NON-INVASIVE BLOOD GLUCOSE MONITORING DEVICE

Dr. Manjula E[1], Rohini A Tirakannavar[2], Shilpa B Sali [3], Shilpa M Itnal[4], Zoya Roshan Desai[5]

[1]Doctor, SG Balekundri Institute of Technology, Belagavi, Karnataka, India
[2,3,4,5]Student, SG Balekundri Institute of Technology, Belagavi, Karnataka, India

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Abstract- *Noninvasive glucose sensing has emerged as a key research area, mainly due to the worldwide rise of diabetes, and the drawbacks of the traditional invasive glucose measurement methods. Although finger pricks are accurate, they are painful, inconvenient, and not suitable for continuous monitoring. This paper details the conceptualization, creation, and testing of blood Glucose level without plucking of the blood and creation of a inexpensive, non-invasive glucose measurement system based on Near Infrared (NIR) spectroscopy. The system incorporates an NIR LED source, a photodiode sensor, an Adriano-based processing unit, and a Wi-Fi module for wireless data transmission. The prototype decodes the signals of the reflected NIR light from human skin to find the glucose concentration. Experimental findings show that the behavior is quite promising and therefore, suitable for the very first stage of research and implementation in the academic field. This research is a step forward in portable health monitoring and can serve as a model for the community, in terms of system architecture, the calibration process, and performance evaluation, all of which are easily reproducible.*

Keywords- Non-Invasive monitoring, NIR spectroscopy, IOT healthcare, Adriano, Glucose estimation, biomedical electronics.

1. Introduction

Diabetes mellitus is on its way to becoming the main health problem that is rapidly expanding all over the globe. The (WHO-WORLD HEALTH ORGANIZATION) has been reporting that the number of individual diagnosed with diabetes worldwide has exceeded 422 million and the trend is going to be even steeper in a pretty short time in the future. To be able to manage the disease well and avoid long-term complications it is necessary to constantly monitor blood glucose levels. Unfortunately, the currently prevalent invasive methods entail noxious skin puncture by means of lancets, hence the caused pain, risk for infection, and test frequency lowering due to user discouragement.

Non-Invasive monitoring solutions have been discussed when talking about state-of-the-art sensing technologies. In particular, Near-Infrared (NIR) spectroscopy is the dominant promising one since it ia well suited to go through the tissue and bond with glucose
Molecules. Glucose has significant absorption peaks in the NIR wavelength band (700-2500 nm).

This invention is intended to come up with a pocket-size, easy-to-operate, and low-price non-Invasive glucose monitoring prototype. The system incorporates an NIR LED source, a photodiode, and an ESP8266 Wi-Fi module for wireless communication. The goal is to present a proof-of- concept prototype that can perform glucose level estimation from a non-blood source.

1.1 LITERATURE SURVEY

Multiple Research studies have been widely explored on the non-invasive glucose monitoring by different principles. These principles include optical, thermal, ultrasonic, and electromagnetic sensing.

A. Optical Glucose Sensing-

Near-infrared (NIR) spectroscopy has been one of the most intensively studied methods in this area. The researchers like Ikeda et al. demonstrated that glucose molecules absorb specific NIR wavelengths, thus allowing concentrations to be estimated by.

B. Challenges in Previous Studies-

- Previous research studies have identified multiple significant challenges:
  • Signal noise due to skin thickness variation • Ambient light Interference
  • Non-linear optical absorption patterns

• Calibration requiring individual skin properties. These limitations impact the level of accuracy and repeatability. In addition, enhancements in sensors, microcontrollers, and digital filtering have turned up the reliability of low-cost optical systems to a great extent.

C. Gaps Addressed in this Work- This research offers:

• A simplified and reproducible hardware prototype
• Low-cost components suitable for academic research
• Wireless monitoring capability.
• Basic calibration methodology.

2. METHODOLGY

The methodology presents the entire sequence of hardware, sensing, signal processing, and calibration steps that were implemented to develop the prototype.

