Posture Sensing Smart Chair

Proposal

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1 Introduction

1.1 Problem and Solution Overview:

Back problems due to slouching have become a huge cause for concern as people spend more and more time sitting in cubicles, hunched over a computer for hours upon hours every single day. In fact, according to a University of Washington study, forty-five percent of Americans between the ages of 35 and 55 suffer acute back pain each year [1]. Moreover, other studies carried out by the Social Security Administration identified back pain as the top cause of disability under the age of 45 in the United States [1]. Not only is poor posture unsightly, but it also introduces stress on the neck and spine, causing further muscular tension as the body attempts to compensate for the lack of support.

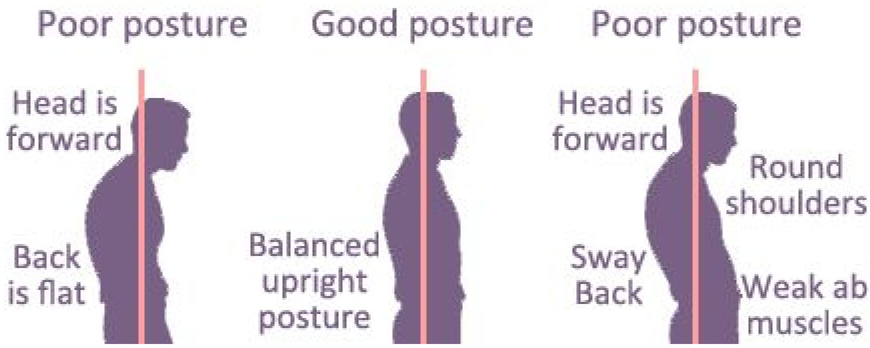


Figure 1: Good and Poor Posture

While maintaining proper posture is something that needs to be taken seriously in perpetuity, we have decided to combat this problem by focusing on time spent sitting in front of a computer, like in a traditional office environment, for example. After all, many adults spend a significant portion of their lives in this position! In response to this, we have set out to create a computer vision system that uses video input of the user's sitting position to determine whether or not they are sitting with proper posture. We will calculate the relative positions of the head, neck, shoulders, upper/lower back, and legs to determine if the user's alignment is safe and healthy. Should the user revert back to a poor sitting position, they will be notified via a combination of flashing lights and vibrations originating from within their chair.

1.2 Background:

From our own experiences with posture-related back problems, we know the hardest part about changing our habits is accountability. While strengthening postural muscles is important in correcting kyphotic posture, it is useless if you are unable to *remember* to put those muscles to use. By using our product, we hope to make people more aware of the way they are sitting and allow them to monitor their progress as they try to break the habit.

Because poor posture is such a widespread problem there currently exist many solutions on the market. A large portion of these solutions fall under the umbrella of electronic wearables [3], like the Upright GO, shown in figure 2, which attaches to the user's back between the shoulder blades. While we did initially consider the idea of designing our own wearable, we ultimately decided against it because we suspect that many people would find them uncomfortable. Other solutions involve harnesses that physically pull the shoulder blades back, shown in figure 3. The problem with these lies in the fact that they don't support the development of stronger postural muscles and therefore won't actually fix the problem. The last major class of solutions to poor posture in the workplace are ergonomic workstations and include things like standing desks and using an inflatable ball instead of a chair. While these solutions have the right idea in mind, the average person does not want to stand or roll around on a ball for eight hours a day; it's exhausting and unsustainable for many! We believe our proposed solution would have many advantages over the existing products on the market.

Figure 2: Upright Go

Figure 3: Harness

Originally, we wanted to approach this chair with a robust method of using various sensors to read a user's sitting posture, but after more research we figured this could be improved for more accuracy and reliability using computer software. Our first proposed idea had two separate subsystems to gather user information -- a back subsystem and a seating subsystem. Although this method may work, it would be more efficient and reliable to reduce the two measuring systems into one. By having just the software subsystem, we do not have to worry about faulty/inaccurate measurements from the sensors nor do we need the subsystems to be dependent on each other. Our computer vision subsystem will be a module that is placed a few feet away from the side of the chair. We believe this is by nature the best way to measure since the camera would not be able to see all of the user's segments from other placements (front and back). In addition, computer vision allows a better visual display of a user's sitting posture. Instead of gathering raw numbers to show the user, there are now live images that detect the different segments and check its alignment. Finally, our new proposed system has the advantage over the previous proposal in that the chair will no longer be anchored by a cord as all communication to the chair will be handled using bluetooth and all power going to the chair will come from a Li-ion battery.

