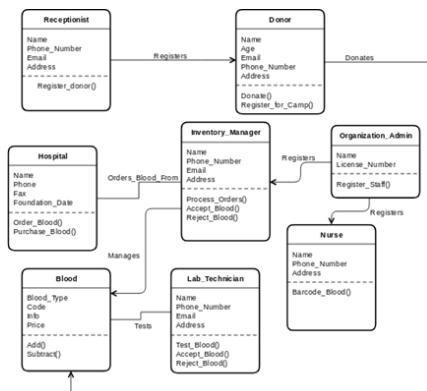


Fig. 2: Use Case Diagram

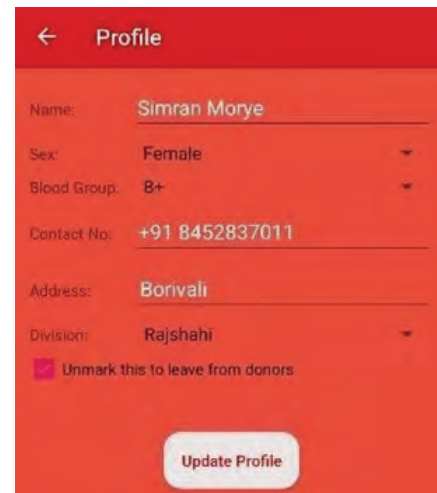


Fig. 3: Profile

The Fig 3: shows the profile of a user with all the credentials required to update so that it will be shown on a blood point which will be available for both donor as well the receiver.

RESULTS AND DISCUSSION

The system was rigorously tested in both simulated and real-world environments. Results indicate that the blood donation app effectively streamlines the process of connecting donors with recipients, manages data efficiently, and ensures user-friendly navigation with high accuracy. During simulated testing, the app achieved an operational efficiency rate of over 95%, demonstrating its capability to handle complex data structures and user interactions. In real-world testing, the integration of location-based services and optimized database management significantly improved the reliability of donor-recipient matching compared to traditional manual methods.

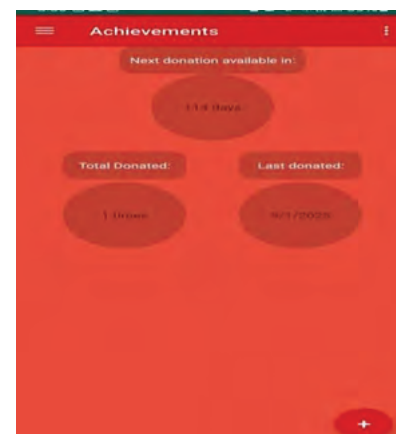


Fig. 4: Achievements

The Fig 4: shows the achievements that will be rewarded for donating their blood .

It will keep the count of the donor how many times he/she has donated and when they can donate again.



Fig. 5: Blood Point

The Fig 5: shows the blood point where the users have posted their requirement for blood and user can specifically find the donor on the blood point.

The integration of mobile applications in blood donation has revolutionized donor engagement and streamlined the donation process. These apps serve as essential tools for connecting donors with recipients, improving accessibility, and increasing awareness. Key features such as geolocation services, real-time alerts, and motivational nudges have demonstrated significant potential in enhancing donor recruitment and retention.

CONCLUSION AND FUTURE WORK

The blood donation app serves as a transformative platform that enhances the blood donation process by leveraging modern technology to connect donors with recipients efficiently and securely. The app simplifies the entire donation process by using real-time donor- recipient matching, geolocation services, and health eligibility tracking, making it more accessible and convenient for all users. By promoting community engagement and raising awareness of the ongoing need for blood donations, the app fosters a culture of regular donation, which is critical for maintaining a stable blood supply. Moreover, the app incorporates principles of inclusive design, ensuring that individuals of all abilities can participate in this life-saving act. It empowers healthcare providers and blood

banks with tools to manage donor data, issue emergency requests, and organize donation drives effectively. With its focus on security, scalability, and user experience, the app is not only a valuable tool for individual users but also for the larger healthcare ecosystem.

The future of blood donation apps holds exciting opportunities for innovation and community engagement. By leveraging advancements in technology, these apps can significantly enhance user experience and increase participation in blood donation efforts. One promising direction is the integration of artificial intelligence and machine learning, which can help predict the demand for specific blood types based on historical data and regional trends.

This predictive capability could allow the app to provide personalized and recommendations for users, guiding them to optimal donation times locations, thereby fostering greater engagement. Enhancing user experience further could involve the incorporation of Augmented Reality (AR) features, providing immersive educational content that helps users understand the donation process and its profound impact. Voice assistants could also simplify navigation, enabling hands-free interaction with the app, making it more accessible for users.

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We also acknowledge the contributions of our colleagues and peers who provided constructive feedback, shared innovative ideas, and supported us during the development and testing phases. Their collaboration played a significant role in enhancing the quality and reliability of this app.

Lastly, we express our sincere appreciation to our families and friends for their patience, understanding, and continuous motivation. Their unwavering support

enabled us to overcome challenges and stay focused on our objectives.

This blood donation bank app represents a collaborative effort and shared vision, and we are immensely grateful to everyone who played a role in making it a reality.

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Revolutionizing Induction Motor Drive Efficiency through Advanced Soft Computing Techniques

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ABSTRACT

This paper introduces a novel approach for minimizing copper and iron losses in variable-speed induction motor drives by optimizing efficiency using a field-oriented control (FOC) model. The method integrates fuzzy model identification with Particle Swarm Optimization (PSO) to adjust the magnetizing current relative to the torque current. Simulated in MATLAB 7.6, the results show that the fuzzy-PSO approach outperforms other soft computing techniques in efficiency optimization. This strategy significantly reduces both copper and iron losses.

KEYWORDS: Efficiency, Optimization, Field-oriented control (FOC), Induction motor (IM), Fuzzy controller design, Genetic algorithm (GA), Particle swarm optimization (PSO).

INTRODUCTION

Induction motors (IMs) account for over 50% of global electrical energy consumption, with squirrel-cage IMs contributing significantly. This paper focuses on optimizing efficiency by balancing copper and iron losses, which together account for around 80% of total losses. Electromagnetic torque allows achieving the same torque with different flux-current combinations, and minimizing iron loss reduces stator copper losses but increases rotor current. Using a genetic algorithm (GA) for optimization, this work provides global optimal solutions for dynamic control, compared to conventional methods. in Table 1.

Isq	Z	P
Isd		
	Z	P
	P	P

Table 1. Fuzzy Rules (Z:Zero,P:Positive)

This paper employs Fuzzy model identification through PSO to minimize IM losses and optimize magnetizing current for maximum efficiency. Simulation results are compared with conventional and proposed methods.

METHODS OF LOSS REDUCTION AND CONTROL TECHNIQUES

Induction motor losses include copper, core, mechanical,

and stray load losses, with core and copper losses being controllable. This paper investigates advanced control strategies to minimize variable losses and reduce overall energy loss.

Loss Model Control (LMC)

LMC computes optimum flux analytically based on the IM loss model and is easily implemented without additional hardware, but it requires precise motor parameter knowledge, which can vary due to factors like temperature, saturation, and skin effect.

On-Line Power Measure Search Control

This approach minimizes input power using search algorithms to optimize flux without needing motor parameter knowledge. The new gain derivative method, based on LMC results and improved fuzzy sets, offers fast, precise performance, reducing oscillations in steady-state IM conditions.

PROBLEM FORMULATION-MOTOR LOSS MODEL

Losses of Induction Motor

The d-q model for a three-phase induction motor (IM) in the synchronous reference frame can be expressed by selecting the stator current components (isd, isq and the

rotor flux linkages. (Φ_{rd} , Φ_{rq}) as state variables. The total loss equation is arrived at [3].

$$V_{sd} = R_s' I_{sd} + \sigma L_s \frac{di_{sd}}{dt} + M/L_r \frac{d\Phi_{rd}}{dt} - \omega_s \sigma L_s i_{sq} + R_{fs}/L_r \Phi_{rd} - \omega_s M/L_r \Phi_{rq} \quad (1)$$

$$V_{sq} = R_s' I_{sq} + \sigma L_s \frac{di_{sq}}{dt} + M/L_r \frac{d\Phi_{rq}}{dt} - \omega_s \sigma L_s i_{sd} + R_{fs}/L_r \Phi_{rq} - \omega_s M/L_r \Phi_{rd} \quad (2)$$

$$V_{rd} = (R_r' M/T_r) i_{sd} + (R_r' + R_{fr}/L_r) \Phi_{rd} - \omega_r \Phi_{rq} + d\Phi_{rd}/dt \quad (3)$$

$$V_{rq} = (R_r' M/T_r) i_{sq} + (R_r' + R_{fr}/L_r) \Phi_{rq} - \omega_r \Phi_{rd} + d\Phi_{rq}/dt \quad (4)$$

Machine's Operating losses described as

$$P_{loss} = P_{js} + P_{jr} + P_{fe} + P_m \quad (5)$$

The motor torque can be expressed as

$$T_e = 3/2 p M/L_r \Phi_r i_{sq} \quad (6)$$

$$P_{loss} = (R_s + R_{fs}) I_m^2 + (R_s + R_r/(1 + \Sigma R_r)^2) (T_e/P(1 - \Sigma) L_s I_m)^2 + K_M \Omega R^2 \quad (7)$$

LOSS MINIMIZING STRATEGY

Control Block Diagram

A streamline block diagram of the optimization procedure presented in Schematic 1, integrated within the framework of traditional rotor flux-oriented control (FOC). A fuzzy Particle Swarm Optimization (PSO) algorithm employed, utilizing measurements of two-phase currents and rotor velocity. These measurements compute the magnetic torque and the excitation current (i_μ), allowing for the calculation of the total motor losses.

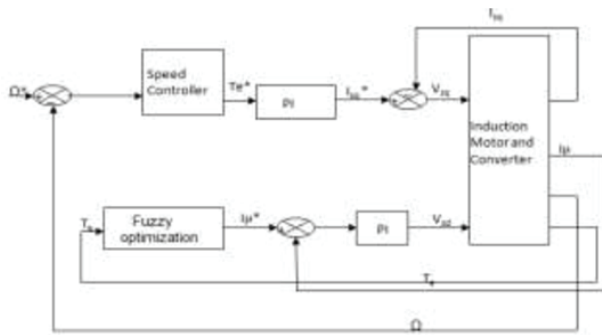


Fig. 1. Block diagram of the optimization control system

FUZZY LOGIC APPROACH

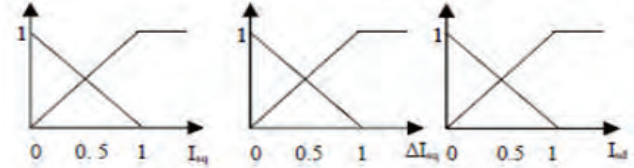
Fuzzy Controller Design

Based on the optimization theory depicted in Schematic 2, the inputs to the system represents torque current component and its divergence ΔI_{sq} , while the fuzzy controller result is the stator current component, need to be adjusted to reduce both copper and iron losses. Input and output sets are normalized and control rules are summarized in Table 1.

$$I_{sqn} = |I_{sq}/I_{sqmax}| \quad (8)$$

$$\Delta I_{sqn} = |\Delta I_{sq}/I_{sqmax}| \quad (9)$$

$$I_{sdn} = |I_{sd}/I_{sdmax}| \quad (10)$$



Membership Functions

Schematic 2. Membership Functions for proposed scheme

6. GA OPTIMIZATION PROCEDURE

Genetic algorithms (GA) are a powerful stochastic optimization technique based on natural evolution, emulating the mechanics of selection and genetics. By utilizing reproduction mechanisms such as selection, crossover, and mutation, GA searches for the optimal magnetizing current (flux) value for a given load torque. The loss equation [3] can be expressed as follows.

$$P_{loss} = (R_s + R_{fs}) I_m^2 + (R_s + R_r/(1 + \Sigma R_r)^2) (T_e/P(1 - \Sigma) L_s I_m)^2 + K_M \Omega R^2 \quad (11)$$

Selecting the best individuals for reproduction is the objective (fitness) function.

FUZZY MODEL IDENTIFICATION THROUGH PSO

Particle Swarm Optimization (PSO) utilizes a swarm of particles that explore the solution space, each having a dynamic velocity and a memory of its best-found position, known as pbest, while the global best position across all particles is referred to as gbest. In a d-dimensional space, the i-th particle is represented by $X_i = (x_{i1}, x_{i2}, \dots, x_{id})$, and its velocity is denoted by $V_i = (v_{i1}, v_{i2}, \dots, v_{id})$. The particle's personal best position is $P_i = (p_{i1}, p_{i2}, \dots, p_{id})$, and at each iteration, the entire swarm is updated based on the position of the global best particle.

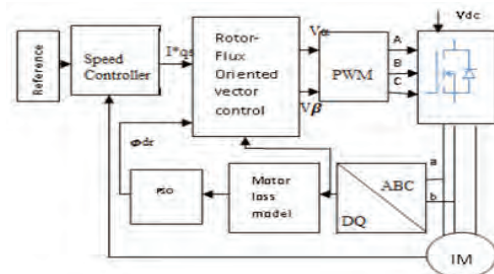


Fig. 3. Proposed Loss minimization algorithm

The objective of the optimization problem is to determine the values of the variables that meet the specified constraints while either maximizing or minimizing the objective function. The Mean Squared Error (MSE) serves as the fitness function, used to assess the performance of the fuzzy model.

$$MSE = \frac{1}{2} \sum_{k=1}^Z [y(k) - \hat{y}(k)]^2 \quad (12)$$

where,

$y(k)$ – preferred result

$y(k)$ – existing result of the model

Z – number of data samples applied in model validation

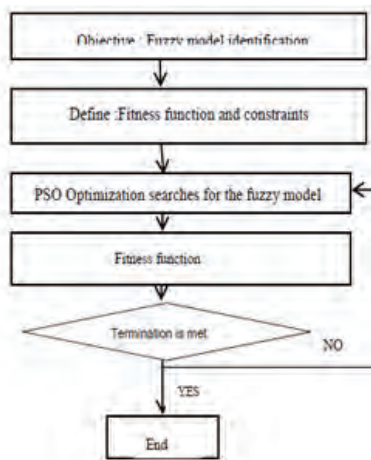


Fig. 4. Flowchart for the PSO algorithm

Table 2. Collection of MATLAB functions

i	Random particle
ii	Constraint Population
iii	Constraint Particle
iv	Constraint membership Function
v	Constraint Rules
vi	Obtain FIS
vii	Compute MSE

List 3. Specifications for fuzzy system identification

Population Size	30
Recurrence	2500
C1	2
Ws(initial inertia weight in a PSO execution)	0.9
We(final inertia weight in a PSO execution)	0.3
Maximum velocity	75

RESULTS AND DISCUSSION

A numerical simulation using Matlab/Simulink was conducted to achieve energy savings in the IM, with the motor's parameters shown in Table 5. The fuzzy PSO optimization provided an optimal magnetizing current vector, improving efficiency, especially in the light load region compared to conventional methods.

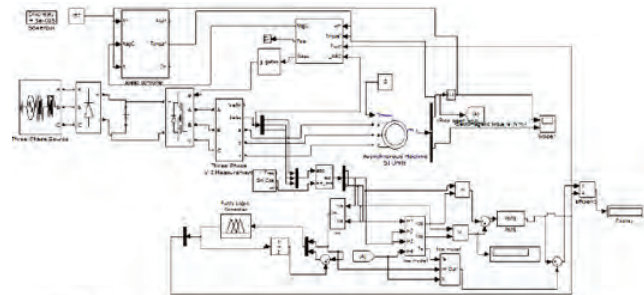


Fig. 7: Matlab simulation model of fuzzy controller based optimization of Induction motor

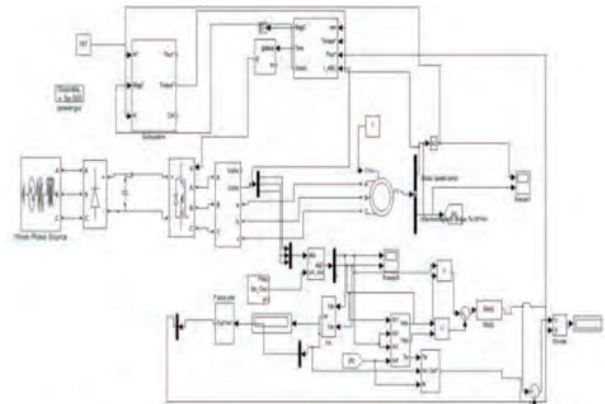


Fig. 8. Matlab simulation of fuzzy PSO based optimization of Induction motor

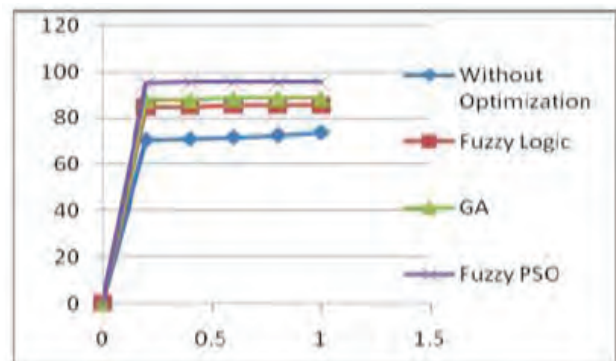


Fig. 9. Efficiency vs load for different optimization techniques

List 4. Evaluation of Global Optimization algorithms

Load	Conventional Method	Proposed Approach		
0.2	70.78	84.41	87.81	95.21
0.4	71.18	84.84	88.81	95.48
0.6	71.88	85.35	88.5	95.46
0.8	72.8	85.43	88.67	95.31
1	73.97	85.53	88.63	95.33

Table 5. Specifications and Parameters of Induction Motor

Power P	4kW
Number of pole pairs np	2
Electrical Resistance of stator windings Rs	1.15Ω,
Electrical Resistance of Rotor windings Rr	1.44Ω
Combined leakage factor σ	0.12,
Cross Inductance M	0.143 H
Inductive reactance of stator and rotor windings = Lr	0.156 H
Inertia J	0.0240 SI
Viscous friction coefficient f	0.00 SI
Rated Load torque TL	7 N.m

CONCLUSION

This study explores Soft Computing approaches, including Fuzzy Logic and Fuzzy PSO, to optimize Induction Motor (IM) efficiency by adjusting the magnetizing current. Fuzzy PSO significantly improves efficiency across load

conditions, offering a promising solution for reducing energy consumption.

Advanced fuzzy logic techniques: Employing more sophisticated fuzzy logic approaches like type-2 fuzzy sets can enhance the ability to handle complex uncertainties.

Hybrid approaches with other optimization methods: Combining PSO with other optimization algorithms like genetic algorithms could potentially improve the exploration capability in complex search spaces

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Energy Conservation and Audit for an Engineering Institute Hostel

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ABSTRACT

The proper and sufficient type of energy is required for human society to evolve sustainably. We must take the required actions to close the gap between supply and demand because of the steadily rising demand. The procedure of conducting an energy audit in an academic institution to recommend different conservative measures to make energy use more economical is the main subject of the study. The hostel and mess of NIT Sringar have so undergone an energy audit. This study presents a detailed analysis of energy usage and waste through appliances in an attempt to raise awareness of energy use and promote energy conservation techniques. We were able to identify recommendations for cost reduction, environmental pollution reduction, and demand-supply gap monitoring thanks to the thorough investigation we conducted for this article.

KEYWORDS: *Energy audit, Energy conservation measures, Payback period, Load demand.*

INTRODUCTION

Enough energy is necessary for the modern society to develop sustainably. As of February 2024, India had 4,46,190MW of installed power plant capacity. By 2035, India is expected to increase its energy consumption by 4.2% annually. More focus should be placed on renewable energy sources because of the enormous demand for them. It becomes necessary to perform energy audits in order to mitigate the burden of energy production to a certain degree when large amounts appear on the electricity bill. Energy conservation is the practice of using energy efficiently and, as a result, minimizing waste.

This paper discusses the idea of lowering the overall electricity bill by replacing existing devices with those that consume less power and are more energy efficient, in contrast to other energy audits where the main focus areas are consumption reduction and various methods to cut down usage. The implementation of solar water heaters and biogas systems is the primary emphasis of this study, which includes the entire approach for energy conservation in the best feasible way.

LITERATURE REVIEW

Many researchers have done various energy audit in different areas like industry, academic institutions etc.

After carefully studying the energy consumption pattern, in an Institution and educational building, researchers proposed some general recommendations like replacing incandescent bulbs with CFLs and use of motion sensors [1-2]. Besides this energy audit also holds immense relevance in the residential areas and industrial areas too, as presented by R. Sharma, V. Jadhav, R. Pieterse [3-4] [8]. The suggestions made in the paper [6] by Ramkiran et al substantiates the claim in context with financially and technically viable alternatives for reducing energy usage. Moreover, a detailed work on Energy Conservation reiterates the inevitable role of energy in near future and how its conservation holds extreme importance [5][7]. As far as the results and conclusions are concerned, the reference in [9] points out the significant energy savings with fewer changes and adjustments.

DATA COLLECTION AND METHODOLOGY

For the collection of data we have taken in account room-wise details of the lighting load, fans, air conditioners, PCs, switches, exhaust load etc. that are present in each floor of the NIT SRINGAR GIRLS HOSTEL building, to estimate the present load and the load that can be expanded in the future.

The methodology adopted for this audit was:

- Grouping of students to perform audit in specific areas for inspections and data collection.
- Observation on daily consumptions of various loads and facilities present in NIT SRINGAR Girls hostel and mess.
- Measurements of energy consumptions and other parameters.
- Investments and payback period estimations.
- Recommendations regarding implementation of various kind of energy conservation methods.

Some technical data have been gathered regarding the total load present in the NIT SRINGAR GIRLS building which can be analyzed and studied through the pie charts and table given below in table 1 and figure1.

Table 1: Electrical Distribution in Hostel

Electric Load	Quantity in hostel area	Rating	P.F.
Fan	142	80W	0.5-0.7
Tube			
Light	185	40W	0.5
Socket	147	90W	
Bulb	118	15W	0.5-0.9
Exhaust Fan	32	65W, 70W	0.6-0.7
AC	1	2kW	0.8

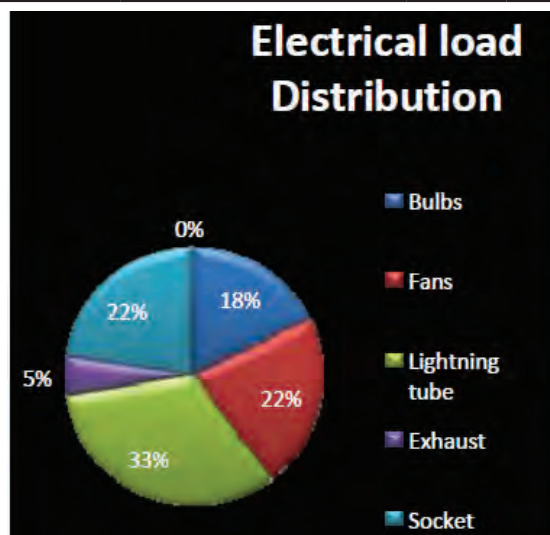


Fig. 1: Electrical Load Distribution

MEASUREMENTS PERFORMED

For calculation of energy cost savings and further payback period we first needed to measure the energy consumption in a day and then in a year for different areas.

The following measurements and clear view is explained through table and graphs below:

Measurements were performed in Girls hostel and girls hostel and calculations on energy consumptions were done which are tabulated in following table 2 and table 3 respectively.

Table 2: Energy Consumption in Boys Hostel

Electric Load	Wattage (W)	Qty	Daily hours of use	kWh used in a day	kWh used in a year
Tubelight	40	67	10	26.8	7772
Fan	80	67	17	91.12	16857.2
Bulb	15	67	6	6.03	1748.7
Laptop	60	67	3	12.06	3497.4
Mobile Charger	5	120	6	3.6	1044

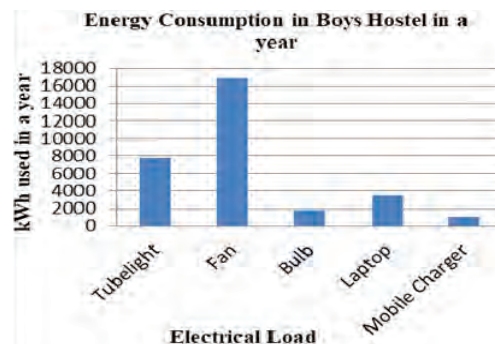


Fig. 2: Energy Consumption in Boys hostel room

Table 3: Energy consumption in girls hostel

Electrical Load	Wattage (W)	Quantity	Daily hours of use	kWh used in a day	kWh used in a year
Tube light	40	50	10	20	5800
Fan	80	50	17	68	12580
Bulb	15	50	6	4.5	652.5
Laptop	60	50	3	9	2610
Mobile Charger	5	90	6	2.7	783

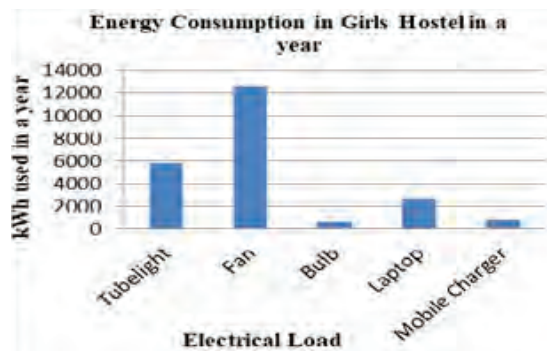


Fig. 3: Energy Consumption in Girls hostel rooms

Also, further measurements were done in mess to calculate their daily consumptions as shown in table 4.

Table 4: Energy Consumption in Hostel Mess

Electrical Load	Wattage W	Quantity	Daily hours of use	kWh used in a day	kWh used in a year
Tubelight	40	28	10.5	11.68	3387.2
Fan	80	16	10.5	13.28	2456.8
Bulb	15	1	24	0.96	278.4
Exhaust	70	2	8	1.12	324.8

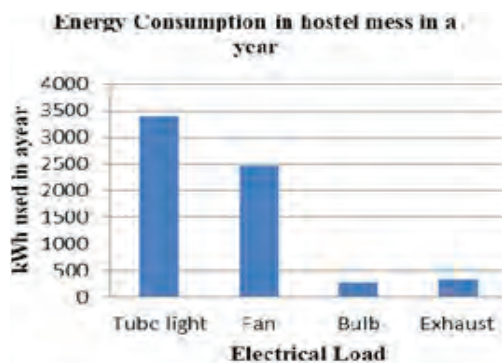


Fig. 4: Energy consumption in Mess

ENERGY CONSERVATION MEASURES

Current Lightning Scheme in Hostel

Total number of tube lights = 185

Wattage of Tube light: 40W which consumes 54W power with 14W conventional chokes

Assumptions of operational hours and days: 10 hours per day for 290 days.

Total energy used in a Month:

$$\text{No. of lights} \times (\text{Hours} \div \text{Day}) \times \text{Days in a month} \times \text{Wattage} \\ = 18 \times 54 \times 10 \times 290$$

$$= 28971 \text{ kWh}$$

i. Replacement of 40W tubes with 36W tubes

The 36W tube consumes 50W power with conventional choke of 14W. Therefore Total Energy

$$= 185 \times 50 \times 10 \times 290 = 26825 \text{ kWh}$$

Hence Energy Saved = 2146 kWh

Cost of electricity saved at the rate of ₹11.44 = ₹24550.24

The cost of 36W tube is ₹45, therefore the total investment of replacing 185 tubes would be ₹8325

Therefore Payback Period would be

$$= (8325 \div 24550.24) \times 12$$

$$= 4 \text{ months}$$

ii. Using T5 FTL

Characteristics of Conventional 40W:

Expected life hours: 5000 hours Energy input per hour: 45 hours

Consumption in 10 hours per day: 0.45 kWh

Annual Consumption in 290 working days: 130.5 units

Annual Consumption at the rate of ₹11.44 per unit = ₹1493

Characteristics of T5

Expected life hours: 20000 hours Energy input per hour: 28 hours

Consumption in 10 hours per day: 0.28 kWh Annual

Consumption 290 working days: 81.2 units Annual

Consumption at the rate of ₹11.44 per unit = ₹929

Cost of electricity saved = 1493 – 929 = ₹564

Total savings per year considering we replace 185 T8 FTLs with T5 we can save around ₹104340

Total investment = 185x400 = ₹74000 Therefore Payback Period would be 8.5 months

iii. Replacement of conventional chokes with electronic chokes

Table 5: Payback Period of electronic chokes

Parameter	Conventional Choke	Electronic Choke
Investment p.a	150x185=27750	220x185=40700
Cost of starters	10x185=1850	-
Net Investment	40700-(27750+1850)=11,100	
Power Rating (W)	(40+14)x185=9990	(40+3)x185=7955
Annual Energy Consumption(kWh)	9990x10x290/1000=28971	7955x10x290/1000=23069.5
Cost of energy@11.4	331428	263915
Net Amount of annual savings	67512	
Simple Payback Period	11,100x12/67512=2months	

Calculation of payback period when using electronic choke by comparing it with conventional choke in the above table 5.

Energy conservation scheme for Fans

Replacement of Rheostatic regulators with electronic regulators. Cost of one electronic fan regulator: ₹180
Duration for which fan is used: 16 hours per day
Operational days: 200 days

Rating of Fan: 80W

Annual energy consumed by a fan= $80 \times 16 \times 200 = 256$ kWh

If we use electronic fan regulators there is 25% reduction against Conventional Fan Regulators.

Cost of energy saved = $0.25 \times 256 \times 11.44 = ₹732.16$

Therefore Payback Period = cost of electric fan regulator ÷ cost of energy saved = $180 \div 732.16 = 0.24$ year

Installation of Solar Water Heater system

Residents: 250

Assuming average requirement of 20 L of hot water per day. Thus daily amount of hot water used= $250 \times 20 = 5000$ L

An average flat plate collector area of 2 m² gives 125L of hot water per day.

Thus total collector area required = $5000 \div 125 \times 2 = 20$ m²

Assuming cost of installation to be around 10,000/m² total capital cost comes out to be = ₹200,000

Total geyser energy consumption if used in the hostel for approximately 12 hrs on a typical cold day for 2.3 kW geysers installed in the hostel then

$10 \times 2.3 \times 10 = 230$ kWh

Geysers will be typically operational in NIT SRINGAR

GIRLS for about 130 days from November to February. Thus total energy consumption = $130 \times 230 = 29,900$ kWh

Total expense with geysers = $29,900 \times 11.44 / \text{kWh} = ₹342,056$

Thus simple payback period = $200000 \div 342056 = 0.58$ years

Installation of Bio gas plant

Typical waste food density is 30 Kg/m³

Total volume of waste food per day is about 30 L
Installation cost of Biogas = 1.5Lakhs.

Operational and maintenance cost=₹2000 If 1m³ of biogas produce 4.6kWh energy Then we need 5.87m³ of biogas

Therefore we need an urban bio gas unit of approx.200 kg capacity.

Assumptions-

Calorific value of biogas = 6kWh/m³ = 20MJ/m³

Calorific value of LPG = 26.1kWh/ kg=46.1MJ/kg Energy output of biogas plant per day:175 MJ This implies that LPG saved = $175 \div 46.1 = 3.79$ kg = 0.199 LPG cylinders per day Therefore, LPG saved = 5.99= 6 LPG/month

Total working days : 290 days approximately Total annual savings = $290 \times 0.199 \times 600 = 34626$

Payback period = $152000 / 34626 \times 12 = 4$ years approx.

RECOMMENDATIONS AND CONCLUSIONS

In this paper, efforts have been made to shed light on how we can significantly cut down on energy wastage by making some basic modifications that include :

1. Replacing conventional ballast [chokes] FTL with Electronic Ballasts of high frequency that reduces energy usage by 25%. Also, the capital cost recovery time for replacing it is around 2 months.
2. When it comes to lighting, it was found that replacement of 40W tubes with that of 36W, will also serve the purpose. It shall prove very convenient and economical as payback period is only 4 months.
3. Moving further, we also deduced that using T5 FTL instead of T8 can yet be another measure so as to reduce the energy consumption meanwhile improving the luminous efficiency. It's payback period is found out to be 8.5 months which is more than the above mentioned changes.

Realizing the vital role of renewable energy sources to tackle any energy crisis, in this paper emphasis have been laid on usage of solar water heating system and installation of biogas plant. In the mess, 6 LPG cylinder per month can be saved that will eventually bring down the costs increased.

Table 6: Summary of different payback period for different energy saving measures

Energy Saving Measure	Payback Period
Replacement of 40W with	
36W tubes	4 months
Using T5 FTL instead of T8	8.5 months
Replacement of conventional	2 months
chokes with electronic chokes	
Replacement of Rheostatic regulators with electronic one	0.24 year
Installation of Solar Water heating System	0.58 year
Installation of Bio Gas Plant	4 year

CONCLUSIONS

Based on this study, it can be said that this is only a step in the right direction toward making a hostel more energy efficient. For universities and other educational institutions, regular energy audits are necessary to ensure appropriate energy use and equipment upkeep. The study also demonstrates that restricting primary and secondary sources is necessary to increase a hostel's energy efficiency. The suggested course of action suggests conserving and making effective use of our limited resources, as well as identifying ways to reduce excessive energy use. This use of energy-saving devices will be favourable from an economic stand point, and energy conservation will assist lessen the environmental impact.

Significant changes in the pattern of energy usage can be achieved with the aid of energy audits and the numerous effective methods and technologies that we have presented in this article. Energy waste and conservation have been highlighted in the article. It aids in the identification and management of renewable energy sources. Table 6 illustrates that the payback period is comparatively short and will recover the investment amount quickly.

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Federated Learning for Privacy-Preserving Machine Learning

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ABSTRACT

Federated Learning (FL) is a decentralized machine learning framework that allows multiple clients (e.g., smartphones, IoT devices, or edge nodes) to collaboratively train a shared model while keeping their local data private. This decentralized approach mitigates the privacy concerns that arise in traditional centralized machine learning, where sensitive data must be aggregated on a central server. [8] This paper explores the fundamental principles of Federated Learning, its architecture, challenges, and applications, with a particular focus on privacy-preserving techniques. We examine key advances in the field, such as model synchronization, communication efficiency, and privacy-enhancing mechanisms like differential privacy and secure aggregation. By enabling data to remain localized on devices, FL provides a promising solution for privacy-sensitive applications in healthcare, finance, and IoT.

KEYWORDS: Machine learning, Federated learning, Privacy, Model accuracy, Performance metrics.

INTRODUCTION

The rise of machine learning (ML) technologies has revolutionized industries, offering significant advancements in areas such as healthcare, finance, and consumer services. However, traditional centralized machine learning models often require large datasets to be aggregated in a single location, posing serious privacy and security risks. The need for data privacy has become even more urgent as concerns about data breaches, surveillance, and misuse increase. Federated Learning (FL) offers a decentralized approach to model training, ensuring that raw data remains on local devices and only model updates are shared with a central server [2]. This paper aims to highlight the capabilities and challenges of Federated Learning in enabling privacy-preserving machine learning.

OVERVIEW OF FEDERATED LEARNING

Federated Learning Architecture

The diagram below represents the architecture of Federated Learning, where multiple clients collaborate to train a machine learning model without sharing their data with the central server.

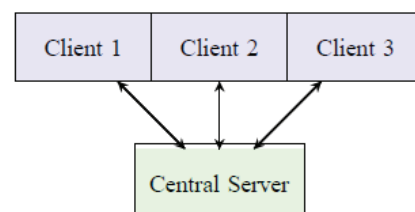


Fig. 1. Federated Learning Architecture

The core concept of Federated Learning is that multiple clients collaborate to train a machine learning model, while each client's data stays on their local device. The process works as follows:

- **Model Initialization:** A global model is initialized on the central server.
- **Local Training:** The server sends the current model to each client. Clients then train the model using their local datasets.
- **Model Updates:** Clients send only the updated model parameters (e.g., gradients or weights) back to the server.

- Aggregation: The server aggregates the updates from all clients to improve the global model.
- Iteration: Steps 2 through 4 are repeated iteratively until the model reaches satisfactory performance [4].

This decentralized approach ensures that sensitive user data does not need to leave the local devices, which significantly enhances privacy protection.

Types of Federated Learning

There are several types of Federated Learning, each suited for different scenarios.

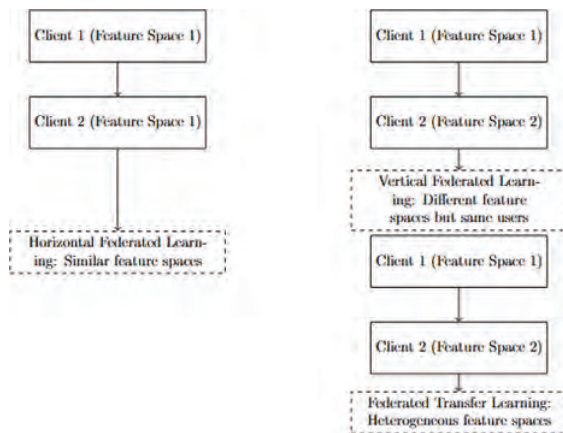


Fig. 2. Types of Federated Learning: HFL, VFL, and Federated Transfer Learning

- Horizontal Federated Learning (HFL): Clients have similar feature spaces (e.g., different mobile phones with similar apps) [6].
- Vertical Federated Learning (VFL): Clients have data in different feature spaces but share the same set of users (e.g., a client with demographic data and another with transaction data) [7].
- Federated Transfer Learning: Clients have heterogeneous feature spaces and user populations, requiring techniques to adapt models across diverse datasets [9].

PRIVACY-PRESERVING MECHANISMS IN FEDERATED LEARNING

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

Differential Privacy (DP)

Differential Privacy ensures that the model's outputs do not reveal sensitive information about individual data points. By adding noise to the gradients before they are shared with the central server, DP provides mathematical guarantees that individual data cannot be extracted from the aggregated updates [3].

Secure Aggregation

Secure aggregation protocols ensure that the server can only see the aggregated model updates, not the individual updates from each client. This prevents potential attacks where adversaries might learn information about the data on a particular client. Techniques like homomorphic encryption can be used to achieve secure aggregation [2].

Homomorphic Encryption

Homomorphic encryption enables computations on encrypted data, allowing for model updates to remain encrypted during the aggregation process. This ensures that even if an attacker gains access to the model updates, they cannot decrypt or infer sensitive data [11].

Federated Averaging (FedAvg)

Federated Averaging (FedAvg) is one of the most commonly used algorithms in FL. It aggregates local model updates by averaging them, which simplifies the process of training on decentralized data. However, FedAvg is vulnerable to model inversion attacks, which is why it is often combined with other privacy-enhancing techniques like differential privacy [8].

CHALLENGES IN FEDERATED LEARNING

While Federated Learning offers substantial privacy benefits, it faces several challenges that hinder its full potential. Some of the major challenges include:

Data Heterogeneity

Data across clients can vary significantly in terms of distribution, which can affect the performance of the global model. Heterogeneity, also known as Non-Identically and Independently Distributed (Non-IID) data, can lead to biased or overfitted models [6]. Solutions like personalized Federated Learning, where models are adapted to individual client data, are being explored to address this challenge.

Communication Efficiency

Frequent communication between clients and the central server is required in Federated Learning, which can be inefficient in scenarios with limited bandwidth or where large models are involved. Techniques like model compression, gradient quantization, and federated distillation are being researched to reduce the communication overhead [4].

Model Inversion and Membership Inference Attacks

Although Federated Learning keeps raw data local, attackers can still perform model inversion and membership inference attacks to extract sensitive information [5]. To mitigate these risks, FL can combine differential privacy and secure aggregation, but the trade-offs in model accuracy need careful consideration.

System and Resource Constraints

Federated Learning often involves resource-constrained clients, such as mobile devices or IoT sensors, which may have limited computational power, memory, and battery life. Developing lightweight models and resource-efficient algorithms is crucial to ensure that FL can function effectively in such environments [9].

CASE STUDY: FEDERATED LEARNING IN HEALTHCARE

Background

Healthcare data is highly sensitive, making it difficult for institutions to share patient records for model training due to privacy regulations such as HIPAA. Federated Learning offers an ideal solution by enabling the training of machine learning models without compromising patient privacy [12].

Case Study Setup: Multi-Hospital Federated Learning

In this case study, Federated Learning was deployed across multiple hospitals to predict the likelihood of heart disease based on patient medical data. The hospitals could not share data due to privacy concerns, so each hospital trained a local model and sent model updates to a central server for aggregation.

Data:

- Number of Hospitals: 3
- Number of Patients: 10,000 patients (approximately 3,000 per hospital)

- Features Used: Age, blood pressure, cholesterol levels, medical history

Federated Learning Algorithm: Federated Averaging (FedAvg) Privacy Techniques: Differential Privacy, Secure Aggregation

Results and Numerical Analysis

Model Accuracy

- Before Aggregation: Hospital 1: 83.5 Hospital 2: 81.2 Hospital 3: 85.0
- After Aggregation: The global model achieved an accuracy of 84.3

Communication Efficiency

- By using Federated Learning, communication overhead was reduced by 90 compared to centralized models where data would need to be sent to a central server.

Privacy Preservation

- Differential Privacy was applied to model updates, which added noise to the gradients, increasing model error by 5 but ensuring the protection of patient data.

Latency

- Latency increased by 10 in FL compared to centralized approaches due to the additional steps required for secure aggregation and privacy protection.

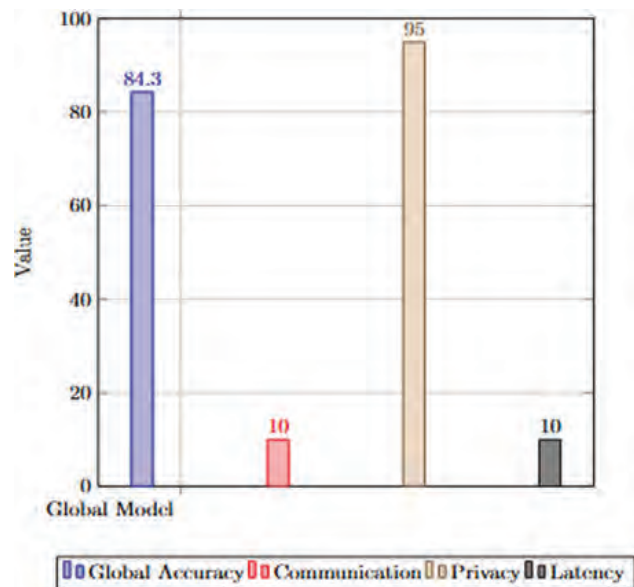


Fig. 3. Federated Learning Performance Metrics

Federated Learning Performance Metrics

In this section, we analyze the performance of Federated Learning, focusing on various metrics such as model accuracy, communication efficiency, privacy preservation, and latency. Below, we illustrate these metrics with a figure.

Analysis from figure

As seen in the previous figure, there is a significant improvement in the communication efficiency and privacy preservation metrics. These results highlight the advantages of using Federated Learning, particularly in scenarios where data privacy is a concern.

Conclusion

This case study illustrates the effectiveness of Federated Learning in healthcare. Despite challenges such as increased latency and model error due to privacy mechanisms, FL enables collaboration across hospitals while preserving the confidentiality of patient data.

APPLICATIONS OF FEDERATED LEARNING

Federated Learning is increasingly being applied in several domains, particularly where data privacy is a critical concern:

- 1) Healthcare: FL is used to train machine learning models on medical data while ensuring compliance with privacy regulations. Applications include predictive modeling for disease diagnosis and personalized treatment recommendations, all without the need to centralize sensitive patient data [12].
- 2) Finance: In the financial sector, FL allows banks and institutions to train models for fraud detection, risk analysis, and customer profiling without compromising user privacy [8]. It is especially valuable when regulatory compliance requires data to remain private.
- 3) Internet of Things (IoT): With the growing number of IoT devices generating sensitive data, FL offers a way for devices to collaboratively improve models for predictive maintenance, anomaly detection, and more, while keeping user data on the local devices [6].

