INTELLIGENT DIABETES PREDICTION AND MANAGEMENT SYSTEM: A COMPREHENSIVE APPROACH

PROJECT REPORT

submitted by

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to

the APJ Abdul Kalam Technological University

in partial fulfilment of the requirements for the award of the degree

of

Bachelor of Technology
in
Computer Science and Engineering (Data Science)

Department of Artificial Intelligence and Data Science

SCMS School of Engineering and Technology

Vidya Nagar, Karukutty, Ernakulam

Kerala – 683 576

March 2025

DECLARATION

We undersigned hereby declare that the project report "Intelligent Diabetes Prediction and Management System: A Comprehensive Approach", submitted for partial fulfilment of the requirements for the award of the degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under the supervision of Project Guide, Ms. Binu John. This submission represents our ideas in our own words, and where ideas or words of others have been included, we have adequately and accurately cited and referenced the sources. We also declare that we have adhered to the ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or factor source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources that have thus not been properly cited or from whom proper permission has not been obtained. This report has not previously formed the basis for the award of any degree, diploma, or similar title of any other University.

Place: Ernakulam

Date: March 2025

Signature

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CERTIFICATE

This is to certify that the report entitled **“Intelligent Diabetes Prediction and Management System: A Comprehensive Approach”** submitted by **Deva Deleep, Gasteena Laurienda Pess, Vishnu K V** and **Vyshnavi Krishnakumar** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Bachelor of Technology is a bonafide record of the project work carried out by her under my guidance and supervision.

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ACKNOWLEDGEMENT

We would like to extend our heartfelt appreciation to Dr. Anitha G Pillai, Principal of SCMS School of Engineering and Technology, Ernakulam, for their unwavering support and provision of resources that have been instrumental in bringing this project to fruition. Their guidance and encouragement have paved the way for our learning journey, and we are profoundly grateful for the opportunities they have afforded us during our time at this esteemed institution.

A special word of gratitude goes to our Head of Department and project coordinator, Dr. Sonal Ayyappan, Associate Professor, and Ms. Binu John, Assistant professor, Department of Artificial Intelligence & Data Science, whose invaluable guidance and unwavering support have been the cornerstone of our project. Their expertise and insightful feedback have significantly enriched the quality of our work, and we are immensely thankful for their continuous encouragement throughout the duration of the project.

Furthermore, we extend our sincere thanks to the faculty members of Department of Artificial Intelligence & Data Science for their dedication in imparting knowledge and skills that have played a pivotal role in shaping our project. Their commitment to excellence and passion for teaching have been a constant source of inspiration to us.

To everyone who has contributed to the success of this project, we offer our heartfelt thanks. Your involvement has been indispensable, and we are truly grateful for your support.

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ABSTRACT

This project presents an innovative healthcare solution that combines independent hardware and software to monitor and predict health conditions in real time. The system focuses on the continuous tracking of vital health metrics, including glucose levels and heart rate, offering a non-invasive method for managing diabetes and related health concerns. The hardware component is designed to continuously measure glucose levels and heart rates, displaying the information on a screen for easy monitoring.

The software, a mobile application, allows users to manually input the observed glucose values and utilizes predictive algorithms to assess the likelihood of diabetes. Additionally, the app provides an integrated service for booking doctor appointments and emergency SMS services, adding further convenience for users.

A key feature of the system is its ability to predict diabetes, empowering users to take preventive measures before critical health issues arise. The application offers an easy-to-use platform that combines health monitoring with essential healthcare services, ensuring proactive management of health conditions.

The project's objectives include creating a user-friendly, scalable platform that integrates seamlessly with hardware, providing real-time updates on health parameters. The system is designed to offer an accessible, reliable, and efficient solution for health monitoring, improving patient outcomes and reducing potential risks associated with diabetes and other health conditions.

This project contributes to the broader vision of IoT in healthcare, where connected devices work together to provide actionable insights, early detection of health issues, and prompt intervention, ultimately improving the quality of care and patient well-being.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ANN	Artificial Neural Network
BGL	Blood Glucose Level
BPM	Beats Per Minute (Heart Rate)
CGM	Continuous Glucose Monitoring
IoT	Internet of Things
LSTM	Long Short-Term Memory
MSE	Mean Squared Error
SPO2	Blood Oxygen Saturation
SMOTE	Synthetic Minority Oversampling Technique
SVR	Support Vector Regression

CHAPTER 1

INTRODUCTION

The integration of technology in healthcare has transformed how we monitor and manage health, especially for individuals with chronic conditions. This project, titled "IoT-based Health Monitoring and Glucose Prediction System," aims to develop a comprehensive solution by combining advanced hardware and software to monitor key health parameters, particularly glucose levels and heart rate.

The project includes two main components: the hardware and the software. The hardware continuously tracks glucose levels and heart rates, displaying the data in real-time on a screen. The software is a mobile application where users can manually input the glucose values observed on the hardware display. Based on this data, the app uses predictive algorithms to assess whether the patient is at risk of diabetes.

In addition to glucose monitoring, the system also tracks heart rate, a vital sign for overall health management. This dual monitoring is essential for individuals with diabetes and other chronic conditions, ensuring that both glucose and heart rate are carefully managed. The app not only provides predictions for diabetes but also offers users the ability to book appointments with healthcare professionals, ensuring timely medical interventions when necessary. Should any health parameter exceed predefined thresholds, the system will alert the patient and their designated contacts (family members or caregivers). In emergency cases, the system is capable of requesting ambulance services for immediate medical assistance[1].

The system leverages Internet of Things (IoT) protocols to enable real-time communication between the hardware and the mobile application. This seamless integration ensures that data is transmitted efficiently, enabling accurate monitoring and timely updates for users.

By combining predictive algorithms, real-time health monitoring, and easy access to healthcare services, this project aims to provide a comprehensive solution for managing diabetes and other chronic health conditions. It empowers users to make informed decisions about their health while offering a safety net in case of emergencies. This project represents a significant step in the advancement of IoT-driven healthcare solutions, with the potential to improve health outcomes and enhance the quality of life for patients. The project report is structured into four subsequent chapters, each covering essential aspects of the Intelligent Diabetes Prediction and Management System.

The second chapter, Literature Review, explores existing research on diabetes prediction models, health monitoring technologies, and machine learning approaches. It identifies the limitations of current methodologies and justifies the need for an improved system that integrates real-time data tracking with predictive analytics.

The third chapter, System Design, describes the hardware and software architecture of the system. It explains the integration of sensors for glucose, heart rate, and SPO2 monitoring with a mobile application for data processing and user interaction. The chapter also details the Bidirectional LSTM model used for diabetes prediction, the data preprocessing techniques employed, and the overall system workflow. Additionally, it discusses the integration between hardware and software, as well as the evaluation metrics used to assess model performance.

The fourth chapter, Results, presents the development, testing, and evaluation of the system. It includes an analysis of the model's accuracy, which achieved 94.62%, along with insights into real-time performance and user feedback. A comparative analysis with existing solutions demonstrates the system's effectiveness, and key findings from experimental results are discussed.

The final chapter, Conclusion, summarizes the project's contributions, challenges, and overall impact. Recommendations for improvement include integrating continuous glucose monitoring, expanding the dataset for better accuracy, and enhancing AI-based insights. Future enhancements will focus on refining the model and expanding the system's functionality for broader healthcare applications.

CHAPTER 2

LITERATURE REVIEW

Zhu et al. [1] proposed a Bi-LSTM-based deep learning model for predicting blood glucose (BG) levels using continuous glucose monitoring (CGM) data. Their research demonstrated that bidirectional long short-term memory (Bi-LSTM) networks effectively capture temporal dependencies in glucose fluctuations, improving prediction accuracy. By considering past and future context, the Bi-LSTM model offers a more reliable approach for forecasting glucose levels, which is crucial for managing diabetes and preventing hypo- or hyperglycemia.

Zhu et al. [2] further investigated the use of long short-term memory (LSTM) neural networks for BG prediction in type 1 diabetes (T1D) patients. Their study focused on training the model using CGM data, assessing its performance over short-term and long-term prediction horizons. The results indicated that LSTMs are well-suited for handling sequential glucose data, demonstrating robust predictive capabilities. This work emphasizes the importance of deep learning techniques in enhancing personalized diabetes management strategies.

Cappon et al. [3] developed a neural network model that integrates past glucose levels with additional patient data, such as meal intake, physical activity, and insulin dosage, to enhance BG prediction accuracy. Their study showed that neural network-based approaches outperform traditional statistical models like AutoRegressive Integrated Moving Average (ARIMA), which rely on linear assumptions. By leveraging machine learning, the proposed model provides a more dynamic and adaptive method for forecasting BG trends, enabling more effective diabetes management.

Faruqui et al. [4] proposed an IoT-based diabetes management system incorporating artificial neural networks (ANNs). This system integrates IoT devices for continuous glucose monitoring and uses machine learning algorithms to analyze data in real time. Their study demonstrated the potential of combining IoT and AI for remote patient monitoring, automated insulin recommendations, and personalized diabetes care. The findings highlight how smart healthcare solutions can improve patient outcomes and reduce the burden of diabetes management.

Georga et al. [5] explored the use of Support Vector Regression (SVR) for data-driven glucose level prediction. Their study highlighted the advantages of SVR in forecasting BG trends while maintaining low computational complexity. Unlike deep learning models, SVR requires fewer resources, making it suitable for real-time applications with limited processing power. Their findings suggest that regression-based methods can provide an efficient alternative for BG prediction, particularly in resource-constrained environments.

