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Real-Time Health Monitoring with IoT

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Abstract:
In today's lives, continuously monitoring health has become the biggest challenge especially with the increasing risks of sudden health-related issues which occurs because of delayed medical attention. Our research focuses to this urgent need by crafting a smart, Internet of Things (IoT) based system which continuously monitors patients' health in real time and share the record in cloud database. Our proposed setup is based on Arduino UNO, and several health sensors such as temperature, heart rate, and blood oxygen levels in real-time. The proposed system not only collects the data but also uses ML based algorithms like support vector machine (SVM) to distinguish between safe and potentially dangerous health states of patients. By making the system, physicians can easily see and manage the records of patients and similarly patients can also see their health records by using the proposed system.

Index terms: Health Monitoring Systems, Internet of Things (IoT), Support Vector Machine (SVM), Sensor Technology.

I. INTRODUCTION

This Nowadays healthcare industry plays pivotal role within our society. Healthcare industry includes several doctors, health professionals, Pharmaceuticals, Insurance companies, and the involvement of Internet of Things (IoT) to smartly monitor the health records of patients. Because of the significant growth of the population, traditional healthcare methods are still struggling to keep up the demands of individuals. Moreover, for all individuals, accessing the medical services are not affordable or accessible. For this reason, many healthcare industries are adopting IoT devices to popup the challenges faced by the traditional healthcare systems [1]–[3]. Smart IoT aims to make healthcare department more efficient, intelligent and sustainable by monitoring the patients' health remotely and getting the automatic alert in case if there is something wrong. By monitoring patients remotely, IoT makes the life more comfortable, and improves the ease of communication between healthcare providers and the patients.

IoT is a technology which uses several sensors such as, temperature sensor, heart pulse sensor and blood pressure sensors to monitor the health records of individuals and smartly share these records over cloud via network routers [4]. By using these sensors, individuals and doctors can easily monitor their health records and get precautionary measures if something getting wrong. By doing so, IoT can save millions of lives which dies because of ineffective medical treatment.

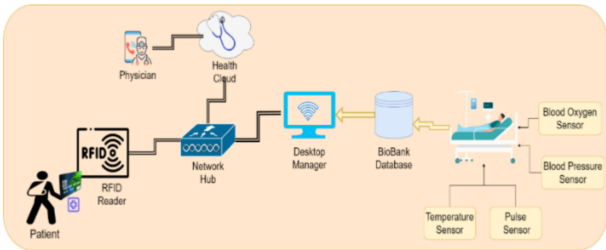

Figure 1: how IoT in hospitals can be

sFigure 1, illustrates a representation of a smart health monitoring system inside healthcare departments. These includes various components to streamline the patient health record data and the communication between patients and Physicians. Whenever, the patient is admitted or visit to hospital, it will be recognized by its specific RFID (Radio-Frequency Identification). RFID reader reads the patient's record and match to its database via Network Hub. And Network Hub stores it's data inside Health Cloud, or also known as cloud storage. The main purpose of the network hub is to act as central point which communicates with patients ,health clouds and sensors data coming from the biobank and makes the communication smoothly and efficient whereas, the desktop manager is responsible for organizing and analyzing data coming from Biobank and serving as user interface for healthcare providers. Beside these, the system takes input data from patients using different sensors such as blood oxygen, blood pressure, temperature, and pulse sensors which are placed to continuously collect the health metrics and send the data to BioBank database. BioBank database communicates with desktop manager and desktop manager synchronize the data with health cloud in real time. At the other end, physicians can easily login to the Health Cloud and see the patient's health records in real time. One of the main challenges in healthcare is for physicians is to efficiently manage and interpret the vast influx of patient data from IoT devices. The lack of such system which real-time monitor and predicts patients' health to provide them timely and proactive healthcare interventions [5].

