JOURNAL OF ELECTRONIC VOLTAGE AND APPLICATION
e-ISSN: 2716-6074

JEVA

Vol. 5 No. 2 (2024) 36-55
https://publisher.uthm.edu.my/ojs/index.php/jeva

A Smart Chair for Sitting Postures Monitoring and Seat Occupancy Detection

Mohamad Syahmi Hilmi Zaharuddin[1], Shaharil Mohd Shah[2]*

[1] *Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA*
[2] *Advanced Telecommunication Research Center (ATRC), Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: shaharil@uthm.edu.my
DOI: https://doi.org/10.30880/jeva.2024.05.02.004

Article Info

Received: 2 July 2024
Accepted: Day 11 October 2024
Available online: 31 December 2024

Keywords

Ultrasonic sensors, Force Sensing Resistor (FSR), sitting postures monitoring, seat occupancy detection, Blynk application

Abstract

In recent years, occupational roles often require extended periods of sedentary activity, particularly sitting in front of computer screens. Incorrect sitting postures adopted during such activities can lead to various health issues such as muscular imbalances and spinal misalignment. Therefore, a Smart Chair for Sitting Postures Monitoring and Seat Occupancy Detection is proposed in this work to overcome those health issues. The Smart Chair design incorporates four ultrasonic sensors to actively monitor the distance between the user's back and the seat cushion. When poor posture is detected, the Blynk application sends alert notifications to the user's mobile phone. Additionally, the seat occupancy detection system, powered by four Force Sensing Resistor (FSR) sensors, proves useful in multi-user environments. Real-time alerts via the Blynk application enhance the operational efficiency of the Smart Chair. Validation assessments conducted with three volunteers of varying heights and weights confirmed the effectiveness of the ultrasonic sensors in monitoring sitting postures. The sensors operate consistently with the predefined truth table. Additionally, the validation process for seat occupancy detection, using the same volunteers, demonstrates system reliability and responsiveness. Alert notifications are accurately sent to users' mobile phones upon detecting physical pressure. In a nutshell, the Smart Chair has demonstrated its effectiveness in continuously monitoring sitting postures and detecting seat occupancy which contributes to a health-conscious and intelligent seating solution, enhancing the overall user experience.

1. Introduction

The lifestyle of individuals in post-industrial societies has undergone significant transformation in recent decades due to remarkable scientific and technological progress. In today's context, heavy manual labor has largely been replaced by machines, leading to a prevalence of office-based occupations where personal soft skills are valued over hard skills. A common practice in these roles involves prolonged periods of sitting in front of computer screens, which, if done in incorrect postures, can give rise to health issues [1]. Technological advancements, exemplified by the Internet of Things (IoT) paradigm, aim to benefit humanity. The IoT has introduced the potential of connected sensor systems to enhance the health conditions of all living beings [2].

The application of IoT in the area of seat occupancy detection system has been a transition process and movement from traditional system to new and more active system. The incorporation of these technologies in the seat detection system eases management challenges experienced with regards to self-servicing, monitoring and detection of seats [3]. This innovative system utilizes a range of sensors and technologies to determine the presence or absence of individuals in seats. Numerous studies have been carried out to detect the occupancy of people in the library, office and classroom using ultrasonic and Force Sensing Resistor (FSR) sensors [4]. Seat occupancy detection can also enhance security by alerting authorities to unattended bags or suspicious behavior in public places.

In recent years, employment in sedentary occupations has continuously risen. Office workers are more prone to prolonged static sitting, spending 65–80% of work hours sitting, increasing risks for multiple health problems [5]. Today, most high-income countries' economy has transitioned from the production of goods to the provision of services. This transition has resulted in an increasing number of people employed in sedentary occupations, in which work is primarily carried out while sitting down. Prolonged sitting has become a common issue in modern society, contributing to a range of health problems and negatively impacting overall well-being. Therefore, a Smart Chair for Sitting Postures Monitoring and Seat Occupancy Detection is proposed in this work to overcome those problems. This Smart Chair is equipped with four ultrasonic sensors embedded in the back seat cushion which measure user's body distance from the sensors for correct sitting postures. The distance between the sensors and user's body has set so as not to exceed a threshold value of 15 cm, upon which alert notification shall trigger to notify the user via Blynk application. Those alert notification help users easily detect and correct stressful postures with minimal distractions. In addition, the Smart Chair is also equipped with four Force Sensing Resistor (FSR) sensors to accurately identify whether a seat is occupied or not and Blynk application shall send alert notification to user's mobile phone if the seat is occupied. This functionality proves especially beneficial for tracking seat occupancy in communal or public areas.

2. Research Methodology

This section discusses the methodology applied in completing this work. The work planning, block diagram, process flow and electronic components employed in this work are among the tasks.

2.1 Block Diagram

Fig. 1 show the block diagram of the Smart Chair for Sitting Postures Monitoring and Seat Occupancy Detection. From the figure, it can be seen that the Smart Chair is controlled by ESP32 Wi-Fi module with NodeMCU-32S Base module as the main controlling unit. The key component, which is four ultrasonic sensors, acts as the input for the distance measurement between back seat cushion and user (the user body must touch all the sensors for correct posture) in order to alert the user to correct his posture. Alongside the four Force Sensing Resistor (FSR), the sensors that allow the Smart Chair to detect physical pressure for seat occupancy detection, these inputs will send signals to the microcontroller to be analyzed and processed. There are eight postures to be analyzed which are upright sitting (the correct posture), slouching, leaning forward, leaning backward, leaning left, leaning right, right leg crossed and left leg crossed. The processed signals will then be sent to the output which includes Blynk application as an IoT platform to alert the user. One is for seat occupancy detection and another one is for the correct sitting posture.

