Intelligent, Secured Smart App For Complete Diabetes Lifestyle Management – "DiaBeta"

Jayasekara J.T.N.N
Software Engineering
Faculty of Computing, Sri Lanka
Institute of Information Technology,
Malabe, Sri Lanka
nethsaraj@gmail.com

Gunasekera R.H.
Software Engineering
Faculty of Computing, Sri Lanka
Institute of Information Technology,
Malabe, Sri Lanka
hansanig28@gmail.com

Ravindu Hasanka V.G.
Information Technology
Faculty of Computing, Sri Lanka
Institute of Information Technology,
Malabe, Sri Lanka
ravinduhasanka@gmail.com

Hasintha Kashmika H.B.G.
Computer Systems & Network Engineering
Faculty of Computing, Sri Lanka
Institute of Information Technology,
Malabe, Sri Lanka
hbghasinthakashmika@gmail.com

Ms. P.K.Suriyaa Kumari
Information Technology
Faculty of Computing, Sri Lanka
Institute of Information Technology,
Malabe, Sri Lanka
suriyaa.k@sliit.lk

Mr. N.H.P. Ravi Supunya Swarnakantha
Information Technology
Faculty of Computing, Sri Lanka
Institute of Information Technology,
Malabe, Sri Lanka
ravi.s@sliit.lk

Abstract— **Especially today's society tends to use new technological devices instead of relying on document materials in daily life. While there are diabetes-related apps that more accurately predict users' prediabetes or diabetes type 2 using machine learning approaches, predicting health risks by analyzing glucose monitoring data, recommend meal and exercise plan, and using a non-invasive approach to measure and monitor blood glucose level, heart rate and blood oxygen level, and over Wi-Fi using NodeMCU makes the proposed DiaBeta application unique among diabetes applications. Other secondary functions such as digital logbook, reminders, lifestyle-based meal recommendation, medical guidelines, and efforts such as glucose monitoring data can be easily performed with a smartphone. The proposed DiaBeta app will help users reduce their risk of diabetes. DiaBeta is a life-saving app that can be used not only by diabetics but also by non-diabetics around the world to get a more accurate and personalized meal plan. DiaBeta offers precise, clinical, validated, and standardized solution for diabetes patient. Additionally, the system will automatically deliver surveys to registered users to assess their understanding of diabetes.**

Keywords— non-invasive, diabetes prediction, Machine Learning, NodeMCU, IoT

I. INTRODUCTION

Diabetes is an ongoing non-transferable illness that requires everyday prescription and close observing. Self-management is important to stay away from complexities, and great information is expected to oversee self-management appropriately. Currently, more than one in ten people worldwide have diabetes. Additionally, a list of countries where one in five people with diabetes is growing. Since the initial publication in 2000, the absolute prevalence of diabetes mellitus among adults aged 20 to 79 has increased from 151 million people, or 4.6% of the world's population, to 537 million people, or 10.5% of the current global population. [1].

The use of information technology has permeated every aspect of our lives. Online resources are expanding quickly. It is not feasible to bring along books and notes on various diseases in the present era. Nearly everyone has a mobile phone these days, and many of them are smartphones and tablets that can run a variety of apps and games. However, there aren't many apps out there that are made with scientific foundation, easy to use user interfaces for diabetes management and made for specific countries or regions so that people can use it without much prior knowledge. If we speak about Sri Lanka, there is hardly any application available which supports both Sinhala and English [3].

DiaBeta system is a mobile application which support both android and iOS, registered users can predict whether they have prediabetes or diabetes type 2. System can recommend meal plan which contains Sri Lankan cuisines and exercises plan for the users according to their preferences, users can identify whether they have any health risks. Other than that, users can measure their blood glucose level non-invasively and can measure heart rate and blood oxygen level as well via our DiaBeta hardware device. We hope to add our DiaBeta mobile application to Google play store and introduce the application for the patients in local diabetes clinics in Sri Lanka. By delivering notifications to the user's account about important announcements, easily created quizzes, and news, this study aims to determine the degree of knowledge, attitude, and commitment among individuals. The digital logbook feature is an additional feature that enables users to add, edit, and delete information about their daily blood sugar, insulin, and medication intake. Users can also generate reports from their logged data, receive reminders about when to take their medications, clinic dates, and other crucial information, and educate others about diabetes. Finally, this application will offer the public a very effective and productive service by utilizing all these services.

