Orthopedic Chair

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1 Introduction

1.1 Objective

According to the American Chiropractic Association, back pain is the leading cause of disability worldwide where it is estimated that 31 million Americans experience back pain [1]. The cost to remedy these back pain issues is reported at about $50 billion [1]. Among the many potential causes of back pain is improper posture that causes harm to the spine and many muscle groups in the body (depending on the pose) [2], [3]. Looking further at the displays of bad posture, it is noted that unhealthy sitting can lead to poor body positioning for prolonged periods of time, which adds stress the muscles and bones [2]. It was found that people with ‘S’ shaped spines (possibly due to excessive slouching) tend to have more back problems than people with ‘J’ shaped spines [3]. Therefore, proper posture is essential to recovery and prevention of back problems, but it’s much easier said than done once poor posture has been adopted [2].

Our goal is to develop a system of sensors embedded on a chair that can detect poor posture and notify the user of the presence of poor body positioning. We will use a grid of pressure/force sensors on the seat and the splat as the main component of recognizing the weight distributions as well as a range sensor to map out the position of the user. From this sensor data, it can then classify the user’s posture and then notify the user through physical means such as vibration with vibration motors. The sensor data can also be used to analyze trends and visualize potential issues in a meaningful manner. This addresses the problem of prolonged poor sitting posture since it notifies and educates the user about the risks of the current and past positions.

1.2 Background

As mentioned above, bad posture is a serious problem that could lead to health issues after prolonged use. Unfortunately, it’s possible to adopt bad posture subconsciously, which can be effectively countered by maintaining awareness for the user of such an issue and repeatedly correcting it [4]. As technology advances and more jobs require sitting for long periods of time, it’s becoming more important to develop safe methods that maintain the health and well-being of users [3]. Thus, a product that can aid in the correction of posture that isn’t as physically intrusive as many other proposed solutions would be ideal.

The features that make this project marketable include the many sensors embedded in a commonly used object (chair) that can help provide granular data to improve the health of the user. Not only does it remind the user to correct their posture, the data can also be processed and displayed for the user to understand what's going on and how they can improve their positioning on their own. This project essentially aims to combat the common issue of bad posture with the use of a chair, which is commonly used for sitting for long periods of time.

1.3 High-Level Requirements

- Pressure sensors must be sensitive enough to detect changes in sitting positions for children and adults, which may require robustness to handle hundreds of pounds of force.
- Posture detection must be as accurate as possible to warn about bad posture instead of encouraging bad posture.
- Chair must be power-efficient, ideally able to last at least 10 hours without changing batteries.

2 Design

The following modules shown in Figure 1 are needed to implement the project: power, sensors, control system, user interface, data stream, and software. The power module is an important component that sends a steady supply of power to all the devices as they interact with each other. This is important to satisfy the high-level requirement of having enough power to last an entire day of nonstop use. A grid of pressure sensors can help gather data from different parts of the chair to satisfy the granularity requirement. The sensors send their data to a control system microcontroller and also to the data stream. The microcontroller is needed to determine signals to send to the user interface regarding the vibration mechanism. The data stream is the connection to the computer that will perform the analysis using the software. The memory block within the data stream subsystem is designed to allow data to be sent in batches instead of attempting to do potentially bandwidth-heavy realtime processing. Finally, the software processes the data and provides visualizations for the user. The software can help satisfy the accuracy requirement since many powerful inferencing techniques can be utilized in the software.

