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Wireless and Wearable Real-time Health Monitoring Systems: A Review of Recent Developments

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Abstract

This paper explores the interdependent relationship between mental and physical health, highlighting the impact of stress and anxiety on the body by introducing an innovative Real- Time Health Monitoring System. This system monitors both mental well-being and physical health using advanced physical health sensors and Facial Emotion Recognition (FER) technology. Leveraging high-precision sensors such as Temperature and pulse oximeters, it continuously monitors vital physiological parameters such as Body Temperature and Pulse Rate (SpO_2) in real time. Simultaneously, a FER-based Deep Learning model captures and analyzes emotional states, ranging from happiness to anxiety and everything in between. Processed by an ESP32 microcontroller, the data is seamlessly acquired, graphically displayed, and stored on a Cloud Platform, allowing for in-depth analysis. Quantitative data has been used to analyze patterns and relationships between emotional states and health parameters for deeper understanding of the mind-body connection. The results demonstrate the real-time monitoring of an individual's emotional state and its impact on vital health parameters, such as Temperature and Pulse Rate. In conclusion, our findings highlight the importance of integrating mental health into physical health and the potential impact of cutting-edge technologies on healthcare management by providing a holistic understanding of each person's well-being.

Keywords: Real-time health monitoring, facial emotion recognition (FER), body temperature, pulse oximeter (SPO_2), mind-body connection

INTRODUCTION

The intricate relationship between mental and physical health is central to our research, which aims to advance our understanding of the impact of stress and anxiety on the human body. Contrary to the traditional dichotomy between mind and body, a close connection between mental and physical well-being has been established, with WHO emphasizing the pivotal role of mental health in overall wellness. Prominent researchers such as Dr. Susan David and Dr. Bruce Lipton have highlighted the direct impact that mental health has on physical health [2,3].

Given how common stress and anxiety are in modern culture, there has been a lot of discussion about the possible negative impacts on physical and mental health. In order to understand how stress and anxiety appear in the human body, this study suggests a proactive strategy that combines real-time physical health data gathering with face expression detection. The fundamental aspiration is to empower individuals to understand and manage the impact of stress and anxiety on their overall health, by leveraging real-time data collection and analysis and cloud-based storage [15,6].

The significant relationship that exists between mental and physical health is highlighted by the

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significant influence that each has on the other. For example, stress triggers important physiological reactions, such as the production of stress hormones like adrenaline and cortisol, which can cause a variety of long-term health problems even though they are adaptive in the short term [8, 5].

The application of face emotion detection technology demands that ethical and practical considerations be carefully considered, especially with regard to guaranteeing the integrity and supervision of data related to important health factors [9, 10].

In summary, this study represents a novel advancement in health monitoring as it integrates real-time physical health sensors with facial emotion recognition technology, which may empower people to take a more active role in their longevity and health by promoting a better understanding of the mind-body connection.

MATERIAL & METHODOLOGY

The methodology employed in this research is designed to capture and analyze real-time data [3, 7] to elucidate the intricate connections between emotions and physical well-being. To achieve this objective, we utilize a Real-Time Health Monitoring System equipped with various sensors and advanced facial emotion recognition technology as shown in Figure 1.