Alsalemi et al. [6] introduced a deep learning-based health monitoring system designed specifically for diabetes patients. Their model utilizes deep neural networks to enhance glucose level prediction accuracy, leveraging CGM data for continuous patient monitoring. The study emphasized the importance of deep learning in improving patient care, allowing for timely interventions and better glycemic control. By providing real-time insights into glucose trends, the system supports proactive diabetes management and reduces the risk of complications.

CHAPTER 3

SYSTEM DESIGN

This project aims to predict whether an individual is diabetic or non-diabetic using physiological data collected through various sensors and processed with machine learning algorithms. The system consists of both hardware and software components to ensure efficient data collection, processing, and user interaction. The hardware component includes a measurement site equipped with sensors that capture physiological parameters such as glucose levels and heart rate, which are then processed by an Arduino microcontroller. The Arduino transmits the data to an OLED display for real-time visualization and also sends it via the HC-05 Bluetooth module to a mobile application for remote monitoring. Meanwhile, the software component operates independently, allowing users to manually input their health data for analysis. The machine learning model within the software predicts whether the user is diabetic or non-diabetic based on the provided data. The system's real-time feedback capabilities, both through the OLED display and the mobile app, enhance accessibility and usability, providing users with continuous health monitoring. Additionally, by integrating IoT-based data collection with AI-driven analysis, this system ensures a high degree of accuracy in diabetes prediction. Its automation reduces the dependency on traditional diagnostic methods while offering users an intuitive and non-invasive way to track and manage their health. The mobile app also facilitates remote monitoring, allowing users to share their health data with healthcare professionals for better medical guidance. Overall, this system represents a significant advancement in diabetes prediction and management, providing an efficient, accurate, and user-friendly approach to health monitoring[9].

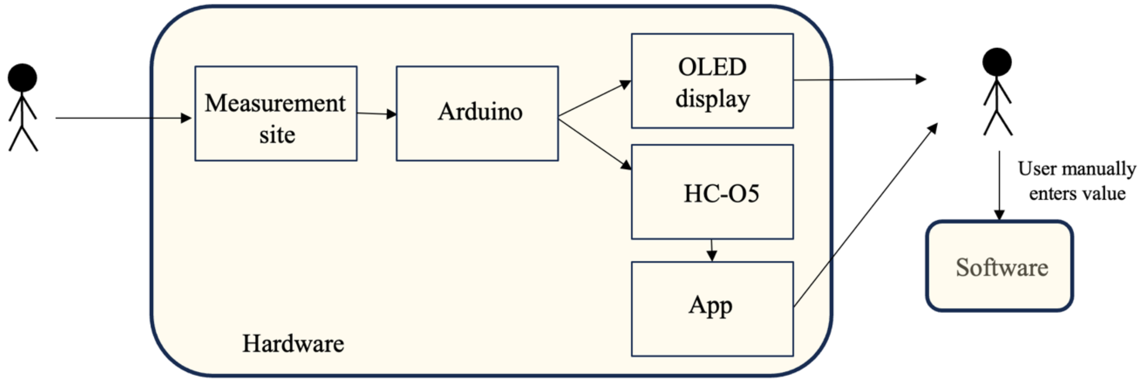

Fig 3.1 Overall Architecture

3.1 HARDWARE

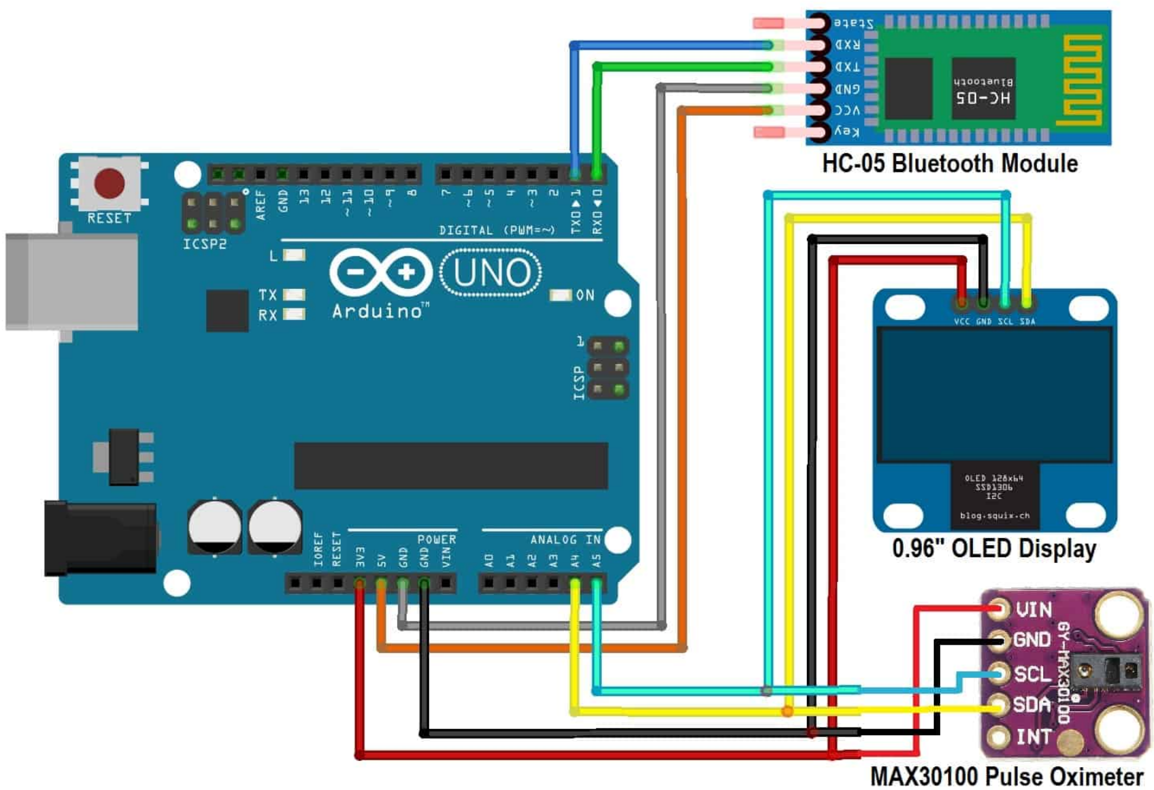

Fig 3.1.1 Hardware Circuit Diagram[11]

Arduino Uno

The Arduino Uno acts as the central processing unit for the hardware setup. It collects data from the sensors, processes it, and sends it to the OLED display for real-time metrics display. Additionally, it transmits this data to the mobile application via the HC05 Bluetooth module for further analysis.

MAX30100 Sensor

The MAX30100 sensor is a combined heart rate and pulse oximetry module that provides two key physiological measurements:

- **Heart Rate (BPM):** Indicates the user's pulse rate.
- **Oxygen Saturation (SPO2):** Measures the percentage of oxygen-saturated hemoglobin relative to total hemoglobin in the blood. These measurements are essential inputs for predicting glucose levels using the trained regression model.

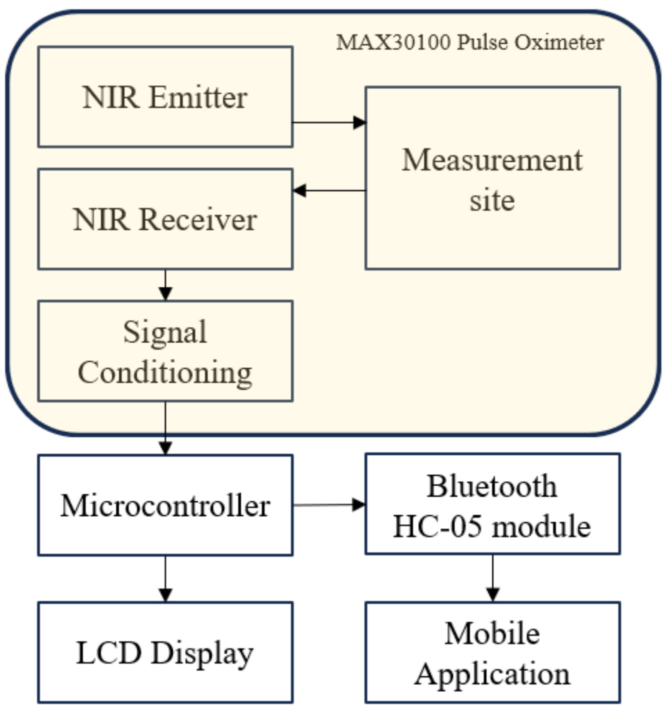

Fig 3.1.2 MAX 30100 Sensor[7]

Glucose Prediction Equation

The equation used for glucose prediction is a trained second-degree polynomial regression model:

glucose_level = 16714.61 + 0.47 * bpm - 351.045 * spo2 + 1.85 * (spo2 * spo2)

This equation is derived statistically by minimizing the mean squared error (MSE). It takes BPM and SPO2 (independent variables) values from the MAX30100 sensor, generates polynomial features, and predicts the glucose level (dependent variable). The equation allows for a quick estimation of glucose levels based on real-time sensor readings[7].

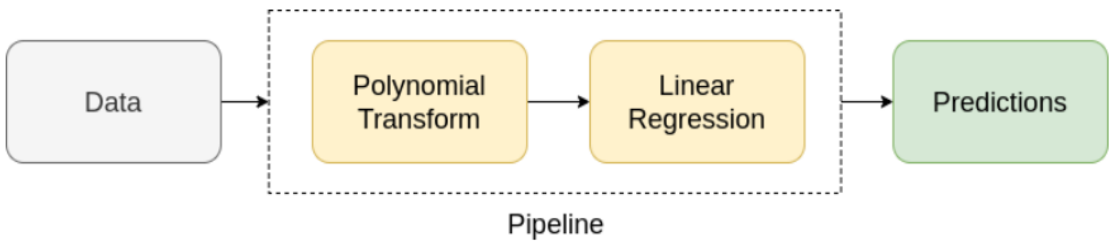

Fig 3.1.3 Glucose level equation pipeline[7]

OLED Display

The OLED display is used to show real-time health metrics, including heart rate, SPO2 levels, and alerts. This allows users to visually monitor their health status at any time.

