iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** VI **Month of publication:** June 2024

DOI: https://doi.org/10.22214/ijraset.2024.63492

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VI June 2024- Available at www.ijraset.com

Intelligent Health Surveillance: Cognitive IoT Enhanced by Rapid Machine Learning

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Abstract: The quality of life for diabetic patients is significantly improved through continuous monitoring. Integrating various technologies such as the Internet of Things (IoT), embedded software, communication technologies, artificial intelligence, and smart devices helps reduce the financial burden on the healthcare system. Advances in communication technologies have facilitated personalized and remote healthcare. To meet the growing demand for advanced e-health applications, developing intelligent healthcare systems and increasing the number of applications connected to the network is essential. Consequently, to achieve critical needs like high bandwidth and energy efficiency, the 5G network must support smart healthcare applications. This research proposes an intelligent infrastructure for monitoring diabetes patients using machine learning methods. The architecture incorporates smart devices, sensors, and mobile phones to provide comprehensive coverage of the patient's body. Data collected from the patient is analyzed and classified using machine learning to produce a diagnosis. Several machine learning methods were tested to evaluate the proposed prediction system, and simulation results indicated that the Sequential Minimum Optimization (SMO) method provides higher classification accuracy, sensitivity, and precision than other techniques.
Keywords: Machine learning; Internet of Things; healthcare; diabetic patient monitoring and data classification

I. INTRODUCTION

The quality of life for diabetic patients can be significantly enhanced through continuous monitoring. The use of various technologies such as the Internet of Things (IoT), embedded software, communication technologies, artificial intelligence, and smart devices helps to reduce healthcare costs. Different communication technologies have enabled the provision of personalized and remote healthcare services.

To meet the growing demand for advanced e-health applications, it is crucial to develop intelligent healthcare systems and increase the number of applications connected to the network. As a result, to meet critical needs such as high bandwidth and energy efficiency, the 5G network must support smart healthcare applications.

1) *Intelligent Monitoring Infrastructure for Diabetes:* This research proposes an intelligent infrastructure for monitoring diabetes patients using machine learning techniques. The architecture includes smart devices, sensors, and mobile phones to provide comprehensive coverage of the patient's body. Data collected from the patient is analyzed and classified using machine learning to produce a diagnosis. Various machine learning methods were tested to evaluate the proposed prediction system, and simulation results indicated that the Sequential Minimum Optimization (SMO) method provides higher classification accuracy, sensitivity, and precision compared to other techniques.
2) *Importance of Continuous Monitoring:* Diabetes is a chronic condition caused by the dysfunction of the pancreas, which occurs when the organ does not produce enough insulin or the body does not use it effectively. High or low blood sugar levels can cause organ malfunction and deterioration, affecting the eyes, nerves, and blood vessels. Consequently, continuous and daily monitoring is crucial to prevent the health of diabetic patients from deteriorating. The increasing number of diabetes patients in recent years has necessitated the use of advanced methods for monitoring these individuals. Blood glucose levels of diabetic patients are regularly monitored using tracking equipment, allowing patients, families, and doctors to monitor glucose levels continuously and respond quickly if an abnormal reading is detected.
3) *Benefits of Mobile Monitoring Systems:* Mobile monitoring systems for diabetes patients offer numerous benefits, including improving the quality of life for diabetic patients by reducing hospital visits. As a result, the deployment of wireless technology with robust coverage that allows data to be sent from patients to doctors is highly attractive. In this regard, fifth-generation (5G) technology, referred to as the next generation of mobile networks, enables high-speed transmission, improved network capacity, and scalability. However, the current focus on this technology's evaluation is primarily on increasing data transfer rates.

4) *Proposed System Design*: We developed a smart and secure monitoring system for diabetic patients using a machine-learning algorithm with statistical classification. Our proposed design includes mobile sensors that measure the patient's blood sugar level, temperature, and physical activity. Through the 5G cellular network, a smartphone transmits sensor data to a database station. The collected data is processed and classified using various classification techniques. Additionally, the proposed method aids diabetic patients in predicting future blood sugar levels.

