

A REVIEW ON BLOOD GLUCOSE MONITORING SYSTEMS AND DEVICES

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ABSTRACT

Over the last few decades, modern technology has been integrated into various fields, including healthcare. Digital technologies are increasingly used in the healthcare sector to automate various processes, ranging from patient registration to complex medical operations. With the development of technology, the number of various diseases is also increasing; one of the most common diseases among people is diabetes mellitus. Continuous monitoring of blood glucose levels in diabetic patients is crucial. This paper aims to review the various systems and devices used for monitoring blood glucose levels.

Introduction

Human health monitoring is one of the most critical issues in the healthcare sector [1-3]. Depending on the type of disease, different monitoring methods are used. One of the most common diseases in recent years is diabetes. Diabetes mellitus is a group of diseases that affect how the body uses blood sugar (glucose), an important energy source for the cells that make up the muscles and tissues [4]. Glucose is also the main fuel source for the brain. The causes of diabetes vary by type, but having too much sugar in the blood can lead to serious health problems. Therefore, it is important to continuously monitor and measure blood glucose levels to prevent diabetes. Self-monitoring of blood glucose by diabetic patients offers a quick way to measure blood sugar, unlike traditional laboratory measurements. Frequent medical check-ups can help patients prevent and detect hyper- or hypoglycemic events.

There are several techniques for blood glucose monitoring. The following figure shows all types of blood glucose monitoring techniques.