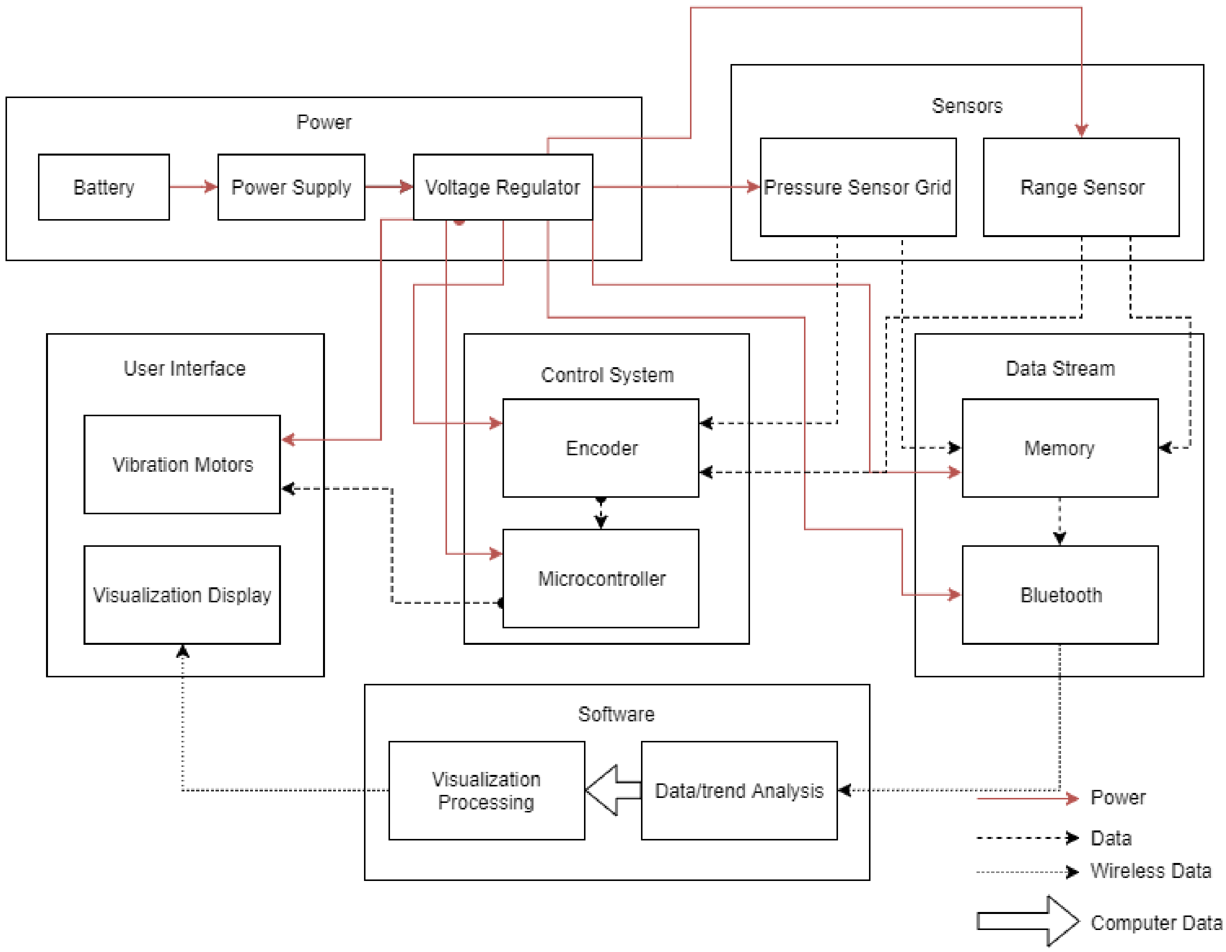

Figure 1. Block Diagram

2.1 Power

Power is needed to allow the sensors, motors, and data communication to continue running.

2.1.1 Battery

A 10V battery will be used to power the sensors, the microcontroller and the user interface. The battery first feeds into the power supply that will then forward the power.

Requirement: Must last, at least, 10 hours without the need of being charged.

2.1.2 Power Supply

The power supply takes the battery power as input and forwards the power to the voltage regulator for distribution to the other modules.

Requirement: Must be able to send power to the voltage regulator for distribution.

2.1.3 Voltage Regulator

A voltage regulator will be used to supply the 5V as input to the microcontroller. It is relied on to ensure the voltage is regulated for other components in the system that need power from the battery.

Requirement: Must be able to regulate the voltage to 5V for the microcontroller and various sensors and vibration motors.