1.3 High-level requirements list

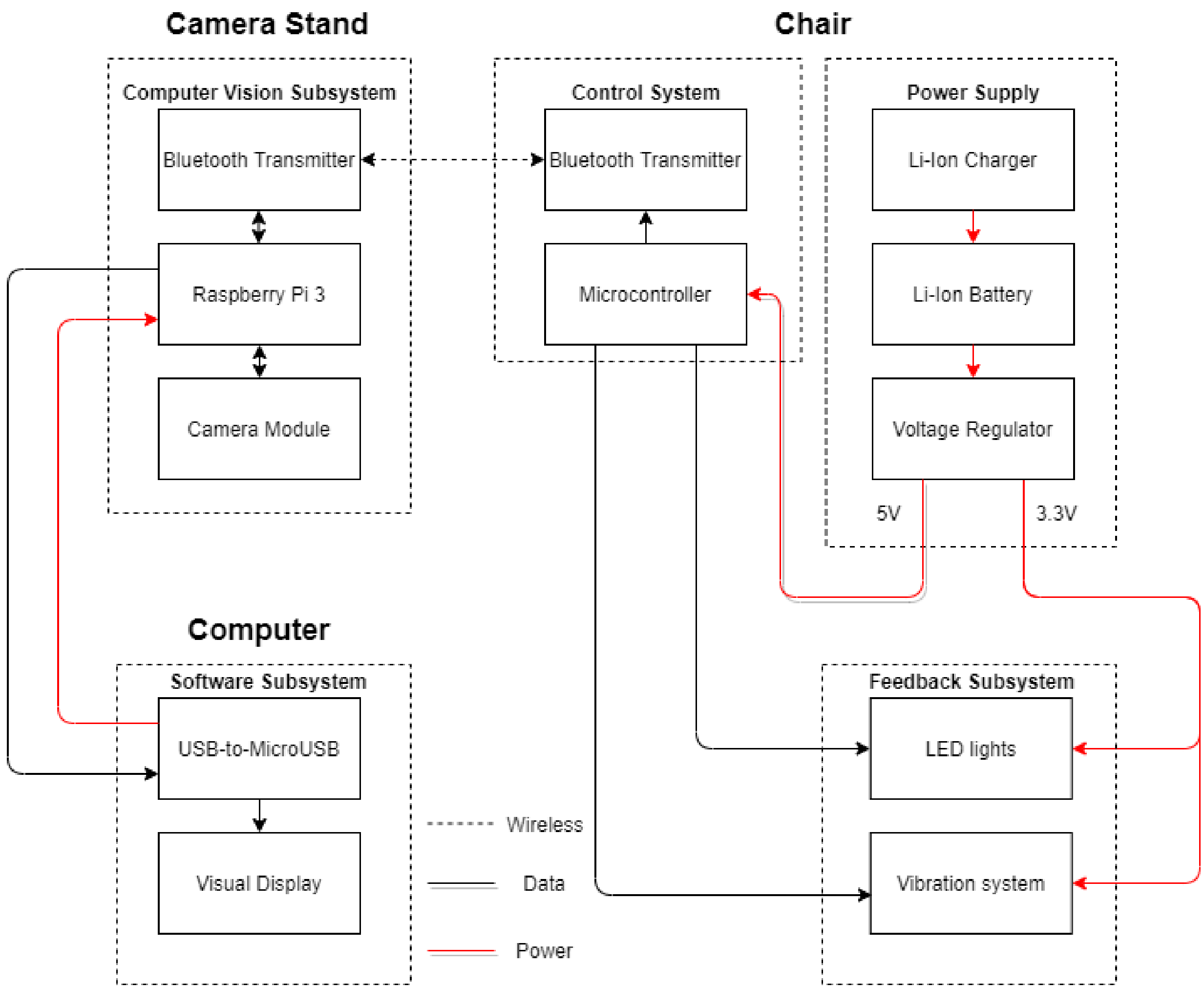
1.Using computer vision software, the system must be able to accurately classify the users posture as either good or poor with at least 70% accuracy.

2.The computer must be able to collectively analyze the data provided from the computer vision subsystem and send feedback back to the chair’s LEDs and vibrating system to notify the user’s current posture.

