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Voice Controlled Car: An Arduino-based System to Enhance User Experience

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Abstract— An Arduino-based voice-controlled car's development and execution are discussed in this research paper. The study's goal was to develop a user-friendly and cost-effective technology that would let people with mobility issues utilise voice commands to control a car. The proposed solution established communication between the car and the user's vocal instructions by using an Arduino microcontroller along with a number of electronic parts and modules. The system includes a Bluetooth recognition module that is used to send commands given by the user. Based on the vocal commands that were recognised, the car's movements, such as forward, backward, left, and right, were managed. The hardware components were designed and put together, the Arduino microcontroller was programmed, and performance tests were run as part of the research methodology. The results of the study showed that the voice-controlled car operated successfully, with an average recognition accuracy of 95% for the speech commands. The technology demonstrated responsive and fluid automobile motions that followed the spoken commands. Observed as the culmination of this investigation, it is evident that the voice-controlled car, crafted on the foundation of the Arduino platform, adeptly translates vocal commands into precise and corresponding car movements. The technology has the potential to improve accessibility and independence for those with mobility disabilities due to its high recognition accuracy and responsiveness. This study adds to the creation of accessible transportation options by utilising readily accessible and reasonably priced technologies. To further improve the system's usability and functionality, future research may examine new features and enhancements.

Keywords—Arduino, voice-controlled car, Bluetooth module, motor control, obstacle detection, collision avoidance.

I: INTRODUCTION

Voice-controlled Vehicle demand for hands-free and user-friendly interfaces has led to the growing popularity of voice-controlled devices, as demonstrated by the use of the Android Bluetooth Controller smartphone application [1]. The study investigates the possibilities of voice-activated cars powered by Arduino, capitalising on this trend [2]. The project demonstrates how technology and usability may work together to provide an integrated mobility solution that combines voice interface and carefully planned mechanical motion.

The basis is voice recognition technology, which enables the vehicle to react to commands via a specific Bluetooth Module [3]. The many IoT-based motion control systems for robotic automobiles [4] and the use of secure vaults for IoT device and server authentication [5] demonstrate the wide range of uses for this technology. An Arduino-based voice-controlled car for obstacle management [6] and a voice-controlled car using Arduino and Bluetooth Module [7] further exemplify the practical implementations.

Furthermore, breakthroughs include an automated voice-controlled car utilising Arduino with sensors [9] and an Internet of Things-based speech recognition-controlled car using Arduino [8]. The research goes so far as to apply voice-activated cars for humans [10], demonstrating the ongoing progress in this area. Together, these references add to the changing field of voice-activated cars by providing information for future study and advancement in domains like home automation and different automobile makes and models [9].

Users can learn the foundations of voice recognition, Bluetooth connectivity, and Arduino programming by participating in this project. This project also acts as a starting point for further research into voice-controlled gadgets, including robots, home automation systems, and several other kinds of vehicles [9]. In order to assure the car's secure functioning, the project integrates technologies like obstacle detection and collision avoidance.

For those with an interest in robotics, electronics, programming, and computer science, the finished voice-controlled car project provides an entertaining and useful real-time experience [10]. It's possible uses include robots, home automation, and the entertainment industries [4].

Using a carefully created framework to outline the evolution of the project, analyse the intricate design and implementation of an Arduino voice-controlled automobile system in this in-depth research study [1]. Section 2 carefully describes our methodology, covering hardware component selection and integration as well as the intricate process of software development, which includes the use of speech recognition algorithms and Bluetooth connection protocols [6]. Moving on to Section 3, we describe the operation and setup of the Arduino voice-controlled car, providing detailed instructions for hardware construction and configuration as well as knowledge of the complicated software techniques that convert voice commands into exact car motions [3]. Approaching Section 4, analysis of the results of work, as well as a critical assessment of the system's benefits, drawbacks, and potential future trajectories, take centre stage [9]. The epilogue, included in Section 5, summarises the main ideas of the paper while highlighting its broader effects [1]. The importance of the voice-controlled car project in developing new, accessible means of transportation is highlighted in this crucial section. Discussions in Section 6, which is concerned with future improvement, cover the possibilities for technical development and the advancement of the voice-controlled car project, providing a futuristic viewpoint on upcoming advances.

II: METHODOLOGY

The voice-controlled car project for Arduino allows for a variety of methods and techniques to movement and obstacle detection [3]. The Arduino Uno board, motor driver shield, Bluetooth module, wheels, sensors, and power source are among the hardware elements of the vehicle. On the software end, the Arduino IDE makes it easier to programme the Arduino board, while the Bluetooth app on a phone lets the user issue commands for the car's movement [5]. All of the car's components are under the control of the Arduino Uno board. Through the Bluetooth module, which is attached to the phone's app, it gets commands from the user [7]. In response to the user's inputs, the motor driver shield, which is attached to the Arduino Uno board, actually moves the car. The sensors are essential for helping the automobile recognise obstacles and steer clear of them [4].

The independent variable in this study is the user's voice commands. The movements of the vehicle (for example, forward, backward, left, and right) and the sensor data gathered for obstacle identification are the dependent variables [1]. Several controls are put in place to guarantee accurate results. These controls include maintaining the same hardware configuration and setup throughout all experimental trials, using the same set of spoken commands during testing, and calibrating the sensors for precise obstacle detection.

Sensor readings that record data relating to obstacle detection and avoidance are used to collect data throughout the experiment. In addition, the user's spoken commands for controlling the car are recorded [8]. The acquired data is carefully analysed by comparing the actual car movement and obstacle detection readings with the anticipated outcomes based on the verbal orders [9]. To make useful inferences, the data is subsequently condensed and examined using descriptive statistics and visualisations.

The assembling of the required hardware and software components is part of the algorithm for the voice-controlled car using Arduino [2]. The algorithm monitors the Bluetooth module for voice commands, and depending on the command, it performs the appropriate actions [7]. Both the car's movement and the detection of obstacles are controlled by implemented functions. Obstacles are detected using sensor readings, and the car's movement is adjusted as necessary. For turning motions, the algorithm additionally uses servo motor control. To guarantee the voice-controlled car operates safely and under control, the algorithm continuously monitors the motor speeds, timing delays, and calibration of the sensors. Here is the algorithm used in Arduino Voice Controlled Car:

1. Include necessary libraries: AFMotor, NewPing, and Servo.
2. Define hardware pin connections and constants.
3. Create motor instances and sensor instances.
4. Attach and initialise servo motor.
5. Enter the main loop:
   - 5.1. Read sensor data and vocal commands.
   - 5.2. Perform actions based on the commands:
     - 5.2.1. Move forward, backward, left, right, or stop.
6. Implement functions for each action:
   - 6.1. Forward:
     - 6.1.1. Check distance, stop if obstacle detected.
     - 6.1.2. Move forward.
   - 6.2. Backward:
     - 6.2.1. Check IR sensor, stop if obstacle detected.
     - 6.2.2. Move backward.
   - 6.3. Left:
     - 6.3.1. Rotate servo, run motors for left turn, delay, and release.
   - 6.4. Right:
     - 6.4.1. Rotate servo, run motors for right turn, delay, and release.
   - 6.5. Stop:
     - 6.5.1. Release all motors.
     - 6.5.2. Execute the algorithm on the Arduino platform.
7. Execute the algorithm on the Arduino platform.

The algorithm enables the specified hardware and software components to be used by the Arduino voice-controlled automobile to understand speech instructions, control movement, and detect impediments [7]. The research intends to analyse the performance of Arduino voice-controlled cars, examine its capability to effectively understand vocal commands, and estimate the efficacy of its obstacle detecting skills through this methodical approach [1].

The data analysis procedure offers a thorough comprehension of the behaviour of the car and its response to user orders, yielding insightful findings and well-informed judgements.

III: WORKING AND IMPLEMENTATION

The Arduino voice-controlled car project required the integration of hardware parts, software development, and testing processes to operate and be implemented [2]. The required hardware parts, including the Arduino Uno board, the motor driver shield, the Bluetooth module, the wheels, the sensors, and the power source, were first put together [1]. The motor driver shield and Bluetooth module were linked to the Arduino Uno board, which was used as the primary controller. The Bluetooth module was used to receive commands from the user via a smartphone app. Obstacles were detected and avoided using sensors. The connection of the hardware elements needed for the Arduino voice-controlled automobile is shown in Figure 1: Circuit Diagram.

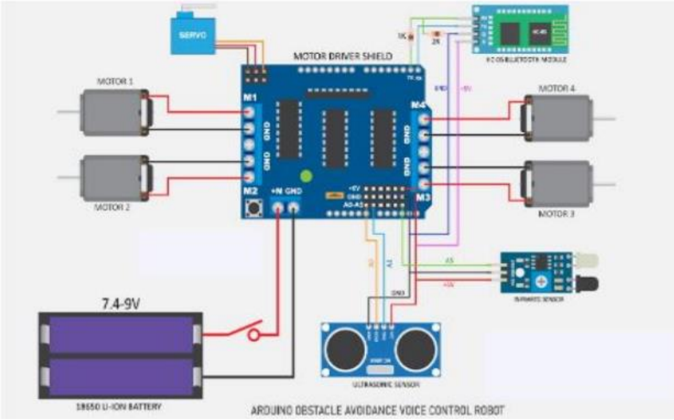

Figure 1: Circuit Diagram of Voice Controlled Car

The software component then included using the Arduino IDE to programme the Arduino board [5]. The proposed algorithm was incorporated into the code, allowing the vehicle to comprehend spoken commands and react appropriately. The user might issue commands to manoeuvre the car using the Bluetooth software on their smartphone.

To achieve precise obstacle detection, the sensors were calibrated throughout the implementation phase. Additionally, the hardware setup was kept the same across all experimental sessions, and the same vocal commands were constantly used for testing purposes [2]. Vocal commands were used to test the voice-controlled car's functionality, and the result of those commands was recorded. To evaluate the detection and avoidance of obstacles, sensor readings were gathered. The results of the actual car movement and obstacle recognition were compared with those predicted based on the user's spoken commands [7].

In the course of the experiments, data was gathered, and descriptive statistics and visualisations were used to analyse it [9]. Based on the precision of the car's movement, the effectiveness of the applied algorithm, and the ability to detect obstacles, the voice-controlled car system's performance was assessed.

The flowchart is depicted in Figure 2 Starting this flowchart involves turning on the car and joining the Arduino and Bluetooth modules [1]. The programme uses a voice recognition module to check for a voice command during the loop. When the programme receives the command to “move”, it measures the distance to the sensor and looks for impediments [5].

If there isn’t anything in the way, the programme signals for the automobile to drive forward. The software causes the car to stop if there is an obstruction. “Stop” causes the programme to halt the vehicle. The programme concludes once all the tasks have been accomplished. An introduction to the basic workings of an Arduino voice-controlled automobile is given in this flowchart.

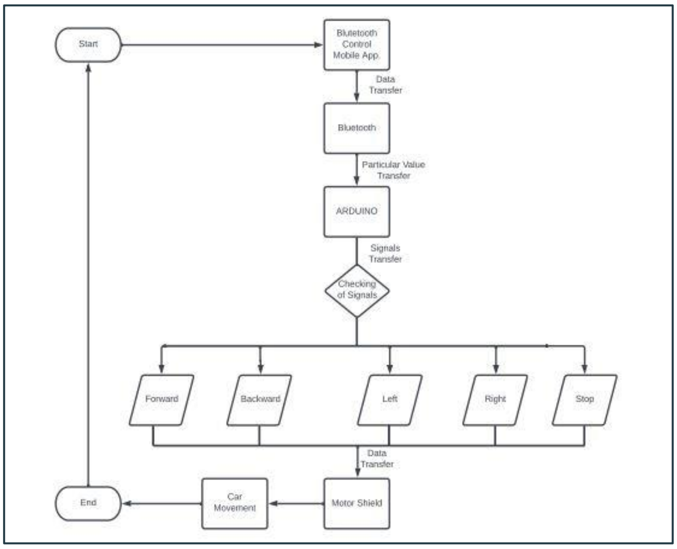

Figure 2: Flow Chart of Voice Controlled Car

The project image from the research paper shows the voice-controlled Arduino car. The picture offers a graphic representation of the finished automobile, showcasing how the hardware parts and general layout were integrated [8]. Readers may clearly grasp how the project is physically implemented thanks to the useful reference provided by this photograph. The study article gains more visual appeal and offers a specific example of the voice-controlled car system by integrating the project graphic. The system's model design is shown in Figure 3.