Power Supply

A stable power supply is essential to ensure uninterrupted operation of all components. The power supply provides the necessary voltage and current for the Arduino Uno, MAX30100 sensor, OLED display, and Bluetooth module.

Breadboard & Connectors

Breadboards and connectors are used to facilitate connections and prototyping among the various hardware components. They enable easy modifications and troubleshooting during development.

HC05 Bluetooth Module

The HC05 Bluetooth module is used for wireless communication between the hardware system and the mobile application. It transmits sensor data to the mobile application in real-time for analysis and display.

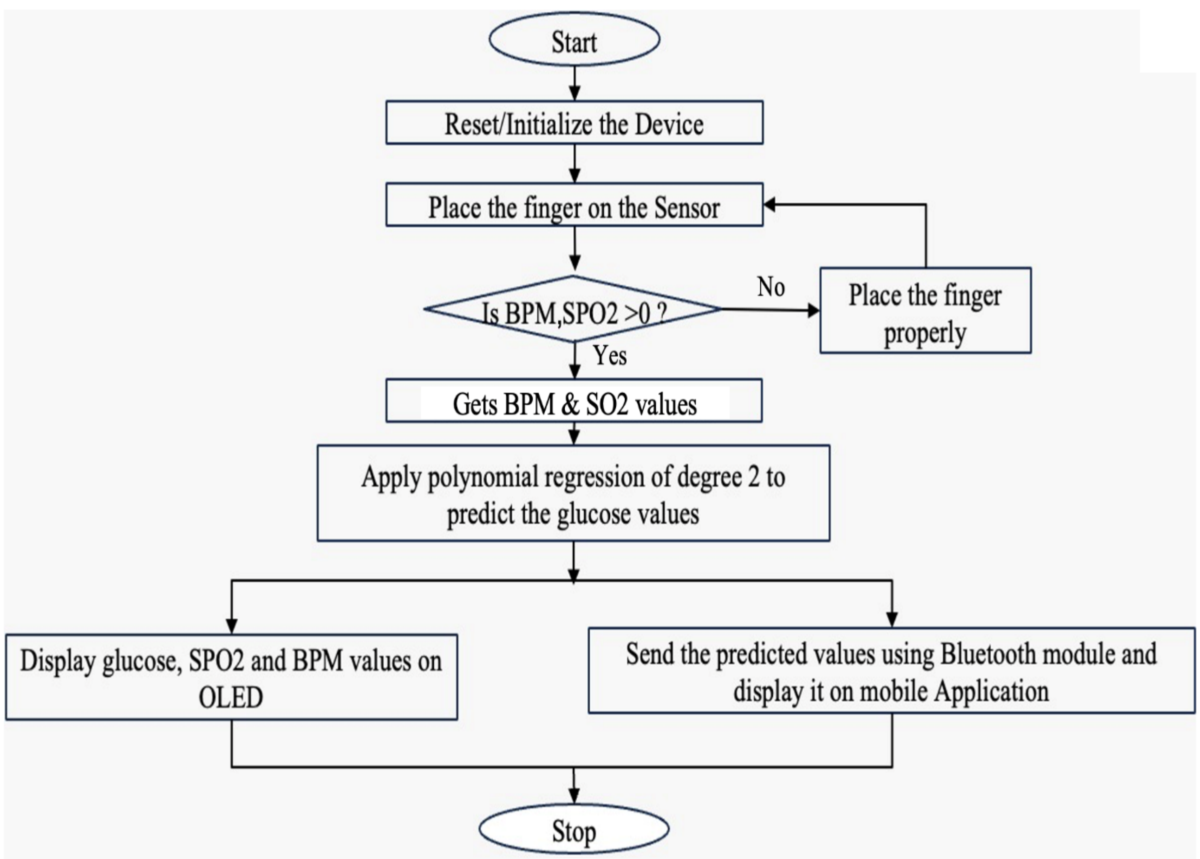

Fig 3.1.4 Hardware flow chart

The given **flowchart** represents the process of predicting glucose and cholesterol levels using BPM (Beats Per Minute) and SPO2 (Oxygen Saturation) values obtained from a sensor.

1. **Start:** The process begins.
2. **Reset / Initialize the device:** The system or device is reset and prepared for measurement.
3. **Place the finger on the sensor:** The user is required to place their finger on the sensor to capture readings.
4. **Check if BPM and SPO2 > 0:**
   - If **NO**, prompt the user to place the finger properly and retry.
   - If **YES**, proceed to the next step.
5. **Get BPM and SPO2 Values:** The system collects heartbeat (BPM) and oxygen saturation (SPO2) values.
6. **Apply polynomial regression (degree 2) to predict glucose values:** A machine learning model (polynomial regression) is used to estimate glucose levels based on BPM and SPO2 values.
7. **Display glucose value on LCD:** The calculated glucose level is displayed on an LCD screen.
8. **Use glucose value to predict cholesterol level & display on LCD:** The system further predicts cholesterol levels using the obtained glucose value and shows it on the LCD.
9. **Send predicted values to Bluetooth module & display on mobile:** The final results are transmitted via Bluetooth to a mobile device for remote monitoring.
10. **Stop:** The process ends.

3.2 SOFTWARE – MOBILE APPLICATION

The Intelligent Diabetes Prediction and Management System mobile application provides users with an interactive and personalized experience for monitoring, predicting, and managing diabetes. The system integrates real-time health tracking and healthcare services to assist users in diabetes management effectively. The mobile application is built using Flutter and provides an interface for users to interact with the system. Users manually enter glucose values displayed on the hardware, and predictive algorithms analyze the data for diabetes risk. Key features include:

- **Personalized user Account**
  Each user has a secure, personalized account that allows them to track their health data and diabetes risk. The system stores historical health records, making it easy for users to monitor their progress over time and gain insights into their health trends. Additionally, the app ensures data security through a secure login and authentication process, safeguarding user privacy and personal health information.

- **Doctor Follow-up Bookings**
  The app enables users to schedule appointments with healthcare professionals directly through a user-friendly interface. To ensure continuity of care, integrated reminder notifications alert users about upcoming check-ups. Additionally, teleconsultation options are available, allowing users to consult doctors remotely, ensuring access to medical support even from the comfort of their homes.

- **Manual Entry for Diabetes Prediction**
  Users can manually input key health parameters such as Blood Glucose Level (BGL), Blood Pressure (BP), Heart Rate (BPM), and SPO2 Levels. These inputs are analyzed using an AI-powered **Bidirectional LSTM model**, which predicts whether the user is at risk of diabetes or diabetes. The system then displays the results in real-time through an intuitive interface, empowering users to make informed health decisions.

- **Filtered Meal Plans for Diabetes Management**

  The app provides users with personalized meal recommendations based on their health data. These recommendations help users maintain stable glucose levels by allowing them to filter meal options based on dietary preferences, calorie intake, and specific nutritional requirements. By offering tailored diet plans, the app supports healthier eating habits and better diabetes management.

- **Insulin Dosage Calculation**

  The system automatically calculates the recommended insulin dosage based on the user's blood glucose levels and health data. It also provides timely reminders and alerts to ensure that insulin is taken correctly and at the right time. By preventing under- or overdosing, this feature helps users maintain stable blood sugar levels and avoid potential health complications.

- **Emergency Alerts for Critical Health Situations**

  The app continuously monitors health parameters in real-time and triggers alerts if any values exceed safe thresholds. In case of a health emergency, automatic notifications are sent to designated emergency contacts, such as family members and doctors. Additionally, users can manually trigger an **SOS alert** to request immediate medical assistance, ensuring timely intervention in critical situations.

3.3 SOFTWARE WORKFLOW

The step-by-step user data flow in a diabetes prediction system with automated emergency alerts and manual alert options is as follows:

- User Inputs Health Data via App

  The user enters health-related parameters (such as heart rate, SPO2, etc.) into the mobile application. These values serve as input for the diabetes prediction model.

- Data Sent to Flask API

  The application transmits the collected data to a Flask-based API for processing. The Flask API acts as a bridge between the user interface and the deep learning model, ensuring that the input data reaches the prediction system efficiently.

- Pass Data to Trained Neural Network

  Once received, the health data undergoes preprocessing before being fed into a trained neural network for analysis. The deep learning model evaluates the input to determine whether the user is diabetic or non-diabetic based on learned patterns.
- Generate Prediction (Diabetic/Non-Diabetic)

  After analyzing the data, the neural network generates a prediction result, which can be either Diabetic or Non-Diabetic. If the user is diabetic, an additional check is performed to assess their glucose levels to determine if immediate action is required.
- Check for Diabetic & High Glucose Level

  If the user is diabetic, the system verifies whether their glucose level is dangerously high. This decision point determines the next course of action.

  If the glucose level is high, the system automatically sends an emergency alert to a registered phone number (e.g., guardian, doctor, or emergency contact). This ensures timely medical intervention and enhances patient safety.

  If the glucose level is normal, the system does not trigger an automatic alert but instead presents the user with an option to send a manual alert to a registered contact.
- User Chooses to Send Manual Alert?

