Smart Chair for Body Posture Monitoring

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ABSTRACT

Smart chair for body posture monitoring is proposed for assessing the body posture of a person sitting on a chair. There is a need for assessing the unpredictable working posture found in services sector and other industries leading to the development of body posture analysis. Monitoring of body posture is done in two parts with each phase being implemented as a separate node. Node 1 identifies the presence of a person on the chair, monitors the lower back position and movement of fingers and eyes. Node 2 monitors the heart beat and weight of the person sitting on the chair, leading to up and down movement of the smart chair. On detection of the presence of a man on the smart chair, a relay between node 1 and node 2 is energized, to provide the power supply to node 2. Zigbee standard is used for communication between the two nodes. Various sensors like infrared sensor, ultrasonic sensor, pressure sensor, accelerometer, pulse sensor are incorporated for monitoring the body postures and voice messages are generated to notify wrong body postures. Further, the smart chair monitors, on demand, the blood pressure of the person.

Keywords: Smart chair, body posture, auto height adjust, blood pressure monitoring.

1. INTRODUCTION

Smart chair for a body posture monitoring is a powerful technique for assessing work activities. Musculoskeletal pain can be reduced by maintaining proper body posture. A need for assessing the unpredictable working posture found in industries and other areas lead to the development of body posture analysis. Due to wrong body posture musculoskeletal pain is found in nerves, joints, mainly to upper limb and lower back [1]. Musculoskeletal pain is a very common occupational hazard in both developed and developing countries, leading to decreasing productivity and lower quality of life. Wrong body posture is observed among people sitting on the chair while studying, operating computer and other activities while at work place or at home [2]. Prolonged wrong body posture leads to lower back pain (LBP), found in 60-80% of adults at some stage of their life [3]. Over a period of time, wrong postures can cause misalignment within the spine, leading to more aching. Joints, which are covered with connective tissues for supportive cushion, have to endure a heavier load that may be more than it may manage. This leads to pain and degradation of the tissues surrounding the joints. In order to address all these health issues related to wrong body posture, a smart chair for monitoring the body posture of a person sitting on the chair is proposed. While sensors are incorporated for identifying the body posture, voice messages and text messages are generated to alert when wrong body postures are sensed.

The paper is organized as follows: Section 2 introduces the proposed architecture of smart chair along with hardware and software requirements. While Section 3 describes the design and implementation of smart chair with its working, Section 4 presents results and discussion. Section 5 outlines the conclusions of the work.

2. SMART CHAIR ARCHITECTURE

The work of monitoring of body posture is carried out in two parts: each part is implemented as a separate node or a card. The block diagram, as shown in Figure 1, includes Node 1 and Node 2 and a relay between two nodes to support a single supply unit.

Node 1: At the core of node 1 is ARM7 LPC2148 controller. While a Liquid crystal display (LCD) is provided to display required messages, a loudspeaker is included to output audio messages. Infrared sensor is used to detect the presence of person on the chair. The finger movements are monitored using flex sensors [4]. Ultrasonic sensor is deployed to monitor the eye movement. Accelerometer1 senses the back movement of the person sitting on the chair and accelerometer 2 detects the falling movement of the chair. A voltage regulator ensures constant voltage. Zigbee standard is used for serial communication between node 1 and node 2.

Node 2: ARM7 LPC2148 micro controller is used in node 2. The weight of the person sitting on the chair is detected using a pressure sensor [5]. Pulse sensor detects the pulse rate of heart per minute. M1, M2 are the DC motors used in node2, for up and down movement of chair respectively.

