IoT-Based Smart Posture Correcting Chair Design

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Abstract -- **During and post-COVID-19 pandemic, chronic back and neck pain-related health concerns have demanded smart posture-correcting systems due to home confinement, longer sitting online schools and working hours. Such a system can help elderly personnel, young working professionals as well as school children to enhance their quality of life. To address this major concern, posture-correcting systems available are first reviewed in this paper and referring to the existing healthcare systems used for posture correction, a cost-effective posture-correcting IoT-based smart chair design solution is presented.**

This cost-effective smart design uses ultrasound pressure sensors at the bottom part of the chair and distance sensors at the back of the chair. A microcontroller-based system integrates these sensors, and the data stored in a database makes self-learning ability to be incorporated into the system. The highlight of the design is a mobile application that keeps track of the correct posture, comparing the critical value stored in the system to warn an individual user against posture imperfections. The cloud connectivity provided using a wireless sensor node enables sharing of data with a distant medical professional for seeking necessary guidance and support.

Keywords: *Posture imperfections, Sensors, Smart chair, Mobile application, IoT, Cloud connectivity*

I. INTRODUCTION

POSTURE is a phase of body mechanics, defined by the orthopedic subcommittee of the Hoover White House Conference as “the mechanical correlation of the various systems of the body with special reference to the skeletal, muscular, and visceral systems and their neurological associations”[1]. Studies carried out on sitting positions of working professionals having long working hours revealed that bad postures and sitting symmetry lead to lower back pain [2]. COVID -19 pandemic impacted the health conditions [3] of the elderly facing home confinement, working from home with working professionals, and online school culture in children increased the severity of these back and neck pain concerns, grabbing the attention of researchers to develop a solution to address this major issue [4]–[6]. The need for such corrective smart health equipment is presented through health assessment of cervical spine stresses caused due to wrong postures resulting from handling electronic hand-held gadgets, mobile devices, and sitting on a chair for longer durations. The study carried out through explicit modelling proved that these stresses may lead to early wear, tear, and degeneration, which if not timely addressed may lead to critical surgery of the spine [7].

To address this serious health concern, the work presented in this paper reviews the existing systems evolved to address these back and neck or posture-related concerns in the first part and suggests a cost-effective solution in the subsequent part. The design concept is discussed in detail highlighting the features of each component of the proposed system.

II. A REVIEW OF EXISTING POSTURE CORRECTING SYSTEMS

A very first significant attempt at a smart cushion designed with a textile yarn having arrays of piezoelectric sensing devices was presented [8]. This Smart Cushion system designed for sitting posture monitoring uses a re-sampling-based method to calibrate the sensor values to overcome offset, scaling, crosstalk, and rotation effects. The system was developed to verify seven different sitting postures and was having more than 80% accuracy. However, it was lacking in identifying correct sitting posture [8]. Measuring posture correctness using an angular displacement measurement using the vector method has also been presented [9]. An improved device design is presented to monitor body posture using three sensors attached to the torso [10]. The development, design and evaluation of this proposed system are presented in two stages: first by developing a posture monitoring device that takes account of technological factors as well as user experience factors; and second understanding attitudes and perceptions of older persons in residential homes towards the monitoring of bodily posture using a portable device attached to the torso. The system suffered from degradation in device performance and bulky un-friendly structure [10]. To overcome these limitations an improved system has been presented using IoT interface ARM MCU and cloud-based connectivity for posture correction [11]. The sensors and IoT applications were specifically designed where the service, calibration and design cost were a major concern. There has been an assistive device design presented for posture correction using a vibration motor and pressure sensors that have been practically tested [12]. But this system suffered from accuracy issues.

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With technological advancements, IoT has been a boon to millions of people worldwide by allowing a more intelligent and customizable interface for them to interact with in their daily lives. The smart chair design for healthcare [13] as well as other IoT-based multiple smart applications have been projected with design objectives focusing towards energy harvesting, healthcare, security as well as smart city applications [14 - 17]. This paper aims to develop a smart chair design that also reviews the use of advanced or improved sensors that measure the sitting position of an individual. The data collection in such systems is mainly done by the force sensors [18-20], pressure sensors, servo motors, ultrasound sensors, [18] and trainability of the system is imparted by the machine learning algorithms etc. [19], [21- 24].

III. PROPOSED DESIGN

The proposed design is implemented referring to the data available in the existing literature. The different components of the proposed posture-correcting system are mentioned below.

(a)

(b)

Figure 1. Sensors used for data acquisition (*a*) Force Sensor (*b*) Ultrasound sensor.

