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MENTAL STRESS EARLY WARNING WEARABLE

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Abstract :

The increasing pace of modern life has led to a rise in stress-related mental health issues, highlighting the need for continuous and objective stress monitoring. Conventional assessment methods rely on self-reporting or periodic clinical evaluations, which lack real-time capability and reliability. This paper presents the design and implementation of a low-cost mental stress early-warning wearable system for real-time monitoring and alert generation. The proposed system uses an ESP32 microcontroller integrated with multiple physiological sensors, including heart rate variability (HRV), galvanic skin response (GSR), skin temperature, and an accelerometer to analyze stress-related indicators. Sensor data are processed locally and displayed on an LCD, while simultaneously transmitted to a cloud platform for remote monitoring and data analysis. When detected stress levels exceed predefined thresholds, the system generates immediate alerts through buzzer, vibration, or notification mechanisms. Powered by a regulated 5V DC supply, the wearable ensures stable performance and low power consumption, making it suitable for continuous use. The proposed system enables early stress detection and proactive management, with potential applications in healthcare monitoring, workplace wellness, personal fitness, and telemedicine environments.

Index Terms — Mental stress monitoring, wearable device, ESP32, heart rate variability, galvanic skin response, skin temperature monitoring, accelerometer, Internet of Things.

I. INTRODUCTION

Mental stress has become a significant concern in modern society due to increasing work demands, sedentary lifestyles, and continuous exposure to environmental and social pressures. Prolonged or unmanaged stress can lead to serious mental and physical health disorders, including anxiety, depression, cardiovascular diseases, and reduced productivity. Early identification and timely intervention are therefore essential to prevent long-term health consequences and improve overall well-being.

Traditional approaches for stress assessment mainly rely on self-reported questionnaires, psychological evaluations, or periodic clinical examinations. Although these methods are widely used, they are subjective, time-consuming, and incapable of providing continuous real-time monitoring. Moreover, individuals may fail to recognize early stress symptoms or may underreport their condition, limiting the effectiveness of such approaches. These limitations highlight the need for an automated, objective, and continuous stress monitoring system.

Recent advancements in wearable technology and embedded systems have enabled real-time monitoring of physiological parameters associated with mental stress. Physiological signals such as heart rate variability (HRV), galvanic skin response (GSR), skin temperature, and physical activity levels have been shown to reflect stress-induced changes in the human body. By continuously analyzing these parameters, it is possible to detect stress patterns more accurately and promptly than conventional methods.

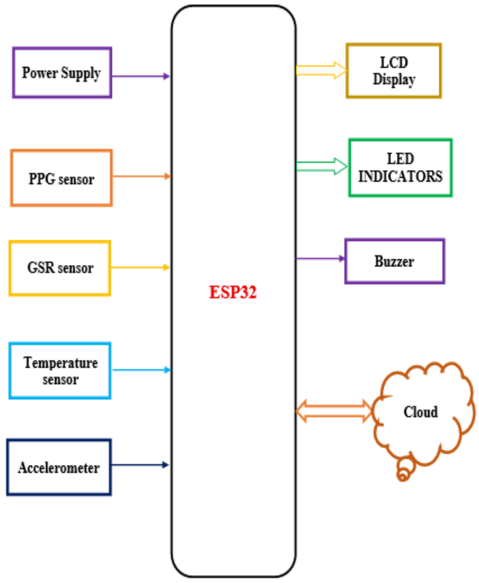
In this context, this paper presents the design and development of a mental stress early-warning wearable system based on an ESP32 microcontroller. The proposed system integrates multiple sensors to measure HRV, GSR, skin temperature, and motion using an accelerometer. The collected sensor data are processed in real time to determine stress levels and are displayed locally as well as transmitted to a cloud platform for remote monitoring. When stress indicators exceed predefined thresholds, the system generates immediate alerts through notification mechanisms, enabling proactive stress management.

The proposed wearable system is designed to be low-cost, energy-efficient, and suitable for continuous daily use. Its potential applications include healthcare monitoring, workplace stress management, personal fitness tracking, and telemedicine support. By enabling early detection and timely intervention, the system aims to improve mental health awareness and promote preventive healthcare practices.

II. LITERATURE REVIEW

Mental stress monitoring has gained significant attention due to its impact on physical and psychological health. Traditional stress assessment methods based on questionnaires and clinical observations are subjective and unsuitable for continuous monitoring, leading researchers to explore physiological signal–based approaches.

Previous studies have shown that heart rate variability (HRV) is a reliable indicator of stress, as it reflects autonomic nervous system activity. Galvanic skin response (GSR) has also been widely used to measure stress-related changes in skin



conductance caused by emotional arousal. Additionally, variations in skin temperature have been linked to stress-induced vascular responses, making it a useful complementary parameter.