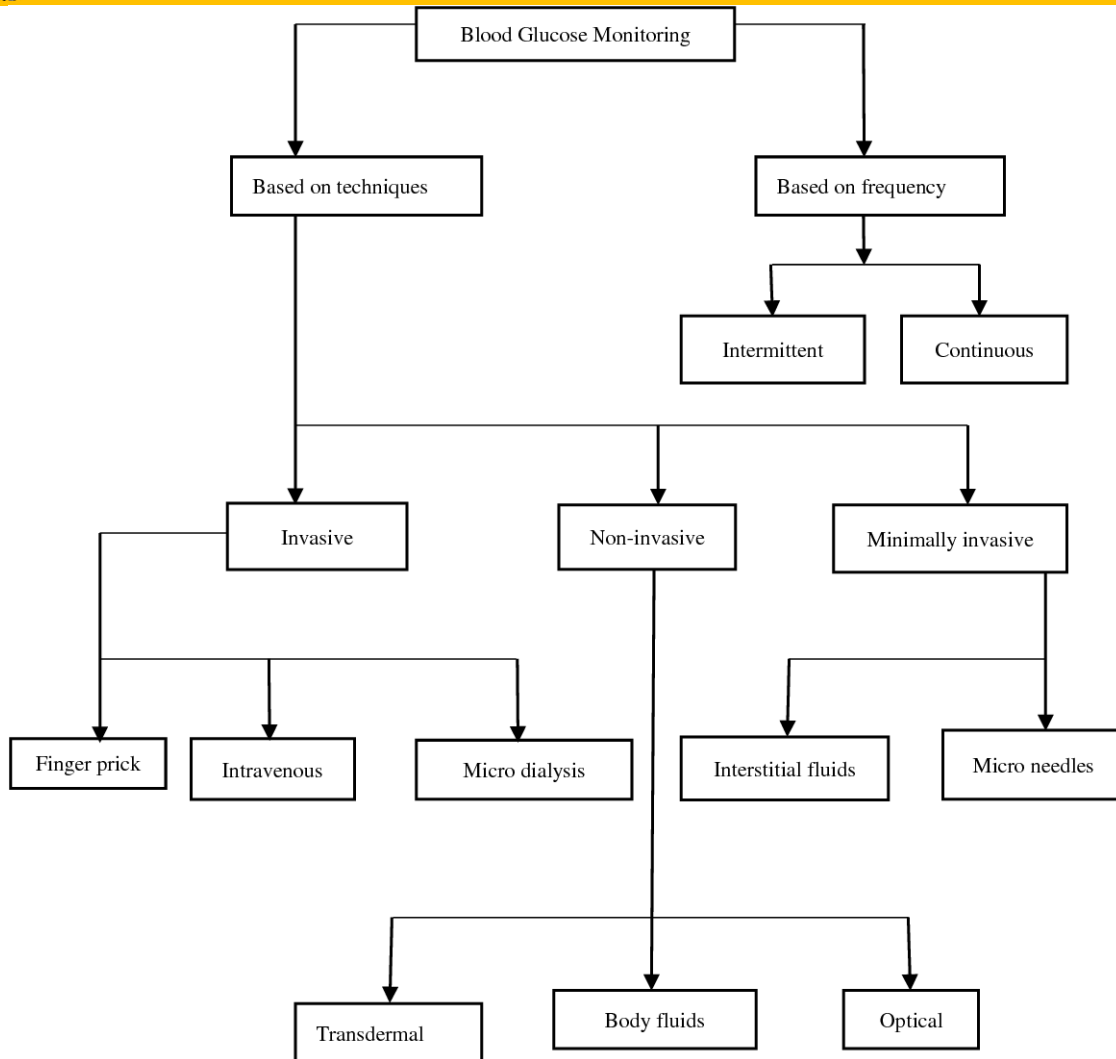


Fig. 1. An overview of blood glucose monitoring techniques [5]

The rest of the paper follows this structure: The section “Analysis of blood glucose monitoring systems and devices” reviewed up-to-date research done in the related field. The section “Results Obtained in the Analyzed Studies” compared the results gained in the analyzed studies. The section “Conclusion” concludes this paper.

Analysis of blood glucose monitoring systems and devices.

In recent years, researchers worldwide have conducted significant studies on the development of blood glucose monitoring devices. In [6], it is conducted research on the practicality of an invasive and continuous blood glucose monitoring system that utilizes an IoT-based approach. The authors developed a system architecture that uses an IoT-based sensor device to provide real-time blood sugar levels, body temperature, and contextual information such as ambient temperature to end-users such as patients and physicians in graphical and human-readable formats. The nRF communication protocol was adapted for the blood sugar monitoring system to achieve high energy efficiency. In addition, the energy consumption of the sensor device was studied and energy harvesting devices were designed for the device. The research work also provides advanced services at the gateway level, such as a push notification service that notifies patients and doctors in case of abnormal situations such as when the blood sugar is too low or too high. The research results demonstrate that the developed system

enables remote monitoring of blood sugar levels in real-time. In [7], it is developed an electronic system that measures blood sugar using Arduino UNO. The device is comprised of two main components: 1) A glucose sensor, which is an electrochemical diagnostic line that utilizes glucose oxidizing enzymes; 2) An LCD module, which displays the measured blood sugar value.

In [8], it is created a non-invasive blood glucose monitoring system. The system is made up of a Raspberry Pi 3 Model B+ single-board computer and a Max30100 sensor. The device's design is based on the principle of Beer Lambert's law, which states that light absorption is directly proportional to the concentration of the medium. The study's findings showed that glucose could be measured with a 10% error rate using this non-invasive method, which was compared with the traditional invasive type of glucometer. The glucose monitoring system is portable and self-monitoring. It is recommended that web and Android applications be developed for this device to make it easy for healthcare centers and doctors to provide assistance to patients. In [9], the goal was to find a way to measure blood sugar without the need for invasive methods. The researchers developed a system that uses NIR spectroscopy with a light source that has a wavelength of 950 nm to determine blood glucose parameters. The photodiode receiver captures the reflected light from a light source illuminating the skin on the wrist. The conditional signal is received and digitized by the Arduino UNO microcontroller. The Arduino board then calculates the spectrum based on the subject's blood glucose level.

An interesting study was conducted in reference [10]. The study describes the development of a patient monitoring system that relies on the Internet of Things (IoT) and a diagnostic predictive tool specifically designed for diabetic patients. This system provides real-time information on blood sugar levels. By using this system, patients can monitor their blood sugar levels regularly and take necessary actions in case of any changes. The main advantage of this system is that it reports the blood sugar level instantly, enabling patients to adjust their insulin intake accordingly.