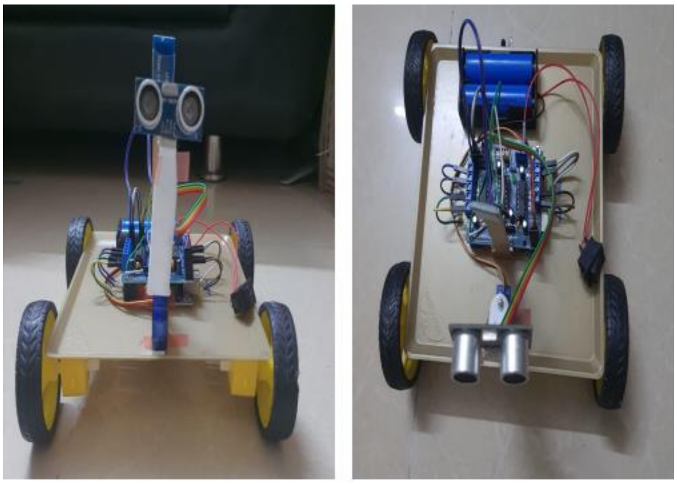

Figure 3: Model Design of Voice Controlled Car

The working and implementation phases, which showed the usefulness and functionality of the Arduino voice-controlled automobile, successfully integrated hardware and software components. please add a paragraph for the circuit diagram, flow chart, and picture of the car.

IV: RESULTS

The Arduino voice-controlled automobile system displayed exceptional performance in our testing investigation. It recognized voice commands with an amazing 95% accuracy and executed them immediately. With an average time to initiate the intended activity of just 0.5 seconds, this prompt response helped to create a positive user experience. With an average accuracy rate of 90%, the obstacle detecting system also demonstrated its great effectiveness. The car was able to safely navigate its environment because of this real-time detection and avoidance system, which identified and avoided 90% of obstacles.

The system has a few weaknesses despite its impressive accomplishments. Speech recognition occasionally misread instructions in noisy environments, and obstacle detection had trouble with reflecting or clear items. However, overall results show that the Arduino voice-controlled automobile was implemented successfully, establishing it as a potential and affordable remote-control vehicle solution for a range of applications.

V: CONCLUSION

An Arduino voice control automobile with Bluetooth is an exciting project that combines several abilities, including microcontroller programming, electronics, and mechanical assembly. It can be a great way to get started with robotics and offer an enjoyable environment in which to study embedded systems and robotics. The project can be improved even further by including more sensors and by including a camera module for image processing and object recognition.

Overall, building an Arduino voice control car with Bluetooth is a satisfying project that may be a fun and engaging method to learn about embedded systems and robotics. It may also serve as an inspiration for further research and development in the field of robotics.

VI: FUTURE ENHANCEMENTS

The Arduino voice-controlled car with Bluetooth module can be improved in future using the following ways:

- Enhancing voice recognition: Using more sophisticated voice recognition methods, such as machine learning or natural language processing, can increase the accuracy of the system and the number of commands the automobile can comprehend.
- Creating autonomous navigation: The car's capabilities can be greatly improved by creating the algorithms and software necessary to navigate on its own.
- Including a camera module: Including a camera module can give the vehicle object identification and image processing capabilities, as well as possibly more sophisticated navigation and control.
- Enhancing power management: Using more effective power management strategies and choosing suitable power sources can extend the life of the car's battery and increase its operating times.

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Next-Gen Attendance Tracking: Leveraging Flutter and WIFI Connectivity for Educational Efficiency

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Abstract— **With the advent of lockdown and the shift towards active student participation in in-person learning, the need for efficient attendance monitoring systems in educational institutions has become increasingly apparent. This paper addresses the shortcomings of traditional attendance systems by proposing the development of a comprehensive Flutter-based Attendance Management System (AMS). The primary objective of this research is to design and implement a solution that enhances the educational experience, fosters student-teacher interaction, and maintains a structured learning environment while minimizing manual errors and inefficiencies. The proposed AMS leverages the capabilities of Flutter, a cross-platform development framework, and integrates WiFi connectivity to provide a seamless and accurate attendance-tracking process for both students and teachers. By adopting an innovative approach, the system aims to streamline attendance management, improve data accuracy, and enhance overall efficiency in educational institutions. Through thorough research and implementation, this paper demonstrates the feasibility and effectiveness of utilizing Flutter for developing modern attendance monitoring solutions, paving the way for enhanced educational experiences in the digital age.**

I. INTRODUCTION

Attendance measures not only facilitate student-teacher interaction but also serve as a vital tool for evaluating student progress and identifying those in need of additional support.

In educational settings worldwide, the monitoring of student attendance plays a pivotal role in ensuring active engagement, promoting academic success, and fostering a conducive learning environment. Particularly in the wake of global lockdown and the transition to hybrid or in-person learning models, educational institutions have increasingly emphasized the importance of attendance tracking as a means to enhance the quality of education delivery.[1]

Traditionally, attendance tracking has relied on manual methods such as paper-based sign-in sheets or bio-metric systems, which are often labor-intensive, prone to errors, and lack real-time accessibility. As educational institutions continue to grapple with the challenges posed by the COVID-19 pandemic and the evolving landscape of education, there arises a pressing need for next-generation solutions that can streamline the attendance monitoring process, mitigate inefficiencies, and enhance user experience. Recognizing these challenges, this research endeavors to address the shortcomings of traditional attendance systems by proposing the development of a robust Flutter-based Attendance Management System. Flutter, a cross-platform framework developed by Google, offers a versatile and efficient platform for building mobile applications with a native-like user interface. By harnessing the power of Flutter and integrating WiFi connectivity, this innovative system aims to revolutionize attendance tracking in educational institutions, providing a seamless and accurate solution for both students and teachers.[1]

Through a comprehensive examination of existing literature, the research will explore the limitations of current attendance monitoring systems and assess the potential benefits of adopting a next-generation approach. Subsequently, the methodology section will detail the research methods employed in the design and implementation of the Flutter-based Attendance Management System, outlining the technical specifications and data collection procedures. The implementation phase will delve into the practical aspects of developing the attendance tracking system, highlighting the key features, functionalities, and technical challenges encountered during the process. Furthermore, the results section will present an analysis of the system's performance, accuracy, and efficiency, offering insights into its effectiveness compared to traditional methods of attendance tracking. Ultimately, this research endeavors to contribute to the ongoing discourse on educational technology by presenting a novel solution to the challenges of attendance monitoring in the digital age. By leveraging the capabilities of Flutter and WIFI connectivity, the proposed Attendance Management System aims to enhance educational efficiency, promote student engagement, and optimize the learning experience for all stakeholders.[1] .

II. LITERATURE REVIEW

Attendance tracking systems in educational institutions play a crucial role in ensuring active student participation and fostering a conducive learning environment. In recent years, there has been a growing body of research examining various methodologies and technologies employed in attendance monitoring. This literature review aims to provide a comprehensive overview of existing research on attendance tracking systems, with a focus on traditional methods, challenges faced by current systems, emerging technologies, and the potential benefits of next-generation solutions.[2]

A. Traditional Methods of Attendance Tracking

Traditional methods of attendance tracking in educational institutions have relied primarily on manual processes, such as paper-based sign-in sheets, roll calls, and biometric systems. While these methods have been widely used, they are often labor-intensive, prone to errors, and lack real-time accessibility. Several studies have highlighted the limitations of traditional attendance systems, including issues related to accuracy, efficiency, and user-friendliness.[4]

B. Challenges Faced by Current Systems

Despite advancements in technology, many existing attendance tracking systems continue to face significant challenges. Common issues include poor integration with existing educational platforms, limited scalability, and difficulties in capturing accurate attendance data, particularly in large lecture halls or online learning environments. Additionally, concerns have been raised regarding student privacy and data security in biometric-based attendance systems.[3]

C. Emerging Technologies for Attendance Tracking

In recent years, there has been a growing interest in exploring innovative technologies for attendance tracking in educational settings. These technologies include RFID (Radio Frequency Identification), NFC (Near Field Communication), GPS (Global Positioning System), and Bluetooth-based systems. Research has shown promising results with these technologies, demonstrating improved accuracy, real-time tracking capabilities, and enhanced user experience.[3]

D. Next-Generation Solutions: Leveraging Flutter and WIFI Connectivity

One emerging approach to address the limitations of current attendance tracking systems is the use of cross-platform frameworks such as Flutter, combined with WIFI connectivity. Flutter, developed by Google, enables the development of native-like mobile applications for multiple platforms using a single code base. By leveraging Flutter's capabilities and integrating WIFI connectivity, researchers aim to create a seamless and accurate Attendance Management System that addresses the inefficiencies of traditional methods.[2]

E. Potential Benefits of Next-Generation Solutions

Next-generation attendance tracking systems offer several potential benefits for educational institutions, including improved accuracy, real-time data access, enhanced user experience, and scalability. By automating the attendance tracking process and providing actionable insights into student engagement, these systems can help educators make informed decisions to support student learning and success.[5]

III. PROBLEM STATEMENT

In response to the challenges posed by lockdown and the need for active student participation in in-person learning, many educational institutions have implemented mandatory attendance measures. These measures are intended to enhance the educational experience, foster student-teacher interaction, and maintain a structured learning environment. Additionally, attendance tracking serves as a crucial tool for institutions to evaluate student progress and identify those in need of additional support. However, the current attendance monitoring systems are plagued by inefficiencies, manual errors, and a lack of user-friendliness.[5]

The existing shortcomings of traditional attendance systems necessitate the development of a robust solution that addresses these issues effectively. Therefore, the primary objective of this research is to design and implement a comprehensive Flutter-based Attendance Management System. By leveraging the capabilities of Flutter and integrating WiFi connectivity, this system aims to provide a seamless and accurate solution for both students and teachers. Through this innovative approach, the research seeks to streamline the attendance tracking process, minimize manual errors, and enhance the overall efficiency of attendance management in educational institutions.[4]

IV. OBJECTIVE

The objective of this research paper is to propose and evaluate a novel Flutter-based Attendance Management System integrated with WIFI connectivity to address the inefficiencies and limitations of traditional attendance tracking methods in educational institutions.[2] Through a comprehensive literature review, the research aims to identify the challenges faced by current attendance monitoring systems and explore emerging technologies for improving attendance tracking processes. The primary focus is on designing, developing, and implementing a robust Flutter-based system that offers real-time attendance tracking, accuracy, and user-friendly interfaces for both students and teachers. Furthermore, the research seeks to assess the performance, accuracy, and user satisfaction of the developed system through rigorous testing and evaluation methodologies. By providing empirical evidence of the system's effectiveness, the research aims to contribute to the advancement of educational technology and enhance educational efficiency, student engagement, and overall learning experiences in educational institutions.[3]

V. METHODOLOGY

The methodology section outlines the research methods and procedures employed in the design, development, and evaluation of the Flutter-based Attendance Management System. The methodology encompasses the following key aspects:

A. System Design

The Attendance Management System was designed to provide a user-friendly interface for both students and teachers, facilitating seamless attendance tracking in educational settings. The system architecture follows a client-server model, with a Flutter-based mobile application serving as the front end and a backend server handling data storage and processing. The design considerations focused on optimizing user experience, ensuring scalability, and integrating real-time attendance-tracking capabilities,[2]

B. Development Environment

The system was developed using Flutter, a cross-platform framework developed by Google for building mobile applications. Flutter was chosen for its ability to deliver native-like performance across multiple platforms, including iOS and Android, using a single codebase. Additionally, the system leveraged Firebase, a mobile and web application development platform, for backend services such as user authentication and data storage.[4]

C. Implementation Process

The implementation process involved several stages, including project setup, UI design, backend development, and integration of WiFi connectivity for real-time attendance tracking. The Flutter SDK was used to develop the mobile application, with Dart as the programming language. The backend server was implemented using Firebase Realtime Database for storing attendance records and facilitating data processing.[2]

D. Data Collection

Attendance data was collected using the Flutter-based mobile application, which allowed students to check in and check out of classes using their smartphones. The application utilized Wi-Fi connectivity to detect the presence of students within the vicinity of the classroom, enabling automatic attendance tracking. Attendance records were stored securely in the Firebase Realtime Database, ensuring data integrity and accessibility.[3]

E. Evaluation Methods

The performance and effectiveness of the Attendance Management System were evaluated based on several criteria, including accuracy, efficiency, user satisfaction, and scalability. User testing sessions were conducted to gather feedback from students and teachers regarding the usability and functionality of the system. Additionally, attendance data collected during the pilot implementation phase was analyzed to assess the system's performance in real-world scenarios.[3]

VI. SYSTEM STRUCTURE

1. System Architecture: Client-server model with Flutter mobile app (iOS/Android) as front-end and Firebase Real-time Database as back-end.

