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RESEARCH ARTICLE - ENGINEERING (MISCELLANEOUS)

Real-time Sitting Correction Using Arduino-Based Ultrasonic Sensor at the Workplace

Huda Farooq Jameel[1*]

[1]Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq

[*] Corresponding author E-mail: huda_baban@mtu.edu.iq

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Abstract

People who work from home or in offices typically sit at a computer for most of their workday, often sitting with bad posture. Therefore, the decision was made to develop chairs to find a solution for the medical problems that arise from sitting for long periods during work. The intended audience for the chair includes office workers, students, and homemakers. Gamers who spend a lot of time sitting in their chairs could benefit from the technology. This research aims to solve the problem of unhealthy sitting. The hardware configuration includes a DC motor, power supply, microcontroller, ultrasonic sensor, buzzer, and a chair. The software configuration uses Arduino software to evaluate the system's overall accuracy. Four categorization models are used: true positive, false positive, true negative, and false negative. The system development process has been exceptionally successful, achieving a total accuracy of approximately 97.434%. For future work, it is expected to increase the accuracy of the system with an IR sensor and speaker to alert the user.

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Keywords: Accuracy; DC Motor; Microcontroller; Ultrasonic Sensor; Smart Chair.

1. Introduction

A sedentary lifestyle is now practically universal among most people in modern nations. Long periods spent sitting can be unhealthy, especially if done incorrectly. The health problems brought on by a contemporary lifestyle can be prevented with the aid of a sophisticated chair that can detect various sitting postures. A systematic review was conducted where a smart chair and smartphone app were tested for their ability to accurately quantify sitting duration and disruptions compared to camera-derived monitoring and activPAL. As a result, in a professional setting, a chair or app may be effective as a personal tool to determine its effectiveness in decreasing adult desk sitting. To discover more about how well the personal monitoring tool works to reduce adult desk sitting, additional study is nonetheless required [1]. Also, a smart chair sensor system that could recognize sitting postures was developed, implemented, and evaluated. Eight pressure detectors were used in the system, and they were attached to the backrest and sitting cushion of the chair [2]. Moreover, a system that utilizes four load cells mounted on the seat pan to monitor the load on the seat pan and the weight transferred to the backrest was tested. Six different sitting positions were investigated for variations in body weight ratios based on three computed body weight proportions. The results support industrialization and further study that takes gender and physical attribute differences into account [3]. Additionally, by combining a comfortable office chair with a microcontroller, vibration mechanisms, and a smartphone app, a functioning model of a smart office chair was developed [4]. Furthermore, a smart sensing technology was used to monitor orientation to minimize occupational low back discomfort. The system consisting of an intelligent shirt linked to a mobile application that provides feedback and recommendations on low back position, was discussed in detail. To facilitate posture adjustment over longer periods, more research was required to increase the system's stability and develop appropriate behavior modification methods [5]. Even though scientists did not assess productivity, research shows that using a computer increases muscle activity in the neck, shoulder, and forearm, whereas using a smartphone increases muscular activity in the thumb. According to this analysis, a posture chosen based on personal preference was not preferable to the ergonomic norms already established for smartphone use [6]. To solve the problem of waist tension brought on by extended sitting and improper sitting positions at work, an independent design of an intelligent corrective seat has been made based on the STM32 single microcontroller [7]. Consequently, a system for identifying inappropriate seating positions was discussed using six flexible force sensors. These sensors were connected to the system through an Arduino-based Internet of Things (IoT) node. When incorrect seating arrangements are found, the system alerts the users. A mobile application was created to receive notifications [8]. A sitting posture identification system that depends mainly on radio frequency signals and doesn't infringe on users' privacy or necessitate the wearing of several sensors on the body was established. With just three thin, inexpensive RFID tags applied to the user's back, the SitR could distinguish seven common sitting postures. Ten volunteers helped to assess SitR's performance in two distinct scenarios [9]. To increase employee performance and comfort, workplace behaviour studies and initiatives should be able to detect and alter people's behaviour. Furthermore, it provides ideas for potential workplaces as well as some of the associated accomplishments. A permanent posture-sensing seat was designed for physical state tracking and will be offered commercially. It recommends using interactive digital signage to display reminders to change habits.