- **System Architecture**

The system comprises four essential elements: Optical Sensing Unit – NIR LED (940 nm) and photodiode fixed on the opposite edges of the fingertip, Signal Conditioning Circuit – Photodiode output is amplified and filtered, Processing Unit – Arudino UNO functions as a tool for digitization and computation, Output and Connectivity – LCD display and ESP8266 Wi-Fi module, Data processing: Starts with the optical signal and ends with the estimation of glucose on the display.

- **Optical Sensing Mechanism NIR Illumination**

Light from a Near-Infrared LED with 940nm wavelength travels through the fingertip. Part of this light is absorbed by glucose molecules, while the rest goes out.

Photodiode Detection – A photodiode placed opposite the LED collects the transmitted light. When the amount of glucose concentration fluctuates, it also changes the amount of light that reaches the detector. This change in light creates variations can be quantified.

- **Signal Conditioning Stage**

The Photodiode generates a very small current, which has to be converted and cleaned before digital processing. The conditioning circuit has - a Trans impedance amplifier to convert current to voltage, Band-Pass filter to remove noise, motion artifacts, and ambient light interference, A voltage amplification stage is employed to elevate the signal detected to a level which is suitable for input to the Arduino. At this point, the microcontroller is ensured to receive only those optical modifications which are required for accurate processing.

- **Digital Processing and Glucose Estimation**

The Arduino takes on several roles:

1) Analog-to-Digital Conversion – The conditioned signal is sampled by the ADC and averaged to lessen noise. Besides this, it also involves peak voltage; Normalized transmitted intensity, Absorption index values.
2) Regression- Based Calibration – By comparing optical readings with standard glucometer values, a polynomial regression model is generated. The calibrated model is then employed to determine glucose level, reduce signal variations, and improve overall measurement accuracy.

- **Display and wireless Output**

The estimated glucose value is shown to the user by a 16X2 LCD. For remote monitoring, the ESP8266 module can be connected to the app or cloud service. The system supports real-time data updates and continuous tracking.

- **Calibration Procedure**

The process of calibration is the key to precision. It involved: Gathering sensor readings, measuring reference values with a glucometer, using regression to relate both data sets, updating the coefficients in the Arudino Program and, finally, performing Calibration repeatedly until the error reached an acceptable level.

- **Framework**

Besides security, the framework features adaptive intelligence that can learn each user's behavioral patterns, which allows the system to tailor reminders, anticipate confusion or stress, and regulate support as the patient's cognitive condition evolves. Being aware that a lot of care environments have unstable internet connectivity, the system is also designed for dependable offline working through local data storage, uninterrupted operation of essential modules, and fallback communication methods, such as SMS or Bluetooth, for emergencies.

To make the technology accessible to individuals with limited digital literacy or cognitive impairments, the system has been created to be simple, intuitive, and easy to use. The interface is intended to be inclusion and intuitive, with simplified controls for caregivers and clear visual, auditory, and multilingual options for patients. Altogether, these features are aimed at creating a more trustworthy, adaptable, and user-friendly solution that meets the challenges of dementia care in the real world.

A. Block Diagram

The system can monitor glucose level in a person's blood by utilization of NIR light emitted from a specialized source and a photo detector that is situated on the opposite side of the fingertip. When NIR light hits the biological tissue, in the blood. Portion of the light is absorbed depending on the glucose levels, while the other is allowed to pass through the fingertip. The strength of the transmitted light varies according to the quantity of glucose present in the blood, making it possible to estimate the concentration.

The photo detector is employed to capture the transmitted light signal and produces minor current, which is then converted into voltage. This voltage is filtered to remove Noise and is amplified to a level that may be utilized by the microcontroller.

The conditioned signal is delivered to the Arduino microcontroller, where it is digitally processed. A second- order regression model is utilized for glucose level estimation. The glucose concentration that has been determined is visually presented on the LCD screen and at the same time, it is sent via Bluetooth to a mobile application. Hence, this information accessible to the user viahis/her mobile phone.

