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An IoT-Based Real-Time Posture Monitoring and Correction System for Students

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***Abstract* - As students tend to spend so much time on digital platforms for learning, their use of poor sitting postures over extended periods has been identified as a potential source of back, neck, and other physical problems, including postural deformities. Therefore, with the increasing use of digital learning platforms, continued monitoring of posture is imperative to build awareness of proper ergonomics, reduce the risk of long-term physical ailments and improve overall health and well-being. This paper presents an Internet of Things (IoT)-based posture-correction alert system for monitoring students' sitting posture and providing feedback in real time. The proposed system uses MPU9250 IMU sensors to detect the body's tilt angle (pitch and roll) in real-time to monitor a person's sitting posture and their orientation. The collected data is processed by a ESP32 microcontroller to compare the values to predetermined threshold values for evaluating whether the subject has maintained a correct or incorrect posture. If the subject has maintained an incorrect posture for a prolonged period of time, the alert system will trigger an auditory/vibratory alert, providing immediate feedback to the subject. The collected data is transmitted wirelessly via an Internet or wireless network to a cloud-based solution for storage, analysis, and presentation to the user using a graphical user interface (GUI). Results from experiments have shown that the proposed solution provides effective detection of poor sitting posture, as well as timely corrective feedback to the user, thus reducing the risks associated with sitting posture-related health problems. The proposed system is very affordable, requires little power to operate, and can easily be implemented in schools and smart learning environments.**

Keywords: Internet of Things (IoT), Posture Monitoring, ESP32, MPU9250 Sensor

I. INTRODUCTION

The increase in the worldwide use of digital learning platforms has dramatically changed the face of education today. Students now have access to a wide variety of academic resources at any time and from any location. However, the rise in the number of hours spent using computers, tablets, and mobile devices has resulted in increased sedentary (i.e., non-active) behavior on the part of students and often leads to students maintaining improper positions for long periods. Maintaining a poor posture during these learning activities is considered a leading factor in the development of musculoskeletal issues such as pain in the back, neck, or shoulders and long-term postural deformities like changes in normal alignment of the spine in both school and college age students. maintaining good posture is vital to keeping your back aligned, helping to eliminate excess strain on muscles and improving your health and efficiency when studying and/or working(1,2). Although public awareness of ergonomics continues to improve, students generally do not know how to sit in a good posture because they do not receive ongoing monitoring or immediate feedback about how they sit while in school. Students receive evaluations of their posture through manual assessments or clinical evaluations, however these types of assessments are not suited for ongoing assessment of how well students maintain proper seating positions in the regular classroom. A therefore strong need exists for an automated, real-time system that is capable of providing feedback immediately after an incorrect sitting position is detected so that the user has the opportunity and chance to correct the incorrect position of the body, prior to any damage being caused to their bodies; due to improper body positioning(3). In today's world, many technologies such as wearable sensors, embedded systems and IoT (Internet of Things) are helping to create intelligent health monitoring systems. IoT based systems will allow real-time data capture, wireless communication, low energy consumption and will allow data to be analysed in the cloud. Sensors and Inertial Measurement Units (IMUs) can measure body position and movement accurately to allow a true assessment of one's posture when sitting down. In this study, a real-time alert system that monitors a student's sitting posture is presented through an Internet of Things (IoT) framework(4,5). The proposed solution uses flex sensors and inertial measurement units (IMUs) to gather information about students' sitting postures, which is then processed with a microcontroller and compared to predetermined threshold values to classify it as either "correct" or "incorrect." An assessment will be considered "incorrect" if a student continues to exhibit a certain posture for an extended period of time and after this happens, auditory or vibratory alerts are generated, prompting the user to correct their posture. Wireless transmission of posture information to a cloud-based platform allows for the storage, visualization and long-term analysis of the information through a graphical user interface.

Proposed systems have been sufficiently tested for detecting poor sitting posture and give timely feedback to reduce the risks associated with poor posture doing. The proposed system will also be inexpensive, have low power consumption, be easy to implement and deploy, making it a good candidate for installation in schools, universities and smart-learning technology.

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II. METHODOLOGY

A. Architecture of the Proposed IoT-Based Posture Monitoring System

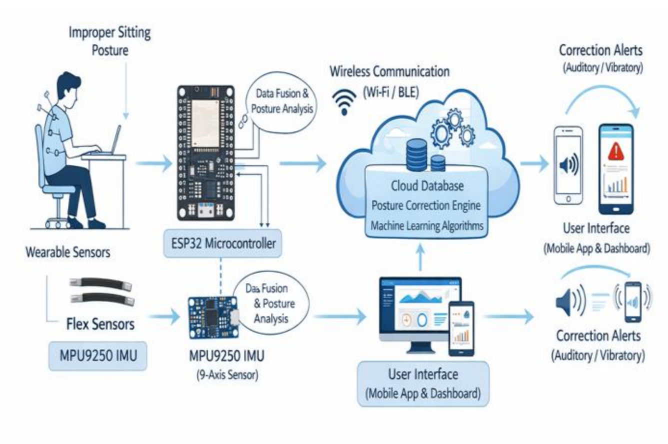

Fig.1 : IoT-Based Posture Monitoring System Architecture

The IoT-based posture awareness and correction system is designed on a layered architecture that allows for continuous posture sensing, real-time decision-making and remote monitoring of individuals. The architecture is designed for efficient flow of data from the wearables to the user-facing applications while providing low latency and scalability as shown in Fig.1.