  If the user is not diabetic or their glucose levels are within a safe range, they are given an option to manually notify a registered phone number.

  If the user chooses to send a manual alert, the system sends a notification to the registered contact, informing them of the user's current health status.

  If the user does not wish to send an alert, the workflow proceeds to the next step without triggering any notifications.
- Send Prediction Back to Flask API

  The prediction result (Diabetic/Non-Diabetic) is sent back to the Flask API for further processing. This ensures that the result is correctly handled and transmitted back to the mobile application for display.
- Display Result in Flutter App

  The final prediction result is displayed in the Flutter-based mobile application. The user can view whether they are diabetic or non-diabetic, along with their key health metrics, providing a clear and interactive health monitoring experience.

Dataset

Timestamp	Blood Glucose Level (BGL)	Diastolic Blood Pressure	Systolic Blood Pressure	Heart Rate	Body Temperature (*F)	SPO2 Levels	Sweating	Shivering
2024-01-01 00:00:00	70.498	73.267	106.756	92.433	97.794	94.646	Yes	Yes
2024-01-01 00:01:00	72.308	74.578	109.249	65.078	98.619	98.343	Yes	No
2024-01-01 00:02:00	134.765	85.767	122.229	82.989	97.541	98.066	No	Yes
2024-01-01 00:03:00	72.163	73.741	97.381	83.706	99.081	96.746	No	Yes
2024-01-01 00:04:00	78.185	88.302	92.184	95.362	98.376	92.207	No	Yes
2024-01-01 00:05:00	115.214	87.017	113.48	79.864	98.073	99.183	No	No
2024-01-01 00:06:00	114.763	61.112	110.296	85.278	97.456	90.774	Yes	Yes
2024-01-01 00:07:00	98.905	65.451	131.137	97.322	98.414	93.485	No	Yes
2024-01-01 00:08:00	143.077	74.855	92.378	62.534	97.238	94.646	No	Yes
2024-01-01 00:09:00	77.369	64.016	92.86	82.842	99.246	94.816	Yes	No
2024-01-01 00:10:00	101.573	86.243	125.642	63.161	98.395	99.912	Yes	Yes
2024-01-01 00:11:00	146.438	73.34	123.375	90.616	98.683	97.322	No	No
2024-01-01 00:12:00	81.646	64.837	104.176	74.941	98.408	97.684	No	No
2024-01-01 00:13:00	148.182	80.35	101.104	80.148	97.831	95.175	Yes	No
2024-01-01 00:14:00	71.757	81.009	118.042	78.199	98.405	94.034	No	Yes
2024-01-01 00:15:00	147.211	75.331	121.171	61.28	97.219	99.734	No	No
2024-01-01 00:16:00	156.544	64.377	132.444	64.045	99.056	90.274	Yes	Yes
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

kaggle.com

Table 3.3.1 Preprocessed Training Dataset

Timestamp	Blood Glucose Level (BGL)	Diastolic Blood Pressure	Systolic Blood Pressure	Heart Rate	Body Temperature (*F)	SPO2 Levels	Sweating	Shivering
2025-01-01 00:00:00	108.752	66.91	116.484	111.683	100.465	94.86	1	0
2025-01-01 00:01:00	174.379	78.052	131.081	83.015	98.732	97.237	0	0
2025-01-01 00:02:00	160.813	82.747	109.257	72.357	98.682	93.927	1	1
2025-01-01 00:03:00	115.058	72.451	112.303	63.762	100.402	96.963	1	1
2025-01-01 00:04:00	117.752	84.153	128.213	115.814	100.282	94.914	0	1
2025-01-01 00:05:00	179.481	70.731	97.611	113.059	100.475	90.619	1	0
2025-01-01 00:06:00	143.554	63.587	134.791	63.961	97.757	92.74	1	1
2025-01-01 00:07:00	119.367	76.645	110.844	102.902	99.426	95.097	1	0
2025-01-01 00:08:00	80.55	64.738	116.513	116.223	97.222	91.742	1	0
2025-01-01 00:09:00	117.745	85.892	138.225	95.306	99.372	97.483	1	1
2025-01-01 00:10:00	147.138	64.522	93.293	99.387	99.745	95.92	1	1
2025-01-01 00:11:00	78.916	64.84	136.886	100.196	99.456	97.504	1	0
2025-01-01 00:12:00	154.938	69.236	127.062	80.657	97.915	91.773	0	1
2025-01-01 00:13:00	113.896	63.669	91.29	83.309	98.736	90.387	0	0
2025-01-01 00:14:00	98.81	81.217	136.029	82.051	100.018	96.255	1	0
2025-01-01 00:15:00	71.532	89.231	121.193	79.156	98.389	96.128	1	1
2025-01-01 00:16:00	92.818	61.347	134.607	77.84	100.39	99.725	1	1

Table 3.3.2 Preprocessed testing Dataset

Timestamp – The time at which the health data is recorded. This is crucial for tracking trends over time, identifying daily fluctuations in blood glucose levels, and analyzing the impact of meals, exercise, and medication.

Blood Glucose Level (BGL) – The amount of glucose presents in the blood. This is the most critical feature in diabetes prediction since elevated blood glucose levels (hyperglycemia) indicate diabetes, while low levels (hypoglycemia) can be dangerous, especially for those on insulin therapy.

Diastolic Blood Pressure – The pressure in the arteries when the heart is at rest between beats. High diastolic pressure is associated with cardiovascular complications in diabetics, as diabetes increases the risk of hypertension.

Systolic Blood Pressure – The pressure in the arteries when the heart beats. Diabetes often leads to higher systolic pressure due to insulin resistance and artery damage, increasing the risk of heart disease and stroke.

Heart Rate – The number of heartbeats per minute. Diabetics may experience an increased or irregular heart rate due to autonomic neuropathy, a complication of long-term high blood sugar.

Body Temperature (°F) – A measure of body heat regulation. People with diabetes may have an altered thermoregulation system due to nerve damage, affecting how their body manages temperature changes.

SPO2 Levels (Oxygen Saturation) – The percentage of oxygen in the blood. Low oxygen levels (hypoxia) may be linked to diabetes-related complications, such as sleep apnea, cardiovascular issues, and poor wound healing.

Sweating – Excessive or reduced sweating can indicate autonomic dysfunction, a common issue in diabetes. Hyperhidrosis (excessive sweating) can occur due to low blood sugar, while anhidrosis (reduced sweating) may be due to nerve damage.

Shivering – Uncontrollable body shakes, often due to temperature dysregulation or hypoglycemia. Shivering can be an early warning sign of dangerously low blood sugar levels.

Input Features

The system uses the following input features to make predictions:

- Blood Glucose Level (BGL)
- Diastolic and Systolic Blood Pressure
- Heart Rate
- Body Temperature
- SPO2 Levels
- Sweating
- Shivering

Data Balancing with SMOTE

SMOTE is used to address the imbalance in the dataset by generating synthetic samples for the minority class. This ensures that diabetic cases are adequately represented, leading to improved accuracy and classification performance.

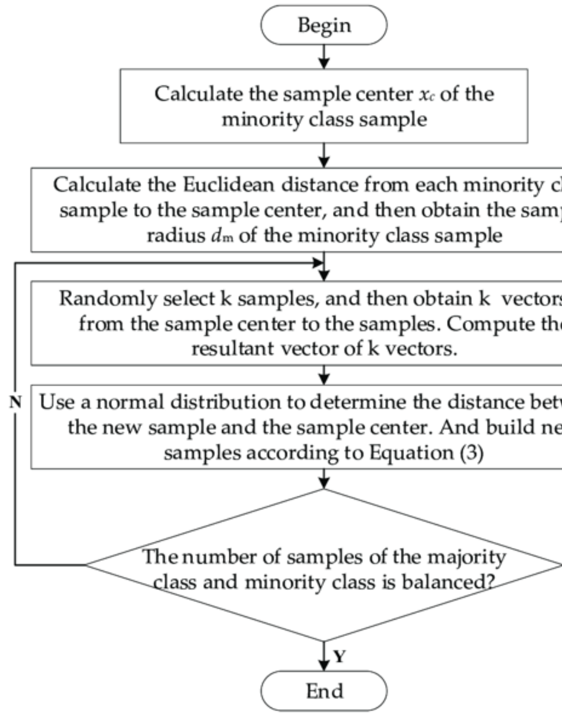

Fig 3.3.1 SMOTE Algorithm[8]