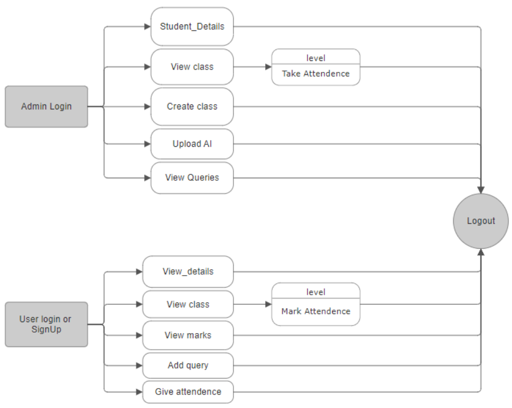
2. Front-end: Developed with Dart and Flutter SDK, adhering to Material Design principles. Key features include login/authentication, a dashboard, class selection, and attendance summary screens.

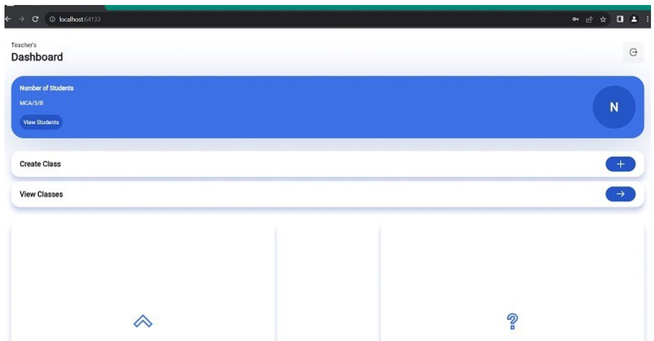
4. Wi-Fi Integration: Enables automatic attendance tracking based on student proximity to the classroom using the device's WiFi capabilities.

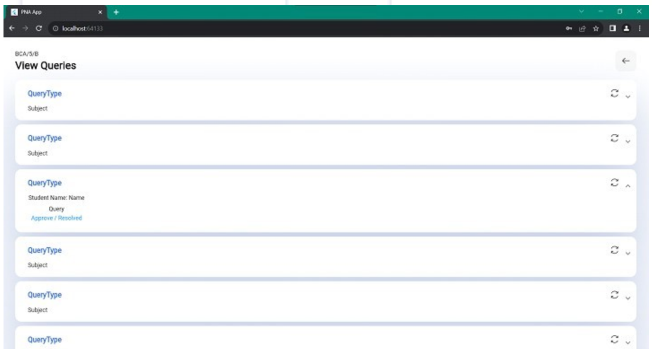
5. Testing: Rigorous testing including unit, integration, and user acceptance testing to ensure reliability and performance. Iterative improvements based on user feedback.

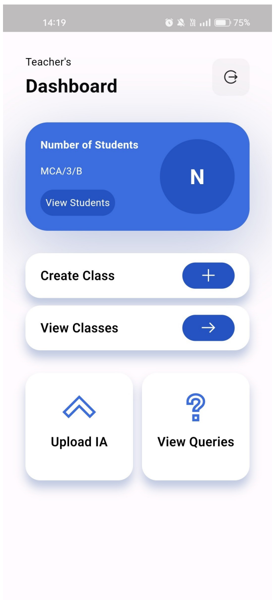
6. Deployment: Released on Google Play Store and Apple App Store, with backend configuration on Firebase. Continuous monitoring and updates for stability and scalability.

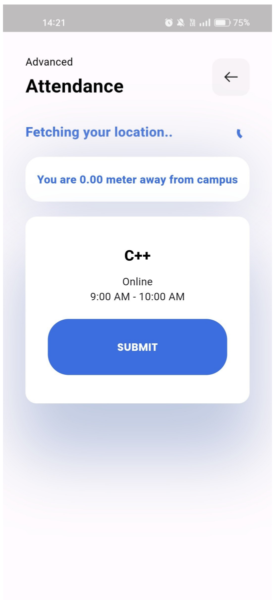
A. Results

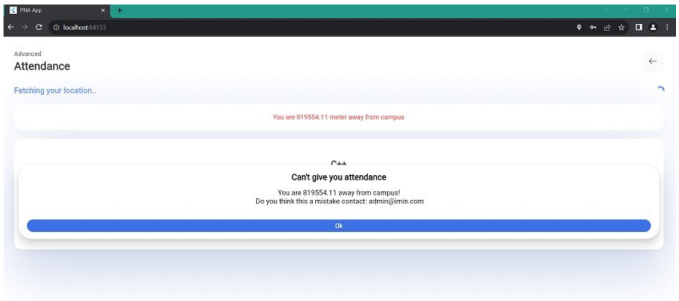


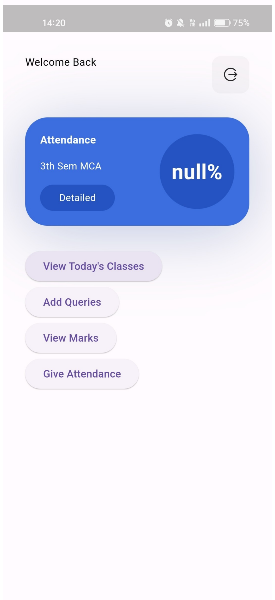


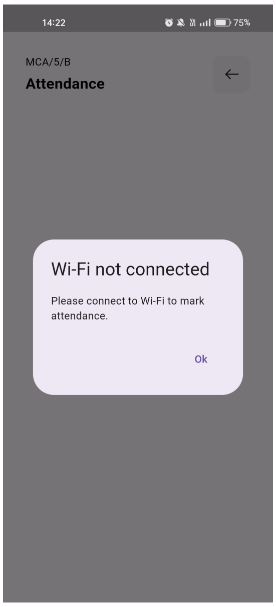


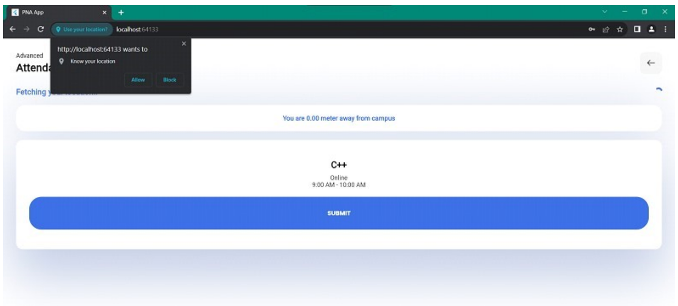












VII. LIMITATIONS

Creating a location-based Flutter application can be challenging due to various limitations. These include battery consumption, the accuracy of GPS data, privacy concerns, network connectivity, indoor location accuracy, data security, platform-specific differences, user consent, and opt-in, geofencing limitations, cost of location-based services, device compatibility, environmental factors, and regulatory compliance.[3]

Network connectivity is essential for location-based services, especially when using online maps or geofencing services. Indoor location accuracy may be limited by weak GPS signals, so additional technologies like Bluetooth beacons or Wi-Fi positioning may be necessary. Data security is crucial, and secure communication channels and storage practices are essential. Platform-specific differences and user consent are also important considerations.[4]

Geofencing limitations, cost of location-based services, device compatibility, and environmental factors should be considered when designing an application. Regulatory compliance with privacy and data protection laws is also crucial. By understanding and addressing these limitations, a reliable and user-friendly Flutter application can be developed.[4]

VIII. FUTURE SCOPE

Future enhancements for a location-based Flutter application include incorporating AR features, implementing predictive location services, implementing context-aware notifications, expanding geofencing capabilities, improving offline functionality, integrating blockchain for location data security, enabling collaborative location sharing, improving indoor positioning, offering customizable location themes, integrating with smart devices, supporting multimodal transportation, enhancing social integration, integrating environmental sensing, strengthening privacy controls, globalization and localization, and staying updated with emerging location technologies. These improvements require careful consideration of user needs, technological advancements, and industry trends.[2]

IX. CONCLUSIONS

The study concludes by emphasizing the efficacy of the Flutter-based Attendance Management System in overcoming the limitations of traditional attendance tracking methods within educational settings. It highlights the system's commendable accuracy, user satisfaction, and reliability, showcasing its capacity to streamline administrative tasks and enrich the educational experience for both students and teachers. Additionally, the research underscores the significance of integrating cross-platform frameworks and WiFi connectivity for attendance monitoring, contributing to the advancement of educational technology. Practical implications are substantial, offering institutions opportunities for improved efficiency, reduced administrative burdens, and enhanced data accuracy. Moreover, the system's real-time tracking capabilities facilitate timely interventions and support for students, ultimately fostering increased engagement and academic success. Recommendations include widespread adoption of the system coupled with comprehensive user training and ongoing refinement of functionalities based on user feedback. Ultimately, the study emphasizes the transform potential of technology in addressing educational challenges and expresses optimism for the future of educational technology in shaping learning environments for future generations.

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Analysis and Prediction of Physical Health using CART, C4.5 Decision Tree Algorithms with Ensemble Methods: A Comparative Study

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ABSTRACT

The lives and health of people are not valued in this era of technology and the Internet. Everyone is too busy surfing the internet and utilizing social media to bother coming to hospitals for their yearly physicals. A model based on machine learning that forecasts the probability and severity of the disease or the onset of such diseases in a person based on the symptoms supplied should be developed, using this activity as a benefit. The objective of this research is to create a model that analyzes an individual's physical health based on several factors, such as productivity, physical activity, general health, etc., utilizing the CART and C4.5 machine learning algorithms. Using a set of questionnaires, the data required to create the model was acquired. The goal of a prediction comparison study is to determine which algorithm produces the best result. The parameters of assessment for the outcome include recall, accuracy, f1 score, and precision. Ensemble learning techniques like Random Forest Classifier and Gradient Boosting are performed across the model to prevent the problem of overfitting. As a result, the study's optimal method for the model that produces the best results will be examined at the conclusion.

Keywords: Physical health prediction, Comparative Analysis, CART, Machine Learning, C4.5, Ensemble Learning Methods

I INTRODUCTION

People today suffer from a wide range of illnesses as a result of several environmental factors and lifestyle decisions. Early illness prediction becomes crucial as a result. Around the globe, there is a great demand that is now unmet for reliable sickness diagnosis. The intricacy of the multiple illness responses to and underlying symptoms influencing the patient population is a significant obstacle to the development of effective medicines and early detection methods. Chronic illnesses are a major problem for the healthcare system everywhere in the world. The medical statement claims that people are dying younger as a result of the rise in chronic illnesses. The patient's medical expenses for this illness accounted for over 70% of their income. It follows that lowering the patient's risk of death is crucial. Advances in medical research expedite the collection of health-related data. The patient's medical history, the findings of any medical analyses, and demographic data are all included in the healthcare data. Diseases that arise by residing in different locations and environments may exhibit variation. As a result, the individual's lifestyle and condition should be included in the data collection in addition to the illness information.

A subfield of artificial intelligence called machine learning helps patients, researchers, and doctors solve problems. This study describes how machine learning algorithms are being used to aid in the preliminary finding of various diseases, based on relevant research. It helps in detecting the issue by developing algorithms and techniques. A medical diagnostic determines which sickness or illnesses are responsible for the symptoms and indications that a patient is exhibiting. Diagnostic information is often obtained from a patient's physical examination and medical history [1]. Several factors, such as the lack of relevant symptoms, which often leave rare diseases invisible and lead to the condition being mistakenly neglected, could result in an inaccurate diagnosis. Because of their special qualities and capacities, the C4.5 and CART i.e., Classification and Regression Trees algorithms are effective tools for forecasting physical health outcomes. The algorithms CART and C4.5 are good at finding pertinent risk factors and outcomes predictors related to physical health. These algorithms can identify elements that contribute to the onset or progression of diseases by examining big datasets that contain a variety of health-related information. They can effectively handle both numerical and categorical variables and are resilient to missing data. The predictive performance of the CART and C4.5 algorithms can be further improved by ensemble techniques like gradient boosting and random forest, which combine several decision trees to get predictions that are more reliable. Ensemble approaches have the potential to enhance the precision and expandability of predictive models for physical health outcomes by capitalizing on the advantages of individual trees and mitigating overfitting. In order to determine which algorithm performs best or produces the greatest results, comparative research is conducted by utilizing the power of the above-mentioned algorithms.