FUTURE WORK

Although Federated Learning presents significant advan-

tages in privacy preservation, several areas require further research and development:

- Improving Communication Efficiency: As FL systems grow in scale, reducing communication overhead without compromising model accuracy will be crucial. Techniques such as gradient sparsification and federated distillation are promising but need further optimization.
- Handling Heterogeneous Data: Solutions for handling non-IID data are still under development. Personalization techniques and transfer learning in Federated Learning can be explored to make FL more robust in real-world applications.
- Advanced Privacy-Preserving Techniques: While differential privacy and secure aggregation are effective, new cryptographic and privacy-preserving techniques need to be explored to mitigate the risks of model inversion and membership inference attacks.
- Edge and Resource-Constrained Devices: Research into lightweight models and energy-efficient training algorithms is necessary to make Federated Learning feasible in edge environments, such as low-power IoT devices or mobile phones.

CONCLUSION

Federated Learning offers a powerful and privacy-conscious approach to training machine learning models by decentralizing the learning process. It enables sensitive data to remain on local devices, providing a promising alternative to traditional machine learning approaches. However, challenges remain, including communication efficiency, data heterogeneity, and privacy vulnerabilities. Continued research and development in these areas will help realize the full potential of Federated Learning in real-world applications such as healthcare, finance, and IoT.

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Optimizing User Satisfaction through WUM-based Online Recommendation Systems Enhanced by NLP Technology

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ABSTRACT

The rapid development of the World Wide Web has resulted in issues with information overload. Web Usage Mining (WUM) is a new application area that integrates analysis, pattern recognition, and data preprocessing. Web server logs are used by WUM to extract web navigational patterns, however semantic information is frequently left out. When user preferences are not known, recommendation lists can be generated using natural language processing (NLP) approaches to increase accuracy. NLP can create vector representations of books, determine the optimal presentation, and parse user questions. For keyword-based search and tailored recommendations, this strategy can be combined with recommendation algorithms. Improving online user support is the aim.

KEYWORDS: *Web usage mining, Personalized, Books recommender system, Pattern mining, NLP.*

INTRODUCTION

The World Wide Web has experienced rapid growth, leading to an Information Overload problem. Due to the inefficiency of traditional information analysis methods, Web Usage Mining (WUM) was created in order to forecast web access behavior and personalize websites. Preprocessing raw data, finding patterns and schemas, and assessing the outcomes are the three steps of WUM. Web logs are valuable information for understanding user navigation behavior and forecasting future movements.

Web usage mining extracts commonly visited web navigational paths from server logs, but semantic information is often not included. To improve accuracy, semantics from web pages stored in server logs can be integrated with WUM techniques.

Recommender systems struggle when users have limited information or preferences. Natural language processing (NLP) techniques can be used to create recommendation lists when users' preferences are unavailable. NLP can parse user queries, understand them, and decide which

way to present recommendations. Topic signature category similarity algorithms can generate vector representations of each book for recommendation.

NLP can be merged with recommendation systems for functionalities like keyword-based search when user history is unavailable. This approach helps find information, refine it, organize it, keep it updated, and generate patterns for visual presentations. Gaining more insight into how consumers behave when browsing the web is intended to improve user assistance. Extracting commonly used navigational paths in terms of Web page URLs from Web server logs and preprocessing to remove extraneous information is the standard approach to Web usage mining. The preprocessing task within the WUM process involves[2] cleaning, session identification and user profiling stored in an undirected graph whose nodes are associated to the identifiers of the accessed pages to prepare it for the pattern discovery task using weighted graph algorithm.

We propose to incorporate the concept of Natural

Language Processing (NLP) alongside Web Usage Mining (WUM) to enhance the understanding of user queries and optimize the presentation of recommendations within the system. Specifically, we suggest the integration of the NLP tool BookNet, which serves as a comprehensive training set encompassing all terms associated with various book categories, into the recommendation framework.

In certain instances, such as when a user submits a query containing terms that do not explicitly reference a book title or author, the system will analyze the query in relation to the training set using similarity metrics. This approach will yield the most relevant and frequently viewed book within the corresponding category. Recommendation systems that rely on keyword matching have demonstrated effectiveness. The usual method for Web use mining involves extracting frequently used navigational pathways in terms of Web page URLs from Web server logs and preprocessing to eliminate unnecessary information.

LITERATURE SURVEY

A relatively new area of study called “web mining” looks for intriguing and practical patterns in website data. Web mining is created using three domains: web usage mining, web content mining, and web structure data mining, depending on the type of data.[1]. User profiles and online usage trends inform the works that go into personalizing a website. Finding groups of users with similar characteristics and interests may be accomplished by clustering user profiles, but this method relies on reliable user input. Websites that retain real users and occasionally give them pertinent returns based on their categories, like online banking, insurance providers, and corporate and business houses, might find this strategy helpful[2]. Numerous methods, including statistical analysis, association rules, sequential patterns, clustering[3], classification[4], and dependency modeling[5], have been applied to web server logs in web usage mining in order to find rules and patterns. Separating irrelevant and refined log entries for the mining process is the goal of data cleaning. Records with filename suffixes like GIF, JPEG, CSS, etc. that could be downloaded without the user’s explicit consent need to be deleted. HTTP errors, crawler-generated records, and other records that don’t accurately reflect user behavior are examples of additional removal records[6]. Among online personalization strategies is the recommendation system, which is separated into two categories: Systems for content- based (CB) and collaborative filtering (CF) recommendations[7].

PROPOSED SYSTEM

Architectural Overview of WUM

When leveraging NLP-based recommendation systems in comparison to using WUM alone, achieving high accuracy levels becomes more feasible. This is because WUM solely focuses on basic information such as book names and usage patterns for making recommendations, without delving into the deeper details of the books themselves. As a result, WUM lacks the capability to differentiate between successful and unsuccessful books when a user queries based on the content present in the books. Conversely, NLP algorithms analyze the semantic content of the books by considering factors like categorization and topic signatures to determine similarity among categories. By taking into account these intricate details, NLP enhances recommendation accuracy by providing more nuanced and contextually relevant suggestions to users. In essence, the integration of NLP into recommendation systems not only improves precision but also increases user satisfaction and engagement with the platform by offering personalized and insightful book recommendations tailored to their preferences and interests.

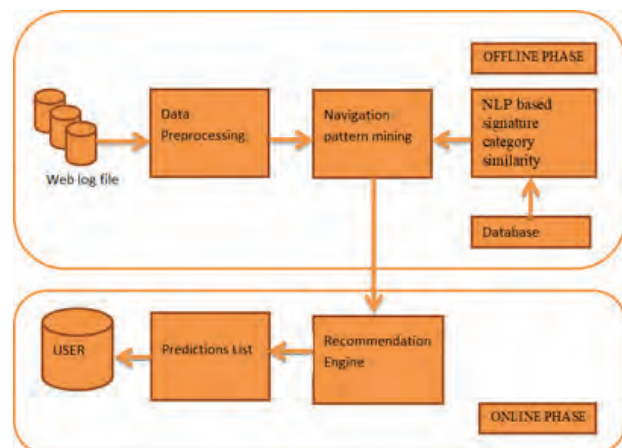


Fig. 1. Architecture of WUM-based Online Recommendation Systems Enhanced by NLP Technology

Web servers accumulate substantial amounts of data from website usage, which is recorded in web access log files. The information contained within these logs is diverse and unstructured, necessitating a preprocessing phase to identify patterns effectively. In addition to web access log files, other data sources such as cookies can be utilized in Web Usage Mining; however, these sources often contain significant noise and missing information. A log file is a simple text document that organizes requests in

chronological order based on the time the user accessed the resource. The preprocessing step of a Web Usage Mining process aims to remove irrelevant or noisy requests, like implicit requests or requests from web crawlers, and convert the raw log file into a collection of transactions, each of which represents the list of pages a specific user has visited. In order to prepare data for the pattern finding objective, the WUM process's preprocessing step entails [4] cleaning, organizing, filtering, and summarizing the data. This proposed system outlines a comprehensive methodology for transforming raw HTTP logs into a structured format.

Offline Phase of the Architecture

The preprocessing step of a Web Usage Mining process aims to remove irrelevant or noisy requests, like implicit requests or requests from web crawlers, and convert the raw log file into a collection of transactions, each of which represents the list of pages a specific user has visited. In order to prepare data for the pattern finding objective, the WUM process's preprocessing step entails [4] cleaning, organizing, filtering, and summarizing the data.

Web log data

Web server logs include information on user navigation. This contains the client ID, IP address, request date, requested URL, and HTTP information of the user making the request. Whether in a relational database or as plain text files, logs can be kept in a variety of forms, such as Common Log Format (CLF) or Extended Common Log Format (ECLF), to aid in additional analysis. Relational databases might have difficulties in the case of a system crash, even if they place restrictions on data to make sure it is queryable. To reduce reliance on other system processes, plain text file format is utilized.

Algorithm Steps :

1. Retrieve the web log from the server side, specifically the server log.
2. Save the server log in the Common Log Format (CLF). The format should be as follows:

```
<ip_addr><base_url><date><method><file><protocol>
<code><bytes>.
```
3. Store or map all requests from the logs into a Microsoft SQL Server database utilizing the query analyzer.

Web log preprocessing

The data found within web logs is diverse and lacks a

structured format. Therefore, the preprocessing stage is essential for identifying patterns. Certain elements of the information may be either incomplete or irrelevant, necessitating the cleaning of the data prior to advancing to the subsequent phase through web log preprocessing. The preprocessing task within the WUM process involves[3] cleaning, session identification data to prepare it for the pattern discovery task.

Data cleaning

Usually, requests for images and multimedia files, methods different from "GET", Failed and corrupted requests does not indicated any user navigation patterns hence these requests are filtered out as well as Web robots' sessions[3]. Reference Length is the time taken by the user to view a particular page is also calculated[3]. The calculation is typically based on the difference in access times between a given record and the subsequent record.

Algorithm Steps:

1. Requests for graphical page content, such as (*.jpg and *.gif images), are excluded.
2. Requests made by robots and web spiders, identifiable by their bulk request patterns, are filtered out.
3. Requests that do not utilize the "GET" method, which are not initiated by users, are discarded.
4. Requests that fail or are corrupted, classified under the 400 status series, are removed.

Session identification

In this phase, the entries from the raw log file are organized according to user sessions. A session is characterized as a specific collection of resources that are available to the same user during a particular visit..

Algorithm Steps:

User Identification: Grouping Requests by User

- i. If two records exhibit different IP addresses, they are classified as distinct users. Conversely, if both records share the same IP address, the User Agent field is examined.
- ii. If the browser and operating system information within the User Agent field differs between the two records, they are recognized as separate users.

Session Identification

A user session is defined as follows: $s(i) = (Bid1, Bid2,$

Bid3, ..., Bidn), where “i” represents the ith session and Bid denotes the book identifier. Consequently, each session comprises a collection of books that a user has viewed during that specific session.

- i. Method Based on Total Session Duration: This approach considers the total duration of pages visited by a user, with a default session time that fluctuates by 30 minutes, as noted by R. CoolEY[8]
- ii. Method Based on Individual Page Duration: This method relies on the time spent on each page, which is determined by the interval between two recorded timestamps. If the duration exceeds 10 minutes, the subsequent entry is regarded as a new session[3].

Finally in this process, the log file generated during this process will comprise a collection of transactions, with each transaction representing a user session that records and retains details such as the IP address, requested resources during the session, and the date and time of the requests. The primary objective of Web Log Processing is to remove any incomplete data and to format the information in order to accurately identify web access sessions. The subsequent module, which operates in an offline phase of the architecture, focuses on Navigation-based User Profiling..

Navigation Based User Profiling

After the Web Log has been preprocessed, the next step is to identify common navigation patterns in the user profiles that have been created and saved as session models in a data structure. The weights are stored in an adjacency matrix data structure, where each item corresponds to the weight of a pair of accessed pages. Login credentials are used to identify user sessions, which are then used to build “Session Clusters,” which in turn provide a list of suggestions. This procedure uses a weighted network algorithm based on its linked components to find groupings of highly associated pages.

NLP based topic signature category similarity

In the module, all extracted feature profile vectors are stored, which are generated following the categorization of the uploaded books. This facilitates recommendations through the semantically enriched database dictionary known as BookNet

Database of training words

This database comprises all keywords associated with specific categories of books, which are utilized for

recommendations when a user provides insufficient information while searching for a book on the website.

ONLINE PHASE OF THE ARCHITECTURE

Recommendation Phase

The objective of a recommender system is to identify which web pages are most likely to be visited by the user in the future. Currently, the active navigation history of the user is analyzed in conjunction with identified navigation patterns to provide real-time recommendations for new pages. In this context, the “interest” in a page is determined not by its content but by the sequence in which it is accessed during a session. Consequently, to calculate the weighted frequency of each edge in the graph, we have developed an innovative formula:

$$FCX = \text{Max} \{ NXb1, NXb2, NXb3, \dots, NXbi \}$$

Where, NXb1 = number of sessions containing both books X and b1, NXb2 = number of sessions containing both books X and b2 and so on.

Database module using Term frequency algorithm

This algorithm identifies the distinct indexes or terms present in the book while also assessing the degree to which the book fits within a specific category of literature. Additionally, the categorization process occurs during the preprocessing phase of Natural Language Processing (NLP).

CONCLUSION

A web personalized recommender system is proposed that automatically customizes a website’s content and structure to individual user needs. The system uses web usage mining and semantically enriched natural language processing techniques to predict users’ future intentions. The system uses offline phase to classify user navigation patterns and predicts future intentions through web server logs. The system integrates web usage patterns with advanced NLP techniques, recommending accurate and related books to users visiting the website. Web usage patterns are acquired by preprocessing logs and identifying user sessions. The recommendation is based on users’ history and usage patterns. A semantically enriched NLP-based database dictionary is used to match queries with books of interest. Vector representations of each book are stored for recommendation. The system can be extended to different book categories, languages, and user interfaces. Future areas of focus include time complexity in user session

cluster calculation, improving mining algorithms for new books, and exploring ease of use, recommendation list feedback, and larger data sets.

APPLICATIONS

Web usage mining is used in the following areas:
Personalization: By monitoring previously visited pages, personalization for users can be achieved. This data helps in understanding a user's typical browsing patterns, enabling the prediction of pages they are likely to prefer.

Recommendation system: Analyzing frequently visited web pages allows for the identification of the most popular links on a website, thereby enhancing the effectiveness of future user recommendations.

Caching: The frequent access patterns of web pages can be utilized for caching purposes, which in turn improves the system's time efficiency.

Business intelligence: Various web usage mining algorithms contribute to enhanced business intelligence by refining marketing strategies and advertisements. Additionally, they can help attract customers to the website by displaying information that aligns with user interests on frequently visited pages, thereby fostering customer retention.

Web traffic behavior: By examining server and proxy log files, one can gain insights into web traffic patterns, which aids in addressing network transmission challenges, optimizing load balancing, and effectively managing site traffic.

Unethical hacking: Analyzing various logs allows for the identification and tracking of unethical or harmful actions by suspected users, facilitating the detection of intrusion attempts and enhancing system security against potential hackers.

Web usage mining through Natural Language Processing can be applied in several domains:

Semantically enhanced recommendation systems: This approach significantly contributes to the development of intelligent web applications that can autonomously interpret user access patterns and suggest relevant content by employing various NLP methodologies.

Sentiment analysis: The process of deriving insights from unstructured or free-form text presents considerable challenges, as it involves discerning the semantic meaning of the content and integrating artificial intelligence into the system. This is particularly relevant in contexts such as social media monitoring and the analysis of blog reviews.

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Corrosion of Inorganic Materials in Industrial Applications

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ABSTRACT

The degradation of inorganic materials due to corrosion presents significant challenges in industrial sectors, including petrochemicals, nuclear power, desalination, and aerospace. This paper reviews corrosion mechanisms affecting inorganic materials and highlights mitigation strategies such as material selection, protective coatings, and monitoring technologies. Future directions emphasize innovative approaches like nanotechnology and smart materials to address corrosion challenges effectively.

KEYWORDS: *Corrosion mechanisms, Inorganic materials, Industrial applications, Corrosion mitigation, Protective coatings, Corrosion monitoring.*

INTRODUCTION

Corrosion, a process where materials deteriorate through interaction with their environment, has severe consequences in industrial applications [1][2]. Inorganic materials, such as metals, ceramics, and alloys, are particularly vulnerable to corrosion in harsh environments [3]. Industries like petrochemical processing, energy production, and marine operations frequently encounter conditions that exacerbate corrosion, including elevated temperatures and chemically aggressive surroundings. This review examines corrosion mechanisms, their industrial implications, and advancements in prevention and monitoring techniques [4].

CORROSION MECHANISMS IN INORGANIC MATERIALS

Electrochemical Corrosion: Electrochemical corrosion involves oxidation-reduction reactions, typically affecting metals and alloys [5]. In marine environments, chloride ions cause uniform corrosion of steel, while localized forms like pitting are common in stainless steels [6].

High-Temperature Oxidation: High temperatures in industries such as power generation cause oxidation in superalloys, where protective oxide layers may form but degrade over time [7].



Stress Corrosion Cracking (SCC): SCC results from tensile stress combined with a corrosive environment, posing challenges in materials like stainless steel and titanium alloys used in chemical industries [8].

Corrosion in Ceramics: Ceramics, while generally resistant to corrosion, can degrade under specific conditions. For example, zirconia used in nuclear reactors may undergo structural changes due to radiation and moisture [9].



INDUSTRIAL APPLICATIONS AND CORROSION CHALLENGES

Petrochemical Industry: Corrosion in petrochemical plants arises from sulfur compounds, carbon dioxide, and water. High-temperature hydrogen attack in carbon steel is a critical issue, mitigated by using alloys like Inconel [5].

Nuclear Power Plants: Nuclear environments expose materials to radiation, high temperatures, and pressurized water. Zirconium alloys, used for fuel rod cladding, often face oxidation challenges [3].

Desalination Plants: Desalination processes operate in saline environments, accelerating corrosion. Materials like duplex stainless steel and titanium alloys are preferred for their chloride resistance [6][7].

Aerospace Industry: Aerospace materials, including aluminum and magnesium alloys, are prone to galvanic corrosion under extreme conditions. Advanced protective measures are essential for maintaining safety and performance [8].

CORROSION MITIGATION STRATEGIES

Material Selection: The selection of corrosion-resistant materials, such as high-entropy alloys, minimizes degradation in harsh conditions [7].

Protective Coatings: Coatings, including ceramic-based and nanocomposite options, provide effective barriers against corrosive agents. Techniques like chemical vapor deposition improve durability [8].

Cathodic Protection: Sacrificial anodes and impressed current systems effectively protect pipelines and offshore structures from electrochemical corrosion [9].

Corrosion Monitoring Technologies: Modern methods, such as electrochemical impedance spectroscopy (EIS) and acoustic emission testing, enable proactive maintenance by monitoring corrosion in real-time [9].

FUTURE PERSPECTIVES

Emerging technologies, including nanostructured coatings and self-healing materials, offer promising solutions for corrosion prevention. Research into machine learning integration for monitoring systems aims to enhance predictive maintenance and reduce costs [10].

CONCLUSION

Corrosion challenges in industrial applications necessitate innovative strategies for material protection and monitoring. Advances in material science, coating technologies, and real-time monitoring systems have reduced corrosion impacts, but continuous research is vital to address evolving demands. Future efforts focusing on sustainable and data-driven solutions hold great potential for improving corrosion resistance.

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The Foundations and Latest Advancements in Graph Coloring

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ABSTRACT

In today's world, graph theory has a wide range of operations across various fields such as data science, operations research, computer science, and more. This paper provides an overview of crucial generalities in graph coloring, pressing its practical operations in real-world problems, including Academic and Test scheduling, register allocation in compilers, and frequency assignment in telecommunications etc. The focus of this paper is on working the class scheduling problem, as presented in the book *Applied Combinatorics* by Mitchell T. Keller and William T. Trotter.

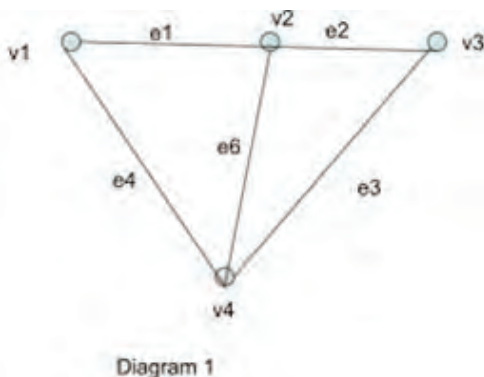
KEYWORDS: Graph theory, Graph coloring, Graph coloring application class scheduling.

INTRODUCTION

The Graph is a set of vertices and set of edges denoted by $G(V, E)$ where V represents the vertices and E represents the edges is called Graph.

A edge is always connected with two vertices. For illustration:

- $V = \{v1, v2, v3, v4\}$ set of vertices.
- $E = \{e1, e2, e3, e4\}$ set of edges. The graph is illustrated as follows:



Two Vertices are said to be adjacent if there is an edge between them. Edges are said to be incident if they shares common vertex.

In above illustration $V1$ and $V2$ are adjacent because $e1$ is edge between them. $e1$ is incident to vertices $v1$ and $v2$.

The degree of vertex is number of edges incident of it. from above graph degree of $V1$ is 2, $e1$ and $e4$ are incident with $v1$ A graph is said to be simple if it has no loops or parallel edges.

GRAPH COLORING

Graph coloring is a fundamental problem in graph theory. It involves assigning different colors to adjacent vertices. The goal is to determine the minimum number of colors needed to color the graph. This minimum number is called the chromatic number (χ). The chromatic number plays a crucial role in data sorting. There are three types of graph coloring:

- 1) Vertex Coloring: In vertex coloring Assign colors to vertices such that no two adjacent vertices share the same color.

- 2) **Edge Coloring:** In an edge coloring assign minimum colors to edges such that no two edges sharing a vertex have the same color.
- 3) **Face Coloring:** In planar graphs, assign colors to regions (faces) such that adjacent regions have different colors.

APPLICATIONS OF GRAPH COLORING

Graph coloring is a technique used to assign colors (or markers) to the elements of a graph, such as vertices or edges, subject to certain constraints. The conception of graph coloring has numerous practical applications in various fields. Below are some notable applications of graph coloring:

Scheduling Problems

- **Classroom Scheduling:** In educational institutions, graph coloring is used to record classes in a way that no two classes that bear the same classroom do at the same time. The classrooms are treated as "colors," and the edges between vertices represent conflicts in time places.
- **Exam Scheduling:** This is analogous to classroom scheduling, but the graph represents the examinations, and the vertices are connected if students are taking both examinations. The thing is to assign time slots (colors) to examinations so that no two clashing examinations are scheduled simultaneously.
- **Project Scheduling:** In project management, tasks that bear the same resources (e.g., machinery or labor force) can be represented as vertices, and conflicts between tasks as edges. The thing is to record tasks without resource clashes, with "colors" representing different time slots or resource allocations.

Register Allocation in Compilers

- **Optimizing Memory Usage:** Graph coloring is used to assign registers in the CPU to variables in the program, optimizing memory usage. Each variable in the program is represented as a vertex, and an edge exists between two vertices if the corresponding variables are used in apping times (i.e., they need to be stored in different registers
- **Reducing Overhead:** Efficient register allocation helps to reduce the need for accessing memory, improving the overall performance of programs by minimizing the time spent on memory access.

Map Coloring

- **Geographical Map Coloring:** The classic example of map coloring involves coloring countries or regions on a map such that adjacent countries do not share the same color. This is a practical application for creating easily distinguishable regions in maps and geographic representations.
- **Political Divisions:** In political mapping, it helps in assigning different colors to political parties or campaigners in a region, where the regions (vertices) must be distinguishable when adjacent.

Frequency Assignment

- **Cellular Networks:** In wireless communication, graph coloring can be used to assign frequencies to radio towers or cells in a network. The vertices represent towers, and edges represent interference between two towers. The goal is to assign frequencies (colors) in such a way that adjacent towers do not interfere by using the same frequency.
- **Broadcasting:** In broadcasting systems, where multiple signals are transmitted simultaneously, graph coloring helps to assign frequencies or channels in a way that minimizes interference.

Resource Allocation Problems

- **Task Assignment in Parallel Computing:** When assigning tasks to processors in a parallel computing environment, graph coloring is used to insure that tasks that bear the same resource are not assigned to run simultaneously.
- **Network Resource Allocation:** In computer networks, graph coloring can help manage the allocation of bandwidth or connections in such a way that neighboring nodes do not interfere with one another.

Circuit Design

- **Electronic Circuit Design** in the design of electronic circuits, such as VLSI (Very-Large-Scale Integration) systems, graph coloring is used to allocate resources like wires or gates efficiently. The goal is to reduce the number of resources required while avoiding conflicts or interference.
- **Conflict-Free Routing** When designing circuit layouts, it is essential to avoid conflicts in wire routing. Graph coloring can help to assign channels or paths in such a way that no two wires that need the same routing overlap.

Sudoku and Puzzle Solving

- **Puzzle Game Solutions:** numerous puzzles, such as Sudoku, can be modeled as graph coloring problems. The aim is to color the graph's vertices (corresponding to the cells of the puzzle) in such a way that adjacent vertices (cells) do not have the same color (value).
- **Graph Coloring in Games:** Similar to Sudoku, other types of constraint satisfaction puzzles, like scheduling games or resource allocation problems, can be modeled using graph coloring.

Social Network Analysis

- **Community Detection:** In social network analysis, graph coloring can be used to identify communities or clusters of individualities that have strong connections within the group but weaker connections with other groups.
- **Conflict Resolution:** In a group of people or organizations, graph coloring helps to minimize conflicts by assigning different tasks or roles (colors) to individualities (vertices) with interactions (edges) in such a way that no two clashing individualities the same role.

Network Topology and Optimization

- **Routing and Network Design:** Graph coloring can be used in designing network topologies in which each node or link needs to be assigned a distinct resource, such as bandwidth or path, to avoid congestion and interference.
- **Load Balancing:** In distributed networks, graph coloring helps to ensure that no two nodes or processes (represented as vertices) overload the same resource simultaneously.

Artificial Intelligence

- **Constraint Satisfaction Problems (CSP):** Graph coloring is frequently used to model CSPs in AI. The vertices represent variables, the edges represent constraints, and the colors represent possible values that satisfy the constraints.
- **Search Algorithms:** In AI search problems, graph coloring can be part of the search space, helping in finding solutions that meet certain conditions, like minimizing conflicts between actions or constraints.

Problem: Scheduling of Class schedule

A academy is organizing the class schedule for the forthcoming academic year. They need to arrange single sections for the following subjects: calculus, English, statistics, physics, economics, chemistry, and German. The table below lists the required courses for six students to meet their graduation requirements. The aim is to determine the minimal number of class periods needed to accommodate these courses, ensuring that each student takes no further than one course per period. Additionally, explain why it is not possible to use fewer class periods.[1]

Table 1 Courses Taken by Students

Student	Courses
1	Chemistry, Physics, Economics
2	English, German, Statistics
3	Statistics, Calculus, German
4	Chemistry, Physics
5	English, Chemistry
6	Chemistry, Economics

We can break this problem by using two different methods.

By vertex coloring

To solve this scheduling problem, we can model it as a graph coloring problem, where:

- Vertices represent courses.
- An edge is drawn between two vertices if any student is required to take both courses (since they cannot occur in the same class period for that student).
- The smallest number of class periods corresponds to the chromatic number of the graph, i.e., the minimum number of colors needed to color the vertices such that no two adjacent vertices share the same color.

Step 1: Determine the adjacency relationships

Using the student-course data, we establish the relationships between courses:

Student 1

Chemistry $\longleftrightarrow$ Physics $\longleftrightarrow$ Economics

Student 2

English $\longleftrightarrow$ German $\longleftrightarrow$ Statistics

Student 3

Statistics $\longleftrightarrow$ Calculus $\longleftrightarrow$ German

Student 4

- Chemistry $\longleftrightarrow$ Physics

Student 6

Chemistry $\longleftrightarrow$ Economics

From these, the edges between courses are: Chemistry: Physics, Economics, English Physics: Chemistry, Economics English: Chemistry, Physics German, Statistics, Chemistry German: Statistics, Calculus, English Statistics: English, German, Calculus Calculus: Statistics, German

Step 2 : Draw the graph

The graph of courses and edges are as follows:

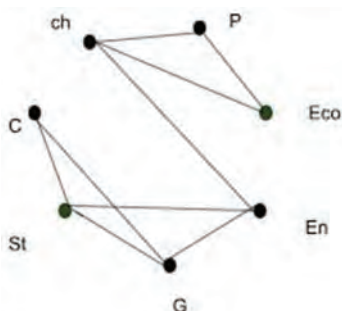


Fig 2

Step 3 : Determine the chromatic number

We need to color the vertices of graph such that no two connected vertices share the same color.

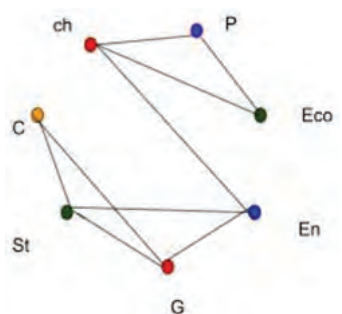


Fig 3

- Chemistry and German not adjacent, colored both vertices by Red color
- English and Physics has no adjacency, color them by Blue color

- Economics and Statistics are not adjacent, color them by Green color.
- Color Calculus by orange color

Here we need 4 colors for coloring the given vertices. So chromatic number is 4. Same colors have same time slot. eg. vertices (subjects) who has Red color has time slot 8am to 9am. Vertices (subjects) who has blue color has time slot 9am to 10am. similarly green color has time slot 10am - 11am and vertex of orange color has time slot 11am - 12 noon. It is shown in below

Class timetable is as follows

Table 2. Class Timetable

Timing	Class-1	Class-2
8am - 9am	Chemistry	German
9am - 10am	Physics	English
10am - 11am	Statistics	Economics
11am - 12noon	Calculus	—

Here for seven different subjects we need four time slot and two classrooms. Since Chromatic Number of this graph is 4. so it is not possible fewer than 4 class period.

CHALLENGES AND OPEN PROBLEMS

While graph coloring is a well-established field, challenges remain:

- Coloring large, sparse, or dense graphs efficiently.
- Addressing dynamic graph coloring where the graph changes over time.
- Applying graph coloring in emerging fields such as quantum computing and bio-informatics.

CONCLUSION

Graph coloring is a versatile and widely applicable problem in graph theory. Its relevance spans numerous domains, from academia to industry. Continued research promises to unlock new applications and refine existing algorithms, addressing ever-evolving challenges.

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Bridging Tradition and Innovation: Legacy of Indian Scientists and Nobel Laureates in Research through the Lens of the Indian Knowledge System

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ABSTRACT

The rich legacy of Indian scientists and Nobel Laureates embodies a profound synergy between the timeless wisdom of the Indian Knowledge System and modern scientific innovation. This paper explores how the contributions of these luminaries have shaped global research paradigms, bridging tradition and innovation. Drawing from the foundational principles of the Indian Knowledge System—rooted in holistic thinking, interdisciplinary approaches, and ethical introspection—this study highlights the impact of pioneering figures. Their work not only advanced their respective fields but also underscored the universal applicability of India's intellectual heritage.

By examining case studies and breakthroughs across disciplines, the paper illuminates how these scientists integrated indigenous knowledge with contemporary science to inspire transformative solutions. The analysis further delves into the global relevance of this integration in addressing contemporary challenges such as sustainability, healthcare, and education. Ultimately, the paper emphasizes how these contributions not only enriched specific fields but also fostered interdisciplinary approaches and ethical considerations in research, inspiring solutions to contemporary global challenges.

KEYWORDS: *Indian knowledge system, Heritage, Contributions, Global, etc.*

INTRODUCTION

India's rich intellectual heritage, rooted in the Indian Knowledge System, has profoundly shaped global thought and scientific progress. The Indian Knowledge System, characterized by holistic and integrative approaches, has consistently emphasized the interconnectedness of disciplines and the importance of ethical examination. From the precise geometrical principles of Baudhayan to Aryabhatta's foundational work in mathematics and astronomy, Indian scholars have laid the groundwork for numerous scientific and technological advancements. The holistic and integrative nature of the Indian Knowledge System has facilitated a unique blending of tradition and innovation, which remains a hallmark of India's intellectual legacy.

From ancient times, Indian scholars demonstrated a remarkable understanding of diverse disciplines such as mathematics, astronomy, medicine, and philosophy. Their contributions laid the groundwork for scientific advancements that continue to influence modern research paradigms.

In the modern era, Indian Nobel Laureates have carried forward this legacy by making transformative contributions across fields such as literature, physics, medicine, economics, and peace. Their achievements have not only enriched global research but also showcased the universality and relevance of India's intellectual and cultural traditions. This paper seeks to explore the contributions of key figures, both ancient and modern, to illustrate how the Indian Knowledge System continues to inspire and shape global innovation.

CONTRIBUTIONS OF ANCIENT INDIAN SCIENTISTS AND THEIR IMPACT ON THE WORLD

Baudhayana: Known for his Sulba Sutras, Baudhayana introduced early principles of geometry, including the Pythagorean theorem. His works laid the foundation for practical applications in construction and measurement. These principles have influenced modern architecture and engineering.

Aryabhata: A luminary in mathematics and astronomy, Aryabhata introduced the concept of zero, provided accurate calculations of celestial phenomena, and proposed a heliocentric model of the solar system. His work significantly influenced both Eastern and Western astronomy and mathematics, paving the way for modern numerical systems.

Brahmagupta: A pioneer in algebra and astronomy, Brahmagupta introduced methods for solving quadratic equations, developed rules for negative numbers, and significantly advanced mathematical understanding. His work influenced the development of algebra and calculus in later centuries.

Bhaskaracharya (Bhaskara II): A mathematician and astronomer, he introduced early concepts of calculus and made significant contributions to algebra, including solutions to indeterminate equations. His ideas on calculus predated those of Newton and Leibniz and have influenced modern mathematics.

Varahamihira: His work in astronomy, meteorology, and astrology showcased a profound integration of empirical observation with theoretical knowledge, contributing to various scientific disciplines. His treatises provided insights into weather patterns and planetary movements.

Nagarjuna: Known as the “Father of Indian Alchemy,” Nagarjuna made significant advancements in chemistry and metallurgy, including the development of medicinal and chemical processes. His work laid the groundwork for modern chemistry and pharmacology.

Susruta: Regarded as the “Father of Surgery,” Susruta’s Sushruta Samhita detailed surgical techniques, anatomical studies, and Ayurvedic practices, forming the foundation of modern surgery and medicine. His work is a precursor to many surgical techniques used today.

Kanada: The founder of the Vaisheshika school of philosophy, Kanada proposed atomic theory, suggesting

that all matter is composed of indivisible atoms, predating similar Western theories by centuries. His ideas form a cornerstone of modern physics and material science.

Charaka: A pioneer in Ayurveda, Charaka’s Charaka Samhita emphasized holistic health, preventive care, and the ethical practice of medicine, laying the groundwork for personalized healthcare. His contributions influence global approaches to integrative medicine.

CONTRIBUTIONS OF INDIAN NOBEL LAUREATES AND THEIR IMPACT ON THE WORLD

Rabindranath Tagore (Literature, 1913): The first non-European Nobel Laureate, Tagore’s literary works blended Indian spirituality with universal humanism, fostering cultural and intellectual dialogue. His contributions continue to inspire thinkers, artists, and educators worldwide.

C.V. Raman (Physics, 1930): He discovered the Raman Effect, revolutionizing the understanding of light scattering. This breakthrough has applications in diverse fields such as material science, chemistry, and medical diagnostics.

Har Gobind Khorana (Physiology or Medicine, 1968): His pioneering work in genetics unraveled the genetic code, advancing the understanding of DNA synthesis and genetic engineering. Khorana’s contributions have driven innovations in biotechnology and medicine.

Mother Teresa (Peace, 1979): She is renowned for her humanitarian work, Mother Teresa’s mission of compassion and care for the marginalized has inspired global movements for social justice and human rights.

Subrahmanyan Chandrasekhar (Physics, 1983): His research on the structure and evolution of stars, including the Chandrasekhar Limit, has become a cornerstone in astrophysics. His work paved the way for modern research on black holes and stellar dynamics.

Amartya Sen (Economic Sciences, 1998): Known for his work in welfare economics, Sen’s research on poverty, inequality, and human development has reshaped global economic policies, emphasizing social justice and inclusive growth.

V. S. Naipaul (Literature, 2001): A novelist and essayist, Naipaul’s works explored themes of identity, migration, and post-colonialism, offering profound insights into the human condition and cultural transformations.

Venkatraman Ramakrishnan (Chemistry, 2009): His studies on ribosome structure and function revolutionized molecular biology, enhancing our understanding of protein synthesis and its implications for medicine and biotechnology.

Kailash Satyarthi (Peace, 2014): An advocate for children's rights, Satyarthi's efforts to eradicate child labor have transformed global policies and improved the lives of millions of children worldwide.

Abhijit Banerjee (Economic Sciences, 2019): Along with Esther Duflo, Banerjee's innovative approach to development economics has provided actionable insights into alleviating global poverty through evidence-based interventions.

These contributions illustrate the enduring relevance of India's intellectual and cultural heritage in addressing modern challenges, underscoring the transformative power of bridging tradition with innovation.

Case Study: Aryabhatta and Nagarjuna – Pioneering Indian Scientists and their Global Impact

India has a rich heritage of scientific and philosophical inquiry, with Aryabhatta and Nagarjuna standing out as two of its most celebrated ancient scholars. This case study explores their contributions to mathematics, astronomy, medicine, and chemistry, demonstrating their enduring impact on science and society.

Aryabhatta (476–550 CE): Aryabhatta was a pioneering mathematician and astronomer, often regarded as one of the earliest contributors to the fields of mathematics and astronomy. His work laid the foundation for several scientific advancements in both India and the world.

His Contributions

Mathematics: He is an author of *Aryabhatiya*, a seminal text covering algebra, arithmetic, trigonometry, and geometry. He introduced the concept of zero as a placeholder, a cornerstone for modern mathematics. He developed methods for solving quadratic equations and approximated the value of π (π) as 3.1416, remarkably close to its actual value.

Astronomy: He proposed that the Earth rotates on its axis, a revolutionary idea during his time. He accurately calculated the duration of a solar year (365.258 days) and described the elliptical orbits of planets. He Suggested a heliocentric model, where celestial motions are relative to the observer on Earth.

Impact: Aryabhatta's contributions influenced the development of astronomy and mathematics in ancient India and later spread to the Islamic world and Europe. His insights are still studied for their historical significance in the evolution of scientific thought.

Nagarjuna (Circa 10th Century CE): Nagarjuna, often referred to as the "Father of Indian Alchemy and Chemistry," was a scientist and philosopher who advanced the fields of medicine, metallurgy, and alchemical processes.

Contributions

Alchemy and Chemistry: He has written texts such as *Rasaratnakara*, which detailed methods for the preparation of medicinal compounds, metallic extractions, and alchemical processes. He explored the transmutation of base metals into gold and contributed to the early development of chemical processes. He developed techniques for creating and purifying alloys and medicines.

Medicine: He applied alchemical knowledge to enhance Ayurveda, particularly in developing formulations for curing ailments and rejuvenation. His works significantly influenced subsequent Indian medical and chemical traditions.

Philosophy: He integrated scientific practices with Buddhist philosophy, emphasizing ethical considerations in scientific pursuits.

Impact: Nagarjuna's experiments in alchemy and medicine paved the way for advancements in metallurgy and chemistry in medieval India. His texts served as foundational references for Indian and Islamic scholars in subsequent centuries.

Aryabhatta and Nagarjuna represent the pinnacle of ancient Indian scientific thought, excelling in theoretical and experimental sciences. Aryabhatta's pioneering work in mathematics and astronomy provided the intellectual tools that shaped modern science, while Nagarjuna's advancements in alchemy and medicine emphasized practical applications of chemistry and metallurgy. Their contributions continue to inspire research and underscore the timelessness of Indian scientific heritage.

Case Study: The Raman Effect and Its Global Impact

The discovery of the Raman Effect by C.V. Raman in 1928 marked a milestone in the field of physics and spectroscopy. This phenomenon, which describes the scattering of light

and the change in its wavelength when it interacts with a medium, has had profound implications for scientific and industrial advancements worldwide.

The Raman Effect revolutionized material science by providing a non-destructive analytical tool for studying molecular structures. Raman spectroscopy is now widely used in diverse fields such as chemistry, biology, medicine, and environmental science. For instance, it plays a critical role in pharmaceutical research for drug development and quality control. In forensic science, Raman spectroscopy helps in the analysis of substances such as drugs, explosives, and trace evidence.

Moreover, Raman's discovery has driven innovations in medical diagnostics. Techniques based on Raman spectroscopy enable early detection of diseases, including cancer, by identifying molecular changes in tissues and cells. Environmental monitoring also benefits from this technology, as it facilitates the detection of pollutants and assessment of air and water quality.

The global adoption of Raman spectroscopy underscores the transformative impact of C.V. Raman's work, highlighting the enduring relevance of Indian scientific contributions in addressing contemporary challenges.

Case Study: Rabindranath Tagore and His Global Impact (1861–1941)

Rabindranath Tagore, an Indian polymath, reshaped Indian literature, music, and art. Known as the first non-European to win the Nobel Prize in Literature (1913), his contributions extended beyond art to education, philosophy, and the Indian independence movement.

Literature and Art: His works, such as *Gitanjali* (Song Offerings), transcend cultural barriers, emphasizing universal themes like spirituality, human connection, and nature. He wrote national anthems for India ("Jana Gana Mana") and Bangladesh ("Amar Shonar Bangla"), symbolizing unity and cultural pride.

Education: Rabindranath Tagore founded Visva-Bharati University in Santiniketan in 1921, focusing on holistic education and global cultural exchange. He advocated for education that blends Western scientific thought with Eastern spirituality.

Social Impact: Championed Indian self-reliance and cultural revival during British rule. Critiqued colonialism and worked to foster a global vision of unity through art and philosophy.

Case Study: Kailash Satyarthi and His Global Impact

Kailash Satyarthi, an Indian child rights activist, has dedicated his life to combating child labor and promoting education for all. He was awarded the Nobel Peace Prize in 2014, alongside Malala Yousafzai.

Child Rights Advocacy: Founded the Bachpan Bachao Andolan (Save Childhood Movement), which has rescued over 100,000 children from trafficking, forced labor, and slavery. He played a pivotal role in the Global March Against Child Labour, mobilizing international support to ban child labor.

Policy Influence: Instrumental in the adoption of conventions on child labor by the International Labour Organization (ILO). He advocated for Sustainable Development Goals (SDG) 8.7, focusing on eradicating child labor.

Education Initiatives: He promoted the right to free and compulsory education in India and globally. His activism highlights education as a tool for breaking the cycle of poverty.

CONCLUSION

The legacy of Indian scientists and Nobel Laureates exemplifies the timeless relevance of the Indian Knowledge System in addressing the complexities of modern research and societal challenges. From the ancient wisdom of scholars like Aryabhata, Susruta, and Kanada to the ground-breaking contributions of Nobel Laureates such as C.V.

Raman, Amartya Sen, and Abhijit Banerjee, India's intellectual tradition showcases a profound ability to integrate tradition with innovation. This synthesis has fostered advancements across diverse fields, inspiring global research and offering solutions to pressing issues such as poverty, healthcare, and sustainable development.

By bridging the ancient and the modern, these luminaries have demonstrated that knowledge transcends time and geography, reinforcing the need for interdisciplinary collaboration and ethical introspection. Their achievements underscore the transformative power of a holistic approach to knowledge, rooted in cultural heritage yet forward-looking in its applications. As the world continues to face unprecedented challenges, the Indian Knowledge System, enriched by its legacy of scientists and Nobel Laureates, serves as a beacon for future generations, inspiring a harmonious blend of tradition and innovation in the pursuit of global progress.