II. LITERATURE REVIEW

In the literature survey we have mainly focused on similar research functionalities in the same area. The main objective of our research is to design and develop intelligent, secure smart mobile applications for complete diabetes lifestyle management. In the beginning, we did some preliminary research for this using various secondary sources. From this we were able to know the existing features and it helped us to determine our work outline.

By inventing the mHealth application [4], Nabila Shahnaz Khan and Mehedi Hasan Muaz have suggested a machine learning based solution for detecting whether a patient has diabetes or not using Naive Bayes Classifier. For the prediction they used four patient characteristics that are mutually independent: age, gender, BMI, and family history of diabetes. They have used a survey to gather necessary information. They have proposed a Diabetes Predictor mobile application and it only contains functionality to predict diabetes while DiaBeta consists of many more functionalities to manage patient diabetes lifestyle.

Researchers under the direction of Mr. A.K. De Alwis have developed a non-invasive technique for measuring blood glucose levels by absorbing light using NIR spectroscopy and projecting glucose to reach the necessary penetration depth [5]. They obtained blood glucose levels using a CJMCU OPT-11 photodiode. Glucose levels are taken and transmitted to the Arduino microcontroller and connected to their DiabiTech Mobile app via the HC-05 Bluetooth module. The innovative team led by Mr. Aveen Uthman Hassan has performed non-invasive real-time monitoring of blood oxygen levels and heart rate for professionals using fingerprint sensors [6]. The suggested architecture makes use of the Blynk app and NodeMCU to monitor heart rate and blood oxygen levels through a Wi-Fi network.

Table 1: comparison of existing system

	Existing System				
	Diabetes :M	mHealth	mySugr	Intelin	DiaBeta
Diabetes Prediction	×	✓	×	×	✓
Digital Logbook	✓	×	✓	✓	✓
Generate Questionaries and Analyse Answers	✓	×	×	✓	✓
Recommended Diet Plans	✓	×	×	×	✓
Recommended Exercises	×	×	×	×	✓
BMI Calculation	×	×	×	×	✓
Food Value and Calorie Burn	×	×	×	✓	✓
Identify Heart, Eye, Kidney Risks	✓	×	×	×	✓
Diabetes Education	✓	×	×	✓	✓
Blood Glucose Monitor	×	×	×	✓	✓
Blood Oxygen & Heart Rate Level Monitor	×	×	×	×	✓

Analysts under the course of S. Ananthi and V. Bhuvaneswari have created testing apparatuses for early discovery of diabetes risk. They utilized diabetes clinical information to build a fluffy grouping calculation to recognize heart and renal issues in this review. To gauge the heart and renal issues that diabetic individuals are inclined to, a fluffy order model was imagined and carried out. Information mining techniques are utilized to figure the gamble factors of diabetes information. Viewed as a solid term that actions the sum to which at least two factors change together. The connection lattice is determined by utilizing the relationship formula [7].

The Sardar Patel Institute of Technology in Mumbai, India, under the direction of Divya Mogaveera, Vedant Mathur, and Sagar Waghela, conducted a study on an e-Health Monitoring System with Diet and Fitness Recommendation Using Machine Learning. A decision tree is the categorization technique used in the module that recommends diet and exercise. With regard to tailored datasets, decision trees will assist in making recommendations and determining whether or not a certain food item and exercise should just be offered to a particular individual [8].

III. RESEARCH OBJECTIVES

Main objective of this research is to design and develop intelligent, secure smart mobile applications for complete diabetes lifestyle management.

The Sub Objectives are as follows:

A. Predict Diabetes;

The DiaBeta system can predict whether the patients have prediabetes or diabetes by using users' data like Glucose, Blood Pressure, Insulin, Skin Thickness, BMI, Age and Gender. It helps patients to be more engaged with their diabetes, keep track of their healthy habits, and avoid getting into critical situations.

B. Recommend Diets and Exercise Plans;

The DiaBeta system is obligated to help users perceive the calculated calorie count of their desired diet and the calculated calorie burned count of their desired exercises. The DiaBeta system also recommends users the most fitting exercise plan or diet that he/she craves based on their requirements.