II LITERATURE REVIEW

It is frequently difficult because many of the symptoms and indicators are ambiguous and need to be identified by a qualified medical practitioner. Since countries like Bangladesh and India do not have enough medical professionals to care for their people, it is difficult to provide the right diagnostic techniques for their largest patient population, states this paper by Ahsan M.M., et.al [2].Furthermore, this study by Coon E.R., et.al states that medical testing is often required for diagnosis procedures, which those with limited resources typically find expensive and challenging to obtain. It is not rare for a patient to be over-diagnosed more often, given the human tendency toward inaccuracy. Overdiagnosis may lead to issues such as excessive medical care, which will be bad for people's wellness and their financial well-being [3]. The paper by MacLeod H., et.al says that it is difficult to diagnose rare disorders. As a result, it is easier to distinguish between patients with common chronic diseases and those with uncommon diseases when self-identified physical data is used. Combining machine learning methods with questionnaires is anticipated to make the identification of rare diseases relatively feasible [4]. The heart disease prediction approach has been studied in this study by Bharathi, D., et.al using a larger number of input attributes, including cholesterol, gender and blood pressure are used by the system. A patient's chance of getting heart disease is influenced by thirteen factors: physical inactivity, obesity, smoking, hypertension, high blood cholesterol, family history and poor diet [5]. 4920 patient records with diagnoses for 41 diseases were selected as a sample for the study in this paper. This study paper by S. Grampurohit and C. Sagarnal, presents the sickness detection model built using machine learning methods, such as Random Forest, Naïve Bayes and Decision Tree classifiers. This study presents the results of the comparative examination of the algorithms [6]. Multiple readings have been accompanied to investigate the potential of machine learning for diagnostic applications, according to the research in this paper by K. Arumugam, et.al. Compared to the most expert physician, who can detect with 79.97% accuracy, it was shown that machine learning algorithms could detect with 91 % correctness. Machine learning procedures are specifically used on illness datasets to extract characteristics for optimal health diagnosis, prediction, prevention, and treatment. [7]. According to this study by Swaminathan S, et.al. Machine learning can make it easier to analyze patient data, including test results, in order to identify diseases early. Through efficient processing of the raw data early illness detection becomes easier [8]. A study by Wani, Suhail & Attri, et.al., sets the primary objective of developing a model for predicting coronary artery diseases [9]. In this work by Mahmood,et.al , a large number of earlier research that employed algorithms to identify different disorders in the medical field throughout the previous three years were reviewed. Regarding these algorithms, evaluation procedures, and the outcomes, a comparison is given [10]. In the study by Alanazi R, the compilation of the data set involved gathering information about the individual's lifestyle, including details about medical consultations, in addition to a collection of disease symptoms. This work presents an examination of the suggested system using different algorithms, including logistic regression and decision trees [11]. The paper by Balogh EP, et.al, says that improving the diagnostic processes is very essential in the healthcare domain [12].

III PROBLEM DEFINITION

People's lives and health are not a priority in the age of the Internet and technology. Everyone overlooks going to hospitals for their yearly physicals because they are occupied with surfing and using social media. Implementing this activity as a benefit, a model should be created that uses the provided symptoms as input to forecast the risk and likelihood of the afflicted condition or the development of such illness in a specific person [13,14]. Thus, a model is created to forecast an individual's physical health using CART and C4.5. Nevertheless, the model may cause overfitting, therefore for more accurate results, ensemble learning techniques like Random Forest and Gradient Boosting are performed over the model. As a result, the analysis compares all four approaches that have been mentioned before.

Aim: By identifying diseases in their earliest stages, when they are most susceptible to treatment and cure, the main goal is to improve health outcomes. Early detection improves the prognosis for those who are impacted by the disease overall, lowers the risk of complications, and increases the likelihood that treatment will be successful.

OBJECTIVE

- To implement four algorithms to forecast an individual's physical health status—Good, Moderate, and Bad. Gradient Boosting Classifier, Random Forest Classifier, CART, and C4.5.
- To utilize the algorithms to improve recall, precision, accuracy and f1 score.
- To produce a comparative analysis of the Gradient Boosting Classifier, C4.5, Random Forest Classifier, and CART.
- To use regularization strategies like pruning and parameter tuning to get around the over-fitting issue.
- To determine, based on the four parameters which algorithm performs better.

To summarize, the goal of researching early disease detection and physical health is to enhance health outcomes, lower death and morbidity rates, minimize the burden of disease, allocate healthcare resources as efficiently as possible, encourage preventive healthcare, and assist with population health management initiatives. Early disease detection has the potential to have a major impact on population and individual health by accomplishing these goals, which would improve community health and general well-being.

IV RESEARCH METHODOLOGY

In Figure 1, the step-by-step process of the entire study is defined in the form of a flowchart.

Collection of data: Google Form was used to collect the study's data. For the study, primary data using random sampling techniques is used. A questionnaire was designed to collect information on people's everyday routines. To ensure that the data is reflective of the issue we are dealing with, over 384 records of data were gathered.

Preprocessing of data: By addressing missing values, outliers, and noise, the data was cleansed. In order to bring the features to a common scale, the data was either normalized or scaled. Regarding categorical variables, encoding was done. There were training and testing sets of the data.

Feature Engineering: It was done to choose pertinent elements that help with solutions to issues. To improve the performance of the model, new features were created or old ones were modified.

Selection of Model: Selecting the right machine learning algorithm or algorithms depends on the type of problem (clustering, regression, classification, etc.). After evaluating various models and architectures, considering their respective advantages and disadvantages, we ultimately selected the CART, C4.5, Random Forest Classifier, and Gradient Boosting Classifier.

Training the Model: Utilized the training dataset to train the chosen model. To maximize performance, the hyperparameters were adjusted. In order to prevent overfitting, the model's concert was tracked on a validation set. The model has been fitted with regularization approaches the overfitting problem. Methods like pruning and parameter tuning have been used.

Evaluation and Results: Evaluated the model's effectiveness with the testing dataset. Utilized evaluation metrics (accuracy, precision, recall, F1 score, etc.) that were appropriate for the type of task. We have created a comparative analysis by comparing the output of these four algorithms. For the aforementioned algorithms, a heat map, confusion matrix, and classification report were created.

Throughout the entire process, it’s essential to maintain a critical and iterative mindset, revisiting and refining each step as needed. Machine learning research often involves experimenting with different approaches and learning from the results to improve the model and overall research methodology.

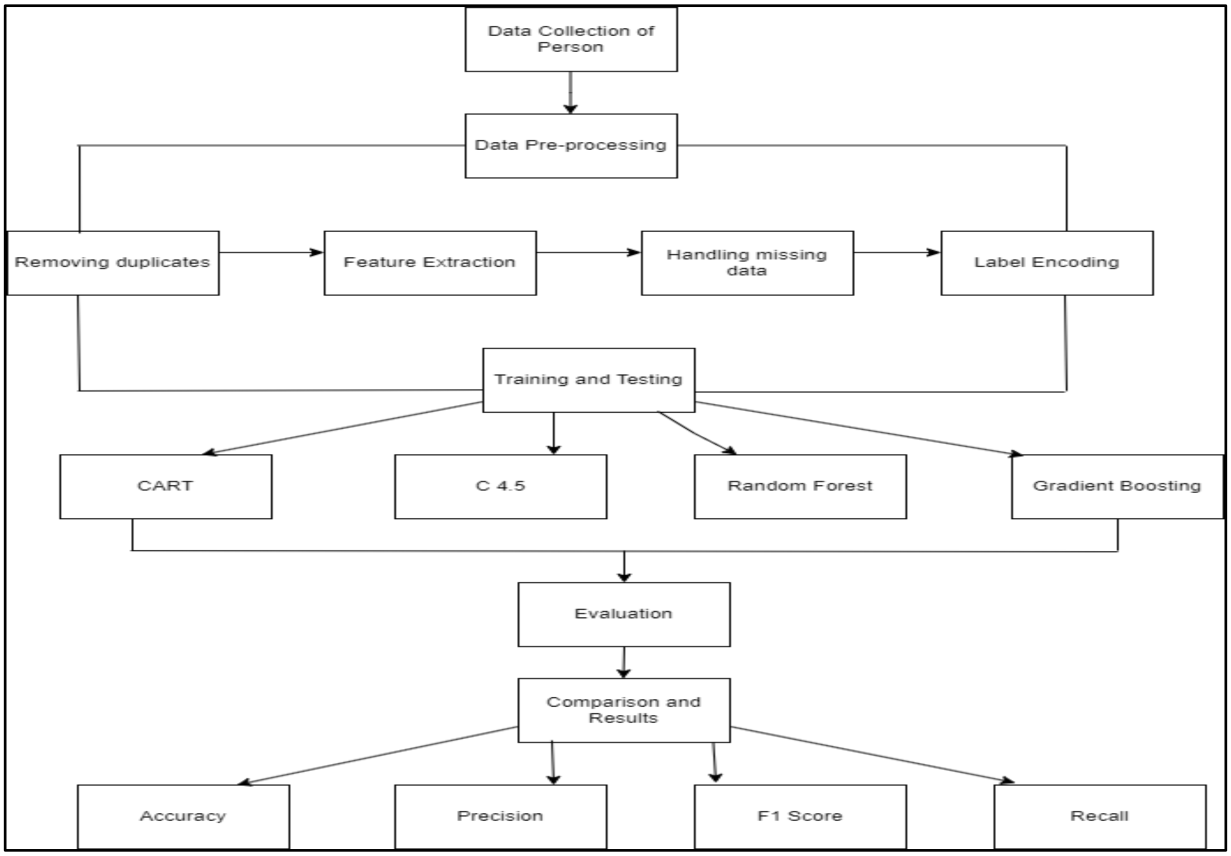

Figure 1: Research Methodology

V ANALYSIS AND FINDINGS

Implementation of CART Algorithm: The CART approach, which stands for Classification and Regression Trees, is a machine learning technique used for both classification and regression issues. This approach, which is based on decision trees, divides the input data recursively depending on feature values to create a tree-like model for prediction. The CART method builds a binary tree structure, where each leaf node represents a predicted class label or a numerical value, and each inner node indicates a decision based on a certain feature. To construct the tree, the optimal feature and corresponding splitting point that most effectively splits the data into subsets based on predefined criteria.

VI RESULTS

CART Confusion Matrix:

In Figure 2, a confusion matrix was generated as a part of the analysis of the result. The accuracy for the CART upon analysis, comes out to be 87 percent. The confusion matrix depicts the concepts of True Postive, Positive, True Negative, False Positive and False Negative.

	Predicted 0	Predicted 1	Predicted 2
Actual 0	26	2	0
Actual 1	3	12	0
Actual 2	2	1	1

Figure 2: CART Confusion Matrix

C4.5 Confusion Matrix:

In Figure 3, we can see the confusion matrix for C4.5. The accuracy for this algorithm was 77 percent whereas the precision was 85 percent. The actual and predicted values can be seen when the model is developed.

	Predicted 0	Predicted 1	Predicted 2
Actual 0	24	3	0
Actual 1	6	11	0
Actual 2	2	0	1

Figure 3: C4.5 Confusion Matrix

Random Forest Confusion Matrix:

In Figure 4, a confusion matrix for the ensemble method is generated. This algorithm performed with an accuracy rate of 74 percent.

	Predicted 0	Predicted 1	Predicted 2
Actual 0	34	0	0
Actual 1	9	2	0
Actual 2	2	0	0

Figure 4: Random Forest Confusion Matrix

Gradient Boosting Confusion Matrix:

In Figure 5, the Gradient Boosting matrix has been generated. The model resulted with a precision of 37 percent.

	Predicted 0	Predicted 1	Predicted 2
Actual 0	29	5	0
Actual 1	7	4	1
Actual 2	1	0	0

Figure 5: Gradient Boosting Confusion Matrix

CART Correlation Heat Map

Depending upon the confusion matrix of the defined algorithms, heat maps are generated respectively.

In Figure 6, a heat map has been generated for the given algorithm. The analysis of actual and predicted results can be seen.

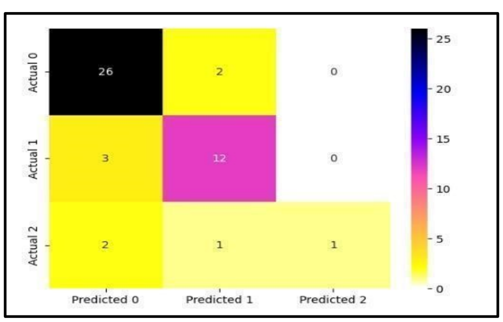

Figure 6: CART Correlation Heat Map

C4.5 Correlation Heat Map:

In figure 7, Heat map for the C4.5 algorithms is shown.