2.2 Sensors

The sensors collect data from how the user interacts with the chair. The data from the sensors will be sent to the Control System as well as the Data Stream for processing.

2.2.1 Pressure Sensor Grid

The grid of pressure sensors will collect pressure data to tell where the user is applying pressure (sitting). The distribution of weight is important to understand the posture being used. We will use two grids of 12 force sensors, one in the back and one on the seat itself where each sensor is spaced out enough to collect data in different areas of the seat/back. The sensors will vary their resistance as voltage is applied, so that relationship will be mapped to determine the pressure at a point in the grid.

Requirement 1: Must be strong enough to handle a weight of 100kg.
Requirement 2: Must be able to collect data that is granular enough to distinguish changes in sitting positions.

2.2.2 Range Sensor

We will use a range sensor to determine if there is a user to begin collecting data on and also it will be used to determine how far the user may be slouching. It will be in the back, in order to detect the distance between the person and the back of the chair.

Requirement: Detect the distances of objects up to 50 cm away.

2.3 Control System

The control system sends outputs to the vibration motors based on what the readings of the sensor data indicate.

2.3.1 Encoder

As a lot of sensors will be used, the microcontroller will not have enough GPIO pins to handle all the inputs. An encoder will be used for each pressure grid, in order to decrease the number of pins needed: from 12 to 4 per grid.

Requirement: Must be able to reduce the pins needed to collect the sensor data and process it in the microcontroller.

2.3.2 Microcontroller

We will program the control system in a microcontroller. The microcontroller will collect data from the sensors each minute, and an algorithm will be implemented to detect if the user is badly sat.

Requirement: Correctly determine posture based on sensor readings from the sensors through the encoder.

2.4 User Interface

The user interface is how the system interfaces with the user. In this case, the output uses vibrations to indicate bad posture and it also sends visualizations that can be viewed in software based on the data collected.

2.4.1 Vibration Motors

If the user is badly sat, the microcontroller will turn on some vibration motors. These motors must be powerful enough to ensure the user will notice them.

Requirement: Must be able to be felt in varying intensities to notify the user of poor posture based on signals from the microcontroller.

2.4.2 Visualization Display

Apart from the vibration motors, we will use a visualization, in order to tell the user what he or she is doing wrong, and how to fix it.

Requirement: Convert the sensor data into human-interpretable format with an analysis provided from the visualization processing software component.

2.5 Data Stream

The data stream deals with sending readings from the sensors to a computer that will perform the processing through the software module.

2.5.1 Memory

Memory is needed to store some of the sensor readings to avoid constantly sending redundant data if no change is found. This can also be used to batch the data instead of relying on real-time transportation and processing.

Requirement: Must be able to store enough sensor data for a minute to send data in batches and eliminate redundant sends.

2.5.2 Bluetooth

The bluetooth component is how the circuit is going to send the data to the computer. It takes the data stored in memory and relays it over to a computer that is receiving the data.

Requirement: Must be able to send the pressure sensor grid and range sensor data reliably and quickly.

2.6 Software

The software module consists of programs on the computer that do all the processing of incoming sensor data from the data stream. The output is sent over to the user interface for display. It involves a website that the user will log onto and that is the way the user will be obtaining the in-depth information from the chair.

2.6.1 Data/trend Analysis

Data/trend analysis is needed to provide meaningful information that the user might want to know. Much like how fitness apps track activity throughout the day, it's useful to understand how the user's posture is varying. It will adapt to the user, and map out an ideal posture fixing guide through machine learning algorithms. This means that the chair will slowly guide the user to the optimal position, and at the same time will be reevaluating the optimal guide on a daily basis.

Requirement: Extract meaningful data and inferences from the input sensor data.

2.6.2 Visualization Processing

This component deals with processing the data for visualizations. This may involve heatmaps to display raw pressure readings or even the trend analysis results with possible recommendations. The data will be processed into maps/graphs in python and R, and displayed through the website.

Requirement: Must be able to process data to a visualizable form.

