Journal of Physics: Conference Series

Design and Analytics of Smart Posture Monitoring System

To cite this article: A Chaitanya Kumar and V G Sridhar 2021 *J. Phys.: Conf. Ser.* **2115** 012048

Design and Analytics of Smart Posture Monitoring System

Chaitanya Kumar A[1,*] and V G Sridhar[2]

[1] Student, School of Electronics Engineering, Vellore Institute of Technology - Chennai, Tamil Nadu, India
[2] Professor, School of Mechanical Engineering, Vellore Institute of Technology - Chennai, Tamil Nadu, India

[*]chaitanyakumar.a2018@vitstudent.ac.in

Abstract. Instances of low-back pain in people of all ages is one of the most common issues in the world. Over 50% of the world population report of being affected by low-back pain at least once a year. It is therefore of paramount importance for individuals to realize the necessity and importance of a proper sitting posture, to interact and work in an ergonomically supportive environment. With the advent of the Internet of Things, it is now evident that communication technology coupled with the mechanics of the seating device can help produce meaningful insights, and help in undertaking data-driven decisions. There have been various attempts at designing "smart chairs". These smart chairs in addition to the above mentioned functionalities, can also be deployed as robust health-monitoring systems. Using embedded sensors within, these chairs can function as an alert mechanism to the user, when he/she is sitting with an incorrect posture, that could be detrimental to the physical health of the individual. In this paper, the researchers conduct a comprehensive analysis of the existing products, by a customer survey and propose a solution that could potentially serve the people with back pain to use the proposed chair: embedded with sensors, and supplemented by data analytics. The system designed is a cost-effective low-power consuming posture monitoring system, that simultaneously works as an accurate health monitoring system as well.

1. Introduction

Considering the high frequency and severity of issues pertaining to lower back pain among a large population, it is of paramount importance to develop an efficient system that could help mitigate the pain, and engender an ergonomic workspace. Unfortunately, low-back pain is prevalent in around 15-45% of people all over the world every year, according to the World Health Organization, being more common among adults, than children. It is one of the leading causes of absence from work, and activity halt. Low-back-pain is also a precedent to various other serious issues regarding physical health. Research studies indicate the proven benefits of ergonomics, in the form of enhanced productivity, mental health, blood circulation etc. In the current scenario of the COVID 19 pandemic, an increasing number of people are subjected to use their mobile and laptop screens, during most part of the day. During this period, sitting in a wrong posture might induce adverse effects at a later stage, hence it is important to maintain a proper seating posture.

With the advent of the Internet of Things (IoT), many conventional applications in the field of healthcare, transport, agriculture, business, etc., have been replaced by automated systems that are versatile and make the underlying process more convenient than ever before. Wearable device production is on the rise, and is one of the booming industries in the current market. The proposed model described in this paper, is a sensor based application, that aims in the amelioration of lower-back pain and other physical health. The proposed system not only helps in the detection of improper posture in the user, but also provides an appropriate recourse, by intimating the user about the history of the improper usage of the chair. A suitable communication protocol is used to transmit data from the chair to the gateway, where further analytics enable the generation of feedback. Most systems designed in the past limit themselves to the detection stage alone. The system proposed in this paper consists of an efficient intimation system, as well as a mechanism to track the history of sitting postures of the individual. This defines the novelty in this system. An open-ended general survey is initially carried out, to understand the grievances among the general public pertaining to the issue. The results of the survey are further considered, and incorporated in the design of a prototype.

