IoT Based Non-Invasive Blood Glucose Measurement Using Galvinic Skin Response Sensor

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Abstract

A non-invasive blood glucose testing method would encourage continued use, provide better diabetic treatment, and allow for long-term continuous glucose monitoring without any discomfort. This study describes the creation of a non-invasive glucose measuring device employing a Convolution Neural Network (CNN) algorithm and a very effective regression model. Using electrochemical properties measured by a GSR sensor, this approach allows painless assessment of the glucose level at a preset interval of time. The ThingSpeak IoT cloud receives continuously recorded data in the future. With user defined authentication, you may aggregate, visualise, and analyse real-time data streams in the cloud using the ThingSpeak IoT analytics platform service.

Keywords: Non-invasive, FBGL, CNN, GSR sensor.

I. Introduction

Diabetics mellitus is a widespread health problem among common people globally. At present, 415 million people are suffering worldwide and estimated to reach 642 million by 2040 [1]. Untreated diabetics can cause various medical complications such as heart diseases, diabetic retinopathy and kidney dysfunction. Hence, to avoid the health complication, the most common invasive method is adopted to regularly monitor Fast Blood Glucose Level (FBGL). However, it poses a risk of contamination and sepsis through the self-test kits. To mitigate the invasive method of

FBGL monitoring, alternate non-invasive methods are under studies to monitor FBGL through biofluids such as urine, saliva, tears and sweat. This has enabled the development of continuous glucose monitoring system that provide glucose information at any specified interval of time. Increase in the development of sensor technology, interest has been recently increasing in non-invasive diagnostic testing for glucose using Galvanic skin response (GSR) [2]. A quick, practical, and repeatable technique for measuring autonomic nerve responses as indicators of sweat gland function is galvanic skin response (GSR). Electrodermal activity (EDA), psychogalvanic reflexes, or skin conductance responses are other names for the galvanic skin response (GSR). GSR signals are created by variations in body conductivity and body resistance as a result of the body's reactions to sweat gland secretions. The prototype of the system that was created utilising galvanic skin response transfers data to a PC using a USB cable. However, since data transfer using a USB cable has a flaw in terms of measurement distance, it can be modified to include wireless data transfer. A single user sees the obtained results, and the corresponding medical gadget is utilised for self-monitoring. The authorised users may receive access to the monitored data over the Internet. The results can typically be obtained immediately or after a brief delay. They are classified as near real time if the delay is under two minutes, or as real time if it is under thirty seconds. The monitored data is transferred to ThingSpeak, a private cloud for the Internet of Things (IoT). ThingSpeak is an IoT analytics platform service that enables user-defined authentication while aggregating, visualising, and analysing real-time data streams in the cloud. From your devices, you can send data to ThingSpeak, visualise live data instantly, and send alerts[3].Further in this paper, literature survey is done on various non-invasive methods and is given in section 2, section 3 briefs about the adoption of CNN algorithm with logistic regression model and development of hardware prototype. Section 4 discuss about outcomes of the experimental trials with the prototype. Finally, in section 5 conclusion of the proposed work is briefed.

II. Literature Review

Establishing reliable non-invasive calibration models to measure FBGL in the typical settings of a patient's life is the difficult task of this research. Finally, the new generation of bloodless glucose instruments should be equipped with technologies that eliminate competing biochemical pathways and interfering species with low cost, quick response, accuracy, and simple calibration procedures, improving patient comfort and preventing long-term complications.

Sarul Malik et al. (2019) proposed that it is possible to assess FBGLs in healthy and diabetic adults by combining salivary electrochemical factors like oxidation-reduction potential (ORP), pH, conductivity, and specific cationic concentrations. The mathematical procedures used for this was that the output classes were restricted. That is, the value 0 below a threshold FBGL and the value 1 above it. The algorithms artificial neural network, logistic regression, and support vector machine were included for modelling the prototype.