An MPU9250 inertial measurement unit (IMU) sensor and flex sensors located on the user's upper body are used to sense the user's posture. The MPU9250 collects information about the user's orientation and motion by capturing parameters such as tilt and angular displacement, while the flex sensors measure how much bend occurs at the spine in relation to the user's spinal posture. The resulting posture data generated by the sensors at all times are transmitted to the ESP32 microcontroller(6–8).

The ESP32 serves as the central processing unit of the entire system. It processes raw sensor data, does some preprocessing and performs sensor fusion and compares measured values against predefined threshold limits in order to evaluate the user's posture. After this analysis is complete, it determines whether or not the user's posture is correct. The ESP32's ability to process data locally allows for quick determination of posture and decreases system delays (ie., lowering system latency).

Processed posture data is transmitted over the wireless connection of the ESP32 using either its internal Wi-Fi to a cloud-based solution. Posture data collected in the cloud system allows for long-term data storage and visual representation on a GUI. The GUI permits users to see their posture status in real-time, view their past patterns of posture, and receive alerts to help them correct their posture. The system will sound off or vibrate should the user continue to remain in an unhealthy posture for an extended period of time, thus encouraging more ergonomic seating habits when doing so(9).

B. Hardware Components

The embedded control system uses an **ESP32 microcontroller** board to provide the electrical interface for the control system and the sensors. A compact, user-friendly enclosure surrounds the ESP32 board to provide portability and comfort to the user. The hardware feedback module consists of a vibration motor or buzzer that is mounted in such a way that the user can receive feedback immediately, while not being distracted by the feedback device(10).

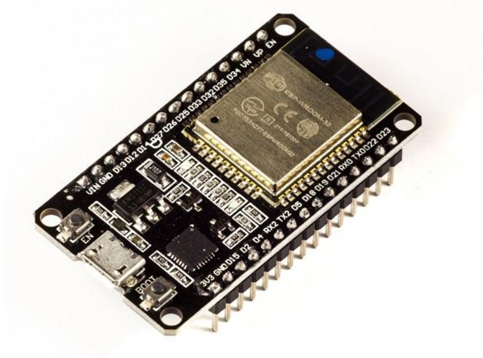

Fig.2 ESP 32

The **MPU9250 IMU** (Inertial Measurement Unit) serves as the main source of posture information by being placed physically on the upper back of the user. This allows it to accurately measure rotations that occur when someone slouches or bends forward. Because of the way it's placed, Body angle can be measured reliably while sitting in a comfortable manner with free movement, and will not affect the ability of the user to move naturally. Flex sensors are placed along the spine or at key bending joints to provide additional information regarding curvature of the spine based upon poor posture, and this information complements the orientation information provided by the MPU9250(11).

Fig.3 MPU9250 IMU (Inertial Measurement Unit)

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III. DATA ACQUISITION AND PREPROCESSING

This system continually acquires posture-the related data of the individual using wearable sensors. One of the wearable sensors is an inertial measurement unit (IMU), which will provide data regarding three axes of acceleration and angular velocity. Another type of wearable sensor will be known as flex sensors and will give an analog (voltage) output when spinal flexion occurs. The acquired data from all the different wearables will be sampled at an agreed-upon frequency (sampling rate), which allows for continued real-time posture monitoring, while consuming as little power as possible.

The raw data readings produced by each of the sensors are susceptible to error due to the influence of both noise and small movements of the body. Therefore, prior to evaluating the posture of an individual, these readings will undergo preprocessing. Raw data will be filtered using a low-pass filter to eliminate high-frequency noise and sudden spikes(12).Once filtered, the data will then be normalised to provide a consistent scale across all of the different sensors, thus enhancing the precision of the thresholds used for classification.

To improve reliability in estimating posture, all posture-related data from all of the sensors will be fused together (sensor fusion). More specifically, the IMU's orientation data will be used in conjunction with the flex sensors' bending data to increase robustness, while decreasing errors related to drift. The final output data (after combining and preprocessing the data) will be sent to a posture detection algorithm to produce output data for classification and corrective action feedback*(13)*.

