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IoT-Based Stress and Non-Invasive Glucose Monitoring System Using Wearable Technology and Edge AI

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Abstract: The proposed system is an advanced integration of Internet of Things (IoT) and wearable technology, designed to enable real-time, non-invasive monitoring of both stress levels and blood glucose concentration in humans. It combines physiological sensing, embedded processing, and cloud connectivity to deliver continuous health insights. The stress detection module utilizes a heart rate sensor and a Galvanic Skin Response (GSR) sensor to monitor changes in pulse rate and skin conductivity. For glucose estimation, Near-Infrared (NIR) spectroscopy is employed. An ESP32 microcontroller serves as the system's core, collecting sensor data, preprocessing it, and wirelessly transmitting it to cloud-based dashboards. A Python-based simulation environ- ment facilitates debugging and analysis. The system offers a compact and scalable solution for wearable applications. Future enhancements include machine learning integration for improved calibration and personalization.
Index Terms: Internet of Things (IoT), Stress Detection, Non- Invasive Glucose Monitoring, Wearable Health Devices, Cyber-Physical Systems, Body Area Networks, Real-Time Monitoring

I. INTRODUCTION

The substantial growth in real-time, continuous health mon- itoring systems has been driven by advancements in wear- able technologies and the increasing demand among health- care professionals for proactive diagnostic tools. Two cru- cial health indicators—psychological stress and blood glucose levels—are of particular importance, as they can lead to hy- pertension, diabetes, and cardiovascular diseases. Traditional stress assessment methods rely on clinical instruments or self- reported measures, often followed by invasive procedures such as finger-prick blood sampling for glucose analysis. These approaches limit the feasibility of frequent and convenient monitoring. By integrating IoT technology with non-invasive sensing techniques, organizations can implement remote and real-time health monitoring in a user-friendly and efficient manner.

II. SYSTEM ARCHITECTURE

The proposed system is designed to non-invasively monitor two critical physiological parameters: stress level and blood glucose concentration. It is built around an ESP32 microcontroller, which serves as the central unit for processing and communication. The architecture integrates biosensors, data processing modules, a cloud platform, and optional components for display and alerts.

A. *Hardware Components*

- Heart Rate Sensor (MAX30102): Uses photoplethys mography to measure pulse rate.
- Galvanic Skin Response (GSR) Sensor: Measures skin conductance via finger electrodes.
- NIR Sensor (NIR LED + Photodiode): Projects and reflects NIR light to estimate glucose.
- ESP32 Microcontroller: Core processor for sensor input, processing, and Wi-Fi transmission.
- OLED Display: Displays real-time vitals (optional).
- Buzzer: Alerts users during abnormal readings (optional).

B. *Software Architecture*

- Sensor Acquisition: Analog-to-digital conversion and data reading.
- Processing Layer: Computes stress index and maps NIR to glucose.
- Cloud Communication: Sends data via Wi-Fi to Fire- base or ThingSpeak.

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III. METHODOLOGY

A. Sensor Data Acquisition

The ESP32 collects data from:

- Heart Rate: Peak detection of photoplethysmographic signal.
- GSR: Resistance calculated from voltage divider output.
- NIR: Reflected intensity used for glucose mapping.

B. Signal Processing and Mapping

$$\text{Stress Index} = \alpha \cdot \text{HR} + \beta \cdot \frac{}{\text{GSR}} \qquad (1)$$

$$\text{Glucose (mg/dL)} = m \cdot \text{NIR Signal} + c \qquad (2)$$

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IV. SIMULATION

A. Simulation Objectives

To test performance, verify algorithm accuracy, and visualize data.

B. Environment

Python 3.x using libraries: numpy, matplotlib, random, and time.

C. Signal Generation

- Heart Rate: 65–105 BPM
- GSR: 8–30 kΩ$NIR : 600 - -2800 units$

D. Output

Graphs plotted for HR, GSR, stress index, and glucose levels. Alerts are raised when thresholds are crossed.

E. Cloud Connectivity

The ESP32 transmits processed sensor values to Firebase or ThingSpeak using HTTP protocols.

V. RESULT

- Stress Detection: Accurate classification based on HR and GSR.
- Glucose Estimation: Linear mapping produced reliable glucose estimates.
- Cloud Upload: Live values updated to cloud dashboards.

