Posture Perfect

Jacob Barr, Johnny Claros, Freddie Lopera, and Floyd Petersen

Dept. of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450

***Abstract* — In the modern era, with almost all aspects of our lives being computerized, people are sitting for far too long which encourages bad posture. Bad posture leads to increasingly common health problems. To curb this problem, a "smart" chair was designed to monitor and record the user's sitting activity and posture habits. The chair is outfitted with various sensors along the backrest and the seat in order to gather the necessary data in order to determine the user's posture and activity. The system will be battery powered and have wireless connectivity in order to communicate between the chair, the "Cloud", and the companion mobile application. The "Cloud" is used for data storage and heavy computations whilst the mobile application is for user interaction. This yields a user friendly solution.**

***Index Terms* - Acoustic Sensors, Diseases, Internet of Things, Mobile Applications, Pressure Sensors, Temperature Sensors, Web Services.**

I. INTRODUCTION

A majority of today's jobs consist of long hours spent seated on a chair. To make things worse, the overall lifestyle in America has progressively become sedentary. Its no surprise back problems have become an increasing epidemic in this country and all around the world. Due to this, there has also been an increase in demand for posture-correcting gadgets. This project seeks to be a solution to this ever growing problem.

Several ergonomic options already exist in the market but they're far too limited and can be costly. While many ergonomic chairs do exist in the market today, they only address the posture of someone with the approximate height the chair was designed for. Ergonomic chairs can only provide a convenient chair design that promotes comfort and avoids stress on a user's spine. Whereas, this project will promote awareness of the health effects caused by a sedentary lifestyle and notify the user when their posture is less than optimal. The chair will do this by reminding users to stand up after a prolonged period of inactivity. Simply reminding consumers of their slouching every so often will dramatically reduce back problems that may arise in the future. In addition, it will vibrate whenever the user has shown key signs of poor posture.

Life expectancy is dangerously overlooked when examining side effects of a sedentary lifestyle. Studies show if you limit time spent sitting every day to 3 hours you could increase your life expectancy by 2 years.[6] Not only can sitting down too long effect your life expectancy but it can also affect your overall health. Sitting down in front of a desk for an extended period of time can lead to organ damage, brain damage, posture problems, muscle degeneration, and leg disorders. Additionally, living a sedentary lifestyle or spending long hours seated can easily lead to depression.[6][7] This project seeks to improve a user's well being alongside improving their back posture.

The main motivation behind developing this smart chair, the Posture Perfect, is that it has never been done before by a senior design group and it also still hasn't been perfected in the market. Originality is something every engineer takes pride in, so we set out to accomplish something that no one has ever been able to do before. The market is full of "smart" gadgets such as smartphones, smart TVs, and smart cars. There is a demand for creating devices that are capable of doing more than one thing and we set out to fill that demand with our "smart" chair. On top of that, we firmly believe this project will have a long lasting effect in society. A majority of the population have poor seating posture so this device will help those who are worried on the effects of sitting down for long hours with poor posture.

II. OVERVIEW

The main objectives for our project are to adequately analyze the user's posture, notify the user after a prolonged period of inactivity, and to give helpful suggestions on how to improve their posture. The Posture Perfect will be different than any other gadget in the market intended to improve posture because it isn't attached to the chair or the person. We are creating a "smart" chair that will not only provide the support the user needs need but it will improve their posture as well. In order to do that, it must first understand what a correct posture is defined as for each user. This will be the most grueling task for us as the developers. The Posture Perfect will use all the sensors placed on the chair in order to decide what is deemed as a good posture for each user. There will be sensors on the back rest of the chair which no other device in the market has. These will be used to read the curvature of the spine. Distance sensors will be used alongside temperature sensors that will be placed on the lower part of the backrest. More specifically, the sensors will be located near the lumbar region of the user's spine. The neck placement will be one of the most important contributors. Distance sensors will be used in order to read the neck placement. This will help the chair determine if the user is slouching. If a user's head is overly inward then they must be slouching especially if all other sensors point to the user being close to the backrest of the chair.

In addition, there will be pressure sensors placed on top of the chair seat. The sensors will be individually placed across the entire seat. These sensors are extremely important because they will show if a user is favoring one side over another. In other words, it will check if the user is putting more weight on either side; this will help in determining the user's posture. If the user spends a prolonged period favoring a side we will notify them to straighten up with vibration motors. Similarly, if the user spends a prolonged period of inactivity we will notify them by vibrating the chair. We will develop a system in order to differentiate these different notifications. One way of doing this is by setting each notification to a different amount of vibrations. That way if the user feels multiple vibrations then they will know it means it might be time to get up and stretch or go for a brisk walk.