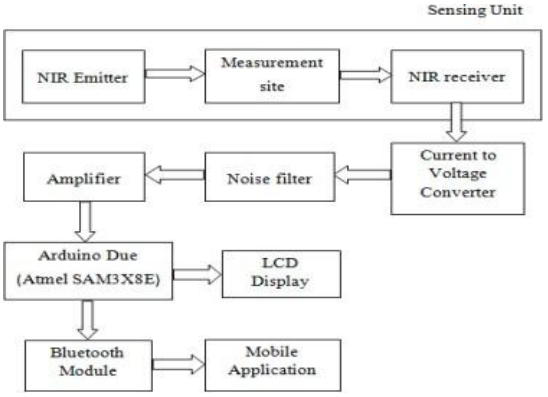


Fig .3 1. Block Diagram

- WI-FI Module:

ESP 8266 Description:

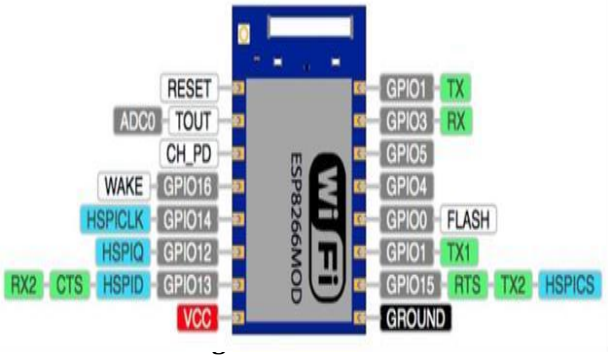
The ESP8266 is a WIFI module based on a single chip compact system-on-chip (SoC) with the TCP/IP stack already included, which makes any microcontroller capable of connecting to a Wi-Fi network. Besides Wi-Fi and internet protocol stack, it can work as a stand-alone device with its own application or as a Wi-Fi co- Another processor. ESP8266 comes with AT command firmware, which allows easy communication with Arduino boards, thus adding wireless capabilities easily as if by a Wi- Fi Shield. One of the cheapest and most popular devices out there is also supported by a large and constantly growing developer community.

The module contains enough computational power and onboard memory to directly interface with sensors and other application-specific hardware. It can very well be a part of IoT-driven designs.

In an Internet of Things (IoT) environment, numerous devices -usually embedded software-equipped- either communicates with the internet or among themselves. Individually, these are very limited in their capabilities so they have to be interconnected in order to function properly. The real power of IoT is when these devices connect to a central service, which manages data, handles communication, and performs functions ranging from simple monitoring to complex analytics. This service is the backbone of the ecosystem that guarantees the smoothness of the interaction among all connected elements.

The unit supports Wi-Fi 802.11 b /g /n standards, and thus can use Wi-Fi Direct (P2P) along with soft-AP mode. It is a fully integrated TCP / IP protocol stack kind of device and also includes a TR switch, balun, low-noise amplifier (LNA), power amplifier, and matching network for efficient RF performance. The device also has key parts like PLLs, regulators, a DCXO, and power management units.

It has a maximum output power of +19.5dBm in 802.11b mode and extremely low power-down leakage current of less than 10 μA. The device is equipped with 1 MB of flash memory, and a low power 32-bit CPU, which can function as an application processor. A few of the connectivity options are SDIO 1.1/2.0, SPI, and UART interfaces.



Thing speak

The internet of things (IOT) represent a system made up of 'connected things'. These things generally consist part of an embedded operating system and the ability to communicate with the internet or with the 'neighboring' things. One of the core elements of a generic IoT system that acts as a bridge for various 'things' is an IoT service. An interesting implication of 'things' that make up the IoT systems is that things alone cannot do anything. They must at least be capable of connect to other 'things'. However, the real power of IoT is obtained when the 'things' connect to a 'service' either directly or through other'things'. In such systems, the service acts as an invisible manager by offering functionalities that range from simple data collection and monitoring to complex data analytics. The diagram below shows where an IoT service is positioned.

