Healthy Chair

ECE 445 Project Proposal

Team 5

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1.Introduction

1.1 Problem

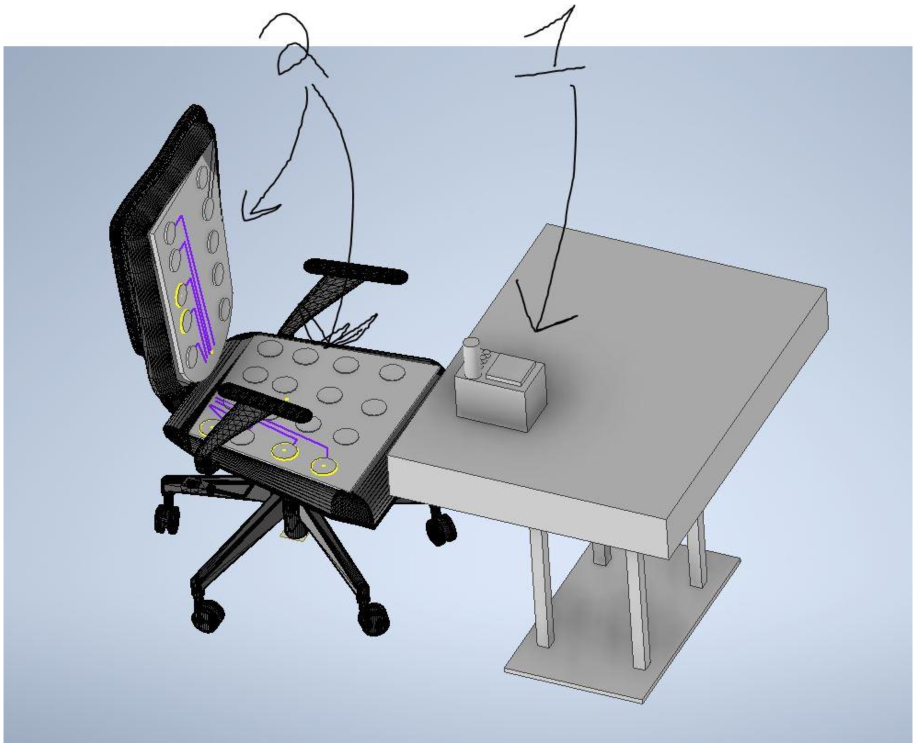
The majority of the population sits for most of the day, whether it’s students doing homework or employees working at a desk. In particular, during the covid era where many people are either working at home or quarantining for long periods of time, they tend to work out less and sit longer, making it more likely for people to result in obesity, hemorrhoids, and even heart diseases [1]. In addition, sitting too long is detrimental to one’s bottom and urinary tract, and can result in urinary urgency, and poor sitting posture can lead to reduced blood circulation, joint and muscle pain, and other health-related issues.

1.2 Solution

Our team’s project is to develop a healthy chair that aims at addressing the problems mentioned above by reminding people if they have been sitting for too long, using a fan to cool off the chair, and making people aware of their unhealthy leaning posture.

1. It uses thin film pressure sensors under the chair’s seat to detect the presence of a user, and pressure sensors on the chair’s back to detect the leaning posture of the user
2. It uses a temperature sensor under the chair’s seat, and if the seat’s temperature goes beyond a set temperature threshold, a fan below will be turned on by the microcontroller
3. It utilizes an LCD display with a programmable user interface. The user is able to input the duration of time the chair will alert the user
4. It uses a voice module to remind the user if he or she has been sitting for too long. The sitting time is inputted by the user and tracked by the microcontroller
5. Utilize only a voice chip instead of the existing speech module to construct our own voice module
6. The "smart" chair is able to analyze the situation that the chair surface temperature exceeds a certain temperature within 24 hours and warns the user about it