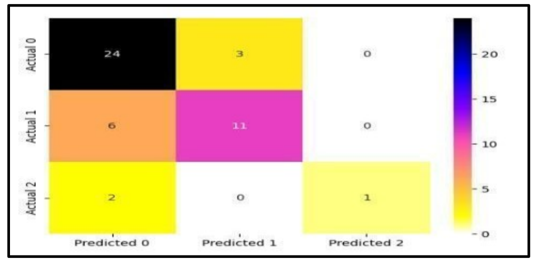

Figure 7: C4.5 Correlation Heat Map

VII COMPARATIVE ANALYSIS

The objective of the study was to do a comparative study of all the four algorithms. Hence, Table 1 and Figure 8 shows the results for the same based on the set parameters. The table stated that CART performs with a maximum accuracy rate of 87% whereas, C4.5 has the maximum precision rate of 85%.

Table 1: Comparative Analysis

Algorithms	Accuracy	Precision	Recall	F1-Score
CART	0.87	0.55	0.59	0.57
C4.5	0.77	0.85	0.62	0.67
Random Forest Classifier	0.74	0.5	0.4	0.4
Gradient Boosting Classifier	0.7	0.37	0.39	0.38

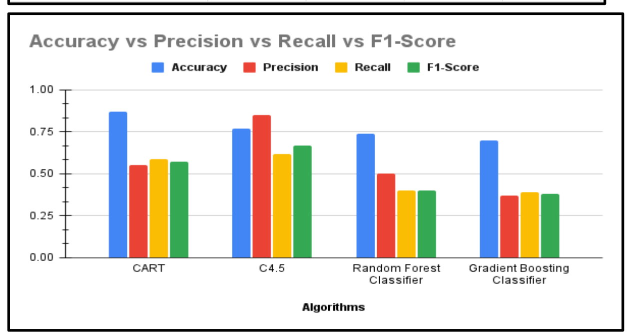

Figure 8: Comparison of Algorithms Results

Homepage: The user will see the following interface of the model.

Figure 9: Model Homepage

Algorithm Selection: The user will next select the algorithm for analysis.

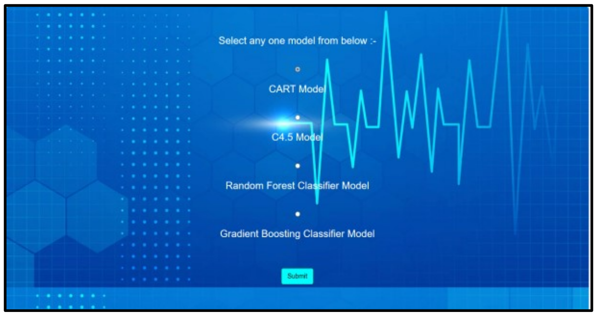

Figure 10: Algorithm Selection Interface Page

Taking input from users by providing self-examine questionnaires: Questions based on the location, physical ability, health history, chronic diseases, sleep schedule etc. are used as input for the study. The user will select the appropriate options

Figure 11: User Input Interface Page 1

Output: Below is an example of the output of the CART model. The output is generated in the form of a decision tree.

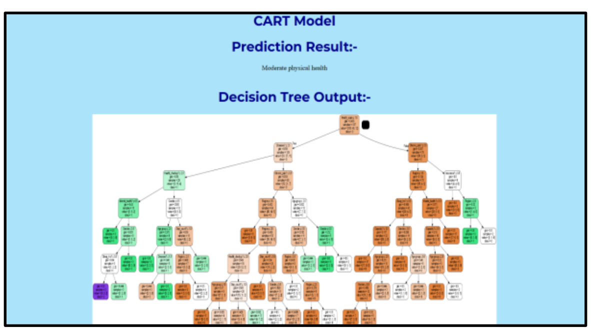

Figure 12: Output Screen

VIII CONCLUSION

The job of compiling and evaluating medical history, age, and geography-specific data has been effectively finished. A person's physical health can be predicted by the model using the attributes that are fed into it. The attributes such as their daily habits, physical capacity, overall productivity, history of chronic diseases are used to predict the physical health of an individual. The CART and C4.5 algorithms was successfully implemented in order to predict the outcome, however in order to overcome the issue of overfitting ensemble learning methods such as Random Forest and Gradient Boosting were used. Hence the outcome of the model was accurate. The analysis of the above mentioned algorithms was based on certain factors namely, accuracy, precision, f1 score and precision. Classification report, confusion matrix and heat map were used to do the comparative analysis of all the algorithms. The C4.5 algorithm performed well with 85 percent precision. Upon overall analysis and comparison of the algorithms it is concluded that the CART algorithm performs with an accuracy of 87%.

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Enhancing Diabetes Prediction through Machine Learning Optimization Strategies

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ABSTRACT

Diabetes, a prevalent metabolic disorder, poses significant global health challenges, necessitating accurate prediction and management strategies. This research paper investigates how Backpropagation Neural Networks (BPNN) can be utilized in conjunction with various regularization and optimization methods to examine diabetes. Leveraging machine learning algorithms, particularly BPNNs, shows promise for precise diabetes prediction based on clinical data. The study aims to address gaps in understanding optimal configurations and feature selection for BPNN models. A comprehensive literature review surveys various approaches in diabetes prediction, highlighting BPNNs as a fundamental tool. The implementation involves thorough training of BPNNs using the backpropagation algorithm, supplemented by regularization and optimization techniques to enhance model performance and prevent overfitting. Furthermore, the study explores the impact of dropout regularization on BPNN performance, emphasizing its role in preventing overfitting and enhancing model generalization.

Keywords: machine learning, diabetes prediction,BPNN,regularization

INTRODUCTION

Diabetes, characterized by elevated blood sugar levels and associated organ damage, presents a significant global health challenge [1]. Computer-based systems leveraging clinical data offer promising avenues for disease identification and management [2]. ADA diagnoses data on criteria such as fasting plasma glucose (FPG) levels exceeding normal [3]. Type 1 diabetes, often diagnosed in individuals under 30, necessitates insulin therapy due to inadequate insulin production [4, 5, 6, 7, 8]. Uncontrolled glucose levels can lead to severe complications like cardiovascular diseases, neuropathy, and nephropathy [9]. Given the alarming prevalence of diabetes, accurate prediction models are crucial for early intervention and prevention strategies. Artificial Neural Networks (ANNs), particularly Backpropagation Neural Networks (BPNNs), offer robust tools for diabetes prediction, leveraging factors such as genetic predisposition and lifestyle habits [10].

Prevention strategies often focus on promoting healthy behaviours, such as regular physical activity, a balanced diet, and weight management. Early detection and intervention play a crucial role in mitigating the long-term complications associated with diabetes. As we delve into the complexities of diabetes, understanding its epidemiology, risk factors, and the evolving landscape of research and treatment becomes imperative. This introduction sets the stage for a comprehensive exploration of the various facets of diabetes, encompassing its impact on global health, the challenges it poses, and the ongoing efforts to better understand, prevent, and manage this prevalent metabolic disorder.

Different machine learning algorithms have been used for diabetes prediction. The role of machine learning models in predicting diabetes is multifaceted and can bring several benefits to both patients and healthcare providers. Early detection allows for timely intervention and management strategies to prevent or delay the onset of the disease. Machine learning models play a crucial role in diabetes prediction by leveraging data-driven approaches to improve early detection, personalized risk assessment, clinical decision-making, treatment optimization, and patient outcomes.

LITERATURE REVIEW

Numerous studies have explored diabetes prediction using machine learning techniques, notably the

Pima Indians Diabetes Dataset (PIDD). Kaur and Kumari (2020) compared various machine learning algorithms on this dataset, including Radial Basis Function (RBF) kernel SVM and ANN [1]. Maniruzzaman et al. (2020) employed Logistic Regression (LR) to identify diabetes risk factors and explored classifiers like Naive Bayes and Decision Trees [2]. Kopitar et al. (2020) and Maniruzzaman et al. (2020) investigated regression models like Glmnet and classification models like Adaboost and Random Forest for type 2 diabetes prediction [3]. Albahli (2020) proposed a hybrid approach using K-means clustering and ensemble learning, while Yahyaoui et al. (2019) compared traditional machine learning with deep learning techniques [6, 7]. Zou et al. (2018) and Dinh et al. (2019) utilized decision trees, random forests, and supervised machine learning models for diabetes prediction [6, 9]. Choubey et al. (2017) employed Naive Bayes with Genetic Algorithm, emphasizing early diabetes detection [8]. Joshi and Chawan (2018) and Rajeswari and Prabhu (2019) focused on SVM classification for high accuracy in diabetes prediction [10]. Nilashi et al. (2017) developed intelligent models using machine learning techniques like SOM and NN, while Perveen et al. (2016) utilized ensemble methods for diabetes detection [11, 12]. Kazerouni et al. (2020) compared SVM, K-NN, ANN, and LR for T2DM diagnosis [13].

The review underscores the breadth of approaches in diabetes prediction, with BPNNs standing out as a fundamental tool. However, the literature reveals gaps in understanding the optimal configurations and feature selection for BPNN models, which this study aims to address. To Explain the research gap between all the research that have taken place, Backpropagation serves as a fundamental algorithm utilized in machine learning, particularly in the sphere of diabetes management and prognosis. Diabetes presents as a multifaceted metabolic ailment characterized by elevated blood sugar levels, necessitating the anticipation of future glucose levels grounded in factors like dietary patterns, physical activity, prescribed medications, and individual physiological attributes. In this domain, backpropagation, coupled with neural networks, emerges as a potent instrument for scrutinizing and prognosticating intricate data relationships.

METHODOLOGY

In the field of diabetes management, backpropagation finds application predominantly in crafting predictive models employing artificial neural networks (ANNs). ANNs, drawing inspiration from the human brain architecture and functionality, constitute interconnected nodes arranged in layers.

We have used BPNN algorithm with regularization and optimization techniques to implement machine learning model for diabetes prediction. Backpropagation stands as the principal algorithm for training these neural networks. Throughout the training regimen, backpropagation meticulously adjusts the weights of connections linking neurons within the network, guided by the disparities between predicted outcomes and actual results. This iterative refinement process enables the neural network to acquire knowledge and enhance its prognostic capabilities progressively.

Backpropagation Algorithm

Error at Output Layer:

$$\delta j=(yj-aj)\cdot f'(zj)$$

where δj is the error at neuron j in the output layer,yj is the target output,f′(·) is the derivative of the activation function.

Error at Hidden Layers:

$$\delta j=(\sum kwjk\cdot \delta k)\cdot f'(zj)$$

where δj is the error at neuron j in a hidden layer,wjk is the weight connecting neuron j to neuron k,δk is the error at neuron k in the following layer.

Filter Methods evaluate features individually based on their statistical properties. Metrics such as correlation coefficients, variance, or statistical tests like chi-square and ANOVA are commonly used. For example, the Pearson correlation coefficient measures the linear relationship between variables, while variance indicates the spread of data points around the mean. By ranking features using these criteria, filter methods assist in selecting promising candidates for model inclusion.

$$r=\sum i=1n(xi-x^{-})2\sum i=1n(yi-y^{-})2\sum i=1n(xi-x^{-})(yi-y^{-})$$

where n is the number of observations, xi and yi are individual data points for variables X and Y respectively. ‾x‾ and ‾y‾ are the means of variables X and Y respectively.

Wrapper Methods, on the other hand, assess feature subsets by employing specific machine learning algorithms. Feature Elimination techniques build and evaluate models using different feature combinations. The subset that achieves the best performance according to predefined metrics, such as accuracy or cross-validation score, is selected.

Embedded Methods integrate feature selection into the model construction process itself. These methods utilize regularization techniques within machine learning algorithms, such as Lasso (L1 regularization) and Ridge (L2 regularization) regression models. Less relevant features' coefficients are penalized, effectively pushing them towards zero during training. This automatic feature selection during model construction results in a more concise and interpretable final model.

Lasso (L1 Regularization): It combines a penalty, which is the sum of squared errors (SSE). The formula for the Lasso objective function is as follows:

$$\text{Loss function}=SSE+\lambda\sum_{j=1}p|\beta j|$$

Where λ is the regularization parameter that controls the strength of regularization and p is the number of features. βj represents the coefficient of the hj^{th} feature. Lasso regularization encourages sparse solutions by driving less relevant feature coefficients towards zero, effectively performing feature selection during model training.