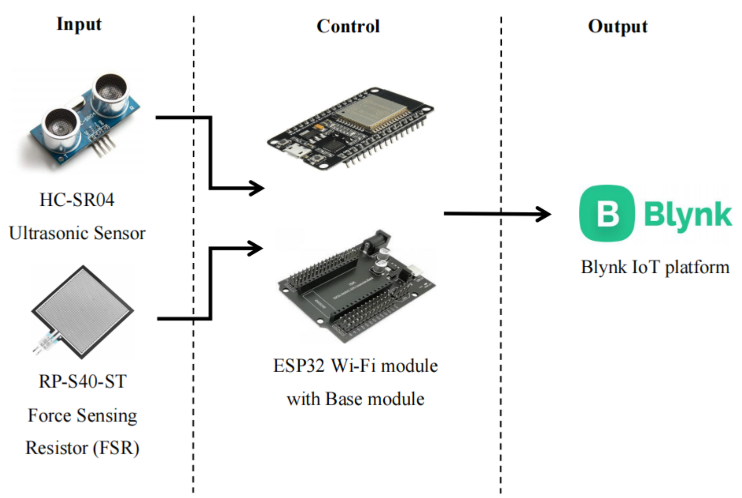


Fig. 1 *Block diagram of the Smart Chair for sitting postures monitoring and seat occupancy detection*

2.2 The Sketch Idea for the Smart Chair

The sketch idea for the Smart Chair that integrates four ultrasonic sensors embedded in the back seat cushion for sitting posture monitoring and four FSR sensors in the seat cushion for seat occupancy detection can be seen in Fig. 2. This innovative combination not only provides real-time feedback via Blynk application on users' posture but also ensures seamless and reliable detection of seat occupancy, enhancing the overall user experience and contributing to the development of a health-conscious and intelligent seating solution.

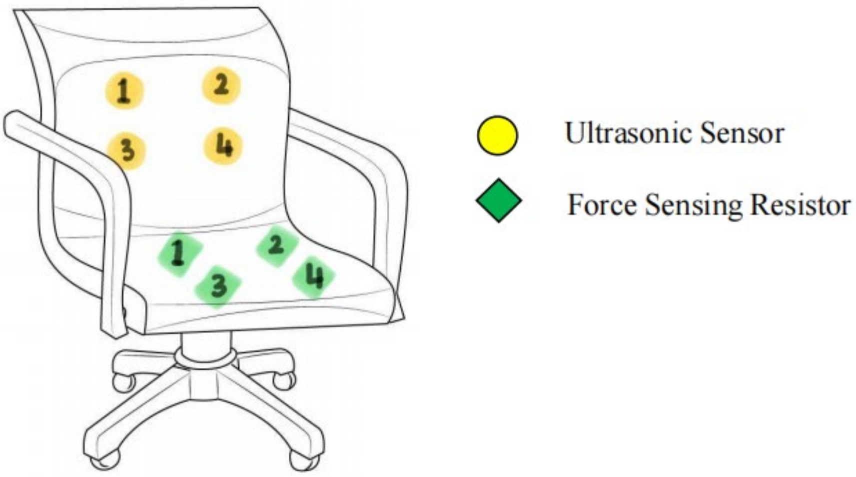


Fig. 2 *The sketch idea of the Smart Chair for Sitting Posture Monitoring and Seat Occupancy Detection*

2.3 Blynk Application

Blynk application is an IoT software that offers a platform for developing mobile (IOS and Android) applications that may connect electronic equipment to the Internet and remotely monitor and control them. With white-label smartphone applications, private clouds, system management, data mining, and deep learning, Blynk is a hardware-agnostic IoT platform. Enter the most common IoT network to connect the devices to the cloud, design control applications, evaluate telemetry information, and manage the product deployed on a scale. In this work, the coordinates in terms of latitude and longitude shall be displayed on the Blynk application. The car owner can also view the location of his car on Google maps in the same application.

3. Results and Discussion

This section discusses the result obtained and analysis on the Smart Chair. This section is divided into the final product, sitting postures monitoring and seat occupancy detection.

3.1 Final Product

The final product of the Smart Chair for Sitting Postures Monitoring and Seat Occupancy Detection can be seen in Fig. 3. It consists of four ultrasonic sensors to measure the distance between back seat cushion and user in order to alert the user to correct his posture using Blynk application. The real-time feedback provided by this system encourages healthier sitting habits and enhances overall comfort for users. Next, four FSR sensors are used to allow the Smart Chair to detect any physical pressure for seat occupancy detection. These sensors are strategically placed to cover key areas of the seat cushion, ensuring accurate detection regardless of the occupant's seating position. The controlling unit for the Smart Chair consists of two which are sitting postures monitoring and seat occupancy detection.