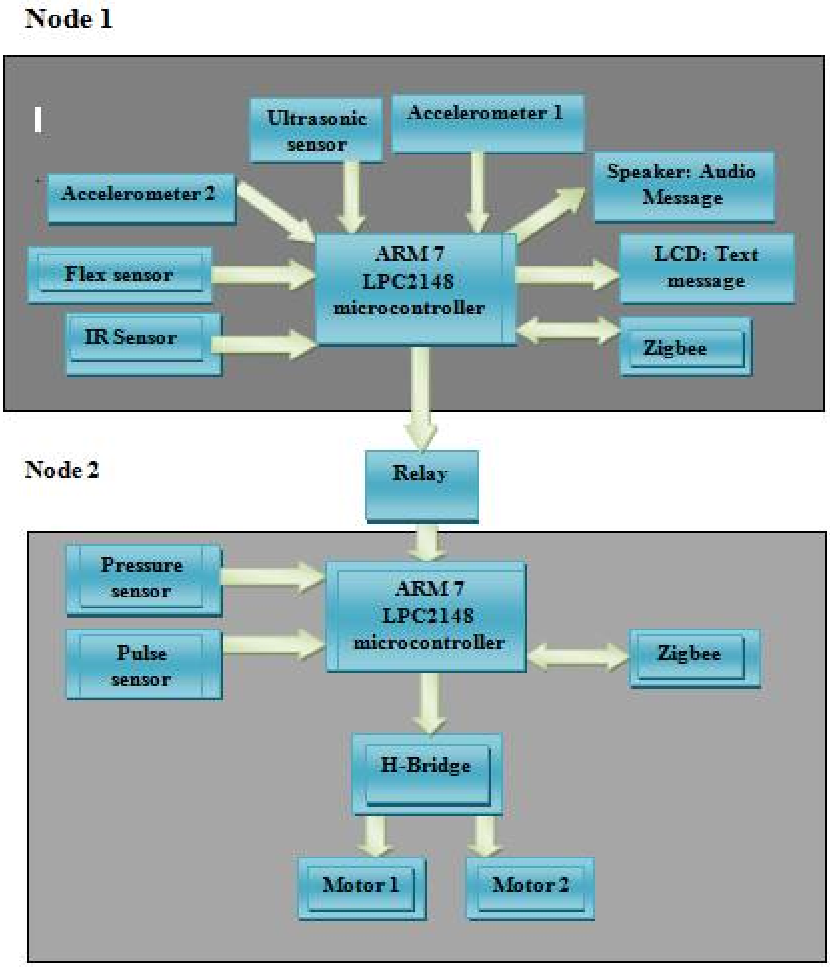

Figure 1: Block diagram of smart chair.

H-bridge is the driver circuit used for the motor. A voltage regulator provides a regulated power supply to node 2. Upon power up to node 1, the infrared sensor of node 1 senses the presence of a person on the chair, the relay gets energized. The relay, being connected to node 2, powers up node 2 eliminating the need for an additional source on node 2.

To facilitate the deployment of a comprehensive set of sensors, as an enhancement over work [5], for robust monitoring of body posture in real time, a 2-node architecture with independent microcontrollers is proposed. The node 1 and node 2 are implemented as cards and can be mounted on the bottom side of the smart chair.

3. DESIGN AND IMPLEMENTATION

3.1 Experimental setup of smart chair

The experimental setup, shown in Figure 2, consists of a model chair, node1 and node 2. While node1 consists of IR sensor, ultrasonic sensors, flex sensor and accelerometers, node 2 consists of pressure sensor and pulse sensor. A relay is connected between two nodes. ARM7 microcontroller is the heart of the system. Sensors are attached to the chair to monitor body posture. While DC motor 1 is used for up and down movement of chair, DC motor 2 is used to maintain the back of the chair in vertical position.

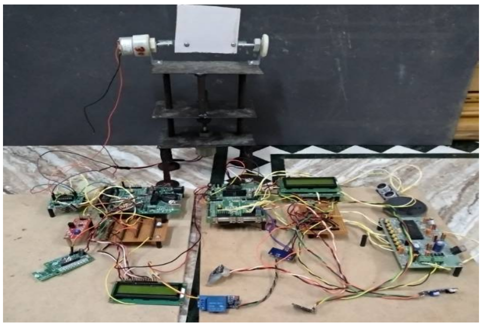

Figure 2: Experimental setup of smart chair.

3.2 Graphical representation of working of smart chair

The graphical representation of functioning of smart chair is illustrated in Figure 3.