C. Identify Health Risk & Give Health Education;

The DiaBeta System helps to identify and reduce the risk of diabetes.The application can be accessed with the help of automated algorithms to explore the potential risks of heart, eye and kidney. Users using the application can be informed about health education.

D. Measure Glucose Level, Heart Rate and SpO2;

Established a low-cost blood oxygen level(SpO2), heart rate, and non-invasive blood glucose monitoring system for the DiaBeta application.

IV. METHODOLOGY

High level architecture

Overall research contains a mobile application, web-based system, and hardware device. Mobile application support both android and ios. Users can be diabetes and non-diabetes people. The system has three services which are diabetes prediction service, health risk identification service and meal and exercise recommendation service. These services are developed and deployed separately using microservice architecture. Mobile application has more user specific services like managing digital logbook, and web-based system contains services which are generic to the users (i.e., Diabetes Prediction, Health Risk Identification). The hardware device is connected with the mobile application, and it is used to measure Glucose, Heart Rate and SpO2 level.

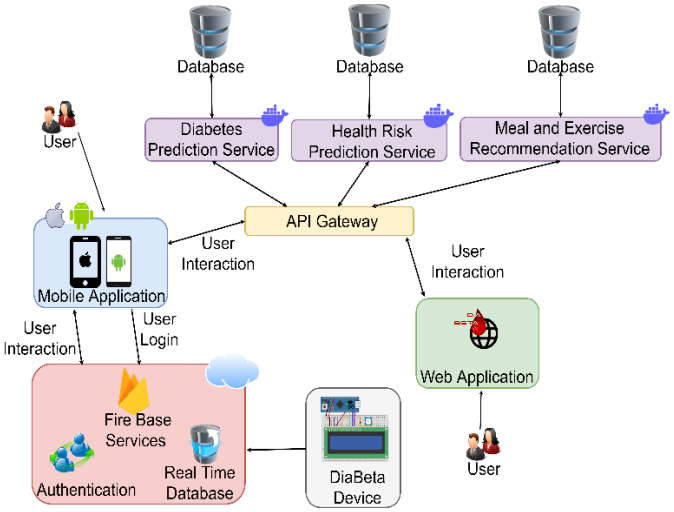

Figure 1: System Design

"DieBeta" system has developed for 4 components as follows;

Main objective of this research is to design and develop intelligent, secure smart mobile applications for complete diabetes lifestyle management.

The Sub Objectives are as follows:

A. Diabetes Prediction

When predicting diabetes, the system used a data set which is the Pima Indian Diabetes dataset consisting of information on 768 patients (268 tested_positive instances and 500 tested_negative)[10]. The dataset consists of several medical predictive (independent) variables and an outcome that is one dependent variable. Independent variables are Glucose, Blood Pressure, Insulin, Skin Thickness, BMI, Age and Gender. For the prediabetes detection, the system used a data set that has been collected using direct questionnaires from the patients of Sylhet Diabetes Hospital in Sylhet, Bangladesh [9] and approved by a doctor. This dataset contains the sign and symptoms data of newly diabetic or would be diabetic patients. The dataset consists of 15 features and one target variable named class.

In data analysis, it is essential to analyze the data and discover any features with missing values, as well as how they will affect the dataset. According to the analysis in the Pima Indian dataset there are a high percentage of missing values in key features for diabetes prediction. Such as insulin and skin thickness. Since these features are usually important predictors of presence of diabetes cannot remove the features, Instead, have removed the rows that contain the missing values for insulin. This will drastically reduce the dataset size, yet it will be increasing the model's accuracy. For the data standardization we have used Standard Scaler from sklearn. In Sylhet dataset, since the number of features are high, look at feature importance and select top 10 features for the model training.

Since this is a classification problem we have used several classification algorithms (i.e. Logistic Regression, SVM Random Forest, XgBoost) and have selected the model with higher accuracy to predict diabetes. Then we deployed the model using flask and docker. For the container orchestration we used kubernetes.

Users can access diabetes prediction services via both DiaBeta mobile application and DiaBeta web. They need to answer a questionnaire that includes necessary information for the diabetes prediction. After a questionnaire filled by the patient, the system predicts the result and sends it back to the user in a descriptive manner.

B. Recommend Diets and Exercise Plans

The ability of patients to achieve and maintain normal blood sugar levels may be improved by making dietary adjustments and losing weight. So, a healthy diet plan with a well-organized, balanced, and counted calorie intake is very important for controlling and preventing high blood glucose levels.