Nomenclature & Symbols			
IoT	Internet of Things	TN	True Negative
TP	True Positive	FN	False Negative
FP	False Positive		

It was proven during a one-month experiment that the technology was practical for everyday use [10]. Also, a prototype of a posture-tracking system was created where the gadget can periodically collect information on the user's seating position. The prototype uses sensors that could be used to accurately measure bodily vitals. The system is a low-power consumption technology that can help track human posture and function as a health monitoring device [11]. Microsoft Kinect was used to detect and follow the significant bone structures of the human body. Using imagery perception and semantic evaluation, abnormal sitting position detection in the camera was attempted. To effectively recognize elements and retrieve essential data, a deep learning algorithm known as Faster R-CNN was added to the method's scenario identification [12]. Besides, a creative resourceful chair with built-in sensors was developed to detect and classify a worker's sitting postures in real-time. The mixed sensor design of the resourceful chair system combines six pressure sensors with six infrared reflecting distance detectors [13]. Moreover, a virtualized IoT-enabled intelligent chair was suggested that continuously analyzes a user's seating posture, alerts them when they are seated incorrectly, and stores the data online. The proposed works, which were composed of sensors, controllers, and cloud platforms, provided smooth connectivity and warning while allowing the system to adapt to any environment [14]. The methodological quality of the studies that were included was assessed using a thirteen-item checklist based on the Cochrane risk of bias criteria. The findings showed mixed evidence regarding the impact of chair modification on office workers' decreased pain and discomfort, as well as the activation of their trunk muscles [15]. Back troubles are one of the most common problems in today's culture. People today spend an increasing amount of time sitting, often in an uncomfortable position. So, a smart chair was used based on IoT to find a solution to this issue. The chair has sensors built in that can detect the user's position and signal when it changes [16]. Establish Sitsen, a sitting-attitude identification system that uses RFID technology. Taking into consideration that the monitor and a transmitter-receiver are placed on opposite sides of the individual, the gadget can accurately recognize five typical sitting positions [17]. A smart chair with pressure detectors to recognize the user, the activity, and the objects depending on the person's posture while seated was created. To collect pressure sensor data, eight participants were asked to use laptops while seated in chairs. Ten trials were used to gather data for each object and action [18]. In addition, a SitR, a system for recognizing sitting postures from RF signals was presented. The experiment's findings demonstrate SitR's capacity for excellent performance and reliability. Additionally, the technique could track sedentary people's sitting posture and detect their irregular breathing patterns [19]. Also, a system for classifying seven distinct health-related seating positions on an office chair was described. The system had six flex detectors, an analog/digital converter, and a Spartan-6 field programmable gate array [20].

The contributions of this study are:

- Design and development of a healthy chair.
- The system operates manually and automatically.
- Alarm the user by sound to correct the sitting.
- Two motors and an ultrasonic sensor are used to correct the sitting in a relaxed situation.