According to Gaobo Zhang et al. (2018), their implementation procedures include a novel algorithm for acquiring PPG signals recorded using video camera in the smart phone. The PPG signals are categorized by using fitting-based sliding window algorithm to remove varying degrees of baseline drifts and segment the signal into single periods and extricating characteristic features from the Gaussian functions by comparing Photoplethysmography (PPG) signals at various blood glucose levels.

Praful P. Pai and others, 2017. A continuous non-invasive glucose monitoring system for diabetics is being developed using near infrared photoacoustic spectroscopy. Field Programmable Gate Array (FPGA) is used to construct a portable embedded system for photoacoustic measurements on tissues to calculate glucose levels. The author suggests a cloud computing platform for automatic blood glucose monitoring so that people with diabetes can communicate with their doctors and carers. A mobile device is used to connect the created system to the cloud service, which makes it easier to carry out computationally demanding calibration operations and to store and analyse measurement data for treatment and monitoring.

In Sarah Ali Siddiquib et al.'s (2018) classification of non-invasive procedures, we further divided them into optical, non-optimal, intermittent, and continuous techniques. According to Satyanarayana et al. (2019), optical methods are one of the painless and promising approaches that can be employed for non-invasive blood glucose measurement. Since near-infrared light (NIR) penetrates the skin so deeply, it is thought to be the optical technique that is utilised the most frequently. These methods are used on the earlobe, finger, forearm, and palm, among other parts of the body.

An on-chip disposable nano-biosensor offering a painless test methodology and adequate sensitivity was proposed by Wenjun Zhang et al. in 2016. Since it is disposable, substantial cleaning or electrode pre-treatment between measurements are no longer necessary. According to S. Lekha and Suchetha.M. (2020), analysing a person's breath can be a useful, non-invasive way to keep track of their blood sugar levels. certain biomarkers are found in breath, and tracking their levels reveals the potential presence of certain chronic conditions.

A method for fabricating and validating a standalone portable optical biosensor for non-invasive glucose monitoring using saliva was developed by Amit Kumar Singh and Sandeep Kumar Jha in 2019. To address this, a biodegradable, inexpensive glucose test strip was created by co-immobilizing the glucose oxidase enzyme with the pH-sensitive bromocresol purple dye. A freestanding electronic metre was used to monitor the pH change that the enzymatic reaction caused, which in turn caused a change in the colour of a filter paper strip.

Using saliva samples and a smartphone, Anuradha Soni and Sandeep Kumar Jha's (2017) research focuses on the creation of a non-invasive optical glucose biosensor. The sensor was created using a straightforward process by immobilising glucose oxidase enzyme and a pH-responsive dye on a strip made of filter paper. Red Green Blue (RGB) profiling on a smartphone camera was used to detect the colour changes caused by the strip's response with salivary glucose.

The invention of a non-invasive method to measure blood glucose using a galvanic skin response (GSR) methodology is presented by Saad et al. in their paper from 2020. GSR has already been employed in numerous applications, including lie detection and emotion monitoring. Blood glucose reading detection using GSR application has demonstrated remarkable potential. The goal of the experimental investigation was to investigate the relationship between skin conductance and blood glucose levels by analysing the conductivity of the GSR sensor.

III. Proposed Methodology

The proposed work presents a high efficiency proof-of-concept study in which blood glucose monitoring by galvanic skin response sensor to estimate FBGL. The estimation is based on the variation of electrochemical parameters of sweat is sensed by GSR sensor. An efficient CNN algorithm with logistic regression model predicts the glucose levels with good accuracy.