When calculating, the system uses an API service to show the listed nutrition separately for the searched food items. The system displays results for a serving size of 100g by default for each item. Calories contained in the desired food item along with many other nutrients such as cholesterol, sodium, carbohydrate, fiber, and protein are shown in a table card. The total of every nutrition and calorie is displayed on the top as a separate table card.

There is no one-size-fits-all approach to meal planning due to variations in custom, culture, preference, and financial situation. So, the system suggests several options for the recommendation of a diet plan, taking the necessary conditions of the DiaBeta users into consideration. The system asks for several factors when recommending the diet, such as users preference in veg or non-veg, type of cuisine as dessert, snack, etc. The system uses the feature extraction technique witch is TfidfVectorizer for recommendation. Then the system shows a sorted list of recommended diets.

Diabetes is a significant, long-term condition in which the body cannot produce any or enough use the insulin that is produced effectively. Exercises can boost the number of insulin receptors in diabetes patients' external tissues, improve insulin sensitivity for improved function of the body's insulin, and cause

skeletal muscles to burn glucose in tissues and blood to lower blood glucose levels.

The system uses an API service to calculate estimated calories burned for searched exercises for a certain time period. For the recommendation of exercises system uses TfidfVectorizer for the feature extraction of the exercise dataset and according to user inputs system recommend exercises from the values retrieve from cosine similarity for the extract data.

C. Identify Health Risk & Give Health Education

In the Health Risk Identification part, a person must face a questionnaire before being identified for health risks. Uses data obtained by machine learning algorithms to determine if a user has a health risk. Since this indicates the health status of the person at risk for diabetes, it is possible to reduce the risk by giving the person a self-study about him or her. The system shows the user which organ of the body is at risk for the person at risk. The system predicts individual health risk levels, primarily targeting the eyes, heart, and kidneys. The data obtained in the first stage finds out whether the person has a health risk and the second shows the level of that risk. The system indicates that the at-risk person is seeking health counseling or, if the person is at high risk, they should see a physician related to the at-risk organ. This system differs from the others in that it automatically detects health risks and gives the best possible advice on how to avoid them. Therefore, all health tips and automation methods depend on the data provided by the patient. Users using the application can be informed about health education.

D. Measure Blood Oxygen Level, Heart Rate and Blood Glucose Level

The DiaBeta hardware device shown in figure 2 can be The DiaBeta hardware device shown in the picture above can be divided into two main parts a heart rate and blood oxygen level (SpO2) measuring system and a non-invasive blood glucose measuring system. The components used for the entire DiaBeta hardware device are MAX30100 sensor, NodeMCU, Jumper wires, Breadboard, OLED Display, two CJMCU OPT-101 photodiode, LED Bulbs, KY003 RGB SMD 5050 LED Module, and two 38 KHz 940nm IR Emitter Modules

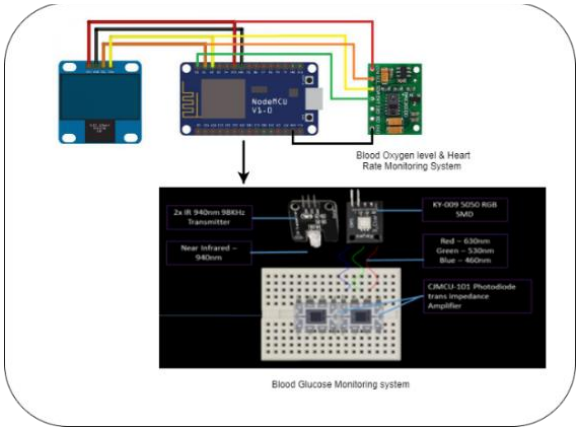

Figure 2: DiaBeta Hardware Device

By placing the finger on the MAX30100 sensor, the heart rate and blood oxygen level are measured. NodeMCU is an ESP8266-based open-source software and hardware development environment that was cost-effective and includes RAM, wi-fi, CPU, and operating system. NodeMCU was used and the system was connected to the Firebase real-time database with the DiaBeta Mobile app via wi-fi. In addition, blood oxygen levels and heart rate measurements were also output through the OLED Display.