IV. POSTURE DETECTION FLOWCHART

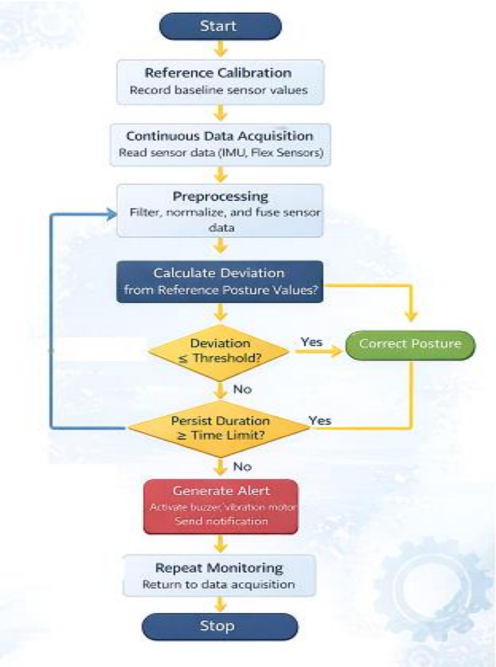

Fig.4 Posture Detection Flowchart

The alert system will activate when a detected deviation of posture exceeds set threshold levels and exists for a period of time above the threshold level. Once a deviation in posture has been confirmed, an immediate corrective feedback signal will be produced for the user. The corrective signal will either be created from an auditory buzzer or from a vibration motor located in the portable attached module. The volume or intensity of the feedback signal, as well as the length of time the feedback signal exists, will be configured to provide an indication to the user while avoiding any distractions to the user.

Posture status will be sent to the corresponding mobile application or dashboard, enabling real-time monitoring of the posture status in addition to providing local alerts for identified incorrect postures. Together, the feedback generated through both hardware and software will encourage users to correct their posture immediately and reinforce healthy posture while sitting, particularly among the student population.

V. WIRELESS COMMUNICATION AND CLOUD INTEGRATION

The system proposed allows for the tracking of posture in real time through cloud access and wireless communication. Processed posture data will be transmitted from an embedded controller to external devices via the embedded Wi-Fi and Bluetooth Low Energy (BLE) capabilities. This wireless transfer allows users to move freely without the restriction of a wire.

To securely collect posture data for future analysis, the data collected will be sent to a cloud platform. The cloud platform will allow for historical documentation of posture status so the trends can be evaluated, and performance can be followed throughout long study times. Some of the more basic types of posture analytic reports generated by this system will be types of bad postures and how long you were slouched.

A graphical user interface (GUI) will allow for a user to see in real time how their posture is by utilizing either a mobile application or web dashboard. The GUI will show the user their posture indicators, any alerts regarding their posture, and statistics regarding the performance of their posture, in an easy-to-read format. These combined attributes of wireless communication, cloud storage, and visibility will provide the user with a user-friendly system that is easy to access, scalable, and allows for remote monitoring(14).

4.1 Experimental Setup

An experimental assessment was performed with numerous participants who engaged in either sitting for long periods, or working at a desk as shown in fig. Each participant was evaluated by means of a study or chair session of approximately 30 - 45 minutes. Posture analysis was performed and an alert generated every time a participant displayed inappropriate postures.

The wireless communication module sends subject's posture data to the cloud platform through a web interface for storage and visualization (i.e., latency~10 seconds). Along with

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providing statements of historical posture, the web-based interface provided the ability to view the current posture status and alert history in real time(15).

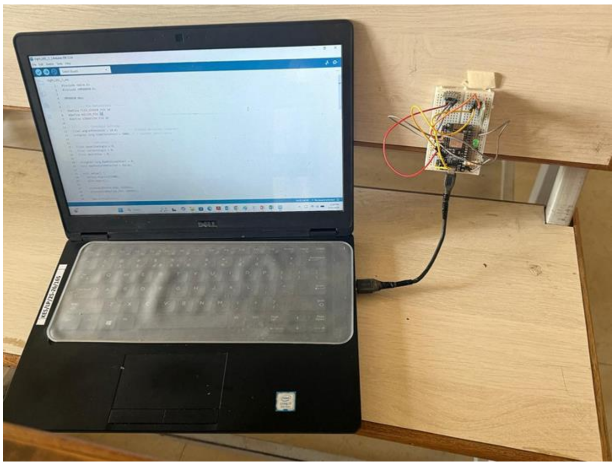

Fig.5 Experimental Setup

4.1 CONCLUSION

This paper presented both the design, and implementation, of a real-time posture detection and monitoring device. Using a combination of an ESP32 Microcontroller, an IMU sensor, and a flex sensor, the system detects poor posture by performing reference calibration, including continuous acquisition of data points, analysis of deviations in data points, and classification of postures based on a user's input and predetermined values for each posture.

To make sure that the system is as reliable as possible in detecting poor posture and to reduce false alarms, a mechanism to verify the validity of results persistently was added. The prototype developed gives users immediate feedback via audio alerts, as well as vibration alerts; therefore, allowing the user to correct their posture as quickly as possible. The system is also capable of storing data in the cloud for remote viewing via a graphical interface using Wi-Fi/Bluetooth, which further expands the system's capabilities. When validated through experimental evaluations, the proposed system was able to reliably detect poor posture with low response times and stable wireless performance, both indoors. Additionally, the entire system is low cost, portable, and applicable for student/office workers and long-duration computer users.

In future work, we anticipate the incorporation of machine learning technologies to develop adaptive classification methods of postures, the addition of multi-point sensors to increase accuracy, and the development of longer-term analytics for health assessment.

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