The main goal of this research is to develop a healthcare monitoring system which can efficiently manage the patients data. This research is structured in two main parts. The first part involves employing sensors to capture patients' vital signs. Whereas, the subsequent part deals with the storage of critical health data. The analysis of these vital signs was conducted using Python. Consequently, the proposed framework involves the collection of sensor data through an Arduino microcontroller, followed by a series of analyses. The main objectives of this research is to gather real-time medical data from patients through IoT technologies and processing and organize the collected patient data. After organizing, employ data mining techniques to detect and predict potential health issues at their onset, thereby enabling a strategic decision-making process. Moreover, this IoT based infrastructure will be accessible at anywhere, at any time.

II. LITERATURE REVIEW

Several studies have introduced various frameworks for integrating IoT in healthcare and diagnosing different conditions using a range of approaches. Such as in [6], Ahmad and colleagues take a deep dive into how IoT evolved into healthcare by time, and the methods used, and the significant impacts of these changes. The authors analyzed, how improvements in network services shaped healthcare. Moreover, they also highlight the importance of these developments in both social and scientific contexts. Their study goes further to trace the healthcare systems from the early days of healthcare 1.0 to the modern era of healthcare 4.0, examining how each stage has contributed to societal well-being, scientific progress, and technological innovation. Moreover, Raeesi et al. [7] introduced a system that manage IoT and data mining techniques to predict the diseases inside healthcare industry. The authors discussed and applied the application of machine learning (ML) algorithms on collected data from healthcare devices to enhance disease diagnosis and prediction. The paper starts with an overview of the history of machine learning, and highlights the key algorithms that hold particular significance in the healthcare sector. The main aim of this study was to elaborate, how ML methodologies, tailored for IoT data, can be effectively employed for identifying health issues, culminating in the development of an IoT-based Disease Prediction and Diagnosis System that integrates these advanced techniques for healthcare improvement. In another research, Hamim developed an innovative health monitoring system that integrates IoT architecture with health sensors to monitor patients' health which includes body temperature, heart rate, and galvanic skin response (GSR). Their proposed system captured real-time health data and stored the data in the Google Firebase Database. This data can be accessed via Android application, and can be seen by patient as well as by physicians. The main motive of this application was to reduce the need for going physically inside hospitals for routine checkups, this approach not only enhanced patient convenience but also provided a detailed discussion on the IoT architecture stages and the cardiac cycle's phases [8]. Similarly, another research, [9] proposed the integration of IoT in healthcare monitoring devices. The authors emphasized the importance of efficient management of healthcare data generated by sensors, and also discussed how IoT can give a better solution. Moreover, in another work, [10] proposed a detailed review of several Sensors and Smart Devices for IoT Enabled Healthcare System. The author analyzed the articles between 2016 to 2023 and gives a brief study on IoT based sensor.

In IoT, researchers also proposed frameworks for regular patient health monitoring. Such as [11] proposed an IoT based framework which ensures continues and regular examination of patient's health data, and forecast about any disease for immediate interventions which also helps the patients to prevent. Similarly, in another work, [12] also proposed an IoT based health monitoring system which measure oxygen saturation and pulse rate of patient and show on LCD in real-time. Moreover, these sensor results also received by an application and can be seen from anywhere. Similarly, in another research, author used Temperature and heartbeat sensors to measure patients health data and display the health data on LCD, and in case of any abnormal change in statistics of data, the proposed system give alert to patient for immediate checkup [13]. In another research, [14] proposed a framework for predicting disease or unwellness of patients by using data mining. Moreover, the authors modified algorithm that is typically used to determine the hyperlink weight of websites in order to accomplish their purpose.

III. SYSTEM ARCHITECTURE

Figure 2, illustrates the architecture of the proposed health monitoring system that utilizes various sensors and machine learning for predicting the health condition of a patient as normal or abnormal. The proposed system is designed by using Arduino UNO microcontroller, which serves as the central processing unit. In this proposed system, two different types of sensors (temperature sensor and a heart rate & SpO2 sensor) were used for data collection. The data from human body is collected and fed into Arduino that uses Arduino software to collect the data in real time, and creates a dataset which will be stored in a csv file using Ardospreadsheet extension. After creating a comprehensive dataset, it will be uploaded to google colab for further analysis. This collected data is used to fed to predictive model based on Support Vector Machine (SVM) algorithms. SVM is a supervised machine learning model that is known for its robustness in classification tasks, and it is utilized here to distinguish between normal and abnormal health conditions based on the sensor data. After that, the model undergoes towards training and testing phase to learn the patterns and evaluate their predictive analysis. This proposed architecture presents a continuous monitoring where health predictions can potentially be used to alert doctor or the patient themself in case of detection of abnormal health conditions.

