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Smart Chair Development using ESP32 Microcontroller – A Preliminary Study

Muhammad Norman Nurhakim Mohd Shahriman[1], Tan Xi Ning[1], Mahmud Thaqif Mahmud Rasid[1], Batrisyia Inanda Sari Yusri[1], Nurul Ashikin Abdul-Kadir[1], Norlaili Binti Mat Safri[1*]

[1]Department of Electronic and Computer Engineering, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru, 81310, Malaysia

*Corresponding Author norlaili@utm.my

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Abstract:
In response to the coronavirus disease 2019 (COVID-19) pandemic, the shift to online delivery mode for most teaching faculties has increased the risk of chronic back and neck pain for students and teachers. While short-term adjustments like working from the couch or using an uncomfortable kitchen chair might seem tolerable for working adults or university students, these habits can have detrimental long-term impacts on body and health. Although the pandemic situation has improved, and people are gradually returning to physical workplaces and classrooms, many individuals still spend a significant amount of time sitting in front of screens for work and other activities. This explains why 70% of adults in Malaysia have experienced back and neck pain at least once in their lives. This pre-study proposes a smart chair equipped with sensors that alert users to correct their sitting posture and take screen breaks for stretching, potentially reducing the risk of future muscle aches and pain.

Keywords: Back pain; Smart chair; Neck pain

1. INTRODUCTION

Nowadays, with the development of technology, prolonged sitting has become ingrained in daily life, especially for students. However, extended periods of sitting can significantly increase the risk of chronic health problems for instance, back pain, numbness, spinal disease. Research suggests that sitting for 11 hours per day puts individuals at high risk for developing sitting disease (1). The COVID-19 pandemic may have exacerbated this issue, as students often sit at home for more than 11 hours engaged in online activities like games, lectures and watching movies. Sitting too long without standing can lead to cancer (2). Beyond contributing to sitting disease, research links prolonged sitting to a wider range of health concerns, including obesity and metabolic syndrome, which encompasses elevated blood pressure, blood sugar, and abnormal cholesterol levels, along with excess body fat around the waist.

The evidence is clear: increased activity and reduced sitting time led to better health. Harnessing the inverse relationship between sedentary and active behaviors, particularly by replacing sitting with standing and incorporating light- to moderate-intensity exercise, can yield significant health benefits, especially for individuals with low activity levels. This is supported by recent observational research. Whenever possible, prioritize standing over sitting. Alternatively, consider incorporating short walks into your workday (3). Beyond reducing the specific risks associated with excessive sitting, these postural changes can also increase overall physical activity levels, potentially improving the health of individuals with existing or pre-existing cardiovascular disease (4).

To achieve a proper fit between students' anthropometry and their furniture, adjustable ergonomic chairs offer a potential solution (5). Key anthropometric measurements include height, weight, head circumference, body mass index (BMI), body circumferences (waist, hip, and limbs), and skinfold thickness (6). Based on these measurements, the optimal chair size can be determined. Ergonomic design should be a top priority for students, considering the significant amount of time they spend sitting for studies and other activities. Therefore, addressing the current seating arrangements in educational settings is crucial, not only for students' physical well-being but also for financial considerations. Health problems arising from uncomfortable sitting postures can lead to costly medical expenses, posing a burden on individuals and healthcare systems.

Thus, this project aims to design and develop a smart chair that leverages technology to monitor and alert users of prolonged sitting and poor posture. The smart chair's design focuses on promoting healthy sitting habits by alerting users when they have been sitting for an extended period or when their posture deviates from healthy norms. Equipped with two sensors, the chair detects user presence and monitor posture. The system triggers reminders for users to take breaks or adjust their posture when it detects slouching or other unhealthy positions during activities. This feature empowers users to maintain a healthy and active lifestyle by mitigating the risks associated with prolonged sitting and poor posture.

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2. DESIGN STATEMENT

Leveraging the concept of personification and considering the pain points, user needs, and user profile, the design statement for this project can be summarized as: ‘How can we help users avoid body pain and improve their posture during activities?’.