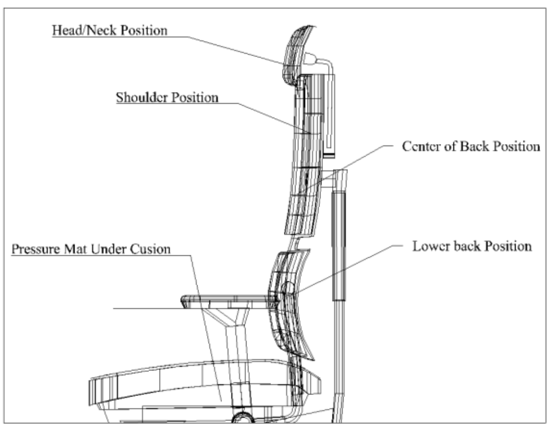

Figure 1

Subsequently, the sensors spread across the chair must come together to notify the user when their posture is incrementally becoming worse, these sensors are spread out in the chair as shown from in figure 1. Additionally, the algorithm must be well designed in order to accurately read and determine if the user's posture is out-of-place. There will be a variety of flags set into place so that if any are triggered then the chair will alert the user to straighten up. The chair will have to communicate with the "cloud" in order to do most of its calculations. The mobile application will connect to the data stored in the "cloud" and present the information gathered neatly to the user. They will be able to see the amount of time spent sitting down, and other sitting tendencies. Alongside, a "hotspot" map of where pressure is being applied the most while the user is seated.

III. POWER

To power our system, the power supply must output five volts or more in order to accommodate the various sensors and electronic components. We chose to go with a battery powered solution in order to minimize permanent wires that could lead to entanglement with the chair's wheels and to avoid the overall inconvenience it poses.

Many different battery technologies of various sizes were researched and the original plan was to go with a lithium-ion rechargeable battery.[5] However, a suitable alternative battery was donated by one of the group members. The donated battery is a sealed lead acid battery rated at 6 volts and 4 amp hour.[4] Since it is six volts, it has sufficient voltage to power our entire system, with enough amp hours to power the system for roughly a week. The reason we opted to use this battery was to avoid a costly purchase and stay within our designated budget.

Since the battery will be mounted onto the chair, there needs to be a way to charge it. A charging solution was designed on the printed circuit board to charge the battery using a 2.1mm power jack. The charging solution consists of a TI bq24450. This integrated charge controller for lead-acid batteries has three different charging modes which allows us to safely charge the battery for any given battery charge level and allow us to have some flexibility with the charging power supply. In input to the charging circuit can be between 9 to 13 volts.

In order to supply voltage to the rest of the system, buck converters (switching converters) were used to step down the voltages to the appropriate component voltages. The TI TPS62163 and the TPS62162 were chosen for the 5 volt and 3.3 volt voltage levels respectively. This voltage converter was chosen for its phenomenal efficiency and relative low cost.

IV. SENSING THE USER

In order for our chair to reserve as much power as possible without the user having to turn the chair on and off manually we decided to enable the chair with the capability to sense a potential user. At first we thought about allowing the pressure sensors to take care of it. By waking the microcontroller when pressure was applied, but we ran into the problem of the chair waking up from an inanimate object like a box being placed on it. So we decided to use a temperature sensor. This would allow the chair to sense a living human that is potentially going to sit in the chair. The placement of the sensors, as noted before, will be aimed at the lower back as to guarantee line of sight with a human no matter the height. The ideal temperature sensor that would be most beneficial would be one that has a small field of view and that could detect a signature reading of a living human as shown below in Figure 2.

Figure 2

The component that best fits our requirements is the Melexis MLX90615 IR Thermometer. The sensor is small enough so it can placed anywhere on the chair without disturbing the user. The field of view is 80 degrees for this sensor. This provides the chair with a reasonable field of view. The temperature range is more than enough, with a range of -70 degrees to 380 degrees Celsius to be considered medical grade accuracy.

V. PRESSURE SENSORS

The use of pressure sensors is one of the most important aspects of our project. These sensors will be used a great deal when designing an algorithm to determine proper posture. The concentration of the user's weight will be mapped by these sensors and give us an idea of the user's posture. Since, each pressure sensor outputs a digital reading, this can be compared to all the other pressure sensors. A sign of poor weight distribution is when neighboring sensor readings are extremely volatile. A healthy looking posture can be determined when a majority of pressure sensors have readings within close proximity. For example, figure 3 displays the weight distribution of a healthy looking posture. When you examine the figure you'll see how there is no jump from the pressure sensor readings. It has an even flow of pressure throughout entire seat.