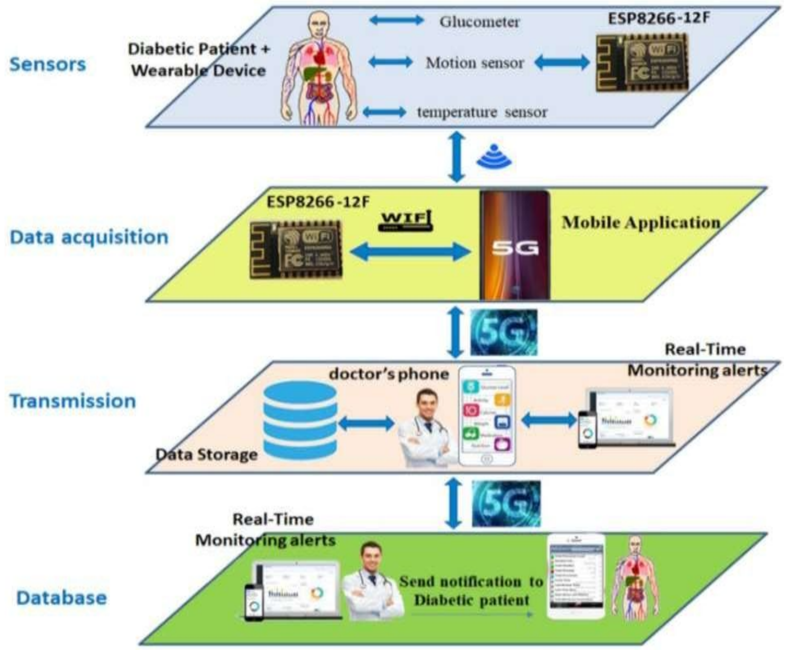

Figure 1. Proposed design structure for monitoring diabetic patient

5) *Data Processing and Classification:* The diabetes dataset was processed using naive Bayes, random forest (RF), simple logistic, Sequential Minimum Optimization (SMO), and J48 classification algorithms to determine which method was the most effective in assessing the patient's risk level. It is possible to manage diabetes using deterministic predictive models. However, there have been limited studies on predictive models of diabetes mellitus in the literature. Using stochastic numerical analysis to investigate the epidemic propensity of diabetes mellitus remains an exploratory approach. To gather data for classification, we employed a primary sensor with low-cost and low-energy solutions for glucose measurement in our proposed system. The patient's data was updated daily in the cloud, allowing doctors to monitor glucose changes and provide appropriate hospital treatment in case of abnormal glucose levels.

This paper is structured as follows: Section II covers the relevant work. Section III presents the proposed architecture for diabetic patient monitoring. Section IV discusses the findings and results. Finally, Section V concludes with a summary of the findings

II. LITERATURE SURVEY

In this work, we provide an overview of previously published research on 5G-based devices for monitoring diabetic blood sugar levels. This section also includes existing efforts on big data and predictive analytics in healthcare that utilize classification to anticipate potential episodes of blood sugar spikes or dips. Classification in e-health monitoring is crucial for future disease management.

A. Summary of Related Works

In one study, an overview of 5G technologies and IoT-enabled smart healthcare applications is presented. The authors discuss the challenges, research trends, and future research goals in 5G healthcare. Another study describes an architecture and protocol for 5G-based continuous e-health monitoring. This design focuses on collecting patients' vital signs using a 5G smartphone and wearable devices. The collected data is stored in a database and analysed using big data and machine learning techniques to provide intelligent responses and trigger alerts when the system detects anomalies.

Researchers have also proposed a mobile health system based on 5G for continuous monitoring and assessment of diabetic patients. This 5G-smart Diabetes system combines existing technologies such as Wearable2.0, machine learning, and big data to offer comprehensive diabetes monitoring and analysis. The authors illustrate the data-sharing mechanism and data analysis for 5G-smart Diabetes and developed a 5G-smart Diabetes testbed, demonstrating the system's capability to provide personalized prognostics and treatment for patients.