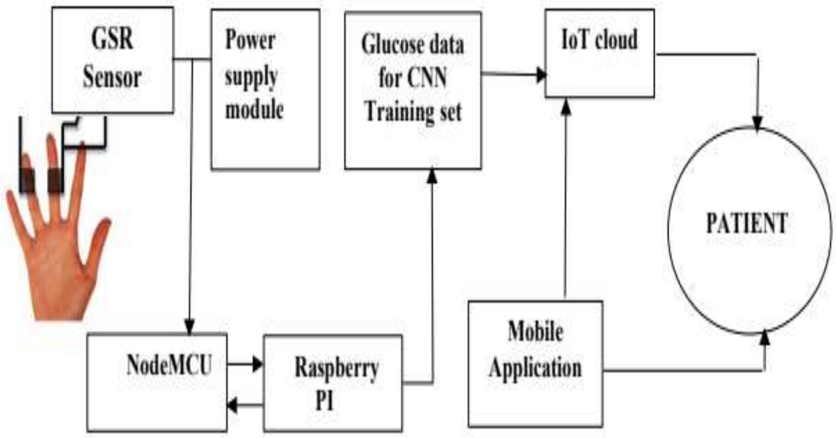

Figure 1: Block Diagram of proposed Non-Invasive glucose measurement using GSR Sensor

The simple block diagram of the proposed system is shown in the fig 3.1. The detecting algorithm uses machine learning techniques such as CNN algorithm with logistic regression (LR) model. The ooccurrence of elevated FBGL was estimated noninvasively using the status of an individual's electrochemical parameters of sweat such as pH and conductivity.

Meanwhile, Accu-check is a commercial usage kit with medical ethical clearance, the initial dataset was gathered utilising an intrusive manner using Accu-check. The tool comprises of a lancing device that is used to prickle the subject's finger and draw blood. The blood sample that was collected is put on the accu-chek. The performa strip is inserted into the device, and the accu-chek device displays the quantity of glucose concentration. For assessing blood glucose levels, the procedure uses an average of 0.6 L of blood and yields an immediate response in 5 seconds. To reduce battery usage, it automatically turns on when the strip is inserted and turns off when the testing is over. It can store the data for 72 h when the battery is removed.

A. GSR Measurement

We can monitor sweat gland activity, which is correlated with emotional arousal, using a GSR sensor. We make use of the electrical characteristics of the skin to measure GSR. Specifically, the relationship between skin resistance and sweat gland activity, i.e., how perspiration increases with sweat gland activity and decreases skin resistance. Resistance is not the most typical way to measure a GSR signal; rather, conductance is. Since conductance equals one divided by resistance, it is the polar opposite of resistance and is measured in siemens. Since the skin conductance increases with sweat gland activity, the conductance facilitates the interpretation of signals. The most popular approach for measuring a GSR signal for emotional study is the exosmotic method. It is based on a system with continuous voltage. Any variation in the current flow results from a change in the electrical characteristics of the skin, which in turn affects the activity of the sweat glands. The signal is sent from the electrode to the wire, which is often a lead, and then to the GSR device. Data is gathered at sampling rates ranging from 1 to 10 Hz, and it is measured in micro-Siemens (S) units. Once the data has reached the GSR device, it is either stored there to be uploaded later, wirelessly communicated to a computer system, or the signal is relayed through a subsequent cable linking to a computer.

IV. Simulation and Results

The primary algorithm utilised in this study is logistic regression, and Python IDE is used to conduct the analysis. The experiment primarily makes use of two datasets, one with few data collected from the medical labs locally and the other, the Indians Diabetes dataset PIMA, which was originally from the National Institute of Diabetes and Digestive and Kidney Diseases. The two approaches used for feature selection which boost performance by making more accurate predictions than a single model. With reference to the few data obtained, for experimental analysis of our proposed system, the input data parameters are pH values of sweat samples, age, gender, type of diabetics as shown in table 4.1.

Table 4.1. Glucose Parameters/ Input Data for Implementing CNN using Python

Parameters	Values
Gender	Male, Female
Sweat pH	6.3 mg/mol Range 4.5 to 7.0 mg/mol
Sweat Glucose	18.9 mg/mol
Type	A or B

A. Simulation Output

To estimate the FBGL, the inputs are fed to the CNN algorithm with logistic regression model is embedded in Raspberry pi 4.0 interfaced with GSR sensor. The GSR sensors electrical parameters and evaluates the glucose level equivalent to FBGL.