The pressure sensors can also be used to determine if too much weight is being applied to a specific side of the seat by the user. This would cause the user to have their spine curved either to the right or left which would result in backache after a prolonged period of time. The pressure sensors are placed under the padding of the seat in a 4 by 4 matrix. If the 8 leftmost pressure sensors output similar readings and output larger digital readings the 8 rightmost pressure sensors then the user is favoring the left side. It would be determined that the user is favoring the right side of the seat if the situation described earlier was to be reversed.

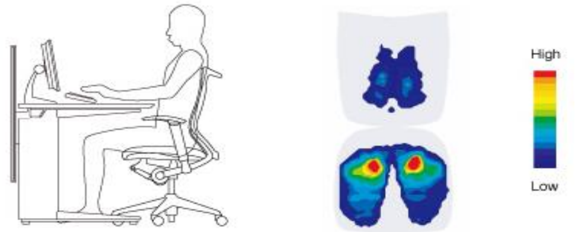

Figure 3

Piezoresistive force sensors were selected for our project due to the cost effectiveness and high accuracy that they provide. This pressure sensor requires a simple voltage divider circuit in order to get a desirable output. The measuring resistor, Rm, determines the force sensitivity for the system. A lower resistance will allow the pressure sensor to be more sensitive to weight change. The output voltage has a larger rate of change which will help when trying to identify and analyze weight change applied by the user.

Our design requires a sensor with the highest possible accuracy, and surface area. Due to this, the sensor chosen for our final design is FSR Model 406 by Interlink Electronics. This model has the largest width and surface area. It also has the best accuracy, response time, and is relatively cost effective.

Figure 4

VI. DISTANCE SENSOR

A great deal of posture information can be obtained from the weight distribution part of our project. For instance, seeing if the user is leaning forward or backward or slouching to one side. However, measuring the curvature of the user's spine is essential in determining the overall posture. The technologies explored by our team have shown that the two most promising types of sensors that can achieve the project's requirements are optical IR sensors and ultrasonic sensors.[1][2] They allow for a noncontact and reliable method of measuring the distance from the chair's backrest to the user's back.

In this project we found the ultrasonic depth sensors to be more accurate and less reliant on ambient light conditions to function properly. Unlike the optical sensors that use light as their mechanism of measuring distance, ultrasonic sensors use high frequency sound waves that are inaudible to humans to measure the distance between the target object and the sensor. Even when faced with a porous object like heavy clothing the sound based sensor could still retrieve a return signature. We confirmed the sensor could work with clothing by testing the accuracy in the lab using a tape measurer and articles of clothing as test pieces. These pieces of clothing varied in size, material, and thickness to make sure the sensors would work with all clothing.

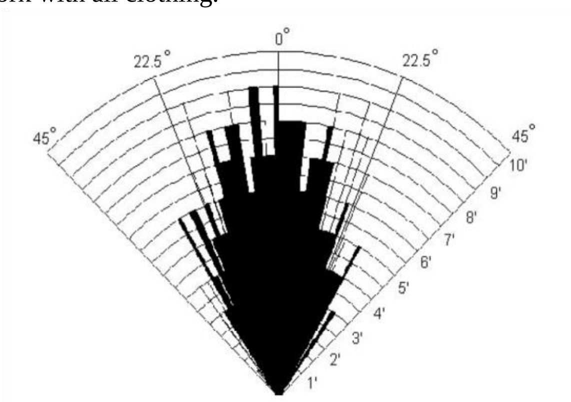

Figure 5

The spread pattern of the ultrasonic sensor's detector is somewhat cone shaped, as depicted by the figure above (Figure 5), which allows for a distance measurement even when the object, or person, is off center. Changes in the environment such as humidity, pressure, temperature, and airborne particles (like dust and smoke) may affect the ultrasonic sensor's response. Even background noise may interfere with the sensors accuracy if the noise is really loud and powerful such as the hissing sounds produced from air hoses or motor engines. Fortunately the environment factors experienced by a standard office chair are usually less extreme, as such these shortcomings are much less likely to affect our results.

The ultrasonic distance sensor we chose is Parallax's Ping))) due to its excellent range and accuracy. By having two of these sensors, we can compare their distance measurements to the user's back in order to approximate the user's back posture.