1.3 Visual Aid



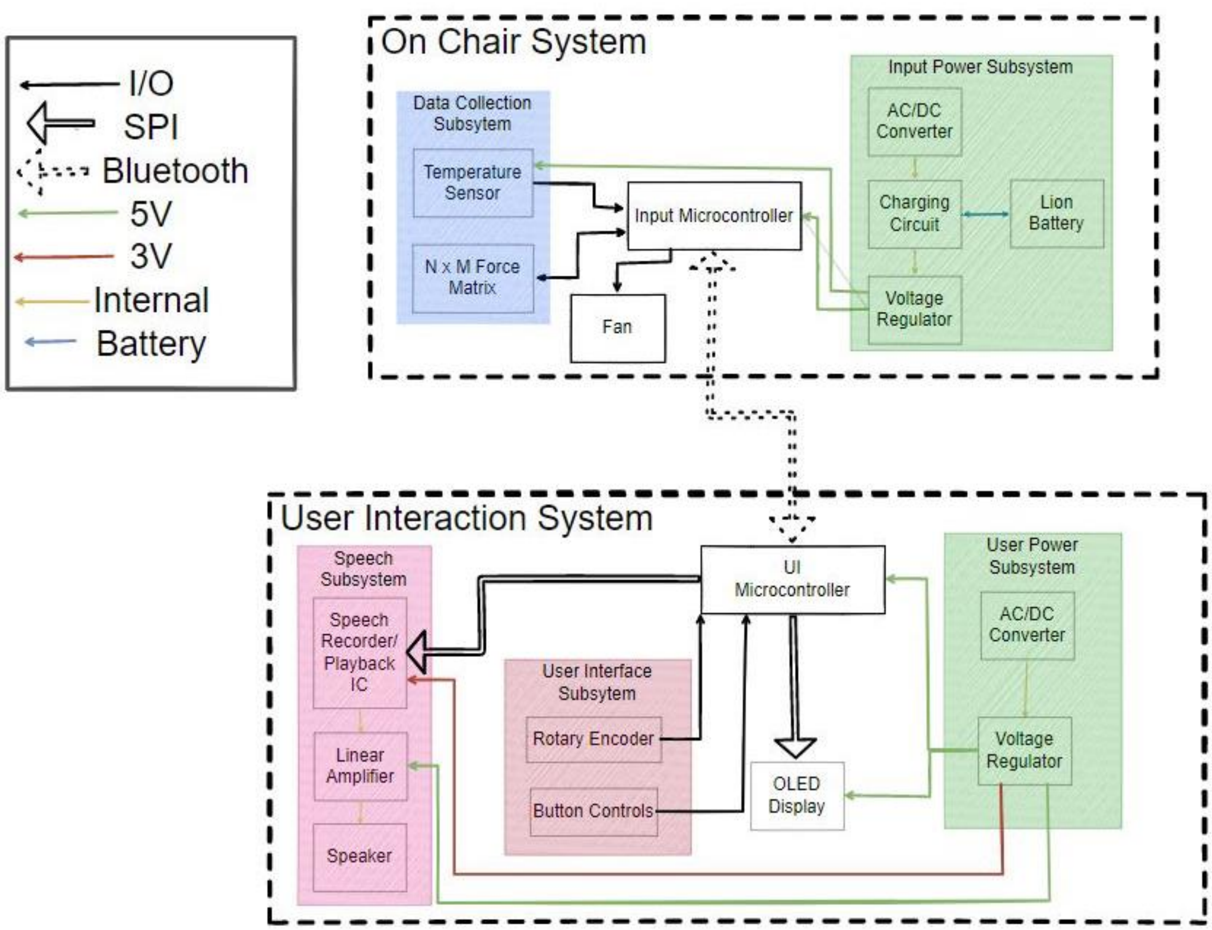
1: User Interface System, 2: Force Sensors 3: Housing for the On Chair System

1.4 High-Level Requirements List

- The healthy chair must be able to alert the user to leave the chair through the speech module after the exact time duration inputted by the user through the user interface system. In addition, the healthy chair must not warn the user if he or she leaves the chair for less than five minutes.
- The OLED display must display the real time temperature of the healthy chair's seat as well as which pressure sensor on the chair is activated.
- The healthy chair must be able to switch its power supply between a 5V Li-ion battery and the 120 AC, 60Hz wall supply voltage.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview and Requirements

On Chair System

Input Power Subsystem

The power system is in charge of charging and powering the entire chair system. The AC/DC converter will be used to power the charging circuit. The charging circuit also will be responsible for making sure the battery doesn't overcharge. The charging circuit will also determine if the battery or wall is powering the system. The voltage regulator will be used to make sure that the output voltage of the battery is constant when the chair is running on battery power. The power system will provide 5 volts (except the speech recorder and playback IC that requires 3 volts) to everything that needs it in the system including the microcontrollers and peripherals that need it.