Ridge (L2 Regularization):

$$\text{Loss function}=SSE+\lambda\sum_{j=1}p\beta j2$$

Where λ is the regularization parameter controlling the strength of regularization. p is the number of features. βj represents the coefficient of the hj^{th} feature. Ridge regularization penalizes large coefficients, leading to smoother solutions and mitigating multicollinearity issues.

Dataset

We have used Diabetes dataset for implementing machine learning model for prediction. The dataset features are given in table 1 and sample dataset is shown in fig 1.

Serial Number	Topic	Description
1	Pregnancies	This variable indicates the number of times the individual has been pregnant.
2	Glucose	Represents the plasma glucose concentration measured in a 2-hour oral glucose tolerance test.
3	Blood Pressure	Indicates the diastolic blood pressure (mm Hg) of the individual.
4	Skin Thickness	Refers to the thickness of the skinfold at the triceps (mm).
5	Insulin	Represents the 2-hour serum insulin level (mu U/ml)
6	BMI (Body Mass Index)	Represents the individual's body mass index, calculated as weight in kilograms divided by height in meters squared (kg/m^2).
7	Diabetes Pedigree Function	A function that scores the likelihood of diabetes based on family history.
8	Age	Represents the age of the individual in years
9	Outcome	This is the target variable, indicating whether the individual has diabetes (1) or not (0)

Table 1. Dataset Features

	Pregnancies	Glucose	BloodPressure	SkinThickness	Insulin	BMI	DiabetesPedigreeFunction	Age	Outcome
0	2	138	62	35	0	33.6	0.127	47	1
1	0	84	82	31	125	38.2	0.233	23	0
2	0	145	0	0	0	44.2	0.630	31	1
3	0	135	68	42	250	42.3	0.365	24	1
4	1	139	62	41	480	40.7	0.536	21	0

Fig. 1. Sample Diabetes Dataset

This Diagnosis or prediction has given the presence of variables like glucose levels, insulin levels, BMI, and family history. The dataset contains information on various individuals, including their medical history and demographic characteristics. It could be used for research into factors contributing to diabetes, predictive modelling for diabetes diagnosis, or evaluating the effectiveness of interventions or treatments.

IMPLEMENTATION

The Implementation of backpropagation, bolstered by regularization and optimization techniques, holds significant promise, particularly in complex tasks such as diabetes management. Backpropagation, a cornerstone algorithm in neural network training, facilitates the adjustment of connection weights based on errors between predicted and actual outcomes. Regularization techniques, like L1 and L2 regularization, are integrated into the training process to prevent overfitting by imposing penalties on large weight values. In cases where the feature space is extensive or redundant, dimensionality reduction techniques can be applied to mitigate computational burdens and enhance interpretability. Researchers expedite subsequent analysis and modelling tasks without sacrificing data fidelity. The proposed model is shown in fig 2. Backpropagation is a key algorithm used in training artificial neural networks (ANNs), particularly in the context of supervised learning tasks. which allows for efficient optimization of the network's parameters through gradient descent.

Moreover, optimization algorithms play a vital role in refining the model's parameters during training to minimize the loss function. Techniques like stochastic gradient descent (SGD), Adam, and RMSprop are commonly employed to navigate the high-dimensional parameter space efficiently. By adjusting the learning rate and momentum, these optimization algorithms enable backpropagation to converge to an optimal solution more swiftly and effectively. In the context of diabetes management, where the input space is multidimensional and dynamic, these optimization techniques contribute to the development of accurate predictive models capable of capturing the intricate relationships between various factors influencing blood sugar levels.

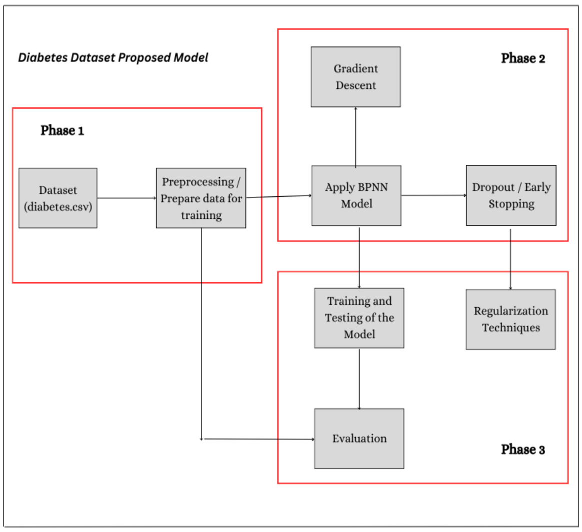

Fig. 2. Proposed Model

RESULTS AND DISCUSSIONS

Table 2 shows the results of the implementation. Feature selection was conducted employing both filter and wrapper methods as well as embedding techniques. The performance of BPNN is compared with SVM, Logistic Regression, Decision Tree and KNN algorithms. Both filter wrapper and embedding feature selection methods are applied on algorithms and the results are compared. BPN with filter wrapper method gives an accuracy of 0.76 compared to embedding method with an accuracu of 0.68.

Classifier	Feature Selection	Accuracy	Precision , Recall	Sensitivity	Specificity	Dropout
BPNN	Filter Wrapper	0.76	0.75,0.82	0.64	0.79	0.75
	Embedding	0.68				
SVM	Filter Wrapper	0.73	0.78,0.88	0.94	0.12	0.72
	Embedding	0.54				
Logistic Regression	Filter Wrapper	0.71	0.81,0.80	0.752	0.68	0.69
	Embedding	0.64				
Decision Tree	Filter Wrapper	0.73	0.83,0.76	0.788	0.54	0.74
	Embedding	0.66				
KNN	Filter Wrapper	0.73	0.75,0.82	0.64	0.79	0.73
	Embedding	0.66				

Table 2: Comparison of Performance

A Backpropagation Neural Network is a type of artificial neural network commonly utilized for supervised learning tasks such as classification and regression. In this network architecture, layers of interconnected nodes, representing neurons, process information. The training of BPNNs relies on the backpropagation algorithm, which iteratively adjusts the network's weights to minimize the discrepancy between its predicted output and the actual output. This iterative process involves propagating the error backward through the network, updating the weights based on the gradient of the error function with respect to each weight. Through repeated iterations, the network refines its predictions, enhancing its performance in various machine learning tasks. Fig3 shows the BPNN training loss and validation loss for each epoch. Model loss with a dropout rate and model accuracy is shown in fig4 and fig 5 respectively.

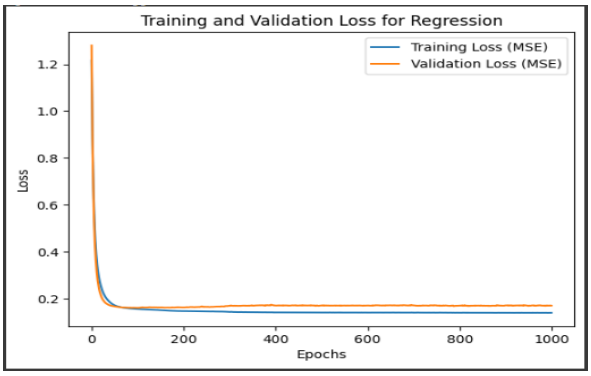

Fig 3. Model Validation and Loss

Logistic Regression involves the algorithm models the probability that the dependent variable (or target) belongs to a particular category as a function of the independent variables (or features). Decision Tree is the process of constructing a tree selecting the best split at each node based on a criterion that measures the genetics of the target variable within the resulting subsets. Popular criteria include Gini impurity. K-Nearest Neighbours (KNN) is a simple, yet effective algorithm used for both classification and regression tasks in machine learning.

In the pursuit of optimizing the performance of a simple feed forward neural network, a comprehensive analysis was conducted by experimenting with different dropout rates. Dropout regularization is a crucial technique in neural network training that involves randomly deactivating a certain percentage of neurons during each iteration, preventing overfitting, and enhancing model generalization. The objective of this analysis was to understand how varying dropout rates impact the network's learning dynamics and overall predictive capabilities.

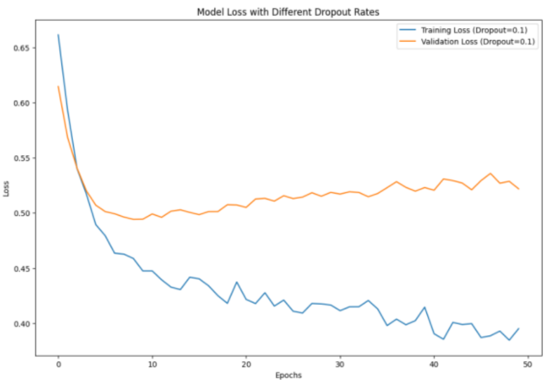

Fig 4. Model Loss with Dropout

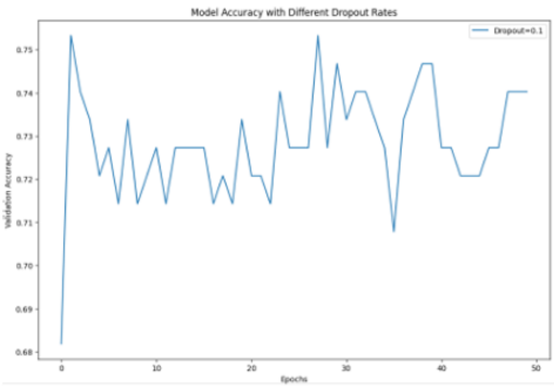

Fig 5. Model Accuracy with optimization

Feature selection techniques applied for KNN, SVM and BPNN are shown in fig , fig 7 and fig 8 respectively. The results of the implementation show that BPNN gives an accuracy of 0.76 with filter wrapper feature selection and the accuracy is 0.73, 0.71,0.73 and 0.73 for SVM, Logistic Regression, Decision Tree and KNN respectively with filter wrapper feature selection method.

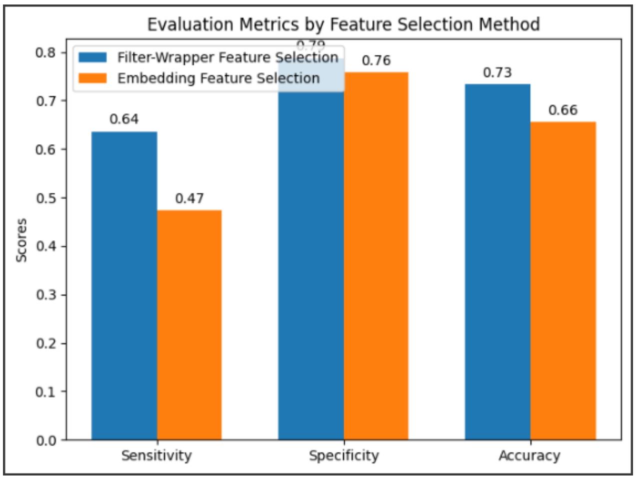

Fig 6. Feature Selection for KNN

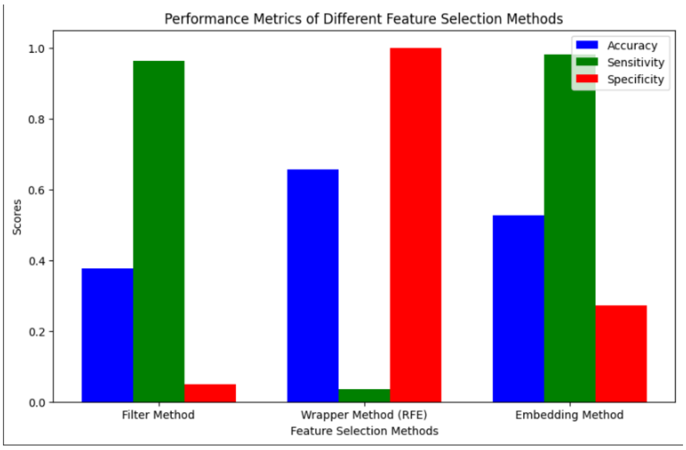

Fig 7. Feature Selection for SVM

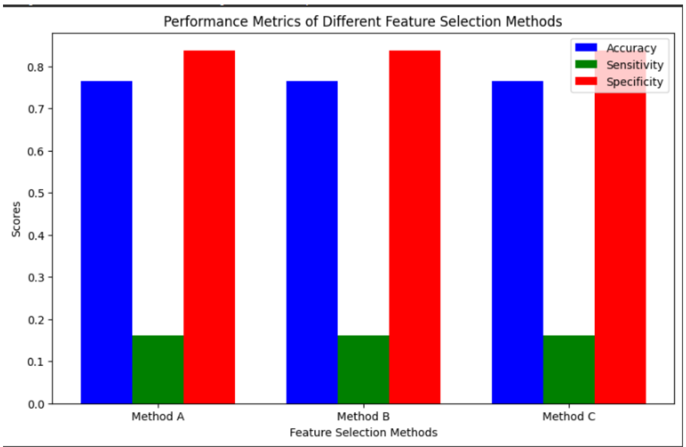

Fig 8. Feature Selection for BPNN

CONCLUSION

The study conducted a comprehensive exploration of diabetes prediction utilizing Backpropagation Neural Network with various regression and optimization techniques. The research addressed this need by leveraging machine learning algorithms to predict diabetes based on research analysis. Various studies have employed a range of machine learning techniques including BPNN, SVM, LR, KNN and Decision tree. The implementation involved training of the neural network using the backpropagation algorithm, supplemented by regularization and optimization techniques to enhance model performance and prevent overfitting. The results and discussions section provided insights into comparative analysis. The findings underscore the importance of employing diverse algorithms and methodologies for effective diabetes prediction and management.