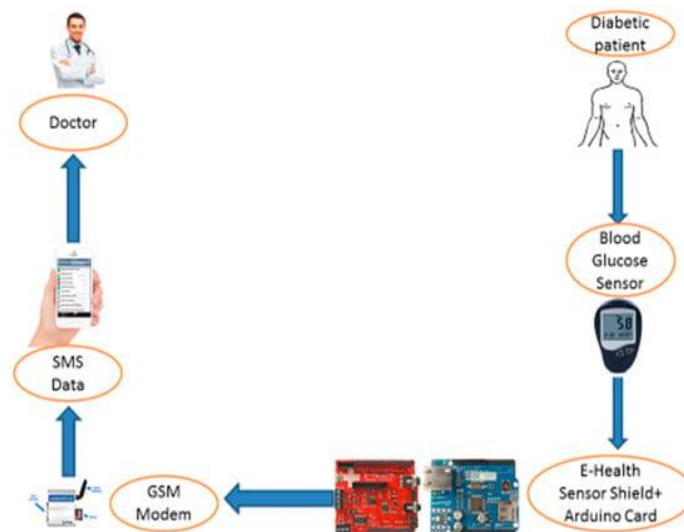


Fig. 2. Illustration of blood glucose measurement [10]

In [11], it is developed a cost-effective portable glucose monitoring system that allows remote data access. This system is based on a novel e-oscilloscope and uses a glucose biofuel cell and a capacitor circuit that is interfaced to an ESP microcontroller. The microcontroller is

programmed to convert the charge and discharge rates of the capacitor, which functions as a transducer, into glucose concentration readings that can be monitored remotely. The glucose monitoring system consists of a glucose biofuel cell, a charge pump circuit, a capacitor, and an ESP microcontroller. The anode of the biofuel cell was fabricated by modifying a gold microwire with nanoporous colloidal platinum (Au-co-Pt), while the cathode was constructed using a mesh dense network of multiwalled carbon nanotubes modified with bilirubin oxidase.

In [12], the Freestyle Free sensor is described along with its many benefits. It offers a low-cost and integrated environment for patients, which allows for continuous monitoring of blood glucose rates. This information can be accessed remotely by doctors and caregivers. Moreover, the data collected from the sensor can be used for data mining techniques to better understand the disease. The patient's data is integrated with the environment using a near-field communication sensor on an Internet of Things card. This data is then sent to the LibreMonitor mobile application. To verify the effectiveness of the integrated environment, the authors compared the glucose rates measured by the official Freestyle Libre software during the same period. Their assessment led to the conclusion that the integrated environment is a cost-effective solution for continuous glucose monitoring of diabetic patients.

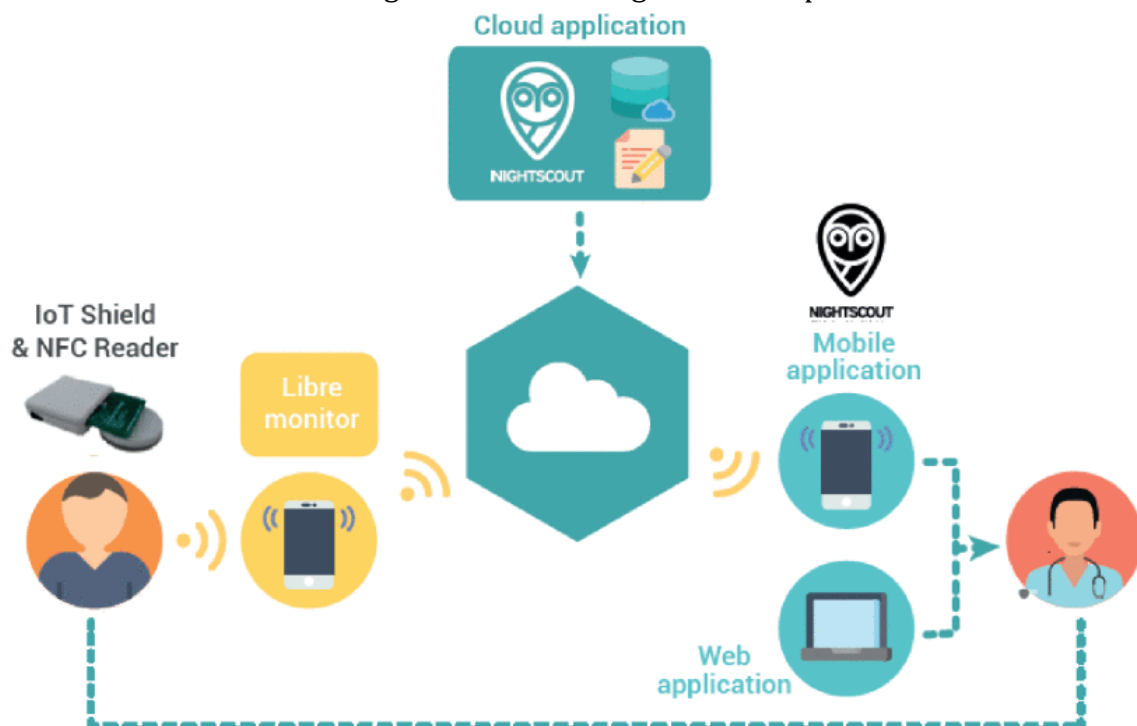


Fig. 3. The proposed architecture. The healthcare professional receives glucose-related data from IoT board devices via a cloud application [12]