2.1 Interviews and Analysis

Interviews were conducted to understand users’ problems and needs. A total of 17 interviewees, all university students participated. The questions focused on leisure-time activities, experienced discomfort, problem causes, and self-initiated solutions. Cluster analysis of the interview data helped identify pain points and needs. The data was then transformed into graphs and charts for further understanding.

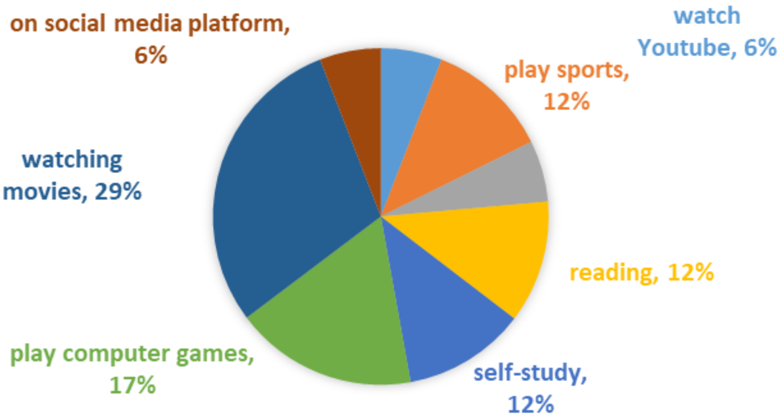

Figure 1. Activities of UTM students during leisure time.

Figure 1 shows the leisure activities of UTM students. The data shows that students most frequently dedicate their leisure time to watching movies (29.4%), followed by playing computer games (17.6%). Activities like playing sports, reading, and self-study each occupy around 11.8% of their leisure time. The least common activities are watching YouTube, online sports, and social media, each representing only 5.9% of leisure time. Overall, the majority of students engaged in sedentary activities during their leisure time.

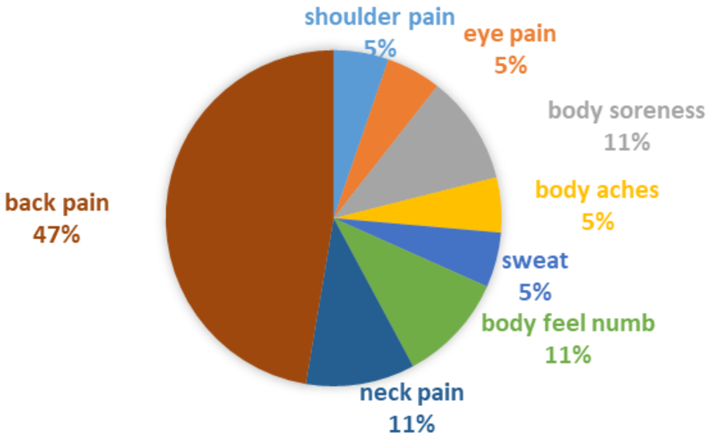

Figure 2. Discomforts experienced by interviewees.

Figure 2 shows the types of discomfort reported by the interviewees. Back pain emerged as the most prevalent discomfort, experienced by a majority of participants. Body soreness, body numbness, and neck pain each affected 10.5% of interviewees. Shoulder pain, eye pain, body aches, and sweating were reported by 5.3% of participants.

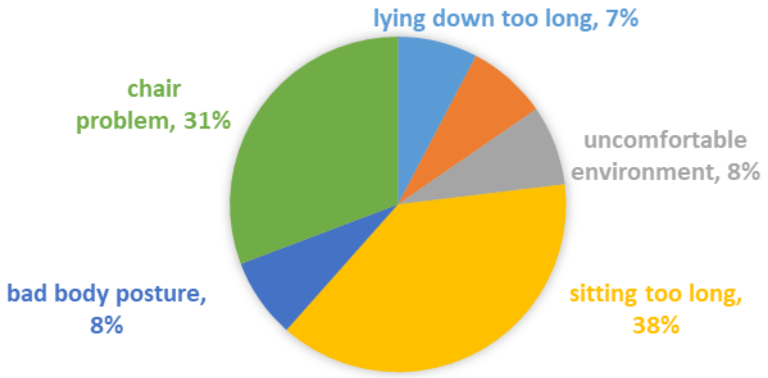

Figure 3. Cause of discomfort reported by interviewees.