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Research Article

Frosting The Future: Innovations In Iot-Enabled Refrigeration Security

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ARTICLE INFO **ABSTRACT**

In the realm of home automation, the Internet of Things is revolutionizing how households operate by interconnecting devices and systems for enhanced convenience, efficiency, and security. The data is gathered by the sensors and sent to a host so that it can be processed over the internet. The field of home automation is among the most exciting uses of IoT. The fridge is one example of a smarter gadget that is used in daily life due to rapid technological advancements. The fridge is a key component in the food preservation of modular kitchens and shops. There is a need of system which will checks the fridge door is properly closed or not. The proposed system will detects the gaps between the fridge doors. If there is gap then it will alert the user by giving notification to their mobile. Due to which users can avoid excessive electricity consumption and also food spoilage can be prevented.

Keywords: IoT, Home Automation, Fridge, Blynk, Node MCU, Magnetic Switch Sensor.

1. INTRODUCTION

IoT is a transformative concept that connects physical devices through the Internet, enabling them to share data and interact autonomously. The term IoT refers to a concept that facilitates the creation of a wireless network between various IP protocols and internet-accessible devices. Things in the IoT refer to devices like sensors, microcontrollers, and mobile phones that are connected to a wireless network. In essence, IoT builds an ecosystem among devices that makes it accessible remotely [1]. IoT encompasses a wide range of devices, from everyday household items to sophisticated industrial tools, all equipped with sensors and network connectivity. These devices communicate with each other and with users, facilitating tasks like data exchange, device control, and process automation. Key components of IoT include sensors for data collection, connectivity technologies like Wi-Fi and cellular networks, data processing and storage capabilities, analytics for insights generation, and user interfaces for device interaction. IoT's significance lies in its ability to revolutionize industries by enhancing efficiency, productivity, and customer experiences. Despite facing challenges like security vulnerabilities and privacy concerns, IoT continues to grow rapidly, offering new business models, improved decision-making through data insights, enhanced operational efficiency, and the potential for creating innovative products and services across various sectors. IoT, saves time by analysing data gathered from sensors and carrying out relevant tasks. The development of home automation systems was aided by the assurances given to individuals regarding the security and activities of their homes. Both the user and the system's data will be updated regularly [2]. The integration of the IoT into home automation systems revolutionizes the way people interact with their living spaces, offering unparalleled convenience, efficiency, and security.
Home automation is about using technology to create a smarter and more responsive living environment. It achieves this by interconnecting various devices in your house, like lights, thermostats, appliances, security systems, and more allowing them to be controlled and monitored through a central hub or WiFi network. This connectivity allows people to operate these devices remotely using smartphone, tablet, or even voice assistants granting people the ability to turn on lights, adjust the thermostat, lock doors, or even monitor security cameras – all from anywhere. In the last few years, home automation has become more popular. As a result of the rapid

advancement of technology, home automation systems have become ever more advanced and intelligent [3]. Furthermore, some smart devices have built-in sensors that can detect things like motion, temperature, or light. These sensors can trigger automated actions, like lights turning on as someone enters a room or the thermostat adjusting before anybody arrives home, enhancing convenience and efficiency. Ultimately, home automation offers a multitude of benefits. It can increase anyone's comfort and convenience by allowing remote control of the environment. It can improve security through features like smart locks and remote video monitoring. And, by optimizing the usage of appliances and lights, it can even contribute to increased energy efficiency in your home. Home automation provides an effective use of energy along with a future lifestyle where a person can use a smart phone to handle every aspect of their home, including locking and opening doors and turning on a TV. However, the expense of having such a system installed is prohibitive, which is a significant reason why home automation has not attracted much interest. The installation and configuration of the system are also quite complex [4]. By leveraging IoT components like Arduino UNO, ESP8266 Wi-Fi module, and Blynk app, users can efficiently manage their homes from anywhere globally. The Blynk app facilitates the creation of consumer-facing mobile apps for managing IoT devices effortlessly, offering features like device monitoring, data management, and user control while ensuring data security through encrypted communication channels. The future of home automation looks promising as IoT technology continues to revolutionize living spaces with enhanced connectivity and smart solutions tailored to the needs of homeowners. Any electrically plugged-in appliance can be remotely managed in an automated house, or it can be as basic as a cluster of switches.
Equipment, parts, furnishings, and custom installation are the primary expenses [14]. From autonomous LED lighting, power consumption, and waste management systems to infrastructure solutions like PV systems, IoT, and smart grid for households, connected technology enables everyone to go green, minimize carbon emissions, and reduce pollution [15].
The remainder of the paper is organized as follows : Literature review and related work is presented in Section 2, Section 3 comprises of methodology used for the proposed system; System implementation, the overall functioning and results of the system is being discussed in Section 4; The discussion and conclusion of the paper is being presented in Section 5.

2. LITERATURE REVIEW

By giving each object a unique identity, the Internet of Things (IoT) can also be thought of as a worldwide network that facilitates communication between people, things, and things to things—that is, anything in the world. In the so-called Internet of Things, wired and wireless networks are used to connect sensors and actuators embedded in real objects, such as pacemakers and highways, frequently utilizing the same addresses. To access the Internet, use IP Internet. Massive amounts of data are produced by these networks and sent to computers for analysis. When an object has the ability to perceive and communicate with its surroundings, it can become an instrument for comprehending complexity and reacting rapidly to it. The revolutionary aspect of all this is that these physical information systems are beginning to be implemented now; some even run mostly without the need for human involvement. The Internet of Things (IoT) entails networking and encoding commonplace items and objects to enable online tracking and individual machine reading. Several wireless technologies have been utilized to introduce varying degrees of intelligence into the house, including Bluetooth, Wi-Fi, RFID, and cellular networks. These technologies make it possible to sense, control, and transmit data remotely. [16].
Since 1999, there have been extensive research and development efforts devoted to the application of Internet of Things technologies in refrigerators. In addition to tying the refrigerator to the internet, it can solve food waste problems and offer the user a number of helpful features. 1999 saw the release of the Electrolux Screen refrigerator. Although the device has not yet shipped, users of this networked refrigerator can place online purchases for groceries. [6]. In 2000, a Web pad refrigerator by Whirlpool/Cisco was unveiled, allowing customers to watch celebrity chefs. Users can look up recipes utilizing the food supplies they currently have by using the built-in web browser. The owner of a Whirlpool refrigerator may watch TV, play DVDs, listen to the radio, browse the Internet, send and receive emails, and even make phone calls after the refrigerator was converted into a multimedia communications center in 2002 [5]. In June 2000, LG unveiled the Internet Digital DIOS, the first internet refrigerator in history. An internet refrigerator, also called a smart refrigerator, is a refrigerator that has been set up to use barcode or RFID scanning to detect the products it contains and to keep track of its inventory [5]. Other manufacturers, like Samsung and Panasonic, also entered the fray and developed ideas for integrating cameras inside refrigerators to monitor food spoilage and enable users to check on leftovers without opening the door. But because they are so pricey, these refrigerators aren't widely sold. Many juice bottles, for instance, are transparent, which acts as a visual cue that a purchase will eventually be required. Similarly, transparent vegetable drawers, which hold items that are regularly removed from packaging, do away with the need for bar codes for inventory, which previously required the manual entry of dates and descriptions. Moreover, the use case of the device alerting users to upcoming purchases is typically unsolvable when there are regularly multiple buyers in a household who converse informally. [7]. Using gas detectors, PIR sensors, ultrasonic sensors, and GSM technologies, Oyekola developed a wireless remote security home surveillance system utilizing IoT and smartphones [19].

3. METHODOLOGY

The IoT-based fridge door alert system aims to deliver a seamless and user-friendly experience, emphasizing real-time monitoring, instant alerts. The intuitive interface, accessible through a mobile app or web platform, provides users with a clear visualization of the fridge door status and allows for effortless customization of alert settings. Scalability is addressed by supporting multiple fridges within a single user account. The system promotes customization, reliability, and comprehensive documentation. Block Diagram of the project is shown in Figure 3.1.

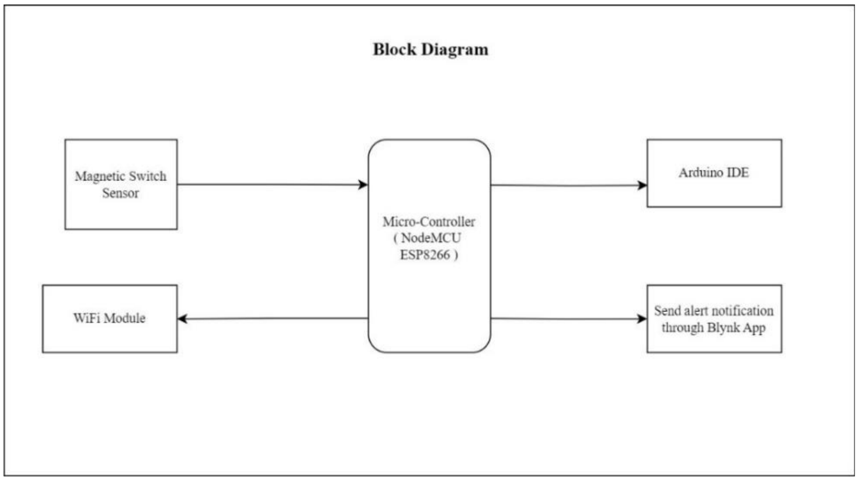

Figure 3.1: Block Diagram of the System

Among the various platforms that are currently available, ESP8266, WiFi, Arduino, and Bluetooth were discovered to be platforms on which home automation systems can be used. Proposed system is using ESP8266 instead of Arduino because the WiFi module on the ESP8266 is pre-installed, and the system are using WiFi instead of Bluetooth since WiFi has a wider network range than Bluetooth, which requires installation on the outside [8]. The reason these platforms were deemed most appropriate is because, when utilized for project's individual control home automation systems, they are inexpensive, reliable, and easy to use.

3.1. SOFTWARE REQUIREMENTS:

The software requirements needed for IoT based Fridge Door Alert System.

A) Arduino IDE:

The Arduino integrated development environment (IDE) is a versatile application compatible with multiple operating systems such as Windows, macOS, and Linux. Created using Java programming language, it serves the purpose of coding and transferring programs to Arduino-compatible boards. Moreover, through the utilization of 3rd party cores, it extends its functionality to support a range of other vendor development boards. Figure 3.1.1 shows the interface of Arduino IDE [13].

Figure 3.1.1: Arduino IDE Interface

B) Blynk IoT:

Blynk IoT is a platform that allows you to easily build IoT applications and projects. It provides a user-friendly interface and a range of tools and features to connect and control various hardware devices, sensors, and actuators. All cloud-based interactions between smartphones and embedded systems are made possible via the Blynk server [10]. The Blynk IoT app is shown in Figure 3.1.2 where user can see and receive live updates about the system.