Recent research has focused on wearable and IoT-based systems that integrate multiple physiological sensors for real-time stress monitoring. Microcontrollers such as ESP32 are commonly used due to their low cost, low power consumption, and built-in wireless communication. Motion sensors and accelerometers are often included to distinguish stress responses from physical activity, thereby improving detection accuracy.Although existing systems demonstrate effective stress detection, many lack real-time alert mechanisms, involve complex designs, or depend heavily

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on cloud processing. The proposed system overcomes these limitations by combining multiple physiological parameters with local processing and instant alert generation in a compact wearable platform.

III. PROPOSED SYSTEM

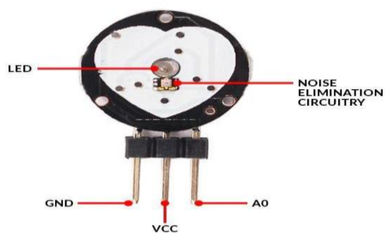
The proposed system is a wearable mental stress early-warning device designed to monitor physiological parameters in real time and provide timely alerts. As shown in the block diagram, the system is centered around an ESP32 microcontroller, which acts as the main processing and control unit.

Physiological data are collected using multiple sensors, including a PPG sensor for heart rate and heart rate variability (HRV), a GSR sensor for measuring skin conductance, a temperature sensor for monitoring skin temperature, and an accelerometer to track user movement and physical activity. These sensors continuously send data to the ESP32 for processing and analysis.The ESP32 processes the incoming sensor data to evaluate stress levels based on predefined thresholds. The calculated results are displayed on an LCD screen, while LED indicators and a buzzer provide immediate local alerts when abnormal stress levels are detected. To enable remote monitoring and data storage, the processed data are transmitted to a cloud platform using the built-in wireless communication capabilities of the ESP32.

The entire system is powered by a regulated power supply to ensure stable operation and low power consumption, making it suitable for continuous wearable use. By integrating multi-sensor data acquisition, real-time processing, alert mechanisms, and cloud connectivity, the proposed system enables early detection of mental stress and supports proactive stress management.

A. ESP32

The ESP32 serves as the core processing unit of the proposed wearable system. It is responsible for acquiring data from multiple physiological sensors, performing real-time signal processing, and



determining stress levels based on

predefined thresholds. The ESP32 also controls output devices such as the LCD, LEDs, and buzzer, and enables wireless data transmission to a cloud platform using its integrated Wi-Fi module. Its low power consumption and high processing capability make it suitable for continuous wearable health monitoring.

B. PPG Sensor

The PPG (Photoplethysmography) sensor is used to measure heart rate and heart rate variability (HRV) by detecting variations in blood volume. HRV is a

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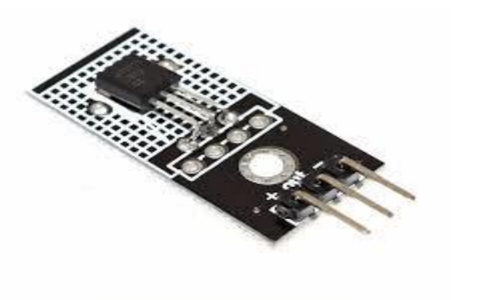
widely accepted physiological marker for stress assessment, as it reflects autonomic nervous system activity. The sensor provides continuous cardiac data required for real-time stress evaluation

C. GSR Sensor

The Galvanic Skin Response (GSR) sensor measures skin conductance changes caused by sweat gland activity. Since emotional arousal and stress increase skin conductivity, GSR serves as an effective indicator of psychological stress. The sensor complements HRV measurements, improving the accuracy of stress detection.

D. Temperature Sensor

The temperature sensor monitors



skin temperature variations, which can change under stress conditions due to peripheral vasoconstriction. Incorporating skin temperature data enhances the robustness of stress classification when combined with other physiological signals.