On the humanitarian and cultural front, laureates like Rabindranath Tagore, the first non-European Nobel Prize winner in Literature, and Kailash Satyarthi, a relentless advocate for children's rights, have inspired movements for cultural and social reform. Their contributions embody the values of creativity, compassion, and the pursuit of justice. The collective achievements of Indian Nobel laureates underscore the nation's capacity for intellectual excellence and its commitment to addressing the world's most pressing challenges. Their work continues to serve as a beacon for innovation, human progress, and the global good, reaffirming India's role as a thought leader and change maker on the world stage.

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Incorporating Sustainable Development through Indian Knowledge Systems: Analyzing the Role of NEP 2020 in Higher Education

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ABSTRACT

The incorporation of Indian Knowledge Systems (IKS) into higher education presents a promising pathway toward addressing global sustainability challenges. The National Education Policy (NEP) 2020 envisions the integration of IKS into education, recognizing its potential to contribute to environmental, social, and economic sustainability. This study explores the relevance of IKS in promoting sustainable development, analyzing its connection to the goals set by NEP 2020. By investigating case studies and traditional practices across sectors such as agriculture, water management, disaster management, forest conservation, waste management and health, the paper highlights how IKS provides effective solutions to contemporary sustainability challenges while fostering a holistic and inclusive education system.

KEYWORDS: *Indian knowledge systems (IKS), Sustainable development, National education policy 2020 (NEP), Traditional practices, Higher education.*

INTRODUCTION

Sustainable development is a critical global challenge that requires balancing economic growth, social well-being, and environmental protection. As the world strives to achieve the United Nations Sustainable Development Goals (SDGs), education is increasingly recognized as a vital tool in fostering sustainability by creating informed and responsible citizens. A revolutionary framework called the National Education Policy (NEP) 2020 aims to modernize India's educational system and bring it into compliance with international norms while also making it more flexible and inclusive. It reduces strict topic silos and introduces transdisciplinary approaches, emphasizing creativity, critical thinking, and holistic growth. NEP 2020 seeks to guarantee universal access to basic literacy and numeracy, universalize early childhood care and education, and advance fair access to high-quality education at all levels. Additionally, the policy places a high priority on the usage of Indian languages, the integration of

technology, and the preservation of cultural heritage through education. With an emphasis on research, lifelong learning, and vocational training, NEP 2020 aims to create an educational system that empowers people, encourages creativity, and equips students for a world that is changing quickly, which will boost India's economy.

In this context, India's National Education Policy (NEP) 2020 introduces a transformative framework that integrates Indian Knowledge Systems (IKS) into education. IKS, encompassing indigenous, traditional, and interdisciplinary knowledge developed over millennia in India, presents time-tested solutions for contemporary challenges. Indian Knowledge Systems are deeply rooted in ecological, social, and cultural wisdom, emphasizing harmony between humanity and nature. These systems encompass practices such as organic farming, Ayurveda, Yoga, sustainable water management, disaster management, and community governance, offering viable alternatives to modern sustainability issues like climate change,

resource conservation, and inequality. The NEP 2020 aims to revitalize education in India by bridging traditional knowledge with modern scientific advancements, enabling students to address complex sustainability challenges. The incorporation of IKS into higher education curricula provides a framework for fostering holistic education, ethics, and interdisciplinary thinking to address the needs of present and future generations.

RELEVANCE OF INDIAN KNOWLEDGE SYSTEMS FOR SUSTAINABLE DEVELOPMENT

A comprehensive strategy for growth and advancement, sustainable development gratifies current demands without endangering the capacity of future generations to satisfy their own. It highlights striking a balance between social justice, environmental preservation, and economic progress. Sustainable development encourages responsible consumption, the use of renewable energy, biodiversity conservation, and inclusive policies that improve communities in the face of issues like climate change, resource depletion, and growing inequality. Sustainable development aims to establish systems that are socially just, economically feasible, and environmentally sustainable by emphasizing long-term resilience over immediate rewards. In order to effectively address global issues and guarantee a prosperous and harmonious coexistence between humans and the natural world, it combines traditional knowledge systems, contemporary technologies, and community-driven initiatives.

Indian Knowledge Systems have long provided models for sustainable living. Rooted in the principles of ecology, community well-being, and ethical responsibility, these systems offer practical solutions aligned with the SDGs. For instance, the practice of rainwater harvesting, organic farming methods and forest conservation through sacred groves all demonstrate the practical application of IKS in promoting sustainability. In addition to ecological sustainability, IKS offers valuable social and economic insights. The concept of Sarvodaya (universal upliftment) and Ahimsa (non-violence) promotes social equity, inclusivity, and respect for the environment. These principles resonate with global sustainability goals, particularly in addressing issues such as environmental degradation, inequality, and community well-being.

The NEP 2020 acknowledges the importance of integrating IKS into education to create an informed citizenry capable of addressing global challenges while

preserving India's rich cultural heritage. By incorporating these principles into higher education, the policy seeks to empower students with the knowledge, skills, and ethical frameworks needed to create a sustainable and equitable future. Over 300 universities in India offer courses in Ayurveda, Yoga, Vedic studies, and traditional ecological knowledge, equipping students to apply these practices in modern contexts. Research is also focused on sustainable practices based on IKS, such as organic farming, water management, and renewable energy, with collaborations between universities and local communities. Organic farming in India, for example, has grown by 20% annually, reflecting the effectiveness of IKS in addressing agricultural sustainability. Higher education's role in promoting IKS helps create an informed, ethical society that prioritizes sustainability and preserves India's cultural heritage.

Moreover, the inclusion of Indian Knowledge Systems (IKS) in education fosters a deep connection with nature and a sense of responsibility towards the planet. By embracing traditional practices such as sustainable agriculture, natural medicine, and eco-friendly construction techniques, students can gain insights into environmentally harmonious living. This approach not only nurtures sustainable development but also strengthens cultural resilience, encouraging a shift toward holistic development. By incorporating IKS into curricula, the NEP 2020 envisions an educational framework that aligns with the global aspirations of sustainability, contributing to the creation of a more conscious, balanced, and resilient society.

CASE STUDIES: SUCCESSFUL INTEGRATION OF IKS FOR SUSTAINABILITY

Indian Knowledge Systems are not only relevant in theory but have also been successfully integrated into modern practices, particularly in fields such as agriculture, water management, health, and disaster management. Today, the growing global challenges of climate change, resource depletion, and environmental degradation make IKS even more relevant as they offer time-tested, holistic solutions that align with modern sustainable development goals (SDGs). The integration of traditional knowledge with modern technologies presents an opportunity to develop scalable, eco-friendly solutions. IKS fosters a deep respect for nature and encourages practices that prioritize long-term sustainability over short-term gains. Case studies

from various sectors — agriculture, water conservation, health, and disaster management — exemplify how these ancient practices can be adapted to address current issues and provide effective, low-cost, community-driven solutions. From the revival of traditional irrigation systems in Tamil Nadu to the global spread of Ayurveda and Yoga, the fusion of IKS with contemporary advancements is proving to be a powerful tool for promoting sustainable development. By preserving and revitalizing IKS, we can ensure that future generations inherit a world that is not only resilient and resource-efficient but also culturally enriched and ecologically balanced. The following case studies illustrate how traditional knowledge, when blended with contemporary innovations, can offer effective solutions for sustainable development.

Agriculture: Organic Farming Practices in Sikkim

Sikkim's transition to the world's first fully organic state in 2016 stands as a testimony to the potential of Indian Knowledge Systems in achieving sustainable agricultural practices. It covers approximately 75,000 hectares of agricultural land. This shift has boosted the production of key crops such as organic rice, cardamom, ginger, and turmeric. The state produces about 2,500 tonnes of organic cardamom annually, gaining access to premium markets domestically and internationally. Rooted in ancient practices such as Vrikshayurveda (the science of plants) and traditional farming methods, Sikkim's approach emphasizes organic practices such as crop rotation, composting, and the use of bio-manures. The success of the Sikkim Organic Mission, launched in 2003, has provided farmers with training, resources, and financial support, increasing soil fertility and promoting environmental sustainability. Additionally, organic farming has positively impacted gender equality, with women actively participating in agricultural activities. The results have been transformative: improved soil health, increased biodiversity, and reduced water pollution. Moreover, the economic benefits for farmers, including access to premium markets for organic produce, have contributed to sustainable livelihoods. Sikkim's model serves as an inspiration for other regions looking to integrate traditional agricultural wisdom with contemporary sustainability goals. In conclusion, Sikkim's transition to organic farming has not only promoted environmental sustainability but also enhanced social equity and economic prosperity, making it a model for sustainable agricultural practices worldwide.

Water Management: Stepwells and Tank Irrigation Systems in Tamil Nadu

Tamil Nadu's traditional water management systems, particularly its network of tanks and stepwells, offer valuable insights into sustainable water use. These systems, dating back to ancient times, were designed to capture and store monsoon rains, ensuring water availability even during dry seasons. The community-driven approach to water management emphasized collective responsibility and equitable distribution. The revival of these systems, including the use of modern technologies like GIS mapping and desilting, has led to increased groundwater recharge and improved agricultural productivity. Tamil Nadu's traditional water management systems highlight the potential of blending IKS with modern technology to address water scarcity and climate variability. Tamil Nadu's ancient tank irrigation systems include 39,000 tanks covering 1.5 million acres of farmland. These systems, along with stepwells, provide 60% of the state's irrigation needs. Reviving them has raised groundwater levels by 15%, boosting agricultural productivity and benefiting over 10 million people. This system is key to sustainable development, ensuring efficient water use, supporting agriculture, and mitigating climate change, emphasizing the need to preserve and enhance these traditional practices.

Health and Wellness: Mainstreaming Ayurveda and Yoga

Ayurveda and Yoga, integral components of IKS, are gaining global recognition for their contributions to health and wellness. Ayurveda, an ancient system of medicine, advocates personalized healthcare through natural remedies and lifestyle modifications, while Yoga emphasizes the holistic integration of mind, body, and spirit. Ayurveda and Yoga, integral to India's cultural heritage, have gained global recognition for their health benefits. The Ministry of AYUSH, established in 2014, promotes these practices through various initiatives, including International Yoga Day, which is celebrated by over 190 countries annually. Ayurveda is now a \$10 billion industry globally, with India being a major exporter of Ayurvedic products. Yoga's global following exceeds 300 million practitioners. In India, over 300 universities offer Ayurveda and Yoga-related courses, reflecting their growing integration into mainstream healthcare and wellness practices, supporting both preventive and therapeutic care.

Moreover, the integration of these practices into healthcare systems supports sustainable wellness by promoting preventive care, reducing reliance on pharmaceutical products, and addressing non-communicable diseases such as hypertension and diabetes. These practices contribute to sustainable development by promoting holistic health, reducing dependence on synthetic medicines, and fostering environmental awareness, making them essential for long-term well-being.

Forest Conservation: Sacred Groves in the Western Ghats

Sacred groves, forest areas preserved due to religious and cultural significance, have played a crucial role in forest conservation across India. In the Western Ghats, sacred groves serve as biodiversity hotspots, protect soil and water resources, and provide ecosystem services such as pollination and climate regulation. Sacred groves in the Western Ghats, a UNESCO World Heritage site, are vital for biodiversity conservation. These groves, ranging from small patches to vast forests, cover approximately 1.5 million hectares. They host over 2,000 species of flora and fauna, many of which are endemic and endangered. Local communities, through cultural and religious practices, have preserved these groves for centuries. They play a key role in water conservation, carbon sequestration, and soil fertility. The preservation of sacred groves aligns with sustainable development goals by safeguarding biodiversity and supporting climate resilience, underscoring the importance of cultural and ecological integration in conservation efforts.

Waste Management: Traditional Practices in Zero-Waste Villages

India's traditional waste management practices, grounded in the principles of reduce, reuse, and recycle, are being revived in zero-waste villages like Mawlynnong in Meghalaya and Hiware Bazar in Maharashtra. These villages focus on composting organic waste, recycling, and reducing plastic consumption, with community engagement ensuring waste is treated as a resource. Mawlynnong, Asia's cleanest village, has reduced waste by 95%, while Hiware Bazar has adopted rainwater harvesting and organic farming, reducing water consumption by 40% and waste by 50%. Mawlynnong also has 100% waste segregation and promotes eco-tourism. These efforts benefit the environment and the local economy, conserving over 1,000 tons of waste annually in Mawlynnong alone. Their success is crucial for sustainable development,

conserving resources, reducing waste, and addressing global challenges like pollution and resource depletion.

Disaster Management: Traditional Knowledge in Resilient Housing

Traditional knowledge has played a crucial role in disaster management, particularly in resilient housing, where indigenous techniques and materials are used to create structures that can withstand natural disasters. In regions like Uttarakhand and Himachal Pradesh, traditional houses are built with locally sourced materials such as stone, wood, and mud, designed to be earthquake-resistant. For instance, the traditional "Kathkuni" architecture in Himachal Pradesh, which uses interlocking wooden beams, is known to be highly earthquake-resistant. In Gujarat, traditional Bhunga houses, circular in design and made of mud and thatch, have proven effective in withstanding cyclones and heavy rains.

Following the 2001 earthquake in Gujarat, over 400,000 houses were rebuilt using Bhunga-style designs, which were more resilient and cost-effective than conventional concrete structures. Studies show that such houses have a survival rate of over 80% during earthquakes, compared to only 40% for modern concrete buildings. These traditional housing methods, when combined with modern disaster-resistant technologies, can significantly improve resilience, reduce disaster risk, and promote sustainable housing solutions.

In order to address global issues like resource depletion, climate change, and environmental degradation while maintaining social justice and economic expansion, sustainable development is essential. The aforementioned case studies show how combining contemporary methods with Indian Knowledge Systems (IKS) might lead to sustainability. From the global adoption of Ayurveda, yoga, and resilient building designs to Sikkim's organic farming revolution and Tamil Nadu's traditional water management techniques, these examples demonstrate how tried-and-true, locally driven, and environmentally friendly methods may successfully handle contemporary concerns. We can design scalable solutions that support sustainable development goals and promote a harmonious coexistence of humans and nature by utilizing IKS for agriculture, health, conservation, waste management, and catastrophe resilience

CONCLUSION

The integration of Indian Knowledge Systems into

education, as outlined by NEP 2020, offers a transformative approach to achieving sustainability goals. IKS provides practical, time-tested solutions to contemporary challenges in agriculture, disaster management, water management, health, and conservation. The case studies presented demonstrate how traditional knowledge, when integrated with modern innovations, can address pressing sustainability issues.

To fully harness the potential of IKS, a comprehensive approach is required. Policymakers should prioritize the development of research centers, digital repositories, and curricula that integrate IKS into higher education. Educators must be trained to deliver interdisciplinary content that bridges traditional and modern knowledge systems. Furthermore, leveraging technology to modernize traditional practices and fostering collaborations between academia, industry, and local communities will amplify the impact of IKS.

By incorporating IKS into sustainability strategies, NEP 2020 can lead India toward a future that balances cultural heritage with global sustainability objectives. The integration of these systems into education not only fosters sustainability but also strengthens India's cultural identity, making it a vital component of holistic and inclusive development.

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Evolution of Waste Management Practices: Lessons from Ancient Techniques and Modern Innovations for Environmental Sustainability

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ABSTRACT

This paper explores the evolution of waste management practices from ancient techniques to modern innovations, emphasizing their impact on environmental sustainability. Waste management has been a vital aspect of human civilization, addressing the disposal and treatment of waste generated by human activities. Ancient societies adopted practices such as composting and reuse, which were simple yet effective in reducing waste accumulation. In contrast, modern methods leverage advanced technologies like waste-to-energy systems, recycling plants, and AI-driven sorting mechanisms, offering more efficient solutions to manage diverse waste types. By analyzing historical methods, contemporary advancements, and the roles of various stakeholders, the paper highlights deficiencies in the current system, particularly in India. It also explores the environmental and socioeconomic effects of subpar waste management approaches. The study additionally explores public policy, commercial sector participation, non-governmental organisations, and community projects, demonstrating cooperative attempts to address waste issues.

KEYWORDS: *Waste management, Environmental sustainability, Ancient techniques, Modern innovations.*

INTRODUCTION

Waste is an unavoidable byproduct of human activity that includes a variety of materials discarded away because they are no longer needed or valuable. It can take various forms, such as solid, liquid, or gaseous, and is generated in households, industries, businesses, and even through natural processes. With the growing global population and increasing consumption patterns, waste management has become a critical issue, posing challenges to environmental sustainability and public health. Proper disposal, recycling, and reduction of waste are essential in minimizing its harmful impact on ecosystems and promoting a circular economy that conserves resources and reduces pollution. Addressing waste effectively is crucial for ensuring a cleaner, healthier, and more sustainable future for all.

Effective waste management is a cornerstone of

environmental sustainability, aiming to minimize the adverse impacts of waste on human health and ecosystems. From ancient methods of reuse and composting to modern techniques such as recycling and waste-to-energy systems, waste management has evolved significantly. However, the current system faces numerous challenges, particularly in developing countries like India. This paper examines the concepts, elements, and threats of waste management, the evolution of practices, and the roles of various stakeholders, concluding with recommendations for improvement and a case study analysis.

WASTE MANAGEMENT: CONCEPT, ELEMENTS, AND THREATS

The collection, movement, processing, and disposal of waste materials are all included in waste management. Reducing the detrimental effects of waste on the environment and public health is its main goal. Key elements

include waste generation, segregation, storage, collection, processing, and disposal. Despite advancements, threats such as improper disposal, leachate contamination, and greenhouse gas emissions remain significant concerns.

Types and Characteristics of Waste Waste can be categorized into several types:

1. Municipal Solid Waste (MSW): Household and urban waste.
2. Industrial Waste: By-products of industrial processes.
3. Hazardous Waste: Toxic, reactive, and potentially dangerous materials.
4. Biomedical Waste: Medical and clinical waste.
5. E-Waste: Discarded electronic devices. Each type has unique characteristics, requiring tailored management approaches.

The Waste Management Hierarchy and the 3R Concept The waste management hierarchy prioritizes waste prevention, followed by reduction, reuse, and recycling. The 3R concept—Reduce, Reuse, Recycle—forms the foundation of sustainable waste management by encouraging resource conservation and minimizing landfill dependency.

EVOLUTION OF WASTE MANAGEMENT PRACTICES

Ancient Techniques and Modern Innovations of Waste Management Practices

In ancient civilizations, waste was managed through simple yet effective methods like composting, reusing materials, and dumping waste in designated areas. Modern innovations, including mechanized segregation, advanced recycling technologies, and waste-to-energy systems, have enhanced efficiency and reduced environmental impacts. Comparing these practices highlights valuable lessons for sustainable waste management.

The evolution of waste management practices has undergone significant changes over time, reflecting advancements in technology, shifts in societal attitudes, and an increased understanding of environmental impacts. Below is a general overview of how waste management practices have evolved:

Pre-industrial Era (Before the 18th Century)

- **Waste Generation:** In ancient times, waste was

primarily organic (food scraps, human waste, plant material). The amount of waste generated was relatively small due to the lower population and more agrarian lifestyles.

- **Waste Disposal:** Waste was either composted, used for agricultural purposes, or discarded in nearby rivers, ditches, or pits. Human and animal waste was often collected in cesspits or used as fertilizer.
- **Recycling:** Items like metal and pottery were often reused or repurposed.

Industrial Revolution (18th - 19th Century)

- **Increase in Waste Production:** The

Industrial Revolution led to urbanization and a dramatic increase in waste production, particularly in cities. This was due to rising populations, increased manufacturing, and the widespread use of new materials like coal, plastics, and chemicals.

- **Waste Disposal:** Many cities lacked effective waste management systems, leading to unsanitary conditions and public health issues. Waste was often dumped on streets or into bodies of water, creating significant environmental and health problems.
- **Early Waste Collection:** The first organized waste collection systems began to emerge in the 19th century in response to growing concerns about public health.

Early 20th Century

- **Development of Landfills:** As cities grew, waste management systems became more organized, with landfills becoming a common method of disposal. However, these landfills were often poorly regulated, leading to pollution of surrounding areas.
- **Sanitation Services:** By the early 20th century, cities began implementing regular sanitation services to collect waste, and the development of municipal waste management systems became more structured.
- **Waste Treatment:** Methods like incineration began to be used, though concerns about air pollution began to rise.

Mid-20th Century

- **Post-WWII Boom:** The aftermath of World War II saw rapid economic growth, consumerism,

and mass production, which led to an increase in both municipal and industrial waste.

- **Increased Landfills and Incineration:** Landfills remained the dominant method of waste disposal, while incineration became more common in cities, though concerns about environmental impacts (air pollution, dioxins) also grew.
- **Rise of Recycling Programs:** During this time, the importance of recycling began to be acknowledged, but recycling rates remained low.

Late 20th Century (1970s - 1990s)

- **Environmental Awareness:** The environmental movement, spurred by events like the publication of “Silent Spring” in the 1960s and the first Earth Day in 1970, raised awareness about the environmental impacts of waste, pollution, and resource depletion.
- **Landfill Limitations:** Landfills became increasingly problematic due to limited space, potential groundwater contamination, and the environmental damage they caused.
- **Recycling and Waste Reduction**

Policies: By the late 20th century, many countries introduced formal recycling programs and began promoting waste reduction, leading to an increase in recycling rates. Local governments and businesses began to experiment with composting, waste-to-energy technologies, and resource recovery.

- **Circular Economy Concepts:** The idea of a circular economy (which focuses on reducing, reusing, and recycling materials) began to gain traction.

21st Century

- **Waste-to-Energy Technologies:** More sophisticated waste-to-energy technologies, including incineration with energy recovery and anaerobic digestion, have become more common. These systems help reduce landfill use while generating energy.
- **Zero Waste Initiatives:** The concept of zero waste—aiming to eliminate all forms of waste through the redesign of product life cycles and systems—has been adopted by several cities and businesses worldwide.
- **Sustainability and Circular Economy:** Waste management is now integrated with broader sustainability and circular economy goals. There is a greater emphasis on resource recovery, waste

diversion, and environmentally friendly materials. Concepts like “extended producer responsibility” (EPR), where manufacturers are responsible for the entire lifecycle of their products, are increasingly being implemented.

- **Technological Advances:** Advances in technology, such as smart bins, sensor technologies for waste tracking, and AI-powered sorting systems, are improving efficiency in waste management processes. Additionally, biotechnology and new recycling methods (like chemical recycling) are being explored to handle complex waste materials.
- **Global Challenges:** While waste management is becoming more efficient in many places, challenges remain, especially in rapidly developing countries. Plastic waste, electronic waste (e-waste), and food waste are some of the most pressing issues globally.

Key Trends in Modern Waste Management

- **Waste Minimization:** Emphasis is placed on reducing waste generation through better product design, reducing packaging, and adopting sustainable practices in industries and households.
- **Recycling and Reuse:** There is an increasing focus on improving recycling rates, closing material loops, and encouraging the reuse of products and materials.
- **Public Awareness and Education:** Many cities and organizations are promoting public education campaigns about waste reduction, recycling, and composting to drive behavioral change.
- **Policy and Regulation:** Governments worldwide are implementing stricter regulations on waste management, including waste segregation at the source, mandatory recycling, and bans on single-use plastics.

Future of Waste Management

- **Circular Economy:** The future of waste management is likely to be dominated by circular economy principles, aiming for a closed-loop system where products and materials are continuously reused and recycled.
- **Sustainable Practices:** Innovations such as biodegradable packaging, sustainable production practices, and green technologies will play a key role in reducing waste generation.

- **AI and Automation:** The continued integration of AI and automation into waste sorting and collection systems will lead to more efficient and cost-effective waste management operations.
- **Global Cooperation:** Addressing global waste challenges will require international cooperation, particularly in tackling plastic pollution and e-waste, as well as enhancing waste management infrastructure in developing countries.

Overall, waste management practices have evolved from rudimentary systems to increasingly sophisticated, sustainable approaches, reflecting the growing awareness of environmental impacts and the need for responsible resource use.

GOVERNMENTAL MEASURES FOR WASTE MANAGEMENT

Governments play a critical role through policies, regulations, and infrastructure development. In India, initiatives like the Swachh Bharat Mission and Solid Waste Management Rules, 2016, aim to improve waste management systems. However, implementation gaps and resource constraints hinder their effectiveness.

Governmental measures for waste management vary by country and region, but they generally aim to reduce waste, promote recycling, and ensure the safe disposal of waste.

Role of Private Sector, NGOs, and Community in Waste Management

The private sector and NGOs have been instrumental in introducing innovative solutions and raising awareness. Community participation is equally vital, as effective waste management requires behavioural changes at the grassroots level. Collaborative efforts among these stakeholders can drive significant improvements.

The private sector, non-governmental organizations (NGOs), and local communities all play significant roles in waste management. While governments set regulations and policies, these entities contribute by fostering innovation, raising awareness, and ensuring effective implementation of waste management practices at the ground level. India's waste management system faces a complex set of challenges. To address these, there needs to be a focus on improving infrastructure, ensuring public participation, promoting waste segregation, increasing recycling rates, and enforcing policies effectively. Sustainable waste management will require coordinated efforts from the government, industries, and the public.

Recommendations to Manage Waste Efficiently

1. **Strengthen Policy Implementation:** Enforce existing regulations and introduce stringent penalties for non-compliance.
2. **Promote Source Segregation:** Educate citizens on waste segregation practices.
3. **Leverage Technology:** Invest in advanced waste processing technologies.
4. **Encourage Public-Private Partnerships (PPPs):** Facilitate collaboration for better infrastructure and services.
5. **Raise Awareness:** Conduct campaigns to change public attitudes toward waste.

CONCLUSION

Waste management has undergone a profound transformation, evolving from primitive waste disposal practices to highly organized and sustainable systems. Over time, societies have faced the challenges of increasing waste production driven by population growth, industrialization, and consumerism. As awareness of the detrimental effects of improper waste management on public health and the environment has grown, there has been a shift toward more sustainable and efficient approaches. Today, waste management is not just about disposal; it is about minimizing waste, maximizing resource recovery, and ensuring environmental protection.

There is a urgent need for shift from landfill disposal to an emphasis on recycling, composting, and waste-to-energy systems is indicative of a greater awareness of the limited supply of resources and the significance of circular economic models. As an eco-friendly method of managing organic waste and lowering the usage of landfills, composting has also gained popularity.

Future developments in waste management techniques will depend on technological advancements, policy modifications, and innovation. Waste collection and recycling efficiency could be increased by integrating smart technologies like data analytics, sensors for waste monitoring, and AI-driven garbage sorting systems. Policies that hold manufacturers accountable for the full lifecycle of their products, such extended producer responsibility (EPR) programs, will encourage the development of sustainable products.

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Review of Gas Sensors: Technologies, Applications, and Future Directions

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ABSTRACT

Gas sensors are critical devices for monitoring environmental conditions and ensuring safety across various applications. This review paper provides a complete summary of the different types of gas sensors, including catalytic combustion, metal oxide semiconductor (MOS), conductivity, electrochemical, and surface acoustic wave (SAW) sensors. Each sensor type is examined in terms of its operating principles, applications, advantages, and limitations. The necessity for effective gas sensing technologies is underscored by the increasing presence of gases from both natural processes, such as volcanic eruptions and microbial activity, and anthropogenic sources, including industrial emissions and transportation.

The review highlights the importance of gas sensors in addressing air quality, climate change, and public health concerns. Furthermore, it discusses emerging trends in gas sensor technology, such as miniaturization, advanced sensing materials, and the integration of Internet of Things (IoT) capabilities, which promise to enhance real-time monitoring and data sharing. Challenges such as cross-sensitivity, calibration, and environmental robustness are also addressed, along with potential solutions. The paper concludes that ongoing advancements in gas sensor technology will play a pivotal role in creating safer, healthier, and more sustainable environments, emphasizing the need for continued research and innovation in this vital field.

KEYWORDS: Air quality, Chemical detection, Environmental monitoring, Gas sensors, Sensor technology.

INTRODUCTION

Gas sensors play a fundamental role in monitoring environmental conditions and ensuring safety in various applications. These sensors are chemical devices that convert chemical information into electronic signals, such as changes in frequency, current, or voltage. The presence of various gases in the atmosphere, both from natural and anthropogenic sources, necessitates the development of effective gas sensing technologies.

Natural processes, such as volcanic eruptions, microbial activity, and vegetation emissions, contribute to the release of gases like sulphur dioxide, carbon dioxide, and methane. Human activities, including fossil fuel extraction, industrial processes, and transportation, further aggravate

the release of flammable and toxic gases. The improper disposal of electronic waste and agricultural practices also contribute to the emission of hazardous gases, impacting air quality and posing risks to human health and the environment.

Monitoring these gases is essential for justifying their adverse effects on air quality, climate change, and ecosystem health. The development of high-performance gas sensors is critical for environmental monitoring, industrial applications, and ensuring public safety [1].

TYPES OF GAS SENSORS

Gas sensors can be categorized based on their operating principles. The main types include catalytic combustion

sensors, Metal Oxide Semiconductor (MOS) sensors, conductivity sensors, surface acoustic wave (SAW) sensors, electrochemical sensors, and optical sensors. Each type has unique characteristics that make it suitable for specific applications.

Catalytic Combustion Gas Sensors

Catalytic sensors are primarily used for detecting combustible gases. They typically consist of two platinum coils: an active bead coated with a catalyst and an inactive reference bead. The detection mechanism depends on the change in resistance of the active bead due to the catalytic oxidation of combustible gases, which generates heat and alters the electrical resistance.

Thermoelectric gas sensors utilize the Seebeck effect to convert temperature changes into electrical signals, due to the heat reaction between a catalyst and gas species [2]. These sensors can detect various gases by changing the catalytic materials used. They do not require an external power supply and exhibit good linearity with respect to gas concentration.

Applications: Catalytic combustion sensors are widely used in residential heating systems, industrial combustion processes, automotive emissions control, environmental monitoring, and laboratory safety systems.

Advantages: High sensitivity, real-time monitoring, versatility, compact design, and cost-effectiveness.

Limitations: Cross-sensitivity to other gases, environmental condition sensitivity, limited detection range, sensor drift, and variable response times.

Conductivity Gas Sensors

Conductivity sensors measure gas concentrations based on thermal conductivity differences. They are effective for detecting gases with high thermal conductivities, such as hydrogen and methane. The detection mechanism involves measuring heat loss from a hot element to a cold element, with changes in resistance indicating the presence of target gases as shown in Fig.1.

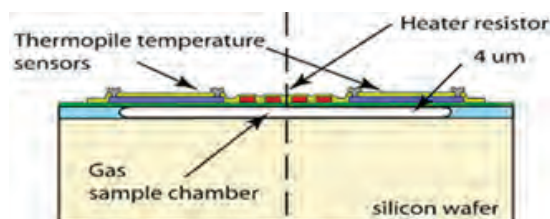


Fig. 1. Micro-thermal conductivity gas sensor [3]

The gas detection based on the thermal conductivity is widely used in automotive industry as well as in medical and environmental monitoring systems [4].

Applications: Conductivity sensors are used in industrial safety, environmental monitoring, toxic gas detection, leak detection, and the mining industry.

Advantages: Wide range of detectable gases, quick response time, cost-effectiveness, robustness, and simple calibration.

Limitations: Lack of selectivity, sensitivity to temperature and humidity, drift over time, and limited sensitivity to low concentrations.

Electrochemical Gas Sensors

Electrochemical sensors detect gases through redox reactions occurring at electrodes. These sensors consist of sensing and counter electrodes separated by an electrolyte. The target gas diffuses through a membrane to the sensing electrode, where it undergoes oxidation or reduction, generating a current proportional to its concentration [5]. In practice, electrochemical sensors are divided into amperometric, potentiometric and conductometric instruments [6].

Applications: Electrochemical sensors are used for carbon monoxide detection, oxygen monitoring, hydrogen sensing, and toxic gas detection in various industries.

Advantages: High specificity, fast response time, compact design, and low power consumption.

Limitations: Cross-sensitivity, electrolyte degradation, temperature dependence, poisoning from certain chemicals, and higher costs compared to other sensor types.

Metal Oxide Semiconductor (MOS) Gas Sensors

MOS sensors consist of a thin film of metal oxide, such as tin oxide, deposited on a substrate. The electrical conductivity of the metal oxide changes in response to gas exposure due to surface reactions. These sensors operate at elevated temperatures to enhance adsorption and desorption processes (Fig.2.) Typically, the active layer is composed of a thin film of metal oxide along with a heating element [7,8]. These sensors generally operate at temperatures ranging from 300°C to 900°C, which can vary based on the design of the sensor and the type of gas being detected. Adjusting these temperatures can enhance the effectiveness of gas detection.

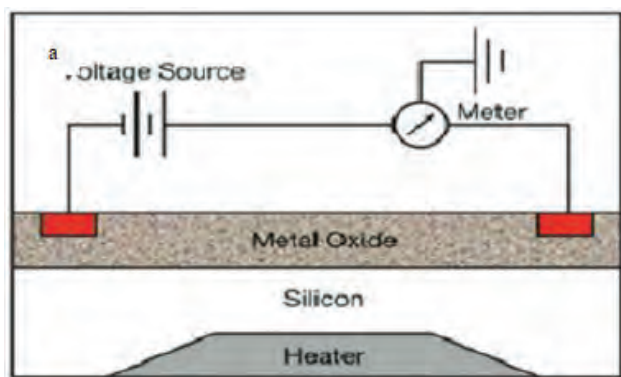


Fig.2. a) The operation concept of a typical semiconductor gas sensor

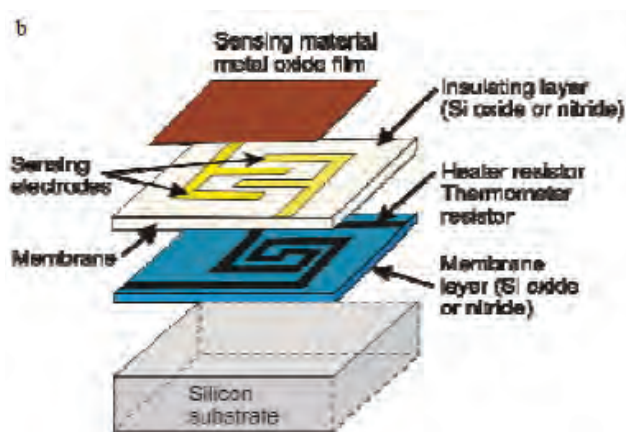


Fig.2. b) an example of its construction.

Applications: MOS sensors are used in industrial safety, environmental monitoring, healthcare, automotive emission control, smart homes, and food safety.

Advantages: High sensitivity, rapid response time, low cost, versatility, and long lifespan.

Limitations: Sensitivity to temperature and humidity, selectivity challenges, interference from other gases, and limited detection range.

Surface Acoustic Wave (SAW) Gas Sensors

SAW sensors convert electrical signals into mechanical waves, measuring their transmission through a sensing layer. There are different kinds of SAW sensors – some examples are presented in Fig.3. The properties of the receptor film change upon exposure to target gases, affecting the frequency and amplitude of the transmitted wave. In recent times, SAW sensors have been extensively used for detection of toxic chemical vapors [9].

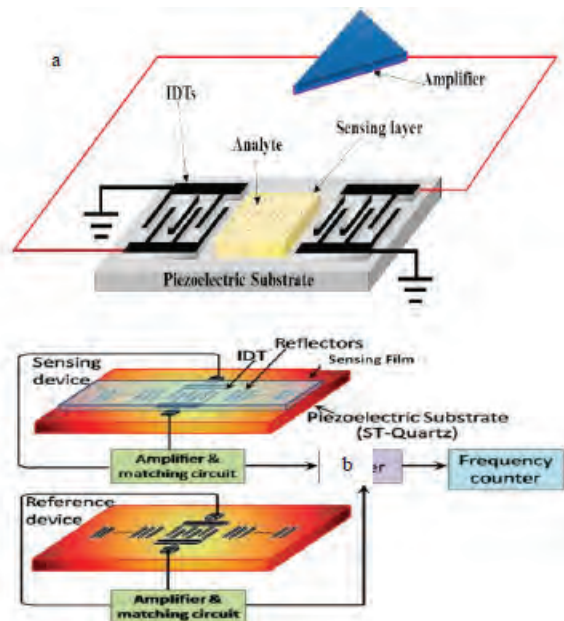


Fig.3. a) The operation concept of a typical SAW gas sensor; b) its structure

Applications: SAW sensors are used for environmental monitoring, industrial gas detection, medical breath analysis, and chemical warfare agent detection.

Advantages: High sensitivity, real-time monitoring, selectivity, and miniaturization potential.

Limitations: Temperature sensitivity, humidity interference, and relatively higher manufacturing costs.

SCOPE OF GAS SENSORS

The scope of gas sensors needs to be broadened to detect a wider range of hazardous gases. Current technologies mainly focus on flammable and toxic gases, but other harmful substances, including flammable liquids like butane, benzene, and gasoline, also require attention. Future research should aim to address these gaps to improve safety and environmental cleanliness.

As technology advances, gas sensors will continue to evolve, expanding into new fields such as environmental monitoring, industrial safety, healthcare, smart cities, and consumer electronics. With innovations in miniaturization and real-time monitoring, gas sensors are set for significant growth and adoption, addressing concerns around pollution, safety, and public health. The future holds exciting potential for these vital tools in ensuring a safer, cleaner world.

Technological Advancements

Miniaturization and Integration: The trend towards smaller, integrated gas sensor technologies will continue, driven by advancements in microelectromechanical systems (MEMS) and nanotechnology. This will enable the development of compact, portable, and low-power devices.

Advanced Sensing Materials: Research will focus on discovering novel sensing materials with improved selectivity, sensitivity, and stability. Materials such as graphene and metal-organic frameworks (MOFs) show promise for enhancing gas sensor performance.

Smart Sensor Networks: The integration of the Internet of Things (IoT) technology will enable interconnected sensor networks, transforming gas sensing applications. These networks will support real-time monitoring, data sharing, and collaborative decision-making in areas like smart cities, industrial automation, and environmental monitoring.

Emerging Applications

Environmental Monitoring: Gas sensors will play a vital role in monitoring air and water quality, detecting greenhouse gas emissions, and assessing indoor air quality. Enhanced sensor technologies will contribute to better environmental protection and public health.

Industrial Safety: Gas sensors will remain essential for ensuring workplace safety in industries such as manufacturing, mining, and chemical processing. Advanced capabilities, including multi-gas detection and real-time data analytics, will enhance risk management.

Healthcare: Gas sensors will find expanded applications in medical diagnostics and personalized healthcare. Breath analysis using gas sensors can aid in non-invasive disease detection and monitoring.

Challenges and Opportunities

Cross-Sensitivity and Selectivity: Addressing cross-sensitivity and selectivity challenges is key research focus for gas sensor development. Advanced signal processing techniques and machine learning algorithms can enhance sensor performance in complex environments.

Calibration and Drift: Developing self-calibrating sensor systems will improve long-term stability and accuracy. Automated calibration routines and drift compensation algorithms will reduce maintenance needs.

Environmental Robustness: Enhancing the durability of gas sensors for harsh conditions is essential for harsh operating conditions, including extreme temperatures, high humidity, and corrosive atmospheres. Protective coatings and ruggedized designs will improve reliability in challenging environments.

Future Trends and Opportunities

Smart Cities and Environmental Monitoring: The demand for integrated gas sensing solutions will grow with the development of smart city initiatives. Gas sensors will be integrated into urban infrastructure for real-time monitoring of air quality and pollution.

Precision Agriculture and Food Safety: Gas sensors will play a crucial role in precision agriculture, optimizing resource use and ensuring food safety. Integration into agricultural machinery and IoT platforms will enhance monitoring capabilities.

Personalized Healthcare and Wearable Sensors: The rise of wearable sensor technologies will enable personalized healthcare monitoring. Gas sensors integrated into wearable devices will provide real-time feedback on health status and environmental exposures [10-19].

CONCLUSIONS

Gas sensors are indispensable tools for ensuring safety, health, and environmental protection. Their diverse applications highlight their value in modern society. Ongoing advancements in materials, miniaturization, and integration with AI technologies are propelling gas sensor technology forward. As we refine and innovate, gas sensors will play a pivotal role in creating a safer, healthier, and more sustainable world. Future research should focus on developing cost-effective sensing materials with desirable properties, ensuring stability under operating conditions, and enhancing gas adsorption capabilities. By addressing these challenges, gas sensing technology can significantly contribute to environmental safety and public health.

This review article explores various advanced sensor models designed for detecting different gases. It discusses several sensing techniques, including catalytic, electrochemical, combustion, thermal, and acoustic methods. Among these, surface acoustic wave (SAW) sensors have seen limited commercial success thus far. The analysis focuses on key sensor characteristics, such as sensitivity, selectivity, response time, and recovery time.

Gas sensors have emerged as essential tools for safeguarding lives, ensuring health, and protecting the environment. Their wide range of applications, from industrial safety to indoor air quality monitoring, underscore their immense value in our modern world. Ongoing advancements in materials, miniaturization, and integration with AI are propelling gas sensor technology forward, paving the way for even more transformative applications in the future. From personalized health monitoring and smart cities to precision agriculture and environmental sustainability, gas sensors are poised to play a critical role in shaping a better tomorrow. As we continue to refine and innovate, these versatile devices hold the promise of creating a safer, healthier, and more sustainable world for all.

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The Effectiveness of Augmented Reality in Marketing Campaigns

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ABSTRACT

Augmented Reality (AR) has become a pivotal tool in modern marketing, providing innovative ways to engage consumers through immersive and interactive experiences. This paper evaluates the effectiveness of AR in marketing campaigns by analyzing various studies, examining its influence on consumer engagement, brand perception, purchase behavior, and marketing outcomes. Through a meta-analysis of empirical research, this study explores how AR enhances consumer experiences, fosters positive brand associations, and drives purchasing decisions. The findings indicate that AR significantly improves consumer interaction with brand content, leads to higher levels of engagement, and positively impacts purchase intent. However, challenges related to technology limitations, adoption barriers, and privacy concerns remain, which need to be addressed to maximize the effectiveness of AR in marketing.

INTRODUCTION

Augmented Reality (AR) applications have become increasingly popular across various industries due to their ability to blend the physical and digital worlds, creating immersive and interactive experiences. These applications offer numerous benefits, from enhancing consumer experiences in marketing to improving operational efficiency in sectors like healthcare, education, and retail, both consumer and enterprise markets.

Below are some prominent applications of AR across different fields:

AR in Marketing

Virtual Try-Ons

In industries such as fashion, beauty, and eyewear, AR allows consumers to “try on” products virtually. This is typically done using a smartphone or tablet to overlay

digital representations of products onto the user’s image or environment.

Interactive Advertising

AR allows advertisers to create immersive and interactive ads that engage consumers. This can include virtual product demonstrations, gamified experiences, or AR billboards that come to life when viewed through a smartphone.

Enhancing Brand Experience

Brands can use AR to create unique experiences at events, trade shows, or even on their product packaging, offering users more information or fun, interactive content.

INNOVATIVE AR

Augmented Reality (AR) has quickly become a transformative tool in digital marketing. By blending the physical world with digital elements, AR offers a unique way to engage consumers, making marketing campaigns

more interactive, immersive, and memorable[1]. Below, we'll explore the key ways in which AR is effective in marketing campaigns:



Fig. 1. The main goals of augmented reality in marketing

Enhanced Consumer Engagement

AR allows brands to create highly interactive experiences that engage consumers on a deeper level. Instead of just watching an ad or browsing products, users can interact with them in real-time through their smartphones or AR glasses. For instance, AR-powered apps let customers visualize how furniture would look in their home or try on clothes and accessories virtually. This type of interactivity encourages prolonged engagement and increases the likelihood of conversion.

Improved Brand Recall

AR offers a memorable and unique way for brands to communicate with their audience, which can lead to better brand recall. A study by Deloitte found that 61% of consumers said they were more likely to remember brands that use AR in their marketing campaigns. The novelty and interactive nature of AR experiences leave lasting impressions on consumers, making it more likely that they will remember the brand later on.

Enhanced Product Visualization

AR allows potential customers to visualize products in their environment or on themselves, which can reduce purchase hesitation and improve customer satisfaction. For example, AR apps can show how makeup will look on a person's face or how a product will fit into their home. This virtual try-before-you-buy approach boosts confidence in purchase decisions.