2. Related Work

For physical well-being and health, it is important to maintain good posture. While the effects of sitting for a long time at work on the ability to move are widely acknowledged, research has been done on how prolonged sitting affects muscular stiffness. Consequently, there is a need for interventional strategies to enhance muscular activation throughout sitting, such as passive massage procedures or electrical muscle stimulation, and development methods to create a suitable chair for extended sitting [21]. Many techniques have been used to promote good sitting posture, such as a shirt with a textile detector attached for posture control and monitoring. The concept was tested by reading the curvatures associated with the wrong posture using textile detectors sewed into a shirt. The outcomes of this prototype indicate that future research on certain muscle groups associated with different postures may be made possible by such adaptable clothing. The integration of continuous posture monitoring into commercially accessible clothes is possible because of the sensor technologies implanted in ordinary clothes [22]. Despite their widespread use, textiles face challenges in harsh conditions due to their limited ability to withstand abuse. While they are suitable for certain situations, textiles have limited capabilities when it comes to data processing. Also, a suit that uses a virtual instructor to guide exercises was developed. To assess the alignment of the limbs subsequently, the suit was equipped with a variety of accelerometer detectors that were placed on lightweight, flexible belts. When there is a match between the values being measured and the predetermined calibrated readings loaded on the microcontroller, the data is transferred to a mobile application. Based on the instructions provided to perform the yoga activity, the smartphone app determines if the user is performing the pose properly or not [23]. Furthermore, a flex sensor that detects improper posture was used and sends a buzzer sound to alert the user. An ATmega328 microprocessor managed the flow of the flex sensing to the auditory alarm output through the Arduino IDE. The proposed posture monitoring item might be deemed beneficial and appropriate to observe people's posture when sitting or standing, especially in places where menial occupations are useful, with a sensitivity of 84.6% during testing of this device [24]. Since the flex sensor is a kind of resistor and is adaptable, it cannot be connected to a high-current supply since doing so would cause it to melt due to heat buildup over time. Moreover, an inertial detector was used to recognize person sitting activities on smartphones. With the use of machine learning classification algorithms, five common sitting activities of office workers were identified, including left movement, right movement, front movement, back movement, and straight movement [25]. Because inertial sensors frequently round off little amounts in computation, they are sensitive to drift, or mistakes that build up over time. If these mistakes are not remedied, they can accumulate and become large ones. However, inertial sensors may be an excellent addition to other sensors when used in conjunction with correcting technology. Besides, a sitting position system based on pressure detectors was implemented, utilizing thirteen pressure detectors to determine the user's sitting position. The results demonstrate the effectiveness of the SVM algorithm in identifying the user's sitting position. However, future arrangements involve developing a simpler circuit and employing low-power devices to reduce battery charging time and expenses [26]. The drawback of pressure sensors is their lack of accuracy, which can result in measurement differences of at least 10%.

This article aims to improve the accuracy in developing chairs that are comfortable for the user while working for long hours. The drawbacks of the related works are the complex circuit design, limited number of sitting postures detected, and high power consumption that leads to rapid battery depletion. To overcome these drawbacks, information from previous research has been collected, compared, and presented through the type of sensors used and the number and types of sitting positions. To achieve the aim of this article, related work has been compared with the proposed work, as shown in Table 1. The information obtained through the type of sensors used and the number and types of sitting positions has been analyzed to improve accuracy in developing chairs that are comfortable for the user while working for long hours. It is noted that there is high accuracy in some previous works, and this is due to the complexity of designing the controlling circuits and the cost.

Table 1. Comparison of related work and proposed work

Ref./Year	Type of sensor	Accuracy (%)	sitting position number
[22] 2022	textile	N.A.	3
[23] 2022	accelerometer	N.A.	N.A.
[24] 2022	flex	84.6	4
[25] 2021	inertial	99.9	5
[26] 2023	pressure	99.1	9
Proposed	ultrasonic	97.434	10

3. Methodology

The establishment and layout of the suggested system are discussed in this section.

3.1. System design and development

The proposed system comprises a power supply with a battery type of New Force 12V/7AH rechargeable [27] and a DC power supply of 24V [28], which are used to feed the system with power. In addition, an UNO Arduino microcontroller is used to control the system [29]. Two DC motors are used to move the chair to the correct position.[30]. These motors are used to adjust the chair to provide more relief and achieve the system's goal. Equally important, the HC-SR ultrasonic sensor module is used [31]. If the user is sitting incorrectly, the ultrasonic sensor will sound an alarm with a buzzer to remind the user to sit correctly. A schematic diagram created using the Multisim program is shown in Fig. 1. Fig. 2 depicts the real-world implementation of the system's components. Additionally, Fig. 3 shows the actual chair components.