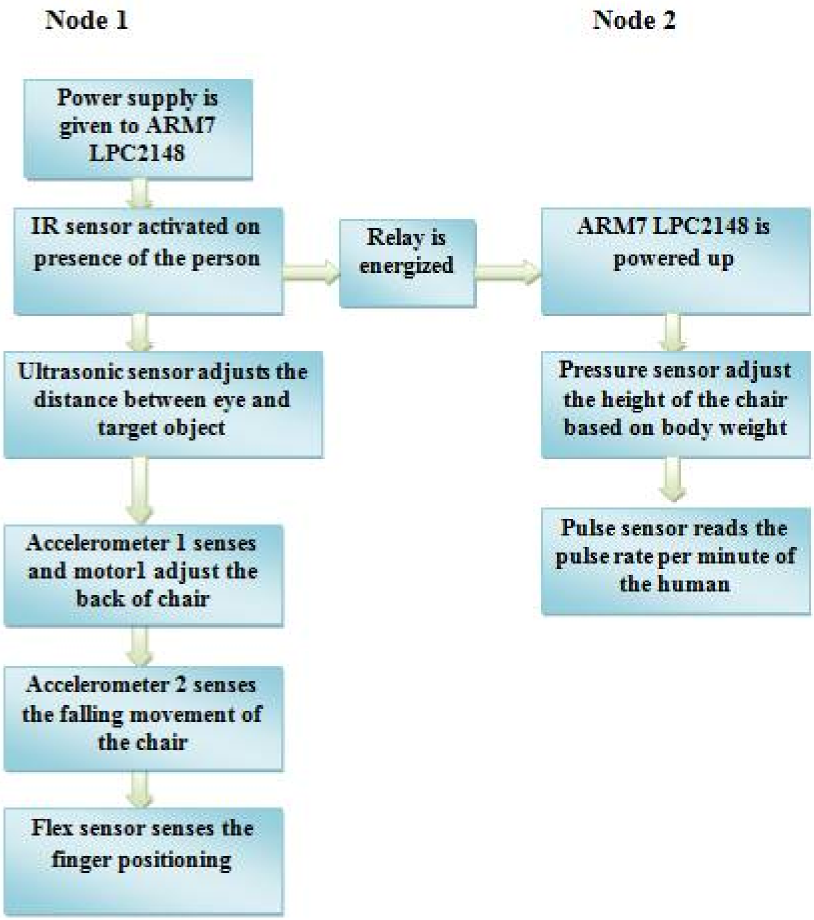

Figure 3: Graphical representation of functioning of smart chair.

3.3 Working of smart chair

A 2-node architecture with independent microcontrollers is proposed to address the increasing power issues due to large multitude of sensors. The ARM 7 Microcontroller and a voltage regulator are present on both the nodes. Zigbee is used for the serial communication between node1 and node2. KEILµVISION IDE is deployed for program development in Embedded C.

Initially LCD is programmed to display SMART CHAIR FOR HUMAN COMFORT. Infrared obstacle avoidance sensor is used for detecting the presence of the person on the chair. When the presence of person is detected, the output port of sensor, connected to the GPIO port of microcontroller, is energized. LCD is programmed to display PERSON IS PRESENT ON THE CHAIR. The relay connected to the output port of IR sensor is energized to power up node 2. Upon IR sensing, the triggering side of the relay is energized, the load side of relay which is NO (normally open) changes to NC (normally closed) thus providing supply to node 2. Hence the need for an extra power supply for node 2 is eliminated. When the person is not present on the chair, LCD is programmed to display PERSON ABSENT ON THE CHAIR.

Accelerometer 1, attached to the back of the smart chair, is used to monitor the lower back position of the person sitting on the chair. A DC motor is connected to the back of the chair to adjust its position. The accelerometer1 is programmed to detect the sensor output X_{out} values of < 480 Hz for leaning front and > 600 Hz for leaning back position. When the accelerometer 1 senses the value X_{out} < 480 Hz, the person is leaning front. For this value, the accelerometer sends the signal to microcontroller1 which in turn sends a signal to node 2 microcontroller through Zigbee. The DC motor attached to back of the chair is turned on and the vertical back position of chair is restored. Voice message AVOID LEANING FRONT will be played. Similarly when the person leans back, X_{out} > 600 Hz and a voice message AVOID LEANING BACK will be played. The DC motor is turned on to restore the vertical back position of chair. To sense the falling movement of the chair, Accelerometer 2 and Y axis and Z axis are considered. When the accelerometer 2 senses the value Y_{out} < 450 Hz and Z_{out} < 450 Hz, a text message CHAIR FALL MOVEMENT is displayed.