NIR spectroscopy was chosen as the most appropriate optical source for non-invasive blood glucose measurement due to its maximum penetration depth in tissues. Many types of research using NIR emitters use NIR Indium Gallium Arsenide (InGaAs) sensors. The use of InGaAs sensors was high cost and high wavelengths around 1550 nm cause NIR radiation effects on the skin. Alternatively, in the research, two IR Emitter Modules with a wavelength of 940nm, which do not cause NIR radiation effects on the skin, and two CJMCU OPT-101 photodiodes, which are more economical and safer, were used to detect wavelengths in the region from 300 nm to 1100 nm.

In addition, KY003 RGB SMD 5050 LED Module is different. It was capable of emitting 3 different light colors at a single wavelength in a single circuit. By placing the emitter on the top side of the finger and the photodiode on the bottom side of the finger, absorption of light is used to calculate the results.

V. RESULTS AND DISCUSSION

Diabetes prediction:

In the section we predict whether a patient has diabetes or not according to the answers given by the user. System provides 2 tests which are an early-stage diabetes detection test and type 2 diabetes detection test. According to our research, highest accuracy of the training data set for the Pima Indian data set is 84% and testing data set is 82%, for the Sylhet dataset accuracy of the training data set is 96% and testing dataset is 93%.

According to the significance score of variables in Sylhet dataset we have selected top 10 features to train our dataset.

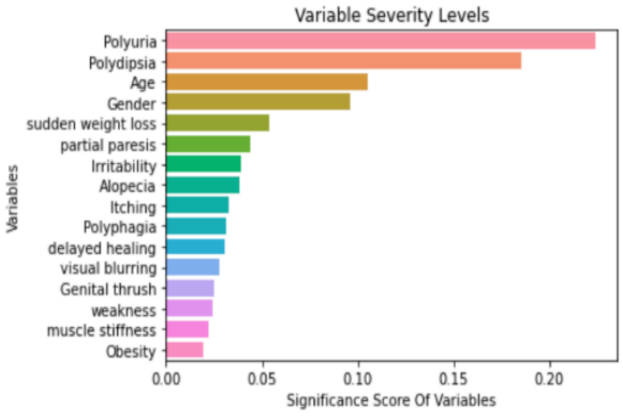

Figure 3: Variable Severity Level

After providing answers for the tests, users can predict that they have prediabetes or type 2 diabetes based on the test. System provides education tips for the diabetes patients so they can know their diabetes well. By developing this system, it was used to improve the attitude and knowledge of people toward Diabetes.

Digital logbook:

Diabetes patients can maintain a digital logbook. They can add, update, and delete glucose, carbs, insulin, and pill information. System illustrates descriptive diagrams using the user's log data and users can export these details to pdf. By using these details, patients can have a track of their daily lifestyle and it helps to control their diabetes.

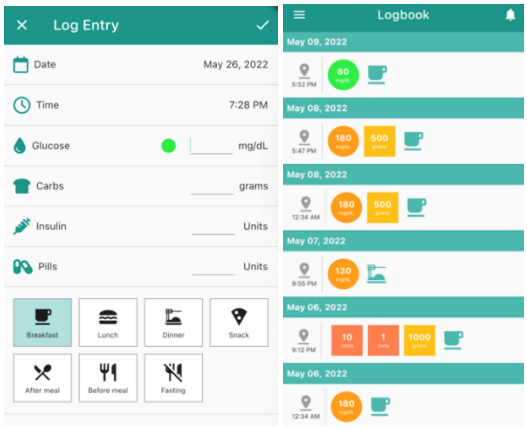

Figure 4: DiaBeta App Digital logbook

Recommend Diets and Exercise Plans

In this section we are providing an online API to check the calorie count of foods and many other nutrient counts as a sum. So, the patients can maintain their daily calorie intake accordingly without letting to exceed too much. System also provides an online API to check out the estimated calorie burned count of different exercises with respective to time periods.