The sensors are mounted as far back as possible to allow the user sit back completely without the sensor's reading becoming compromised and the user remaining comfortable. The location of the bottom ultrasonic sensor is simply placed low enough on the back rest to aim at the lower back. This will not vary much from person to person since when seated, everyone's lower back is generally in the same spot, the tricky part is the top sensor location. The ultrasonic sensor should be aimed between the shoulder blades right below the neck. Since not everyone is the same height, there has to be a way to vary the sensor's vertical location. We came up with a simple rail system that is attached to the back of the chair that moves like a head rest but with the ultrasonic sensor attached. This way no matter the height of the user, the top ultrasonic sensor can be moved accordingly.

VII. VIBRATION MOTORS

A form of communication must exist between the system and the user in order to properly modify the user's activities. That makes alerting the user of poor posture a necessity in our project. As well as reminding them to stand up every so often. The use of vibration motors is a must in order to communicate to the user. The chair will be worthless if it cannot convey its readings and measurements to the user. This motor will alert the user whenever they favor a specific side on the seat, have a concentrated pressure on a large region of the seat, when the back posture is not ideal or after a long period of inactivity has been calculated. The vibrating motors are placed evenly near the pressure sensor so the user can feel they active when needed. Many flags will be built into the algorithm to determine any signs of poor posture and the user will receive notification whenever they need to modify their current posture. There will be a system in place so that the user knows what each vibration means.

The vibration motor selected is made by Precision Microdrives; its part number is Model:312-108. This model has a diameter of 12 mm which was the biggest diameter available by Precision Microdrives. The vibration motors will be used only when flags have been set off in our system. There will be different vibration patterns in order to notify the user of different situations.

VIII. MICROCONTROLLER

The microcontroller is the brain of the whole system. This will be where all the information that is gathered from the sensors is brought together in order to send to the Wi-Fi module. The MCU is going to have communicate with each of the sensors in a specific way. When the user is within field of view of the IR sensor the data would be sent to the microcontroller resulting in it waking up and starting its process of reading from the pressure sensors. Once the pressure sensors start to send a specific pattern of data, that indicates if the user is sitting in the middle of the chair, the microcontroller would then start taking readings from the ultrasonic sensor. The ultrasonic sensor would then send data back to the microcontroller. Once all of the conditions are met for the each sensor the MCU would then take the appropriate data that the cloud service requires and send it to the Wi-Fi module in order for it to be sent to the cloud service. The microcontroller would also activate the vibrating motors in two scenarios.

When a timer that is keeping track of how long the user has been sitting without getting up goes off and when the user is leaning to one side.

A) MCU Module

For the system to come together as efficiently as possible a microcontroller that is capable of obtaining all sensor's reading, maintain the data gathered, and sending it to the Wi-Fi module had to be selected. The microcontroller that was chosen was the ATMEGA32U4. This MCU is low powered and easy to develop on due to the fact it has many development libraries. This MCU allows simple integration of the different sensors, the vibrating motor and the Wi-Fi module.

B) Wi-Fi Module

In order to keep prototyping time and cost low we choose an existing Wi-Fi module to integrate into the system. The ESP8266 chip is a very common integrated Wi-Fi module that has significant library support and comes in a package that costs around five dollars, making it ideal for our prototype. Onboard it has a 32-bit RISC CPU for running the TCP/IP stack, but this processor is only utilized about 20% of the time when operating on the network stack. This extra processing power, and some additional GPIO pins adds to the functionality of the device to act as a standalone unit if necessary. However, in our system the primary MCU handles the heavy lifting and the Wi-Fi module is only used for its network access functionality.

IX. PRINTED CIRCUIT BOARD DESIGN

The printed circuit board that will house all of our components and power charging solution was designed in Cadsoft's Eagle. Since the board and the battery are mounted on the bottom of the chair, wires coming to and from the PCB carry power and data signals. The end result was a 2 layered board with surface mounts and through-hole components soldered on to the top side with wires leading out to the various sensors and the battery. To charge the battery, all one must do is plug the 2.1mm power jack in the socket that's mounted onto the PCB.