Figure 3 shows the causes of discomfort reported by interviewees. Prolonged sitting emerged as the leading factor, accounting for 38% of reported issues. Chair-related problems came in second, representing 30.8% of the reported cases. Lying down for extended periods, table-related issues, and poor posture each contributed to 7.7% of the reported discomfort.

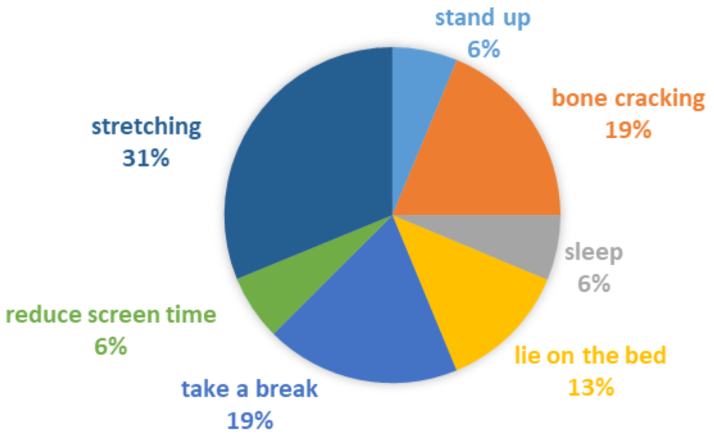

Figure 4. Strategies used by interviewees to address discomfort.

Figure 4 shows the strategies employed by interviewees to manage their discomfort. Stretching was the most common approach, adopted by 31.3% of students to alleviate pain. Cracking their back and taking breaks were equally reported by 18.8% of participants. Lying down on the bed to find relief was used by 12.5% of students. Other strategies implemented by 6.3% of participants included standing up from sitting, reducing screen time, and getting sleep.

3. DESIGN

Figure 5 shows the block diagram of the system. The system comprises two input sensors: one to detect neck posture and another to detect user presence on the chair. Based on sensor inputs, the system utilizes a buzzer and a vibration motor as outputs. These outputs trigger alerts for the user in two scenarios: poor posture and prolonged sitting. The system employs an ESP32 microcontroller integrated with an Internet-of-Things (IoT) module.

The system is activated when the user sits on the chair, detected by both sensors. Upon confirmation, a timer starts and ultrasonic sensors 1 and 2 measure the user's neck-to-chair back distance. The Blynk app displays remaining sitting time until a break is recommended. For neck posture monitoring, if ultrasonic sensor 1 detects a neck length exceeding the good posture limit, a buzzer alerts the user. The Blynk app displays "Bad Posture". The buzzer stops once the user adjusts to a good posture, and the app displays "Good Posture".

For sitting time monitoring, ultrasonic sensor 2 continuously detects user presence. The timer starts upon user detection, and the Blynk app displays the remaining sitting time before a break. If the user sits for over 1 hour, the system triggers a stand-up reminder through the buzzer and vibration motor. If the user doesn't take a 5-minute break and sits back down, the buzzer and vibration motor activate again as a reminder.

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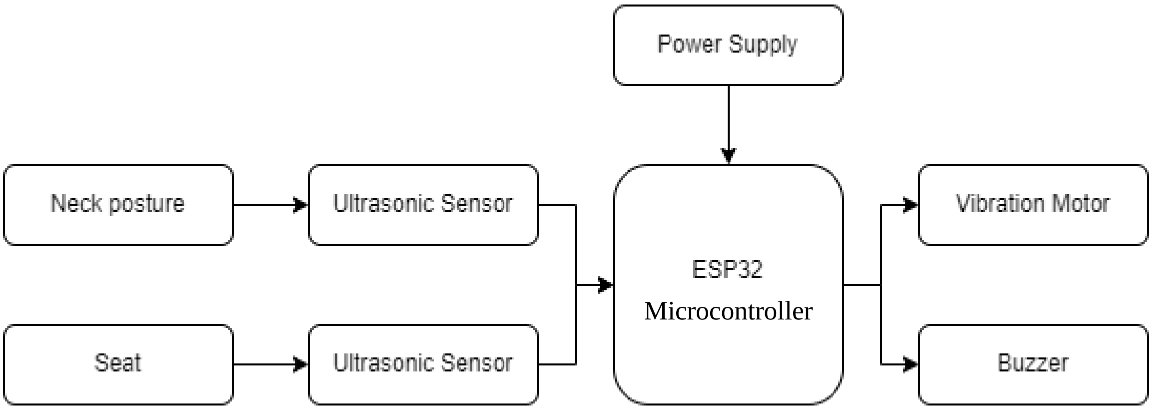


Figure 5. System block diagram.