Another IoT-based solution is the internal anti-collision alarm system (IAAS), which uses Radio Frequency Identification (RFID) technology to detect and monitor passive RFID tags by reading backscatter signals. This system assists visually impaired users in avoiding obstacles by using the received signal strength indicator (RSSI) based on the log-normal distance path loss (LWLR) model and segment profiles as fingerprints. Experiments showed that the system performed well in obstacle avoidance with an accuracy of 94%.

A smart home health monitoring system for detecting type 2 diabetes and high blood pressure was also proposed. The system aims to evaluate patients' blood pressure and glucose levels at home, alerting caregivers if irregularities are detected. It uses supervised machine learning classification algorithms to predict high blood pressure and diabetes status.

In another study, researchers present a new machine learning model based on a decision tree (DT) algorithm to predict traffic flow improvements in 5G IoT wireless sensor networks. The goal is to identify the optimal parametric settings in a 5G environment. Furthermore, a novel method for predicting diabetes patients' glucose levels was introduced. The authors use the GlucoSim software to analyze patient data, employing a continuous glucose monitoring sensor (CGS) and the Kalman filter (KF) to reduce noise, which helps prevent severe outcomes caused by hypo- or hyperglycemia.

Another study aims to improve accuracy and other evaluation metrics in classifying the Pima Indians diabetes dataset. The authors present a deep neural network architecture with stacked autoencoders for diabetes data classification. The tests are conducted using precision, recall, specificity, and F1 score as evaluation criteria.

Several studies focus on applying machine learning techniques in medical contexts. One study offers two approaches for classifying medical implant materials using the Wiener polynomial and support vector machines (SVMs), comparing these methods to existing algorithms. Another study develops a classification technique for creating biocompatible materials in medical devices by employing meticulous logistic regression to reduce the likelihood of incorrect alloy identification.

Lastly, a study compares the results of data classification tasks using the most common classification methods and describes a unique classification approach based on the geometric transformation model's neural-like features.

III. OBJECTIVES

1) *Develop a Novel 5G-Based Monitoring System for Diabetic Patients:* To design and implement a cutting-edge architecture utilizing 5G technology for continuous and reliable monitoring of blood glucose levels in diabetic patients.
2) *Apply Machine Learning Algorithms for Data Categorization:* To integrate and evaluate various machine learning algorithms to effectively classify and analyze data collected from diabetic patients, ensuring precise and timely health insights.
3) *Expand System Capabilities Beyond Diabetes Monitoring:* To create a versatile monitoring framework that, while focused on diabetes, can be adapted to track and manage other health conditions, leveraging the robust and scalable nature of the proposed 5G-based system.

IV. PROPOSED SYSTEM

This section details the proposed 5G architecture for a diabetic patient monitoring system. The goal is to monitor a diabetic patient's blood glucose levels using 5G technology to transfer data and employ wireless intelligence for data analysis and informed decision-making.

A. Proposed 5G Architecture for Diabetic Patient Monitoring: System Design and Data Flow

The proposed system is designed to collect data on diabetic patients' blood glucose levels, temperature, and physical activity. This data is uploaded to a base station using a smartphone connected via a 5G network. The system then intelligently analyzes the data using machine learning and artificial intelligence techniques to assist users in managing their glucose levels and predicting future health trends. Continuous monitoring of blood glucose levels is crucial for diabetic patients because small fluctuations in glucose levels may not indicate immediate problems, but continuous changes can lead to severe conditions such as coma, blindness, or even death. Diabetic individuals typically follow a treatment plan by taking insulin regularly. Thus, we provided a method for continuously monitoring blood glucose levels at home and offering prompt assistance in case of a medical emergency. When incorrect data is detected, doctors receive an alert and can recommend specific actions based on this information.

We chose 5G technology for our system due to its ability to support more than 60,000 connections with very low latency. Our proposed architecture comprises four main layers: sensors, data acquisition, transmission, and database. Figure 1 depicts our suggested architecture for diabetes patient monitoring.

1) *Sensors Layer:* This layer includes the blood glucose level sensor, temperature sensor, and motion sensor. It also incorporates the ESP8266 module, which connects the sensors and provides a Wi-Fi interface for data transmission to the patient's smartphone. Thus, the sensors are responsible for gathering data and transferring it to the patient's phone.