E. Accelerometer

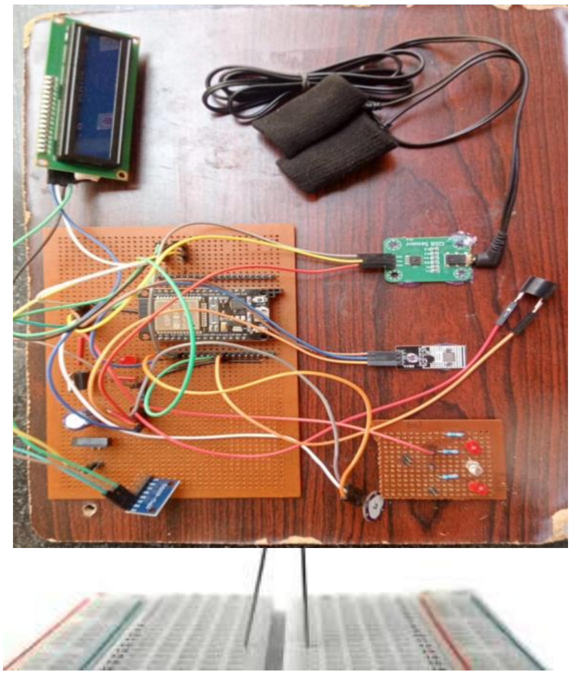
The accelerometer is used to detect user motion and physical activity levels. This information helps differentiate stress-induced physiological responses from those caused by physical movement or exercise, thereby reducing false stress detection.

F. LCD Display

The LCD display provides real-time visualization of sensor readings and stress status. It allows users to continuously monitor their physiological parameters and understand their stress condition instantly.

G. LED Indicators

LED indicators offer a simple and quick



visual representation of stress levels. Different LED states indicate normal or elevated stress conditions, enhancing user awareness without requiring continuous display observation.

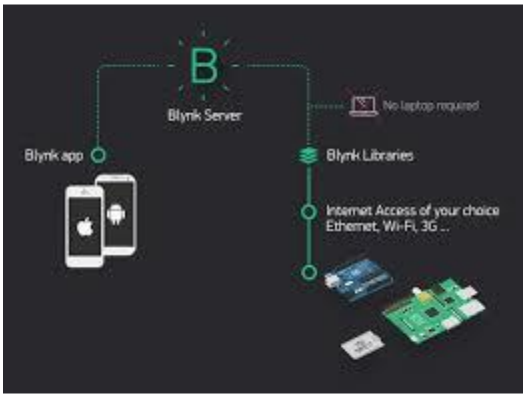
H. Buzzer

The buzzer generates an audible alert when stress levels exceed predefined thresholds. This immediate feedback mechanism ensures timely user notification, enabling prompt stress management actions.

I. BLYNK Cloud Platform

The cloud platform receives physiological data transmitted from the ESP32 for remote monitoring, storage, and analysis. Cloud connectivity supports long-term stress trend analysis and enables access to data from healthcare professionals or caregivers.

VI. RESULTS

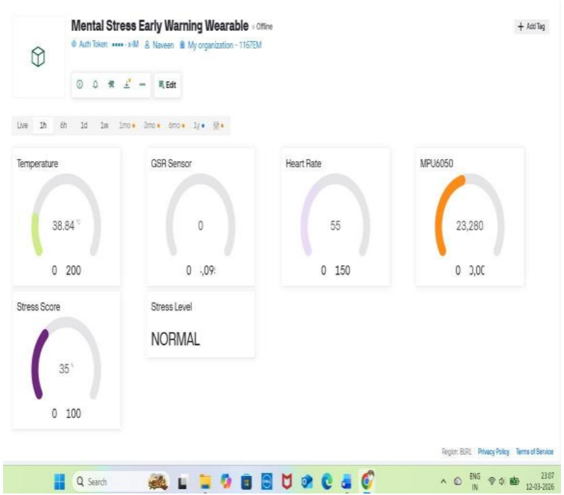


The proposed mental stress early-warning wearable system was successfully developed and evaluated for real-time physiological monitoring. The ESP32 reliably acquired data from PPG, GSR, temperature, and accelerometer sensors without data loss. Significant variations in heart rate variability and galvanic skin response were observed under stress conditions compared to normal states, while skin temperature exhibited gradual changes. Accelerometer data enabled differentiation between stress-induced responses and physical activity. The system effectively detected elevated stress levels using predefined thresholds and generated timely alerts through LED and buzzer indicators.

Real-time sensor data and stress status were displayed on an LCD for continuous user feedback. Cloud integration remained stable, supporting remote monitoring and data storage. Overall, the prototype demonstrated low latency and reliable performance, indicating its suitability for continuous wearable applications.

VII. CONCLUSION

This work successfully demonstrated the design and implementation of a wearable mental stress monitoring system using an ESP32 microcontroller and multiple physiological



sensors. By combining heart rate variability, galvanic skin response, skin temperature, and motion data, the system provides effective real-time stress detection and early warning alerts. The integration of local processing, user notification mechanisms, and cloud connectivity makes the system practical for daily use. The proposed approach offers a low-cost and efficient solution for proactive mental stress management in healthcare, workplace, and personal wellness applications. The modular design allowa easy scalability and integration of advanced algorithms for improved stress classification.

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