3.2. System algorithm

The system operates when the power is ON, functioning according to the program written in the Arduino integrated development environment [32]. The steps of operation are: 1) if the user is sitting on the chair in the correct position, the system is on standby. 2) If the user is sitting in the wrong position or stands up for any reason, the system will remain on standby, anticipating that the person will return to the correct position within a specific time delay programmed into the system. However, if the person does not return to the correct position within this time, the buzzer will sound until the person corrects their sitting posture. 3) If the user is not sitting in the right status after the specific delay time, the two motors are ON and move the back seat and the leg seat to correct the position of the user. Fig. 4 illustrates the algorithm for the system.

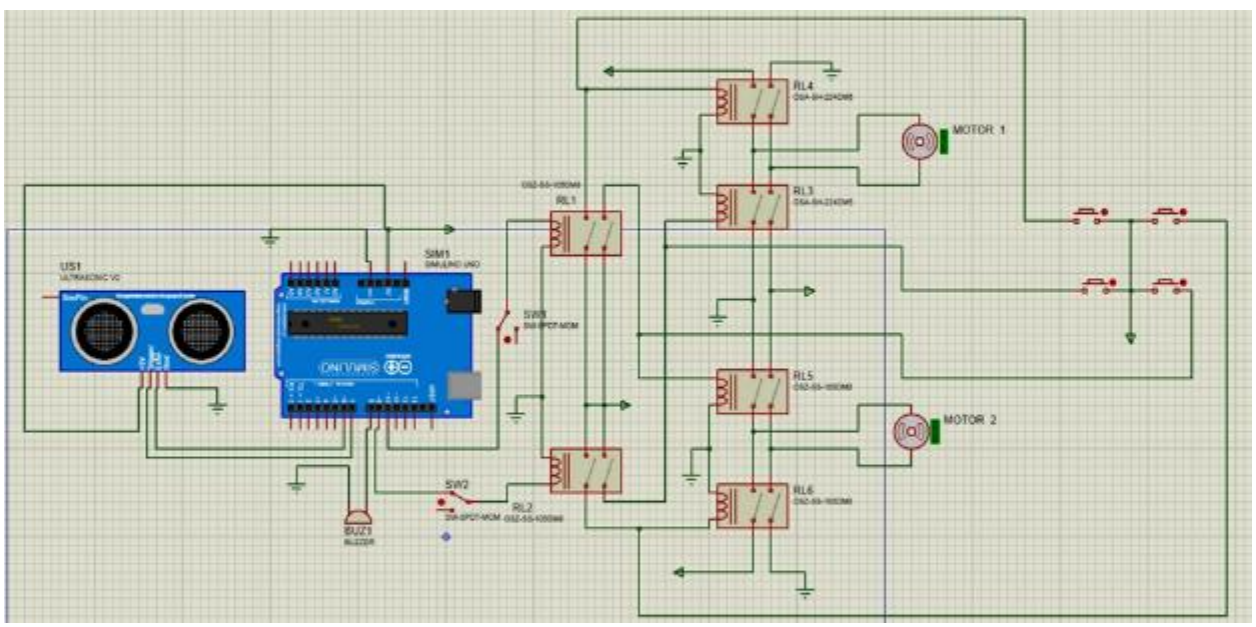

Fig.1. Schematic diagram of the system

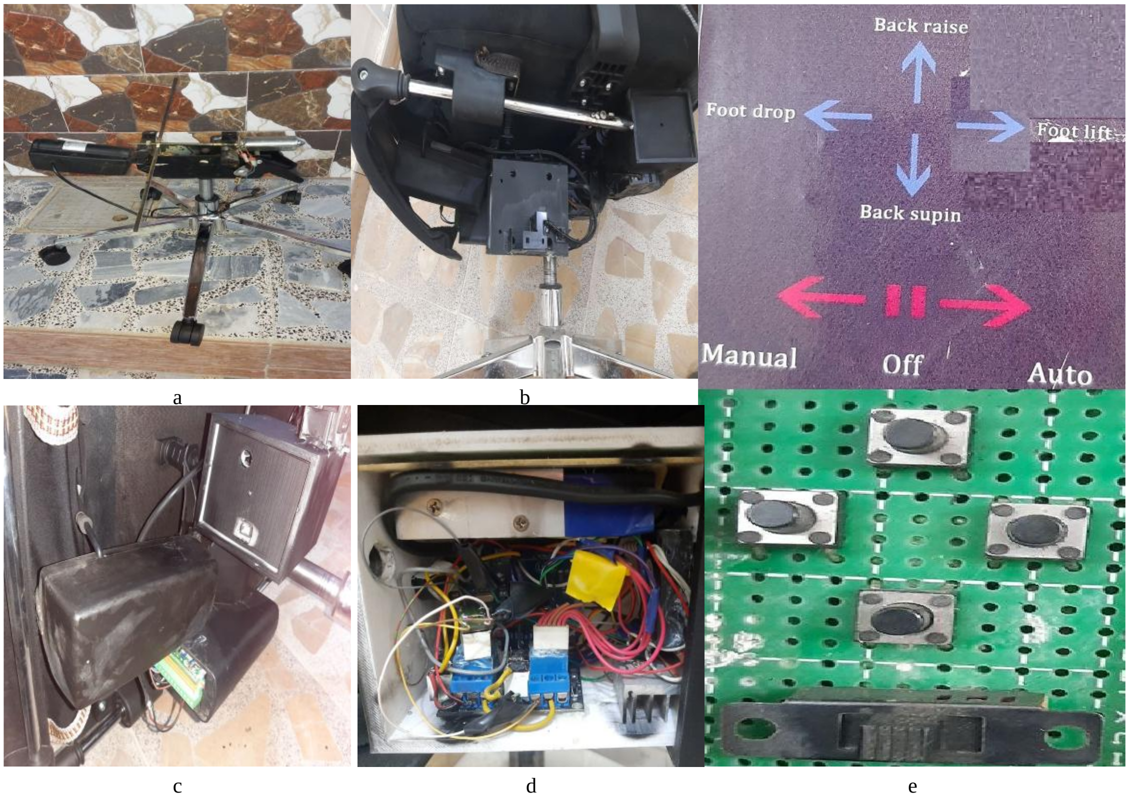