- *Sensors* – This proposed system is designed using two basic types of sensors (*a*) ultrasonic sensors [25] and (*b*) pressure sensors [26]. The system used two ultrasonic sensors for measuring the position of the neck/spine from the chair surface and six pressure/force (FSR- 402) sensors positioned at the base of the chair. The sensors are shown in Fig. 1.
- *Design Details:* The ideal position of various sensors is determined based on the existing experimental research and observations. Adequate isolation between the two sensors is ensured by inserting foam for avoiding cross-talk or electrical interference. The proposed smart chair is using wireless Node and an MCU microcontroller that manages the data received from the sensor, collected data is then stored in a database. A threshold limit may be set by the individual user as per the comfort in the spine posture as per the height-weight of the individual. The correct sitting position is considered from an NHS document available online [27], indicated in Fig. 2. The actual positioning of the sensors on the chair back and the surface cushion is indicated in Fig. 3.

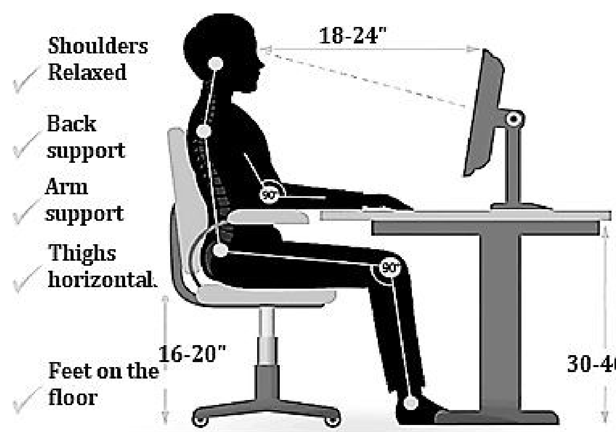

Figure 2. Correct sitting posture [27].

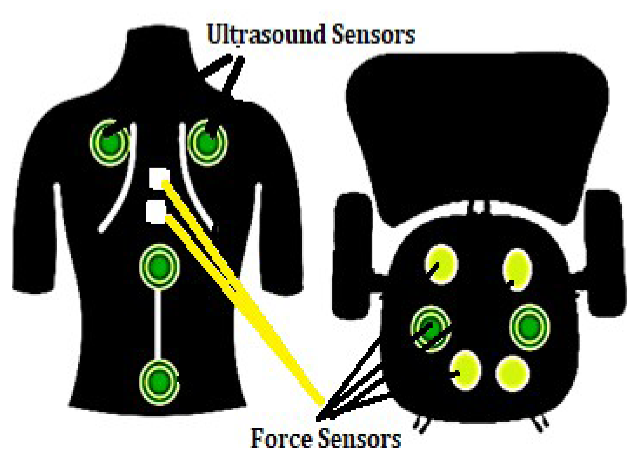

Figure 3. Sensor Positions [11].

Referring to the correct sitting posture [2] [22], different eight sitting positions are considered for imparting trainability to the system. These sitting positions include (i) upright sitting (P_1); (ii) slumped sitting (P_2); (iii) leaning forward (P_3); (iv) leaning backward (P_4); (v)leaning left side (P_5); (vi) leaning right side (P_6); (vii) right leg crossed (P_7); (viii)left leg crossed (P_8).

A significant feature of the system is incorporation of both ultrasonic and force sensors for accurate posture detection. Two ultrasonic sensors in addition to the force sensors are mounted on the back cushion of the chair to measure the distances between the chair's back and the spine. Six force sensors (FSR 402) are embedded in the seat cushions. These are force sensors that accurately sense the sitting pressure distribution thereby verifying the correct sitting posture of an individual. The distribution of force applied by the body is thus precisely sensed by a set of these six sensors. The use of the web application is another improved feature with an added benefit that generates alerts through desktop notifications as well as mobile notifications to the user regarding any posture imperfections. This improved feature aids in monitoring the posture continuously as long as the user is using the chair.

Notable features of this smart posture correction system include (*a*) lightweight structure – as the sensors are embedded in the poly textile material of the cushion of the chair and adequate foam is used for sensor isolation, the system is comparatively lighter in weight. (*b*) The integration of sensors through MCU facilitates data storage. (*c*) Wireless connectivity can make data sharing easy (*d*) the mobile as well as desktop warning system developed can aid in ensuring posture correctnesswithout any disturbance to the ongoing work.

IV. CONCLUSION

The implemented system is a low-cost low power consumption system working on battery support. It is a multi-facilitating system that can warn the user either on a desktop or through a mobile application for posture correction. The task achieved is part of our undergraduate research project. This chair with smart posture detection system can thus improve quality of life of every individual. It can be part of wheelchair system also so that the additional complications arising due to posture imperfections can be avoided.

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