Personalized Experiences

AR can also facilitate highly personalized marketing experiences. By using AR to tailor content to the individual

based on their preferences, location, or past interactions, brands can create more meaningful connections with consumers[2]. Personalized AR campaigns have a higher chance of resonating with consumers and driving engagement.

Increased Social Sharing

Interactive AR experiences are highly shareable. People love to share unique and fun moments on social media, and AR-powered campaigns offer exactly that. When consumers share AR experiences, they indirectly promote the brand to their social networks, increasing the campaign's reach and visibility.

Improved Customer Experience and Convenience

AR enhances the customer journey by making it more seamless and enjoyable. For example, AR can help with in-store navigation, product demonstrations, or providing additional product information. By improving the overall shopping experience, brands can increase customer satisfaction and loyalty.

Data and Analytics Insights

AR marketing campaigns can also provide valuable data and insights. By tracking user interactions with AR experiences, brands can better understand consumer preferences, behavior patterns, and purchase intent. These insights allow for more targeted and data-driven marketing strategies.

Innovation and Differentiation

Incorporating AR into marketing campaigns helps brands stand out from competitors by showcasing innovation. With AR still being an emerging technology in many industries, brands that use it effectively often appear cutting-edge and forward-thinking, which can attract tech-savvy consumers and early adopters..

KEY LEARNINGS

Boosted Consumer Engagement

- Augmented Reality (AR) offers interactive and immersive experiences that capture consumer attention and drive deeper engagement with brands[3].
- AR allows consumers to engage with products in real time—whether it's virtually trying on clothes, visualizing furniture in their space, or interacting with digital elements in physical locations.

Improved Brand Recall and Awareness

- AR campaigns are memorable and create lasting impressions, enhancing brand recall.
- By offering unique, fun, and surprising experiences, AR helps brands stick in consumers' minds, improving long-term brand recognition.

Enhanced Product Visualization

- AR enables consumers to visualize products in their own environment or on themselves, reducing uncertainty and hesitation during the purchasing decision process.
- Virtual "try-before-you-buy" experiences are especially valuable in sectors like fashion, beauty, and home goods, leading to higher confidence and better decision-making.

Personalized Marketing Experiences

- AR allows for tailored experiences based on consumer preferences, behaviors, and location, creating more relevant and meaningful interactions.
- Personalized AR experiences drive deeper connections between brands and consumers, fostering loyalty and satisfaction.

Increased Social Sharing and Viral Potential

- AR experiences are highly shareable, with consumers often eager to post their fun or unique interactions on social media.
- This organic sharing increases the reach of marketing campaigns and generates word-of-mouth exposure, further amplifying brand visibility.

Seamless Customer Experience

- AR can improve the customer journey by providing helpful features like in-store navigation, product information, and interactive demos.

It enhances convenience for consumers, creating a more enjoyable and informative shopping experience, which ultimately strengthens brand loyalty.

Valuable Consumer Insights

- AR marketing provides data on how consumers interact with digital content, offering valuable insights into preferences, behavior patterns, and purchase intent.

- Brands can use this data to refine future campaigns, optimize customer experiences, and implement more targeted marketing strategies.

Innovation and Differentiation

- AR sets brands apart by showcasing their innovation and willingness to embrace new technologies.
- Brands that use AR effectively position themselves as forward-thinking and tech-savvy, which appeals to consumers looking for novel and cutting-edge experiences.

Challenges to Overcome

- High Development Costs: Building high-quality AR experiences can be expensive and resource-intensive, which may be a barrier for smaller brands.
- User Adoption: Not all consumers are familiar with or comfortable using AR technology, so accessibility and ease of use are key.
- Device Limitations: AR experiences may not be compatible with all devices, limiting the potential reach of campaigns.

LITERATURE REVIEW

Augmented Reality (AR) is an emerging technology that overlays digital content onto the physical world, providing interactive and immersive experiences. In the context of marketing, AR has gained significant attention for its ability to engage consumers in new ways and create memorable brand experiences. This literature review explores the existing research on the effectiveness of AR in marketing campaigns, analyzing its impact on consumer behavior, engagement, brand perception, and overall marketing success.

Consumer Engagement and Interaction

A major benefit of AR in marketing is its ability to boost consumer engagement. According to research by Poushneh & Vasquez-P AR enhances engagement by offering a unique, interactive experience that captivates users. Instead of passively receiving information, consumers actively participate in the marketing experience. This involvement increases their emotional connection to the brand, making it more likely that they will remember and recommend the product or service.

Enhanced Brand Recall and Memory

AR campaigns have been shown to improve brand recall.

A study by Luna-Nevarez highlighted that interactive experiences, such as AR, are more memorable compared to traditional marketing methods. Consumers are more likely to remember and share a brand experience when it involves an engaging AR interaction. Furthermore, AR can trigger a positive emotional response, which strengthens brand recall and associations.

Increased Purchase Intent and Conversion Rates

One of the most significant advantages of AR in marketing is its ability to influence purchase intent. Research by Pantano & Gandini found that AR helps bridge the gap between online and offline shopping experiences. By allowing customers to visualize products in their own environment or on themselves, AR aids in reducing uncertainty and encouraging purchase decisions. For example, IKEA's AR app, which allows users to see how furniture will look in their homes, has been linked to increased purchase intent and decreased return rates.

Personalization and Consumer Experience

AR enables highly personalized marketing experiences. Chung et al. argue that personalized AR content, such as custom filters or tailored product recommendations, can make consumers feel more valued and connected to a brand. By integrating consumer data (location, preferences, past behaviors), AR can deliver tailored messages that resonate with individual users. This level of personalization can improve the overall customer experience and foster brand loyalty.

Social Sharing and Viral Marketing

AR campaigns are inherently shareable, particularly on social media platforms. Huang & Liao point out that when users have fun or unique experiences with AR, they are more likely to share their interactions with their social networks. This viral marketing effect extends the reach of AR campaigns, generating organic promotion through user-generated content. The ability of AR to create memorable and shareable experiences is a key driver of its success in marketing.

CHALLENGES & LIMITATIONS

While Augmented Reality (AR) has proven to be an effective tool in modern marketing, there are several challenges and limitations that brands must consider when integrating AR into their marketing strategies. These challenges can affect the success and adoption of AR, particularly for businesses that are new to the technology or have limited resources.

High Development and Implementation Costs

Creating high-quality AR experiences requires significant investment in technology, software development, and hardware. The development of AR apps and interactive content can be expensive, particularly if the campaign requires custom features, advanced graphics, or integration with existing systems (e.g., e-commerce platforms).

- Impact: High upfront costs can be prohibitive for small to medium-sized businesses, making it more difficult for them to leverage AR effectively in their marketing efforts.
- Example: Developing AR experiences like virtual try-ons or interactive 3D product displays often requires skilled AR developers, graphic designers, and testing infrastructure, leading to higher costs.

Technology and Device Limitations

While AR technology is advancing rapidly, it still has certain limitations, particularly in terms of device compatibility and accessibility. Not all consumers have access to high-end smartphones or AR glasses that are required to fully experience AR content. Moreover, the performance of AR applications can vary depending on the user's device capabilities.

- Impact: Consumers with older devices or those without AR-enabled phones may be unable to interact with AR campaigns, reducing the potential reach of the campaign.
- Example: AR apps may require a certain level of processing power, camera quality, or specific operating system versions to function properly. This creates a barrier for some users and limits the effectiveness of the campaign.

User Experience and Usability Issues

The user experience (UX) plays a critical role in the success of AR campaigns. If an AR experience is difficult to use, not intuitive, or technologically flawed, it can frustrate users and lead to disengagement. In addition, AR applications often require the user to download a separate app, which can create friction if users are not willing to make that effort.

- Impact: Poor user experience can lead to low adoption rates, negative perceptions of the brand, and decreased effectiveness of the marketing campaign.
- Example: AR apps that require a lot of time to load,

crash frequently, or are difficult to navigate will not only reduce consumer satisfaction but also diminish the chances of the campaign going viral or being shared on social media.

Consumer Education and Adoption

Although AR technology is growing in popularity, many consumers are still unfamiliar with it or may not be comfortable using it. AR often requires the consumer to engage with technology in a way that they might not be accustomed to, such as using their phone camera to visualize a product or interact with an app.

- Impact: A lack of understanding or familiarity with AR could result in lower engagement rates and missed opportunities for brands. Additionally, educating consumers on how to use AR can be resource-intensive and time-consuming.
- Example: A brand launching an AR campaign might face difficulties if consumers don't know how to use the app or don't understand its value, leading to lower conversion rates.

Privacy and Data Security Concerns

AR applications often collect data about user behaviors, preferences, and interactions, which can raise concerns about privacy and data security. With the increasing emphasis on data privacy laws (such as GDPR in Europe), AR campaigns must ensure they are compliant with regulations and respect consumer privacy.

- Impact: If consumers are concerned about how their data is being collected and used, they may be hesitant to engage with AR experiences, which could negatively impact the brand's reputation.
- Example: If an AR app collects too much personal data (such as facial features for virtual try-ons) without transparent consent or proper security measures, it could result in privacy violations and loss of consumer trust.

Limited Scalability

While AR can create engaging and immersive experiences, scaling those experiences across multiple platforms or locations can be challenging. For example, an AR campaign that works well in a specific location, such as a retail store or pop-up shop, may not translate easily to an online or global audience.

- Impact: Brands may find it difficult to replicate the

same AR experience across different touchpoints (in-store, online, mobile apps), leading to inconsistent consumer experiences and reduced effectiveness of the campaign.

- Example: A location-based AR campaign that requires physical proximity (such as an AR treasure hunt in a specific city) may not have the same impact if scaled to an online or global audience.

Over-Saturation of AR in Marketing

As AR becomes more popular, there is a risk of over-saturation in the market, where consumers are exposed to too many AR campaigns, diluting the novelty and excitement of the technology. Over time, consumers may become desensitized to AR experiences, leading to diminished returns on marketing efforts.

- Impact: AR experiences may lose their effectiveness if they are used too frequently or if they fail to offer something truly unique and innovative. As the novelty wears off, brands may struggle to capture attention with AR campaigns.
- Example: If every brand starts using AR in the same way—such as offering virtual try-ons or product visualizations—consumers may lose interest, reducing the long-term impact of AR campaigns.

Lack of Measurable Metrics and ROI

While AR offers many benefits, measuring its effectiveness and return on investment (ROI) can be difficult. Traditional metrics like click-through rates (CTR) or sales figures may not fully capture the impact of AR experiences, especially if the campaign's goals are related to brand awareness, engagement, or consumer sentiment.

- Impact: Without clear metrics to track success, brands may struggle to justify the cost of AR campaigns or determine whether they are achieving their desired outcomes.
- Example: A brand might implement an AR campaign aimed at boosting brand recall, but measuring success requires a combination of qualitative feedback and indirect sales metrics, which can be difficult to quantify.

CASE STUDIES

IKEA's AR Shopping App: IKEA Place

IKEA's AR app, IKEA Place, allows customers to visualize

how furniture will look in their homes by superimposing 3D models of products into the user's environment. This AR experience allows consumers to interact with products in a personalized way and aids in purchase decision-making. The app's success lies in its ability to reduce uncertainty and enhance the customer experience, making it easier for users to envision their purchases and feel confident in their decisions.

Sephora Virtual Artist

Sephora's Virtual Artist is another successful application of AR in marketing. Through this app, customers can virtually try on makeup, experiment with different looks, and find the right products for their skin tones. The app integrates both AR and AI to provide personalized product recommendations based on the user's preferences, further enhancing engagement and improving the likelihood of purchase.

L'Oreal's AR Beauty Tech

L'Oreal's AR initiatives have revolutionized the beauty industry. Their ModiFace AR technology allows consumers to try on makeup in real-time through their smartphones. L'Oreal's approach has helped them expand customer reach, create more engaging experiences, and drive higher sales, particularly in online channels where consumers cannot physically test products.

CONCLUSIONS

Augmented Reality has proven to be an effective tool in modern marketing campaigns, offering brands an innovative way to engage consumers, enhance emotional connections, and improve purchase decision-making. Theoretical frameworks such as the Technology Acceptance Model (TAM), Elaboration Likelihood Model

(ELM), and Experiential Marketing help explain why AR is so impactful in marketing contexts. The combination of personalization, interactivity, and immersion makes AR a compelling choice for marketers looking to differentiate their campaigns in a crowded marketplace. While there are challenges, including technology limitations and high

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Skill Quest: Integrating Personalized Learning and NLP-Driven Simulations for Career Growth

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ABSTRACT

This research paper addresses the challenges engineering students face in acquiring essential skills and knowledge within their disciplines. Traditional learning platforms often lack personalized and adaptable guidance, leaving students struggling in a rapidly evolving landscape. To address this, Skill Quest, an AI-powered platform tailors learning pathways to individual needs, preferences, and goals. By curating targeted resources and generating customized plans, Skill Quest enhances engagement, improves learning outcomes, and provides a streamlined educational experience, making it a valuable tool in engineering education.

KEYWORDS: *Academia, Assessments, Campus connect, Course ware, Digital platform, Education, Industry, Information technology.*

INTRODUCTION

The engineering field is evolving at an unprecedented pace, driven by rapid technological advancements and the transformative influence of Artificial Intelligence (AI). For students aspiring to thrive in this dynamic landscape, the challenge lies not only in mastering foundational concepts but also in staying current with emerging trends and technologies. The sheer breadth of skills and knowledge required can often feel overwhelming. Traditional educational models, characterized by one-size-fits-all approaches, frequently fall short of addressing the diverse and individual needs of students. This lack of personalized guidance leaves many struggling to navigate their academic and professional journeys effectively. While efforts like Massive Open Online Courses (MOOCs) have broadened access to quality education¹, and studies highlight the potential of personalized learning and AI-driven tools², their targeted application in engineering education remains limited.

Existing educational platforms frequently lack the ability to adapt to individual learner profiles or provide real-time, personalized guidance³. This is particularly problematic in engineering education, where bridging the gap between theoretical understanding and practical, industry-relevant skills are critical. Many graduates enter the workforce with significant gaps in their competencies, underscoring the need for innovative solutions. To address these challenges, this research introduces Skill Quest, an AI-powered platform that combines adaptive learning pathways with problem-based and project-based methodologies. By tailoring resources and feedback to individual progress, Skill Quest empowers students to efficiently develop the skills necessary to meet academic and professional demands.

This study aims to evaluate the potential to transform engineering education by leveraging AI technologies to create dynamic and personalized learning experiences. The platform integrates real-time feedback, targeted

interventions, and project-based learning to bridge existing gaps in skill acquisition. Ultimately, this research seeks to enhance the learning experience for engineering students, equipping them with the competencies required to succeed in a rapidly changing technological environment.

LITERATURE SURVEY

Before initiating the development of Skill Quest, an extensive review of literature on AI-driven educational platforms, adaptive learning systems, and skill enhancement methodologies was conducted. These studies offered valuable insights into existing frameworks, challenges, and best practices, guiding in designing a comprehensive solution that bridges gaps while leveraging established strategies.

[1] This paper examines retention and learner intent in Massive Open Online Courses (MOOCs), highlighting how clear goals and effective course design can enhance engagement. Its strength lies in identifying the relationship between learner intent and retention, emphasizing the importance of goal-setting. However, the study lacks detailed methodologies and actionable strategies for improving retention rates. These insights guided Skill Quest's framework to prioritize personalized learning goals and user-centric design to maintain learner engagement and success.

[2] This paper advocates for the integration of Artificial Intelligence (AI) in education, highlighting its potential to offer personalized tutoring, intelligent support for collaborative learning, and immersive virtual environments. Its strength lies in enabling adaptive, context-aware learning experiences tailored to individual needs. However, challenges such as privacy concerns, accessibility issues, reduced human interaction, and contextual inaccuracies raise important considerations. These insights informed Skill Quest's design by emphasizing a balanced approach that leverages AI for personalization while ensuring transparency, inclusivity, and human-centric interaction.

[3] This paper focuses on personalized learning methodologies aimed at addressing individual student needs to improve educational outcomes. Its strength lies in demonstrating the potential of personalized approaches to enhance achievement. However, challenges like resource-intensive implementation, scalability issues, and increased teacher workload limit its widespread adoption. This insight guided the development of Skill Quest's

adaptive learning modules, ensuring scalability and user accessibility while maintaining a personalized approach.

[4] This paper explores the theory of online learning, highlighting how digital platforms enable flexible and remote access to educational content. Its strength lies in recognizing that learning extends beyond traditional interactions to include diverse forms of collaboration. However, limitations such as reduced peer interaction, isolation, and dependence on internet access and self-discipline present challenges. These findings shaped Skill Quest's design by emphasizing collaborative and engaging features, mitigating isolation, and ensuring accessibility for users with varying resources.

[5] This paper discusses a digital platform designed to deliver educational content, assessments and collaboration tools, emphasizing accessibility for students who cannot afford higher education. Its strength lies in enhancing employability by targeting essential skills and offering flexible learning opportunities. However, it relies heavily on student initiative, as the absence of supervision can hinder consistent engagement. These insights guided Skill Quest's approach to balance autonomy with structured guidance, ensuring active learning and support for users.

METHODOLOGY

Skill Quest is an AI-powered learning platform developed using React.js and Node.js, leveraging GPT- 4 for personalized interactions. It offers a structured learning path with two primary sections: "Skill Up" and "Placement Preparation." The "Skill Up" section focuses on core skill development through interactive exercises and project-based learning, while the "Placement Preparation" section guides students through mock interviews, aptitude tests, and enhances their job readiness. AI-powered tools are integrated throughout, providing personalized feedback and adaptive learning paths to optimize the student learning experience.

User Engagement

Skill Quest is designed to keep learners engaged and motivated throughout their learning journey. It includes key features like personalized learning roadmaps, hands-on projects, student forums for collaboration, a resource center, and aptitude test preparation tools. These features work together to create an interactive and supportive environment that helps users stay focused, build practical skills, and connect with others. This section explains how

each feature contributes to improving user engagement and enhancing the learning experience.

Roadmaps: This involves personalized learning roadmaps tailored to individual goals, guiding students through skill-based modules with curated resources and project suggestions. Users track progress, receive feedback, and adapt their paths for an engaging learning journey.

Project Hub: The Project Hub facilitates hands-on learning through collaborative projects. Students apply theoretical knowledge to real-world problems, enhancing practical skills and building a portfolio.

Student Forums: This facilitates peer-to-peer learning and collaboration. Students engage in discussions, ask questions, and share resources, fostering a supportive community.

TechZone: The TechZone serves as a curated resource center, providing access to tutorials, articles, and videos. This empowers students with the latest knowledge and industry trends.

Aptitude Test Preparation: A dedicated platform that provides practice tests for aptitude assessments, which are commonly used in job recruitment processes. Users can take these tests to improve their skills in numerical reasoning, logical thinking, and verbal reasoning.

Technical Tests: These are practice tests tailored to assess users' technical knowledge relevant to their field. For example, users can test their knowledge of data structures, algorithms, coding languages, or other technical subjects.

Skill Quest enhances employability by simulating real-world scenarios, including 'Dynamic Group Discussions with AI-powered NPCs and Proctored Personal Interviews with AI-powered interviewers. These features provide personalized feedback on communication, teamwork, and interview performance, helping users build the necessary skills for career success.

Integration with NLP powered NPCs

In this section, the integration of NLP-powered Non-Playable Characters (NPCs) to facilitate two key features is discussed that play a significant role in the placement process: Group Discussions (GD) and Personal Interviews (PI). By leveraging advanced NLP techniques, these NPCs are able to engage students in realistic, context-aware interactions, offering a dynamic and immersive learning experience. This integration aims to help students improve their communication, problem-solving, and interview skills, preparing them more effectively for real-world placement scenarios.

The Group Discussion feature in Skill Quest uses Non-Playable Characters (NPCs) within a virtual room to simulate real-life group interactions. This feature is designed to provide students with an immersive and realistic environment for practicing communication, teamwork, and critical thinking skills. By engaging with NPCs, students can participate in group discussions, receive feedback, and improve their ability to express ideas and collaborate effectively.

Entering the Virtual Room: The user journey begins when students access the "Virtual Room," an immersive environment designed to simulate a real-world meeting space.

Selecting a Discussion Topic: Students choose from a diverse range of predefined discussion topics, including current events, technological advancements, ethical dilemmas, and team-building exercises. They also have the option to suggest custom topics for personalized learning.

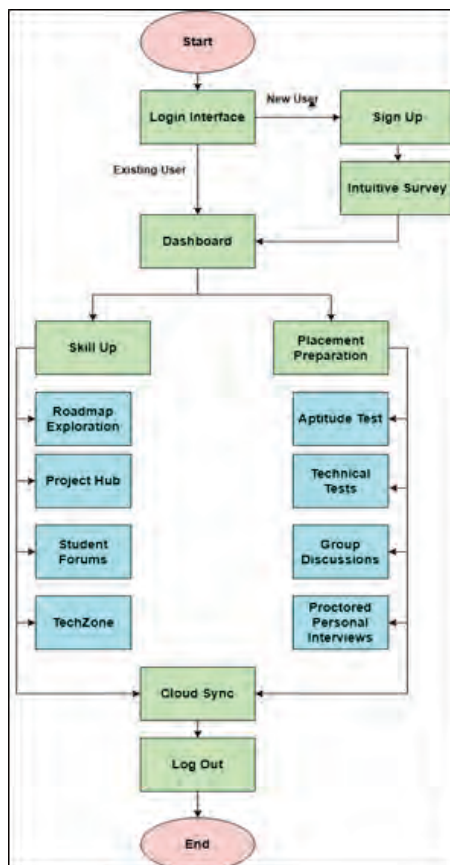


Fig 1. User Engagement Flowchart

NPC Generation: The system dynamically generates Non-Playable Characters (NPCs) with unique personalities and communication styles, such as assertive, reserved, or enthusiastic, to simulate real-world group dynamics.

Initiating the Discussion: The virtual discussion begins with the student taking the lead. NPCs actively participate by introducing themselves and expressing their viewpoints on the chosen topic, setting the stage for a dynamic conversation.

NPC Interaction: NPCs interact with the student realistically, driven by natural language processing algorithms. They respond to student inputs, express their opinions, and challenge their ideas, fostering critical thinking and deeper analysis.

Student Response: As the discussion progresses, students adapt their communication style, employing active listening, persuasive speaking, and effective argumentation techniques to effectively engage with the diverse range of NPC personalities.

Following the same concept and technology, Skill Quest also implements the Personal Interview feature, where users can engage in simulated one-on-one interviews with Non-Playable Characters (NPCs). This feature allows students to practice common interview scenarios, improve their responses, and receive personalized feedback on their performance. By interacting with NPCs in a realistic interview setting, students can enhance their confidence and preparedness for real-world job interviews.

Here instead of other student NPCs, a panel of interviewers is introduced who ask students questions based on various aspects of their skills. These include communication abilities, technical knowledge, and general etiquette. The panel simulates a real interview scenario, providing a realistic environment for students to practice and improve their performance. By facing different types of questions, students can gain valuable experience, receive instant feedback, and refine their responses to be better prepared for actual job interviews.

RESULTS

Now, in order to implement all the mentioned features, utilizing a robust tech stack is essential. The frontend is powered by React.js, while Node.js with Express.js handles the backend. MongoDB serves as the database, and for AI-powered interactions, the OpenAI GPT-4 model is leveraged. Real-time communication is facilitated through WebSocket technology. The platform's code quality is ensured with Mocha, Chai, and Jest, while Docker and Nginx manage containerization, reverse proxy, and load balancing for cloud deployment. Security measures such as Helmet.js for HTTP header protection, rate limiting, and SSL/TLS encryption are incorporated. For user behavior and system performance insights, Google Analytics and Sentry is being utilised. Additionally, the NPC feature is developed using the Unity engine, with WebGL integration for smooth web deployment.

The results presented here stem from the alpha test conducted alongside the development of the Skill Quest platform. The alpha phase focused on evaluating the core features, interface design, and technical performance of the platform, which combines AI-powered learning with a personalized skill development journey.

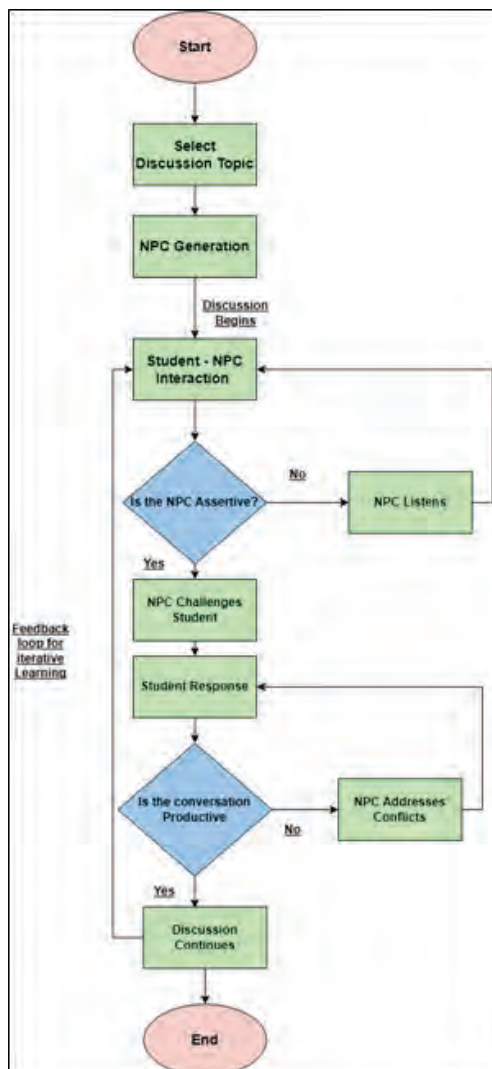


Fig 2. Group Discussions with Adaptive NPC's

Prototype and Interface Design Evaluation

The Figma designs for the Skill Quest dashboard prioritized user-friendly navigation, with iterative refinements based on tester feedback. Key updates included streamlining the dashboard for easier access to learning paths, group discussions, and mock interviews, ensuring users could track progress effortlessly.

Performance of Core Features

Skill Quest's core features, including personalized learning paths, AI-driven group discussions, and mock interview simulations, performed well during alpha testing. The AI effectively adapted content to user progress, and the mock interview system provided valuable real-time feedback. Usability and engagement were rated highly.



Fig. 3: Skill Quest Roadmap section

Technical Evaluation

The platform, built on a MERN stack, demonstrated strong performance in speed and stability during testing. AI-driven features like group discussions and mock interviews ran smoothly with minimal lag. Minor glitches were addressed promptly to improve overall reliability.

User Flow and Interaction Quality

User flow was designed for easy navigation, guiding students seamlessly through onboarding, learning paths, and interactive features. AI-powered NPCs enhanced engagement in group discussions and interviews, providing dynamic, context-aware responses.

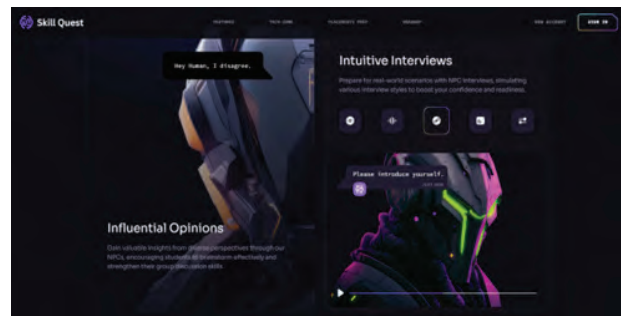


Fig. 4: Storefront and Pricing Model

Storefront and Pricing Model

The storefront showcases Skill Quest's features, including personalized learning, AI-powered interviews, and group discussions, with clear subscription plans. It offers prospective users an overview of the platform's value and accessibility for skill development and career preparation.

The key observations, feedback, and plans for improving Skill Quest based on testing performance are as follows:

Learning Impact

Skill Quest enhances student learning with tailored content based on individual needs. Alpha testing showed that personalized learning paths effectively guided users through skills and interview preparation, while interactive features like group discussions and mock interviews provided practical, real-world practice.

AI-Driven Personalization

The platform's AI dynamically adapts learning paths and feedback to individual progress and goals. During testing, users appreciated the customized recommendations and real-time responses, which ensured a unique and engaging experience.

Future Iterations and Scaling

Plans for improvement include optimizing AI response time and expanding the database of resources to cover more industry-specific skills. Future iterations will focus on scaling up the user base and refining AI features for enhanced skill development and interview readiness.

CONCLUSION

This study underscores Skill Quest's groundbreaking potential to transform engineering education. Its AI-powered personalized learning framework combines adaptive pathways, real-time feedback, and project-based

methodologies to seamlessly bridge theoretical knowledge with practical application. By accommodating diverse learning styles and individual paces, Skill Quest equips students with the critical skills and deep understanding needed to excel in complex academic and professional landscapes, redefining the educational experience in a rapidly evolving technological era.

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Advances, Challenges, and Opportunities in Sustainable and Renewable Energy Systems: A Review

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ABSTRACT

The transition to sustainable and renewable energy systems is critical for addressing global energy demands while mitigating environmental impacts. This review highlights recent advances, challenges, and opportunities in the development and integration of renewable energy technologies, including solar, wind, biomass, hydropower, geothermal, and emerging hydrogen systems. Advances in photovoltaic materials, wind turbine design, biofuel production, and energy storage solutions, such as batteries and super capacitors, are accelerating the adoption of renewable systems. However, challenges persist, including intermittency, high capital costs, material sustainability, and regulatory hurdles. This paper also explores the role of smart grids, artificial intelligence, and hybrid systems in optimizing energy generation and distribution. Finally, it discusses future directions, such as breakthroughs in hydrogen energy, offshore renewables, and circular economy practices, which have the potential to transform global energy landscapes. A multidisciplinary approach, coupled with supportive policies and innovative technologies, is essential for realizing the full potential of renewable energy systems in achieving a sustainable future.

KEYWORDS: Renewable energy, Sustainable energy systems, Solar power, Wind energy, Biomass, Hydropower, Energy storage, Smart grids, Artificial intelligence, Hydrogen energy, Circular economy, Energy transition, Sustainable development.

INTRODUCTION

The global energy landscape is undergoing a fundamental transformation as the need for sustainable and renewable energy systems becomes more urgent. With the increasing demand for energy and the adverse effects of fossil fuel dependency, renewable energy systems offer a promising pathway toward environmental sustainability and energy security. This paper aims to review the recent advances, challenges, and opportunities associated with various renewable energy technologies, emphasizing their integration into global energy systems.

OVERVIEW OF RENEWABLE ENERGY SYSTEMS

Solar Energy

Solar energy is one of the most abundant and widely

harnessed renewable energy sources. Recent advancements in photovoltaic (PV) technologies, such as the development of perovskite solar cells, have significantly improved efficiency and reduced costs. Concentrated solar power (CSP) systems, which use mirrors or lenses to focus sunlight, are increasingly integrated with thermal energy storage systems for consistent energy output. Emerging technologies, such as bifacial solar panels and solar thermoelectric generators, further enhance the versatility of solar energy applications.

Wind Energy

Wind energy is a mature and rapidly growing sector, particularly in offshore wind farms. Advances in wind turbine design, including larger rotor diameters and lightweight materials, have improved efficiency and reduced costs.

Blade design optimization and the integration of advanced control systems contribute to enhanced performance. However, challenges such as grid integration, noise, and ecological impacts remain critical concerns.

Biomass Energy

Biomass energy, derived from organic materials such as agricultural waste and forest residues, offers a versatile and sustainable energy source. Recent advancements in conversion technologies, including gasification, pyrolysis, and anaerobic digestion, have enhanced the efficiency of biofuel production. Waste-to-energy systems provide a circular economy solution by converting waste into valuable energy while reducing environmental impact.

Hydropower

Hydropower remains a cornerstone of renewable energy, providing reliable and scalable electricity generation. Recent innovations in small-scale hydropower systems, such as run-of-river and tidal energy technologies, have expanded the applicability of this energy source. However, environmental concerns related to large-scale dams, such as habitat disruption and water quality issues, require mitigation strategies.

Emerging Technologies

Emerging renewable energy technologies, such as geothermal energy, hydrogen fuel cells, and ocean energy systems, hold significant potential for diversification and innovation. Geothermal energy provides a consistent and low-carbon energy source, while hydrogen is increasingly recognized as a versatile energy carrier. Ocean energy, including wave and tidal systems, offers untapped potential for coastal regions.

LITERATURE REVIEW

A comprehensive literature review is essential to understand the current state of research, identify gaps, and propose future directions in renewable energy systems. This section synthesizes recent studies and key findings in the field.

Solar Energy

Numerous studies have explored advancements in solar PV technology. Green et al. (2020) highlighted the rapid improvements in perovskite solar cells, achieving efficiencies over 25%, while addressing stability and scalability challenges. Research by Kim et al. (2019) emphasized the potential of tandem solar cells for further

efficiency gains. The integration of CSP systems with thermal energy storage was reviewed by Zhang et al. (2021), who identified key advancements in molten salt storage technologies.

Wind Energy

Recent reviews, such as by Sørensen (2020), focused on the aerodynamic optimization of wind turbines, particularly in offshore environments. Advances in composite materials for lighter and more durable turbine blades were discussed by Liu et al. (2018), addressing issues of fatigue and recyclability. Studies on grid integration by Chen et al. (2020) examined challenges related to variability and proposed solutions using energy storage and predictive modeling.

Biomass Energy

The role of biomass energy in the circular economy was extensively reviewed by Johnson et al. (2020), who emphasized the importance of waste-to-energy systems. Advances in anaerobic digestion and bio-refinery technologies were detailed by Sharma et al. (2019), highlighting their potential for sustainable biofuel production. The environmental impacts of large-scale biomass usage were critically assessed by Patel et al. (2021), advocating for the use of agricultural residues over dedicated energy crops.

Hydropower

Small-scale hydropower systems were reviewed by Ahmed et al. (2020), who noted their potential for rural electrification in developing countries. Tidal and wave energy systems were analyzed by Roberts et al. (2019), who identified significant progress in energy capture efficiency and durability of underwater components. However, the environmental trade-offs of hydropower, particularly on aquatic ecosystems, remain a key area of concern as noted by Wang et al. (2021).

Emerging Technologies

Emerging research into hydrogen energy, such as by Tan et al. (2020), highlighted the progress in green hydrogen production through water electrolysis powered by renewables. Studies on ocean energy by Brown et al. (2021) discussed innovations in wave energy converters and tidal stream generators. Geothermal energy's role in decarbonizing heating systems was reviewed by Smith et al. (2019), with a focus on enhanced geothermal systems (EGS) and their scalability.

INTEGRATION AND OPTIMIZATION OF RENEWABLE ENERGY SYSTEMS

Energy Storage Technologies

Energy storage systems, such as lithium-ion batteries, supercapacitors, and pumped hydro storage, are crucial for addressing the intermittency of renewable energy sources. Advancements in solid-state batteries and flow batteries are enhancing energy density and reducing costs, making storage more viable for large-scale applications.

Smart Grids and Microgrids

Smart grids and microgrids enable efficient energy distribution by integrating renewable energy sources with real-time monitoring and control systems. The use of artificial intelligence (AI) and machine learning algorithms further optimizes grid operations, enhances reliability, and reduces energy losses.

Hybrid Renewable Energy Systems

Hybrid systems that combine multiple renewable sources, such as solar and wind, provide greater reliability and efficiency. These systems leverage complementary energy generation profiles to ensure consistent power supply and reduce reliance on storage.

CHALLENGES IN RENEWABLE ENERGY SYSTEMS

Technological Challenges

Renewable energy technologies face several technical challenges, including efficiency limitations, intermittency, and process-induced material degradation. These issues hinder the scalability and reliability of renewable systems.

Economic Challenges

High initial capital costs and the need for subsidies remain significant barriers to widespread adoption. The development of cost-effective energy storage solutions is also essential for improving the economic viability of renewable systems.

Environmental Challenges

While renewable energy systems reduce greenhouse gas emissions, they may have environmental trade-offs, such as land use requirements and the lifecycle impacts of materials. Recycling and disposal of components like solar panels and wind turbine blades are growing concerns.

Social and Policy Challenges

Public resistance to renewable energy installations, such as wind farms, and inconsistent policy frameworks across regions impede progress. Supportive policies, incentives, and public awareness campaigns are needed to address these challenges.

RECENT ADVANCES IN RESEARCH AND DEVELOPMENT

Advances in nanotechnology, materials science, and AI are driving innovation in renewable energy systems. For example, nanostructured materials enhance the efficiency of solar cells and batteries, while AI optimizes energy management and forecasting. Research into bio-based materials and recycling technologies also contributes to the sustainability of renewable energy systems.

FUTURE DIRECTIONS AND OPPORTUNITIES

Future advancements in renewable energy systems include breakthroughs in hydrogen production, offshore wind and solar installations, and the adoption of circular economy practices. Innovations in energy storage and grid infrastructure will be critical for scaling up renewable energy adoption. Collaboration between governments, industries, and academia is essential for accelerating progress and achieving global sustainability goals.

CONCLUSION

Renewable energy systems represent a pivotal solution to global energy and environmental challenges. While significant progress has been made, addressing technical, economic, environmental, and social barriers is crucial for maximizing their potential. A multidisciplinary approach, driven by innovation and policy support, can ensure the transition to a sustainable and resilient energy future.

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Digital Forensics: Techniques, Challenges, and Future Directions

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ABSTRACT

Digital forensics is a critical field concerned with the investigation, analysis, and preservation of digital evidence in a manner that is legally admissible. With the rise of cybercrime, data breaches, and sophisticated cyber-attacks, digital forensics has become an essential tool for law enforcement and cyber security professionals. This paper examines the fundamental techniques, tools, challenges, and emerging trends in the digital forensics landscape. Key areas covered include data acquisition, analysis, reporting, the role of cloud and IoT forensics, and the impact of artificial intelligence. The paper also addresses ethical considerations and legal issues surrounding digital forensics.

KEYWORDS: *Digital forensics, Data acquisition, Cybercrime, forensic tools, Cloud forensics, Artificial intelligence, encryption.*

INTRODUCTION

Digital forensics is a specialized area of cybersecurity that focuses on the investigation of digital devices to identify, preserve, and analyse data relevant to criminal or civil cases. As the volume of digital data continues to grow, driven by increasing numbers of internet-connected devices and cloud computing, so too does the complexity of forensic investigation.

Digital forensic practitioners apply scientific methods to recover and analyse data from computers, mobile devices, servers, and other digital sources. As technology evolves, new challenges emerge, including data encryption, the growth of cloud computing, and the need

for faster and more efficient analysis tools. This paper provides an in-depth exploration of digital forensics methodologies, tools, challenges, and emerging trends that shape the field today and in the future.

DIGITAL FORENSICS METHODOLOGIES

Data Acquisition

Data acquisition is the initial stage of a digital forensic investigation. The goal is to collect digital evidence without altering or damaging it. This process typically

involves imaging storage devices to create exact copies of the data. There are two common methods for data acquisition:

- **Logical Acquisition:** This method involves collecting files and metadata that are accessible to the operating system. It does not involve recovering deleted files or examining the file system structure.
- **Physical Acquisition:** Involves copying the entire contents of the device, including hidden or deleted data, providing a more comprehensive snapshot of the device's state.

Forensic investigators also use write blockers to ensure that no changes are made to the data during acquisition. Proper handling and documentation of the chain of custody are essential for maintaining the integrity of the evidence, ensuring that it will be admissible in court.

Data Analysis

Once data is acquired, the next step is the analysis. Forensic investigators use specialized software tools to examine the data for evidence. The analysis typically involves:

- **File system analysis:** Investigating file systems and structures to recover deleted files and analyze hidden data.

- **Memory analysis:** Examining volatile memory (RAM) to uncover data such as active processes, encryption keys, or session data that could be valuable for the investigation.
- **Keyword searches and pattern recognition:** Investigators search for keywords, file signatures, or patterns that indicate illicit activity such as hacking tools, illicit content, or traces of cybercrime.

Advanced data analysis often requires the use of specialized forensic tools such as FTK Imager, EnCase, and Autopsy that support the recovery of deleted files, email tracing, and timeline analysis.

Reporting

After completing the analysis, the investigator must compile their findings into a detailed report. This report includes:

- **Methodologies used:** A clear description of the techniques, tools, and procedures employed during the investigation.
- **Findings:** Detailed descriptions of the recovered data and its relevance to the case.
- **Conclusion:** A summary of the evidence and its potential implications in the context of the legal or corporate investigation.

Reports must be clear, concise, and written in a manner that can be understood by non-technical stakeholders, including lawyers, judges, or executives

TOOLS AND TECHNIQUES IN DIGITAL FORENSICS

Forensic Software Tools

A variety of software tools are used in digital forensics investigations. Some of the most widely adopted forensic tools include:

- **EnCase:** A powerful and widely used forensic suite, capable of performing data imaging, recovery, and analysis on a variety of devices.
- **FTK (Forensic Toolkit):** Known for its advanced file carving capabilities, FTK is a robust solution for data recovery and analysis.
- **Autopsy:** A free, open-source tool often used for investigating digital crimes, particularly in academic and government settings.

These tools are indispensable for investigating file systems, recovering deleted files, examining system logs, and identifying evidence of malicious activity.

Hardware Tools and Techniques

In addition to software tools, hardware devices are essential for ensuring the integrity of digital evidence. Some of these tools include:

- **Write Blockers:** Devices that allow forensic investigators to read data from a storage device without writing to it, thus ensuring that the original data is not altered during acquisition.
- **Data Imaging Devices:** Specialized hardware used to create exact copies of digital storage devices, ensuring the data is preserved in its original state.

The use of these tools guarantees the proper collection of evidence, which is critical for both the integrity of the investigation and the admissibility of evidence in court.

Cloud Forensics

As more organizations and individuals shift to cloud-based services, digital forensic investigators must develop new methodologies for handling cloud data. Cloud forensics introduces unique challenges such as:

- **Data location:** Cloud data is often stored across multiple geographic locations, creating jurisdictional challenges for investigators.
- **Encryption and access control:** Cloud services frequently encrypt data, which can complicate access for forensic investigators without the proper decryption keys.
- **Multi-tenancy:** Cloud environments may host data from multiple clients, requiring investigators to separate and identify relevant data from large datasets.

Cloud forensics tools such as X1 Social Discovery and CloudForensics help investigators navigate these challenges by providing solutions for extracting, analyzing, and reporting on cloud-based data.

CHALLENGES IN DIGITAL FORENSICS

Data Encryption

Encryption is one of the most significant hurdles in modern digital forensics. Many users and criminals employ strong encryption to protect sensitive data on their devices, making it difficult for investigators to access

critical evidence. The use of encryption software, full disk encryption, and encrypted communications further complicates the investigative process. As encryption technologies evolve, digital forensics professionals must stay ahead of new techniques to unlock encrypted data without compromising evidence integrity.

Data Volume and Complexity

Modern digital devices generate enormous amounts of data. This includes data from emails, social media, file systems, logs, and even location tracking systems. Forensic investigators face the daunting task of sifting through vast amounts of information to identify relevant evidence. The sheer scale and complexity of modern data storage require the development of advanced search algorithms, machine learning, and AI to efficiently process and analyze data.

Legal and Ethical Issues

Digital forensics investigations must comply with strict legal and ethical standards. This includes respecting privacy laws, obtaining proper legal authorization, and adhering to proper evidence handling procedures. Failure to maintain proper chain-of-custody protocols can lead to evidence being inadmissible in court. Additionally, digital forensics professionals must navigate the complex issues of digital privacy and the ethical implications of accessing sensitive information.

EMERGING TRENDS IN DIGITAL FORENSICS

Artificial Intelligence and Machine Learning

Artificial intelligence (AI) and machine learning (ML) are rapidly transforming digital forensics. These technologies can automate repetitive tasks such as data analysis, anomaly detection, and evidence classification. Machine learning algorithms can be trained to recognize patterns of malicious activity, significantly speeding up the investigative process. AI-powered tools can also assist in identifying correlations between disparate pieces of evidence, which would otherwise go unnoticed in manual analysis.