Fig. 2. The real implemented components; a) Two motors, one for the front leg seat and one for the back seat, b) The shaft for the leg seat and controls, as well as the battery location, c) The motor driver and power control, d) Control box containing the microcontroller, relays, and fan to cool the board, e) The operating board that illustrates the ON/OFF and switch between manual and automatic use

Fig. 3. Overall chair components

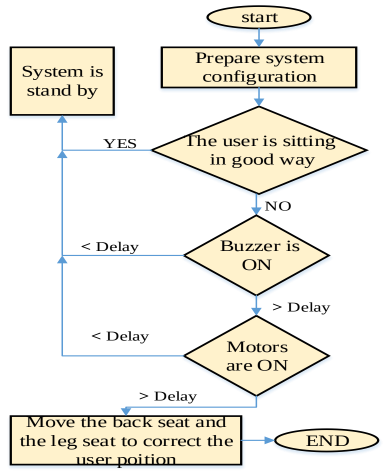

Fig. 4. Algorithm for the system

4. Evaluating the Performance of the System

Recall, precision, and F-measure accuracy statistical analyses [33-36] have been used to classify the effectiveness of the system. These measures are based on the following four indicators, each of which has four potential attempts: True Positive (TP): The engine is ON, the chair is in position, and the ultrasonic sensor is operating properly; False Positive (FP): The chair and ultrasonic sensor are operating properly, but the motor is not functioning; Both True Negative (TN) and False Negative (FN) indicate that the chair and ultrasonic sensor are not functioning properly. True Negative (ON) indicates that the motor is ON and that the chair and ultrasonic sensor are not functioning properly. Recall, as stated in Equation (1), refers to the system's competence to carry out its intended function [33-36].