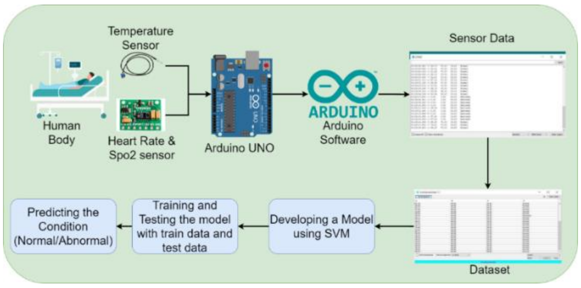

Figure 2: Architecture of Health Monitoring System

IV. DESIGN APPROACH

In this research, advanced health monitoring system is designed for continuous monitoring of patients' critical health such as body temperature, heart rate, and blood oxygen saturation (SpO2). As these sensors are attached by human body and communicate with Arduino. The main purpose of the system is to integrate extensive health data and additional symptomatic information to forecast the chronic conditions or diseases in patients for immediate interventions. Fig. 3 describes the proposed methodology of system architecture which connects interface between the Arduino and various physiological sensors attached to patients body. The raw data collected by the sensors is compiled into a CSV file format, which is conducive to data storage and manipulation. Subsequently, this dataset is uploaded to Google Colab in realtime. Google Colab is a popular cloud-based data analysis platform which initiate the data processing phase. After syncronising the data, once the dataset is collected it goes towards the next phase which involves the training and evaluation of the data using various machine learning algorithms. A set of algorithms, including Support Vector Machines (SVM), Naïve Bayes and Decision Trees, are then applied to determine the patterns within the data, which are helps in the classification of health conditions. The data is classified into two main types which also defines the effectiveness of each algorithm, these algorithms classify the health conditions as either normal or abnormal, with the results visualized through graphical representations. Focusing on the data analytics aspect, the process begins with the integration of essential libraries tailored to the SVM algorithm. The dataset is then integrated, with the variable's 'x' representing the independent features and 'y' representing the dependent target variable. This dataset is further divided into two types such as, training and testing, prepare for the application of the SVM classifier. Upon training the SVM model with the designated training set, predictions are then generated. The final step involves a thorough evaluation of the SVM model's, which takes the data, analyse the data and output as Normal health condition or Abnormal health condition.

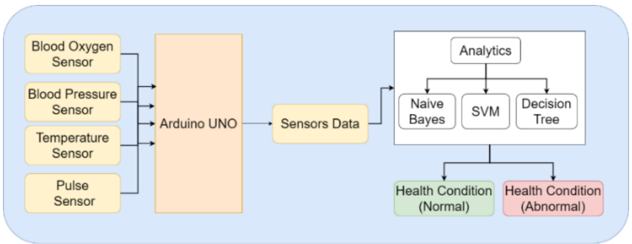

Figure 3: Proposed System Architecture

V. IMPLEMENTATION DETAILS

The implementation of the proposed advanced Health Monitoring System is carried out in two phases, first phase consists of Sensors integration and system configuration while the other phase includes Data Analysis, Model Training and evaluation. Before describing each phase following components has ben used in this research.

- Arduino UNO Board
- Heart Rate and Spo2 Sensor (MAX30100Sensor)
- Temperature Sensor

1) Arduino UNO Board

The Arduino UNO is a user-friendly microcontroller board which have total 14 digital pins, 6 PWM outputs, and 6 analog inputs. This microcontroller is powered by ATmega328P. It is programmable by using USC connection and can be powered by USB cable, or adapter or any power bank. This board is used to control the sensor devices and collects the data from sensors and store it inside CSV file format for further processing. This Arduino board allow for simple chip replacement with low-risk experimentation. The details of Arduino is shown in Figure 4.