Blockchain Forensics

The increasing use of cryptocurrencies and blockchain technology has led to the rise of blockchain forensics.

Blockchain transactions are publicly recorded, but the identities of the parties involved are often pseudonymous. Forensic experts are developing techniques to trace cryptocurrency transactions and uncover links to illicit activities such as money laundering, fraud, and ransomware payments.

IoT Forensics

The rise of the Internet of Things (IoT) devices presents new challenges for digital forensic investigators. IoT forensics involves examining data from interconnected devices such as smart thermostats, security cameras, and wearables. Investigating IoT data requires specialized tools and techniques to extract, analyze, and correlate information from a variety of devices with different operating systems and data formats.

CONCLUSION

Digital forensics is an essential discipline that plays a critical role in the fight against cybercrime and digital misconduct. As technology continues to evolve, so too must the tools, methodologies, and techniques used by forensic investigators. Challenges such as data encryption, large volumes of data, and legal complexities must be addressed with ongoing innovation and the development of new investigative techniques. The future of digital forensics will likely see the increased integration of artificial intelligence, machine learning, and blockchain technologies, helping investigators tackle emerging threats more effectively.

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Mechanical Vibration Analysis and Modelling Using Engineering Programs

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ABSTRACT

Mechanical vibrations significantly affect engineering systems, influencing their performance and longevity. This study explores methodologies for analyzing and managing mechanical vibrations, focusing on finite element analysis, modal analysis, and control algorithms. By integrating advanced signal processing and artificial intelligence (AI) techniques, it enhances fault detection and predictive maintenance. Key findings include the effectiveness of adaptive control systems, the potential of data-driven approaches, and the challenges in fine-tuning semi-active suspension systems. Despite advancements, further research is needed to bridge theoretical and practical gaps, revolutionizing diagnostics and improving industrial efficiency.

KEYWORDS: *Vibration analysis, Finite element analysis (FEA), Modal analysis, Control algorithms, Predictive maintenance, Signal processing, Artificial intelligence (AI), Fault detection, Machinery diagnostics, Semi-active suspension systems.*

INTRODUCTION

Mechanical vibrations significantly impact the performance and stability of engineering systems such as vehicles, industrial equipment, and aeronautical structures. Effective vibration analysis helps identify degradation, monitor machinery, and prevent failures. Sensors measuring acceleration, velocity, or displacement aid this process, with status monitoring providing real-time error alerts. Vibrations caused by external forces or mechanical interactions can lead to wear, reduced component lifespan, and catastrophic failures if left unmanaged.

This study examines methodologies for analyzing and managing mechanical vibrations, offering insights into dynamic system behavior and control techniques. By addressing data-driven methods and artificial intelligence (AI)-based solutions, the research explores effective approaches to vibration monitoring and fault diagnostics.

Key Research Questions

1. What tools are currently used for gathering vibration data?

2. How do popular vibration signal processing methods compare?
3. What are the latest AI techniques for machine vibration monitoring?
4. How do engineers apply vibration analysis for diagnostics?

METHODOLOGY

Recent advances in vibration analysis span experimental validation, computational simulations, and interdisciplinary approaches. Key methods include finite element analysis (FEA), modal analysis, and adaptive control algorithms. These techniques extend machinery lifespan, reduce maintenance costs, and improve structural reliability.

Modal Analysis

Modal analysis identifies structural behavior and natural frequencies under variable loading conditions. Techniques include experimental modal analysis (EMA), operational modal analysis (OMA), and frequency-domain decomposition (FDD). OMA is particularly effective for large structures where artificial stimulation

is impractical. The study highlights the importance of combining frequency-domain methods with singular value decomposition (SVD) to improve accuracy.

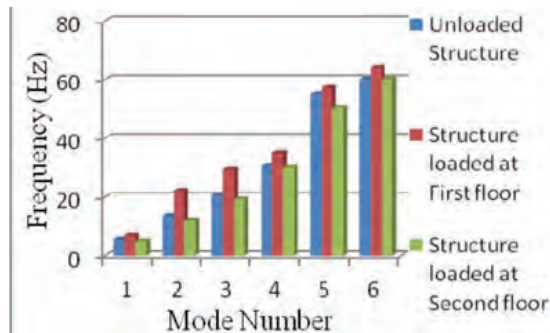


Fig. 1: Natural Frequency vs. Mode Number for Variable Loading Environments

Finite Element Analysis (FEA)

FEA simulates complex structures by breaking them into elements, modeling material behavior, and analyzing reactions to various loading scenarios. Engineers incorporate material properties, such as elasticity and boundary conditions, to predict static and dynamic responses. This method is widely applied to optimize mechanical designs.

Control Algorithms

Control systems, including adaptive algorithms and piezoelectric actuators, effectively manage vibrations. Passive solutions, such as tuned mass dampers, and active strategies, like proportional-integral-derivative (PID) controllers, enhance structural stability. Simulation studies validate their effectiveness in minimizing unwanted vibrations.

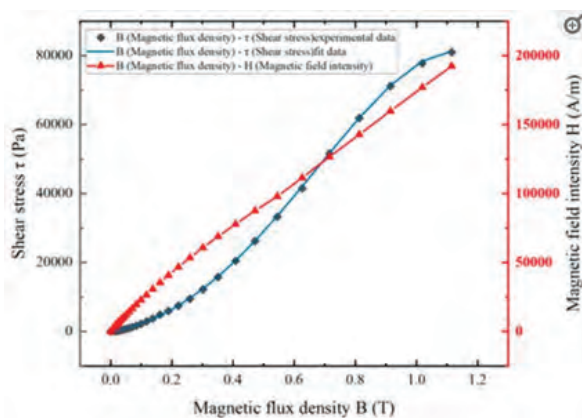


Fig. 2: MRF Magnetization Characteristics and Mechanical Properties

RESULTS AND DISCUSSION

Vibration analysis employs data-driven and model-based approaches. AI techniques, such as neural networks, enhance diagnostics by detecting faults and predicting failure patterns. Machine learning simplifies fault classification and supports predictive maintenance, reducing operational downtime. However, current studies reveal gaps in the practical application of theoretical models, underscoring the need for holistic research to improve vibration diagnostics.

Key findings highlight

- The superiority of advanced signal processing methods for fault detection.
- Challenges in fine-tuning semi-active suspension systems.
- The potential of integrating vibration data into predictive maintenance.

CONCLUSION

Vibration analysis plays a critical role in predictive maintenance and structural health monitoring. It aids in early fault detection, optimizing processes, and extending machinery life. Despite significant advancements, further research is needed to bridge gaps between theoretical models and real-world applications. Enhanced methods, such as integrating AI and advanced FEA tools, hold promise for revolutionizing vibration diagnostics and improving industrial efficiency.

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AI Healthcare Management System

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ABSTRACT

This paper presents a sophisticated AI-driven healthcare management system designed to transform medical practices through the integration of advanced technologies. The system features a centralized dashboard for real-time global health analytics, enabling healthcare providers to monitor trends, allocate resources, and respond effectively to public health challenges. By automating medical history management, it reduces administrative workloads while ensuring accurate and accessible patient data. The platform incorporates advanced diagnostic tools, including automated analysis of Complete Blood Count (CBC) reports and radiological image interpretation using computer vision, significantly enhancing diagnostic precision and efficiency.

A dual-chatbot system, powered by large language models, addresses diverse patient needs, offering personalized medical consultations and mental health support. This fosters a holistic approach to patient engagement and care. The system also includes symptom-based disease prediction for early intervention, an intelligent drug discovery database to accelerate pharmaceutical research, and automated appointment scheduling to streamline healthcare workflows and reduce patient wait times.

Experimental evaluations demonstrate notable improvements in diagnostic accuracy, operational efficiency, and patient satisfaction. By integrating clinical diagnostics, patient care, and administrative automation within a single unified platform, this system establishes a new paradigm in healthcare delivery, advancing medical outcomes and optimizing resource utilization while promoting equitable access to quality care.

INTRODUCTION

The landscape of modern healthcare faces unprecedented challenges in delivering effective patient care while managing vast amounts of medical data. Healthcare providers struggle with increasing patient volumes, complex diagnostic requirements, and the need for rapid, accurate medical decisions. Traditional approaches, which rely heavily on manual interpretation of medical reports, radiological images, and patient histories, often lead to diagnostic delays and resource allocation inefficiencies. Artificial intelligence emerges as a transformative solution, offering innovative approaches to these challenges. By integrating advanced computer vision for medical imaging and CBC report analysis, natural language processing

for medical history documentation, and large language models for patient interaction through medical and mental health chatbots, healthcare providers can now process and analyze medical information with unprecedented efficiency. The implementation of interactive dashboards for global health analytics, combined with intelligent disease prediction systems and drug discovery databases, enables healthcare providers to deliver personalized treatment recommendations while optimizing resource allocation through automated appointment scheduling. This technological advancement addresses the growing demand for personalized medicine, where treatment plans are tailored to individual patient profiles through comprehensive data analysis. The integration of these AI-driven tools promises to streamline operations, reduce

human error, and revolutionize healthcare delivery through a unified, intelligent platform.

LITERATURE SURVEY

The AI Health Management System addresses the growing challenges of modern healthcare, such as increasing patient volumes, diagnostic complexities, and data overload. By integrating artificial intelligence, machine learning, natural language processing (NLP), and computer vision, this system enhances patient care, automates administrative tasks, and enables data-driven decision-making. Through these advanced tools and techniques, healthcare providers can deliver personalized treatments, predict diseases, and optimize resource allocation.

Artificial intelligence has demonstrated remarkable potential in transforming healthcare by enabling precision medicine, optimizing workflows, and improving diagnostic accuracy. Sanjeev Kumar Marimekela et al. [1], in their research “Using AI and Big Data in the HealthCare Sector to Help Build a Smarter and More Intelligent HealthCare System” (2024), examined the use of AI and big data to create data-driven systems. The study demonstrated how AI models analyze diverse data types, including patient history and genetic information, to improve decision-making for vulnerable populations. The authors also addressed challenges in data integration, quality, security, governance, and visualization, emphasizing the need for robust infrastructure, domain expertise, ethical considerations, and privacy to secure healthcare data.

Clinical text, such as physician notes and discharge summaries, holds vital patient information but is often unstructured and challenging to process. Divyanshu Katyan et al. [2], in their paper “Utilizing NLP for Enhanced Clinical Text Mining” (2024), emphasized the transformative potential of Natural Language Processing (NLP) in healthcare. Their research highlighted how NLP empowers healthcare providers by streamlining workflows, enabling precise diagnoses, creating personalized treatment plans, and optimizing decision-making processes. The study also explored topics such as cancer terminologies, EHR analysis, and drug attributes, analyzing their impact on patient care and envisioning a future where clinical text mining becomes integral to superior healthcare services.

The use of machine learning in healthcare is increasing with continuous advancements in early prediction of chronic diseases based on patient symptoms and changes. Sameer

Rai et al. [3], in their study “Multiple Disease Prediction Using ML” (2023), introduced a disease prediction system utilizing machine learning to enhance diagnostic accuracy. The research outlined how Python and Flask-based systems process user- input data from hospital databases to predict potential illnesses. The system demonstrated improved diagnostic precision compared to traditional methods, supporting healthcare providers in making timely evaluations and improving disease prevention and treatment outcomes.

Generative AI (GenAI) and large language models (LLMs) are revolutionizing the healthcare sector by incorporating complex technologies. Chettim Chetty Hemasri et al. [4], in their study “Redefining Medicine: The Power of Generative AI in Modern Healthcare” (2024), explored the impact of generative AI models, including Med-PaLM and BioGPT, on diagnostics, drug discovery, and clinical decision-making. The authors discussed real-world applications, highlighting significant advancements in patient outcomes and resource optimization. However, the study also addressed challenges related to data security, ethical concerns, and regulatory compliance, emphasizing the importance of addressing these issues for widespread adoption of GenAI in healthcare.

Ogunsakin and Anwansedo [5], in their study “Leveraging AI for Healthcare Administration: Streamlining Operations and Reducing Costs” (2024), examined the use of AI technologies like Robotic Process Automation (RPA), predictive analytics, and Natural Language Processing (NLP) in healthcare. They highlighted how AI can automate tasks such as appointment scheduling, billing, and documentation, reducing administrative burdens and improving efficiency. The study also emphasized the role of predictive analytics in optimizing resource allocation and the use of NLP for better communication among healthcare providers. The authors stressed the need for ethical practices and regulatory compliance to fully leverage AI in healthcare administration.

PROPOSED METHODOLOGY

This paper presents the methodology employed in developing a unified AI platform designed to address the challenges of modern healthcare. The platform integrates several AI-driven modules to streamline operations, enhance diagnostic accuracy, and facilitate personalized treatment. This retrospective analysis details the methodologies used in each module’s development.

Overall System Architecture:

This project has various features which prove to be solutions to the existing issues in the current healthcare systems. An overall system architecture is proposed below:

Data Acquisition and Preprocessing: This handles the collection and preprocessing of various data types, including medical images (CT scans, MRIs), CBC reports, patient medical histories (structured and unstructured), and global health datasets.

Data Analysis: The collected data is analyzed to uncover various patterns referring to trends in the medical world. This analysis help us to develop further models to build on a solution for the issues been highlighted through the analysis. **Technology Building:** Here, based on the analysis, the model development is started. Various models like ML models, AI models and LLMs are trained and tested and using a majority pool model selection technique, the best performing model is chosen.

Interface Development: Here, the frontend interface is created for providing an appealing view of the system to the end users. The development is started along with the model development phase.

Module-Specific Methodologies**Appointment Scheduling**

The appointment scheduling system was designed using a rule- based algorithm and extraction models were implemented to get details of all the doctors across the nation, which automated the scheduling process by considering both patient and provider availability. This system streamlined the process, ensuring that appointments were efficiently managed and that healthcare professionals could allocate their time optimally. The algorithm was integrated into the overall healthcare management platform, enhancing operational efficiency.

Interactive Dashboard

A web-based dashboard was developed utilizing data visualization tools like PowerBi online, to present dynamic and interactive visualizations. The dashboard integrates data from all system modules, providing a comprehensive overview of both system performance and global health data, allowing for real-time monitoring and insightful analysis of trends and patterns.

Medical Image Analysis (Computer Vision)

For medical image analysis, publicly available datasets

and anonymized data from collaborating hospitals were used. Convolutional Neural Networks (CNNs), including U-Net and ResNet architectures, were employed for the tasks of segmentation and classification. These models were trained using transfer learning and fine-tuning techniques, with optimization performed via the Adam optimizer and cross- entropy loss function. The evaluation of model performance was based on various metrics such as the Precision, Recall, F1 Score and Accuracy, ensuring high accuracy and reliability in medical image diagnostics.

CBC Report Analysis (Computer Vision and NLP)

The CBC report analysis was approached using a hybrid of computer vision and natural language processing (NLP). For textual components of the CBC reports, an extraction tool; Tesseract OCR was used to extract relevant information and these components were stored as structured data using NLP. The structured data was then used on a pre trained ML model offering a detailed and comprehensive analysis and diagnosis of the CBC reports to assist healthcare professionals.

Medical History Processing (NLP)

The medical history taking leverages webpage with form-like structure to help users and doctors keep a record of the medical history of a particular patient. The webpage has various fields like personal information, current medical condition, medical history, allergies, etc to have a comprehensive collection of the patients' overall medical history thereby, aiding in smoother EHR creations and model improvements.

Symptom-to-Disease Prediction

The symptom-to-disease prediction module uses combination of genomic medical datasets extracted from various public sites like Kaggle, PubMed, MIMIC-IV, etc. Machine learning algorithms, including Naive Bayes, Support Vector Machines (SVMs), and Random Forests, were employed to predict potential diseases based on reported symptoms. The model's performance was evaluated using standard classification metrics, including accuracy, precision, recall, and F1-score, ensuring robust and reliable disease predictions.

Medical and Mental Health Chatbots (LLMs)

Fine-tuned large language models (LLMs) were implemented to power medical and mental health chatbots, focusing on natural language understanding and generation. These chatbots were trained on specialized

medical and mental health dialogue datasets, enabling them to engage in contextually aware conversations with users. The chatbot's performance was assessed using metrics such as user satisfaction, task completion rate, and conversation coherence, ensuring an optimal user experience and efficient interactions.

Drug Discovery Database

A comprehensive drug discovery database was developed, containing detailed information on drugs, including indications, contraindications, and drug interactions. A robust search interface was incorporated into the platform, allowing users to easily search for relevant drugs based on specific medical conditions, facilitating quick access to critical drug information and assisting healthcare providers in treatment decision-making.

PROCESS FLOW

Login/Register: Users begin by logging into their existing accounts or creating a new one, ensuring secure access to their personal and medical data. New users are required to provide basic information for account creation, while returning users authenticate with their credentials to access their profile.

Authentication: The system verifies user credentials through secure login processes. If successful, users are directed to the homepage where they can access various features; if the login fails, they may be prompted to retry their login details or exit the system. This ensures that unauthorized access is prevented.

Database: Serving as the backbone of the system, the database securely stores essential information, such as user credentials, health data, and analysis results. It allows for smooth data retrieval, secure storage, and efficient updates, ensuring that all user-related information is accurately maintained.

Homepage: Upon successful authentication, users are directed to the main dashboard. The homepage presents an overview of the system's features, including options like the Global Health Map and personalized Health Status. Users can quickly navigate to different sections from here, allowing for a seamless experience.

Global Health Map: Selecting this option provides users with a detailed overview of global health trends, including disease patterns and public health statistics.

Health Status: This feature offers personalized health updates and metrics, allowing users to monitor their medical information and progress over time.

Report Analysis: Users can upload medical reports to this section, where the system analyzes the data to provide diagnostic insights for better understanding of their health.

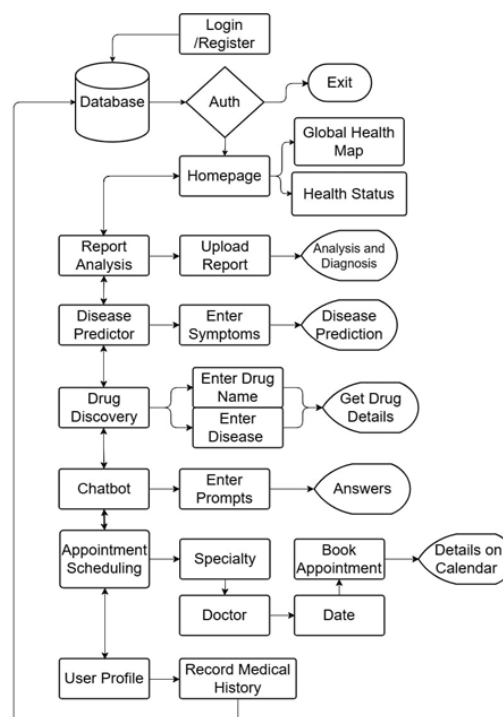


Fig: 1. Flowchart

Disease Predictor: In this step, users input their symptoms, and the system predicts possible diseases or conditions, acting as an initial diagnostic tool.

Drug Discovery: This feature lets users search for drug information by entering a drug name or specifying a disease, providing comprehensive details about medications and treatments.

Chatbot: The chatbot acts as a virtual assistant within the platform, available 24/7 to answer user queries and guide them through various functionalities. Whether users need help navigating the platform or require information about health-related topics, the chatbot provides instant support and assistance.

Appointment Scheduling: Users can book medical appointments by selecting a specialty, choosing a doctor, and setting a date. The scheduled appointment is then displayed on a calendar for their convenience.

Record Medical History: This feature allows users to store or update their medical history within the system, ensuring all relevant information is accessible for future reference.

Exit: Users have the option to exit the system at any time, providing a straightforward way to end their session.

IMPLEMENTATION MODULES

User Interface (Fig: 2., Fig: 3) The user interface serves as the main point of interaction, designed to be simple, intuitive, and responsive for easy navigation. The homepage provides access to key features like report uploads, appointment scheduling, and chatbot services, ensuring accessibility for a wide range of users.



Fig. 2 Interface



Fig. 3 3D Model

Registration and Authentication

This module manages secure user access through registration and login. It protects user data with encryption and password hashing, ensuring only authorized access. Upon successful login, users are directed to the homepage.

Report Analysis and Diagnosis (Fig: 4)

Users can upload medical reports (e.g., PDFs, images), which are then processed using advanced algorithms to extract and analyze data. The system provides diagnostic insights to help users understand their health.

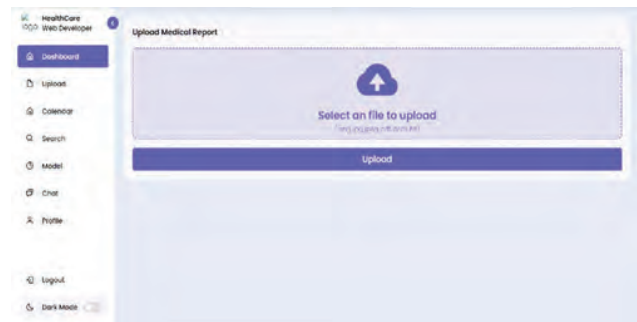


Fig. 4 Report Analysis and Diagnosis

Symptom

Based Disease Prediction

This module enables users to input symptoms, which the system uses to predict potential medical conditions by cross-referencing with a medical database. It aids in early diagnosis and timely medical intervention.

Drug Information Search

Users can search for drug details by name or disease, accessing comprehensive information on usage, side effects, and alternatives. This feature supports informed decision-making regarding treatment options.

Virtual Assistant (Chatbot) (Fig: 5)

The chatbot provides a conversational interface for users to ask questions and receive assistance. It uses natural language processing (NLP) to understand queries and guide users, improving their experience.



Fig. 5. Medical chatbot

Appointment Management (Fig: 6, Fig: 7)

This feature simplifies appointment booking by allowing users to select a specialty, healthcare provider, and date. Scheduled appointments are displayed on the user's calendar, streamlining the process.

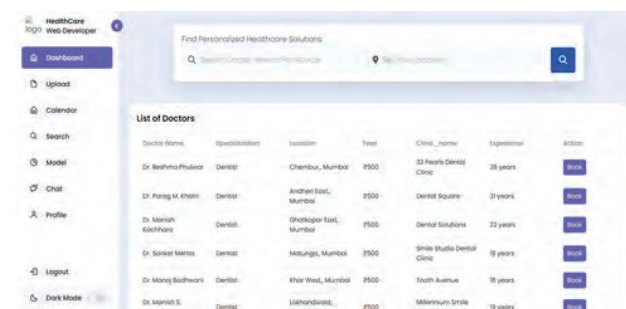


Fig. 6. Appointment Scheduling

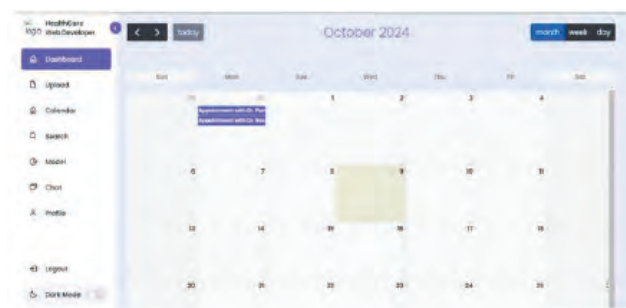


Fig. 7 Calendar

Medical History and Personal Details Recording (Fig. 8) Users can document and manage their personal data and medical history, including past conditions and treatments. This information is securely stored and accessible for future consultations or analysis.

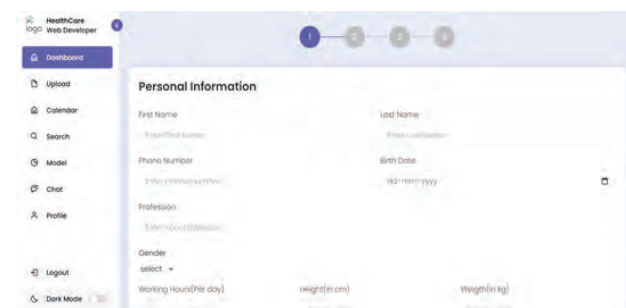


Fig. 8 Medical History and Personal Details Recording

CONCLUSION

This healthcare system offers a modern and efficient solution for managing healthcare tasks by automating processes such as report analysis, disease prediction, and appointment scheduling. This automation not only reduces manual work but also enhances accuracy, providing a smooth and personalized experience for users. As technology advances, the system can evolve by incorporating features like real-time health tracking,

integration with wearable devices, and advanced analytics. These upgrades will ensure the platform stays adaptable and continues to meet the increasing demands of users across diverse healthcare sectors.

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Design of Ring Oscillator using MOSFET at 32nm AND 45nm using MICROWIND Tool with Comparison of Performance Parameters

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ABSTRACT

A ring oscillator is a circuit that oscillates between two voltage levels, representing true and false. A ring oscillator made with MOSFETs is primarily used to measure the delay characteristics of a given manufacturing process. The CMOS technology has advantages, like low power consumption, high noise immunity, and cost-effectiveness. This paper will present the design and performance analysis of a 5-stage ring oscillator using MOSFETs in 32nm and 45nm technology nodes. The design and simulations were done using the Microwind tool. Important performance parameters such as propagation delay, power consumption, and frequency of oscillation have been compared minutely. It reports the effect of technology scaling on ring oscillator performance and gives a glimpse into low-power and high-speed circuit design. It shows extreme improvements in performance of the 32nm node Propagation Delay (ps), Power Consumption (mW), and Frequency (GHz) as compared to that of the 45nm node and shows the merits of advanced technology nodes for high-speed applications.

KEYWORDS: Ring oscillator, MOSFET, 32nm technology, 45nm technology, Microwind tool, Performance analysis, Technology scaling.

INTRODUCTION

Ring oscillators are extensively used in several applications including clock generation, signal synthesis, and on-chip testing [1, 2]. They have simplicity, ease of integration, and scalability which is based on current requirements for modern electronic circuits. With the continuous downscaling of CMOS technology, the design of ring oscillators has become more challenging due to increased variability and power density.

This paper deals with the design of a 5-stage ring oscillator based on MOSFETs at 32nm and 45nm technology nodes. The main performance metrics under evaluation are frequency, power consumption, and delay. All the simulations have been performed by the Microwind tool, which is the most popularly used software in VLSI design and analysis.

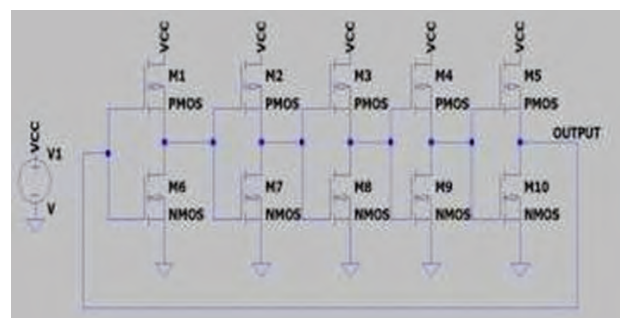


Fig. 1. Schematic of 5-stage Ring Oscillator

RING OSCILLATOR

The basic element in a ring oscillator is an inverter cell. The cell consists of complementary pairs of pmos and nmos. The two cells are also symmetric in the way that

parameters like channel length, doping are same for both the devices. Inverting operation means when input is low output gets high and vice-versa as in [7]. The inverter is now almost used in all digital designs. The behaviour of any complex circuit can be determined by estimating the results obtained for the inverters. All digital as well as analog designs can be fabricated using CMOS technology as in [8]. CMOS inverter is the combination of MOS transistors i.e. pmos and nmos, where pmos is called as pull-up network and nmos is called as pull-down network. When input is low, nmos is OFF, pmos gets ON, pulling the transistor high and when input becomes high, nmos gets ON, driving the network down and output becomes low as in [9]. It is shown in figure 2.

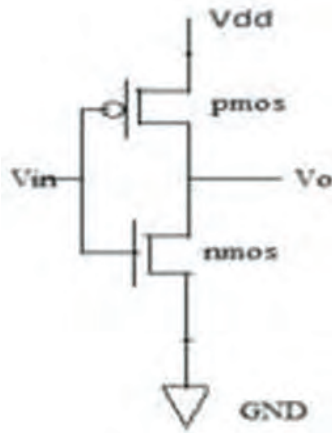


Fig. 2 CMOS Inverter

In a ring oscillator, the gain stages are connected in a loop where output from the last stage is given to the input of the first stage. The circuit must satisfy the Barkhausen criteria in order to provide sustained oscillation, where the circuit should provide unity voltage gain and it must have a phase shift of 2π . The DC inversion provides π phase shift and the remaining π phase shift is divided equally among the stages in the ring oscillator, so each delay gives phase delay of π/N , where N is the number of stages in the oscillator as in [10].

Table 1. Transistor Dimensions in 45nm Ring Oscillator

MOS Type	Mode	Drawn Length (nm)	Effective Length (nm)
nMOS	Low Leakage	40	35
nMOS	High Speed	40	30
pMOS	Low Leakage	40	35
pMOS	High Speed	40	30

Table 2. Transistor Dimensions in 32nm Ring Oscillator

MOS Type	Mode	Drawn Length (nm)	Effective Length (nm)
nMOS	Low Leakage	36	32
nMOS	High Speed	36	26
pMOS	Low Leakage	36	32
pMOS	High Speed	36	26

DESIGN METHODOLOGY

Technology Nodes

The 32nm and 45nm technology nodes were chosen for this work because of their widespread usage in modern semiconductor devices [8, 7]. The major parameters for these nodes, like supply voltage, threshold voltage, and channel length, were extracted from the Microwind library.

Ring Oscillator Architecture

A ring oscillator is the design of an odd number of inverters connected in a loop with feedback to ensure oscillation. The architecture used in this work consists of a 5-stage CMOS inverter ring oscillator.

Five-Stage Ring Oscillator

Provide stable oscillation since there exists an odd number of inversions. It is designed using CMOS inverters which minimize power consumption and maximize performance. Simulation Parameters

VDD = 1.0 V (45nm) and 0.9 V (32nm)

C load= Typical values depending on the technology.

Simulation Tool

In designing and simulation, an advanced VLSI design and simulation tool, known as Microwind, has been utilized that is capable enough to support different layouts of layouts, electrical checking of rules with dynamic simulations within it [11].

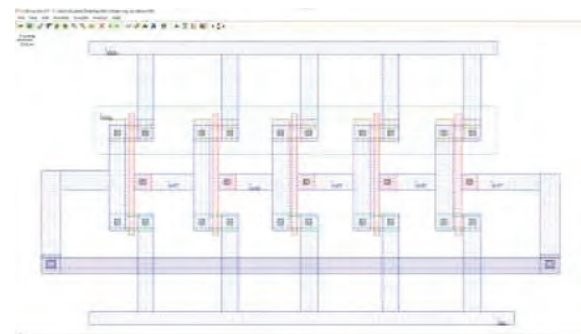


Fig. 3. Stage Ring Oscillator on 32nm and 45nm

PERFORMANCE METRICS

The following is the metrics assessed for both: Propagation Delay is the time spent in signal propagation when it travels down the ring oscillator chain.

Power Dissipation is obtained in static mode and dynamic, respectively.

Frequency of Oscillation: Determined from the output waveform of the ring oscillator.

RESULTS AND DISCUSSION

Simulation Results

Simulation results for 32nm and 45nm 5-stage ring oscillators are reported in Table 1.

Propagation Delay (Ps)

45nm Node: 78.5 ps 32nm Node: 45.2 ps

Propagation delay is the delay taken by a signal to travel through the circuit. For propagation delay, the propagation delay of the 32nm process node is lower (45.2 ps) than that of the 45nm node (78.5 ps), reflecting better speed and response time with the reduction in the nodes' size.

Power Consumption (mW)

45nm Node: 0.89 mW 32nm Node: 0.54 mW

Power consumption is the electrical power the VCO circuit uses to function. It has a number of benefits in terms of power consumption at 0.54 mW, in the instance of the 32nm node, while 45nm node consumes 0.89 mW power, primarily benefits low power designs primarily due to their application in devices powered by the battery or Internet of Things system.

Frequency (GHz):

45nm Node: 12.7 GHz

32nm Node: 22.1 GHz

The rate of oscillation is the oscillation frequency of the VCO, and high frequency leads to good performance in any application requiring the generation of instantaneous signals. The 32nm node is thus proven against the 45nm node to mark 22.1 GHz while the latter manages to reach only 12.7 GHz, thus the smaller node here provides switching with speed as well as high frequency oscillation.

Output

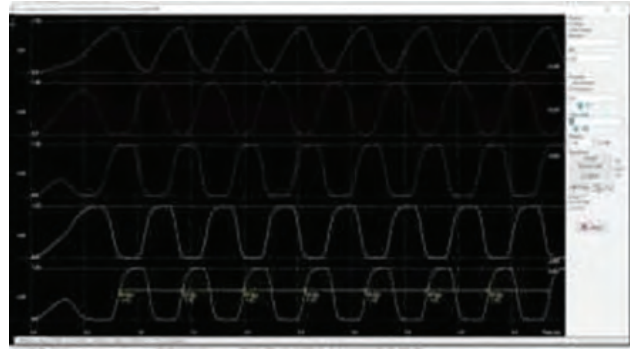


Fig. 4. Output of MOSFET Ring Oscillator using 32nm

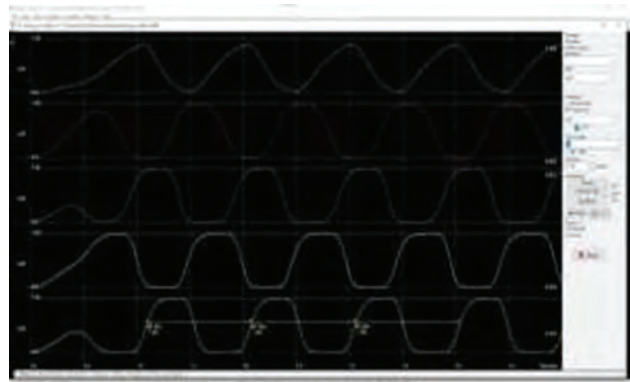


Fig. 5. Output of MOSFET Ring Oscillator using 45nm
Comparison with Existing Work

A comparison is carried out on average delay, power consumption, frequency, and VDD of the designed 5-stage ring oscillator along with available existing designs in literature [13, 16, 7]:

Performance Analysis

The findings based on these performance parameters for 32nm node are shown:

Less Delay: The delay was reduced to about 42% compared to the 45nm node.

Low Power Consumption: The power consumption is reduced by 39% at the 32nm node, thus energy efficiency is seen in this.

Higher Oscillation Frequency: The frequency has increased by about 74%. This makes the design apt for high speed applications.

Design Challenges

Apart from the superior performance of the 32nm node, its

leakage currents and process variability increase, which must be taken care of during design.

Table 3. Comparison with Existing Results

Study	Presented work	[13]	Presented work	[16]	[7]
Technology Node	45nm	45nm	32nm	32nm	65nm
VDD (V)	1.0 nm	1.0	0.9nm	0.9	1.2
Propagation Delay (ps)	78.5nm	85	45.2nm	48	112
Power Consumption (mW)	0.89nm	0.96	0.54nm	0.58	1.20
Frequency (GHz)	12.7nm	11.9	22.1nm	20.9	9.8

CONCLUSION

This paper work depicts the advantages of scaling in technology for ring oscillator design. The 5-stage ring oscillator, at the 32nm node, performs 42% better in speed and 39% better in power efficiency compared to the 45nm node. The propagation delay decreased by 42%, the power consumption was reduced by 39%, and the frequency of oscillation increased by 74% in moving from the 45nm to the 32nm technology node. These improvements highlight that advanced technology nodes are promising for implementing low-power circuits with high operating speeds, very suitable for various modern applications that include high frequency communication systems, IoT devices and many others. However, some of the scaling associated problems, such as increased leakage current and process variation, need particular attention in designs.

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Building Momentum: Machine Learning for Predicting Stock Performance with Technical Indicators

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ABSTRACT

This study explores the application of machine learning (ML) in momentum trading using a simplified approach based on publicly available data such as candlestick charts, volume, and moving averages. By utilizing Long Short-Term Memory (LSTM) networks, the model analyzes historical stock data and key technical indicators to predict future price movements. Emphasizing accessibility over computational complexity, the approach demonstrates the potential of ML to enhance trading strategies while maintaining the fundamental dynamics of equity markets. This research highlights the efficacy of combining traditional technical analysis with ML techniques enhancing buying strategies.

KEYWORDS: Momentum investing, Machine learning, Stock market, Equities trading, Long short-term memory.

INTRODUCTION

Equity markets have long been a cornerstone of the global economy, reflecting the resilience and dynamism of a nation's economic framework. The exchange of shares between investors and traders introduces a human element that has historically insulated these markets from the full effects of automation and artificial intelligence (AI) [10]. While many industries have embraced automation to optimize efficiency, the foundational structure of stock markets relies on human participation to ensure the balance of winners and losers, a dynamic central to their functioning [1, 10].

Trading operates on a zero-sum principle: for every profit gained by one participant, there is a corresponding loss incurred by another. This inherent balance fosters constant interaction among traders, each seeking to gain a competitive edge [8]. The human element introduces subjectivity and unpredictability, preventing any one participant from consistently dominating. This stands in contrast to the objectives of computerized systems, which

aim for near-perfect accuracy and consistent success [6, 7]. Hypothetically, if an AI system were to achieve such flawlessness, it would disrupt this equilibrium, generating significant implications for the market's stability [4, 5].

Such a system would inevitably draw attention, potentially triggering an AI arms race as others seek to replicate its success. Two possible scenarios could emerge. In the first, the original creator monopolizes success, driving other participants out of the market and eroding its functionality due to declining volumes and competition [3]. This outcome would ultimately destabilize the market and undermine the system's own viability. In the second, widespread replication of the system restores equilibrium, as participants lose their competitive edge and the market returns to its inherently unpredictable state [2, 9]. In either case, the zero-sum nature of trading ensures that if everyone is winning, then effectively no one is winning [10].

This paper aims to explore a middle ground by investigating a simplified, machine learning-driven approach to trading.

Unlike advanced quantitative models that demand extensive datasets and complex algorithms, this study focuses on publicly available data parameters, such as candlestick charts, volume, and moving averages [2, 8]. By emphasizing accessibility and simplicity, the research seeks to determine whether such an approach can achieve consistent success without compromising the foundational dynamics of equity markets [4, 6]. Recognizing the critical role of timely selling in maximizing profits, this aspect is left for future research due to its complexity and the challenges it poses for machine learning implementation [7].

Through this investigation, we aim to contribute to the discourse on integrating AI into financial markets, addressing the balance between leveraging technological advancements and preserving the essential characteristics of equity markets.

REVIEW OF LITERATURE

Application of Machine Learning (ML) in financial markets, particularly for momentum trading, has always been the holy grail pursued by techies and finance professionals alike. Momentum strategies, which are based on the assumption that assets with recent price trends will continue to perform in the same direction, offer an interesting challenge for machine learning models. These strategies typically rely on historical price and volume data, alongside technical indicators such as moving averages (MAs), to forecast future price movements. [1,3]

Brenøe (2018) explored the application of artificial intelligence (AI) to momentum trading, emphasizing how machine learning can capture complex patterns in market behavior that traditional models may overlook [1]. By focusing on historical price trends and volumes, AI models can learn the dynamics of momentum, potentially enhancing the prediction of profitable trades. This resonates with the approach of using simpler, more accessible data parameters like volume and MAs, as such models require less computational complexity and may still yield valuable insights into market trends. Similarly, Takeuchi and Lee (2013) introduced deep learning models to enhance momentum trading strategies [2]. By leveraging deep neural networks, they demonstrated that deep learning could improve the accuracy of predictions for stock momentum. While their methods rely on more extensive data sets and sophisticated algorithms, their findings underscore the potential for machine learning to optimize trading decisions based on technical indicators

like volume and MAs. The authors' work suggests that even relatively simple data parameters, when processed by advanced models, could lead to successful momentum strategies.

While more complex models have shown promise, other studies advocate for simplified approaches that focus on more basic data inputs. For instance, Li and Tam (2018) provided a comprehensive overview of machine learning methods in momentum and reversal trading, illustrating that even basic features such as price movements and trading volumes can be effective in predicting stock behavior [3]. Their work suggests that simpler models—such as those based on technical indicators like moving averages—can offer a balance between performance and computational efficiency.

Furthermore, Duan (2024) compared momentum strategies with moving averages and machine learning techniques, emphasizing the potential of combining traditional methods with modern computational tools [8]. His analysis found that while simple moving averages (SMAs) could identify short-term trends, machine learning algorithms could significantly enhance the predictive power of such strategies by capturing non-linear relationships in the data. This supports the idea that combining machine learning with basic indicators like moving averages can be effective for momentum trading, without necessitating overly complex or resource-intensive models.

The works of Pu et al. (2023) and Tan et al. (2023) extend the use of machine learning in optimizing momentum strategies. Pu and colleagues focus on optimizing momentum strategies through learning to learn financial networks, offering insights into how adaptive models could improve the performance of momentum-based trading systems [5]. Their approach could, in theory, be extended to simpler models by using various key parameters for more accessible trading decision-making.

Meanwhile, Tan et al. (2023) take a spatio-temporal approach to momentum strategies, jointly learning time-series and cross-sectional features [9]. This methodology offers a sophisticated take on momentum trading, but it also underscores the increasing complexity of leveraging machine learning for this type of analysis. While their approach focuses on more granular aspects of stock behavior there is still scope for using simpler approaches to testing momentum models without the need for high-dimensional or multi-layered data.

In more recent advancements, Liu et al. (2023) applied Long Short-Term Memory (LSTM) networks for stock return momentum prediction, showcasing the power of deep learning models in capturing long-term dependencies in market data [7]. While their focus is on more complex models, their findings emphasize how deep learning could improve predictions of momentum by accounting for historical patterns. These developments highlight the increasing reliance on deep learning for more accurate and dynamic momentum predictions.

PROPOSED SYSTEM AND METHODOLOGY

The proposed system leverages Long Short-Term Memory (LSTM) networks to develop a simplified momentum-based trading strategy. This methodology integrates rule-based technical analysis with advanced machine learning techniques to analyze historical stock price data and generate actionable buy or ignore recommendations. By combining traditional technical analysis with machine learning, the system ensures a balanced and interpretable stock-picking strategy. The integration of rule-based methods filters out irrelevant data, while the LSTM model leverages historical patterns to make data-driven predictions.

Data Collection and Preprocessing

- 1) **Historical Price Action Data:** The process begins with loading historical stock price data, including daily timeframe open, high, low, close prices, and trading volume.
- 2) **Feature Engineering:** Financial indicators such as Exponential Moving Average (EMA), Relative Strength Index (RSI), Moving Average Convergence Divergence (MACD), Bollinger Bands, and On-Balance Volume (OBV) are computed to capture momentum, trends, and volatility in stock prices.
- 3) **Sequence Generation:** The data is structured into time-series sequences of fixed length (e.g., 30 days), with each sequence used to predict the stock's movement on the subsequent day.
- 4) **Target Variable Creation:** A binary label is generated, where "1" represents an upward trend (buy) and "0" indicates a downward or sideways trend (ignore).

Model Architecture

- 1) **Bidirectional LSTM Layers:** The model uses

Bidirectional LSTMs to capture sequential patterns in stock price data from both past and future contexts, improving trend detection accuracy.

- 2) **Dropout Layers:** Dropout layers are incorporated to prevent overfitting by randomly deactivating neurons during training.
- 3) **Dense Layer:** A fully connected Dense layer maps the LSTM outputs to a binary classification (buy or ignore).