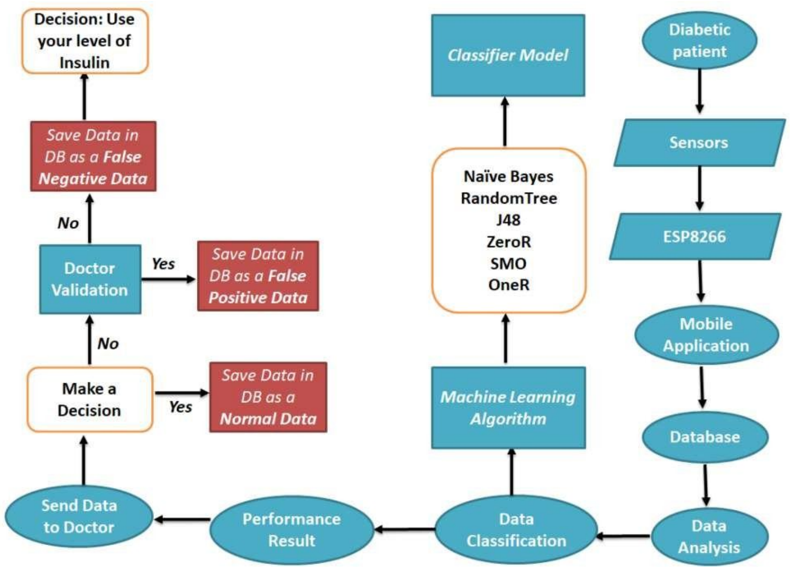

Figure 2. The flow of proposed design structures

2) *Data Acquisition Layer:* This layer consists of the patient's smartphone and the data collection application. The sensor data is displayed on the mobile application. The 5G network also transmits the data to the base station, allowing for many simultaneous connections within a covered area. It aims to support a million devices per square kilo meter, which is ten times more than 4G.
3) *Transmission Layer:* The smartphone uses 5G to send data to the database for processing before it is sent to the healthcare provider's phone for examination.
4) *Database Layer:* This processing unit stores sensor data to be analyzed and classified using various artificial intelligence techniques. The server determines whether the received data indicates a positive (true positive) or negative (false negative) condition using machine learning methods. An alert is issued when the system detects an abnormal condition, and the doctor receives a message from the server. The doctor then sends recommendations and treatments, which are delivered to the patient's phone.

B. Implementation and Testing

To check the blood glucose level, the diabetic patient needs to take a drop of blood from their fingertip and place it in a glucometer at least three times daily. Since it was challenging to conduct practical tests on diabetic patients for our application, we used an SHT 31 temperature and humidity sensor with similar connectors. The glucometer, easy to use with an I2C connection, was connected to the ESP8266-12F module to ensure data transmission to the database.

The ESP8266-12F module handled the processing and communication operations, consuming minimal power. Sensor data was transferred to the ESP8266-12F, where it was processed and analyzed by the onboard microcontroller using the stored code. The ESP8266-12F module connected to the Wi-Fi router, which served as a station node, regularly transferred data from the live sensor to the internet database. This means that, in addition to performing computations, the ESP8266-12F serves as a sensor hub and a wireless communication device.

This proposed system ensures efficient and continuous monitoring of diabetic patients' health, leveraging 5G technology for real-time data transmission and analysis.