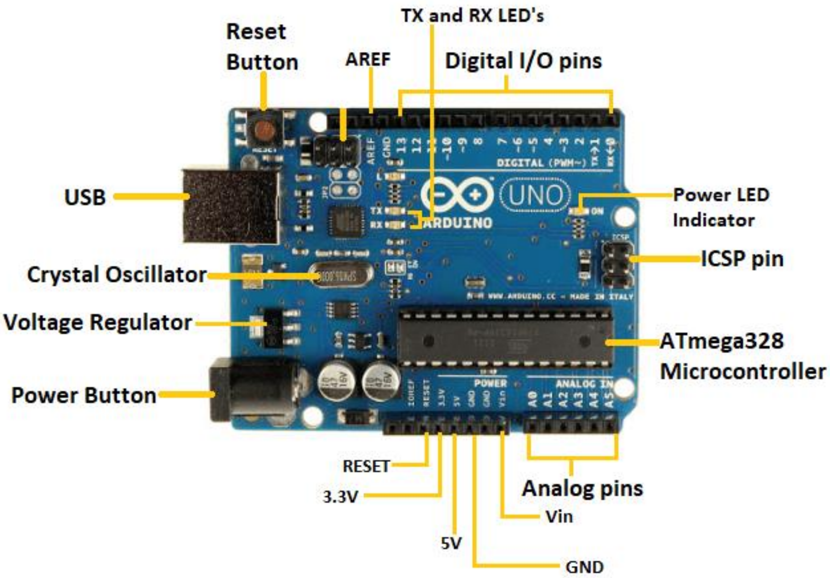

Figure 4: Arduino UNO

2) Heart Rate & Spo2 Sensor (MAX30100Sensor)

The MAX30100 sensor module is used to monitor patient's health specifically it measures two things such as heart rate and blood oxygen saturation also known as Spo2. It measures with the help of it's optical system which utilizes two LEDs, one red and one infrared and a sensitive photodetector to detect the pulse and the level of oxygen in the blood. The both components works together to monitor the light absorption fluctuations which is caused by pulsing blood, which is later converted into electrical signals. These signals are processed and gives the output of pulse rate and SpO2 readings. Figure 5, illustrates it's setup, in which the sensor is connected with Arduino board. The sensor's SCL (clock) and SDA (data) pins are linked to the I2C pins on the Arduino UNO board. It enables two-way communication between the devices. Moreover Power and ground connections are also established from the Arduino in order to run the sensor.

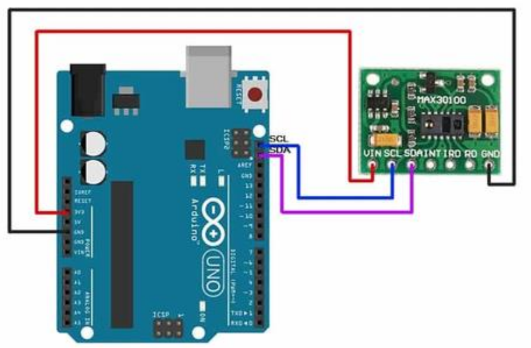

Figure 5. Connection of MAX30100 Sensor with Arduino UNO.

3) Temperature Sensor

The temperature sensor is a temperature measuring tool which measures temperature. Figure 6 shows the configuration of temperature sensor in which red wire connects to the 5V and black wire connects to the ground, whereas yellow wire is the data line, which connects to a digital input/output pin on the Arduino. Temperature sensor is connected with the Arduino using jumper wires and breadboard. Moreover, 4.7kΩ resistor is also used for connecting the red (Vcc) and yellow (data) lines, which detect when the data line is high or low. By just placing the finger, it gives the output data from the sensors and can be easily accessible.