X. COMMUNICATION

Wi-Fi technology allows a device to connect to a wireless local area network (WLAN). Wi-Fi is based on the IEEE 802.11 standards which is a set of media access control (MAC) and physical layer (PHY) specifications for implementing computer communication.[3] Out of the three wireless communication that was talked about, Wi-Fi is the most widely used. Wi-Fi is integrated into vast amount of devices primarily as a method to access the World Wide Web.[3] This form of communication would be implemented in a different way than both Bluetooth and NFC are for our Posture Perfect project. It would allow the user application to access the data without even having to be near the chair's microcontroller. This would most likely involve the use of a cloud server. But by implementing Wi-Fi the microcontroller would connect to an online server to store the information. Then the user application would access this information by connecting to the same server. Using this form of communication would optimize the convenience of using the application. Also this most likely produce the best results for power consumption because the microcontroller would only use Wifi when the controller is active. After sending the information to the cloud service the controller would go into an idle mode.

Accessing this data in a cloud service is most approachable from the perspective of a mobile application or a web interface, due to our desire to learn more about mobile app development this option was chosen. The communication between a mobile app and a cloud based data store is a common practice and as such was achieved with simple JavaScript calls to the cloud based web service we choose. This allows the user to access their data via any network and any place they have an internet connection with their phone.

The final piece of communication that must be handled is the sensor data. As the Wifi transmission takes place in a self-contained module it becomes necessary to transmit the data from the primary microcontroller to the Wifi module for sending to the database. This connection is handled by a simple serial link between the two microprocessors defined by the Universal Asynchronous Receiver Transmitter (UART) interface. Within this UART interface specific bytes of data are transmitted in the form of commands, these commands are part of the microcontroller's firmware and tell the Wifi module what data to transmit and to where.

XI. THE CLOUD

The data collected from the user will be stored in the cloud using an SQL like managed database, that will be split into several categories of data for further organization and classification. First sub division will be time, as the cloud is not limitless in its storage capacity there will be compression of data as time goes on, creating generalized functions that represent historical data and storing them in tables that will store compressed versions of data that has resided in the database for lengthy amounts of time, similar to training a boosting algorithm to optimize the compression capacity of the database. More recent data is in a table that will be optimized for greater ease of access, as this data is most relevant to the user's needs, and the algorithm will place more weight on recent events and less on past events. Second division of data will be by difference in measurement results, like a change in posture while sitting, this will signify when and how your posture changed which is useful for mapping your activity and change in posture throughout the use of the chair. The third subset of data is an attempt at correlating the posture of the user based on how long they've been sitting in the chair. This can be used to find out if the user has some habit that tends to cause them to slouch after an hour of sitting, or if every day at around 2:00 PM they start hunching over. By splitting the data into these sections and using relational databases, the level of analysis required by the algorithm to process this data incurs much less overhead.

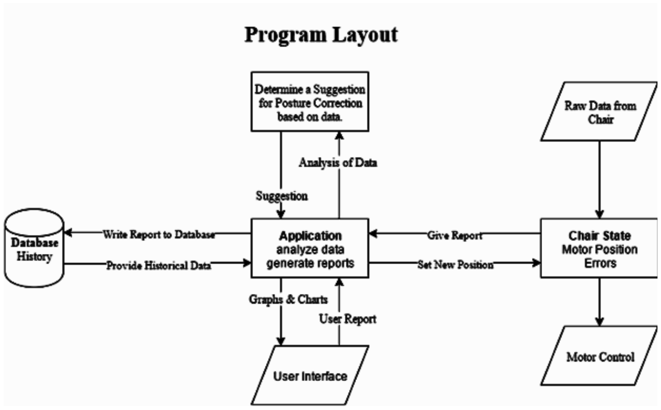

Figure 6

The cloud service will not only store the data sent from the chair, but will also perform these classifications as mentioned before ,as outlined in the figure above (Figure 6). A boosting style algorithm training allows us to make a system that accurately classifies posture, and will not require tedious programming of manual data ranges. In the cloud service we choose to use we can use a virtual server as a kind of classifying machine that will sort the data based on the training we give the system to start with. Several small "weak expert" classifiers will be combined to make a single "strong expert." While the accuracy of the system is dependent on how well the system of experts is trained, for this project only a small set of data is needed. With the data size and significance being constant, and the ease of data collection, it is possible to achieve an accurate system with as little as 200 sets of training data.

The final selection of a cloud service to use was brought down to which service we wanted to use. Almost all services advertising themselves as "cloud" providers could easily provide the services we needed, however there was a distinct winner in resume material, the Amazon Web Services (AWS) is not the most user friendly and the documentation is almost too detailed, but due to the popularity of the service with startup style companies and large web-traffic generators alike it was a sure bet it would be useful for future endeavors.