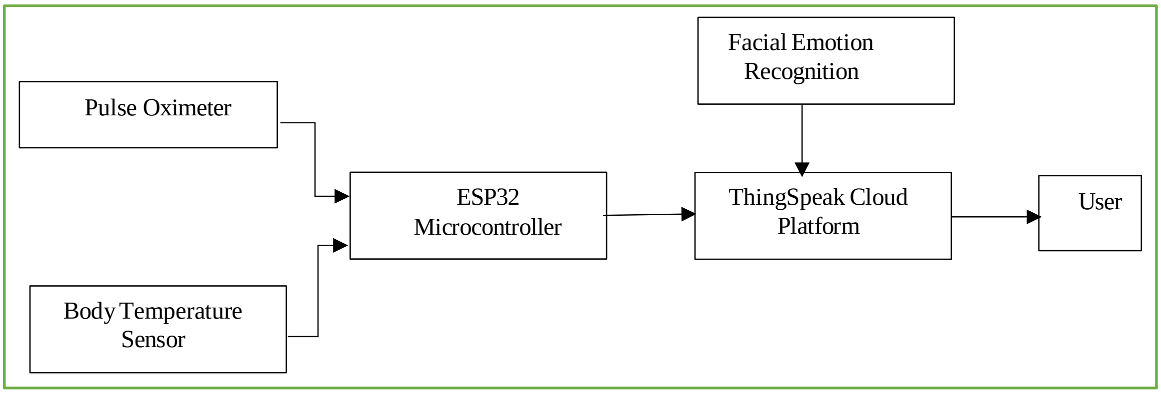

Figure 1. Block diagram of real time health monitoring system.

Temperature Sensor

The DHT11 is a basic temperature and humidity sensor with a temperature range of 0°C to 50°C and humidity range of 20% to 90% RH as shown in Figure 2. It has an accuracy of ±2°C for temperature and ±5% for humidity. It is simple to use with microcontrollers since it runs on a single-wire digital interface. It's commonly used in applications like body temperature measurement and environmental monitoring due to its simplicity and affordability.

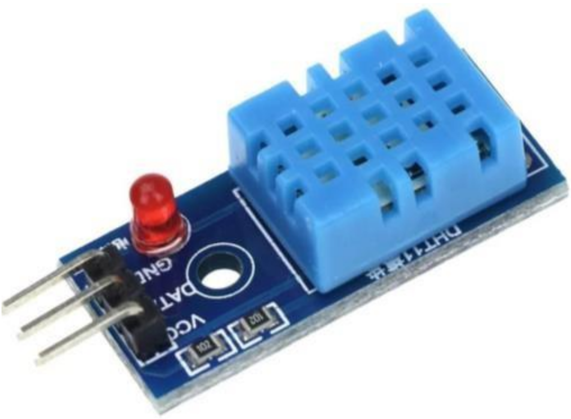

Figure 2. Temperature sensor.

Pulse Oximeter

Pulse oximetry is a used to measure the oxygen level (oxygen saturation) in the blood. It is an easy, painless measure [13, 12] of how well oxygen is being sent to parts of your body furthest from your heart, such as the arms and legs as shown in Figure 3. A probe, which resembles a clip, is applied to a body part—like a finger. It measures the amount of oxygen in the blood using light. This data aids the medical professional in determining whether a patient requires more oxygen.

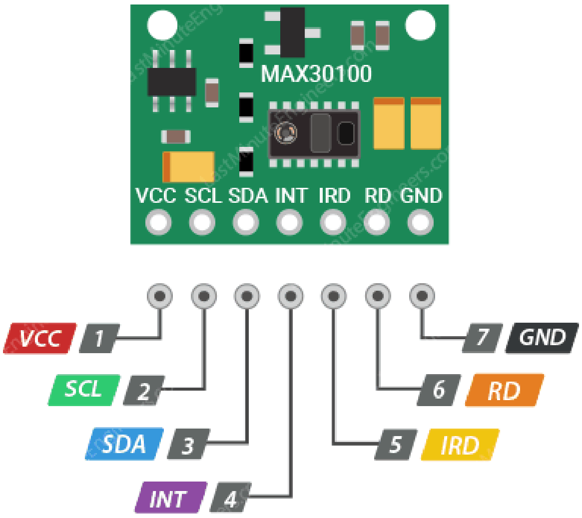

Figure 3. Pulse Oximeter.

ESP32

The ESP32 is a versatile microcontroller module that features a dual-core processor running at up to 240 MHz, built-in Wi-Fi and Bluetooth connectivity, ample GPIO pins, [1] ADC and DAC interfaces, hardware encryption, support for multiple protocols including HTTP, MQTT, and TCP/IP, and compatibility with various development environments such as Arduino IDE and ESP-IDF as shown in Figure 4.

Figure 4. ESP32 Microcontroller.

Facial Emotion Recognition (FER)

FER is one of the most important ways of providing information about emotional state Emotions are known to greatly impact how information is processed, attitudes are formed, and decisions are made in real-world scenarios. According to the research by psychologist Mehrabian on human Information communication, 55% of information is communicated by facial sentiments, 38% via supporting languages such as sound, voice and 7% just through [11] spoken language.