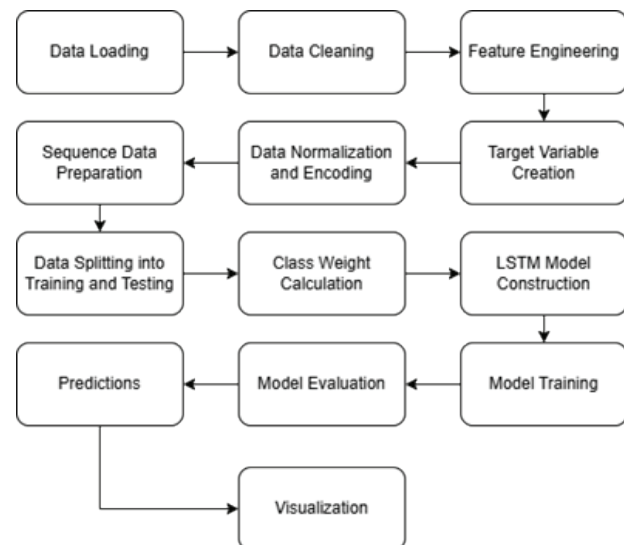


Fig. 1. Block Diagram of Proposed Solution

Training and Optimization

- 1) **Loss Function:** Binary cross-entropy is used to minimize the error between the predicted and actual labels.
- 2) **Class Imbalance Handling:** Class weights are applied to address any imbalance in the "buy" and "ignore" labels in the dataset.
- 3) **Early Stopping:** Training stops automatically when the model's performance on validation data ceases to improve, avoiding overfitting.
- 4) **Rate Scheduling:** Dynamic adjustment of the learning rate during training enhances model convergence.

Prediction and Decision-Making

- 1) **Probability Threshold:** The trained model predicts the probability of a stock's price increase. A threshold (e.g., 0.5) is used to classify predictions into buy or ignore categories.

- 2) Rule-Based Filtering: Stocks that do not meet specific criteria, such as high volatility or proximity to All-Time Highs (ATH), are excluded before making predictions, ensuring relevance.

Scope and Limitations

The proposed system focuses solely on buy recommendations, leaving the critical aspect of timely selling for future research. This ensures a manageable scope while allowing future development to enhance profitability.

The methodology aims to strike a balance between simplicity and effectiveness, making AI-driven trading accessible to individual traders without compromising market dynamics.

RESULTS AND DISCUSSIONS

For this project, we analyze daily candlestick charts, where each candle represents a stock's price movement during the trading day. Candles display the opening, closing, high, and low prices, while their color indicates whether the stock price rose (green) or fell (red). Volatility is represented by the upper and lower wicks.

The analysis begins by filtering stocks trading near their all-time highs (ATH), sorted by percentage change to identify the most volatile stocks. Trends are identified using higher highs and higher lows (HH-HL) or lower highs and lower lows (LH-LL).

Key indicators used include Exponential Moving Averages (10, 21, 50, 200-day), RSI, MACD,

Bollinger Bands, and On-Balance Volume (OBV). Stocks showing consistent trends above the moving averages, validated by volume spikes (1.5x to 2x the average), are considered strong candidates. Breakouts from consolidation stages, confirmed by sudden increase in volume and directional EMA shifts, signal potential buying opportunities.

Additional chart patterns, such as volatility contraction or inverse head-and-shoulders, are reserved for future scope due to their complexity. This approach ensures a systematic and simplified methodology for identifying potential momentum trades.

RESULTS

The model was back tested over the market activity for the financial year 2023-2024. This backtested efficiency data of the stock was compared to the trading performance data

of an experienced trader over the same period. The model recommended stocks to buy before the start of the financial year, however the sell actions were done manually using human intervention due to the lack of selling criteria in the model. While the appropriate selling was done manually, the model was run at regular intervals to frequently make buy decisions and replenish sold positions. This testing yielded a profit of 32% for the given financial year which is a considerable improvement compared to the human trader's 27% profit over the same period.

These results show that the model is successful at identifying profitable stocks, with a notable improvement over human expertise. The model was able to recommend stocks that yielded higher returns while minimizing losses, demonstrating the power of machine learning in financial decision-making.

The success of our model can be attributed to several factors:

1. Effective Use of Financial Indicators: By incorporating a diverse set of indicators such as EMA, RSI, and Bollinger Bands, the model was able to capture important trends and price movements. These indicators not only helped the model understand market sentiment but also acted as decision-making aids for filtering out less promising stocks.
2. LSTM Network's Ability to Capture Temporal Dependencies: The LSTM's ability to analyze sequential data allowed the model to capture long-term trends in stock price movements. The Bidirectional LSTM layers enhanced the model's ability to learn both past and future patterns, improving its predictive capabilities.
3. Backtesting with Real-World Data: The backtesting process, in which the model's predictions were tested on real-world stock data, demonstrated its practical applicability. The model's ability to consistently outperform the professional trader in terms of profit (32% vs. 27%) is a strong indication of the value that machine learning can add to the trading process.

CHALLENGES

- 1) The model employed Bidirectional LSTM layers, which allow the network to learn patterns in both forward and backward time directions, thereby improving the model's ability to capture complex price movements. Dropout layers were added to

prevent overfitting, and a Dense layer at the output converted the LSTM's predictions into binary classification labels (1 for Buy, 0 for Ignore). The model was trained using binary cross-entropy as the loss function and optimized with the Adam optimizer.

- 2) **Class Imbalance:** Stock movements are not always equally distributed across classes (up vs. down), which can lead to an imbalance in the training data. The model addressed this through the use of class weights to ensure more balanced predictions, resulting in improved performance.

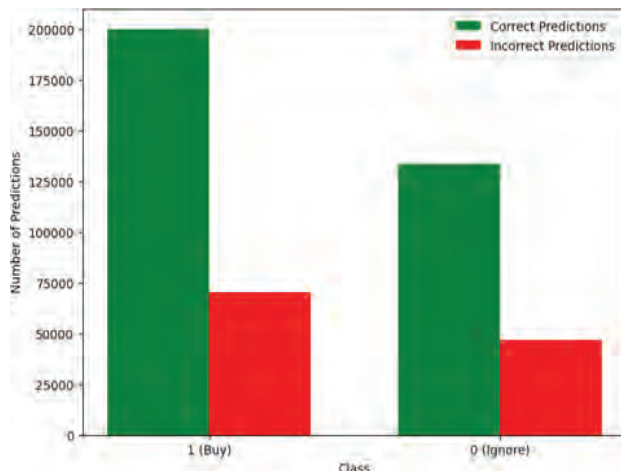


Fig. 2. Classification Results

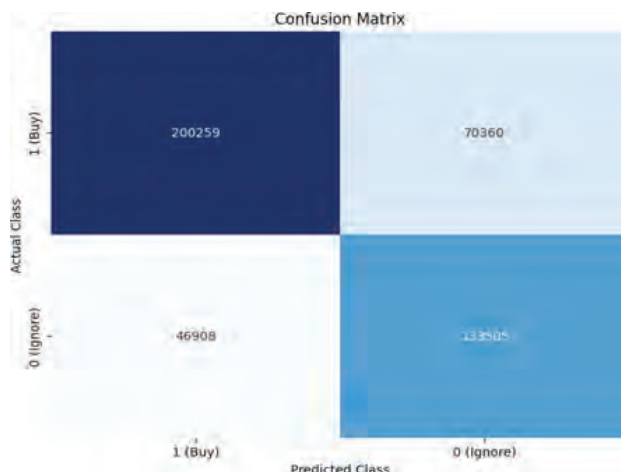


Fig. 3 Confusion Matrix

- 3) **Volatility and Market Anomalies:** While the model performed well in general, it is important to note that stock markets are influenced by numerous external factors, such as political events, economic crises, or sudden market shifts, which can lead to

unpredictability. The model is based on historical price data and may not always account for such external factors.

- 4) **Human Expertise in Decision Making:** While the model's predictions were accurate, human input was still necessary for deciding when to sell stocks. The model focuses on buy recommendations based on historical price movements, but it does not factor in market sentiment or events that may trigger the need for selling. This highlights the importance of combining machine learning-based strategies with human expertise in real-world applications.

CONCLUSION

This project demonstrates the effectiveness of combining technical analysis and machine learning for stock market predictions. By using LSTM networks and a variety of financial indicators, the model was able to consistently predict profitable stock movements, outperforming a professional trader's portfolio in terms of return. However, despite its success, the model is not without limitations, such as its reliance on historical data and inability to fully incorporate external market events. Future work could explore incorporating additional data sources, such as news sentiment or macroeconomic indicators, to further improve the model's predictions.

Currently, this model focuses solely on identifying buying signals, but effective trading requires an equally robust approach to selling. Without timely exits, profitable stocks can quickly lose value, turning gains into losses. Conversely, selling too early may result in missed profit opportunities.

In future work, we aim to incorporate selling and short-selling signals into the model. This requires overcoming the complexity of recognizing chart patterns, which preliminary research suggests can be achieved using computer vision techniques. Adding these capabilities will enable the model to not only optimize exits from long positions but also identify short-selling opportunities, creating a more comprehensive trading strategy.

Ultimately, this project provides a valuable example of how machine learning can be used to enhance trading strategies and assist in making informed financial decisions.

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Solar-Powered Circuit for Charging Electric Vehicles (EVs) Using Incremental Conductance MPPT and Bidirectional DC-DC Converter

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ABSTRACT

An innovative solar-based electric vehicle (EV) charging circuit that makes use of a solar photovoltaic (PV) system to charge an EV battery while guaranteeing effective power conversion is presented in this study. Under standard test circumstances (STC), the system uses the Incremental Conductance The Maximum Power Point Tracking (MPPT) technique is used to optimise solar PV power. For battery charging, a buck converter reduces the voltage to 220V after a boost converter raises it to 400V. The EV gets charged from the grid when there is no solar energy available. Using a corner frequency of 10 rad/sec, a proportional-resonant (PR) controller controls the power. A bidirectional DC-DC converter is equipped with a 400V DC output that was acquired by an H-bridge rectifier. The system's overall efficiency, power flow, and battery charging performance are examined. The findings indicate that EV charging systems offer clean energy charging, smooth vehicle operation with no emissions, and a reduction in grid dependency.

KEYWORDS: Solar-based EV charging, Incremental conductance MPPT, Boost converter, Buck converter, Proportional-resonant controller, Battery charging, grid integration, Electric vehicle, Renewable energy, Power conversion, State of charge (SOC).

INTRODUCTION

The rising demand for electric vehicles (EVs) calls for efficient, environmentally friendly charging systems. Solar energy, as a renewable resource, offers a sustainable solution to charging EVs, reducing reliance on traditional grid sources. This paper proposes a solar-based EV charging system that leverages a solar photovoltaic (PV) panel, a boost converter, a bidirectional DC-DC converter, and Maximum Power Point Tracking (MPPT) technique that uses incremental conductance to charge the EV's battery.

Electric vehicle (EV) charging stations powered by solar energy are becoming more prevalent, especially in residential settings, commercial locations, and parking areas. This system uses an efficient power management approach to ensure optimal charging and power flow, providing clean energy to the vehicle.

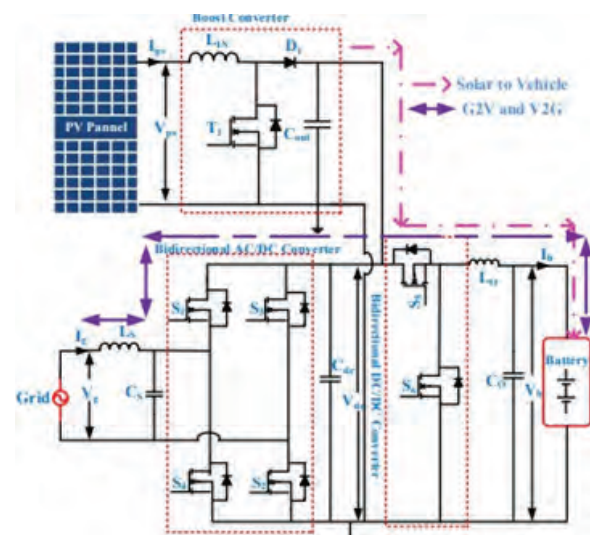


Fig. 1. Electric Vehicle with Solar Charging Configuration

Figure 1 illustrates how to charge an electric vehicle using solar PV, the grid, and solar PV. [2] through [6]. EVs are charged during the day using the electricity produced by the solar PV. The electric vehicle is powered by the grid when solar photovoltaics are not available. Two-stage solar PV-configured electric car charging circuits are mentioned in [7]–[8].

The first stage serves as an inverter and converter, and the second stage is made up of a DC-DC converter that functions as a buck converter during charging and as a step-up converter during discharging. When charging, the battery stores electrical energy as chemical energy, and when discharging, it supplies energy to the grid.

The battery is crucial to an electric vehicle (EV); its state of charge (SOC) is kept within acceptable bounds for a long time. Lithium-ion, lead-acid, and nickel-cadmium batteries are the three types of batteries that are utilized in EVs. Because of its extended working life, high specific energy, and superior discharging capabilities, lithium-ion batteries are the favored choice for EVs [9]. Section II addresses the design of passive components and EV circuit configuration, whereas Section III addresses EV using solar PV for charging. EV charging with a proportional plus resonant controller (PR) is covered in Section IV, and EV support to grid.

EV CIRCUIT CONFIGURATION AND DESIGN

For the EV to operate at its best, the circuit's passive filters need to be properly designed. The way passive components are designed are presented here for the EV considered in the work [10].

(i) DC bus capacitor (C_{dc}):

Single phase converters require a big dc capacitor on the dc side because their output DC voltage contains second order harmonics. The DC capacitor is a unit that device between the input and the output that stores energy. The amount of energy that the capacitor can store will determine its worth. (1) calculates the input power assuming that the input power factor is equal to one.

$$P_{in} = v_{in} \times i_{in} = \frac{VI}{2} - \frac{VI}{2} \cos 2\omega t \quad (1)$$

Input inductor power is given by (2)

$$P_L = \frac{\partial \left(\frac{1}{2} L (I \sin \omega t)^2 \right)}{\partial t} = \omega L I^2 \sin \omega t \cos \omega t \quad (2)$$

The input inductor provides energy to the H-bridge converter, which uses it to charge the output dc capacitor. When device power losses are ignored, the output capacitor's power is equivalent to the variation in inductor power and input power. (3) is used to determine the power flow via the capacitor.

$$P_c = P_{in} - P_L = \left(\frac{VI}{2} - \frac{VI}{2} \cos 2\omega t \right) - \left(\omega L I^2 \sin \omega t \cos \omega t \right) \quad (3)$$

The output DC voltage ripples in equation (3) because a DC component is delivered to the DC output, and the capacitor is charged and discharged by second-order components.. For a half cycle, the ripple energy is represented by (4), and the instantaneous power is computed by simplifying and taking the integration.

$$E_C = \int_0^{T/2} \sqrt{\frac{V^2 I^2}{4} + \frac{\omega^2 L^2 I^4}{4}} \sin 2\omega t dt = \sqrt{\frac{V^2 I^2}{4} + \frac{\omega^2 L^2 I^4}{4}} / \omega \quad (4)$$

One can determine the using the ripple energy in the capacitor to calculate the relationship between the DC capacitor, DC voltage, and input inductor as (5).

$$C_{dc} = \frac{\sqrt{\frac{V^2 I^2}{4} + \frac{\omega^2 L^2 I^4}{4}}}{2 \times V_{dc} \times \Delta V_{dc} \times \omega} \quad (5)$$

Using (5), C_{dc} is obtained to be 2mF.

(ii) Input side filter (L_s and C_s):

The filter inductor is designed based on the ripple current flowing through the inductor (L_s).

$$L_s = \frac{V_{dc} \times \frac{V \sin \omega t}{V_{dc}} \times \left(1 - \frac{V \sin \omega t}{V_{dc}} \right)}{2 \Delta I f_{sw}} \quad (6)$$

Whereas V_{dc} is the DC voltage with ripple, V sin ωt is the instantaneous value of the input AC voltage. The ripple current, ΔI, is taken to equal 10% of the input current, and the switching frequency is denoted by f_{sw}. The input LC filter capacitor is used to damped the output voltage's harmonics, which are provided by (7).

$$C_s = \left(\frac{1}{2\pi f_{sw}} \right)^2 \times \frac{1}{L_s} \quad (7)$$

The capacitor filter C_s and inductor L_s are obtained as 20μF and 0.75 mH.

(iii) Output filter (L_o and C_o):

Calculations are made using (8) and (9) for the output filter inductor L_o and capacitor C_o, respectively.

$$L_o = \frac{(D(1-D)^2 r)}{2f_{sw}} \quad (8)$$

$$C_o = \frac{(1-D)}{8L_o \left(\frac{\Delta V_o}{V_o} \right) f_{sw}^2} \quad (9)$$

It need a very high output side capacitor to keep the output voltage steady. V_o is the buck/boost converters' f_{sw} switching frequency, duty ratio is D , internal resistance is r , and the output voltage, 5% of which is the ripple voltage, or ΔV_o . It is determined that L_o and C_o are $41\mu\text{H}$ and $600\mu\text{F}$. In this paper, a single phase system with a voltage of 120V rms 60Hz is examined.

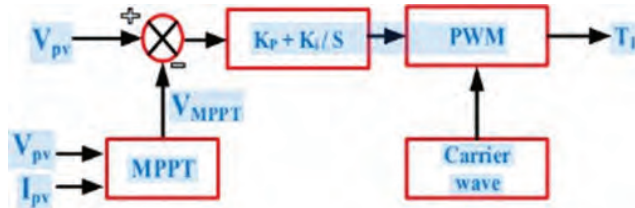


Fig. 2 PV boost converter control circuit

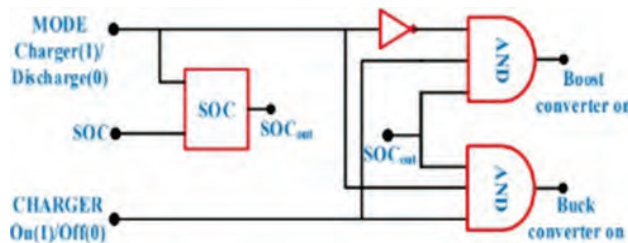


Fig. 3(a) Upper level control

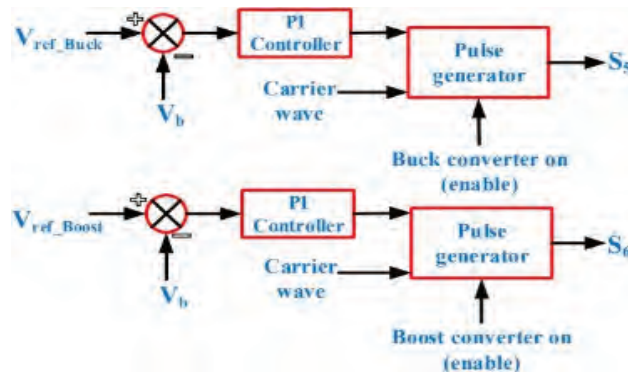


Fig. 3(b) Lower level control for DC-DC converter

Figure 2 displays the control circuit for the solar PV boost converter. A comparison between the PV array voltage and the MPPT voltage is made, and a voltage error is produced.

Error voltage that is produced flows. By comparing the output of the proportional plus integral controller (PI) with a 10 kHz triangle carrier wave, switching pulses are produced for the PV boost converter. The bidirectional DC-DC converter's upper level and lower level controllers are depicted in Figures 3(a) and 3(b). In upper level control, SOCout is determined based on the battery's state of charge (SOC) between 5% and 100% and its operating mode, such as charging or discharging. The logic circuits are then instructed to provide a signal to activate the buck or boost converter by providing SOCout and Charger ON/OFF. Consequently, Switching pulses are produced for the Buck/Boost converter's switches utilising Fig. 3(b). In a similar manner, switching pulses for lower level control are produced using the signal's buck converter and voltage error.

ELECTRIC VEHICLE CHARGING WITH PV

Solar PV energy is used during the day to charge the battery of an electric car. The circuit arrangement is depicted in Figure 1. 400 is the increased voltage of the PV panel. step-up converter to convert voltages. PV boost converter voltage is stepped down using a DC-DC converter in accordance with battery voltage requirements. The battery's 100AH, 230 V (20 kWh) capacity is taken into account here. At home or in a parking lot, there can be an integrated charging circuit. The boost converter's design parameters are shown in Table 1, and the PV panel with input labels is shown in Fig. 4.

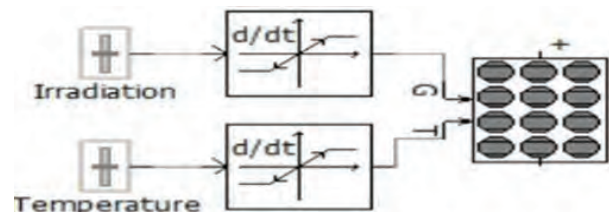


Fig. 4. PV panel with input labels (Source PSCAD software simulator)

ELECTRIC VEHICLE CHARGING FROM GRID

The electric car is charged from the grid when it is operating in this mode. When there is no solar power present, this mode functions. The grid circuit used to charge electric vehicles Fig. 1 displays the configuration, and Table III displays the system parameters used in the simulation. The proportional pulse resonant (PR) controller is

used to produce the single phase H-bridge bidirectional converter's switching pulses. The control block diagram for the PR controller is shown in Fig. 12. With minimal steady state error, PR can follow the sine current waveform [11] and add an infinite gain at the fundamental frequency. To prevent issues with stability at ,In this study, the non-ideal PR controller is an approximation high gain low pass filter, which is essentially a second order transfer function, with infinite gain.

The PR controller $G_{PR}(s)$ is given by (10)

$$G_{PR}(s) = k_p + k_i \frac{2\omega_c s}{s^2 + 2\omega_c s + \omega_o^2} \quad (10)$$

CONCLUSIONS

An electric vehicle charging circuit using solar energy is presented in this research. The PV array is examined Under typical test settings, the solar PV's Current-Voltage and Power-Voltage characteristics are determined. Inactive the design process for filter parameters is described. A boost converter is used to step the 200 V output voltage that the solar PV is intended to provide to 400 V. Using a buck converter, the output voltage is filtered and then stepped down to meet EV battery charging specifications. When it comes to charging the EV battery, the PR controller is effective.

SOC is proven to be effective in both the charging and discharging phases. A corner frequency of 10 rad/s has been suitably selected based on the frequency response characteristic. EV charging from the grid and battery energy returned to the grid are represented by the in-phase and out-of-phase voltage and current, respectively. Grid current and voltage THD values are calculated in accordance with IEEE 519 guidelines. The state of charge (SOC) of the battery is ascertained while charging and discharging. The controller tracks the reference voltage accurately while charging and discharging with a low steady state error.

Solar charging solves distribution network overloading and voltage issues brought on by more generating units and higher power demand because of more Grid-based EV charging.

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Enhancing Skin Cancer Classification with Hybrid Feature Extraction and Machine Learning

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ABSTRACT

Skin cancer is a tumor caused by the rapid growth of several skin cells. Clinical diagnosis of skin cancer involves detecting cancer with the naked eye by using metadata like patient history, age, lesion location, and morphological structures, and is a time-consuming process. Automated systems can assist primary clinicians and healthcare professionals in early diagnosis of skin cancer which would help in reducing unnecessary excisions, lowering the healthcare costs and stress for patients. This paper provides an automated approach of skin cancer detection using hybrid features which are crucial for the accurate diagnosis of skin cancer. The proposed approach includes preprocessing for artifact removal, segmentation for extracting lesion area, spatial transformations for solving imbalance issues, feature extraction for determining texture, color, and shape features from segmented lesions, and feature classification using several machine learning classifiers. The results demonstrate that the support vector machine classifier outperforms other models by providing promising accuracy of 91%, precision 87%, sensitivity 93%, specificity 89% and F1 score 90% on PH2 dataset.

KEYWORDS: *Skin cancer, Segmentation, Feature extraction, Machine learning.*

INTRODUCTION

Skin cancer is a tumor caused by the rapid growth of several skin cells. Skin cancer is classified as either non-melanoma or melanoma. Melanoma is an aggressive and rare form of skin cancer caused by melanocyte cells that produce skin pigment. It accounts for 80% of skin cancer deaths. Non melanoma is a less aggressive type and it includes BCC and SCC. BCC is a locally invasive common cancer that arises from Basal cells in the epidermis layer of skin and Squamous cells in the epidermis layer causes SCC. Melanoma, BCC, and SCC are malignant forms of skin cancer that invade surrounding tissues and spread to other parts. Benign skin cancer is harmless noncancerous lesions that do not invade other tissues or spread [1]. According to the GLOBOCAN 2020 skin cancer database, 3.25 million melanoma cases and 57000 melanoma deaths were reported in 2020, and estimated to increase to 50% new cases and 68% death cases by 2040[2]. Clinical diagnosis of skin cancer involves detecting the cancer with the naked eye by using metadata

like patient history, age, lesion location, and morphological structures. Dermoscopy is a non-invasive tool that helps to differentiate between malignant and Benign skin cancers. Dermoscopy helps provide a detailed look at the morphological structures of cancer that are invisible to the human eye. Dermoscopy increases diagnostic accuracy by 49% as compared to clinical eye inspection [3]. There is a 42% reduction in patients referred for biopsy with the use of dermoscopy. Dermoscopy improves detection, provides diagnostic confidence, and reassures the patients. There are around 15 % of challenging subsets of melanomas that are difficult to diagnose both clinically and with dermoscopy. Automated systems can assist primary clinicians and healthcare professionals in early diagnosis of skin cancer which would help in reducing unnecessary excisions, lowering the healthcare costs and stress for patients [4]. The standard approach in automated detection includes image acquisition, preprocessing, segmentation of lesion area, feature extraction and feature selection, and finally classification of skin cancer. In this paper, we present an

automated method of skin cancer detection. This paper emphasizes on the binary classification of skin cancer by first performing preprocessing, balancing the minority classes using spatial transformations, segmenting the lesion region, extracting hybrid features, and after applying classifiers, assessing the performance using evaluation metrics. The present work is organized as follows: Section 2 provides an overview of the existing literature work on skin cancer; Section 3 presents the proposed approach involving preprocessing, segmentation, feature extraction, and classification. Section 4 demonstrates results and discussion. The conclusion and the potential future advancements are presented in section 5.

EXISTING RESEARCH

In recent years, several significant research has been done on the detection of melanoma addressing the automated methods of detection using several feature descriptors and machine learning classifiers.

Mabrouk et al [5] presented a digitized system that extracts asymmetry, border, color, and novel differential structures and performed classification using the Total Dermoscopy score (TDS) index and ANN classifier. The model provides a promising accuracy of 98.75%.

In another study, Codella et al. [6] suggested a deep learning method and sparse encoding for the extraction of features. The experiment was performed on 2624 images from ISIC database. SVM classifier provided an accuracy of 73.9% while differentiating melanoma and atypical nevi.

The model developed by Balaha et al. [7] gathered datasets from five public sources for binary and 10 class classifications. The optimized MobileNet V2 pre-trained model reported 98.83% accuracy on the HAM10K dataset.

Warsi et al [8] proposed a robust 3D texture color feature method and performed classification using a neural network classifier. The proposed model provides 97.5% accuracy and 98.1 % sensitivity on the PH2 dataset.

In the work proposed by Oliveira et al [9], 408 images collected from several databases were utilized, and extracted features from ABCD and texture features derived from box counting method were given to the SVM classifier. The best results obtained 79% accuracy on the binary classification task.

Viaks et al [10] worked on low level and high level asymmetry features for diagnosis of melanoma. High level

feature achieved 73.46% accuracy compared to low level features.

Table 1 shows summary of existing studies

Reference	Features	Classifier	Dataset	Accuracy
[5]	ABCD	ANN	Dermoscopy Atlas	98.75%
[6]	DL	SVM	ISIC	73.90%
[7]	DL	MobileNetV2	5 Public datasets	98.83%
[8]	3D color texture	NN	PH2	97.50%
[9]	ABCD+box counting	SVM	Hybrid dataset	79%
[10]	color Asymmetry	Clinical method	DermIS	73.46%

MATERIAL AND METHODS

This research aims to recognize the valuable features of the skin lesion using image processing techniques and then classify them using machine learning classifiers. This study is primarily focused on dermoscopic images from the ph2 database [11] provided by the University of Porto and the Dermatology Service of Hospital Pedro Hispano, Matosinhos, Portugal. The database comprises 200 dermoscopic images including 80 benign common nevi, 80 benign atypical nevi, and 40 malignant melanoma images. Every image has a resolution of 768*560 pixels and is 8-bit RGB. Figure 1 illustrates the proposed framework.

Firstly, Preprocessing is done which includes the removal of noise and hairline surrounding the lesions. Noise is removed with the help of a 3*3 Gaussian kernel and hair removal is done using several morphological operations [12].

Secondly, Segmentation is then performed after preprocessing to extract the area of interest. True segmentation is carried out using the binary mask available in the dataset. Then all the segmented lesion images are cropped and resized to standard dimensions of 224*224 using the interpolation method.

Since the dataset is highly imbalanced (1:4 imbalance ratio) having 40 melanoma images and 160 benign images of common and atypical nevi. To avoid overfitting and to solve the imbalance issue, our proposed framework involved augmenting the minority class using spatial transformations like median filtering, histogram equalization, and log transformations. All the augmented images are added to the minority class resulting in a balanced dataset of 320 images consisting of 160 melanoma images and 160 benign images.

For feature extraction, hybrid features are extracted which include texture, color, and shape features. The various texture features include maximum probability, correlation, contrast, homogeneity, dissimilarity, entropy, and angular second moment. All the texture features are extracted from the gray-level co-occurrence matrix (GLCM) [13]. Color features include color average, variance, standard deviation, and color skewness for each RGB channel. Shape features include lesion diameter and lesion area. Feature scaling is performed using a Min-Max Scaler to make all of the pixel values between 0 and 1.

For feature classification, a feature vector is partitioned into 80% for training and the remaining 20% for testing. These features are classified into benign and malignant samples using the Support vector machine classifier [14]. It provides the best hyperplane for differentiating between different classes.

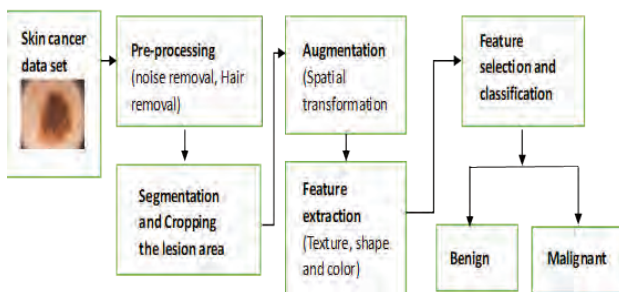


Fig. 1. Proposed Framework

RESULT ANALYSIS AND DISCUSSION

The following part illustrates the result analysis of the proposed framework to validate its performance. Figure 2 highlights the preprocessing and segmentation results using skin cancer images.



Fig. 2. Preprocessing and Segmentation results

The output of machine learning classifier is evaluated by various performance indicators including Accuracy, Sensitivity, Specificity, Precision and F1 score [15]. Table II shows performance of proposed approach using different machine learning classifiers.

Table 2. Performance of proposed framework using different ML classifiers

ML Models	ACC (%)	PR (%)	SE (%)	SP (%)	F1 (%)
LR	89	87	82	89	87
RF	86	83	86	86	84
k-NN	89	89	86	89	87
Adaboost	86	81	89	84	85
XG Boost	86	79	92	81	85
Proposed model	91	87	93	89	90

The result of the proposed model using SVM classifier trained on hybrid features is providing promising accuracy of 91%, precision 87%, sensitivity 93%, specificity 89% and F1 score 90%. Our model is providing the highest true positive rate of 93% as compared to other classifiers which is effective in correct diagnosis of malignant skin cancer. Figure 3 highlights graphical performance comparison of the proposed model with different machine learning classifiers.

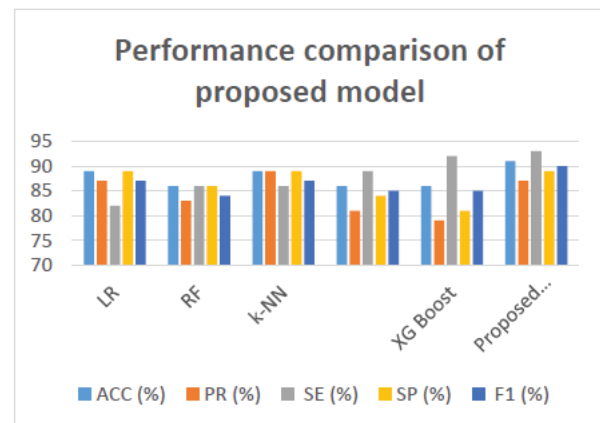


Fig. 3. Performance comparison of the proposed model with different machine learning classifiers.

CONCLUSION AND FUTURE ADVANCEMENTS

This paper provides an automated approach for binary classification of skin cancer. The proposed framework covered all the steps required for the automated detection of skin cancer. Preprocessing steps helps in elimination of noise and hair related artifacts. Segmentation step is used for segmenting the lesion area from the unnecessary background. Spatial transformations resolve the imbalance issues in dataset. Texture, shape and color features provide

all important features used clinically for efficient detection of skin cancer. The proposed framework achieves promising results among all other classifiers.

This approach can be further enhanced by using hybrid dataset from diverse sources and employing sophisticated machine learning models for increasing the model overall performance.

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A Review on Performance Analysis of MOSFET and CNTFET based Mixed-Signal Circuits for Low Power and High-Frequency Applications

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ABSTRACT

The paper provides a comprehensive review of the performance analysis of mixed-signal circuits designed using MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) and CNTFET (Carbon Nanotube Field-Effect Transistor) technologies. The focus is on evaluating their suitability for low-power and high-frequency applications. The rapid demand for high-performance, energy-efficient circuits in modern communication and computing systems has driven research into alternative materials and device structures. The advantages and challenges of MOSFETs and CNTFETs in terms of performance, power consumption, frequency response, and integration into mixed-signal circuits are analyzed. A comparative evaluation is provided based on experimental and simulation results from various studies. Key performance metrics such as power consumption, operating frequency, scalability, and design challenges are discussed. A comparison table summarizes the critical differences and potential advantages of these technologies, highlighting CNTFET's promise as a next-generation alternative to MOSFETs.

KEYWORDS: MOSFET, CNTFET, Mixed-signal circuits, Low power, High-frequency, Performance analysis, Carbon nanotube, Nanoelectronics, Energy-efficient circuits.

INTRODUCTION

The evolution of electronics has been marked by the continuous scaling of MOSFETs, the cornerstone of modern semiconductor devices. Since their invention in the mid-20th century, MOSFETs have revolutionized the electronics industry by enabling compact, efficient, and reliable designs. The rapid evolution of communication and signal processing technologies demands the development of circuits that offer both low power consumption and high-frequency performance. However, as device dimensions approach the atomic scale, issues such as short-channel effects, increased leakage currents, and power dissipation arise, limiting the performance of conventional MOSFETs.

To address these limitations, researchers have explored alternative technologies capable of sustaining the momentum of Moore's Law. CNTFETs, leveraging the unique properties of carbon nanotubes, have emerged as a promising alternative. Carbon nanotubes exhibit exceptional electrical, thermal, and mechanical properties, making them ideal candidates for next-

generation electronics. CNTFETs offer advantages such as reduced power consumption, higher carrier mobility, and scalability beyond the limitations of silicon-based devices. Among the different semiconductor devices used in mixed-signal circuits, Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) have been the standard for several decades. However, with the scaling limitations of MOSFETs, alternative technologies such as Carbon Nanotube Field-Effect Transistors (CNTFETs) have gained attention for their superior electrical properties, particularly in terms of high-speed operation and lower power consumption. This paper aims to analyze and compare the performance of mixed-signal circuits designed with these two technologies, emphasizing their potential for low-power and high-frequency applications.

Mixed-signal circuits, which combine analog and digital functionalities, are critical to modern electronics, including applications such as communication systems, data converters, and signal processors. As the demand for high-performance, energy-efficient devices grows,

understanding the role of device technologies in optimizing mixed-signal circuits becomes essential.

OVERVIEW OF MOSFET AND CNTFET TECHNOLOGIES

Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) Technology:

MOSFETs are fundamental to modern electronics, serving as the primary building blocks for integrated circuits. MOSFETs have been the cornerstone of modern digital and analog circuits. Their performance is characterized by low threshold voltage, high speed, and ease of integration. Their operation is based on controlling current flow through a semiconductor channel using an electric field. Advantages of MOSFETs include mature fabrication processes, high reliability, and cost-effectiveness. However, as scaling continues below 7 nm, significant challenges arise, such as increased leakage currents, reduced gate control, and thermal management issues. These limitations affect performance, especially in low-power and high-frequency applications [1].

Advantages of MOSFETs

- a) High scalability
- b) Well-established fabrication techniques
- c) Mature and reliable technology for low-power applications

Challenges of MOSFETs

- a) Short-channel effects at smaller geometries
- b) High leakage current at advanced nodes
- c) Limited frequency response beyond certain sizes

To mitigate these challenges, researchers have developed techniques such as multi-gate structures (e.g., FinFETs), high-k dielectrics, and strain engineering. While these innovations have extended the life of MOSFET technology, they introduce added complexity and cost, making alternative materials like carbon nanotubes an attractive research avenue

Carbon Nanotube Field-Effect Transistor (CNTFET)

CNTFETs leverage carbon nanotubes as channel materials, providing superior electrical properties such as high carrier mobility and ballistic transport[2-3]. These characteristics enable lower operating voltages and reduced power dissipation compared to MOSFETs.

Additionally, CNTFETs exhibit excellent scalability, making them suitable for advanced nanoscale applications. However, challenges such as chirality control, precise alignment during fabrication, and high production costs hinder their widespread adoption. Despite these obstacles, CNTFETs show immense potential for high-performance and energy-efficient designs

Their unique structure allows for better control of short-channel effects, and they exhibit higher electron mobility compared to silicon-based MOSFETs[8][11].

CNTFETs operate on principles similar to MOSFETs but benefit from the quasi-one-dimensional nature of carbon nanotubes. This unique property reduces scattering and improves current-carrying capabilities, particularly at nanometer scales. As research advances, innovations in fabrication techniques such as chemical vapor deposition (CVD) and transfer printing aim to overcome existing challenges, paving the way for CNTFETs in commercial applications[17][21].

Advantages of CNTFETs

- a) High intrinsic electron mobility
- b) Better electrostatic control at smaller scales
- c) Lower power consumption for high-speed operations

Challenges

- a) Manufacturing difficulties
- b) Variability in device performance
- c) Lack of mature fabrication techniques

MIXED SIGNAL CIRCUITS

Mixed-signal circuits are a class of electronic circuits that combine analog and digital signal processing within a single system.[9-10]. These circuits are essential for applications such as communication systems, signal processing, and sensor interfaces. Common mixed-signal components include:

- Analog-to-Digital Converters (ADCs): These convert analog signals to digital for further processing.
- Digital-to-Analog Converters (DACs): These convert digital signals back to analog for real-world interfacing.
- Phase-Locked Loops (PLLs): Used for frequency synthesis and clock generation.

- Filters: Essential for signal conditioning and noise reduction.

The performance of mixed-signal circuits depends on factors such as linearity, power efficiency, speed, and noise immunity. While CNTFETs show promise for low power and high-frequency applications, several challenges remain in terms of fabrication, variability, and integration with existing CMOS technology[19-20]. Future research will focus on overcoming these challenges, improving device performance, and integrating CNTFETs into mixed-signal systems. Additionally, hybrid systems that combine the strengths of both MOSFETs and CNTFETs may offer promising solutions [12-16].

PERFORMANCE COMPARISON IN MIXED-SIGNAL CIRCUITS

MOSFET-based designs dominate this domain due to their established fabrication processes and proven reliability. However, as performance demands rise, CNTFETs offer significant advantages in reducing power consumption and improving speed, making them attractive candidates for next-generation mixed-signal circuits ([3]).

In applications such as wireless communication and IoT devices, mixed-signal circuits face stringent requirements for energy efficiency and miniaturization. The integration of CNTFETs in these circuits promises to address these challenges by leveraging their high-frequency capabilities and low-power operation. For instance, CNTFET-based ADCs demonstrate enhanced resolution and reduced thermal noise, enabling superior performance in demanding applications.

Low Power Applications

A key consideration in mixed-signal circuit design is the reduction of power consumption while maintaining adequate performance. MOSFETs are typically used in applications where power efficiency is critical. However, CNTFETs offer substantial improvements in terms of power consumption due to their better scalability and reduced leakage current.[5-6]

Table 1: Power Consumption Comparison of MOSFET vs CNTFET for Low Power Applications

Device Type	Power Consumption (W)	Performance (GHz)	Leakage Current (nA)
MOSFET	0.2	10	5
CNTFET	0.1	15	2

High-Frequency Applications

High-frequency circuits, such as RF (Radio Frequency) amplifiers and high-speed analog-to-digital converters (ADC), require transistors with fast switching speeds and low parasitic capacitance. CNTFETs exhibit superior high-frequency performance due to their high electron mobility and reduced parasitic capacitance. On the other hand, MOSFETs struggle with higher parasitic capacitance, limiting their performance at higher frequencies.[4][7]

Table 2: High-Frequency Performance Comparison of MOSFET and CNTFET

Device Type	Cut-off Frequency (GHz)	Gain (dB)	Bandwidth (GHz)
MOSFET	20	18	15
CNTFET	40	25	25

The review focuses on mixed-signal circuits, including amplifiers, filters, and analog-to-digital converters (ADCs). Key performance parameters evaluated include:

- Power consumption
- Operating frequency
- Gain and linearity
- Scalability and manufacturing challenges

This study is based on an extensive review of recent research articles, focusing on publications from the past five years. Comparative analysis is conducted using simulation data, experimental results, and theoretical insights to highlight the strengths and weaknesses of MOSFET and CNTFET technologies.[7-10]

RESULTS AND DISCUSSIONS

While CNTFETs show promise for low power and high-frequency applications, several challenges remain in terms of fabrication, variability, and integration with existing CMOS technology [21] [30]. Future research will focus on overcoming these challenges, improving device performance, and integrating CNTFETs into mixed-signal systems []. Additionally, hybrid systems that combine the strengths of both MOSFETs and CNTFETs may offer promising solutions.

Power Consumption

CNTFET-based circuits demonstrate a significant reduction in power consumption due to their lower operating voltages and reduced leakage currents. For instance, a comparative study showed that CNTFET circuits consumed 35% less power than their MOSFET counterparts [22-24].

MOSFETs, while efficient in larger nodes, struggle with power dissipation as dimensions shrink, making them less suitable for ultra-low-power designs.

Operating Frequency

CNTFETs exhibit higher cut-off frequencies owing to their ballistic transport characteristics. This enables their application in high-frequency domains, outperforming MOSFETs in GHz-range operations [25] [27]. MOSFETs, on the other hand, face limitations due to parasitic capacitances and resistances that impede performance at high frequencies.

Scalability and Manufacturing Challenges

MOSFET technology benefits from decades of development and a well-established manufacturing ecosystem, ensuring high yield and scalability. In contrast, CNTFETs, while inherently more scalable due to their atomic-scale dimensions, face significant fabrication challenges. These include ensuring uniformity in nanotube chirality and achieving defect-free synthesis. Addressing these challenges is crucial for the large-scale adoption of CNTFETs [26].

Performance Metrics

Additional performance metrics, such as noise immunity and thermal stability, further underscore the advantages of CNTFETs in mixed-signal applications. CNTFETs' ability to maintain stable operation under varying thermal conditions makes them suitable for environments with high temperature fluctuations, such as automotive and aerospace applications. [18]

Table 3 summarizes the comparison of the performance metrics

Table 3 Comparison of performance metrics of MOSFET and CNTFET

Parameter	MOSFET	CNTFET
Power Consumption	Higher	Lower (up to 35% reduction)
Operating Frequency	Moderate	Higher (GHz range)
Scalability	Limited	Better scalability
Manufacturing	Mature	Emerging, with challenges
Cost	Lower	Potentially higher
Applications	General-purpose	High-performance/low-power

CONCLUSION

This review highlights the advantages and challenges associated with MOSFET and CNTFET technologies in mixed-signal circuits. It underscores the potential of CNTFETs in addressing the limitations of conventional MOSFETs for low-power and high-frequency applications. MOSFETs remain a robust choice for many applications due to their mature manufacturing processes and lower cost. However, as the demand for ultra-low-power and high-frequency devices grows, CNTFETs offer a compelling alternative. While CNTFETs offer superior performance metrics, challenges in their synthesis and manufacturing must be addressed to achieve widespread adoption. Continued research in this field is crucial to unlocking the full potential of CNTFET technology.