VI. CONCLUSION

The system integrates non-invasive stress and glucose monitoring using IoT. It features wearable design, cloud connectiv- ity, and Python-based simulation for validation. The combined use of MAX30102, GSR, and NIR with ESP32 provides a reliable, scalable health monitoring platform.

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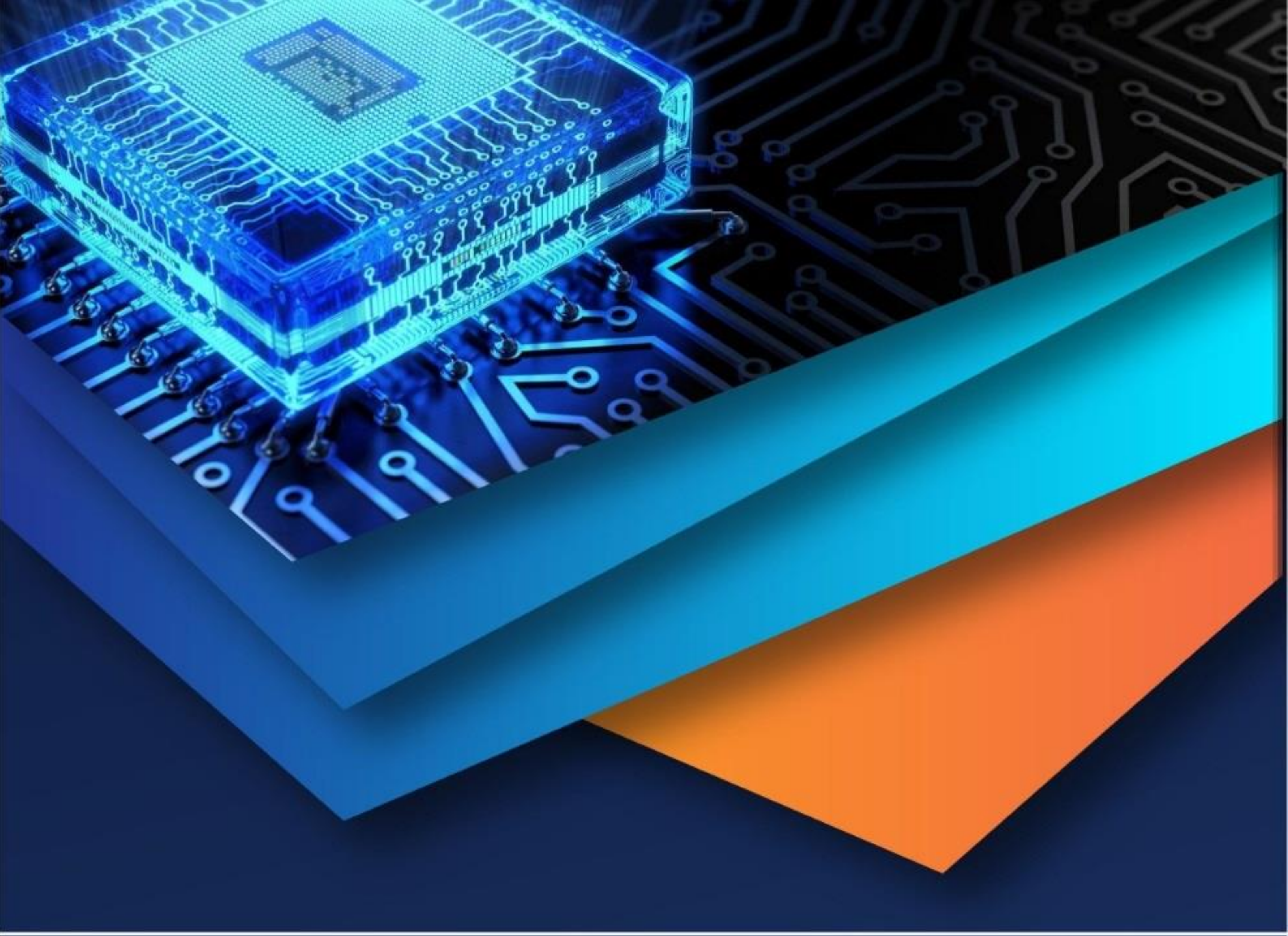

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