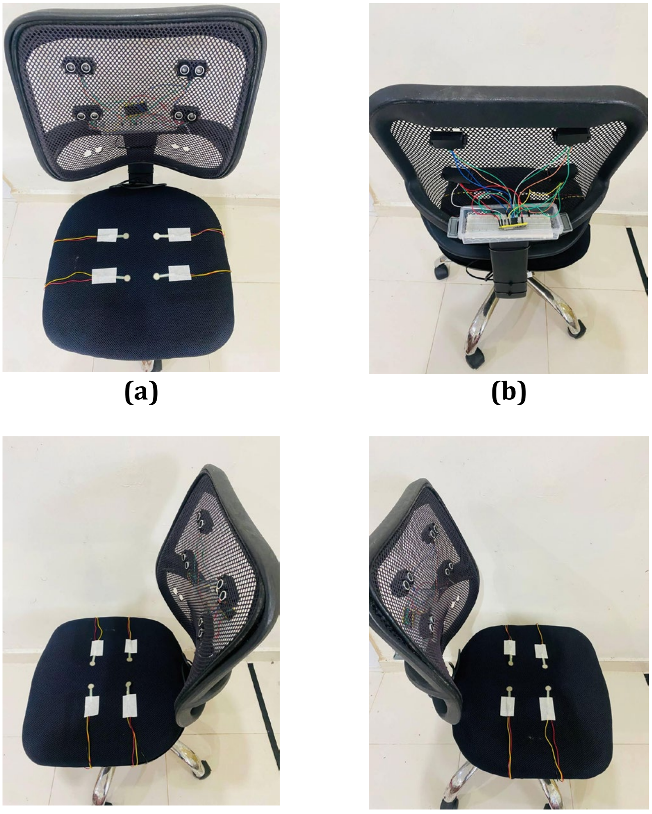


Fig. 3 *The final product (a) Front view; (b) Back view; (c) Left side view; (d) Right side view*

3.2 Sitting Postures Monitoring

Fig. 4 shows the configuration of four ultrasonic sensors on the back seat cushion of the Smart Chair. As soon as the user sit on the Smart Chair, the sensors will detect the distance between back seat cushion and the user's body. The processed signals will then be sent to the output which includes Blynk application as an IoT platform as the distance exceeded 15 cm to alert the user regarding sitting posture. The 15 cm distance is selected because when the user's body moves away from the back seat cushion by more than 15 cm, it is categorized as poor posture.

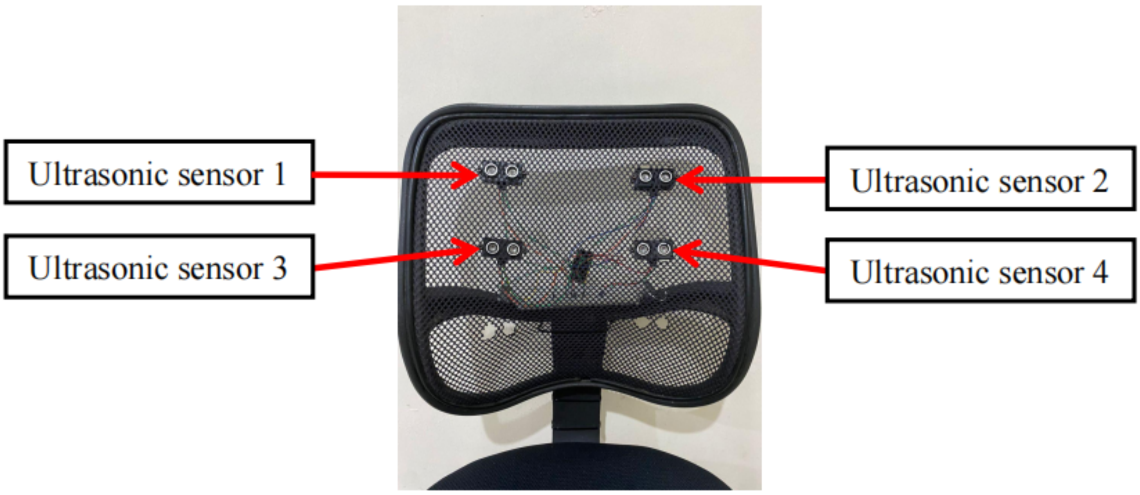


Fig. 4 *The configuration of sitting postures monitoring on the Smart Chair*

A truth table for user's sitting postures is constructed to correlate with the reading from the ultrasonic sensors, as can be seen in Table 1. A truth table serves as a comprehensive guide, mapping each sitting posture to a specific pattern of sensor readings. This allows for real-time posture identification and immediate feedback through the Blynk application, enhancing the user's awareness and ability to correct their sitting habits. From the table, when all the sensors detect the user's back, no notification is received by the user via Blynk application which are the case for upright sitting, leaning backward, right leg crossed and left leg crossed postures. This is due to the fact that when the user's body is in direct contact with the four ultrasonic sensors, the sensor could not collect accurate data because the emitted sound waves are partially absorbed by the user's body and clothes. Therefore, no processed signal is sent from the ultrasonic sensor to the Blynk application.