Neural Network Architecture

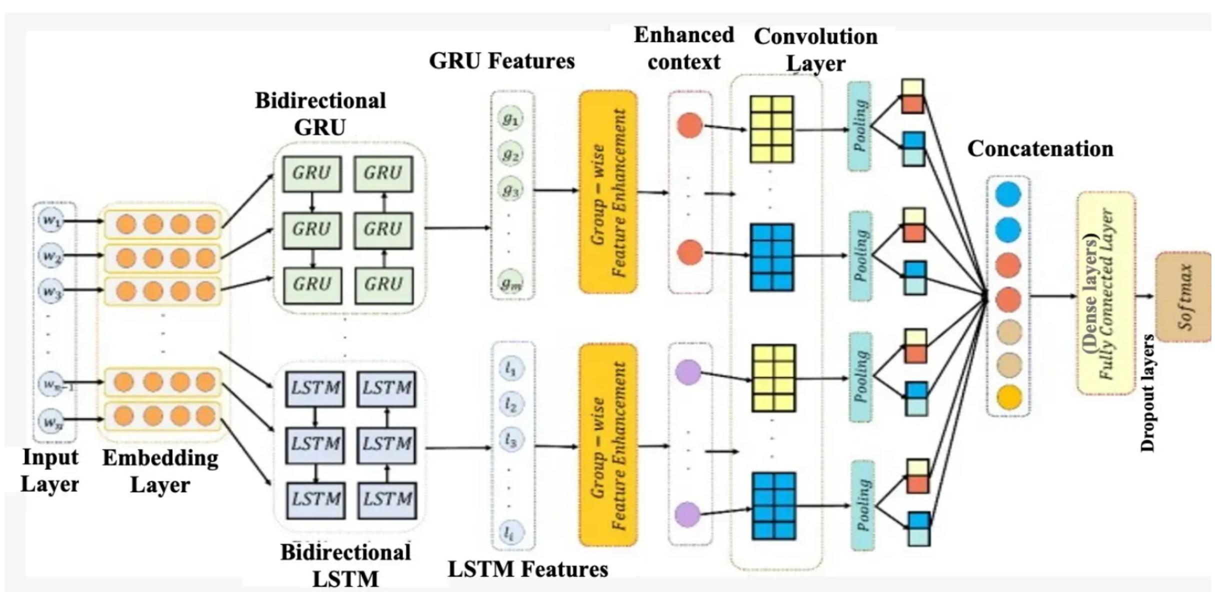

Fig 3.3.2 LSTM Neural Network[13]

The neural network used for prediction consists of the following components:

- **Bidirectional LSTM Layers:** These layers analyse the sequential input data from both forward and backward directions, capturing comprehensive temporal patterns.
- **Dropout Layers:** Dropout layers are used to prevent overfitting by randomly deactivating neurons during training.
- **Dense Layers:** Fully connected layers are responsible for outputting the final prediction.
- **Activation Function:** An appropriate activation function is applied to the output layer to produce binary classification results ("Diabetic" or "Non-Diabetic").

3.4 MODEL TRAINING

Loss Function: The binary cross-entropy loss function is used to evaluate the model's performance during training. It measures the difference between predicted probabilities and actual class labels.
Performance: The trained Bidirectional LSTM model achieved a classification accuracy of 94.62%, demonstrating high predictive performance.

This system effectively integrates hardware components, a mobile application, and a robust machine learning model to provide accurate diabetes predictions and actionable insights for users. With its real-time health metrics display and comprehensive analysis features, the system aims to enhance diabetes management and early risk detection.

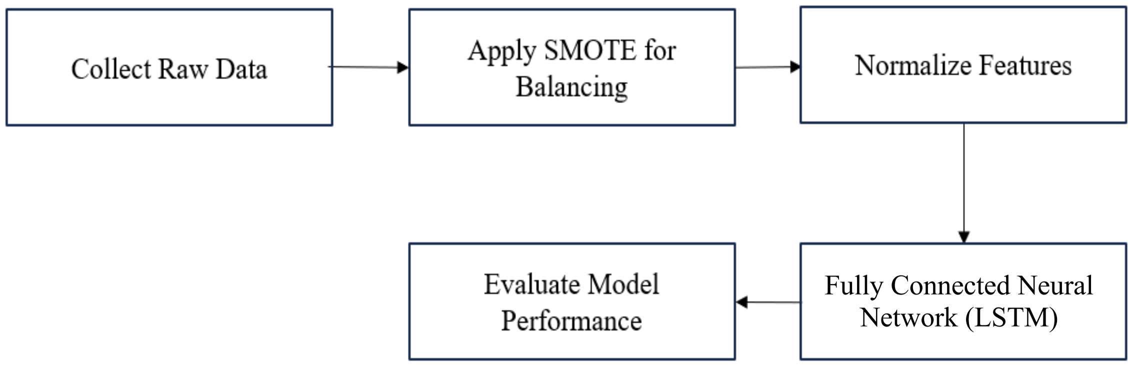

Fig 3.3.3 Training

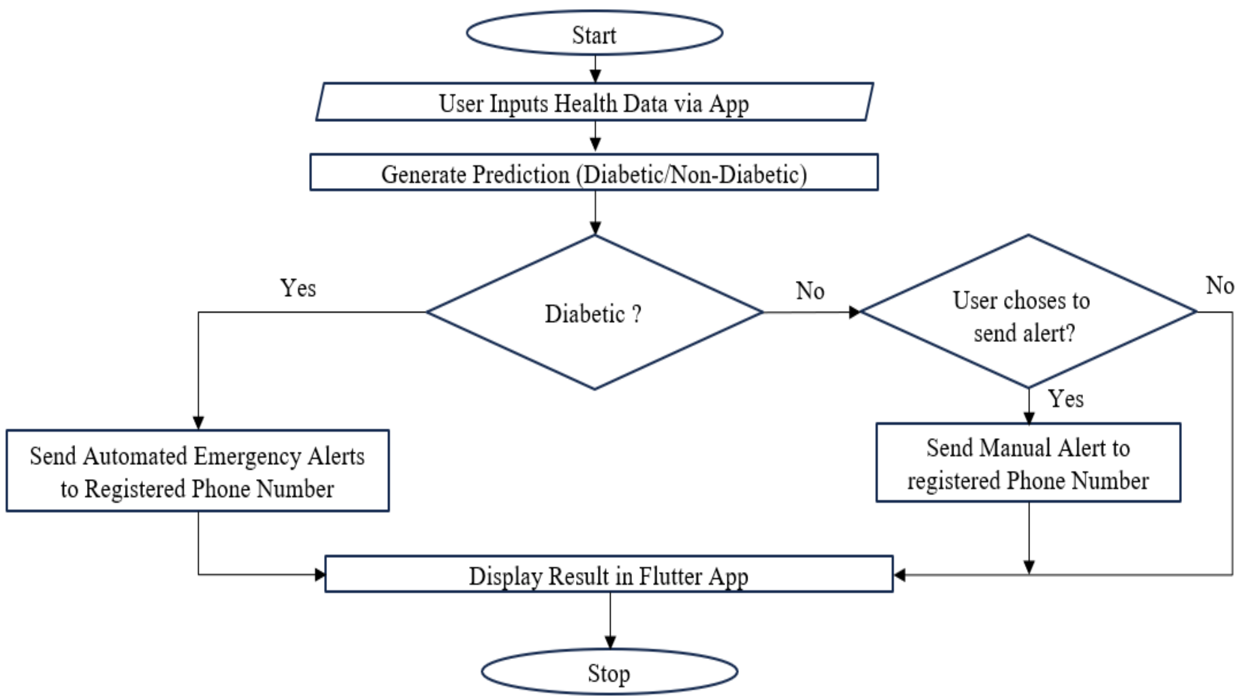

Fig 3.3.4 User data flow

CHAPTER 4

RESULTS

The Intelligent Diabetes Prediction and Management System integrates real-time health monitoring with machine learning techniques to predict diabetes risk accurately. This chapter presents the system's results, including the performance of the AI model, hardware functionality, software usability, and overall system effectiveness. The evaluation is based on experimental data, accuracy metrics, and system performance in real-world scenarios.

Model Performance

The machine learning model used in the system is a Bidirectional Long Short-Term Memory (LSTM) network**,** trained on real-time physiological data. The model achieved an accuracy of 94.62%**,** outperforming traditional models such as Decision Trees (91.87%) and Artificial Neural Networks (80%). The dataset was balanced using the Synthetic Minority Oversampling Technique (SMOTE) to improve classification performance for underrepresented diabetic cases.

Accuracy Comparison with Other Models

Model	**Methodology**	**Accuracy**
Our System	Bidirectional LSTM + SMOTE	**94.62%**
Medibuddy Smart Disease Prediction	Decision Tree	91.87%
Advisor Pro by Dreamed Diabetes	Artificial Neural Networks (ANNs)	80%

Table 4.1 Comparison of Models for Diabetes Risk Assessment

The results demonstrate that the Bidirectional LSTM model significantly enhances prediction accuracy, making the system highly reliable for diabetes risk assessment.

Hardware Performance

The hardware component of the system was tested for its efficiency in capturing and transmitting real-time health data. The hardware setup includes:

- **Arduino Uno** (Processes sensor data)
- **MAX30100 Sensor** (Measures heart rate and SPO2 levels)
- **OLED Display** (Displays real-time health metrics and alerts)
- **HC05 Bluetooth Module** (Ensures seamless data transmission to the mobile app)

The glucose level prediction equation derived from the regression model:

Glucose_level = 16714.61 + 0.47 * bpm - 351.045 * spo2 + 1.85 * (spo2 * spo2)

is used for testing accuracy, yielding minimal error margins and reliable predictions.

Software Performance

The Flutter-based mobile application played a crucial role in providing a user-friendly interface for tracking and managing diabetes-related health data. The software results were evaluated based on usability, response time, and feature effectiveness.

Key Software Features and Their Performance

- **Personalized User Account:** Users could securely create profiles and track historical health data.