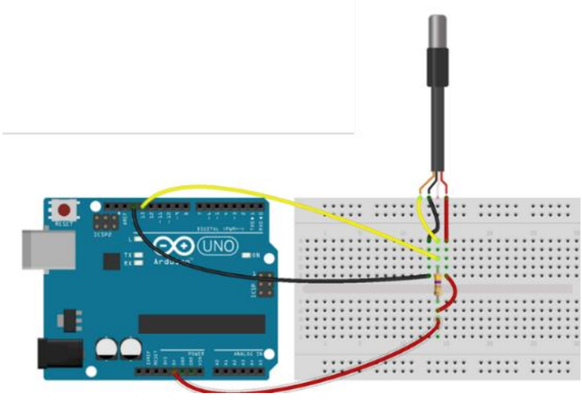

Figure 6: Connection of MAX30100 Sensor with Arduino UNO.

The description of phase 1 and phase 2 is described below.

Phase 1: System Configuration and Sensor Integration

- Phase one is initiated by installing the Arduino platform and validating its compatibility with our system.
- The next step is to connect the health monitoring sensors such as temperature sensor, Heart Rate and Spo2 Sensor, to the Arduino Uno.
- After making the hardware connection, next step is launching the Arduino Integrated Development Environment (IDE) and configuring the board specifications using the 'Tools' menu to match with our system requirements.
- After establishing connection, next step is to develop and upload a custom program into Arduino IDE to collect data from the connected sensors.
- Once the program compile, monitor the incoming data in real-time using the Serial Monitor feature within the Arduino IDE.

- After monitoring, automate the storage of the sensor data by exporting it to a CSV file with the assistance of the Ardo spreadsheet tool.

By following these steps, we will have the comprehensive dataset for data analysis and Model training which is explained in the next phase.

Phase 2: Data Analysis and Model Training

- After having a specific dataset, collected from Ardo spreadsheet tool, the next step is the data analysis phase, which is initiated by uploading the sensors data into a Google Collab notebook into the CSV file.
- Once the data is uploaded to Google Collab, it integrates the necessary analytical libraries and prepare the data for data manipulation and machine learning processes.
- After specific classification and applying several machine learning algorithms, the uploaded data is divided into two parts, training and testing, which leads towards an effective learning and future predictions for highest accuracy in determining the continues health conditions.
- In the final step, the trained model acts as a predictive tool for patients' health status, which distinguish the received data as normal or abnormal conditions effectively.

VI. RESULTS

1) The Arduino IDE

Fig. 7 illustrates the Arduino IDE, which is used to display the incoming of data via serial port from microcontroller. The output in Arduino IDE showing real time data collected from patient via several sensors as mentioned in above section. The system illustrates and track the data of patient's heart rate, blood oxygen level and temperature in real time with a specific timestamp to keep the record of data in specific sequence. Moreover, each input row also categorizes the values in two types, such as, "Normal" or "Abnormal", which reflect the immediate analysis of patient's condition. This automated classification, helps the health care industry for identification of potential health issues. The integration of such a system into patient care protocols could significantly enhance the responsiveness and effectiveness of medical interventions.

