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GlucoScan: Noninvasive Glucose Monitoring Device

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ABSTRACT

Prediabetes impacts many worldwide and may progress to diabetes. Prediabetes may be treatable, but most are unaware they have it. This paper proposes a new device for non-invasive measurement of change in blood glucose through a wearable finger clamp system using optical spectroscopy with visible wavelengths. Change in blood glucose discretely and over time provides valuable information for health tracking, prediabetes, and diabetes.

KEYWORDS

wearable technology, optical spectroscopy, glucose tracking

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1 INTRODUCTION

Diabetes is a disease that impacts around 400 million people across the world [9]. It causes numerous issues including shortened life expectancy, decreased quality of life, cardiovascular issues, and more. Prediabetes can be a precursor to diabetes characterized by blood sugar levels that are higher than normal but lower than diabetes [8]. Prediabetes may be treatable and reversed through lifestyle changes, but most people are unaware they have it. Diabetes is traditionally monitored with frequent blood glucose testing which is invasive and requires drawing blood for accuracy. By tracking blood glucose and overall trends, we can monitor the progression of prediabetes.

Blood glucose monitoring has other applications outside of diabetes and has led to a new class of devices that are less invasive by tracking biomarkers as estimations of blood glucose. Continuous Glucose Monitors (CGM) measure interstitial fluid in the body to provide frequent glucose readings [9]. Breath Ketone Analyzers measure the ketones in your breath. These devices have the ability to less invasively monitor proxies for blood sugar levels. Knowing your personal blood glucose response can help people make blood sugar conscious food choices and identify precursors to diabetes.

Thus, a noninvasive continuous blood glucose monitor can lead to advancements in diabetes monitoring, prediabetes identification, and nutrition planning. The goal of this study is to demonstrate a proof of concept for such a device. We created GlucoScan, a non-invasive system that uses optical spectroscopy to monitor change in blood glucose. This not only allows us to take instantaneous measurement but is capable of generating longitudinal datasets. The results of the study show a strong correlation of various wavelengths in the visible region with blood glucose.

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2 GLUCOSCAN DEVICE

Optical spectroscopy is the interaction between optical photons and matter [10]. Given a lightsource, a medium, and a set of photodectors, as shown in Figure 1, we can measure the optical response of the medium. When photons are absorbed by the medium, there will be fewer photons measured by the photodetectors. When photons pass through or excite the medium, there will be more photons measured by the photodetector. To create a wearable optical spectrometer, there are two choices: reflection and transmission. Reflection is commercially available in devices like smartwatches, while transmission appears in devices such as fingertip pulse oximeters. As an early prototype, we decided to focus on transmission sensors to reduce parameter consideration, such as angle of the source, and literature supports the decision for transmission measurements [3]. Thus, we use transmission fingertip spectroscopy in a similar design to a pulse oximeter.

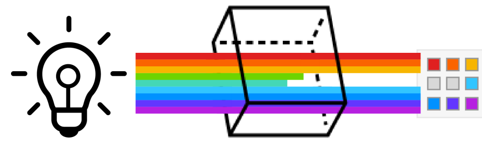
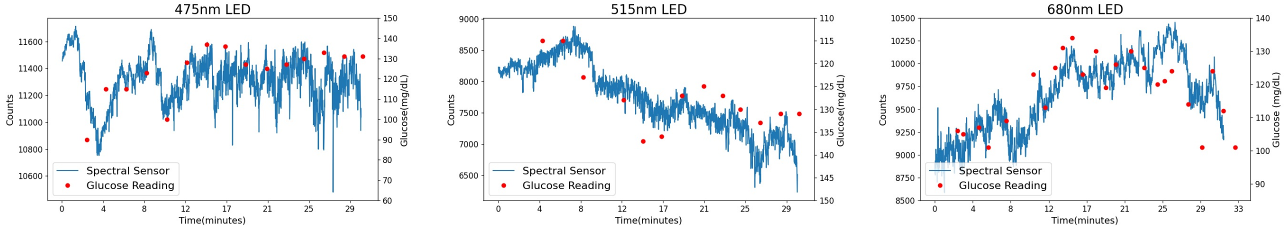