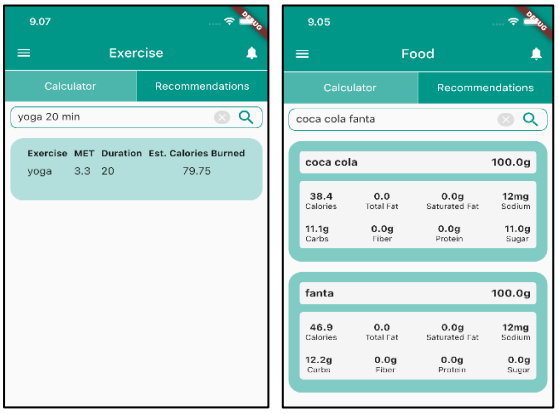

Figure 5: DiaBeta App calorie calculator

Recommending a diet plan and exercises for the patients is done by extracting and mapping all the necessary details from user. As user preference system ask to choose as liking of different countries or meal course or veg or nonveg. System use TfidfVectorizer for the feature extraction pf the dataset for both exercise and food data. After that system create cosine similarity matrix according to the features. For the recommendation user need to input necessary data through DiaBeta mobile application and using cosine similarity matrix values system recommended 10 type of exercises and 10 cousins accordingly.

Identify the Health Risk

Health risk identification is based on Machine Learning algorithms. The data provided by the patient predicts the side effects of the diabetic patient through ML algorithms. It shows the patient's risk level. Therefore, the patient can get a rough idea about his health risk level. The system automatically sends simple questionnaires for each solid organ to be registered to evaluate their knowledge of health risk level, problems, failure, and probability. The system analyzes the answers of the questionnaire and provides the health tips for each organ and self-action that can be taken to get rid of that risk. Furthermore, this system informs a user about the diseases that can occur due to diabetes through the medical education section.

54.5% of the participants in the heart risk test were people with heart risk and among these participants 68.3% were men and 31.7% were women. Logistic regression accuracy for the dataset: 85.25%, Support vector machine accuracy: 81.97%, Decision tree accuracy: 78.69%, Random Forest accuracy: 86.89%. 37.5% of the participants in the kidney risk test were people with kidney risk, and among these participants, 53.5% were men and 46.5% were women. Support Vector Machine Accuracy: 80.07% , Decision Tree Accuracy: 72.59% , Random Forest Accuracy: 76.69% .This system is designed using Logistic Regression Algorithm trained with the help of ML algorithm and its accuracy value is the highest among 167 eye risk test participants Value was, 40.36% were people with eye risk and among these participants 56.02% were male and 43.97% were female. Dataset Logistic Regression Algorithm Accuracy: 82.35 %, SVM Accuracy: 76.47 %, Decision Tree Accuracy: 73.53 %, Random Forest Accuracy: 70.59 %. The system is designed using the highest accuracy Logistic Regression Algorithm. According to the conclusion given by the prognosis, health advice is given to the patient to prevent it. It can reduce the risk of disease.

Medical Education

The system provides educational tips for patients with health risks so they can better know their diabetes. In providing education for health risks, firstly an introduction to the disease is made and secondly the symptoms are given to identify the disease. After that, it provides information about the measures

to be taken to prevent it. By developing this method, it was used to improve people's attitude and knowledge about health risks.

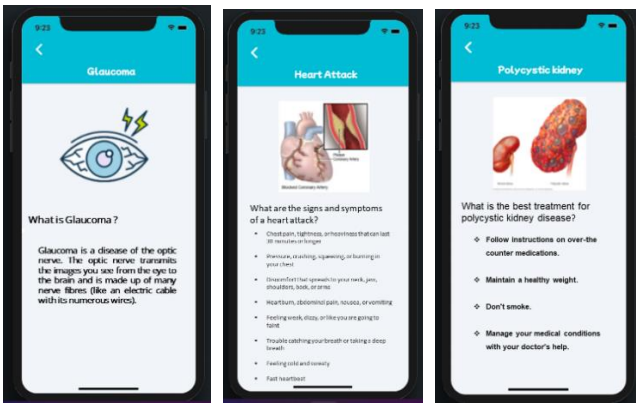

Figure 6: Health Education

Measure Blood Oxygen Level, Heart Rate and Blood Glucose Level

Figure 7 shows the DiaBeta device, which transmits a reading every two seconds while measuring blood glucose levels, during which the 940nm IR emitter emits for 1.3 seconds and the 630nm red emitter for 0.7 seconds. Typically, the output blood glucose levels were transmitted to the NodeMCU where the system was connected via Wi-Fi to the DiaBeta mobile app with Firebase real-time data storage. The measurement of patients' blood oxygen levels and heart rate by touching the MAX30102 sensor manually. Blood oxygen level and heart rate are integrated with the user-friendly DiaBeta mobile app via Wi-Fi.

