iGLU: Non-invasive Device for Continuous Glucose Measurement with IoMT Framework

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***Abstract*—The extended abstract is for a Research Demo Session based on our previous article [1]. There is a requirement of Continuous Glucose Measurement (CGM) to control diabetes by insulin secretion or medications. A novel non-invasive measurement device iGLU is introduced to determine continuous blood glucose value with optical detection technique. iGLU model is integrated with Internet of Medical Things (IoMT) framework for remote located diabetic patients to provide prescribed diet and medication with the help of diabetologist.**

I. Introduction

Diabetic patients have doubled since last decade around the world with an estimated 422 million diabetic people have been reported in 2019. There is a requirement to design the solution for the glucose measurement of the diabetes patients. People would be more aware of their diet control after continuous monitoring [2]. No smart healthcare solution for glucose measurement is available in the market till date.

Sometimes diabetic patients require to measure the glucose atleast 3-4 times in a day during some critical condition [3]. The traditional method of blood glucose measurement is through pricking blood drop. The present available Continuous Glucose Measurement (CGM) devices are neither accurate nor cost-effective [4]. In order to mitigate the issues, we present a non-invasive iGLU device with Internet of Medical Things (IoMT) framework to provide the state of art solution for smart healthcare.

II. The Design Flow for iGLU

The proposed device for blood glucose measurement is a low cost solution with high accuracy. The device is capable to measure the blood glucose of any type of patients at any time. The device is user-friendly, fast operated and effective for smart healthcare [5]. A novel non-invasive intelligent device is proposed using NIR light with specific wavelengths for instant glucose measurement which overcome the chances of blood related diseases. The process flow diagram of proposed solution is shown in Fig. 1.

Proposed iGLU device uses the concept of NIR spectroscopy with multiple short wavelengths. The device is implemented with three channels where each channel is embedded for particular wavelength with emitter and detector. The reflectance and absorption spectroscopy of 940 nm are considered, whereas the absorption spectroscopy at 1300 nm is selected for the detection of glucose molecules [6]. The processing steps for our non-invasive continuous measurement is in Fig. 2.

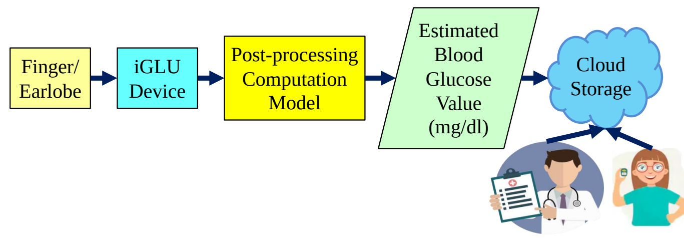


Fig. 1: Non-invasive glucose level measurement using iGLU in IoMT.

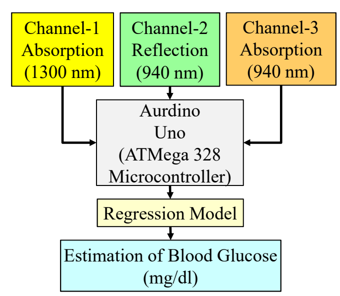


Fig. 2: Processing steps for the Proposed iGLU.

III. Machine Learning based Regression Model

The estimation of blood glucose value is obtained through the calibration process with optimized Regression Models (RM). The output voltages from three channels are considered as input vectors to predict the output value of blood glucose. The trained optimized regression model is cross validated to confirm accuracy in measurement and the device is tested on healthy, prediabetic and diabetic patients by following measuring protocols. There are consideration of total 97 subjects (or samples) and each sample from the subject is used to calibrate the device. The process flow of calibration and validation is shown in Fig. 3. After training and cross validation, all observations are existing in the zone A and zone B according to Clarke error grid analysis which suggest that our proposed device is advisable for measurement [1]. The proposed device is also tested on person aged 17-75 along with different prandial modes with all kinds of people. The proposed non-invasive glucose measurement device is precise in the range of 80-420 mg/dl.