Table 1 *The truth table of user's sitting postures for Smart Chair for sitting postures monitoring and seat occupancy detection*

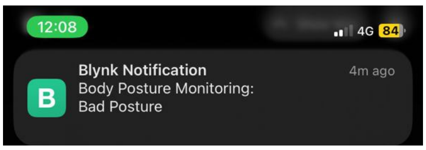
Sitting Position	Ultrasonic Sensors				Notification Received via Blynk Application
	1	2	3	4	
Upright Seating	1	1	1	1	No
Slouching	0	0	1	1	Yes
Leaning Forward	0	0	1	1	Yes
Leaning Backward	1	1	1	1	No
Leaning Right	1	0	1	0	Yes
Leaning Left	0	1	0	1	Yes
Right Leg Crossed	1	1	1	1	No
Left Leg Crossed	1	1	1	1	No

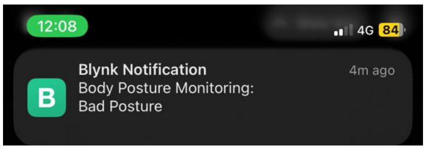
Note: '1' indicates that ultrasonic sensors detect user's body and '0' indicates that ultrasonic sensors does not detect user's body

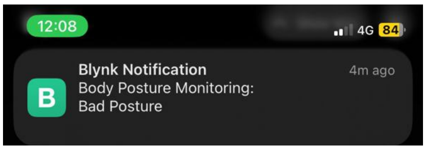
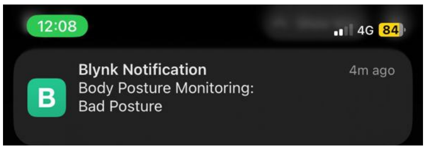
Further assessment are performed on three volunteers to evaluate their sitting postures when using the Smart Chair in order to determine the operating ultrasonic sensors to be consistent with the truth table as can be seen in Table 2 to Table 4.

Table 2 *The assessment of sitting postures monitoring for Volunteer A*

Volunteer A
Height: 180 cm
Weight: 95 kg

Sitting Position	**Operating Sensors**				**Blynk Application**
	1	**2**	**3**	**4**	
Upright Sitting	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** An upright sitting position detected by all operating sensors indicates that the user's back is properly aligned with the chair, suggesting good posture. This position is ideal for maintaining spinal health and preventing muscle fatigue. Maintaining this posture helps in reducing the risk of back pain and other posture-related problems.
Slouching	0	0	1	1	

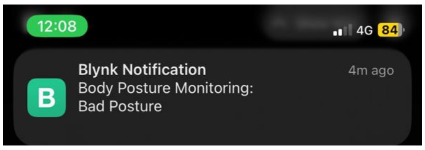
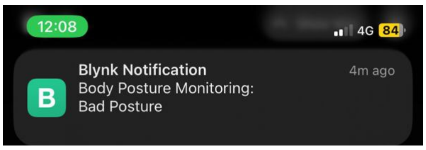
					Observation: Blynk application send alert notification to user's mobile phone. **Analysis:** When only sensors 3 and 4 detect the user's back, it suggests that the upper part of the back is not in contact with the chair, indicating a slouching posture. This could mean that the user is leaning forward or not sitting upright. The Smart Chair system shall alert the user via Blynk application to correct their posture to prevent back pain or discomfort associated with prolonged slouching.
Leaning Forward	0	0	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When sensors 3 and 4 are the only ones detecting the user's back, it indicates that the lower back is likely in contact with the chair, while the upper back is not, which aligns with a forward-leaning sitting position. This posture can strain the lower back over time. The Smart Chair could use this data to prompt the user to sit back fully against the chair to distribute their weight evenly and maintain a healthier posture.
Leaning Backward	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When all operating sensors detect the user's back, it suggests that the user is leaning backward, making full contact with the chair. This position may indicate a relaxed posture or an attempt to stretch after sitting for a prolonged period. While this posture can be comfortable temporarily,

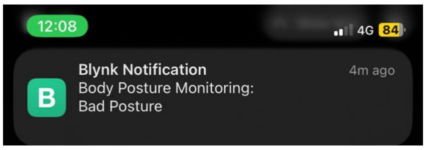
					maintaining it for too long could lead to slouching and potential discomfort. The Smart Chair could monitor the duration of this posture and remind the user to adjust their position regularly to maintain optimal spinal alignment.
Leaning Right	1	0	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When sensors 1, 3, and 4 detect the user's back, it indicates that the user is leaning towards the right side. This could be due to a natural tendency, a momentary shift in position, or even an uneven seating surface. Prolonged leaning to one side can lead to muscular imbalances and spinal misalignment. The Smart Chair can alert the user to adjust their position to center their spine and distribute their weight evenly across both sides of the chair.
Leaning Left	0	1	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When sensors 2, 3, and 4 are activated, it suggests that the user is leaning to the left. This could be a sign of discomfort, a temporary shift to reach for something, or a habit of sitting asymmetrically. Consistent leaning on one side may cause strain on the spine and muscles over time. The Smart Chair can use this information to encourage the user to realign their posture by sitting upright and centered, promoting even weight distribution and reducing the risk of posture-related issues.

Right Leg Crossed	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When all operating sensors detect the user's back while the right leg is crossed, it indicates that despite the change in leg position, the user's back remains in contact with the chair. This posture can cause an imbalance in the hips and lower spine alignment over time. The Smart Chair could identify this pattern and suggest alternative sitting positions or remind the user to uncross their legs periodically to maintain better posture and prevent potential discomfort or musculoskeletal issues.
Left Leg Crossed	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When the left leg is crossed and all sensors detect the user's back, it suggests that the user maintains back contact with the chair despite the asymmetrical leg position. This posture can lead to uneven pressure on the pelvis and misalignment of the spine. The Smart Chair could monitor for such postures and prompt the user to alternate their leg position or sit with both feet on the ground to promote symmetrical posture and reduce the risk of developing musculoskeletal issues.