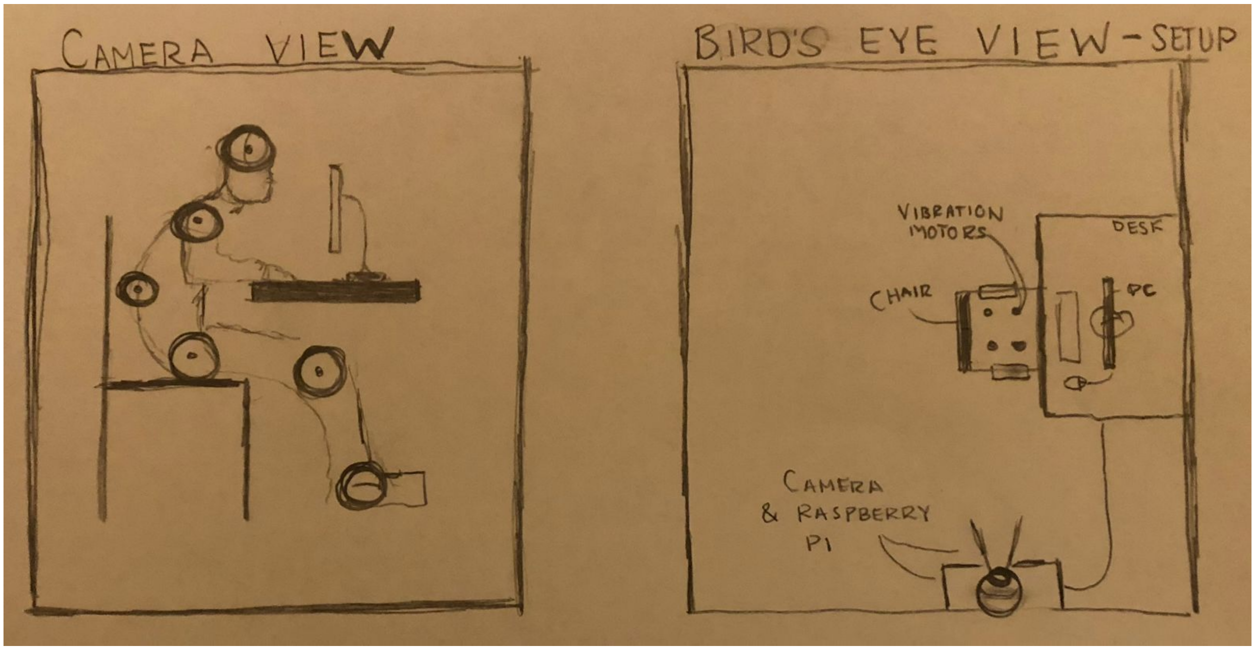
3.The data analyzed must be shown visually through a graphical display -- available via web application -- showing the user’s posture over time.

2 Design

2.1 Block Diagram



2.2 Physical Diagram



2.3 Power Supply

2.3.1 Li-Ion Charger

The Li-Ion charger is a voltage limiting device that will supply power to the battery once it is depleted.

Requirement 1: Must not exceed its operating limit of 45 Celsius during charging.

2.3.2 Li-Ion Battery

Our product will use a 3.7V Li-Ion rechargeable battery. This will be responsible for powering the chair's feedback system with the LEDs and vibrations as well as the bluetooth receiver.

Requirement 1: Must provide voltage between 3.7V and 4.2V.
Requirement 2: Must not exceed its operating limit of 60 Celsius while in use.

2.3.3 Voltage Regulator

The voltage regulator will be used to supply the battery power to the chair, distributing and regulating the voltage for the bluetooth and feedback systems.

Requirement 1: Must regulate the voltage to 5 V ± 5% for the microcontroller.
Requirement 2: Must regulate the voltage to 3.3 V ± 5% for the feedback LEDs and vibration system.

2.4 Control System

2.4.1 Microcontroller

We will be using a high-performance, low-power ATmega328P 8-bit microcontroller for this design. We chose this microcontroller for its affordability and abundance of documentation. We are also most familiar with this microcontroller as it was used in Arduino Uno. Atmega328P has a full suite of programs and system developing tools, such as C compilers, in-circuit emulators, and evaluation kits, which could be used in testing feedback subsystem [6]. The microcontroller will receive the analyzed data from the Raspberry Pi and manage the feedback subsystem.

Requirement 1: Must provide accurate data received from the Raspberry Pi to the feedback subsystem with no inconsistencies.

2.4.2 Bluetooth Transmitter

The Bluetooth transmitter will receive the analyzed data from the Raspberry Pi and relay the information to the microcontroller in the chair.

Requirement 1: Must not take longer than 300ms to receive data from the Raspberry Pi

2.5 Computer Vision Subsystem

2.5.1 Raspberry Pi 3

The RaspberryPi will be used to process the data received from the camera module and run a realtime multi-person 2D pose estimation algorithm to detect and provide feedback of a user's current sitting posture [9]. To implement this algorithm, we will utilize OpenCV's Human Pose Estimation to track all the segments that are essential in determining the posture (segments are listed in the high level requirements). We will implement additional logic in the algorithm to determine whether the existing posture read from the Raspberry Pi is within the threshold of acceptable posture. Once the microcontroller is done processing the posture, it will send information to our software subsystem for data analysis and relay signals to the feedback subsystem to tell the user of his/her current posture status.