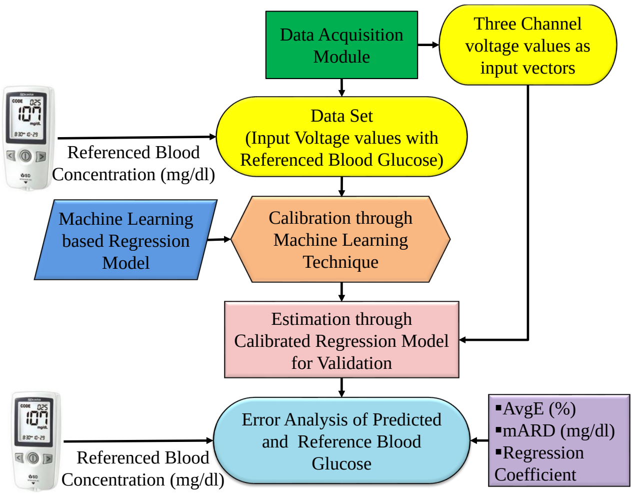


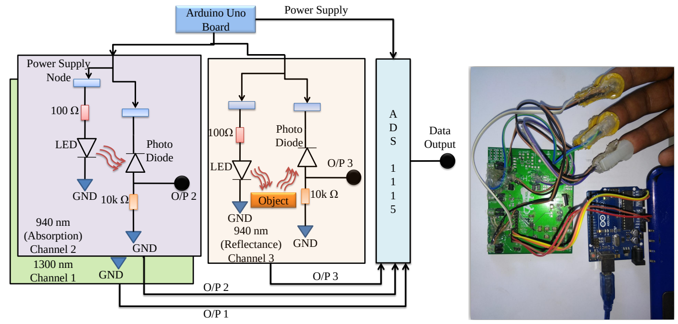
Fig. 3: Calibration and Validation of proposed iGLU device.

IV. iGLU Proof of Concept Prototyping

The proof of concept of iGLU is prototyped using system on chip (SoC) with components like LEDs, detectors, ADC with noise filtering capability and frame acquisition controllability (Fig. 4(a)). These components are embedded on single 2 layer PCB to have portable continuous glucose measurement device. The data is collected and is further processed with help of 16 bit ADC at sampling rate of 128 samples per second. The efficient model for regression is analysed to have accurate blood glucose estimation. The PCB has infra-red emitters (TCRT1000 -for 940 nm,TSAL6200 -for 940 nm, MTE1300W -for 1300 nm) and detectors (TCRT1000 -for 940 nm, 3004MID -for 940 nm, MTPD1364D -for 1300 nm). ATmega328P microcontroller is used for the conversion of the data (in terms of Voltage) to the decimal form. The deployment of iGLU for measurement is shown in Fig. 4(b). The values of voltages from three channel are obtained and are shown in Fig. 5(a).

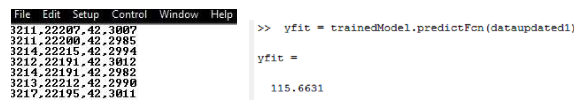
The coherent averaging has been applied on these collected data to stabilize the value. The Deep Neural Network (DNN) is applied to predict the blood glucose values. The sigmoid activation for DNN is considered with training through Levenberg-Marquardt backpropagation algorithm. The proposed neural network has total 10 hidden layers of neurons, whereas each individual layers comprise of 10 neurons. The output from one neuron of a hidden layer is the input the next layer neuron. The overall structure would provide the prediction output value of blood glucose (in mg/dl) and it is shown in Fig. 5(b).

The accuracy of predicted blood glucose values have been compared with standard SD Check glucometer. The results of average error (AvgE) and mean absolute relative difference



(a) iGLU System Schematic (b) iGLU Deployment

Fig. 4: The design and prototype of iGLU [1].



(a) Three channel Data (b) Time interval of 60 minutes

Fig. 5: The results for validation of iGLU.

(mARD) are reported as 4.66% and 4.61% respectively. The value of the regression coefficient is obtained as 0.81.

V. Conclusion

This work presents a novel non-invasive device for the continuous glucose measurement for smart healthcare. NIR lights of specific wavelengths are used for the device prototyping for glucose molecule detection. The developed device has been calibrated and validated through all kinds of subjects. The estimation of glucose values are done using deep neural network. The device has been integrated with IoMT framework for patient monitoring, storage of glucose values and cloud access by caregiver for further treatment.

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