2. Literature Survey

The use of sensors and advanced technology has presented various benefits on the products used by the people. A smart chair is one product that can help monitor the posture of the user, and give necessary feedback to initiate appropriate recourse. There have been various attempts at designing sensor based smart chairs. In [2], propose an embedded system of sensors and microcontrollers, to develop a posture detection and monitoring system. The prototype consists of a series of custom designed sensors, an Arduino in the form of the central microcontroller, a Bluetooth module to serve as the communication medium deployed on a chair. The sensors are used for judging the tilt and pressure, applied due to the force of the user on the chair. The data is collected in periodic intervals, and is synced in a mobile application through the iBeacon and Bluetooth communication modules. By seeing this intimation, the user can correct his/her posture. Further, the system consumes low-power, and can be used to understand the user's sitting habit, promoting a better physical growth, and derivation of medical information. The authors in [3], propose a system that consists of sensors that are rather unobtrusive. The system consists of a series of capacitors placed on the chair and the backrest. The armrests are composed of photoplethysmographic (PPG) sensors deployed along electrodes, to further gather PPG and ECG data. The Pulse Transit Time (PTT) was then calculated, as a difference between the ECG Crests and PPG Troughs. The system aimed to develop a relation between the PTTs obtained, and the corresponding blood pressure. Various best-fit models were designed that helped in the mapping of the PTT to the Blood Pressure, and it was observed that the models were accurate for the diastolic pressures, while not so accurate for Systolic Pressures.

In [4], the authors propose a non-invasive posture detecting and monitoring system. Initially, a set of 8 sitting postures are defined, and fed into the software for developing neural networks to detect various postures. A piezo-resistive sensor is placed on the seat of the chair, to sense the changes in pressure among different postures. The authors use the MATLAB software for the training of neural networks. It was observed that the system was able to detect the different postures with high accuracy. In [5], the authors conduct extensive research to understand if a smart chair could potentially improve the sitting behaviour of office workers. The authors in this paper try to validate the benefits that a smart chair offers and the feedback intimations provided by smart chairs, to muscular pain and sitting postures. The study involved 45 workers of an office, subjected to the effects of the smart chair. The 20 week period of study consisted of workers initially being acclimatized to the smart chair and receiving tactile feedback, followed by a period without feedback. This was iteratively performed. The results were measured in the form of average resting duration, muscular discomfort, and correspond posture. The study demonstrated that smart chairs can be used for monitoring the sitting behaviours, however the feedback signal was not of much significance.

The authors in [6] develop an embedded health monitoring system deployed on a chair. The user sitting on the smart chair, can observe vital health monitoring metrics including pulse rate, blood pressure, temperature, and weight, in real time. The data can also be transmitted to a medical professional for monitoring and initiating any treatment if found necessary. The system uses a WiFi and GSM module to render periodic suggestions to the user. The system uses fog computing to transmit data and provide notifications. The authors also demonstrate the use of an encryption algorithm in the system, “Signcryption”, which consists of a combination of Encryption and Data Signatures, to ensure better privacy and prevent data theft. In [7], the author proposes an intelligent office chair that consists of a combination of visual and vibrotactile feedbacks. It was evident that vibrotactile feedback was an efficient method to alert the user about an incorrect posture, when detected. However, vibrotactile feedback is unable to guide users to the appropriate sitting postures. On the other hand, visual feedback, was an efficient method to instruct users to maintain the right sitting posture, but it was often disregarded. This shows that both by themselves do not have enough significance, but when used in unison, can produce significant results. In this system, pressure sensor pads are placed on the seat and the backrest. The system initially is trained using the MATLAB Neural Network toolbox, to detect various sitting postures. Based on predefined conditions, when a user sits longer than a threshold in the same position, a notification is sent to the mobile, as a part of visual feedback. At the same time, vibrational actuators placed on the smart chair, help in alerting the user in the form of vibrotactile feedback.

In [8], the authors design an embedded system consisting of infrared distance and pressure sensors, to facilitate the classification of the user’s postures. The system uses seatback distance sensors, distinguishing it from previous systems in this regard. The pressure sensors are placed on the seat, to further gather data about the user’s postures. The system, through using a blend of mixed sensors was found to have achieved a high accuracy in analysing the ergonomics of the chair. [9] proposes the uses of pressure sensors on the seating face and the backrest. The author uses multiple analog tactile sensors (ATS) to detect and classify the posture of the user. The authors use the Stroop test to validate their system, and prove the benefits in the form of improved cognitive engagement. In [10], the authors use the CC3200 as the central microcontroller, embedded with pressure sensors. The frequency obtained, is further transmitted to the Google cloud, using a suitable WiFi module, for further processing and data visualization. The authors create a web user interface and a mobile application to facilitate interaction at the client side.