3.1 Software Development

The software architecture revolves into two primary components: system coding and IoT coding. The system coding manages core chair functionality, which includes sensor data processing and posture detection. It enables features such as posture detection, sitting time tracking, and break/adjustment reminders. This coding is written in Arduino IDE and specifically designed for execution on the chair's control unit (7, 8).

IoT coding facilitates chair connectivity and communication with external devices such as smartphones and computers. It plays a crucial role in enabling real-time posture and sitting habit tracking, along with the functionality of setting reminders and goals. This coding is specifically intended for operation on a device or cloud server.

Collaboration for seamless user experience involves the integration of system coding, responsible for sensor data processing and actuator activation, and IoT coding, which provides user access and control through a mobile app or web interface. This cohesive integration empowers users, allowing them to monitor and manage their posture and sitting habits effectively.

3.2 Circuit Design

Figure 6 shows the circuit connections for the system, comprising two ultrasonic sensors, one piezo buzzer, one vibration motor, and an ESP32 microcontroller. The VCC pins of both ultrasonic sensors are linked to the 5V supply from the ESP32. The negative and ground pins of the ultrasonic sensors, piezo buzzer, and vibration motor connect to the ground supplied from the GROUND pin of the ESP32. The positive pin of the vibration motor and piezo buzzer are connected to pins 15 and 4 of the EPS32, respectively. For ultrasonic sensor 1, the trigger pin and echo pin are connected to ESP32 pins 12 and 13, respectively. Similarly, the trigger pin of ultrasonic sensor 2 is connected to pin 27, and the echo pin is connected to pin 14. The coding of the system specifies the number of pins used, defining the assignment of each pin for a specific component.

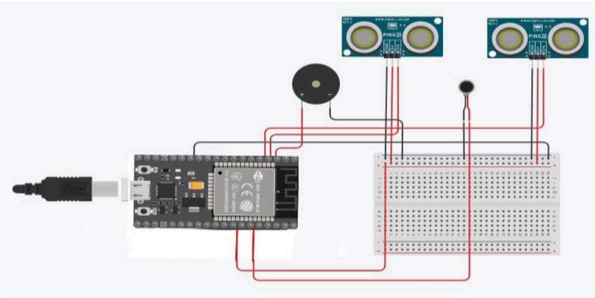


Figure 6. Circuit connection of Smart Chair.

4. RESULTS AND DISCUSSIONS

The Smart Chair prototype incorporates two ultrasonic sensors, a buzzer, and a vibration motor. Strategically placed on the chair, the ultrasonic sensors detect the users' postures and prolonged periods of sitting. The buzzer serves as an audible reminder for users to take breaks or adjust their posture. Additionally, the vibration motor, mounted on the chair, provides a gentle physical reminder for users to move or adjust their posture. These sensors, along with the buzzer and vibration motor, work collectively to offer real-time feedback on the users' postures and sitting habits, reminding them to take breaks and make necessary adjustments.

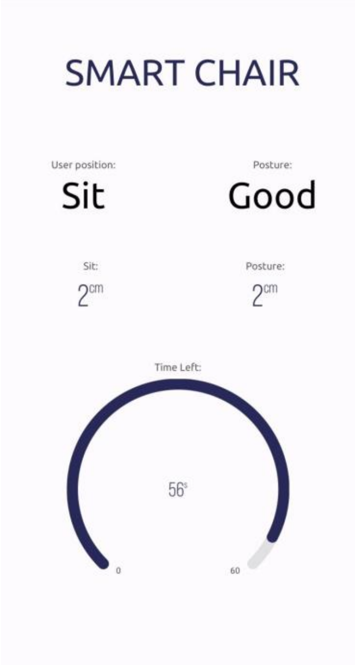
An alarm system consists of a piezo buzzer and vibration motor designed to operate under two conditions. The first condition is triggered when a users’ postures are deemed unfavorable, determined by the distance between the neck and the chair. If this distance exceeds the designated threshold for good posture, the piezo buzzer produces a sound to alert users about their poor posture. The second condition is activated when users remain seated for an extended period, surpassing the preset time limit for continuous sitting. This serves as a reminder for users to stand up and take a break, preventing potential back pain. Ultrasonic sensors detect the users’ distances from the chair, transmitting the data to the control unit. The control unit processes the information and, if necessary, activates the buzzer and vibration motor.