Requirement 1: Must be able to accurately detect segments of user posture and move accurately in accordance to the user instantaneously.
Requirement 2: Must be able to read a good posture with a threshold acceptance of +/- 10%.
Requirement 3: Must be able to efficiently collect and encode data at every 1 minute interval then sent to the computer for data analysis. Upon reading the analyzed data, the module must be able to send signals to notify the user.

2.5.2 Camera Module

We will attach the camera module to our microcontroller to record and compare the user's current sitting posture in respect to the chair. This will be placed on the side to see all essential segments of a user.

Requirement 1: Must clearly view the entire side posture of a user from head to toe.
Requirement 2: Must be set on a default setting without any changes that would blur the view of the user (no autofocusing functions)

2.5.3 Bluetooth Transmitter

The bluetooth transmitter is used as a communication pipeline between the chair and the computer vision subsystem. Since the camera and microcontroller is separate from the chair we want to avoid as much wiring as possible to prevent accidental damages.

Requirement 1: Must reliably transmit data between the chair's feedback system with the camera and raspberry pi module at 3Mb/s

2.6 Software Subsystem

2.6.1 USB-to-MicroUSB

USB-to-MicroUSB cable will be used to power the Raspberry Pi with the computer.

Requirement 1: Must provide 5 V ± 5% for the Raspberry Pi at the current of 2 A minimum.

2.6.1 Visual Display

Our software subsystem is mainly responsible for displaying data to the user in a way that describes their seating posture over time. We will be using Ruby on Rails as the framework to build our web application. This project heavily depends on the data measurements from the sensors, thus we'd figured this development tool would be ideal because of its simplicity and efficiency to abstract these measurements. Using the collection of data, we will implement features on the web application such as frequency of maintaining good posture throughout the day and identifying weak points from the sitting posture.

Requirement 1: Data can be displayed on the web server within 1s of the data being collected.
Requirement 2: Data must be collected and stored in timed intervals to show gradual progression of the user seating posture.

2.7 Feedback Subsystem

This subsystem will be used to alert the user in real time when their posture has been classified as poor. It will contain both LEDs and Vibration motors so the alert can be seen as well as heard and felt.

2.7.1 LED Light system

LEDs will receive power from the Li-ion battery and be turned on and off via I/O pins from the ATMega328P microcontroller upon receiving a signal from the Computer Vision Subsystem when the user's posture is determined to be poor.

Requirement 1: Ensure that LED indicators are visible to the user
Requirement 2: Ensure that LEDs produce at least 8 lumens of light energy when they are fully powered
Requirement 3: Must provide the appropriate signals over 90% of the time.

2.7.2 Vibration system

Vibration motors will also receive power from the Li-ion battery and be turned on and off via I/O pins from the ATMega328P microcontroller upon receiving a signal from the Computer Vision Subsystem when the user's posture is determined to be poor.

Requirement 1: Ensure that the vibration is minimal (< 45 dB) but noticeable under the foam pads.
Requirement 2: Must provide the appropriate signals over 90% of the time.

2.8 Risk Analysis

The computer vision analysis component is the most vital part of our design. Because this is the sole mechanism for classifying the users posture, it is vital that this part is functional. Failing to complete this part of our design could result in inaccurate classification of user posture which could both prevent the user from bettering their posture as well as potentially causing it to worsen over time. To avoid this we must focus our energies on using computer vision to measure the positions of different segments on the user, and using these measurements to classify their posture algorithmically.

3 Ethics and Safety

Our project has several potential safety issues. Like addressed in 2.8 Risk Analysis, our electrical/mechanical components will be attached to where someone will sit on daily. The electrical circuits need to be safely placed in order to prevent potential dangers to the users. In order to prevent this, we need a protective and insulating material that can be put between the sensors and the user. At the same time, we need a material that is comfortable enough that a user can sit on the chair for multiple hours. By ensuring that nobody will be endangered by sitting on this electrical chair with enough insulation and protection, we believe that our posture-sensing system is in compliance with the IEEE Code of Ethics #1 [7].

Another risk we need to be careful is what IEEE Code of Ethics #9 states: to avoid injuring others by false or malicious action. Since our chair measures data with our computer vision and assesses the user's sitting posture, we need to be careful when we make the measurements and accurately analyze these values. Improper reporting of these values may lead to aggravation of back problems or injuries.

We believe that our design follows the ACM Code of Ethics 1.1 in that it contributes to society and human well-being [8]. Like it states, our design supports improving people's poor posture which is an important problem in society today. As the world is becoming more technology-based, people often tend to spend a lot of time sitting on their chair and work in their offices for several hours. Our design contributes to the society by providing feedback to their poor postures and lowering the risk of back or neck injuries.

We also intend to follow the ACM Code of Ethics 1.6: respect privacy. We will not disclose any information or data gathered through this design or share them with any other parties. The data gathered through the chairs will only be for personal use and knowledge.

References

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