3. Methodology

3.1. Research Survey

Researchers have adopted two forms of feedback to alert the user of the sitting position, Visual feedback and Vibrotactile feedback. The systems deployed uses a one-to-one communication system , through which data can be viewed only in a single device. It is also noted that the benefits of vibrotactile feedback are quite obscure, as the user’s incorrect posture was detected, but not corrected.

To understand the problems and issues of long hour usage of chair and understand expectations of end users, the researchers conducted a survey among 100 people. Respondents included people from varying age groups, and occupational backgrounds. It was noted that a majority of the respondents use a chair for 5-7 hours a day on an average. The respondents were presented with the most common sources of discomfort, occurring as they sit on a chair for a prolonged interval. 3 main issues of discomfort were recorded (1) Muscle and Joint pain, (2) Cramps, and (3) Backpain. 97% of the respondents reported to have experienced discomfort at least once as they sat on chairs in a prolonged interval, clearing pointing it out as a pressing issue. The respondents were also presented with a set of possible features that could be incorporated on their existing chair. A majority of the respondents preferred to have the following features. (1) A chair that could analyse the user’s sitting posture over time, (2) A chair that could alert the user, regarding the correct sitting posture, and (3)A chair that could measure body vitals including Heart rate, Blood Pressure, etc, and (4) A chair that could notify the user’s correct arm position, to facilitate an ergonomic armrest, and (5) A chair that could automatically detect the lumbar of the user, and provide support along its region. Based on these observations, the authors propose a scalable, cost-effective, low-power consuming smart posture monitoring system[11]. Figure 1 represents the information collected from various end users with respect to the requirements expected in a chair .

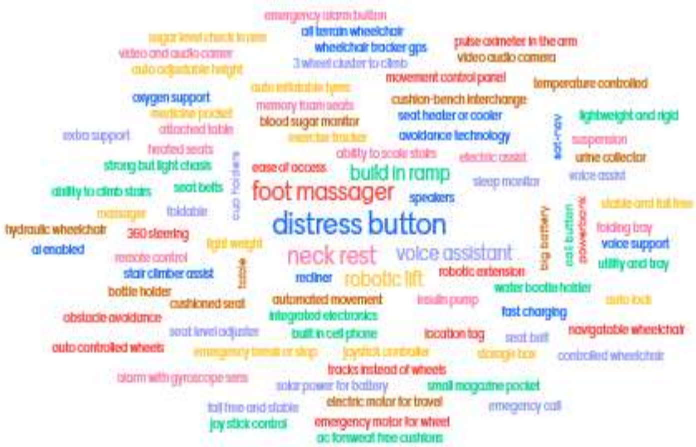

Figure 1. End user expectations of a smart chair.

3.2. System Design

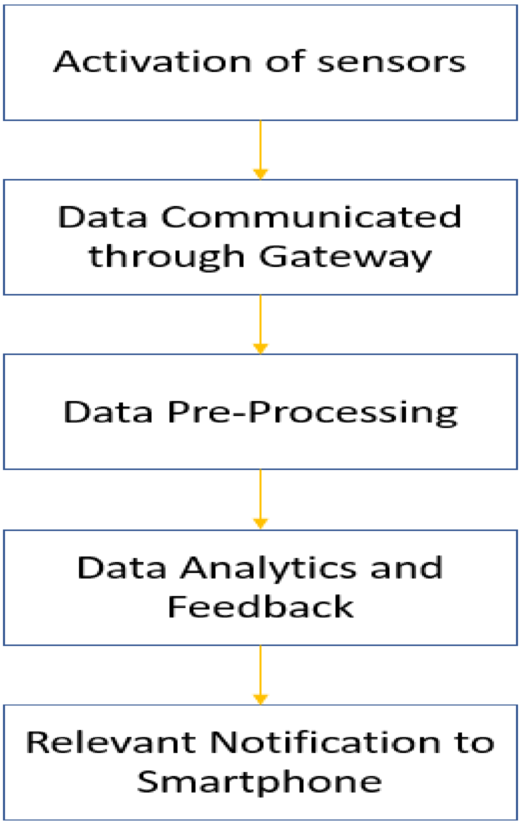

Figure 2. Working principle of the Smart Chair.