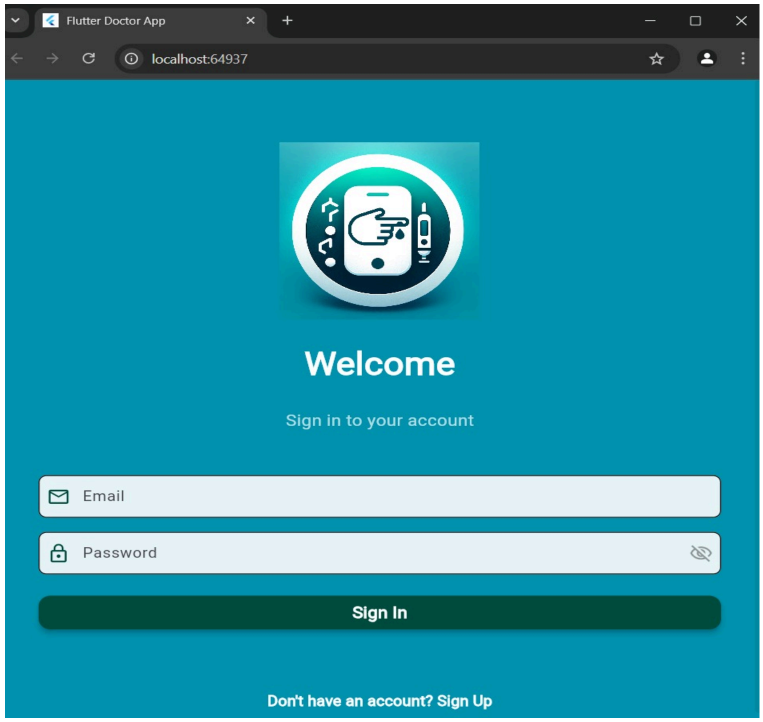

Fig 4.1.1 Sign In Page

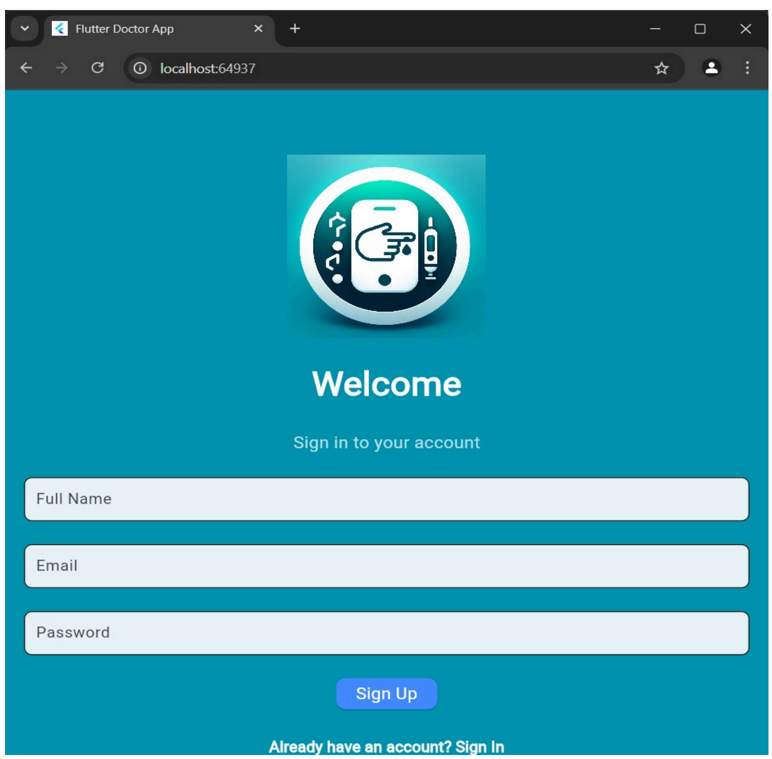

Fig 4.1.2 Sign Up Page

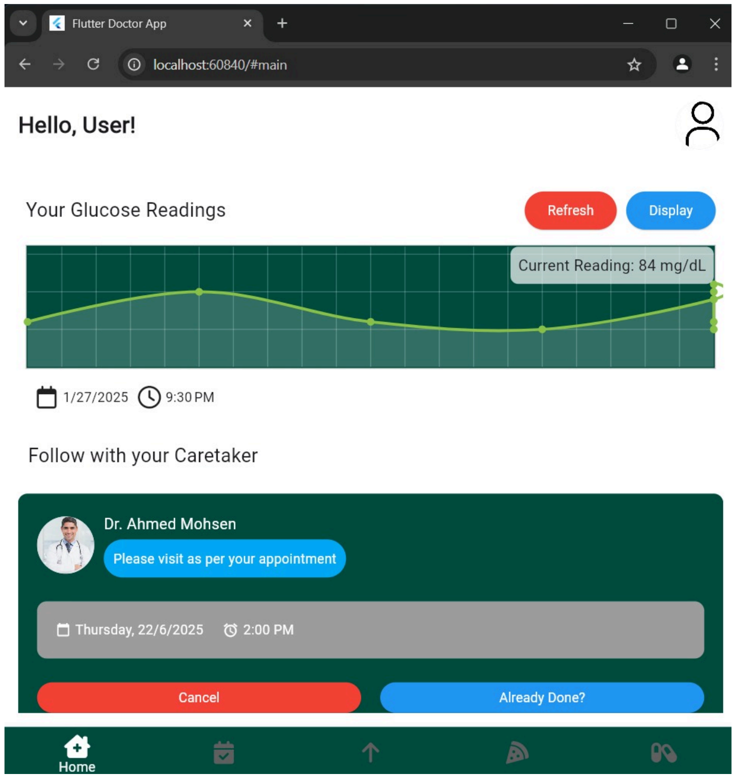

Fig 4.1.3 User Dashboard

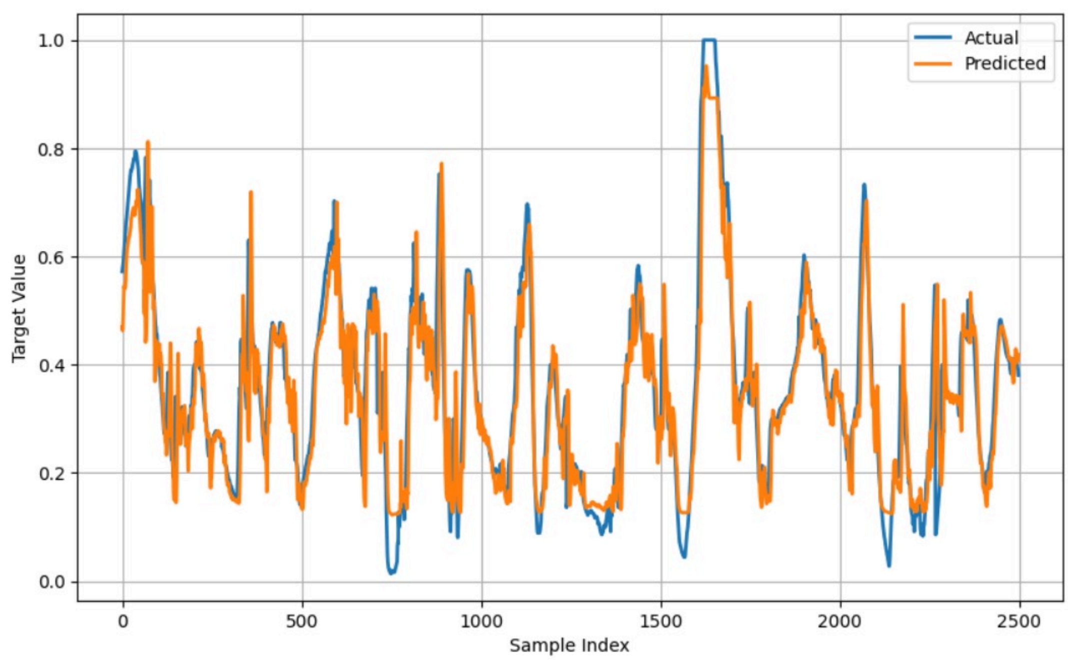

Fig 4.1.4 Comparison of Actual Vs Predicted Glucose Level

- **Doctor Follow-up Bookings:** The system enabled seamless doctor appointment scheduling with timely reminders.

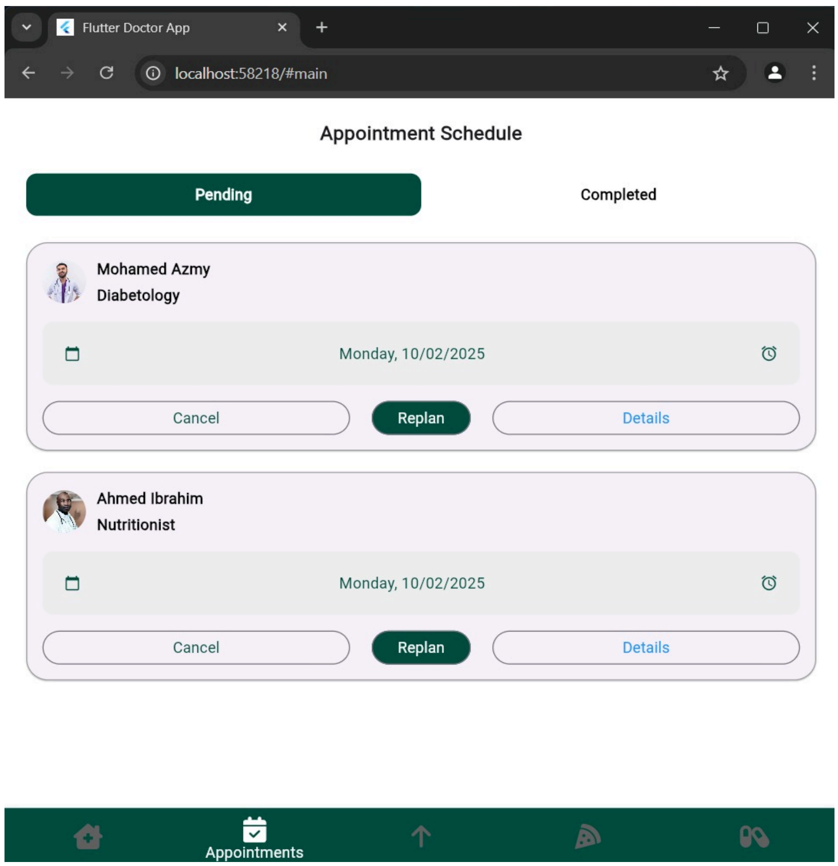

Fig 4.1.5 Appointment Scheduling for Diabetes Management

- **Manual Entry for Diabetes Prediction:** Users manually entered Blood Glucose Level (BGL), Blood Pressure (BP), Heart Rate (BPM), and SPO2 levels for real-time diabetes risk assessment.