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V. RESULTS AND DISCUSSIONS

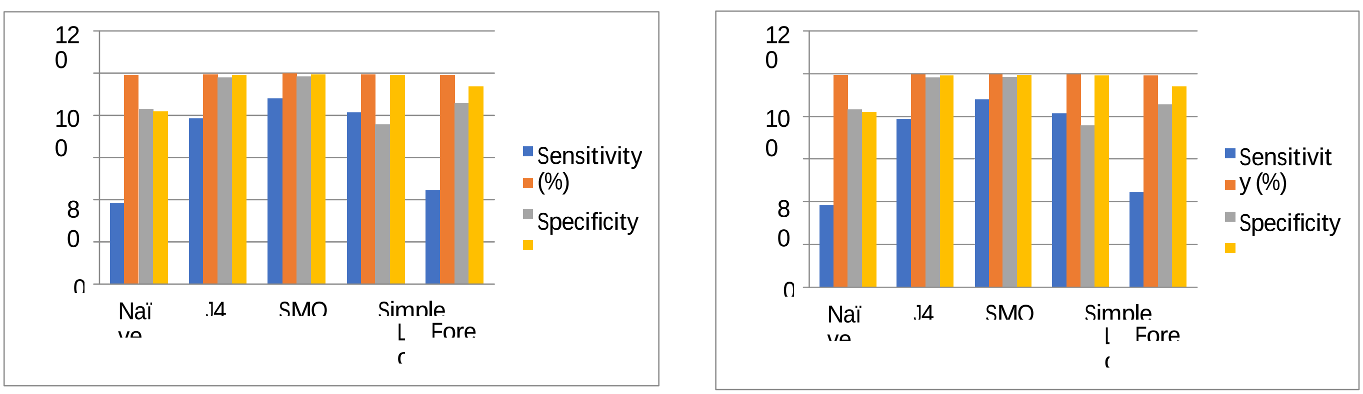
This proposed system ensures efficient and continuous monitoring of diabetic patients' health, leveraging 5G technology for real-time data transmission and analysis.

1) *Performance Findings and Analysis:* This section presents the performance results in terms of precision, receiver operating characteristics (ROC), and accuracy, as well as a discussion of these findings.
2) *Dataset and Methods:* The dataset utilized for this study is shown in Table 1. It comprises data collected from individuals with diabetes, including gender, age, measurement days, blood glucose levels, insulin usage, body temperature, and physical activity. This dataset was used to test various machine-learning techniques for detecting and predicting diabetes.

Table 1. Temperature, Physical activity and Glucose level [19]

Day	Temperature	Blood Sugar Level (mg/dL)			No. of Steps
		Morning	Afternoon	Evening	
Day1	36	97	101	101	4312
Day2	35	155	142	113	5211
Day3	36	102	100	103	3765
Day4	36	123	61	87	3546
Day5	37	151	136	77	7400
Day6	35	140	67	112	3580
Day7	37	59	103	71	7657
Day8	36	90	76	101	3010
Day9	36	89	60	75	6712
Day10	37	51	50	66	7432

This section highlights the core aspects of machine learning algorithms in data collection and processing. The dataset provided key insights and was instrumental in evaluating the effectiveness of various machine-learning approaches in predicting and managing diabetes. The performance was measured by analyzing precision, ROC, and accuracy, which are critical metrics for assessing the reliability and efficacy of predictive models in healthcare.



(a) (b)

Figure 3: (a) Different algorithms with different parameters Values like sensitivity, specificity, precision, and accuracy. (b) Different algorithms with different parameters Values like mean absolute error (MAE), and mean squared error (MSE)

Various algorithms exhibit varying performance across metrics such as sensitivity, specificity, precision, and accuracy, which are crucial in evaluating their efficacy. These metrics provide insights into how well each algorithm correctly identifies positive and negative instances, distinguishes true positives from false positives, and overall, accurately predicts outcomes. Evaluating algorithms based on these metrics helps in understanding their strengths and weaknesses in handling diverse datasets and optimizing their parameters for specific applications. Such comprehensive evaluation ensures that the selected algorithms meet the performance criteria necessary for robust and reliable data categorization and analysis.

VI. CONCLUSIONS

Predictive analytics in healthcare can greatly assist clinicians and researchers by extracting insights from medical data and facilitating informed efficient decisions. This study introduced a diabetic patient monitoring system leveraging 5G technology and machine learning algorithms. An intelligent application was developed using artificial intelligence and big data to analyze patient data and issue alerts during emergencies.

We used the WEKA tool to classify diabetic patients with six machine learning classifiers: Naive Bayes, J48, SMO, random forest, and simple logistics. The precision and accuracy of these algorithms were compared to evaluate the system's performance. Various machine learning techniques (Naive Bayes, SMO, J48, simple logistic, and random forest) were utilized to assess the proposed system.

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