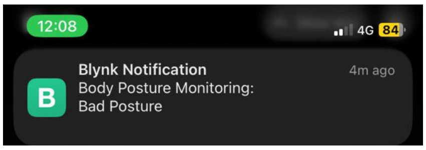
Table 3 *The assessment of sitting postures monitoring for Volunteer B*

Volunteer B Height: 170 cm Weight: 89 kg					
Sitting Position	**Operating Sensors**				**Blynk Application**
	1	**2**	**3**	**4**	
Upright Sitting	1	1	1	1	**Observation:** The Blynk application does not send

					alert notification to the user's mobile phone. **Analysis:** An upright sitting position detected by all operating sensors indicates that the user's back is properly aligned with the chair, suggesting good posture. The result is similar to Volunteer A. This position is ideal for maintaining spinal health and preventing muscle fatigue. The Smart Chair could reinforce this positive behavior by confirming to the user that they are sitting correctly, perhaps through a positive feedback system. Maintaining this posture helps in reducing the risk of back pain and other posture-related problems.
Slouching	0	0	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** In a slouching position, where only sensors 3 and 4 detect the user's back, the readings are similar to those of Volunteer A. This indicates that the mid to lower back is in contact with the chair, but the upper back and shoulders are likely curved forward. This posture can lead to tension in the back muscles and spinal discomfort. The Smart Chair could alert the user to adjust their posture by sitting up straight and using lumbar support if available, to encourage a healthier spine alignment. Consistent reminders can help in developing better sitting habits.
Leaning Forward	0	0	1	1	 **Observation:** Blynk application send alert

					notification to user's mobile phone. **Analysis:** When sensors 3 and 4 are the only ones detecting the user's back, it indicates that the lower back is likely in contact with the chair, while the upper back is not, which aligns with a forward-leaning sitting position. This result is similar to Volunteer A. This posture can strain the lower back over time. The Smart Chair could use this data to prompt the user to sit back fully against the chair to distribute their weight evenly and maintain a healthier posture.
Leaning Backward	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When all operating sensors detect the user's back, it suggests that the user is leaning backward, making full contact with the chair. The result corresponds with the Volunteer A. This position may indicate a relaxed posture or an attempt to stretch after sitting for a prolonged period. While this posture can be comfortable temporarily, maintaining it for too long could lead to slouching and potential discomfort. The Smart Chair could monitor the duration of this posture and remind the user to adjust their position regularly to maintain optimal spinal alignment.
Leaning Right	1	0	1	0	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When only sensors 1 and 3 detect the user's back, it indicates that the user is leaning significantly to the right side. Despite the differences from Volunteer

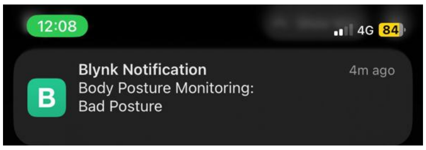
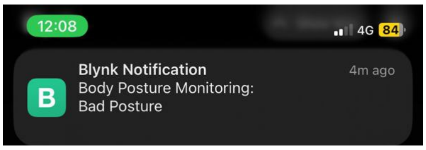
J. of Electronic Voltage and Application Vol. 5 No. 2 (2024) p. 36-55

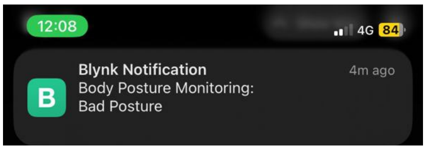
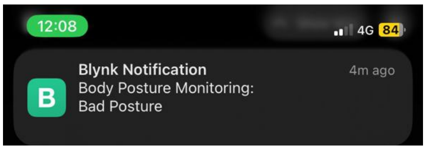
					A's data, this posture is still classified as a leaning right. This could be due to various reasons such as reaching out for something on that side or even discomfort on the left side. The Smart Chair could alert the user to adjust their posture to a more neutral, centered position to prevent potential musculoskeletal issues.
Leaning Left	0	1	0	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When sensors 2 and 4 are activated, it suggests that the user is leaning towards the left side. Even with the variances from Volunteer A's readings, the posture remains identified as a leaning left. This could indicate a natural tendency to lean, a temporary shift in position, or an attempt to alleviate discomfort on the right side. Prolonged leaning to one side can lead to muscle imbalances and spinal misalignment. The Smart Chair can alert the user to adjust their position to center their spine and distribute their weight evenly across both sides of the chair.
Right Leg Crossed	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When all operating sensors detect the user's back while the right leg is crossed, it indicates that despite the change in leg position, the user's back remains in contact with the chair. This results align with those observed for Volunteer A. This posture can cause an imbalance in the hips and lower spine alignment over time. The Smart Chair could identify this pattern and suggest

					alternative sitting positions to maintain better posture and prevent potential discomfort.
Left Leg Crossed	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When the left leg is crossed and all sensors detect the user's back, it suggests that the user maintains back contact with the chair despite the asymmetrical leg position. The result is similar to Volunteer A. This posture can lead to uneven pressure on the pelvis and misalignment of the spine. The Smart Chair could monitor for such postures and prompt the user to alternate their leg position or sit with both feet on the ground to promote symmetrical posture and reduce the risk of developing musculoskeletal issues.