Figure 2 gives a high level design of the prototype as show in the block diagram constituting tilt, pressure sensors, along with necessary body sensors that can measure heartrate, blood pressure, and temperature. In [11], the authors develop and simulate a set of pressure sensors in 9 different seating positions. The authors use a pressure sensor sheet, to be placed on the seating face.

Initial development of the product begins at identifying and articulating the opportunity in the market. It is evident that the issue of discomfort arising from sitting for prolonged intervals is a ubiquitous one. The next stage involves the development of the concept. Here, the needs of the customer are identified, the target groups. This was addressed in the research survey discussed above. Investigating the feasibility of the product is an important step to ensure the success of the product. It is noted that various attempts of similar products earlier have been successful. They, however do not completely satisfy the needs of the customers in the market. In the next step, the product architecture is developed, identifying viable hardware, and communication modules that can be deployed on the chair, to develop a smart posture monitoring system. This would be followed by software testing, to ensure performance and reliability of the developed product. It was also noted that the majority of people prefer a chair with cushion[12].

The sensors that are deployed on the chair , namely the pressure[13] and tilt sensors[14] , would be placed on the bottom of the seat. 4 sensors would be placed on the seat, and 2 sensors would be placed on the backrest of the chair. The sensors are calibrated in such a way, that when uneven pressures are sensed among them, a notification is sent through the gateway to the authorized users. Figure 3 represents the situation when the user is leaning on the backrest. In this situation, the pressure applied on the hind sensors are greater than the threshold set, and as a result, a red light glows on the sensors, prompting an alert. Similarly, when a disproportionate amount of pressure is applied on any part of the chair, a vibrotactile feedback is generated to alert the user.

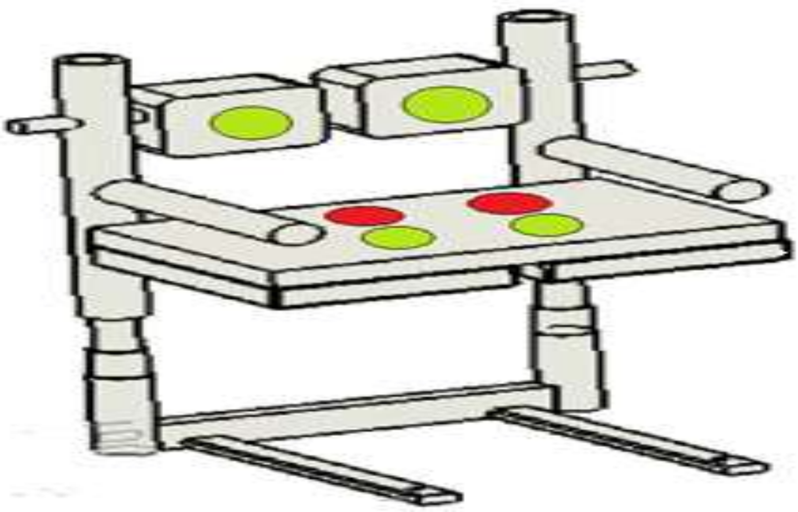

Figure 3. The proposed illustration of the pressure sensor activation.