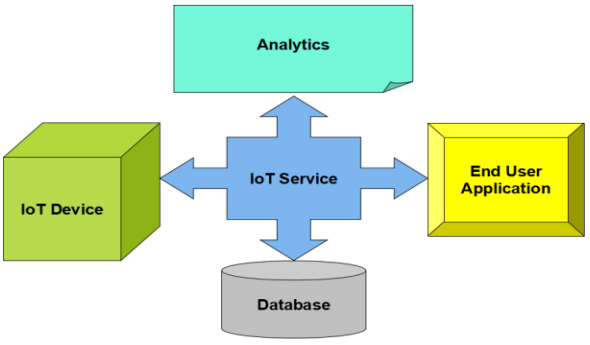


Fig. 3.3 Program the Arudino UNO to function as an ISP

Arduino IDE Compiler:

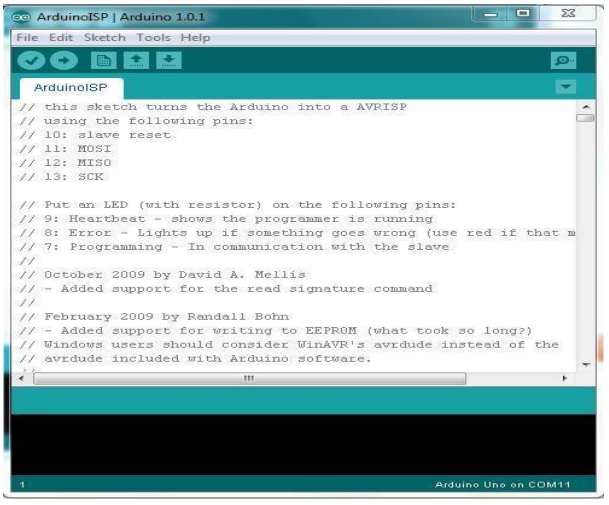
This process goes beyond the simple idea of programming an Arduino on a breadboard. First of all, a microcontroller with a pre-installed boot loader must be used or the boot loader has to be loaded manually if it does not there. (A boot loader is a

small program stored on the microcontroller that allows uploading sketches to the chip). It is important to point out that not all ATmega328 chips are configured in the same way.

In order to put the boot loader It is up to serve and configured on the Arudino UNO In-System Programmer (ISP) , which gives it the functionality of the software-based microcontroller.

Steps:

1. Open the Arudino IDE Software on your computer.
2. Start the Arudino ISP example sketch under File → Examples.
3. For IDE version 1.0 find the heartbeat function void and change the delay value from delay(40); to delay(20);.
4. Connect the Arduino UNO to your PC and make sure that it has no connection with the breadboard circuit at this moment.
5. Choose the right UNO board from the Tools → Board menu and upload the sketch.



In the Arduino IDE open the Tools menu and select Arduino UNO under the Board settings. After that, choose the correct serial port that is connected to your device. Then set the Programmer option to Arduino as ISP. Once all configurations have been set and then use the tools menu to burn the boot loader. The IDE will then show a message that indicates the writing of the boot loader to the target board, and it may be need a short duration to complete. Success boot loader message Once the boot loader is installed, a confirmation

"Congrats: You are now set to transfer sketches to the Arudino connected on a bread board!"

3. CONCLUSION AND FUTURE SCOPE

Every part included within the system hardware has been chosen and put together with the main objective of this device is to good functioning, smoothly and efficiently. The inclusion of each module in the proposed system has been built with a definite idea, thus leading up to the overall capability of the gadget. Backed by current technology and advanced integrated circuits, the project is in its mature stage, i making them inappropriate for frequent or continuous use. Hence, to address these issues, this project proposes a non-invasive glucose monitoring technique based on near-

infrared (NIR) LED sensing. The glucose value obtained by the photo detector is processedAnd displayed both on the LCD screen as well as the connected mobile application. This compact non-invasive instrument is a dependable and easy-to-use device for diabetes management that is equally suitable for home use, as well as healthcare institutions.

- Possibility of improved precision through progress in sensor technology.
- Incorporation of artificial intelligence for real-time data processing and prediction insight..
- Improved connectivity features could allow the device to be smoothly integrated into bigger healthcare networks and digital monitoring platforms.
- Component miniaturization for better portability and user convenience.
- Implementation of cloud-based analytics for personalized healthcare management.

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