CNTFETs offer significant improvements in low power consumption and high-frequency performance, but their manufacturing challenges must be addressed for widespread adoption. Continued research and development in both MOSFET and CNTFET technologies are crucial for the evolution of low-power, high-performance circuits in future communication systems.

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Cloud Based SaaS Management Platform And Website Builder

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ABSTRACT

CloudCreek is a comprehensive SaaS platform designed for marketing, web, and software development agencies. Its multi-tenant architecture ensures secure and isolated operations for multiple agencies on shared infrastructure, providing scalability and efficient resource use. The platform includes a drag-and-drop website builder with customizable templates, SEO tools, and real-time analytics, powered by technologies like HTML5, CSS3, JavaScript, and Next.js. CloudCreek also offers project management tools featuring task tracking, Gantt charts, Kanban boards, and integrated communication for seamless project execution. Its real-time analytics dashboard delivers insights into client engagement, project milestones, and resource utilization. By integrating website creation, project management, and analytics, CloudCreek streamlines workflows, boosts productivity, and supports agency growth.

KEYWORDS: *CloudCreek, SaaS platform, Multi-tenant architecture, Website builder, SEO tools, HTML5, CSS3, JavaScript, Next.js, Project management, Gantt charts, Kanban boards, Real-time analytics, Client engagement, Resource management, Agency productivity.*

INTRODUCTION

CloudCreek is a SaaS platform designed for multi-tenant agencies, combining website building, project management, and real-time analytics into a unified solution. Tailored for digital marketing, creative, web, and software development agencies, it simplifies workflows, enhances productivity, and drives efficiency. The platform features a user-friendly website builder with customizable templates, a centralized project management system for task tracking and resource allocation, and a real-time dashboard for monitoring key metrics and project progress. Its scalable multi-tenant architecture ensures secure data isolation and supports agency growth, eliminating the need for multiple tools and fostering seamless operations [1].

NEED AND MOTIVATION

Agencies often struggle with managing multiple clients, projects, and teams due to the use of disparate tools for website building, project management, and performance tracking. This fragmentation leads to inefficiencies,

miscommunication, and difficulty maintaining oversight, ultimately impacting project delivery and client satisfaction [2]. To streamline operations, agencies need a centralized platform that consolidates these critical functions into one cohesive system, allowing for better workflow coordination, resource management, and real-time tracking.

CloudCreek addresses this need by integrating website development, project management, and analytics into a single, unified solution. This comprehensive platform enables agencies to efficiently manage multiple projects and clients from a centralized hub, reducing operational friction and improving collaboration [3]. By offering a scalable, user-friendly interface, CloudCreek helps agencies focus on delivering quality work while maintaining control over complex workflows and performance metrics.

Basic Concept

CloudCreek revolves around providing a unified, multi-tenant Software-as-a-Service (SaaS) platform specifically

designed for agencies. By integrating key functionalities such as website building, project management, and real-time analytics into one system, CloudCreek aims to streamline agency operations and improve efficiency. The platform's multi-tenant architecture allows multiple agencies to operate within the same environment, with secure data separation, ensuring that each agency can manage its own clients and projects independently [4].

CloudCreek simplifies complex workflows by offering intuitive tools that enable users to create and manage websites, track project progress, allocate resources, and monitor performance metrics—all from a centralized interface. This eliminates the need for multiple disjointed tools, reducing inefficiencies and improving collaboration across teams [5]. The platform is designed to be scalable and adaptable, allowing it to grow alongside the agencies it serves, making it a versatile solution for digital marketing, creative, web development, and software development firms..

SURVEY OF LITERATURE

1. Squarespace from Signup to Launch: Build, customize, and launch robust and user-friendly Squarespace websites with a no-code approach (2024)

Retrieval-Augmented Generation (RAG) has revolutionized the capabilities of large language models (LLMs) by integrating external data retrieval mechanisms, which significantly enhance the accuracy and contextual relevance of responses. By leveraging external databases, RAG ensures that the model is provided with the most up-to-date information, making it particularly valuable in tasks that require real-time or frequently updated content [6]. This integration not only boosts the precision of answers but also ensures a broader understanding of the query context, improving overall performance. However, despite its advantages, the use of RAG comes with certain drawbacks. One of the major challenges is its resource-intensive nature. The integration of external databases demands substantial computational power for storage, processing, and frequent API calls, resulting in increased infrastructure costs [7]. Additionally, while RAG improves data retrieval, it faces issues when merging real-time data (such as screenshots) with external sources, potentially leading to inconsistencies in the information provided. This can affect the reliability and accuracy of the system, especially when real-time content is crucial for user queries.

2. Integration Project Based on Computer Information Technology Management System

Token-based general-purpose text embeddings are powerful tools that convert sentences into meaningful feature vectors, helping to preserve the semantic meaning of the text. These embeddings play a vital role in improving the search efficiency of information retrieval systems by making it easier to match queries with relevant data. However, these models face limitations when dealing with long documents. Due to the need to truncate or split large documents, these embeddings often struggle to retain the full context of the original text. Truncating or splitting the text can lead to incomplete understanding and affect the overall accuracy of information retrieval, making it less reliable for lengthy or complex documents [9].

3. From Show to Tell: A Survey on Deep Learning-Based Image Captioning (2023)

Recent advancements in deep learning-based image captioning have enabled models to generate textual descriptions from images, improving the accessibility and usability of visual content. These systems provide detailed descriptions that help interpret the visual data, making them valuable in various applications [10]. The survey offers a comprehensive overview of the current methods and innovations in the field, highlighting the improvements in captioning accuracy. However, implementing these advanced techniques requires significant computational resources, which can increase the overall cost of using such systems [11]. Moreover, the methodologies discussed in the survey are complex and require expertise in deep learning, making them difficult for non-experts to adopt. This complexity can limit the practical use of these techniques in real-world scenarios.

4. BLIP-2: Bootstrapping Language-Image Pre-training with Frozen Image Encoders and Large Language Models (2023)

BLIP-2 effectively combines image and language models, allowing for more accurate and contextually relevant image captioning. By integrating pre-trained image encoders and LLMs, BLIP-2 improves the precision of captions, making it a powerful tool for interpreting visual data [12]. The system's ability to generate accurate descriptions is enhanced by its focus on context, which improves the relevance of captions. However, the integration of multiple pre-trained models can be complex and requires technical expertise. This process is resource-intensive,

increasing the computational cost and processing time [13]. Furthermore, while BLIP-2 offers improvements in image captioning, it can still struggle with interpreting complex or unclear visuals, which may affect the system's overall accuracy when dealing with ambiguous images.

METHODOLOGY

AIM

The CloudCreek project aims to develop a comprehensive and integrated Software-as-a-Service (SaaS) platform tailored specifically for multi-tenant agencies operating in digital sectors. This platform is designed to streamline and optimize agency operations by consolidating a range of essential functionalities into a single, user-friendly solution. Key features include an intuitive website-building tool, robust project management capabilities, and real-time analytics, all working cohesively to enhance productivity, improve client collaboration, and provide actionable insights [14]. By centralizing these critical functions, CloudCreek reduces the need for multiple disconnected tools, enabling agencies to save time, reduce costs, and focus more effectively on their core objectives.

Objectives

CloudCreek is designed to revolutionize agency operations by providing a unified platform that enhances efficiency, fosters collaboration, and optimizes resource management. By centralizing the management of clients and projects, it eliminates the complexities of using disparate tools, streamlining workflows and reducing administrative overhead [15]. The platform enables seamless collaboration among team members and clients through real-time communication and feedback within a centralized environment, ensuring alignment and responsiveness. Its advanced resource allocation and task-tracking tools help agencies deliver projects on time and within budget, while its scalable multi-tenant architecture allows for easy expansion to meet growing client demands without compromising performance or security [16]. Additionally, CloudCreek's integrated dashboard provides real-time analytics and performance metrics, empowering agencies to make data-driven decisions and refine their workflows.

Implementation

The system begins by collecting diverse types of input data, including timestamps, URLs, on-screen text, images, and videos, which serve as the foundation for

further processing. Timestamps are linked with URLs to retrieve metadata about the accessed websites, providing structured context for user activities, such as specific page visits and access times [17]. On-screen text is extracted using Optical Character Recognition (OCR) tools like PyTesseract or Doctr, or alternatively by directly parsing the HTML content of the webpage. This approach ensures the accurate capture of text data, whether it appears as embedded content or in standard HTML format [18].

Media and images are processed by parsing the HTML elements of the webpage to identify visual content, which is then analyzed using image captioning models. These models generate descriptive captions, improving the interpretability and contextual understanding of the visual data [19]. Videos are handled by extracting frames at regular intervals, typically every 15 seconds, and these frames are further processed using captioning or transcription techniques to summarize or describe the content effectively [20].

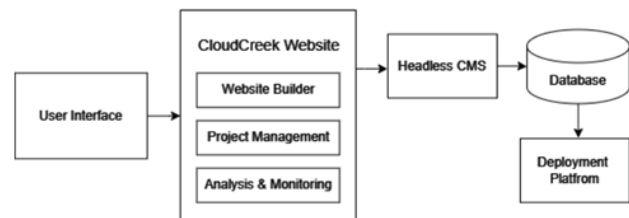


Fig. 1. Block Diagram



Fig. 2. Context Level Diagram

All the processed data—comprising text, images, and video information—is compiled into a unified document. This document provides a comprehensive summary of user activities incorporating metadata, captions, and transcriptions. The final aggregated document is sent to the Retrieval-Augmented Generation (RAG) module,

which leverages this data to produce insights, summaries, or responses tailored to user queries [21]. This integration ensures contextually relevant and detailed outputs, making the system highly effective for capturing and interpreting browsing activities.

SYSTEM REQUIREMENTS

Hardware Requirements

- Processor: Intel Core i5 or equivalent
- RAM: 8GB or higher
- Storage: 500GB SSD for faster data access
- GPU: NVIDIA GTX 1050 or higher for image processing tasks

Software Requirements

- Operating System: Windows 10/11, macOS, or Linux
- Web Browser: Chrome, Firefox, or Safari with the latest updates
- Development Tools: Python 3.8+, TensorFlow, PyTorch, and Flutter SDK
- Database: MySQL or MongoDB for data storage and retrieval

Network Requirements

- Internet Connection: Stable broadband connection with a minimum speed of 10 Mbps
- Cloud Infrastructure: AWS, Google Cloud, or Azure for hosting the SaaS platform

RESULT

The implementation of this system produces a comprehensive and efficient method for capturing and interpreting user activities. By combining data from various sources, such as timestamps, URLs, text, images, and videos, the system creates a unified document that represents the user's browsing behavior. This document is enriched with metadata, descriptive captions, and transcriptions, providing an in-depth understanding of user interactions with digital content [22]. The integration of the Retrieval-Augmented Generation (RAG) module enhances the system's capability to deliver contextually relevant insights and summaries. This makes it easier to retrieve specific information based on user queries, improving both productivity and data accessibility. The results demonstrate the system's ability to streamline

information retrieval, reduce cognitive effort, and provide accurate, context-aware responses by leveraging advanced OCR, captioning models, and dynamic aggregation techniques.

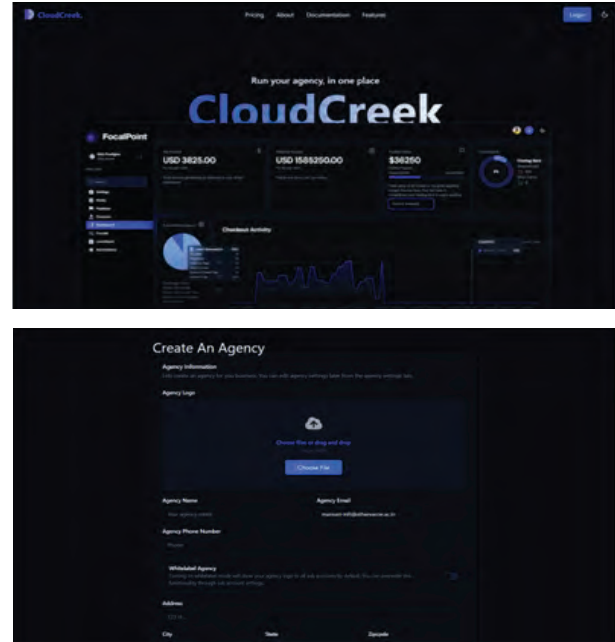


Fig. 3. Website Builder live working

LIMITATIONS

Initial Development Complexity: Designing and implementing a multi-tenant architecture with robust security measures can be challenging and time-intensive. Ensuring seamless scalability while maintaining data isolation and performance requires significant technical expertise [23].

Learning Curve: While the platform is designed to be user-friendly, agencies transitioning from disparate tools may face a learning curve in adapting to the integrated system. Training and onboarding efforts may be necessary to maximize its potential [24].

Customization Constraints: Although the platform offers customizable templates and features, agencies with highly specific or niche requirements may find the level of customization insufficient compared to bespoke solutions [25].

Infrastructure Dependency: As a SaaS platform, CloudCreek relies on stable internet connectivity and cloud infrastructure. Any interruptions in these services could disrupt operations and impact productivity [26].

Initial Cost and Resources: Developing and maintaining a SaaS platform requires a substantial upfront investment in resources, including skilled personnel, infrastructure, and marketing. Agencies adopting the platform may also need to budget for subscription fees and integration costs [27].

Integration Challenges: While CloudCreek aims to consolidate key functionalities, integrating with certain third-party tools or legacy systems used by agencies may pose compatibility challenges [28]

FUTURE ENHANCEMENTS

AAI-Powered Automation: Integrate artificial intelligence to automate repetitive tasks, such as generating client reports, suggesting project timelines, and optimizing resource allocation. AI-driven insights can also help predict project outcomes and identify potential risks [29].

Advanced Integrations: Expand compatibility with popular third-party tools, including CRMs, email marketing platforms, and accounting software, to create a seamless ecosystem for agencies. Offering an open API would allow agencies to build custom integrations based on their specific requirements [30].

Enhanced Customization: Provide greater flexibility for agencies to customize the platform, including advanced branding options, tailored dashboards, and the ability to create custom workflows and modules to suit their unique operational needs [31].

Mobile App Development: Introduce a dedicated mobile app that offers core functionalities on the go. This would enable team members and clients to manage tasks, monitor projects, and access real-time analytics from their smartphones or tablets [32].

Client Portal: Develop a dedicated client portal where agencies can share project updates, gather feedback, and collaborate directly with their clients in a secure and transparent manner [33].

Gamification Features: Incorporate gamification elements to enhance team motivation and engagement. Features like badges, progress tracking, and leaderboards can help encourage productivity and a positive work environment [34].

CONCLUSION

The proposed activity monitoring system integrates advanced technologies such as Retrieval-Augmented Generation (RAG), large language models (LLMs),

and image captioning to enhance productivity and streamline information retrieval. By continuously capturing screenshots, generating real-time captions, and analyzing browser history, the system provides users with a structured timeline of their activities, enabling efficient data management and quick access to relevant information. The system addresses key challenges such as handling large-scale visual data, managing metadata, and ensuring data security, offering a practical solution to reduce cognitive load and improve decision-making.

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IOT Enabled Locking Device for Vehicle

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ABSTRACT

The IoT-Enabled Locking Device for Vehicles is an innovative locking system designed to enhance vehicle security through Internet of Things (IoT) technology. This device integrates with a vehicle's existing locking mechanism and provides remote control and monitoring capabilities via a smartphone app or web interface. By leveraging advanced connectivity and smart technology, the IoT-enabled locking device offers a secure, user-friendly solution for vehicle access and security.

KEYWORDS: *IoT, Locking system.*

INTRODUCTION

Traditional vehicle locking systems rely on mechanical or basic electronic mechanisms to secure a vehicle. While effective, these systems lack advanced features such as remote access control and real-time monitoring. The rise of IoT technology has paved the way for smarter solutions that enhance convenience and security. An IoT-enabled locking device offers a significant upgrade by integrating with existing vehicle systems, enabling users to lock, unlock, and monitor their vehicle remotely through connected devices. This development addresses the need for improved security and ease of access in modern vehicles.

An IoT enabled locking device for a vehicle is a smart lock that utilizes internet connectivity to allow remote locking and unlocking of a vehicle via a mobile app, often including features like GPS tracking, tamper alerts, and real-time status updates, essentially enhancing vehicle security and providing the owner with complete control over their vehicle's access even when they are not physically present.

In recent years vehicle theft has become a major issue which should be traced and detected. The safety and security of the vehicle is essential. Even though there are

many existing mechanisms, they have few limitations like high cost, complexity etc. So, an efficient security mechanism is needed. With the advent of Information and communication technology (ICT) and applying it to fleet management several problems will be resolved particularly to the owner's owning the vehicles. IoT is such a technology where we can interact with the objects without human intervention. This IoT platform can be extended to several applications in the field transportation, medical, home automation

REVIEW OF LITERATURE

An Intelligent Anti-theft Vehicle Locking System using IoT

This functionality is achieved by detecting vehicle status during theft mode by a SMS generating automatically to the owner's mobile. Upon receiving the message, the owner gets the geographical position of the vehicle. The owner then operates his mobile app by which he can control the locking of the engine [1]. In order to achieve this, the developed system controlled by the mobile App is interfaced with node MCU in order to disable the ignition of the vehicle thereby preventing crimes to a great extent. Node MCU is integrated with Wi-Fi and dual-mode Bluetooth operating at low cost and at low power.

An IOT Based Vehicle Theft Detection and Remote Engine Locking System

Once the vehicle is being stolen, the owner of that vehicle cannot track and lock their vehicle. The chances to get their vehicle back are very rare and it is very difficult to get that vehicle back. It's really hard to find a vehicle if there's no evidence to help track it down. So, this system will track and monitor the vehicle's exact location using the android application and remotely locking the engine of vehicle. Vehicle tracking system has been nominated as one of the best tracking systems for the losses of the vehicle. GPS tracking[4] uses a system that helps you find the real location of something, like a car or a phone. So, we make use of GPS and android based smart phones for improving this system.

Vehicle Theft Detection and Remote Engine Locking System

Detection of vehicle start, tracking the vehicles location using GPS is being implemented and also remotely locking the engine which is implemented using an android application that will be present with user's phone. In the system the GPS tracks location of vehicle. Here both the ignition key as well as the start button in the app must be used to start/stop the vehicle. SMS alert is sent to user upon vehicle start and also in case of rash driving conditions. Then owner using the lock option in android app to lock the vehicle permanently. [2] This will help the user from preventing the theft of the vehicle. The android app mainly used to start/stop the vehicle, engine locking function and also to monitor the movement of the vehicle at any given time with its latitude and longitude.

GSM and GPS based vehicle security and controlling system

Idea behind the project is to implement the Vehicle security system using GSM technology. Proposed system will be able to control user Vehicle or any vehicle using GSM based SMS service as a communication media where at both end users need a GSM based modem or phone [5]. Consider a condition if user come to know that his vehicle is not there where it should be. Then user can stop the Vehicle activities

by sending some kind of predefined SMS to the system connected to the Vehicle and Vehicle will operate itself by switching off the can engine ignition system

WORKING

The IoT-Enabled Locking Device for Vehicles consists of several key components and operates as follows:

1. **Connectivity Module:** The device features a connectivity module that supports Wi-Fi, Bluetooth, or cellular networks. This module enables communication between the locking device and the user's smartphone or web application.
2. **Control Unit:** The control unit processes signals from the connectivity module and controls the locking mechanism of the vehicle. It includes a microcontroller that manages the communication protocols and executes locking/unlocking commands.
3. **Locking Mechanism Interface:** The device integrates with the vehicle's existing locking system through a mechanical or electronic interface. This interface allows the IoT-enabled device to control the vehicle's locks without altering the original locking mechanism.
4. **Power Supply:** The device is powered by a rechargeable battery or the vehicle's power supply. It includes a power management system to optimize battery life and ensure reliable operation.
5. **User Interface:** Users interact with the locking device via a smartphone app or web interface. The app provides features such as remote locking/unlocking, real-time status updates, and notifications. Users can also set access permissions and view the locking history.
6. **Security Features:** The device includes encryption and authentication protocols to protect against unauthorized access. It uses secure communication channels and requires user verification for remote commands.

Operational Steps

- **Initialization:** Users install the IoT-enabled device in their vehicle and pair it with their smartphone or web app.
- **Remote Control:** Through the app or web interface, users can send commands to lock or unlock the vehicle from any location with internet access.
- **Real-Time Monitoring:** The device continuously monitors the locking status and provides real-time updates to the user.
- **Notifications:** Users receive

alerts for events such as unauthorized access attempts or low battery warnings.

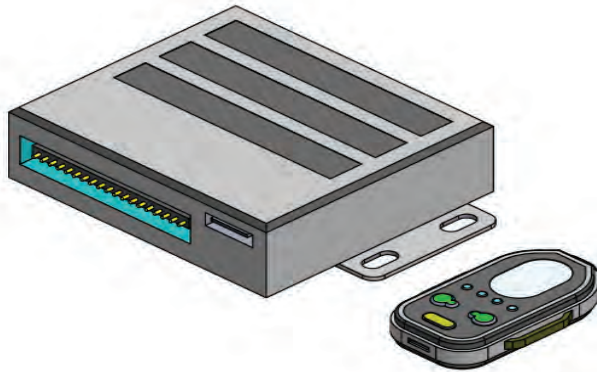


Fig. 1. Perspective view

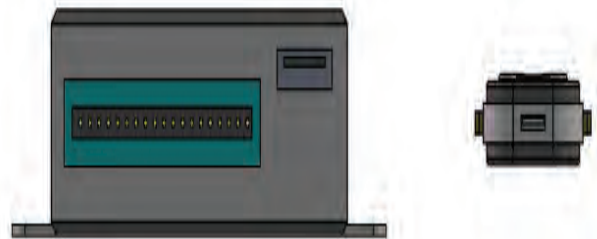


Fig. 2. Front view

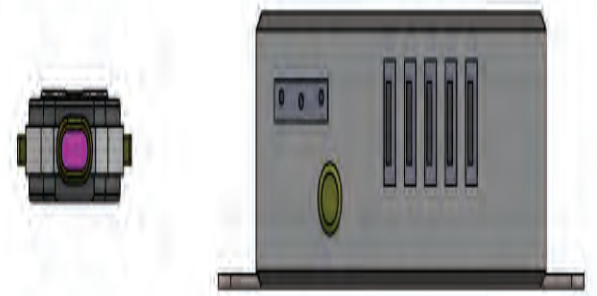


Fig. 3. Rear view

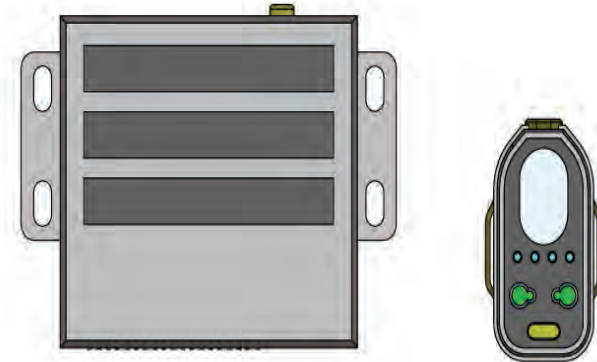


Fig. 4. Top view

Advantages

1. **Enhanced Security:** The IoT-enabled locking device provides advanced security features, including real-time monitoring and notifications, reducing the risk of unauthorized access.
2. **Convenience:** Users can lock or unlock their vehicle remotely, offering increased convenience and control.
3. **Integration:** The device seamlessly integrates with existing vehicle locking systems, preserving the vehicle's original design and functionality.
4. **User-Friendly Interface:** The smartphone app and web interface are intuitive and easy to use, allowing users to manage their vehicle's security with minimal effort.

CONCLUSION

The IoT-Enabled Locking Device for Vehicles represents a significant advancement in vehicle security technology. By integrating IoT capabilities with existing locking mechanisms, the device offers enhanced security, convenience, and user control. Its innovative design and advanced features make it a valuable addition to modern vehicles, addressing the growing demand for smart, connected solutions in automotive security. This design patent aims to protect the unique aspects of the IoT-enabled locking device, ensuring its innovation is recognized and safeguarded.

FUTURE SCOPE

As a future scope of work the project can be extended

1. By adding a few more functions for information to vehicle security systems by sending information to police forces if the vehicle is stolen, by sending GPS location and an alert message for a quick action.
2. By incorporating artificial intelligence (AI) a voice message can be sent to the owner and even intimation to the thief sitting in the car.

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FastShare: A P2P File Sharing Platform with Cloud Integration

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ABSTRACT

FastShare is a versatile web platform designed to enhance data sharing in today's digital world, addressing the need for seamless and secure file-sharing solutions. It offers three core features: Peer-to-Peer (P2P) file sharing, torrent-based file sharing, and temporary cloud storage. The P2P feature leverages WebRTC technology for secure, real-time transfers directly between devices, ensuring end-to-end encryption for data privacy. The torrent feature implements the WebTorrent protocol, allowing users to download large files efficiently from multiple sources while simplifying the user experience. Additionally, temporary cloud storage enables users to share files without permanent commitments, with automatic deletion after a specified period to manage storage effectively. FastShare prioritizes security and user privacy through robust encryption, is cross-platform compatible, and includes advanced features like file size monitoring and transfer speed optimization, catering to both novice and advanced users. improvements or additional features that could be incorporated in future versions of FastShare.

KEYWORDS: *Data sharing, P2P file sharing, Torrent, Cloud storage, Encryption, File transfer, WebRTC, WebTorrent.*

INTRODUCTION

FastShare is an innovative web platform designed to streamline file sharing through three key features: peer-to-peer (P2P) file sharing, torrent-based transfers, and temporary cloud storage. The platform enables users to efficiently share large files directly between devices using WebRTC technology, ensuring secure and fast transfers without relying on centralized servers [1]. For larger datasets, the torrent feature allows decentralized distribution, making file sharing scalable and resilient. Additionally, FastShare offers temporary cloud storage, giving users the flexibility to upload files and generate shareable links, which expire after a set time, ensuring data privacy and controlled access. With its unique combination of features, FastShare provides a seamless, secure, and versatile solution for modern data transfer needs [2].

MOTIVATION

In today's digital landscape, the demand for fast, secure, and efficient file-sharing solutions has never been greater. Whether for personal use, remote work, or collaborative projects, users need reliable platforms that allow them to share large files with ease. However, many existing platforms come with significant drawbacks, such as file size limits, high subscription costs, or concerns over data privacy due to centralized storage. These limitations can hinder productivity and raise concerns about data security. FastShare is designed to address these challenges by offering a more flexible, secure, and scalable solution for file sharing [3]. By incorporating P2P file sharing, torrent support, and temporary cloud storage, FastShare enables users to transfer data quickly and securely, without relying on third-party servers. This ensures that

users maintain control over their data while enjoying a seamless experience, whether sharing files for personal or professional purposes. FastShare's comprehensive features make it an ideal choice for modern data-sharing needs.

RELATED WORK

Several studies have explored the integration of Peer-to-Peer (P2P) networks with cloud storage, aiming to leverage the strengths of both paradigms to enhance file sharing and data distribution. One notable approach is the use of hybrid P2P-cloud architectures, where cloud storage acts as a backup for P2P networks, ensuring data availability and redundancy while still maintaining the decentralized nature of the system. For case, the work by R. Dukiya (2023) proposed a hybrid model that integrates cloud storage with P2P to provide fault tolerance and scalability for file sharing applications [2]. Similarly, in the context of security, many approaches have employed encryption schemes and decentralized authentication methods to protect user data in P2P systems, as seen in the studies by A. S. Hegde, A. N. Hegde (2023) [1]. While these solutions address issues such as data availability and security, they often suffer from scalability bottlenecks and inefficient load balancing between peers and cloud storage. Furthermore, research by K. Istvan and K. Ralf (2023) focuses on optimizing the synchronization of data between peers and cloud environments to ensure consistency and minimize latency [3]. Despite these advancements, challenges such as bandwidth limitations, peer discovery efficiency, and ensuring high throughput remain prevalent. Our proposed system, FastShare, aims to address these issues by combining the strengths of cloud storage integration and a sophisticated P2P framework, offering enhanced performance, security, and scalability.

METHODS

Peer-to-Peer (P2P) File Sharing

Peer-to-Peer (P2P) file sharing is a decentralized network model in which peers, or nodes, directly communicate with each other to share files, resources, or services without relying on a centralized server. In a P2P system, every peer functions both as a client and a server, meaning they can download and upload data to other peers in the network. This decentralized nature allows P2P networks to scale effectively as new nodes can join and share their resources, providing greater capacity and redundancy. P2P networks are particularly beneficial for large-scale file

distribution since files are broken into smaller chunks and distributed across multiple peers. This approach allows files to be downloaded in parallel from different peers, improving speed and efficiency [6].

The advantages of P2P systems include fault tolerance, as data can be retrieved from multiple sources, and reduced server costs, since no central infrastructure is required to host the files. However, the lack of centralized control can lead to certain challenges such as security risks, as malicious peers may introduce harmful files or attempt to compromise the system [5]. Additionally, network performance can be inconsistent due to varying peer availability and bandwidth. Common P2P applications include file-sharing protocols such as BitTorrent, which splits files into chunks that can be downloaded simultaneously from multiple peers. Despite these advantages, P2P systems face challenges like the potential for high bandwidth consumption and complex network management, especially when there is a large number of users or peers with unreliable connectivity [5].

Torrent File Sharing

Torrent file sharing is a popular P2P file distribution method that uses the BitTorrent protocol to break large files into smaller, more manageable pieces. These pieces are distributed across multiple peers in the network, and each peer can download different pieces simultaneously from other peers, while also uploading the pieces they have to others. This process speeds up the overall download time, as users are not reliant on a single server for the entire file [2]. In this way, torrents efficiently utilize available bandwidth by allowing concurrent data transfers from multiple sources. The protocol also ensures that once a file is fully downloaded, the user continues to contribute to the network by sharing the file with other peers, supporting the distribution process.

The Torrent system employs a distributed hash table (DHT) to facilitate peer discovery, which allows new peers to find others in the network without relying on a centralized tracker [1]. This enhances the resilience and scalability of the network, as it avoids a single point of failure. Torrent file sharing is particularly useful for large files, such as movies, software, and games, and is widely used for both legal and illegal distribution of content. However, one of the drawbacks of torrenting is that it can result in inefficient use of resources in certain environments, as peers who are unwilling to share may significantly degrade the performance of the network [3].

TECHNOLOGY USED

Frontend: React JS

React JS is a powerful JavaScript library used for building interactive and dynamic user interfaces. It enables the development of reusable UI components, making the user experience in FastShare responsive and efficient.

Backend: Node.js

Node.js is a JavaScript runtime built on Chrome's V8 engine, enabling asynchronous, event-driven server-side processing. It powers the backend of FastShare, handling real-time data exchange and file-sharing operations with high efficiency.

Library: WebTorrent

WebTorrent is a JavaScript library that facilitates P2P file sharing directly in the browser using the BitTorrent protocol. It enables users of FastShare to easily share and stream files in a decentralized manner without the need for additional software.

Library: WebRTC

WebRTC is an open-source technology that enables real-time peer-to-peer communication, including file sharing and streaming, within web browsers. In FastShare, it supports efficient and secure peer-to-peer file transfers between users.

Library: WebSocket

WebSocket is a protocol that provides real-time, two-way communication between a client and server over a single connection. It is used in FastShare for instant updates on file sharing, user status, and peer connections.

Cloud Storage: Backblaze

BackBlaze is a cost-effective cloud storage service offering scalable and secure solutions for data backup. It provides FastShare with reliable cloud storage, ensuring data redundancy and availability in case of peer unavailability.

EXISTING SYSTEM

Current file-sharing platforms such as Google Drive, Dropbox, and WeTransfer rely on centralized servers for data storage and transfer. While these platforms are user-friendly and widely accessible, they come with significant drawbacks, including file size restrictions, subscription costs for larger storage, and privacy concerns due to third-party data handling. Users must place trust in these

platforms to secure their sensitive information, which isn't always guaranteed [5].

Peer-to-peer (P2P) file-sharing solutions, though available, often require specialized applications and don't always provide the security or efficiency needed for large-scale transfers. Torrent-based systems like WebTorrent are effective for distributing large files, but they are often seen as complex and are commonly associated with illegal content, making them less appealing for casual users [5].

Cloud storage services like OneDrive and iCloud provide temporary storage options but typically require manual file management, and data security is a concern if files are not properly handled [4]. These systems lack an integrated approach for automatic file deletion after a set period, leading to storage bloat and potential privacy risks. The need for a streamlined, secure, and flexible file-sharing platform remains unmet by the current solutions. classify vegetable images, even with subtle differences between categories. The use of convolution, pooling, and softmax activation ensures the model can learn and generalize from complex visual data efficiently.

WEB TORRENT CONCEPT

Web torrent concept is relatively new in technology terms. It is dependent on peer's browser. In past some unreliable methods were available for browser to browser communication so its implementation was not possible. Now all popular browsers have WebRTC. WebRTC is a protocol that allows browser to browser communication, additionally it eliminate the centralize server system requirements. WebRTC is an open source project, additionally it is specially designed for light weight communication.

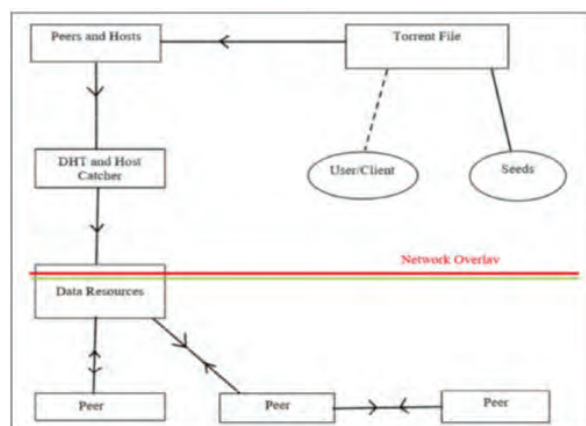


Fig. 4. Data Workflow and Distribution in P2P Networks

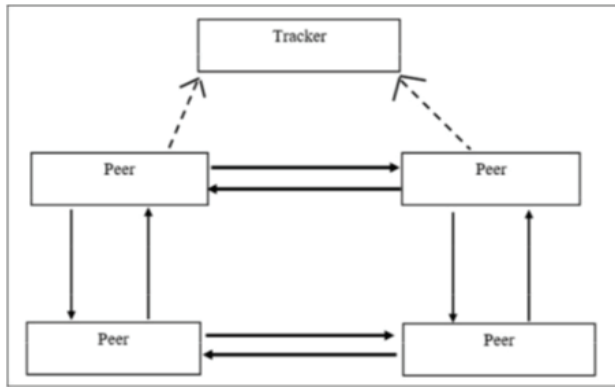


Fig. 5. Peer workflow in the network

Program Design

1. Creating/collecting a .torrent file - During design our first objective is creating or collecting a valid torrent file. This file contains a map of our target download in metadata format. The data is file is encoded in bencode, which is an encoding format.
2. Analysis of a .torrent file - In this step we will decode the file and start analysis of metadata. After decoding we can see tracker information and datamap.
3. Connecting to a tracker - We can get tracker url with 'announce' key in that metafile. The tracker is a just HTTP which contains sharable data and peers info. It do not have desired data but keeps record that how many users are connected, what they are downloading, how much they finished. It response on GET request.
4. Connect to peers - Peer connections are made through TCP to the appropriate host IP and port. Now might be a good time to consider how or if you want to deal with connecting to multiple peers at the same time, as this will influence how you connect to your peers.
5. Handshake with peers - After made once you have a connection

Peer-to-Peer (P2P) sharing method has risen as a critical worldview for providing distributed services, specifically find a node and sharing of information [8]. Right now P2P systems are developed and maintained by members taking after their own particular ungraceful protocols. They therefore experience the bad effects of continuous network overload, partitioning and transfer speed. In this paper, researcher's tires to implement P2P networks using a different distributed method. Author give a distributed protocol to build systems with great topological

properties— to be specific, steady degree, network, what's more, low width. An appealing element of the protocol is that it is easy to actualize. They break down the protocol under a practical element setting and demonstrate thoroughly that it brings about the above properties with huge probability. We likewise demonstrated that our protocol is normally robust to disappointments and that it has decent self-correcting properties, for example, rapid recovery from network error. In this paper the author shows that ISP can collaborate with P2P system to make or earn profits and improve performance [5]. See that the p2p has emerged as a very agnostic in the recent years so to overcome this problem they propose a solution that ISP should collaborate or P2P systems so that ISP can earn much profits and users can enjoy improved performance. So the idea behind if an ISP can issue an Oracle to its user to keep track of neighbors p2p nodes or detail to whom to download the content and this technique tells that whosoever have the greatest potential of giving the most official proper content and it rank to querying nodes bestowing to user's locality. For ranking they proposed a metrics evaluates the impact of using the Oracle method which shows the entities like small mean path lengths and small diameter and node degree the result will be calculated as graph based simulation as well as experimented method can put changes in p2p clients. In this paper here author describes how to make a super-peer Networks so first of all super-peer network is entity of p2p networks that can play the role of both as a server to multiple clients and can be one in a network of super-peers [5]. The authors describes in this paper how they examine the super- peer networks in brief, and showing the performance benchmark tradeoffs and the fundamental characteristics of super node. They also teach the process of design of efficient super-peer networks. As a result they gave 4 rule of thumb.

RESULTS



Fig. 6. Landing Page

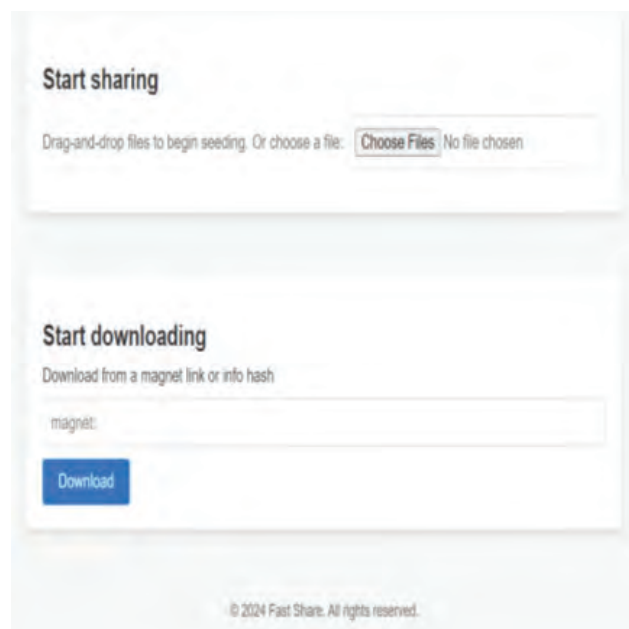


Fig. 7. File sharing

SUMMARY

FastShare addresses the growing need for efficient and secure data sharing in today's digital landscape. By incorporating features such as P2P file sharing, a torrent system, and temporary cloud storage, FastShare offers users a comprehensive solution for managing their data transfer needs. The P2P file sharing feature ensures faster and more reliable uploads and downloads by utilizing the bandwidth of multiple users. The torrent functionality enhances accessibility for larger files, making it easier to share and distribute content. Additionally, the temporary cloud storage option provides users with a secure space for short-term file storage, ensuring privacy and convenience. Through rigorous testing and user feedback, FastShare

has demonstrated its potential to facilitate seamless data sharing while prioritizing security and user experience. As digital content continues to expand, platforms like FastShare are crucial in providing users with innovative tools to navigate their data sharing challenges effectively. Future enhancements could focus on integrating more advanced security measures, optimizing the user interface, and expanding the platform's capabilities to include collaboration tools. Overall, FastShare stands as a promising solution in the realm of data sharing, paving the way for more efficient and user-friendly technologies.

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Applying Augmented Reality in the Fight Against the COVID-19

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ABSTRACT

The COVID-19 pandemic has created an unprecedented global crisis, deeply affecting healthcare systems, economies, and societies. Innovative technologies have become essential in addressing these multifaceted challenges, and Augmented Reality (AR) has emerged as a transformative solution. AR's capacity to seamlessly integrate digital elements into the physical world offers novel applications in healthcare, education, logistics, and public safety. This paper explores the expansive role of AR in combating the COVID-19 crisis, providing an in-depth analysis of its applications, benefits, challenges, and future directions. By presenting detailed case studies and examining technical, social, and ethical dimensions, this study demonstrates AR's potential to revolutionize pandemic response strategies.

KEYWORDS: COVID-19, Patient, Augmented reality, Healthcare, Public safety.

INTRODUCTION

The COVID-19 pandemic has disrupted nearly every aspect of human life, posing significant challenges to healthcare systems, supply chains, education, and public safety. The rapid spread of the virus necessitated innovative approaches to mitigate its impact, and Augmented Reality (AR) emerged as one of the most promising technologies to meet these challenges. AR enhances the real-world environment by overlaying it with digital information, creating an interactive and immersive experience.

This paper provides a comprehensive exploration of AR's applications during the COVID-19 crisis, highlights its transformative potential and limitations by examining specific cases and their implications. We aim to demonstrate how AR can be leveraged to address current and future global challenges.

THE ROLE OF AR IN COMBATING COVID-19

Revolutionizing Healthcare

Healthcare has been one of the most critical areas affected

by the pandemic, and AR has provided innovative solutions to enhance service delivery:

Remote Patient Monitoring and Care: Augmented reality (AR)-enabled devices played a key role in remote patient monitoring by reducing the need for in-person interactions and minimizing the risk of infection. Wearable AR technologies provide healthcare professionals with real-time data on patients' health metrics, such as heart rate, blood pressure, and oxygen levels, directly from their homes. This facilitated timely interventions and allowed for continuous, non-invasive monitoring, ensuring patients received prompt care while minimizing exposure to potential health threats. The integration of AR into healthcare not only improved patient safety but also enhanced the overall efficiency of remote care.

Diagnostics and Imaging: Augmented reality (AR) applications significantly improved diagnostic accuracy by superimposing essential data onto medical imaging, providing doctors with deeper insights[1]. For example, AR tools enabled healthcare professionals to view 3D reconstructions of organs, offering a more detailed and interactive perspective. This enhanced visualization

proved particularly valuable in diagnosing and treating complications arising from COVID-19, as it allowed for better identification of issues like lung damage or respiratory distress. By integrating AR into medical diagnostics, clinicians were able to make more informed decisions, leading to more effective and precise treatments.

Telemedicine: Augmented reality (AR) integration into telemedicine platforms transformed virtual consultations by incorporating interactive diagnostic tools and visual aids that enriched the healthcare experience. These AR features allowed doctors and patients to engage more effectively, with real-time overlays that helped explain symptoms, anatomy, or treatment options. By creating a more immersive and informative environment, AR-enhanced telemedicine improved diagnostic accuracy and patient understanding, ensuring that remote consultations were not only convenient but also of higher quality and precision.

Surgical Assistance: Surgeons increasingly turned to augmented reality (AR) to gain real-time, 3D visualizations of patient-specific anatomical structures, significantly enhancing precision during complex surgeries [2]. By overlaying detailed, personalized data onto the patient's body, AR allowed for more accurate navigation and decision-making, minimizing the risks associated with delicate procedures. This technology not only guided surgeons with greater clarity but also helped them anticipate challenges and tailor their approach, improving outcomes and reducing the likelihood of errors during critical operations.

Enhancing Remote Collaboration

Lockdowns and social distancing measures forced organizations to adopt remote work solutions. AR played a crucial role in maintaining productivity and collaboration:

Immersive Virtual Meetings: Immersive virtual meetings have transformed the way teams collaborate by creating interactive environments where participants can engage with 3D models, shared virtual spaces, and real-time data. Unlike traditional video conferencing, these meetings leverage augmented reality (AR) to bridge physical and digital worlds, enabling participants to interact as if they were in the same room. This innovation is particularly beneficial for industries requiring hands-on collaboration, such as healthcare, engineering, and design, where visualizing concepts in a shared augmented space enhances understanding and decision-making. By fostering a sense

of presence and interactivity, immersive virtual meetings have redefined remote teamwork, making it more dynamic and effective.