Table 4 *The assessment of sitting postures monitoring for Volunteer C*

Volunteer: C Height: 175 cm Weight: 77 kg					
Sitting Position	**Operating Sensors**				**Blynk Application**
	1	**2**	**3**	**4**	
Upright Sitting	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** An upright sitting position detected by all operating sensors indicates that the user's back is properly aligned with the chair, suggesting good posture. The result is similar to the results of both Volunteer A and B.This position is ideal for maintaining spinal health and preventing muscle fatigue. The Smart Chair could reinforce this positive behavior by confirming to the user that they are sitting correctly. Maintaining

					this posture helps in reducing the risk of back pain and other posture-related problems.
Slouching	0	0	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** In a slouching position, where only sensors 3 and 4 detect the user's back, it indicates that the mid to lower back is in contact with the chair, but the upper back and shoulders are likely curved forward. The result is comparable to those of Volunteer A and B.This posture can lead to tension in the back muscles and spinal discomfort. The Smart Chair could alert the user to adjust their posture by sitting up straight and using lumbar support if available, to encourage a healthier spine alignment. Consistent reminders can help in developing better sitting habits.
Leaning Forward	0	0	0	0	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When none of the operating sensors detect the user's back, it suggests that the user is leaning forward significantly, likely away from the backrest of the chair. The result differs from those of Volunteer A and B, yet it still falls under the category of leaning forward. This posture can put a strain on the lower back and neck due to the lack of support. The Smart Chair could alert the user to the potential risk of discomfort or injury due to this posture and encourage them to lean back into

					the chair for proper support.
Leaning Backward	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When all operating sensors detect the user's back, it suggests that the user is leaning backward, making full contact with the chair. The result is in line with what were observed for Volunteer A and B. This position may indicate a relaxed posture or an attempt to stretch after sitting for a prolonged period. While this posture can be comfortable temporarily, maintaining it for too long could lead to slouching. The Smart Chair could monitor the duration of this posture and remind the user to adjust their position regularly to maintain optimal spinal alignment.
Leaning Right	1	0	1	0	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When only sensors 1 and 3 detect the user's back, it indicates that the user is leaning significantly to the right side. The result associated with both Volunteer A and B. This could be due to various reasons such as reaching out for something on that side, a habit of leaning to one side, or even discomfort on the left side. This posture can cause uneven stress on the spine and muscles. The Smart Chair could alert the user to adjust their posture to a more neutral, centered position.
Leaning Left	0	1	0	1	 **Observation:**

					Blynk application send alert notification to user's mobile phone. **Analysis:** When sensors 2 and 4 are activated, it suggests that the user is leaning towards the left side. The result aligns with Volunteer B. This could indicate a natural tendency to lean or an attempt to alleviate discomfort on the right side. Prolonged leaning to one side can lead to muscle imbalances and spinal misalignment. The Smart Chair can alert the user to adjust their position to center their spine and distribute their weight evenly across both sides of the chair.
Right Leg Crossed	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When all operating sensors detect the user's back while the right leg is crossed, it indicates that despite the change in leg position, the user's back remains in contact with the chair. The result is similar to the results of both Volunteer A and B. This posture can cause an imbalance in the hips and lower spine alignment over time. The Smart Chair could identify this pattern and suggest alternative sitting positions or remind the user to uncross their legs periodically to maintain better posture and prevent potential discomfort or musculoskeletal issues.
Left Leg Crossed	1	1	1	1	**Observation:** The Blynk application does not send alert notification to the user's mobile phone. **Analysis:** When the left leg is crossed and all sensors detect the user's back, it suggests that the user maintains back contact with the chair despite the asymmetrical leg position. The result is comparable to those of Volunteer A and B. This posture can lead to uneven pressure on the pelvis and misalignment of the spine. The Smart

			Chair could monitor for such postures and prompt the user to alternate their leg position or sit with both feet on the ground.

Table 5 presents a comparative analysis of the ultrasonic sensors' operation, correlating them with the sitting postures observed across all volunteers. From the table, it is shown that the Smart Chair effectively monitors the volunteers' sitting postures regardless of their different height and weight using Blynk application that shall send alert notification to their mobile phone to correct the poor sitting postures.

Table 5 *The comparison of operating ultrasonic sensors for all volunteers*

Sitting Postures	Operating Sensors											
	Volunteer A				Volunteer B				Volunteer C			
	1	2	3	4	1	2	3	4	1	2	3	4
Upright Seating	1	1	1	1	1	1	1	1	1	1	1	1
Slouching	0	0	1	1	0	0	1	1	0	0	1	1
Leaning Forward	0	0	1	1	0	0	1	1	0	0	0	0
Leaning Backward	1	1	1	1	1	1	1	1	1	1	1	1
Leaning Right	1	0	1	1	1	0	1	0	1	0	1	0
Leaning Left	0	1	1	1	0	1	0	1	0	1	0	1
Right Leg Crossed	1	1	1	1	1	1	1	1	1	1	1	1
Left Leg Crossed	1	1	1	1	1	1	1	1	1	1	1	1

3.3 Seat Occupancy Detection

In the configuration depicted in Fig. 5, seat occupancy detection involves the use of four FSR sensors. These sensors are strategically positioned in the seat cushion of a Smart Chair. Their purpose is to alert the librarian about seat occupancy. Upon detecting pressure from an occupant, the FSR sensors activate the system. The processed signals are then transmitted to an output, which incorporates with a Blynk application serving as an IoT interface. This setup allows for real-time monitoring of seat occupancy and it enhances librarian interaction with the Smart Chair through instant notifications.