Figure 1: Optical Spectroscopy

Glucose measurement via blood sample is the gold standard. It has been tested, validated, and proven effective in diabetes management. Due to the invasiveness of drawing blood, research has begun into less invasive optical methods [1, 6]. These works have shown promise for measuring glucose in the visible [7] and near infrared range [12]. Specifically, [7] shows the fluorescence emission of glucose oxidase has a peak at around 520nm and increases in the presence of glucose. Work from [4] found that as glucose concentration increases, the ratio of the 510nm wavelength to 475nm wavelength of transmission decreases, using Beer-Lambert's law. Additionally, 650nm wavelength of light impinging on a solution has been shown to increase, in transmittance of photons, with glucose [3]. Therefore, in this study, we focus on three wavelengths: 475nm, 515nm, and 680nm. For each of these wavelengths we chose a narrow band LED and photodetector centered at the wavelength.



(a) LED 475nm **(b) LED 515nm** **(c) LED 680nm**

Figure 2: Results from preliminary user study by LED.

Our device is shown in Figure 3. Its components are as follows: The AS7341 spectral sensor [2] with photodiode array that senses between peaks of 415nm to 680nm in the visible range. Importantly, it has photodiodes at 480nm, 515nm, and 680nm. An Arduino Nano 33 IoT to record the data and send it to our data collection system, Raproto [11]. The three LEDs at 470nm, 515nm, and 680nm wavelengths. A 3D printed form factor to house the components and snugly attach to the finger tip.

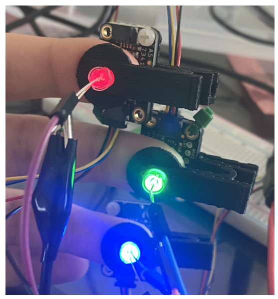


Figure 3: Prototype

3 STUDY AND RESULTS

We conducted a preliminary user study on a single participant where we tested our proof of concept system compared to a commercially available glucometer [5]. We attached the GlucoScan devices on the participants left hand as shown in Figure 3. The 680nm LED was attached to the index finger, the 515nm LED was attached to the middle finger, and the 475nm LED was attached to the ring finger. This setup is shown in Figure 3. Blood glucose readings were drawn from the right hand. This study was performed over approximately half an hour. Our participant started in a fasted state which is shown with the low starting glucose readings. At the start of the study, they drank a sugary drink, and we recorded the effect on their blood sugar. Approximately every two minutes, we took a new blood glucose reading. We continuously sampled the three GlucoScan devices at a rate of approximately 2 Hz.

The results of the study are presented in Figure 2. The patient's blood glucose, as measured by a commercially available glucometer, is shown by the red points and the optical spectroscopy readings from the 480nm, 515nm, and 680nm photodetector channels are shown in blue, respectively. The glucose readings were manually calibrated when overlaying the data. The maximum photodiode counts are 2^{16}, and the initial intensity of the transmitted response was calibrated to be relatively strong. In Figure 2a and Figure 2c, the change in counts positively trends with the change in glucose. In Figure 2b, the change in counts negatively trends with the glucose readings, and the y-axis of the glucose readings is flipped. After interpolation and detrending of the signals in Figure 2, 470nm and 515nm are shown to be statistically significant with p-values of 0.344 and 0.6. These results show that readings from our GlucoScan sensor may be used to track overarching glucose trends, and more research is needed to make accurate and direct glucose measurements.

4 CONCLUSION AND FUTURE WORK

This preliminary study expands on research that blood glucose can be measured via optical spectroscopy. The results show that blood glucose increases with light transmittance from a 475nm LED and inversely with that of a 515nm LED. Future work includes developing a standalone wireless device, creating new form factors, and running a more complete user study. A standalone device will be achieved through miniaturization and custom circuit design, sufficient stand-alone battery life, and a targeted Arduino replacement. Expanding the scope of the system to a wrist device requires measuring reflected photons. Lastly, the system needs more involved user studies: more people, diverse populations, and varying health.

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