3. Risk analysis

The block that poses the most difficulty will be the Sensors block, specifically the Pressure Sensor Grid. This component will pose the greatest difficulty because it's the main source of the readings, so all the other components rely on the data that is being captured by the sensors. Considering the application of this project and the first high-level requirement, it will require very robust yet sensitive sensors to ideally capture all the data we need when someone is sitting on it. Unfortunately, this comes at a very high cost since it's very difficult to find cheap sensors that can support up to 100kg yet tell the difference between someone sitting back or leaning forward on a chair. It will take significant testing to identify the best placement of each sensor in a chair. Having the sensors on the surface of the cushion will obtain the best data but will be exposed to friction and other environmental factors. On the other hand, embedding the sensors too deep into the cushion may make it difficult to pick up accurate readings due to how force is distributed over area and the material properties of the cushion.

As mentioned above, the inputs to the control system and software rely on the sensor readings they receive. So no matter how good the algorithms are, the overall effectiveness of the project relies on the data collected from the sensors. Therefore, the sensors module also impacts the second high-level requirement of accuracy.

It’s expected that the sensors will end up using the most power, so the last requirement of being able to power the chair system for at least 10 hours may be limited by the power consumption of the sensors.

4. Ethics and Safety

There is a certain risk in this project, which must be handled: the risk of having an electrical system at a place in which a human being is going to sit.

The requirement to handle this problem is using enough isolation measures, such as using insulating materials or putting critical components at places which are not too close to the user.

However, it is impossible to move away from the user all the components. For example, the sensors need to be near the user, and in fact, the pressure sensors will be in contact with him or her. These pressure sensors are the most critical part of the system, so an insulating material will be put between the sensors and the user. This material must be enough strong to electrically isolate the sensors and the user, but at the same time it must be soft, so when the user sits on the chair the pressure sensors will be pressed, despite the fact that there is an insulating material between them.

Other risks concern the physical assembly of the chair. However, we do not have the intention of making the chair step by step, but using one to design the electrical system. This means that the assembly of the chair should not be a problem for this project.

This aligns with the IEEE code of ethics. To be more specific, it follows point 1 of IEEE code of ethics: to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment [5]. Our project may be useful to improve the people’s health, which is obviously an ethical action.

For instance, if we follow a duty-based ethical theory, such as Kant's deontology theory, it is obviously ethical, because this theory states that an action is good if people would desire that it would be an universal rule. I think that everybody agrees that helping people to improve their health is something that is desirable for everybody, so it is ethical.

Due to the collection and analysis of data, it's also important not to use the user's personal data in wrong ways as highlighted in IEEE Code of Ethics #2: "to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist." [5] For example, a conflict of interest could occur if we were to sell posture data to clinics or other companies selling posture tools. Of course, this can be avoided by only using the collected data for the purpose of informing the user. This implication also applies to #5 where bribery should be rejected by not selling user data without their permission.

References

[1] Acatoday.org, "Back Pain Facts and Statistics." [Online]. Available: https://www.acatoday.org/Patients/Health-Wellness-Information/Back-Pain-Facts-and-Statistics. [Accessed: 08-Feb-2018].

[2] Acatoday.org, "Tips to Maintain Good Posture," *Posture*. [Online]. Available: https://acatoday.org/content/posture-power-how-to-correct-your-body-alignment. [Accessed: 08-Feb-2018].

[3] D. Brown, "Experts say posture matters: The good ... and the bad," *GoUpstate*, 10-May-2010. [Online]. Available: http://www.goupstate.com/news/20100511/experts-say-posture-matters-the-good--and-the-bad. [Accessed: 08-Feb-2018].

[4] J. Flynn, "Is it possible to cure a bad posture?," *The Independent*, 26-Oct-2015. [Online]. Available: http://www.independent.co.uk/life-style/health-and-families/features/is-it-possible-to-cure-a-bad-posture-a6709781.html. [Accessed: 08-Feb-2018].

[5] Ieee.org, "IEEE IEEE Code of Ethics", 2018. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 08-Feb-2018].