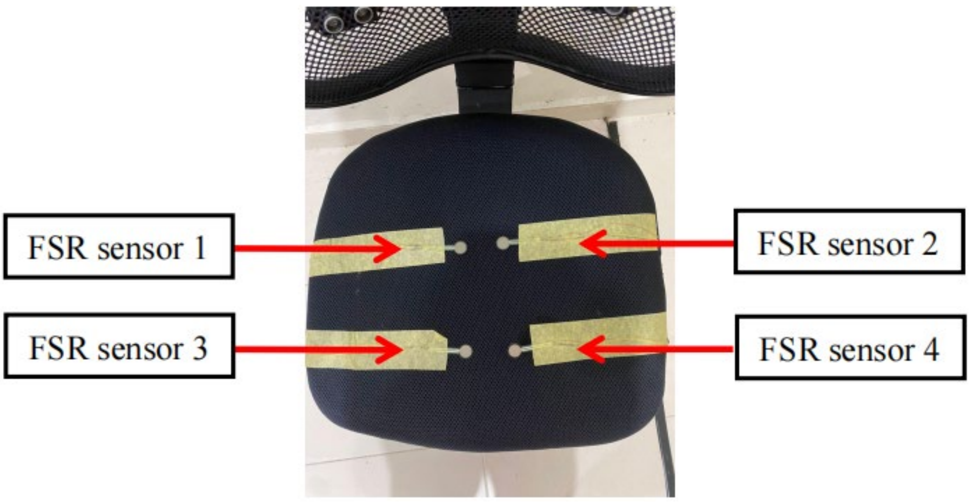


Fig. 5 *The configuration of seat occupancy detection on the Smart Chair*

Table 6 shows a truth table for Smart Chair seat occupancy is devised to correlate with the reading from the FSR sensors. This table acts as an exhaustive reference, linking each seating condition to a distinct sensor output. It

J. of Electronic Voltage and Application Vol. 5 No. 2 (2024) p. 36-55

facilitates instantaneous recognition of whether the seat is occupied and delivers prompt updates via the Blynk application, thereby improving situational awareness to the librarian regarding seat occupancy.

Table 6 *The truth table of seat occupancy for Smart Chair for sitting postures monitoring and seat occupancy detection*

FSR Sensors				Notification Received via Blynk Application
1	2	3	4	
0	0	0	0	No
1	0	0	0	No
0	1	0	0	No
0	0	1	0	No
0	0	0	0	No
1	1	1	1	Yes

Further evaluations are conducted with three volunteers to assess the accuracy of the Smart Chair's seat occupancy detection and ensuring the FSR sensors' performance aligns with the truth table as can be seen in Table 7, Table 8 and Table 9.

Table 7 *The assessment of seat occupancy detection for Volunteer A*

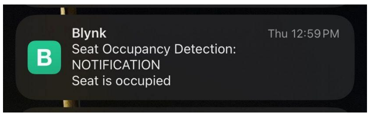
Operating Sensors				**Blynk Application**
1	2	3	4	
1	1	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** When all FSR sensors are triggered, it indicates that there is significant pressure on all contact points of the chair, which typically means the chair is fully occupied. The Blynk application shall then send alert notification to the user's mobile phone to alert the user when the chair is in use. This function is beneficial for monitoring seat occupancy and can be particularly useful in shared or public spaces. It is crucial for the system to function accurately, irrespective of the differences in height and weight of various users, to guarantee precise detection of seat occupancy in settings where the chair might be used by multiple people.

Table 8 *The assessment of seat occupancy detection for Volunteer B*

Operating Sensors	**Blynk Application**

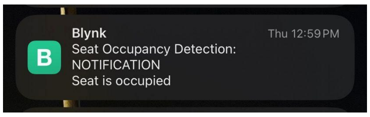
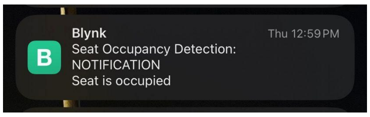
1	2	3	4	
1	1	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** The detection of all FSR sensors indicates full occupancy of the chair, which prompts the system to send a notification to the user's mobile phone via Blynk application. This consistent response, irrespective of the volunteer's height and weight, shows that the chair's sensor system is effectively use to detect occupancy without being influenced by the specific pressure distribution of different body types. This ensures that the Smart Chair can reliably inform users of seat usage, which can be crucial for monitoring purposes in various settings.

Table 9 *The assessment of seat occupancy detection for Volunteer C*

Operating Sensors				Blynk Application
1	2	3	4	
1	1	1	1	 **Observation:** Blynk application send alert notification to user's mobile phone. **Analysis:** The activation of all FSR sensors signifies that the chair is occupied, triggering a notification to the user's mobile phone via the Blynk application. This indicates that the chair's sensor system is effectively detecting occupancy and communicating with the user's mobile device efficiently. The system's ability to operate correctly, regardless of variations in the volunteer's height and weight is essential for ensuring accurate occupancy detection in environments where multiple individuals may use the chair.