Most of the traditional approaches consist of 3 steps the first step in practice is to detect the position of the face followed by extraction of facial geometric features to generate specific vectors and then classifying the sentiments with maximum score. A lot of technical manipulation is required in these methods. The deep learning powered FER recognizes face, estimates age, predicts gender, emotion analysis, and generates face mesh. FER can be implemented through cameras or sensors that capture and analyse facial expressions such as - Happy, Sad, Disgust, Surprised, Angry and Neutral in real-time. This process is comparable to a puzzle solver piecing together scattered clues to reveal the bigger picture, allowing for a deeper understanding of the individual's feelings. In essence, facial emotion recognition serves as a perceptive interpreter, decoding the silent language of emotions conveyed through facial expressions with precision and insight as shown in Figure 5. Through the analysis of facial traits such as mouth shape, eye movement, and eyebrow position, the system is able to precisely determine an individual's emotional state. It generates 68 face mesh for detailed facial Landmark detection for each detected face.

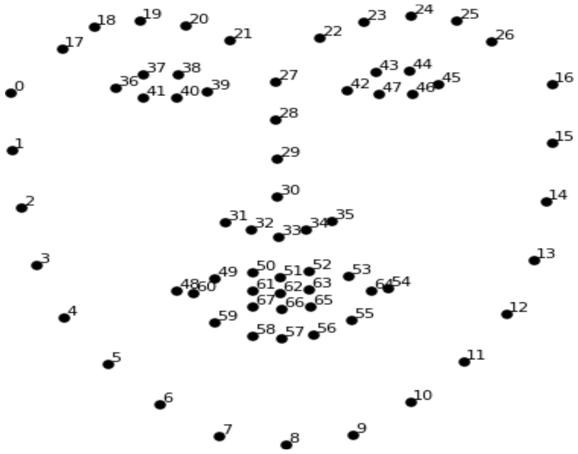

Figure 5. 68 Face Mesh generated.

A live webcam is used. FER task goes through steps like data processing and emotion recognition. A total of 400 tensors are also taken into consideration. A FaceAPI webcam test is also taken to determine the proper working of webcam. The Face API version used here: 1.7.13 and Tensor flow / JS: 4.16.0. For camera settings - aspect ratio, brightness, colour, temperature, contrast, sharpness, exposure are also monitored. One of the disadvantages of using Fer is it is limited by learning only the 6 basic emotions, it conflicts with what is present in everyday life which has emotions that are more complex. Privacy advocates may be among the opponents of facial emotion recognition technologies. However, companies like Apple-acquired firm Emotient have also assisted in the growth of this technology. These people and organizations have been significant in encouraging and advancing the use of facial emotion recognition across a range of industries.

ThingSpeak Cloud Platform

The ThingSpeak Cloud Platform can be likened to a digital filing cabinet where data is stored and organized. Just as a filing cabinet keeps documents for easy access, ThingSpeak organizes and stores data in a structured manner. It functions as a centralized hub for data collection and analysis. Additionally, similar to how a filing cabinet can be accessed and updated with new information, ThingSpeak allows users to input, retrieve, and update data as needed. In essence, ThingSpeak acts as a virtual storage system for data, much like a filing cabinet does for physical documents. It is a cloud service that allows users to collect, analyse, and visualize data from sensors or devices. Users can create channels to store their data and use the platform's built-in tools to analyse and visualize this data.

The platform supports various IoT protocols and can be integrated with different hardware and software systems. All things considered, the objective of ThingSpeak Cloud Platform is to make it easier and more effective for users [13] to manage and use the data generated by IoT devices. It operates by providing devices access to APIs which enables them to communicate data to the platform, which stores and processes it. The ThingSpeak cloud platform offers real-time data collection and analysis capabilities, allowing for immediate insights into various processes. It provides a user-friendly interface.