Training and Education: Training and education have been revolutionized by the integration of augmented reality (AR), offering immersive and interactive learning experiences that go beyond traditional methods. AR allows learners to visualize complex concepts in three dimensions, enabling hands-on practice in a virtual environment that closely simulates real-world scenarios. For instance, medical trainees can practice surgical procedures on virtual patients, while students studying science can explore molecular structures or historical landmarks in an engaging, lifelike manner. This technology also facilitates remote learning, ensuring continuity of education regardless of location, while enhancing knowledge retention and skill development. By merging theoretical knowledge with practical application, AR has set a new benchmark for modern education[7] and professional training.

Public Awareness and Behavioral Change

Educating the public about prevention measures was vital to controlling the pandemic. AR proved instrumental in engaging and informing communities:

Interactive Awareness Campaigns: Interactive awareness campaigns powered by augmented reality (AR) have redefined how information is communicated, making public health education more engaging and impactful. By using AR-enabled apps or devices, individuals can experience visual demonstrations of crucial behaviors, such as proper handwashing techniques or maintaining social distancing, in real time. These campaigns transform static messages into dynamic, interactive experiences, capturing attention and fostering better understanding. For example, an AR app might project a virtual guide demonstrating mask-wearing procedures or overlay distancing markers in crowded spaces. This innovative approach not only increases awareness but also drives behavioral change by providing personalized, memorable interactions tailored to diverse audiences.

Educational Initiatives: Educational initiatives enhanced by augmented reality (AR) have brought a new level of engagement and accessibility to learning experiences. AR transforms

traditional teaching methods by overlaying digital content onto the physical world, enabling students to explore

subjects through immersive, interactive lessons. For example, learners can witness historical events reenacted in 3D, dissect virtual organisms in biology, or manipulate molecular structures in chemistry. These initiatives make abstract concepts tangible, improving comprehension and retention. Additionally, AR bridges the gap in remote education by offering hands-on experiences that were once only possible in physical classrooms. By fostering creativity and curiosity, AR-driven educational programs empower students to learn actively and effectively in an ever-evolving digital landscape.

Streamlining Logistics and Supply Chains

The pandemic exposed vulnerabilities in global supply chains. AR addressed these challenges by:

Optimizing Warehouse Operations: Augmented reality (AR) has revolutionized warehouse operations by providing workers with intuitive, real-time guidance for managing inventory. Through AR-enabled devices, employees can access visual overlays that display precise locations of items, streamline navigation within storage facilities, and offer step-by-step instructions for picking and packing tasks. This technology reduces errors, accelerates workflow, and minimizes the time spent searching for supplies, ensuring critical resources are retrieved efficiently. By integrating AR into warehouse management, organizations have not only enhanced operational accuracy but also optimized the overall supply chain, enabling quicker and more reliable delivery of essential goods.

Real-Time Navigation: Delivery personnel utilized augmented reality (AR) navigation systems to enhance their route planning, enabling them to navigate with precision and efficiency. This cutting-edge technology allowed them to avoid traffic congestion and select the most time-efficient paths, ensuring that medical supplies and essential goods reached their destinations promptly. By integrating real-time data into the AR interface, drivers could dynamically adjust their routes, ensuring timely deliveries while maintaining the highest level of service in critical situations.

Monitoring Vaccine Distribution: Augmented reality (AR) tools played a crucial role in overseeing the distribution of vaccines, offering real-time monitoring of storage conditions and transportation processes. These tools provided instant access to data regarding temperature and environmental conditions, ensuring compliance with

stringent cold chain standards. By overlaying critical information on physical spaces and transportation vehicles, AR enabled healthcare professionals to track and verify that vaccines remained within the necessary temperature ranges throughout the distribution process, minimizing the risk of spoilage and ensuring safe delivery to their final destinations.

Innovations in Public Safety

Public safety measures during the pandemic were supported by AR applications:

Crowd Management: Augmented reality (AR) systems were deployed to efficiently manage crowd flow in public spaces by continuously monitoring crowd density and providing real-time guidance [5]. These systems visually alerted individuals to maintain safe social distances, using dynamic overlays to direct people to less congested areas. By leveraging AR's ability to assess and display crowd patterns instantly, the technology helped reduce overcrowding, ensuring compliance with health guidelines and promoting a safer environment during times when physical distancing was critical.

Thermal Screening: Augmented reality (AR) devices were combined with thermal imaging technology to enhance health monitoring by detecting individuals with elevated body temperatures. These advanced systems allowed for immediate identification of potential fever cases, offering a proactive approach to health screening in crowded or high-risk environments. By seamlessly integrating thermal data into AR displays, the devices facilitated quick responses, enabling personnel to isolate individuals exhibiting symptoms, ensuring early intervention, and helping prevent the spread of illness.

IN-DEPTH CASE STUDIES

This section presents detailed analyses of how organizations and governments have utilized AR to combat the pandemic. Examples include:

AR in Vaccine Rollout

The incorporation of Augmented Reality (AR) technologies into the vaccine rollout process has demonstrated significant potential in addressing logistical challenges. Below is a detailed analysis of how AR contributed to the efficient and safe distribution of vaccines, particularly during the COVID-19 pandemic

Real-Time Visual Overlays for Logistics Management AR

applications provided decision-makers and logistics teams with real-time visual overlays that mapped out routes, highlighted potential obstacles, and optimized travel paths. By integrating AR with GPS systems, logistics teams could view dynamic, visualized routes overlaid on real-world environments. This ensured that delivery trucks or drones navigated through the most efficient paths, even in remote or congested areas. AR dashboards offered a live view of delivery progress, allowing for quick adjustments if roadblocks, weather disruptions, or other unforeseen issues arose.

Monitoring Storage Conditions

Vaccine integrity heavily depends on maintaining strict temperature controls (cold chain requirements). AR played a critical role in ensuring compliance. AR tools, integrated with IoT devices, provided instant visual alerts about storage conditions. For example, if a shipment's temperature began to deviate from the required range, AR interfaces highlighted the affected containers in real-time. AR also visualized data trends, predicting potential equipment failures or environmental risks before they occurred, thus preventing vaccine spoilage.

Coordination Across Diverse Regions

AR technologies were instrumental in ensuring effective coordination, particularly in areas with challenging terrains or limited infrastructure. Using AR headsets or mobile applications, drivers and field personnel received step-by-step navigation instructions, complete with visual guides for loading, unloading, and storage procedures. In regions inaccessible by traditional vehicles, AR-guided drones facilitated last-mile deliveries. Visual overlays helped operators monitor flight paths and avoid obstacles.

Addressing Geographical Barriers

Geographical constraints posed significant challenges during the vaccine rollout. AR mitigated these by Mapping [4] Remote Areas and Simulating Delivery Scenarios AR-enabled systems overlaid geographical and infrastructure data to identify and plan delivery routes in underdeveloped or disaster-affected regions. AR allowed logistics planners to simulate and test delivery strategies in virtual environments before execution, ensuring preparedness for real-world challenges.

Improved Decision-Making Through Data Integration

AR systems integrated data from multiple sources, including weather forecasts, traffic conditions, and storage

analytics, presenting it in an intuitive, visual format. This enabled Faster Response Times and Resource Allocation. Logistics teams could make informed decisions quickly, reacting to delays, disruptions, or emergencies. By visualizing resource availability and requirements, AR systems ensured that critical supplies were allocated where needed most.

Impact on Timeliness and Security

The combined capabilities of AR in logistics enhanced both the speed and security of vaccine distribution: Optimized routes and real-time adjustments reduced delays, ensuring vaccines reached vaccination centers promptly. AR applications monitored shipments for unauthorized access or tampering, providing additional layers of security.

Several organizations such as Pfizer, WHO and UNICEF adopted AR during the vaccine rollout. Pfizer used AR in its Cold Chain Monitoring system AR-integrated systems monitored their ultra-cold storage requirements, ensuring the vaccines remained effective throughout transportation. WHO and UNICEF used AR for Deliveries. In remote areas of Africa, AR-guided drones successfully delivered vaccines, bypassing poor infrastructure.

Disinfection Protocols

The advent of Augmented Reality (AR) in disinfection protocols has ushered in a new era of precision and efficiency in maintaining hygiene standards. By leveraging real-time visual overlays and data-driven insights, AR-powered systems have transformed how cleaning and sanitization efforts are conducted in critical environments such as hospitals, schools, and public spaces. Below is an in-depth analysis of this innovative application.

Targeted Identification of High-Risk Areas

AR technology excels in pinpointing surfaces and zones most susceptible to contamination. Using data from sensors, AR systems highlight high-contact areas, such as door handles, elevator buttons, and shared equipment, guiding cleaning teams to prioritize these spots. AR tools continuously analyze environmental conditions, foot traffic, and usage patterns to adjust the focus of disinfection efforts as needed. This level of precision minimizes resource wastage by ensuring that cleaning agents and efforts are concentrated where they are most effective.

Enhanced Visualization for Cleaning Teams

Traditional cleaning methods often rely on general

guidelines, leaving room for oversight. AR solves this by providing visual instructions overlaid directly onto the physical environment. AR systems project step-by-step cleaning paths onto floors or surfaces, guiding staff through a systematic process and ensuring thorough coverage. Surfaces are highlighted with different colors to denote their sanitization status (e.g., red for untreated, green for sanitized), offering instant clarity and reducing errors. These features empower cleaning personnel to maintain consistent hygiene standards while minimizing redundant or missed tasks.

Integration with IoT and Monitoring Systems

AR-powered disinfection protocols often work in tandem with Internet of Things (IoT) devices to enhance effectiveness. IoT sensors embedded in high-touch areas detect microbial levels or contamination risks, which are then visualized through AR interfaces for immediate action. AR systems also display data on room conditions, such as humidity and airflow, which influence pathogen survival. This information helps cleaning teams adjust protocols accordingly. By combining AR with IoT, organizations can adopt a proactive rather than reactive approach to sanitization.

Applications Across Diverse Settings

The versatility of AR-powered cleaning systems has enabled their application across a wide range of environments such as Hospitals and Healthcare, Schools and Educational Institutions and Public Spaces. In critical care areas, AR highlights contamination-prone zones, ensuring compliance with stringent hygiene protocols and reducing the risk of hospital-acquired infections. AR systems help prioritize cleaning in classrooms, cafeterias, and restrooms, creating safer spaces for students and staff. Airports, shopping malls, and transportation hubs benefit from AR-guided cleaning teams that efficiently tackle high-traffic areas prone to contamination.

Efficiency and Resource Optimization

AR technology not only improves the thoroughness of disinfection but also optimizes the use of resources. AR Reduces Cleaning Time. Visual guidance minimizes guesswork, allowing cleaning teams to complete tasks more quickly without sacrificing quality. By focusing efforts on critical zones, AR systems help avoid the overuse of disinfectants, lowering costs and reducing environmental impact.

Promoting Safety and Confidence

The visible presence of AR-guided cleaning teams enhances public confidence in hygiene measures. Real-time visual cues and status updates reassure employees, patients, and the public that comprehensive cleaning is taking place. For cleaning staff, AR reduces exposure to hazardous chemicals by streamlining processes and minimizing redundant actions.

CHALLENGES AND BARRIERS TO AR IMPLEMENTATION

While AR holds immense promise, its adoption during the pandemic faced several challenges:

Cost and Accessibility: The adoption of augmented reality (AR) technology faced significant barriers in low-income regions due to the high costs associated with both the hardware and software required. These expenses made it difficult for organizations and individuals in such areas to access the benefits of AR, limiting its widespread use and creating a gap in technological equity. As a result, the potential of AR to improve various sectors, from healthcare to education, remained out of reach for many, underscoring the need for more affordable solutions to foster global inclusivity.

Technical Limitations: The widespread adoption of augmented reality (AR) was hindered by several technical challenges, including limited battery life, latency, and device compatibility issues. These limitations often resulted in less-than-optimal user experiences, with delays and disruptions affecting the fluidity of interactions. Additionally, the need for specific hardware configurations or updates across various devices created inconsistencies, preventing seamless integration and widespread use. These technical barriers slowed the broader implementation of AR, emphasizing the need for advancements in performance and universal compatibility to fully unlock its potential.

Privacy and Security Concerns: Augmented reality (AR) applications frequently involve the collection of sensitive personal data, such as location, behavior patterns, or even biometric information, raising significant privacy and security concerns. This data, while essential for enhancing user experiences, also opens the door to potential misuse or breaches, sparking ethical and legal debates over how it should be stored, shared, and protected. As AR technology becomes more prevalent, addressing these concerns is critical to ensure that user privacy is respected and that

security measures are in place to safeguard sensitive information from exploitation.

Skill Gaps: The effective deployment of augmented reality (AR) technology during the pandemic was challenged by a significant shortage of specialized skills required for its implementation. The complexity of AR systems, which demand expertise in areas like software development, data analysis, and hardware integration, made it difficult for many organizations to leverage the technology fully. With the sudden surge in demand for digital solutions, the lack of skilled professionals posed a major obstacle, slowing down the adoption of AR in industries that could have benefited from its capabilities during critical times.

CONCLUSION

The COVID-19 pandemic has underscored the critical need for technological innovation in crisis management. AR has demonstrated its potential to revolutionize healthcare, education, logistics, and public safety, providing unique solutions to unprecedented challenges. By addressing current limitations and embracing future advancements, AR can play a pivotal role in preparing for and responding to global crises. This paper highlights the importance of continued investment and innovation in AR to ensure its readiness for future applications.

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Identifying Mental Health Status Using Machine Learning Model Based on General Psychopathology

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ABSTRACT

The widespread changes in lifestyle and burdens lead to increase in mental health issues which need to be addressed properly. It is therefore required to design and develop applications which will help diagnose and monitor mental health status. Also, recommendations for further treatment need to be considered. This study aims at the design and development of a prediction model based on classification using machine learning algorithms. Various important parameters responsible for mental health issues are considered in the feature selection and prediction model constructed using decision tree and random forest classifier. Also, recommendations which can further be supervised by clinicians for treatment can be provided. Based on the experimental results, it is observed that the decision tree classifier model performs better with accuracy of 95% whereas random forest gives comparatively less accuracy of 74%. The proposed model can help in predicting mental health status of a person and help for relevant clinical diagnosis.

KEYWORDS: Mental health status, Feature selection, Predictions, Decision tree, Random forest, Accuracy.

INTRODUCTION

It is estimated that 264 million people globally suffer from mental illness disorders such as depression and anxiety, which is one of the most common causes of disability [1]. The World Health Organization (WHO) in 2018 has published a guideline related to mental issues and disorders which need to be addressed [2]. These challenges have shown that mental illness has a negative impact on population in general and demands the development of new prevention and intervention methods [3]. To diagnose a patient's problem, the doctor may ask the patient to fill out a questionnaire. The nature of these questions could be situational and objective which mainly includes depression, anxiety [4]. Mental health professionals use face-to-face interviews, self-reporting and questionnaire distribution to diagnose the mental health status of individuals whereas in clinical settings, disorders are identified using the statistical manual of mental disorders [5]. It is therefore required to design and

develop AI-based innovative diagnostic, monitoring, and therapeutic methods which will help to enhance mental health outcomes, reduce the treatment gap and minimise practitioner workload [6,7].

Motivation

The increasing prevalence of mental health issues due to significant lifestyle changes and stressors presents a pressing challenge for modern society. As these conditions become more widespread, effective tools for diagnosis and monitoring are essential. Traditional methods of evaluating mental health often lack the necessary immediacy and scalability to address this growing epidemic. Therefore, there is a critical need for innovative applications that leverage technology to enhance mental health diagnosis and treatment recommendations [18][19]

This research is motivated by the urgent requirement to harness machine learning algorithms to develop a robust prediction model for mental health status assessment. By

focusing on feature selection and incorporating various influential parameters, we aim to provide accurate predictions that can aid healthcare professionals in offering tailored treatment plans. Our study specifically explores the efficacy of decision tree and random forest classifiers, highlighting the potential of decision trees to achieve a remarkable accuracy of 95%.

The implications of this research extend beyond mere statistical analysis; they offer a pathway to facilitate clinical decisions and improve patient outcomes. By equipping clinicians with reliable tools for mental health assessment, we strive to contribute to a holistic approach to mental health care, ensuring timely interventions and personalized treatment strategies.

LITERATURE REVIEW

In recent times, many studies and researches contribute to the work where people have been predicting mental health problems like depression and anxiety using the algorithms of machine learning, like decision tree, support vector machine, random forest and convolution neural network [3]. In many studies, python programming has been used for modelling experiments, with the best result among all the classifiers. The authors of [8] show that the main symptoms of depression from a clinical point of view are loss of memory; lack of concentration; an inability to make decisions which is more dangerous and need immediate and correct diagnosis. Factors like Anxiety and mood disorder were discussed in [8] which can be detected by scanning a patient's facial expressions. Authors of [9] discuss various survey methods to predict mental illness which include offline and online surveys using chatbots also [9]. The work in [10] talks about data of individuals working in the industry and predicts depression based on multiple work-life and personal life-based factors using various machine learning algorithms. The authors of [11] propose ANN based models for mental disorder detection and suggest work life balance also. In [12], authors design and discuss the work related to the Mental Health Prediction application, a one stop solution for all the employees where they can check their mental health regularly. WEKA and SPYDER tools can also be used to apply different data mining techniques for the prediction of mental status [13]. The authors of [14] discuss more severe mental diseases like diagnosing bipolar disorder, automatic depression estimation using deep neural networks.

METHODOLOGY

This research study is carried out using the following workflow.

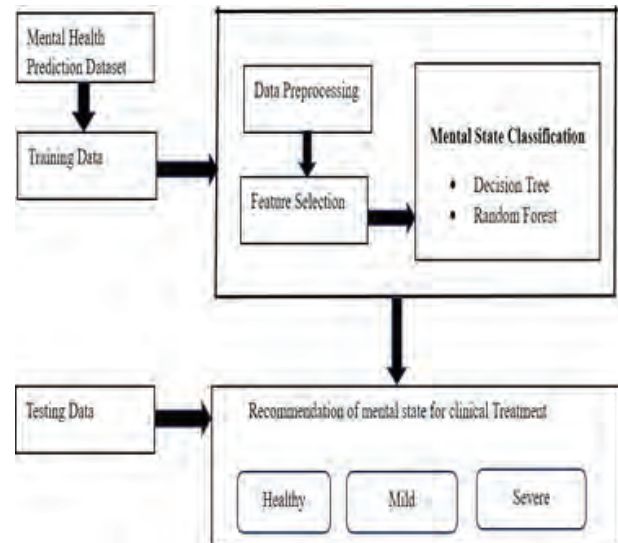


Fig. 1: Proposed Mental Health Status Prediction Model

The methodology, as shown in Figure 1, for this study consists of a systematic approach to predicting mental health status using a well-defined dataset and machine learning techniques. Step 1 focuses on acquiring and preparing the mental health prediction dataset, which includes a wide range of features relevant to mental health assessments. In Step 2, the dataset is divided into training and testing subsets, and the model is trained using two classification models: decision tree and random forest. These models were chosen for their strong classification capabilities and interpretability. Finally, in Step 3, the trained models are tested on the testing dataset, and the predictions are used to categorize individuals' mental health statuses as "healthy," "mild," or "severe." This structured approach makes it easier to identify different levels of mental health, providing valuable insights for future clinical evaluations and interventions.

DATA COLLECTION

The proposed study has been carried out using a thoroughly prepared survey form which collects human mental state related information based on various parameters. Multiple questions related to mental health are asked to various individuals of different age groups and then analyzing every response from the individuals the dataset is made. A sample of the dataset is shown in figure 2.

Variables	Scale/Question	Author	No. of Items/Questions	Likert Response 1	Likert Response 5	How the final scores are taken
General Psychopathology	SCL-R-9	Raphofer and Brähler, 2001	9 items	Not at All	Completely	Mean of 9 items
Coping Strategies	Brief COPE	Carver, 1997	14 items (2 per strategy)	Never	Very Often	Mean of 2 items per coping strategy
Shyness	Clark and West Shyness Scale	Clark and West, 1991	9 items	Not at all	Completely	Mean of 9 items
Loneliness	NYU Loneliness Scale	Robenstein and Shaver, 1982	4 items	Strongly Disagree	Strongly Agree	Mean of 4 items
Self-Esteem	Rosenberg Self-Esteem Scale	Rosenberg, 1979	5 items	Strongly Disagree	Strongly Agree	Mean of 5 items
Life-Satisfaction	Satisfaction with Life Scale	Ed Diener et al., 1985	5 items	Strongly Disagree	Strongly Agree	Mean of 5 items

Fig. 2 : Sample question types in survey

DATA PREPROCESSING

The data collection process has been conducted meticulously; however, there are still certain parameters where the data appears to be insufficient and requires careful cleaning. To address this, several pre-processing steps have been undertaken on the dataset generated from the mental health survey questionnaire. These steps include:

- **Removal of Irrelevant Features:** Features identified as unnecessary for the analysis have been systematically removed from the dataset to enhance focus and efficiency in subsequent processing.
- **Correction of Erroneous Inputs:** Erroneous entries have been identified and corrected, specifically addressing issues such as improperly recorded ages and restricting gender to only male or female categories. This ensures the integrity and reliability of the data.
- **Renaming of Columns:** Columns within the dataset have been renamed as necessary to improve clarity and ensure that they accurately convey the information they represent.
- **Calculation of Mean Values for Each Factor:** The dataset encompasses responses for each question associated with various mental health factors. To simplify analysis and interpretation, the mean value for each factor has been calculated for each individual respondent, providing a clear overview of their mental health status.
- **Encoding of Categorical Features:** To facilitate the application of machine learning algorithms,

categorical features within the dataset have undergone encoding, transforming these non-numeric data points into a numeric format suitable for further analysis.

FEATURE SELECTION

Feature selection aims at identifying a sample of highly distinguishing variables for diverse mental health diagnoses. In this multi-level categorization procedure, every data point could be correlated with many labels. Out of many input features only a few of them are important in the classification of mental health. As a result, the dataset is subjected to the feature selection procedure in order to reduce the input vector size. The highest ratings features contributing the most to the decision-making process are kept and lower scoring features are removed. Based on General Psychopathology following are the parameters which are most relevant to mental health of individuals and these are used for feature selection based on correlation matrix analysis.

- Coping Strategy
- Venting
- Shyness
- Loneliness
- Self Esteem
- Life Satisfaction

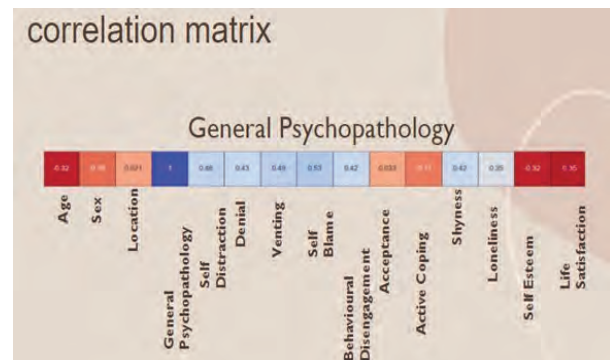


Fig. 3: General Psychopathology Correlation Matrix Details

MACHINE LEARNING TECHNIQUES FOR PROPOSED PREDICTION MODEL

An overview of the machine learning algorithms used in the proposed project for pre-clinical anxiety stages can be found in the subsections that follow.

Decision Tree Classifier: It has a tree-like architecture where each internal node represents a feature or attribute, each branch represents a decision rule based on that feature, and each leaf node represents a class label or a final decision [15]. A decision tree classifier is a supervised machine learning algorithm that is used for classification tasks.

Random Forest Classifier: The Random Forest algorithm is a supervised training algorithm. It creates a “forest” from a group of decision trees trained by the “bagging” method. The bagging method’s key notion is that combining multiple learning models improves overall capacity. The Random Forest adaptive learning method consists of several decision trees and helps to build significantly more reliable and accurate models as compared to single decision tree [16].

EXPERIMENTAL RESULT AND ANALYSIS

After data preprocessing and feature extraction, exploratory data analysis is performed to explore many important facts about data and its behavior. The results are depicted in terms of pie charts for comparative analysis. Few of the important charts are as mentioned below.

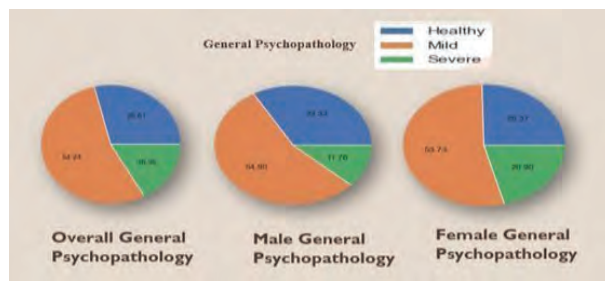


Fig. 4: Gender Value Based General Psychopathology Distribution

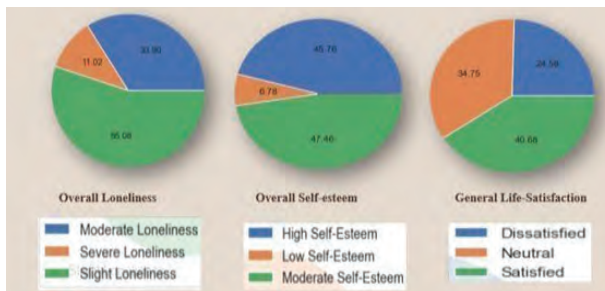


Fig. 5: Gender Value Based Distribution for Shyness

Person Name	Age	Sex	Location	Self-Distraction	Denial	Worrying	Self-Blame	Disengagement	Acceptance	Active coping	Shyness	Loneliness	Self-esteem	Life satisfaction	Predicted Mental Health Status
Samir	22	male	urban	4	2	3.5	2.5	3	4.5	4.5	2.000	2	3	3	Healthy
Priyanka	23	Female	urban	4	1	4	2	3	4	3.5	1.000	1	4.2	3.6	Mild

Fig. 6: Distribution for Loneliness, Self Esteem, Life Satisfaction

The Mental Health Prediction Model is then constructed on training data using Decision tree and random forest classifier. The model is a multi-classification model wherein the mental health status is classified into three classes as healthy, mild, severe. Decision tree classifier performs well with accuracy of 95% whereas random forest could give accuracy of 74% only. The experimental results based on confusion matrix accuracy metric are as mentioned below.

Table1: Experimental Results of Proposed Prediction Model

	Decision Tree Classifier	Random Forest Classifier
Train Data	0.99%	0.76%
Test Data	0.95%	0.74%

The Prediction model is tested on individual person’s data to predict the status and provide recommendations for further clinical decision making and treatment. Following table shows mental health status as healthy, mild or severe based on input parameters.

CONCLUSION AND FUTURE WORK

An efficient prediction model can definitely help clinicians in decision making and planning treatment in a better way. Machine Learning techniques surely give better results like decision trees. The study needs more real time data and also it is required to focus on a multimodal approach. Due to limited sample data, model overfits in case of decision tree which need parameter tuning in future for better results. Apart from machine learning techniques, deep neural network approaches can also help to improve performance of models. In the near future, this study will be extended with high dimensional data along with a multi-dimensional model approach to cover and analyze an individual’s mental health status in a better way.

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A Scheme for Ontology Matching

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ABSTRACT

Today, due to the storage availability across heterogeneous environments, the data is scattered in many database systems as per the requirements of organizations. There are heterogeneity problems while collecting, matching and consolidating such data. Therefore, we present an effective scheme for ontology mapping based on Top-K ontology matching framework. This scheme matches ontology designs that are heterogeneous in nature and effective due to its hierarchical structure.

KEYWORDS: *Ontology, Matching, Schema, Heterogeneity.*

INTRODUCTION

Identifying concepts from different ontologies is a persistent problem for businesses and organizations. Ontology matching is a process that involves aligning concepts and relationships between different ontologies. An ontology is a formal representation of knowledge within a specific domain, structured as concepts (classes), properties, and relationships. The purpose of ontology matching is crucial in areas like data integration, semantic web technologies, and information retrieval. Since ontologies are often created by different systems or for different domains, matching them accurately ensures better interoperability and easier data exchange. The primary objective of this task is to find similarities or equivalences between entities (e.g., classes, properties) in distinct ontologies [1][2][3].

The process can be based on:

Schema Matching: Mapping the structural components of different ontologies.

Instance Matching: Aligning data instances shared between ontologies.

Matching Approaches: Various techniques exist for aligning ontologies, such as:

Lexical Matching: This method compares the labels or names of concepts using string matching or similarity algorithms.

Structural Matching: This technique evaluates how concepts are related within their respective ontologies.

Semantic Matching: Focuses on the underlying meaning of the concepts, even when they are named differently. It leverages external knowledge (e.g., taxonomies or lexical databases) to align concepts based on their meanings rather than just labels.

The ontology matching process is not without difficulties, such as:

Ambiguity: Terms might have different meanings, or two different terms may represent the same concept.

Heterogeneity: The structure and format of ontologies can differ, complicating the matching process.

Scale: Large ontologies with many concepts and relationships can make the matching process computationally intensive.

Ontology matching is vital for enabling seamless communication and data exchange between different systems, even when they represent knowledge in diverse ways [4][5][6][7][8].

LITERATURE REVIEW

In recent years, significant advancements have been made in ontology matching tools and methodologies. Below is an updated overview incorporating developments up to 2024:

SAMBO (System for Aligning and Merging Biomedical Ontologies)

SAMBO is a specialized technique designed to align and merge biomedical ontologies, enhancing interoperability within the biomedical field. By aligning various ontologies used in the semantic web, SAMBO ensures seamless integration of biomedical data and resources [8].

COMA (COmbinatory Matching Algorithm)

Ontology matching plays a significant role in various database applications, such as mapping XML messages, integrating data from web sources, and loading data into warehouses. To minimize manual effort, automated approaches that combine multiple matching strategies are necessary. COMA is a versatile platform that allows for the integration of different matching algorithms, providing a framework to evaluate and compare their effectiveness in achieving accurate ontology alignment [4].

COMA++

COMA++ is an advanced version of the COMA framework. It builds upon the initial COMA concepts by offering enhanced flexibility in combining different matching techniques, thus improving the overall efficiency and accuracy of ontology alignment [11].

YAM (Yet Another Matcher)

YAM and YAM++ are ontology matching tools that adopt alignment of ontologies using techniques of natural language processing. A similarity flooding algorithm propagates the similarity scores. YAM++ is highly refined and performs well in large-scale ontology matching tasks [12][13].

LOMPT (Large Ontology Matching using Partitioning Technique)

Large-scale ontologies present a challenge in ontology matching due to their complexity and size. LOMPT addresses this issue by partitioning large ontologies into smaller sections, making the matching process more manageable. The system identifies anchor pairs between the partitions using a lightweight string matcher called SI-SUB. This partitioning technique ensures that the matching process scales linearly, significantly enhancing efficiency. Future work could involve optimizing anchor discovery by employing even lighter string matchers or adopting random entity selection methods [14].

DSSim

DSSim is an ontology matching system that uses belief functions to quantify similarity between entities. It provides a sophisticated framework for evaluating the trustworthiness of matches, ensuring more accurate and reliable correspondences between ontologies [15].

SEMA

SEMA is an iterative approach to ontology matching, which applies a variety of matchers to find correspondences between entities. These matchers include lexical, latent feature-based, vector space model, instance-based, structural, and property-based matchers. The process continues iteratively until no new mappings are found, ensuring comprehensive and accurate alignment between ontologies [16].

GOMMA (Graph-based Ontology Matching Algorithm)

GOMMA is an ontology matching tool that uses graph theory for effectiveness and maturity in the field [17]. It analyzes both structural and semantic similarities between entities in different ontologies, aiming to improve alignment accuracy, especially when dealing with diverse terminologies or structures.

S-Match

S-Match is an open-source framework designed to establish semantic correspondences between different data structures such as web catalogs, conceptual models, and web service descriptions. By transforming these structures into lightweight ontologies, S-Match facilitates improved semantic interoperability. It includes several algorithms for semantic matching, each tailored to specific types of data. S-Match is widely recognized in academic research and is frequently cited, making it one of the most influential tools in the ontology matching domain [18].

Matcha-DL

Matcha-DL is an extension of the Matcha system, designed to tackle semi-supervised ontology matching tasks using machine learning algorithms. It employs a linear neural network that learns to rank candidate mappings proposed by Matcha, utilizing a partial reference alignment as a training set and confidence scores produced by Matcha's matching algorithms as features. Matcha-DL has demonstrated high performance in ontology matching evaluations [19].

DualLoop

DualLoop employs a combination of matchers, including a short-term learner with a specialized query strategy designed for scenarios involving imbalanced data. Additionally, long-term learners are utilized to investigate potential matches by generating and fine-tuning novel heuristics. Evaluations conducted on various datasets have highlighted the approach's effectiveness in improving ontology matching results [20].

LogMap

LogMap is a robust tool for aligning large-scale ontologies, utilizing a combination of lexical indexing, logical reasoning, and semantic similarity assessment in a multi-step approach. Its performance has proven to be highly effective in a range of challenges and use cases, particularly within the field of biomedicine [21].

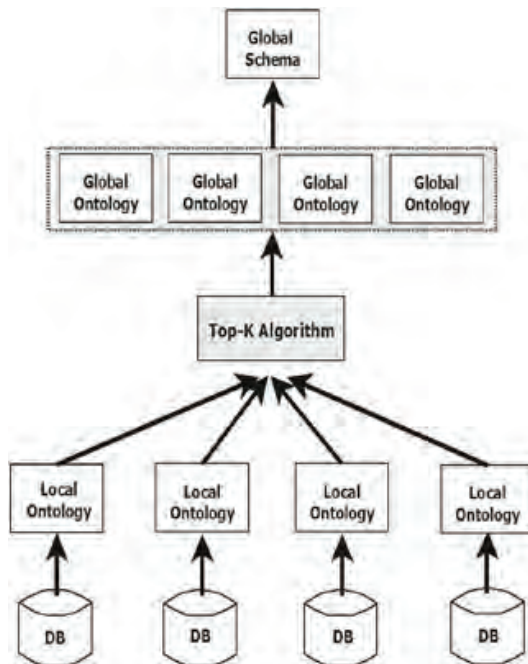


Fig. 1. Architecture of the Ontology-based Schema Integration

Protégé

Protégé is a widely accepted and open-source ontology editor and knowledge management platform created at Stanford University with latest versions in place. It offers a user-friendly graphical interface for designing ontologies and features deductive classifiers that ensure model consistency while enabling the inference of new information through ontology analysis.

ONTOLOGY SCHEME

We present a solution by using a framework for ontology based top-k global schema generation that can merge two databases in an efficient and accurate manner. The framework employs ontology as a base-merging model to create the global schema with higher quality but less user involvement, because ontology can provide semantic and detailed constraints and develop ways to preserve the hierarchical structure and remove redundant entities.

Algorithm

In this section, we introduce an algorithm for Top-K merged ontologies which takes two ontologies and K as an input where K is the number of top merged ontologies. This will produce output of top-K merged ontology [1].

Algorithm: Compute_Top-K-Merged-Ontologies()

Input: local ontology O1, local ontology O2, K

Output: topKMergedOntologies

Step 1: $\text{simArray} := \text{NULL}$, $\text{disArray} := \text{NULL}$, $\text{assignArray} := \text{NULL}$, $\text{diffArray} := \text{NULL}$;

Step 2: foreachclass $C_i \in O1$

Step 3: foreachclass $C_j \in O2$

Step 4: if there exists matched properties between C_i and C_j

Step 5: {

Step 6: Compute simArray_{ij} using Equation (2);

Step 7: $\text{disArray}_{ij} := 1 - \text{simArray}_{ij}$;

Step 8: if $\text{simArray}_{ij} > \text{disArray}_{ij}$

Step 9: { $\text{assignArray}_{ij} := 1$; }

Step 10 else

Step 11: { $\text{assignArray}_{ij} := 0$; }

Step 12: $\text{diffArray}_{ij} := |\text{simArray}_{ij} - \text{disArray}_{ij}|$;

Step 13: }

Step 14: end foreach

Step 15: end foreach

Step 16: foreach $\text{assignArray}_{ij} \in \text{assignArray}$

Step 17: if $\text{assignArray}_{ij} = 1$

Step 18: { $M_{ij} := \text{Merge class } C_i \in O1 \text{ and } C_j \in O2$; }

Step 19: end foreach

Step 20: $\text{TopKMergedOntologies}[1] := M_{ij} + \text{not merged}$

classes in O1 and O2;

Step 21: Sort diffArray in descending order;

Step 22: for $t := 1$ to $K-1$

Step 23: flippedArray:=assignArray;

Step 24: if diffArray_{ij} has the t -th smallest value

Step 25: { flippedArray_{ij}:= 0; }

Step 26: else if $\sum \text{diffArray}_{ij}$ has the t -th smallest value

Step 27: { set all the corresponding flippedArray_{ij}:= 0; }

Step 28: foreach flippedArray_{ij} $\in$ flippedArray

Step 29: if flippedArray_{ij} = 1

Step 30: { M_{ij} = Merge class $C_i \in O1$ and $C_j \in O2$; }

Step 31: end foreach

Step 32: TopKMergedOntologies[t+1] := M_{ij} + not merged classes in O1 and O2;

Step 33: end for

Step 34: return TopKMergedOntologies;

In step 1, the arrays simArray and disArray are declared to store the similarity and dissimilarity between two classes, respectively, the diffArray array is for the difference between simArray and disArray, and the assignArray array is used to determine if two classes should be merged. From step 2–15, the similarity simArray_{ij} as well as the dissimilarity disArray_{ij} between class $C_i \in O1$ and $C_j \in O2$ is computed. If simArray_{ij} is larger than disArray_{ij}, assignArray_{ij} is set to 1; otherwise, assignArray_{ij} is set to 0. diffArray_{ij} is the absolute difference between simArray_{ij} and disArray_{ij}. From step 16–20, the top 1 merged ontology TopKMergedOntologies is generated by merging $C_i \in O1$ and $C_j \in O2$ if assignArray_{ij} equals to 1, and unioning the rest of the classes in O1 and O2.

In step 21, the diffArray array is sorted in descending order. From step 22–33, the top two to K merged ontologies are produced by incrementally modifying the flippedArray (which is initialized to assignArray) based on sorted diffArray. If a diffArray_{ij} has the t -th smallest value, flippedArray_{ij} is set to 0. If the sum of several diffArray_{ij}, $\sum \text{diffArray}_{ij}$, has the t -th smallest value, the corresponding flippedArray_{ij} values are all set to 0. Similarly, the top $t+1$ merged ontology TopKMergedOntologies[t+1] can be generated by merging $C_i \in O1$ and $C_j \in O2$ if flippedArray_{ij} is 1, and unioning other classes in O1 and O2.

In this algorithm similarity between two classes is calculated by using Hausdorff Distance. Hausdorff

Distance is modified to calculate the similarity between any two classes, and the similarity values are used to determine the top- k merged ontology. Let CA and CB be two classes, $CA = \{ap1, ap2, \dots, api, \dots, apn\}$ and $CB = \{bp1, bp2, \dots, bpj, \dots, bpm\}$, where $ap1, ap2, \dots, api, \dots, apn$ and $bp1, bp2, \dots, bpj, \dots, bpm$ are two sets of data type properties in classes CA and CB, respectively. The similarity between CA and CB is defined as:

$$\begin{aligned} s^{\sim}(C_A, C_B) &= 1 - d^{\sim}(C_A, C_B) \\ &= 1 - \frac{1}{2} (\overrightarrow{d}(C_A, C_B) + \overrightarrow{d}(C_B, C_A)) \\ &= 1 - \frac{1}{2} \left(\frac{1}{n} \sum_{i=1}^n \overrightarrow{d}(api, C_B) + \frac{1}{m} \sum_{j=1}^m \overrightarrow{d}(bpj, C_A) \right) \quad (1) \end{aligned}$$

where $d^{\sim}(CA, CB)$ is the average of the two Hausdorff distances. The notation $d(api, CB)$ denotes the distance from the property api to the set of properties in CB. If api does not have any $\rightarrow$ corresponds to any property in CB, then the value of $d(api, CB)$ is 1, otherwise 0. The $\rightarrow$ notation $d(bpj, CA)$ is similarly defined. The modified Hausdorff distance has two properties: one is simple and the other one is that its value increases with the amount of difference between two classes.

We also can use instance matching algorithm to match instance of ontologies as follows:

Step 1: Read ontology file O1

Step 2: Fetch the property (column) and instances (values) in two dimension string array A1[][] from O1.

Step 3: Read ontology file O2.

Step 4: Fetch the property (column) and instances (values) in two dimension string array A2[][] from O2.

Step 5: Compare the arrays created from O1 and O2.

Step 6: Create new array A3[][] containing matching instances from both the arrays.

Step 7: Create new ontology O3 from newly created array A3[][].

Thus, the above algorithm is step-wise and exhibits simplicity in terms of its hierarchical ontology matching.

CONCLUSIONS

In this paper, we performed a literature review of the ontology matching field and presented an accurate top

k ontology scheme. The top k approach for Ontology Matching has discussed and analyzed, with the goal of helping to automatically improve the ontology matching accuracy. In the approach, we treated the ontology mapping problem as a binary problem. Also, system can match instances from both databases. This system better preserves the hierarchical structure and removes the redundant information. There are several extension which can be clearly done to this research work, namely to search for entity relationships with different cardinalities: 1:n, m:1, and m:n for an ontology mapping. The mapping performed by the top k framework match characters by characters but cannot match semantic strings. In future, we would like to perform ontology matching by semantic mapping. Also, the accuracy of mapping multiple ontologies can be estimated using appropriate measures.

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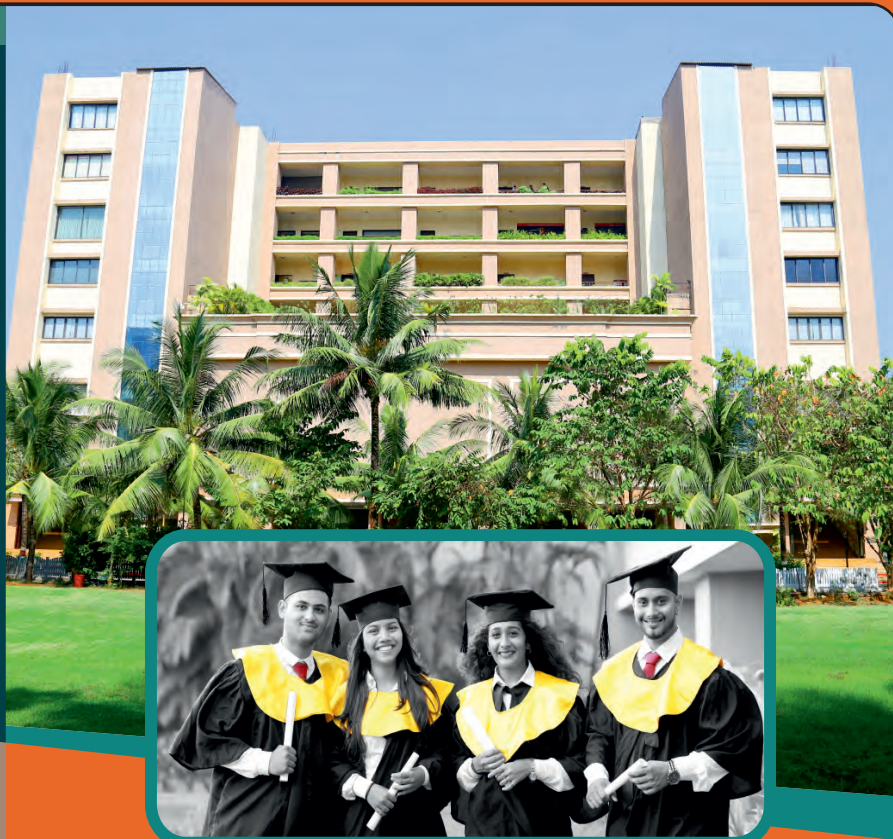


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