In [13], the main objective is to develop a healthcare system that can monitor the glucose level and body temperature of people. The paper proposes the use of two sensors: one for noninvasive blood glucose measurement using near-infrared spectroscopy and the other for measuring body temperature. The system has been designed to consume less power by keeping the microcontroller in standby mode, which will only be activated when there is any change in the measurements detected by the sensors.

In [14], it is introduced an intelligent architecture for monitoring diabetic patients remotely using sensors integrated into smartphones and other smart portable devices. The



architecture includes an intelligent algorithm that can detect whether a parameter has exceeded a threshold, with or without urgency. To test the system, the authors developed a small portable device that measures the level of glucose and body temperature in the blood of diabetics. They also created a secure wireless connection mechanism to link the device with the smartphone.

A non-invasive continuous blood glucose monitoring system, called IR-RING, was developed in [15]. It uses infrared technology to continuously monitor blood glucose levels, heartbeat rate, and oxygen saturation in real-time. The system also monitors heart rate because it varies between glycemic groups. The IR-RING is built on the theoretical concept of Beer Lambert's law and uses an ESP32 microcontroller along with a sensor module identified as MAX30100. The data is transmitted using Bluetooth Low Energy (BLE) through the microcontroller and coded using Arduino IDE 1.8.16. The system generates health vital values that are displayed on a smartphone app built using nRF Connect. Caretakers or physicians can use the app to keep a record of the patient's health, which addresses the most common barrier of keeping track of vital readings.

In [16], it is presented an intelligent system for monitoring diabetic patients using a Node MCU and machine learning algorithms. The Node MCU is connected to the glucometer to periodically record the glucose levels of a diabetic patient. The collected data can be used to remotely monitor patients by their caregivers, including patients, researchers, and doctors. This system aims to simplify the process of adjusting insulin doses and keeping blood sugar levels as close to normal as possible by processing multiple records and interpreting the large amount of data. An intelligent algorithm is implemented in our system, which sends the data to caregivers and stores it in a database as positive or false positive after being validated (or not) by the doctor. In this case study, the included sensors facilitate the monitoring of diabetic diseases.

Results obtained in the analyzed studies.

This section provides information on the results obtained in the articles analyzed in Section 2. The table below shows information about an overview of the developed devices for blood glucose monitoring in terms of functionality presented in the studies analyzed in this paper.



Table 1

An overview of the developed devices for blood glucose monitoring in terms of functionality in the studies analyzed in this research

Ref.	System	Sensor/Component	Applied Network Technology	Microcontroller/Board
[6]	IoT-based continuous glucose monitoring system	Glucose sensor	nRF	ATMega328P
[7]	Digital blood glucose meter	INA219 current sensing module, glucose sensor	N/A	Arduino Uno
[8]	Non-invasive blood glucose monitoring system	Max30100 sensor	Wi-Fi	Raspberry pi 3 Model B+
[9]	Non-invasive glucose monitoring using NIR spectroscopy	IR LED and photodiode pair	N/A	Arduino Uno
[10]	Blood glucose monitoring system	E-Health sensor shield	GSM	Arduino Uno
[11]	Glucose monitoring system with remote data access	S882Z charge pump integrated circuit, glucose biofuel cell	Wi-Fi	ESP8266
[12]	Mobile blood glucose continuous monitoring	Freestyle Libre sensor, NFC BM-019 Module	NFC, BLE, Wi-Fi	RFD77201 board
[13]	Optimized non-invasive blood glucose and temperature body measurement system	AD7793, XL90514 sensor	BLE	CC2640R2F
[14]	Smart glucose monitoring system for diabetic patient	Glucose Sensor, Pedometer	Wi-Fi	ESP8266, Arduino Nano
[15]	IR-RING	Max30100 sensor	BLE	ESP32
[16]	IoT Based diabetic patient Monitoring System	glucose sensor	Wi-Fi	ESP8266

Conclusion.