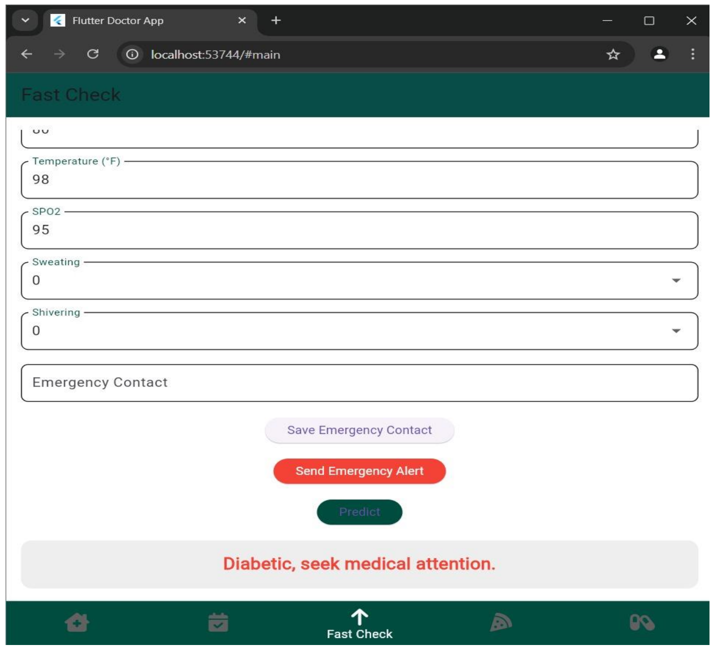

Fig 4.1.6 Based on User Health Parameters Showing Diabetes

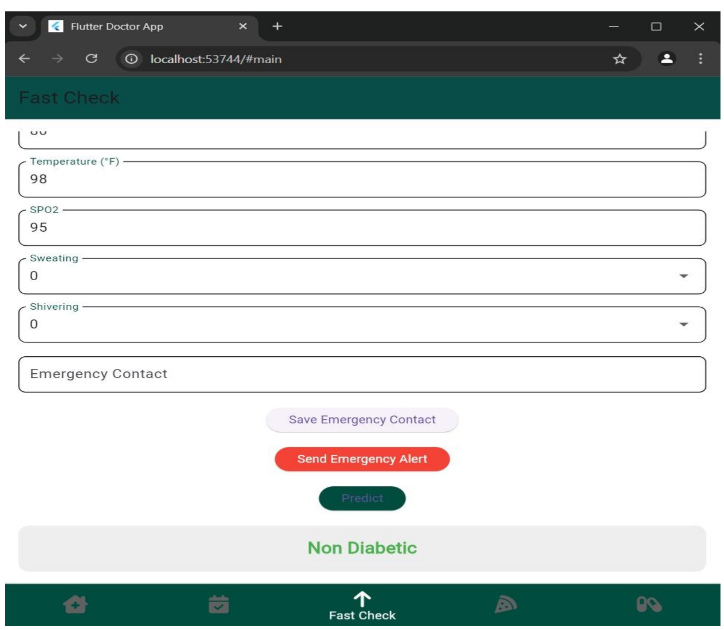

Fig 4.1.7 Based on User Health Parameters Showing Non-Diabetes

- **Filtered Meal Plans:** Users received personalized dietary recommendations based on their health conditions.

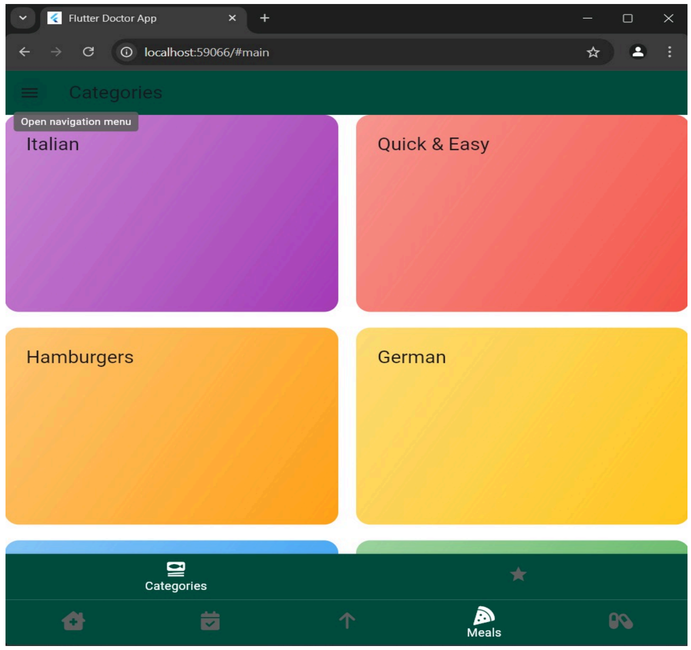

Fig 4.1.8 Personalized Meal plan Categories

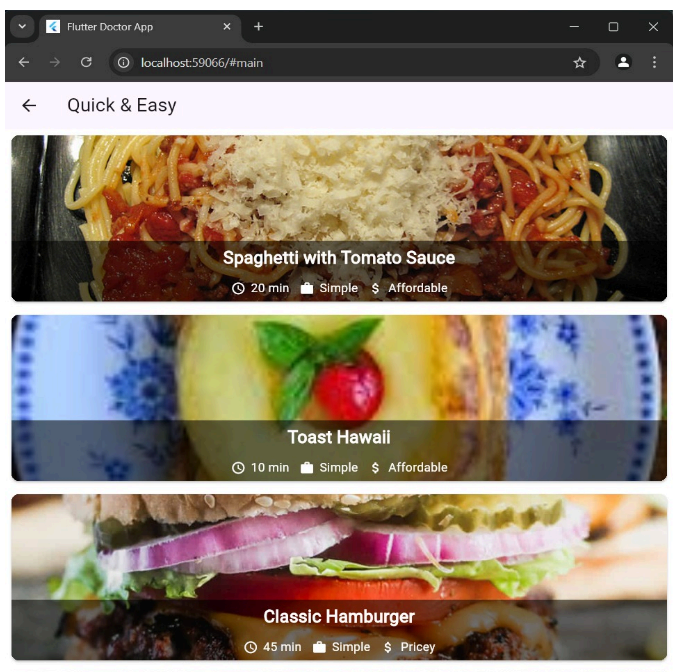

Fig 4.1.9 Recommended Meal Options

- **Insulin Dosage Calculation:** The system accurately computed insulin dosage based on glucose levels and provided timely reminders.

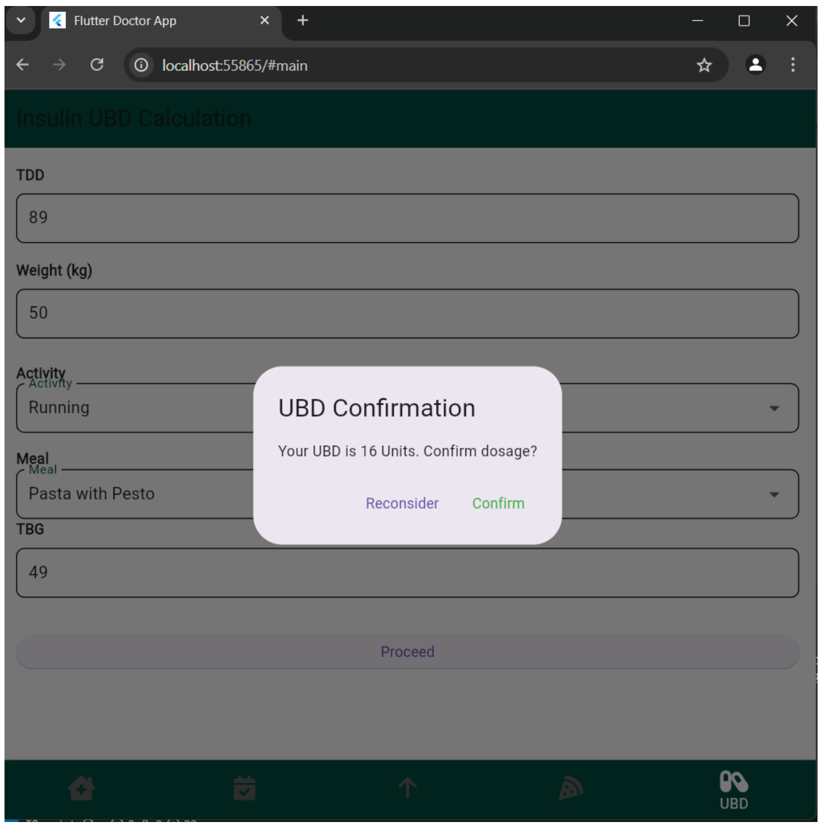

Fig 4.1.10 UBD Confirmation Prompt for Insulin Dosage

- **Emergency Alerts:** Real-time alerts were triggered when health parameters exceeded safe thresholds, notifying emergency contacts.