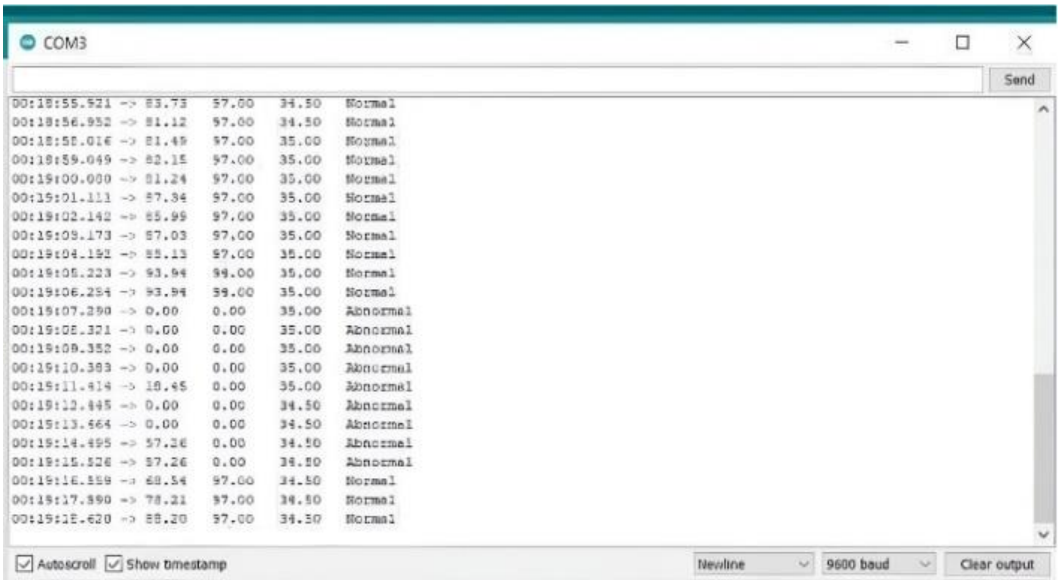

Figure 7: Real-Time Data via Serial Port from Microcontroller

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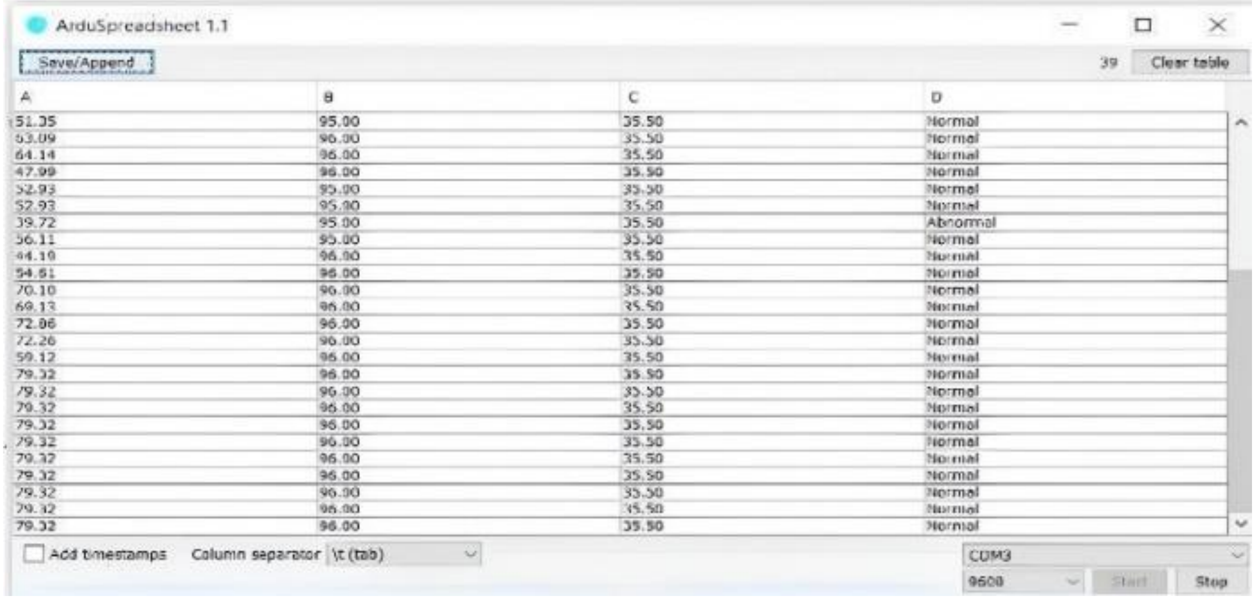
2) Data Collection inside Ardo Spreadsheet

After receiving the data, from microcontroller, Ardo Spreadsheet collects and stores the data in structured format specifically in CSV file. In Figure 8, data from various sensors are tabulated into several columns, each columns represents a unique physiological parameter such as heart rate, temperature, or blood oxygen saturation, with a corresponding evaluation of the condition (Normal/Abnormal).



A	B	C	D
51.35	95.00	35.50	Normal
63.09	96.00	35.50	Normal
64.14	96.00	35.50	Normal
47.99	96.00	35.50	Normal
52.93	95.00	35.50	Normal
52.93	95.00	35.50	Normal
39.72	95.00	35.50	Abnormal
56.11	95.00	35.50	Normal
64.19	96.00	35.50	Normal
54.61	96.00	35.50	Normal
70.10	96.00	35.50	Normal
69.13	96.00	35.50	Normal
72.06	96.00	35.50	Normal
72.26	96.00	35.50	Normal
59.12	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal
79.32	96.00	35.50	Normal

Figure 8: Data Collection inside Ardo Spreadsheet.