$$Recall\ \% = \frac{TP}{TP+FN} \times 100 \quad (1)$$

Similarly, F-measure accuracy has been estimated to assess overall performance to determine overall accuracy [33-36]. Recall and precision are combined to form F-measure accuracy, which can be described as follows:

$$Precision\ \% = \frac{TP}{TP+FP} \times 100 \quad (2)$$

$$F - measure\ accuracy\ \% \ = 2 \times \frac{recall \times precision}{recall + precision} \times 100 \quad (3)$$

4. Results and Discussion

To validate the system, various sitting positions were examined. Eleven participants were tested while sitting in chairs in various positions. Then, the users were told to perform different tasks. Data for every participant and activity were gathered over 42 trials as shown in Table 2 that represented the overall accuracy by using confusion matrix. Fig. 5 illustrates a snapshot of the real system from different angles.

From the tests and results, the system's performance is satisfactory when the user uses the chair.

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Depending on the wrong sitting, the system will give a sound alarm for a specified time, and the user should correct his or her sitting. If the user does not correct the sitting according to the sound, the system will turn ON the two motors to correct the sitting in a relaxed situation for the user. The system has two modes: manual and automatic. Table 3 shows a group of snapshots of several types of incorrect and correct seating to illustrate all test-case scenarios.

Table 2. Overall accuracy of the system

Parameters	Total number of trials
Total number of trials	42
TP	38
FP	1
TN	2
FN	1
Confusion matrix= $TP \quad FN$ $FP \quad TN$	Confusion matrix= 42 1 1 2
Precision (%)	97.435
Recall (%)	97.435
Accuracy (%) = $2 \times \frac{\text{recall} * \text{precision}}{recall + precision} \times 100\ \%$	97.434

Table 3. Various sitting positions

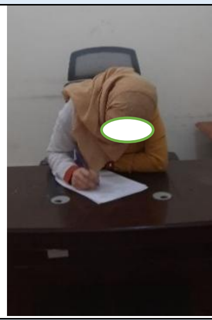
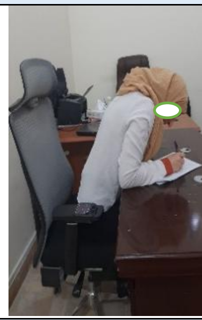
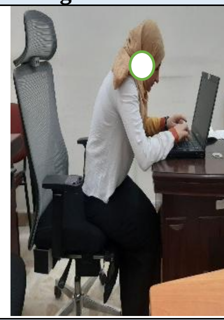
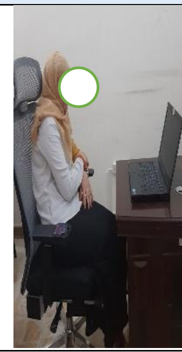
Name	Forward sitting from front side	Forward sitting from the side	Sitting at the front edge of the chair	Sitting backward from the side	Sitting upright from the side
Figure					
Name	**Leaning forward from the side**	**Leaning forward front side**	**Sitting from left side**	**Sitting from right side**	**Sitting upright from the front**
Figure					

Fig. 5. Snapshot for the real system; a, b) male aged 18 years, c, d, e) female aged 41 years, and f, g, h) male aged 24 years

5. Conclusion

The goal of this study was to find a solution to the issue of unhealthy sitting. A DC motor, power source, microcontroller, ultrasonic sensor, buzzer, and chair are all included in the hardware setup. Arduino software is used for the programming. The system's accuracy was experimentally evaluated using categorization models (TP, FP, TN, and FN). With a total accuracy of approximately 97.434%, the system's development process has been highly effective. The system offers a manual mode and an automatic mode.

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