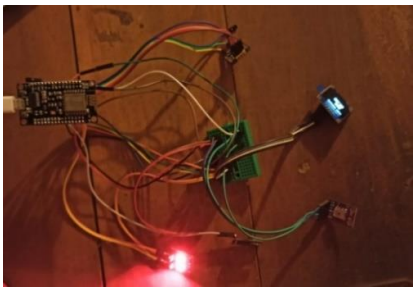

Figure 7 : DiaBeta device

VI. CONCLUSION AND FUTURE RESEARCH

Through this mobile app, users have the ability to get rid of diabetes and diabetic patients can control it. Weaknesses and limitations of each of the tools and techniques developed in the research study are highlighted in the following areas as recommendations for further work. The provision of Recommend Diets in Recommend Diets and Exercise to a certain region but can be used fruitfully by creating it so that it can benefit all the people of the world. In the current research, a health risk questionnaire is prepared to identify the health risk Plans is currently designed to suit South Asian countries. It is not limit and the health risk is predicted according to the answers given and for future research, if a photo of the eye can be taken to identify the eye risk and it can be predicted through an image processing process, it will be a great achievement. The DiaBeta hardware device was developed to non-invasively measure blood oxygen level, heart rate and blood glucose level, and for future research, if this system can be developed to measure blood pressure, it will be a great achievement. It is our good fortune to be able to use the DiaBeta Mobile App to educate people to be aware of the condition of diabetes instead of taking measures to control it after the occurrence of diabetes in country like Sri Lanka.

REFERENCES

[1] "IDF Diabetes Atlas 10th edition 537 million people worldwide have diabetes." [Online]. Available: https://diabetesatlas.org/idfawp/resource-files/2021/07/IDF_Atlas_10th_Edition_2021.pdf.

[2] Md. A. Islam, H. N. Alvi, and K. A. A. Mamun, "DiaHealth: A smart app for complete diabetes lifestyle management," IEEE Xplore, Dec. 01, 2016. https://ieeexplore.ieee.org/document/7835396/references#references

[3] "Sri Lanka - Diabetes Prevalence (% Of Population Ages 20 To 79) - 2010-2019 Data | 2020 Forecast," tradingeconomics.com. https://tradingeconomics.com/sri-lanka/diabetes-prevalence-percent-of-population-ages-20-to-79-wb-data.html.

[4] N. S. Khan, M. H. Muaz, A. Kabir, and M. N. Islam, "Diabetes Predicting mHealth Application Using Machine Learning," IEEE Xplore, Dec. 01, 2017. https://ieeexplore.ieee.org/document/8468885 (accessed Jan. 24, 2022).

[5]]S. S. W. I. Udara, A. K. De Alwis, K. M. W. K. Silva, U. V. D. M. A. Ananda, and K. A. D. C. P. Kahandawaarachchi, "DiabiTech- Non-Invasive Blood Glucose Monitoring System," IEEE Xplore, Dec. 01, 2019. https://ieeexplore.ieee.org/document/9103375

[6] A. U. Hassan, Y. O. Salihu, and M. J. Musa, "Real-Time Monitoring of Heart Beat Rate and SpO2 Based on Internet of Things," IEEE Xplore, Dec. 01, 2021. https://ieeexplore.ieee.org/document/9698527 (accessed Jul. 06, 2022).

[7] S. Ananthi and V. Bhuvaneswari, "Prediction of heart and kidney risks in diabetic prone population using fuzzy classification," in 2017 International Conference on Computer Communication and Informatics (ICCCI), 2017, pp. 1–6.

[8] D. Mogaveera, V. Mathur, and S. Waghela, "e-Health Monitoring System with Diet and Fitness Recommendation using Machine Learning," 2021 6th International Conference on Inventive Computation Technologies (ICICT), Jan. 2021, doi: 10.1109/icict50816.2021.9358605.

[9] "Early Stage Diabetes Risk Prediction Dataset," www.kaggle.com. https://www.kaggle.com/datasets/ishandutta/early-stage-diabetes-risk-prediction-dataset (accessed Aug. 21, 2022).

[10] "Pima Indians Diabetes Database," www.kaggle.com