4. Conclusion

In summary, the Smart Chair for Sitting Postures Monitoring and Seat Occupancy Detection has demonstrated its effectiveness in monitoring correct sitting postures and enhancing seat occupancy detection. The Smart Chair design, featuring four ultrasonic sensors, actively monitors the distance between the user's back and the back seat cushion, engaging the Blynk application to send alert notification to user's mobile phone when poor posture is detected. The comprehensive validation experiment, encompassing eight different sitting postures, demonstrates the chair's capability to accurately discern and respond to various seating positions. Further assessments conducted on three volunteers of varying heights and weights have validated the effectiveness of the ultrasonic sensors in monitoring sitting postures, ensuring their operation is consistent with the predefined truth table. In addition, seat occupancy detection system powered by four FSR sensors might be useful in environments where multiple individuals may use the chair. The system ability to send alert notification to the user in real-time via Blynk application about seat occupancy enhances operational efficiency of the Smart Chair. The validation process involving the same volunteers further demonstrates the system reliability and responsiveness, ensuring that alert notification is accurately sent to users' mobile phone upon detection of any physical pressure. Overall, the Smart Chair has proven itself as an instrumental device for ongoing monitoring of sitting postures and detecting seat occupancy.

Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

References

[1] Aminosharieh Najafi, T., Abramo, A., Kyamakya, K., & Affanni, A. (2022). Development of a Smart Chair Sensors System and Classification of Sitting Postures with Deep Learning Algorithms. *Sensors*, 22(15), 5585. https://doi.org/10.3390/s22155585

[2] Tavares, C., Silva, J. O. E., Mendes, A., Rebolo, L., Domingues, M. D. F., Alberto, N., Lima, M., Radwan, A., Da Silva, H. P., & Da Costa Antunes, P. F. (2023). Smart Office Chair for Working Conditions Optimization. *IEEE Access*, 11, 50497–50509. https://doi.org/10.1109/ACCESS.2023.3276429

[3] S, U., T S R, A. B., V, S., & K, G. B. (2022, September 1). IoT based Approach to Estimate the Vacant Seats Available. ICIRCA 2022, Coimbatore, Tamil Nadu, India. https://doi.org/10.1109/ICIRCA54612.2022.9985657

[4] Matuska, S., Paralic, M., & Hudec, R. (2020). A Smart System for Sitting Posture Detection Based on Force Sensors and Mobile Application. *Mobile Information Systems*, 2020(1), 1–13. https://doi.org/10.1155/2020/6625797

[5] Putsa, B., Jalayondeja, W., Mekhora, K., Bhuanantanondh, P., & Jalayondeja, C. (2022). Factors associated with reduced risk of musculoskeletal disorders among office workers: a cross-sectional study 2017 to 2020. *BMC Public Health*, 22(1), 1503. https://doi.org/10.1186/s12889-022-13940-0

[6] Kim, D., Cho, M., Park, Y., & Yang, Y. (2015). Effect of an exercise program for posture correction on musculoskeletal pain. *Journal of Physical Therapy Science*, 27(6), 1791–1794. https://doi.org/10.1589/jpts.27.1791

[7] Pereira, L., & Plácido da Silva, H. (2023). A Novel Smart Chair System for Posture Classification and Invisible ECG Monitoring. *Sensors*, 23(2), 719. https://doi.org/10.3390/s23020719

[8] La Mura, M., De Gregorio, M., Lamberti, P., & Tucci, V. (2023). IoT System for Real-Time Posture Asymmetry Detection. *Sensors*, 23(10), 4830. https://doi.org/10.3390/s23104830

[9] Sifuentes, E., Gonzalez-Landaeta, R., Cota-Ruiz, J., & Reverter, F. (2019). Seat Occupancy Detection Based on a Low-Power Microcontroller and a Single FSR. *Sensors*, 19(3), 699. https://doi.org/10.3390/s19030699
[10] Bourahmoune, K., Ishac, K., & Amagasa, T. (2022). Intelligent Posture Training: Machine-Learning-Powered Human Sitting Posture Recognition Based on a Pressure-Sensing IoT Cushion. *Sensors*, 22(14), 5337. https://doi.org/10.3390/s22145337
[11] Lazaro, A., Lazaro, M., Villarino, R., & Girbau, D. (2021). Seat-Occupancy Detection System and Breathing Rate Monitoring Based on a Low-Cost mm-Wave Radar at 60 GHz. *IEEE Access*, 9, 115403–115414. https://doi.org/10.1109/access.2021.3105390
[12] Jeong, H., & Park, W. (2021). Developing and Evaluating a Mixed Sensor Smart Chair System for Real-Time Posture Classification: Combining Pressure and Distance Sensors. *IEEE Journal of Biomedical and Health Informatics*, 25(5), 1805–1813. https://doi.org/10.1109/jbhi.2020.3030096
[13] MAsher, A. (2007, June 15). What Causes Bad Posture. Verywell Health; Verywell Health. https://www.verywellhealth.com/posture-fixes-what-are-you-up-against-297037
[14] Hecht, M. (2020, November 19). Types of Posture: How to Correct Bad Posture. Healthline. https://www.healthline.com/health/bone-health/the-4-main-types-of-posture