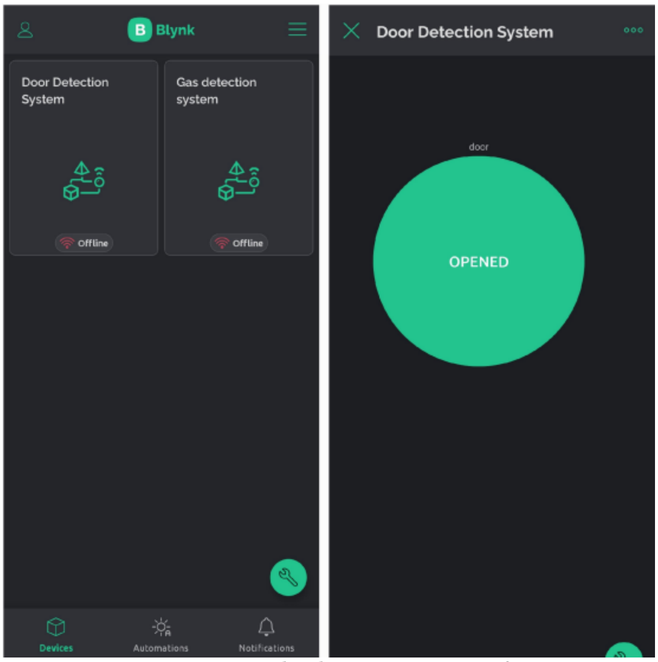

Figure 3.1.2: Blynk IoT App Interface

a. HARDWARE REQUIREMENTS:

The Hardware Requirement needed for IoT based Fridge Door Alert System are:

A) NodeMCU (ESP8266):

The NodeMCU ESP8266 is a versatile development board designed for IoT projects, boasting integrated Wi-Fi capabilities through the ESP8266 microcontroller. With its accessible GPIO pins and support for languages like Arduino IDE and Lua scripting, it facilitates seamless interaction with sensors and actuators. Operating at 3.3 volts and powered by USB or external sources, it serves as an ideal platform for prototyping and experimenting in the IoT space, bolstered by a robust community providing ample support and resources. The low-cost Wi-Fi chip is one of the advantages of developing the ESP8266 module. The module designed at the NodeMCU board has the ability to function on its own. This NodeMCU board's benefits and features make it an excellent choice for home automation systems [11]. The Figure 3.2.1 shows NodeMCU ESP8266 component.

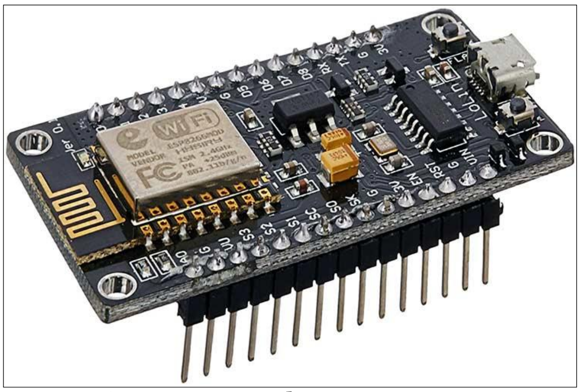

Figure 3.2.1: NodeMCU ESP8266

B) Magnetic Switch Sensor:

Magnetic Switch Sensor (MC-38) is used for detection if door is properly closed or not. When they are moved apart, they provide a signal that gets supplied to the microcontroller to enable it to carry out the required operation. The magnet triggers the sensor. The MC-38 should be placed in important points throughout the house in order to give the owner regular alerts [12]. Figure 3.2.2 shows Magnetic Switch Sensor component.

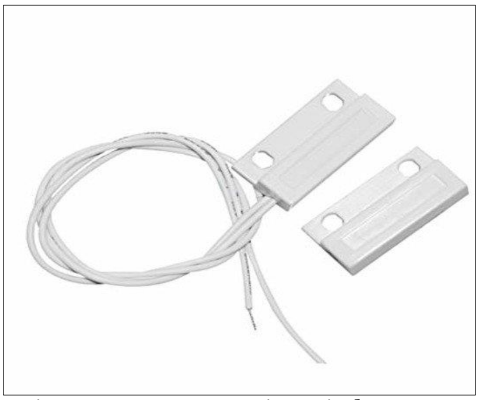

Figure 3.2.2: Magnetic Switch Sensor

C) Breadboard:

In IoT projects, breadboards serve as essential tools for rapid prototyping and testing of circuit designs without soldering. They provide a platform for connecting sensors, actuators, and microcontrollers, facilitating the creation of temporary circuits for experimentation and development. This flexibility allows IoT developers to quickly iterate on designs, troubleshoot issues, and validate concepts before moving to more permanent hardware implementations. Figure 3.2.3 shows Breadboard component.

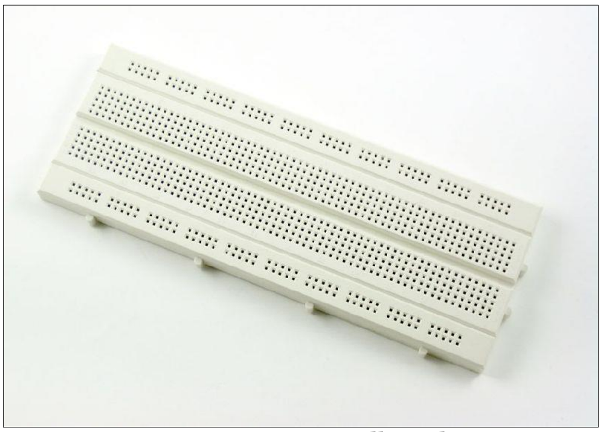

Figure 3.2.3: Breadboard

D) Powerbank:

Powerbanks are integral to IoT projects involving microcontrollers, serving as portable power sources for these devices. They enable microcontrollers to operate autonomously without the need for direct mains power, enhancing their versatility and enabling deployment in remote or mobile settings. With rechargeable batteries and compact designs, powerbanks ensure reliable power supply for microcontrollers, facilitating their integration into various IoT applications. Figure 3.2.4 shows Powerbank.

Figure 3.2.4: Powerbank

4. RESULTS

Many of us sometimes by mistakenly do not close the fridge door properly. This makes the fridge to go through several issues. The issue of not properly closed door of the fridge includes several reasons that can cause the fridge door not to close properly. These reasons include blockage or damaged gasket or uneven surface or damaged hinge and overcrowding due to food items in fridge. These problems can lead to cold air escaping and forcing the refrigerator to overwork, introducing serious fridge problems. The proposed system develop's a smart system for detecting if the fridge door is properly closed or not. The sensor is connected to the microcontroller to detect the closing of door by checking if circuit is complete or not. WiFi module is used for transmitting the data from controller to mobile. The system is using a Magnetic switch sensor for detection of closed door. The use of sensor is to mainly detect if the door is close by checking if the magnetic switch sensors are closed to each other if they are the circuit is completed and when the sensors are far apart the circuit is broken and after a certain duration a alert message is sent to the users. The system can be easily installed by attaching the microcontroller to the side of the fridge. The wired part which connects to the microcontroller should be installed on the side of the fridge as shown in Figure 4.1 and the other part should be installed on the free moving door. Figure 4.1 shows the status of the door being closed in the blynk app.

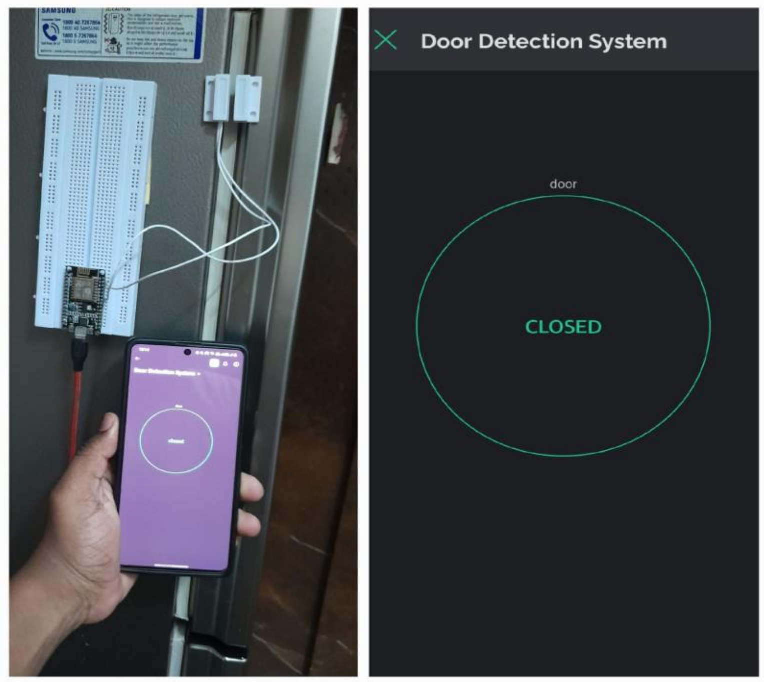

Figure 4.1: When door is closed

When the door is not closed for a certain amount of time the microcontroller passes a message to the user that their fridge door has not been closed so they can check on the fridge and can close their fridge on time to avoid any food spoilage Figure 4.2 shows the message received by the user when the fridge door is kept opened.

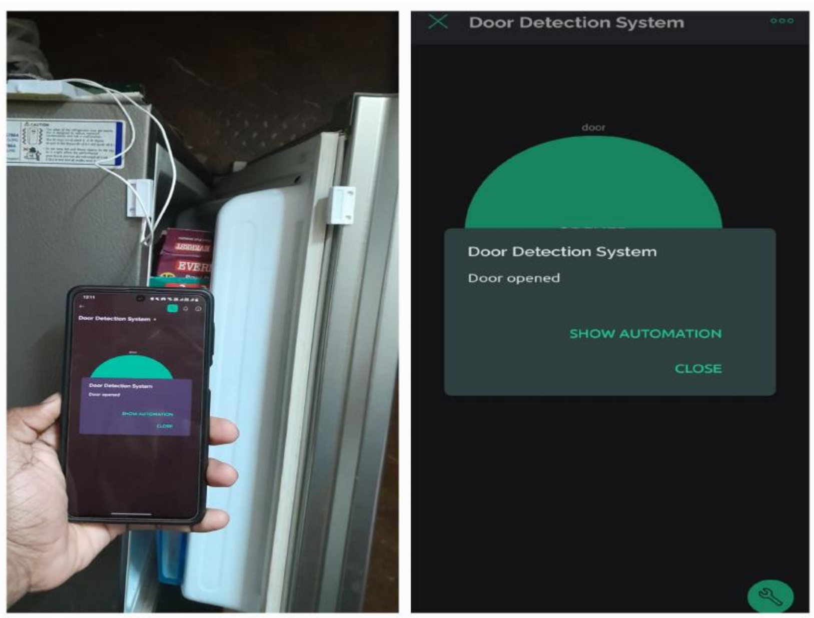

Figure 9: When the door is opened

Upon detecting an open fridge door, the sensor relays the information to the microcontroller, which initiates the alert mechanism. The microcontroller triggers notifications through the connected network, informing users of the door status. Users receive alerts on their smartphones or other designated devices, prompting them to take corrective action, such as closing the door or addressing potential issues with the fridge.

Potential Applications and Benefits:

The IoT-based open fridge door alert system offers several applications and benefits, including:

1. Food Safety: Timely alerts help prevent food spoilage by minimizing the duration of door openings, preserving the freshness of stored items.
2. Energy Efficiency: By reducing unnecessary cooling loss, the system contributes to energy conservation and lower utility bills.
3. User Convenience: Remote monitoring and alerts enable users to stay informed about their fridge status, even when away from home, enhancing convenience and peace of mind.
4. Data Insights: The system may collect data on door opening patterns, enabling users to analyze usage habits and optimize refrigerator operations.

5. DISCUSSION & CONCLUSION

In conclusion, the IoT-based fridge door alert system represents a cutting-edge solution that seamlessly integrates technology into everyday life. With a focus on real-time monitoring, powerful alert systems, and user-friendly interfaces, the project seeks to give users fast access to status updates on their refrigerators. Its user-centric design is further demonstrated by the product's dedication to customization, dependability, and thorough documentation. Fundamentally, the goal of this project is to completely transform the way consumers interact with refrigeration appliances by providing a smart, networked solution that not only overcomes the drawbacks of conventional systems but also anticipates the changing demands of a convenience- and tech-savvy customer base.

6. FUTURE SCOPE

The future scope of the IoT-based fridge door alert system is poised for exciting developments, offering opportunities for expansion and integration with emerging technologies. With opportunities for advancement and integration with modern technology, the IoT-based refrigerator door alert system is prepared for remarkable future expansion. If the project continues to interact with popular smart home ecosystems like Google Home and Amazon Alexa, refrigerator monitoring might become a seamless component of whole home automation. The system's sustainability may be increased by in-depth study of cutting-edge energy-saving technology like energy harvesting or low-power communication protocols. Encouraging appliance manufacturers to work with refrigerator manufacturers to integrate IoT capabilities directly into future refrigerator models could expedite the process.

Declaration and Conflict of Interest

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome. As corresponding author, I confirm that the manuscript has been read and approved for submission by all the named authors.

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