Figure 4 represents the design of the system. The system comprises of a central microcontroller, embedded with various sensors to analyse the sitting posture and various body vitals in this regard. The microcontroller and sensors are powered by a single lithium ion battery, hence ensuring safety from any electrical hazards, while being a cost-effective option. The ESP8266 communication module is used for the communication of measured data between the device, gateway, and the user's smartphone. The data is processed in the fog layer, and following this, is the process of sending alert notification to the authorized user's mobile through the GSM module. Simultaneously, data can be visualized in the Thingsboard API.

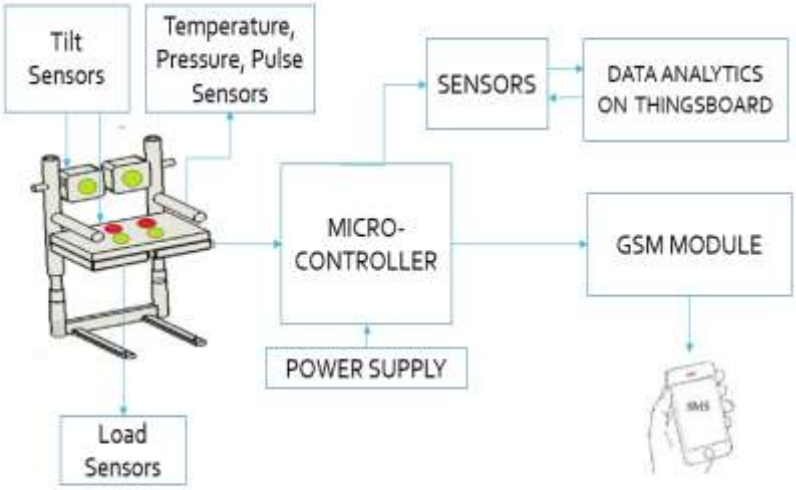

Figure 4. Experimental setup of the proposed system.

Various sensors that have been deployed in the system have been listed below:

3.2.1 DS18B20 Sensor.
The DS18B20 is an accurate low-power consuming temperature sensor that is used in embedded systems. Temperature is an important parameter that can be measured to determine if the user is in good health. Real-time monitoring of temperature could facilitate a physically safe environment, and could help curb the spread of contagious diseases. The temperature sensor is attached as a wearable device on the smart chair, that can be used as and when necessary.

3.2.2 CZL642 Transducer.
The CZL642 Transducer is an efficient load cell that can be used to measure the weight of the user. An abrupt increase or decrease in weight may be a harbinger to an imminent disease. It is hence a very useful parameter that can be measured by the user. A load cell is a transducer that converts the measured strain, into electrical energy. The HX711 is another module that can be used as a load cell amplifier. With an initial calibration, the load cell can be used effectively, by connecting it to a suitable microcontroller.

3.2.3 MP3V5050 Transducer.
The MP3V5050 Transducer is a reliable source for measuring blood pressure as a part of an embedded system. Real-time monitoring of blood pressure would be of great use to individuals of all age, considering their busy schedules. The blood pressure of an individual might vary based on different factors such as age, emotions, exercise, etc. A high or low blood pressure, might eventually lead to a heart attack or a stroke. The transducer in regard helps with the measurement of both systolic and diastolic pressure.

3.2.4 SEN11574 Sensor.
The SEN11574 sensor is a reliable and cost-effective sensor that can be used to measure the pulse rate of the user. The sensor is widely used in embedded systems, and consumes low power while delivering accurate results. The sensor requires connection with a suitable microcontroller. The sensor also constitutes a circuitry with the ability to cancel external noise that might affect the reading. By simply placing the user's fingertip on the sensor, it is possible to obtain accurate results in a short period of time.

3.3. Data Acquisition and Analytics

To further analyze the obtained data, the obtained sensor values can be streamed in real-time on the Thingsboard API. The Thingsboard API is an open-source web API that can be used for data collection and visualization of information obtained from embedded systems. Initially, the sensors placed on the chair detects the values in the form of frequencies, these values are further fed into a suitable microcontroller. A suitable WiFi module is further used to transmit the data as telemetry to Thingsboard. The data transmitted can be numbers, or text. By setting a suitable baud rate, it is possible to visualize data in a variety of gauges and charts, anywhere around the world. Figure 5 represents the dashboard on the Thingsboard API to measure the body vitals in this regard.