Diabetics rely heavily on blood sugar monitoring systems for effective management. While finger pricking for self-monitoring (SMBG) remains common, continuous glucose monitoring (CGM) technology provides a deeper look into blood sugar changes. The future is moving towards non-invasive methods that eliminate finger pricks. Promising research in near-infrared technology is paving the way for this. As advancements continue, blood glucose monitoring systems will remain instrumental in empowering diabetics to manage their health.



References:

1. K. Nosirov, S. Begmatov, and M. Arabboev, "Design of a model for multi-parametric health monitoring system," 2020 Int. Conf. Inf. Sci. Commun. Technol. ICISCT 2020, 2020.
2. K. Nosirov et al., "Real-time multi parametric human health monitoring and prediction system," in World Scientific Proceedings Series on Computer Engineering and Information Science, Developments of Artificial Intelligence Technologies in Computation and Robotics, 2020, pp. 639–646.
3. M. Arabboev, "Lora based health monitoring and emergency alarm device," JournalNX, vol. 7, no. 7, pp. 106–111, 2021.
4. M. Arabboev et al., "Analysis of mobile applications created to assess the risk of developing gestational diabetes mellitus," Cent. Asian J. Math. Theory Comput. Sci., vol. 4, no. 11, pp. 39–49, 2023.
5. T. W. Gamessa, D. Suman, and Z. K. Tadesse, "Blood glucose monitoring techniques: recent advances, challenges and future perspectives," Int. J. Adv. Technol. Eng. Explor., vol. 5, no. 46, pp. 335–344, 2018.
6. T. N. Gia et al., "IoT-based continuous glucose monitoring system: A feasibility study," Procedia Comput. Sci., vol. 109, pp. 327–334, 2017.
7. S. A. El-hamid, A. E. Fetohi, R. S. Amin, and R. M. A. Hameed, "Design of Digital Blood Glucose Meter Based on Arduino UNO," IJournals Int. J. Softw. Hardw. Res. Eng., vol. 3, no. 8, p. 8, 2015.
8. V. Adarsh, B. Bhagavantu, K. Nagavishnu, and S. Veerabhadrapa, "Implementation of Non-Invasive Blood Glucose Monitoring System," Int. Res. J. Eng. Technol., vol. 7, no. 6, pp. 1–4, 2020.
9. P. S. K. Reddy, D. Mahesh, C. Uday Teja, M. Janaki, and K. Mannem, "Non-Invasive Glucose Monitoring Using NIR Spectroscopy," J. Phys. Conf. Ser., vol. 2325, no. 1, 2022.
10. Rghioui, J. Lloret, L. Parra, S. Sendra, and A. Oumnad, "Glucose data classification for diabetic patient monitoring," Appl. Sci., vol. 9, no. 20, 2019.
11. Baingane and G. Slaughter, "A Glucose Monitoring System with Remote Data Access," IEEE Trans. Nanobioscience, vol. 19, no. 4, pp. 622–626, 2020.
12. J. J. Rodrigues Barata, R. Munoz, R. D. De Carvalho Silva, J. J. P. C. Rodrigues, and V. H. C. De Albuquerque, "Internet of Things Based on Electronic and Mobile Health Systems for Blood Glucose Continuous Monitoring and Management," IEEE Access, vol. 7, pp. 175116–175125, 2019.
13. H. Ibrahim, M. S. Darweesh, and A. Soltan, "An Optimized Non-Invasive Blood Glucose and Temperature Body Measurement System," 2022 11th Int. Conf. Mod. Circuits Syst. Technol. MOCASST 2022, pp. 1–4, 2022.
14. Patient, "A Smart Glucose Monitoring System for," pp. 1–18, 2020.
15. S. Sathishkumar, S. Balasubramanian, D. Sridhar, R. Ramesh, and M. G. Sumithra, "IR-RING: Non-invasive Continuous Blood Glucose Monitor," 6th Int. Conf. Electron. Commun. Aerosp. Technol. ICECA 2022 - Proc., pp. 330–334, 2022.
16. Rghioui, A. Naja, J. L. Mauri, and A. Oumnad, "An IoT Based diabetic patient Monitoring System Using Machine Learning and Node MCU," J. Phys. Conf. Ser., vol. 1743, no. 1, 2021.