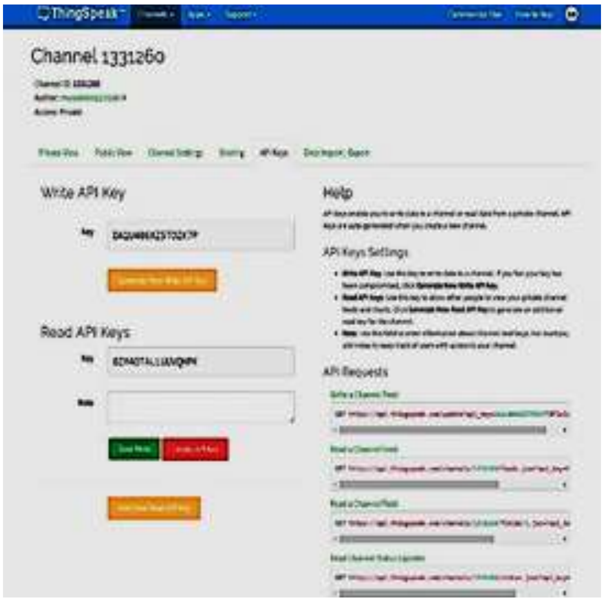

Figure 2: IoT Cloud Server (API Request)

The evaluated data is transferred to the ThingSpeak cloud and using IoT cloud server with Application Program Interface (API) request, it is interfaced to remote mobile devices for data visualization as shown in the figure 2.

Figure 3: Channel status of Non-Invasive BGL

Figure 3 shows the channel status of the non-invasive BGL estimation. The channel status provides visualization updates and is used to show status messages in the ThingSpeak Channel. If channel status is not set, then the data cannot be visualized and authentication by user is failed.

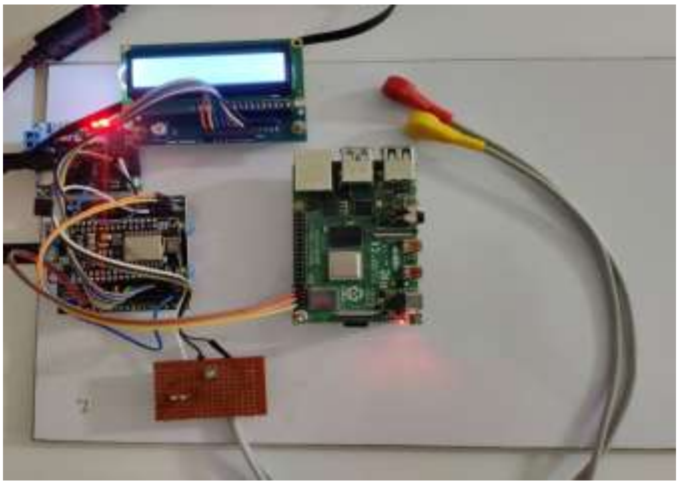

Figure 4 Hardware Prototype

Figure 4 shows the implementation of CNN algorithm with logistic regression model in the embedded processor. The prime components are Bio-sensor, Raspberry pi 4.0, supply unit, display unit and other interfacing accessories. The hardware possesses data management with the help of IOT cloud to access the data for both user interface and the doctor or Hospital.

Figure 5. Glucose level display mobile app interfaced with the cloud.

Figure 5 shows the estimation of glucose level using the proposed non-invasive method through IoT cloud to blynk application in the mobile device.

V. Result and Conclusion

This paper presents a implementation of IOT based Non-invasive FBGL monitoring system with CNN algorithm to measure and estimate the glucose level using electrochemical parameters in GSR sensor. A precise compatible prototype is developed for continuous glucose monitoring system that provide glucose information every 5-10 min. The recorded data is uploaded into the ThingSpeak cloud and the data is visulazed through the mobile devices. The CNN algorithm with logistic regression model is implemented in the hardware component which consists of embedded processor, Bio-sensor. The data management process is achieved with the help of IOT cloud to access the data for both user interface and the doctor or Hospital.

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