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Advancing Non-Invasive Glucose Monitoring through Integrated Physical Factors and Wavelength Optimization

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Abstract

This work examines how skin tone, temperature, thickness, and humidity influence GlucoCheck, a non-invasive glucose monitor using IR technology. It discusses the roles these factors play in altering light absorption and scattering in the skin, affecting IR image quality. The paper reviews studies on how skin humidity affects reflectance, humidity's impact on light transmission, and the varying effects of skin temperature and color on light absorption. These aspects are crucial for accurate glucose level predictions through light transmitted through the skin. The paper proposes integrating real-time data on these factors, collected through advanced sensors, into GlucoCheck's software.

Introduction

GlucoCheck is a laser-imaging based device used for non-invasive blood glucose monitoring. It estimates glucose levels by analyzing light absorption properties of the skin. This technology aims to replace painful finger-pricking methods in diabetes management, while offering continuous monitoring.

Research Question(s)

- RQ1: What physical factors contribute to the model accuracy?
- RQ2: How is each feature assessed for relevance?
- RQ3: Would using photodiodes as a receiver offer any edge?

Materials and Methods

Literature Review: Prior to establishing our data collection proto- col, a thorough literature review will be conducted to glean insights from existing studies. This review will focus on participant demo- graphics, data collection methods, and the technological setup that yielded the most accurate glucose level predictions using PPG-based devices.

Data Collection Protocol: The collection of empirical data will be structured around a protocol designed to address the outlined research questions with high fidelity. Participants for this study will include adults aged 65 years and older, who are in healthy conditions. The cohort will be inclusive of individuals without diabetes, as well as those with diabetes not currently under medication, ensuring a diverse sample for robust model training and testing.

Results

I. Effects of Skin Tone and Tissue Thickness on Transmittance of Lasers [9]

- The study involved 40 volunteers, measuring skin thickness near the elbow with a Jamar caliper, using laser parameters similar to GlucoCheck (635 nm and 808 nm wavelengths).
- Skin tone was estimated using a Pantone Color Cue2 colorimeter.
- Results indicated that dark skin reduced light transmittance at both wavelengths, especially at 635 nm, but this effect diminished with increasing skin thickness.
- At 5 mm skin thickness, skin tone differences in transmittance became statistically insignificant, with higher transmittance at the 808 nm wavelength compared to 635 nm.

II. Simulating Skin Humidity to Retrieve Effects on Transmittance [8]

- JC Ramirez-San-Juan and colleagues from the University of California conducted a study using an agar phantom in an integrating sphere with humidity control to mimic human skin.
- The experimental setup involved Cryogen Cooling Spray to simulate skin humidity effects, and a 633 nm laser to emit towards the phantom, with data captured by a photo detector.
- Humidity levels of 12%, 20%, 40%, and 57% were tested, showing decreasing transmittance with each Cryogen spurt, more significantly as humidity increased.
- The study found that higher environmental humidity led to a greater reduction in transmittance of the agar phantom after Cryogen application, highlighting the impact of humidity on skin-like materials.

III. Potential Temperature Effects [2]

- This study, led by A. Haupt and colleagues, investigated temperature effects on glucose measurements, focusing on how temperature influences internal kinetic energy, a separate physical property from light interaction with the skin.
- Subjects fasted overnight, then had one arm immersed in 15.5°C (cold) water and the other in 35°C (warm) water. Blood Glucose (BG) readings were taken from both forearms and fingertips before and after immersion.
- The experiment involved pre- and post-meal BG measurements with 56 samples per participant. The results showed higher BG readings in warmer conditions: approximately 240 mg/dL in the warm arm and 265 mg/dL in the warm fingertip.
- Significant statistical differences were found between warm and cold conditions, with p-values less than 0.001 for the arm and 0.002 for the fingertip, indicating a substantial impact of temperature on blood glucose measurement discrepancies.

IV. Implementing LED and Photodiode Technology as Alternatives to Laser-Based Imaging [3]

- Bahareh Javid's team from the University of Qom developed a glucose measurement device using LEDs (blue at 470 nm, infrared at 940, 1550, 1650 nm) and corresponding photodiodes, integrated with an ATMega32A microcontroller and an LCD for displaying readings.
- The device's noninvasive measurements varied from 67.5 to 427.5 mg/dl, compared with invasive readings ranging from 77 to 411 mg/dl across seven samples, highlighting discrepancies between methods.
- The percentage error between noninvasive and invasive readings varied, starting at 12.33% for the lowest glucose concentration and generally decreasing with concentration, but with some increase at higher levels, indicating varying degrees of accuracy.

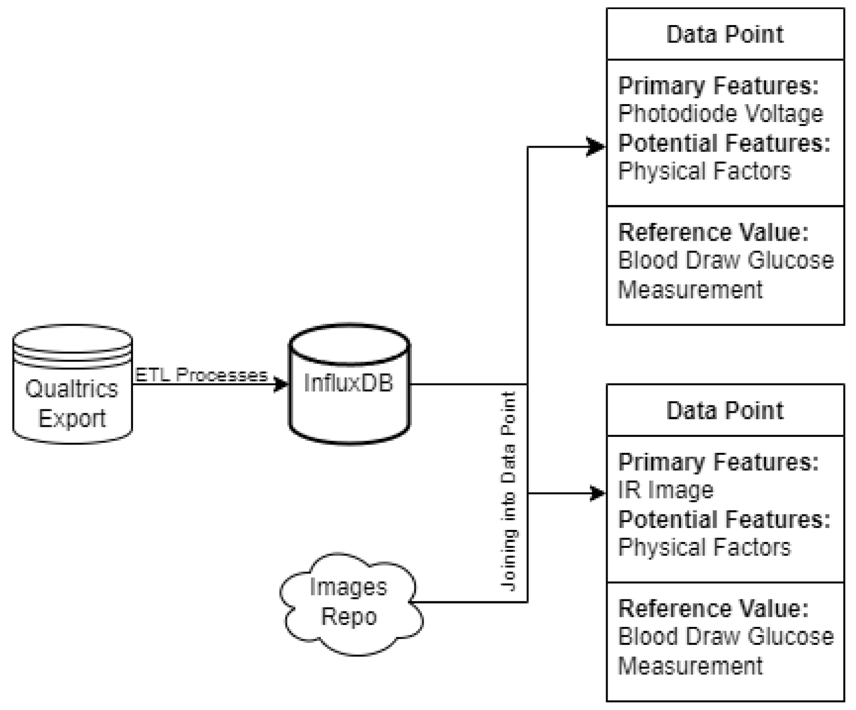

Fig. 1. Data Flow for Model Training and Testing

Conclusions

This research reviewed the effects of physical factors on blood glucose interaction with light, followed by a detailed data collection protocol for reliable data acquisition. It compared photodiodes and lasers, highlighting LEDs' advantages in safety, durability, and wearability. The study proposed a data flow architecture to integrate diverse data sources, crucial for developing a robust machine learning model. This model, using Recursive Feature Elimination (RFE), aims to refine feature selection, improving the accuracy of non-invasive glucose level predictions and future decision-making..

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