Flex sensor in node1 is used for monitoring the finger movement. The sensor is programmed for a bending resistance of 750 Ω and when the sensor reading exceeds this set value, a text message FINGER BENT is displayed and a voice message PROPER FINGER MOVEMENT is played.

Ultrasonic sensor is used to monitor the distance between the eye of the person sitting on the chair and the gadget he is looking at. When the gadget is very near it may strain the eye and hence a proper distance has to be maintained. The sensor is programmed to detect the distance less than 3 cm. Trigger and echo are the input and output signals of the sensor that are connected to GPIO ports of microcontroller. The Trigger port receives input when the distance is less than 3 cm, the echo pin sends signal to controller and a voice message MAINTAIN PROPER EYE CONTACT is played with a text message KEEP DISTANCE on LCD.

The heart beat rate is monitored with pulse sensor located on node2. The signal pulses generated by pulse sensor are equivalent to the human pulse rate. When the person places the finger tip on the sensor, the output port of sensor sends signal to the controller. Based on sensing range, microcontroller on node 2, appropriate voice message and text messages are displayed. The sensing range is classified into LOW BP, NORMAL BP and HIGH BP. When the Pulse Rate Per Minute (PRPM) is < 70, a voice message LOW BP is played and text message is displayed. When 70 < PRPM < 100, a text message NORMAL BP will be displayed. When the PRPM is > 100, a text message HIGH BP is displayed and a voice message is played.

Pressure sensor is used for adjusting the height of the chair based on body weight to ensure its stability. For proof of concept and prototyping, a pressure sensor of 2 Kg rating is selected. The sensor is programmed for a range of 31 - 200 grams. When the weight measured is < 31 g, dc motor turns on and provides the upward movement to the chair. Signal is sent to node1 to display text message and to play voice message as LOW WEIGHT. When the weight measured is > 200 g, dc motor receives signal from the controller and provides downward movement to the chair. The text and audio message HEAVY WEIGHT are played. A toggle switch is provided as user control to stop the up and down movement of the chair. Table 1 summarizes the observation of various sensor outputs and the human body posture.

Table 1: Observation of sensor outputs and the human body posture

Sensor	Observation	Conclusion
Infrared	On condition Off condition	Person present on chair Person absent on chair
Ultrasonic	Distance less than 3cm	Keep distance
Flex	Bending resistance > 750 Ω	Finger bent

Accelerometer 1	Xout < 480 Hz Xout > 600 Hz	Avoid leaning front Avoid leaning back
Accelerometer 2	Yout < 450 Hz and Zout < 450Hz	Chair fall movement
Pulse	PRPM < 70 70 < PRPM < 100 PRPM > 100	Low BP Normal BP High BP
Pressure	Weight < 31 g Weight > 200 g	Low weight Heavy weight

4 RESULTS AND DISCUSSION

The smart chair for body posture monitoring is designed and a prototype is developed. The various functionalities of the smart chair are successfully demonstrated. Accelerometer is used for monitoring the back position for its sensitivity in measuring the tilt angle and low cost as an improved solution over the flex sensor of work [5]. Further, the ability of the accelerometer to work over three axes – X, Y and Z facilitates detection of the falling movement of the chair. Infrared sensor senses the presence or absence of the person on the chair, voice message and text message are displayed accordingly. Pulse sensor, flex sensor, ultrasonic sensor, pressure sensor, accelerometer sense various parameters as per the set limit, for which voice messages and audio messages are displayed.

5 CONCLUSION

Smart chair for body posture monitoring is proposed in this work for assessing the body posture of a person sitting on a chair. A prototype of a smart chair, with all sensors and motors, is developed for its successful demonstration. Sensors are programmed to limit values that are carefully selected for the right body posture while sitting for long hours. Wrong body postures are sensed when the limit values are breached. Appropriate voice messages and text messages are generated to notify wrong body postures and to correct the posture. Further, the smart chair monitors the blood pressure of the person, on demand. The smart chair addresses various health issues related to musculoskeletal pain in nerves, joints, mainly in upper limb and lower back, leading to improved productivity in work places and better quality of life.

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