A cable management system is employed to organize the cables for the ultrasonic sensors, buzzer, and vibration motor, ensuring a clean and organized design. Soldering the cables together is a part of this system to ensure a secure and reliable connection. The soldered cables are then placed in an electrical PVC pipe, providing protection against damage, and maintaining a neat organization. This PVC pipe is mounted on the back of the chair, connecting the sensors and actuators to the control unit, where the data is processed. The cable management system enhances the chair's durability and dependability while also improving its overall aesthetic. It makes identifying and troubleshooting potential issues with the chair's sensors and actuators easier for users. The ultrasonic sensors are placed at a 90° angle to ensure optimal operation, considering the range of detection and sensitivity that affect the distance detected. Figure 7 illustrates the hardware placement of the sensors on the chair. The ultrasonic sensors are positioned at a 90° angle to optimize their operation, ensuring effective detection within the specified range and sensitivity, which impacts the detected distance.

Figure 7. The illustration of hardware implementation.

4.1 Mobile Application Development

Blynk is a platform that enables developers to effortlessly create mobile apps for interacting with IoT devices. Figure 8 illustrates the Smart Chair dashboard within the Blynk App, showing the users' posture, time remaining before the users should stand, neck distance from the chair, and whether the chair is in use or not.


SMART CHAIR

User position: Sit

Posture: Good

Sit: 2cm

Posture: 2cm

Time Left: 56s

Figure 8. The mobile dashboard while the system is running.

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The web developer interface and mobile app offer a user-friendly experience, allowing users to easily control and monitor their IoT devices. Blynk provides customization options, allowing developers to tailor the mobile app’s design to match that of the IoT device, ensuring a seamless user experience. The system utilizes five data pins. The first pin, V0, is declared as an integer and is used to display the distance of the users’ necks and the back of the chair. Following this, pin V1, also an integer, displays the distance between the users’ backs and the chair, detecting whether the users are using the chair. Pins V2 and V3 display the users’ posture status (good or bad) and whether the users are sitting or standing. Finally, pin V5 is used to display the label 'Smart Chair' in the Blynk mobile app.

5. CONCLUSION

In conclusion, the smart chair project has successfully achieved its goal of enhancing posture and preventing neck and back pain associated with prolonged sitting and poor posture. The chair can detect and alert users about poor posture and prolonged sitting by incorporating ultrasonic sensors, a buzzer, and a vibration motor, as well as a cable management system. The chair's ability to promote good posture, coupled with the customization of the sitting plan based on the users’ posture and sitting habits, all contribute to the project's success. By mitigating health risks linked to prolonged sitting and poor posture, the chair's design aims to facilitate users in maintaining a healthy and active lifestyle. It encourages users to take frequent breaks, adjust their posture, and become more aware of their sitting habits. The user-friendly interface, sleek design, and durability make it an ideal solution for individuals who spend extended periods at their desks or seek to enhance their posture. Consequently, the smart chair project has developed a chair that fosters healthy sitting habits, improves posture, and reduces the risk of associated health issues. It proves to be an excellent choice for anyone aiming to enhance their sitting posture and minimize the risk of neck and back pain.

Some improvements can be made for the system to function better. These improvements involve replacing the ultrasonic sensors, which detect the user sitting on the chair and the neck posture, with other sensors such as IR infrared sensors. This change is prompted by the sensitivity and range limitations of the ultrasonic sensors, which can disrupt the system's proper functioning. Ultrasonic sensors may indicate a distance of 400cm when the user leans too close, exceeding the predefined distance for the system to function effectively.

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CONFLICT OF INTEREST

This study has no conflict of interest.

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