3) Data Analysis

The data was analyzed by using different machine learning algorithms such as Decision Tree, Random Forest, Naïve Bayes, and SVM as shown in Fig. 9. Among them, SVM attained a high classification accuracy rate of 96%, which outperformed among other algorithms. The below graph shows the accuracy results by applying different ML based algorithms.

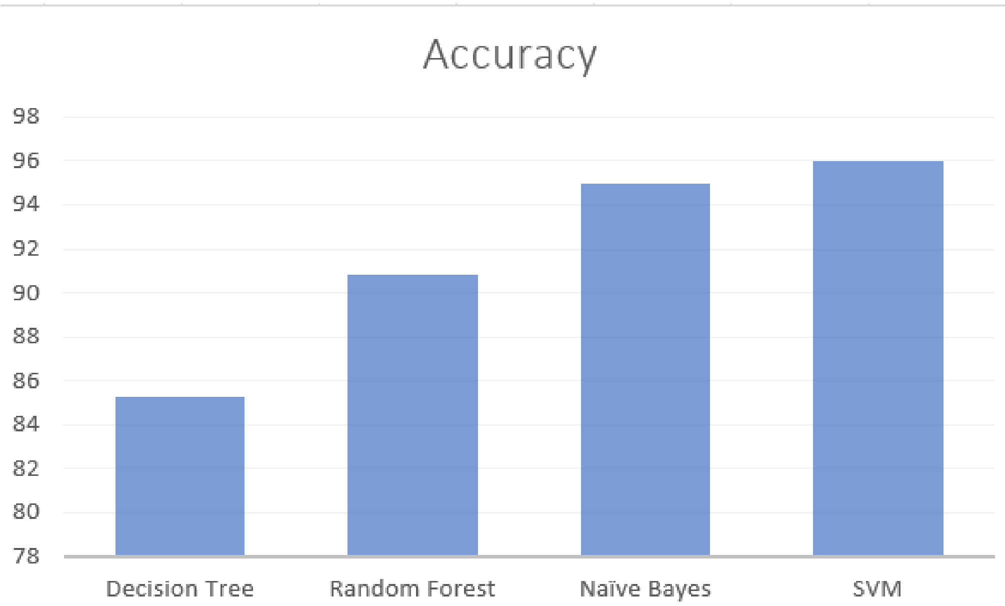


Figure 9: Comparison of Accuracy between different ML algorithms.

proposed solutions have been designed using Xilinx. The area-efficient carry select adder can also achieve an outstanding performance in power consumption. Power consumption can be greatly saved in our proposed area-efficient carry select adder because we only need one XOR gate and one INV gate in each summation operation as well as one AND gate and one OR gate in each carry-out operation after logic simplification and sharing partial circuit. Because of hardware sharing, we can also significantly reduce the occurring chance of glitch. Besides, the improvement of power consumption can be more obvious as the input bit number increases.

CONCLUSION

The main objective of this research was to address the challenge faced by the patients in accessing timely medical consultations due to the busy schedules of both healthcare providers and patients themselves. The study proposed an architecture through which patients health record will be stored and classified as normal or abnormal. The proposed project presents a uses Arduino based system that enables real-time health monitoring by using several sensons. The proposed system allows for continuous tracking of a patient's vital signs using various sensors. The data collected can be transmitted to and reviewed by the patient's physician remotely, offering a clear view of the patient's health status without requiring a physical doctor's visit. The ability to discern between normal and abnormal health states remotely is a significant advancement facilitated by our project.

Moreover, the next phase of our work will be to build a standalone system. That can be easily accessible by patients and physicians in real time. Additionally, In the next phase of our study we will plan to develop both mobile and web platforms-based application, that will assess the health of patient in real time and show to its and it's physicians mobile. This application will not only display real-time health data but also enable users to maintain a history of their health records.

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