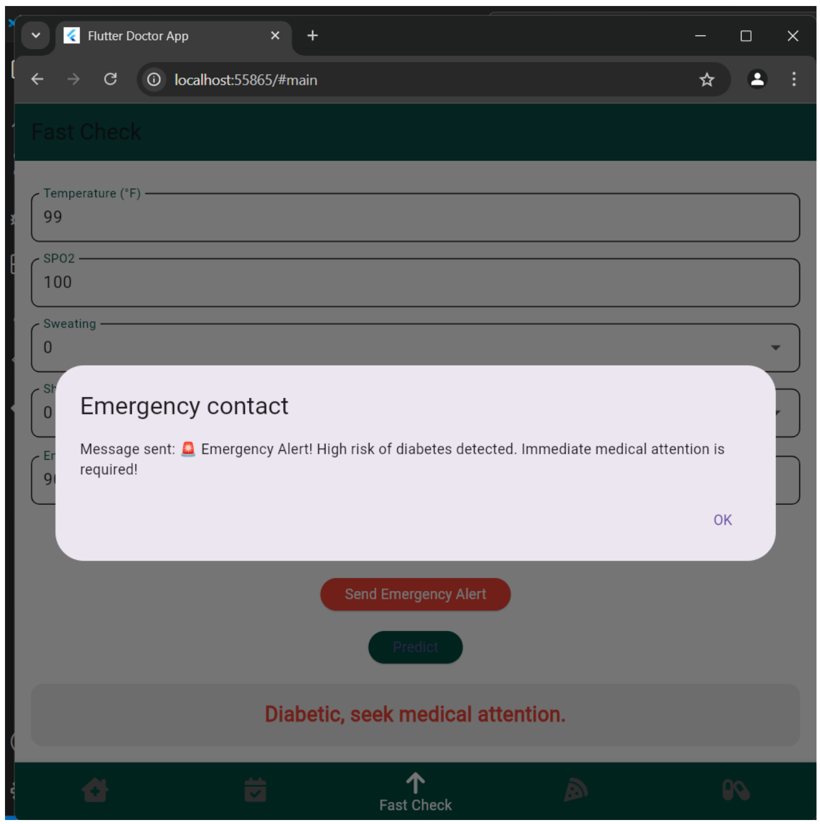

Fig 4.1.11 Emergency Alert Notification

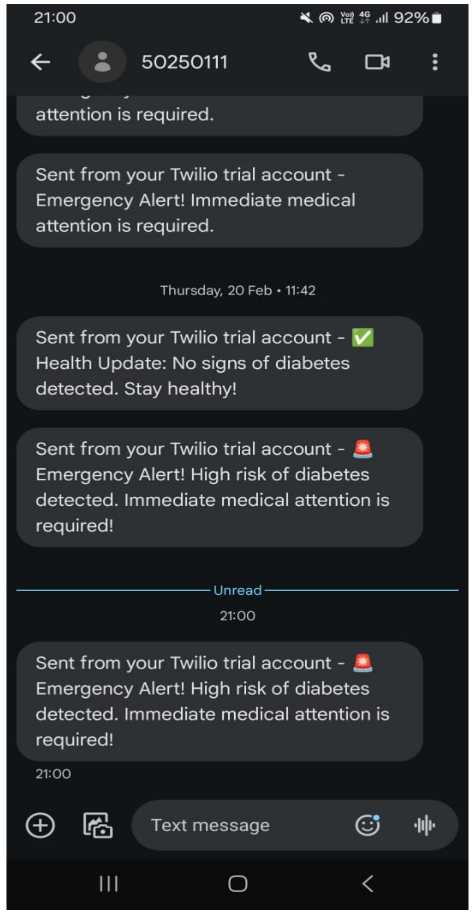

Fig 4.1.12 Automated Diabetes Alert System via Twilio

Diabetes and Physiological Parameters Analysis

This project assesses key physiological parameters to determine diabetes status and its associated risks. The monitored factors include blood glucose levels, blood pressure, heart rate, oxygen saturation, body temperature, sweating patterns, and shivering, all of which provide critical insights into a person's health.

This project evaluates key physiological parameters to assess diabetes and its associated health risks. Blood glucose levels serve as a primary indicator, with fasting values between 70-100 mg/dL considered normal, 101-125 mg/dL classified as pre-diabetic, and anything above 125 mg/dL indicating diabetes. Postprandial levels exceeding 200 mg/dL also confirm diabetes, while diabetes occurs when blood glucose drops below 70 mg/dL, often causing symptoms such as excessive sweating and shivering.

Blood pressure is another critical factor, as diabetics frequently experience hypertension due to insulin resistance and arterial stiffness. Normal systolic blood pressure (SBP) ranges from 90-120 mmHg, but for diabetics, it is essential to keep it below 130 mmHg to minimize complications. Blood pressure values between 130-140 mmHg indicate an increased risk, while anything above 140/90 mmHg requires medical attention. Chronic diabetes can also lead to low blood pressure (SBP <90 mmHg, DBP <60 mmHg), which may cause dizziness and fainting due to autonomic neuropathy.

Heart rate irregularities are another concern, with diabetics often exhibiting resting tachycardia (>100 BPM), a condition linked to nerve damage. Oxygen saturation (SpO2) levels should remain between 95-100%, as levels below 94% may indicate hypoxia, a common complication in diabetes. Temperature fluctuations can also signal health concerns, with diabetics being more vulnerable to infections that cause fevers above 38°C.

Sweating abnormalities, such as excessive upper body sweating but reduced sweating in the lower body, are common due to autonomic dysfunction, while night sweats may indicate diabetes. Similarly, shivering can be a symptom of either low blood sugar or infections, which diabetics are more susceptible to.

Given these risks, it is crucial for diabetics to maintain their blood pressure below 130/80 mmHg and monitor their glucose levels closely to prevent complications such as cardiovascular disease and kidney damage. Proper health monitoring and early intervention can significantly improve diabetes management and overall well-being.

Real-Time Testing and User Feedback

During real-time testing, this project followed a simple testing approach where all four team members served as test subjects. The system exhibited a 2-5% error tolerance, demonstrating high reliability. The team members evaluated the system's interface and found it intuitive, with quick response times for predictions and alerts. The testing process confirmed that integrating Bluetooth data transmission and AI-driven analysis significantly enhanced the overall healthcare experience. The results validated the effectiveness of the system in real-world conditions, ensuring its usability and accuracy for future applications.

Challenges and Limitations

Despite the system's success, certain challenges were observed:

- **Sensor Accuracy:** The performance of the MAX30100 sensor was dependent on proper placement.
- **Manual Data Entry:** Users had to manually input glucose values, which could introduce human error.
- **Limited Dataset:** Expanding the dataset with more real-world data could further improve accuracy.

The results indicate that the Intelligent Diabetes Prediction and Management System successfully integrates AI, real-time health tracking, and predictive analytics to assist individuals in managing diabetes. With an accuracy of 94.62%, real-time monitoring, and emergency response capabilities, the system provides an efficient and accessible healthcare solution. Future enhancements, including automatic glucose monitoring integration and cloud-based AI improvements, will further enhance its effectiveness.

CHAPTER 5

CONCLUSION

The Intelligent Diabetes Prediction and Management System successfully integrates real-time health tracking, AI-driven analytics, and predictive modelling to provide an effective solution for diabetes management. The system combines machine learning-based prediction models, real-time health monitoring sensors, and a user-friendly mobile application to assist individuals in proactively managing their health. The Bidirectional LSTM model employed in the system achieved an accuracy of 94.62%, outperforming traditional models and ensuring reliable diabetes risk prediction. The hardware efficiently tracks blood glucose levels, heart rate, and SPO2 levels, while the software component facilitates manual data entry, doctor follow-up bookings, personalized meal planning, insulin dosage recommendations, and emergency alerts. Real-world testing demonstrated the system's effectiveness, with a low error margin and positive user feedback on usability and accuracy. Despite its promising performance, the system has certain limitations, including sensor dependency, manual data entry errors, and dataset constraints. Addressing these challenges will further enhance the system's accuracy, usability, and overall efficiency.

To improve the system, several recommendations can be considered. Automating glucose monitoring through continuous glucose monitoring (CGM) sensors would eliminate manual data entry and reduce human error. Implementing a cloud-based approach for data storage and real-time AI analysis would enhance accessibility and computational efficiency. Strengthening security measures such as end-to-end encryption and biometric authentication will ensure privacy and protect user health data. Refining the mobile application interface, alert system, and personalized recommendations can improve overall engagement and usability. Additionally, conducting large-scale clinical trials and gathering diverse patient data will enhance the reliability and effectiveness of the model.

While the current system has demonstrated its effectiveness in diabetes prediction and management, there is significant scope for further research and development. Future iterations of the system could integrate with smart insulin pumps to automatically regulate insulin dosage based on glucose levels. The model can also be extended to detect other chronic conditions, such as hypertension, cardiovascular diseases, and kidney disorders, using AI-driven analytics. Incorporating voice-enabled AI assistants will allow users to interact with the system hands-free, making health tracking more accessible. Future enhancements could include compatibility with smartwatches and fitness trackers to continuously monitor health parameters. Additionally, implementing predictive alerts based on historical health trends would allow for earlier intervention and proactive medical consultations.

The Intelligent Diabetes Prediction and Management System represents a significant advancement in AI-driven healthcare solutions, empowering individuals with early disease detection, proactive health management, and emergency assistance. By leveraging machine learning, real-time health tracking, and personalized recommendations, the system has the potential to improve patient outcomes, reduce emergency risks, and enhance the overall quality of life for individuals with diabetes and related conditions. Future developments in automated monitoring, cloud computing, and AI-driven personalization will further solidify its role in next-generation digital healthcare solutions.

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