Figure 5. Dashboard representing body vitals.

4. Summary

A prototype for a potentially viable posture monitoring system was developed. The device has the capability to gather data pertaining to the sitting posture of the user at periodic intervals. The prototype also employs sensors that can be used to measure body vitals effectively. The time-series data obtained can further be leveraged to produce data-driven insights that can help the user with corrective measures.

A smart posture monitoring system with multiple functions was designed. The system was built in consideration of a research survey initially conducted to identify the issues and expectations of people with regard to an ergonomic environment. The system is a cost-effective low-power consuming device that can help with the monitoring the posture of people, and also serve as a health monitoring system effectively. The designed chair is targeted at employees at their office, students, and home makers. The technology can also be exploited by gamers who use chairs for long periods of time. The data collected can further be analysed to detect the user's posture over time, and can deliver actionable insights for further development. Further research is ongoing to add voice assistive functionalities using machine learning and similar technologies [15] to the current system.

References

[1] Park M, Song Y, Lee J and Park J 2016 Design and Implementation of a smart chair system for IoT *International Conference on Information and Communication Technology Convergence (ICTC), 2016* pp 1200-03.

[2] Zazula D, Kranjec J, Kranjec P and Cigale B 2015 Assessing blood pressure unobtrusively by smart chair *2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* pp 2385-89.
[3] Huang M, Gibson I and Yang R 2017 Smart Chair for Monitoring of Sitting Behavior. *KnE Engineering,* 2(1) pp 274-80 .
[4] Roossien CC, Stegenga J, Hodselmans AP, Spook SM, Koolhaas W, Brouwer S, Verkerke GJ and Reneman MF 2017 Can a smart chair improve the sitting behavior of office workers? *Appl Ergon. 2017* pp 355-61.
[5] Lavanya R, Nivetha M, Revasree K and Sandhiya K 2018 Smart Chair-A Telemedicine Based Health Monitoring System *2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA)* pp 459-63.
[6] Liu J 2021 *J. Phys.: Conf. Ser.* 1877 012015.
[7] Jeong H and 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* vol 25, no. 5 pp 1805-13.
[8] Bibbo, Daniele et al. 2019 A Sitting Posture Monitoring Instrument to Assess Different Levels of Cognitive Engagement *Sensors (Basel, Switzerland)* vol 19 p 455.
[9] Flutur G, Movileanu B, Károly L, Danci I, Cosovanu D and O P Stan 2019 Smart Chair System for Posture Correction 2019 *22nd Euromicro Conference on Digital System Design (DSD)* pp 436-41.
[10] Kazuhiro Kamiya, Mineichi Kudo, Hidetoshi Nonaka and Jun Toyama Sitting posture analysis by pressure sensors *2008 19th International Conference on Pattern Recognition* pp 1-4.
[11] Dunne LE, Walsh P, Hermann S, Smyth B and Caulfield B 2008 Wearable monitoring of seated spinal posture *IEEE Trans. Biomed. Circuits. Syst,* vol 2 pp 97-105.
[12] Ma C, Li W, Gravina R and Fortino G 2017 Posture Detection based on smart cushion for wheelchair users *Sensors* vol 17 p 719.
[13] Suzuki S, Kudo M, Nakamura A 2016 Sitting posture diagnosis using a pressure sensor mat 2016 *Proc. ISBA, Sendai, Japan* pp 1-6.
[14] Kim M, Kim H, Park J, Jee k, Lim J, Park M 2018 Real time sitting posture correction system based on highly durable and washable electronic textile pressure sensors *Sensors Actuators, A Phys.* vol 269 pp 394-400.
[15] Roh H, Park H, Lee K, Hyeong J, Kim S and Lee B 2018 Sitting posture monitoring system based on a low-cost load cell using machine learning *Sensors* vol 18 no. 208.