[4] that simplifies the monitoring and visualization of data, making it accessible to users with varying levels of technical expertise. It also allows for the creation of interactive charts and graphs to better understand trends and patterns in the data [14]. Additionally, ThingSpeak' s cloud-based nature ensures scalability [6] and flexibility, accommodating growing data needs and evolving requirements effortlessly. One of the drawback is the potential for data security concerns, as cloud platforms can be vulnerable to cyberattacks or data breaches. Additionally, ThingSpeak may have limitations in terms of customization and flexibility compared to other cloud platforms.

Just like a live feed of your vital signs, this system offers real-time data on your health status. It functions akin to a vigilant guardian, constantly watching over your health.

RESULTS

Figure 6 is the result of real time health monitoring system.

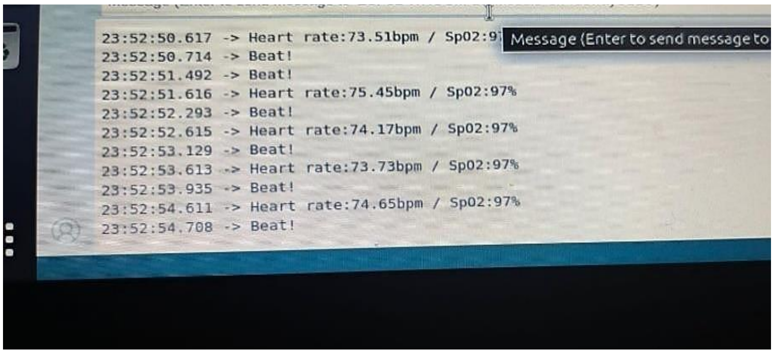

Figure 6. Output of MAX30100.

The above figure is output of MAX30100. It shows heart rate and oxygen saturation (SpO_2) levels. The timestamp indicates sequential readings taken approximately within milliseconds of each other. The data shows fluctuations in heart rate, ranging from 73.51 to 75.45 beats per minute (bpm), with occasional notes of "Beat!" likely indicating the detection of heartbeats.

The SpO_2 levels remain consistent at 97%. Based on these data, it appears that the cardiovascular state is rather stable, with little variations in heart rate that are typical of regular exercise or rest. The device is actively monitoring the person's heart rhythm and giving real-time feedback, as seen by the "Beat!" messages and the varying heart rate readings. Overall, the steady SpO_2 readings and the occasional variations in heart rate point to a stable cardiovascular state over the observation period.

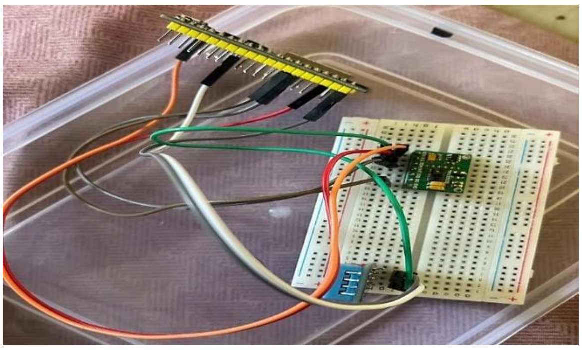

Figure 7. Connections of Real Time Health Monitoring System.

The ESP32 acts as the hub in a real-time health monitoring system, connecting to both the DHT11 for temperature and humidity readings and the MAX30100 for vital signs like heart rate and oxygen levels. This setup provides a thorough picture of the user's health, enabling continuous monitoring as shown in Figure 7.

CONCLUSIONS

The integration of a Real-Time Health Monitoring System equipped with various sensors and advanced facial emotion recognition technology has provided valuable insights into the intricate connections between emotions and physical well-being. By capturing real-time data and applying deep learning models for facial emotion recognition, we successfully correlated emotional fluctuations with changes in physiological parameters, shedding light on the mind-body connection. The consistent SpO2 levels coupled with slight fluctuations in heart rate observed in the real-time monitoring output signify a healthy cardiovascular status during the monitoring period.

Our methodology marks a substantial advancement in health monitoring and offers potential implications for both intervention and treatment. Future tasks could include compiling a report on one's psychological and physical well-being. A report would display health changes over a given time period. An app may also display this info. An app can be used to view the data and generate reports. This will make it easier for someone to access their info anywhere, at any time.

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