XII. USER FEEDBACK

We chose to develop a mobile application in order to relay all the data that was collected from the chair to the user. We considered an LED screen at first that would have been mounted on the chair, but this would have limited the user's ability to only view the acquired data while being seated. We decided to create a mobile application due to the fact that a majority of people use some type of smartphone in their day to day lives. Out of the two big mobile operating system iOS and Android we decided on Android. This decision was made due to the fact that there are wide range of open sources and libraries available that could be helpful when developing an application on android. On top of that, a majority of mobile users have Android so it would be beneficial to select the most prefered operating system.

The mobile application will allow the user to graphically observe their posture and compare it to what an ideal posture would look like. An example is shown below in Figure 7.

Figure 7

This graph would update within every two to five seconds the chair is active. The user would also be able to compare their previous results over time to see if their posture has drastically improved over the span of days or months. If the user feels like they are experiencing back pain when trying to improve their posture we also included a recommended exercise system that gives the user a simple exercise they would do. The recommended exercise would provide detailed instructions on how to perform the suggested exercise. It would also include a picture so that the user would have a visual of how to perform that exercise.

XIII. CONCLUSION

The dream of having perfect posture is difficult, but not impossible. The main motivation behind developing the Posture Perfect is to develop something that would have an everlasting effect in an important aspect of life. We as a group understand firsthand the turmoil that the average person faces when at a desk using their computer for hours on end without taking a break in between. As a group of engineers who commonly go through this hurdle, it made sense for us to come together develop a chair to fix this growing problem. In order to solve this ever growing issue we had to be ambitious. What better way to approach this project then to start researching everything we could. We had to understand everything about the human posture from how good posture could be determined to how a person could gradually develop bad posture. This extensive research gave us ideas as to how we would go about helping a person that is sitting in a chair improperly or seated for too long. After we came to an agreement, we started to brainstorm as to what components were required to create the chair. A crucial part of this project was selecting the variety of sensors that would provide us with the most accurate readings; in order to assess the state of the person's posture. We had to invest more time into this aspect of the project because if the sensors cannot do their job efficiently then the project would be deemed worthless. After we obtained a rough idea of what sensors we wanted to integrate into the chair, we went into researching the sensors more thoroughly. Afterwards, we moved on to the microprocessor. The microprocessor was another important component since it is the brains behind the project. A massive amount of time went into selecting this part. After we decided on what would be the most appropriate board, all we had left was to decide on how we would display the results to the user. The group came to the conclusion that a mobile application would be the best way to relay information back to the user. The data would be sent to a cloud service and then synced to the mobile application. The chair components was specifically chosen for optimization of convenience and power consumption. One of the agreements that we all had from the beginning was to ensure that the chair would be powered by a battery. This means all the components need to be low powered so that the user could avoid having to to recharge the battery constantly. This design was then prototyped and tests were designed to ensure the chair worked as planned.

Posture Perfect is going to change the way that people think about maintaining their back. The chair is going to bring us as humans into the future of a healthy lifestyle. With its constant reminder of limiting the time that one should sit in chair. Also it's available anytime, anywhere access to the user's data with online server. This not only helps the user remember to watch their posture when not using the chair, but also paves the way for the chair to join the growing number of objects that are in the internet of things which is the future. Posture Perfect is PERFECT!

BIOGRAPHY

Freddie Lopera is an Electrical Engineer Major at the University of Central Florida. As the pure electrical engineer in the group, he will be responsible for finding a power solution for the system. Another main role that Freddie has is PCB design and hardware interfacing. During the prototyping phase, he will make sure all the hardware is functioning properly.

Johnny Claros is an Electrical/Computer Engineer Major at the University of Central Florida. As the second electrical engineer in the group, his main job will be to assist with hardware interfacing; specifically with the pressure sensors and vibration motors selected. He will also have a hand in designing the algorithm, app development, and assuring the product is user friendly.

Floyd Petersen is a Computer Engineer Major at the University of Central Florida. One out of the three computer engineers in the group, he will be tasked with the development of the Posture Perfect user application. Developing, troubleshooting, and testing of the application is his primary task. Secondary task is co-development of the code for the microcontroller and/or server.

Jacob Barr, a computer engineering student at the University of Central Florida, is looking for ways to improve the everyday lives of people, and as such he was strongly supportive of creating a chair to help not fall into the habits of bad posture. As yet another computer engineer on the team the positions with hardware have been filled by the most qualified members, leaving the one topic no-one on this team is familiar with, the cloud. A combination of database management and active computation of received data the position is more akin to an IT position but ready to tackle any problems ahead he forges forward in his learning.

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