Requirements:
The power system must be able to run on battery or switch to wall power when the battery voltage runs below the cutoff voltage of 3V. The system will have an indicator to show the user when the battery is running low or has reached full charge. The system must be able to provide enough power to each of the modules without overheating.

Data Collection Subsystem

The data collection subsystem is used to collect all relevant data needed to make decisions. The temperature sensor will scan the temperature of the chair on which you are sitting. The N x M force matrix will be composed of N x M amount of force sensors. This will extend all over the seat of the chair and into the spine support. It will be used to measure how the user is sitting and how long they have been sitting for. Both sensors will talk to the input microcontroller via IO.

Requirements:
The data collection is composed of the temperature sensor and the force matrix. The temperature sensor must relay readings every 30 ± 1 seconds. The temperature sensor must relay data accurate to ±0.5°C of the actual temperature. The force matrix must relay analog data from the chair. It must be able to differentiate between at least 5 different values of force. The force sensors can have a lot of errors so we only need a couple zones to tell how the user is sitting. Both sensors are connected to the microcontroller via IO and on the pins that are on the ADC of the microcontroller.

NOTE: Currently, we are not sure about the viability concerning measuring the precise pressure by the force sensor matrix, and we've purchased some samples to test. Nevertheless, the least the force sensors at the chair's seat will achieve is to detect the presence of a user and to measure his or her sitting posture.

Fan

The fan output consists of a fan placed under the chair to cool the user when the chair's seat overheats. It receives its power from the microcontroller via general IO.

Requirements:
The 470mW fan must turn on and off depending on the microcontroller IO. After it receives an active high signal from the microcontroller, the fan should turn on and cool the chair. It should also turn off if the temperature of the chair's seat goes below our set threshold temperature. The fan should operate with noises less than 25dB.

User Interaction System

User Interface Subsystem

The user interface subsystem is used for user interaction. The buttons and the potentiometer will be used to select settings and adjust temperature cutoffs/sitting time limits. They will be connected to the input microcontroller via IO and talk to only the input microcontroller.

Requirements:
The button controls are used for simple select controls. The potentiometer will be used for analog input. The buttons will perform select, back and other functions. The potentiometer will be used to set time limits, temperature cut offs, and other values that need a variable value.

Speech Subsystem

Controlled by the microcontroller and powered by the power system, the speech subsystem consists of a voice recording chip, a linear amplifier, and a speaker. After it receives an active high signal from the microcontroller, the speech subsystem is able to play our pre-recorded sound to alert the user.

Requirements:
The speech module must be able to receive information from the microcontroller over SPI. It must record our speech/alert for a duration of 20 to 30 seconds and accurately replay them with a delay response of less than 1 second. The voice recording and playback IC must be able to drive an 8-ohm, 1W speaker.

OLED Subsystem

The OLED subsystem consists of an OLED screen and any necessary circuitry needed to run the OLED. The OLED doesn't communicate with anything other than receiving data from the output microcontroller and power from the power subsystem.

Requirements:
The OLED must display to the user the temperature data as well as how the user is sitting on the chair. The force sensors will be updating every 5 seconds so the OLED must update within 2 seconds after the force sensors are updated. The OLED display uses SPI communication with the microcontroller and one thing we have to consider is the interaction with the speech system as that is also using SPI communication.

User Power Subsystem

The user power system is in charge of powering the user element that the user will interact with. The input will be a wall outlet or computer USB port. The AC/DC converter will make sure that we get a constant voltage into the voltage regulator. The voltage regulator will be in charge of providing 3V and 5V to the user system. The voice IC of the speaker module runs on 3V while everything else runs on 5V.

Requirements:
The user power system must provide a constant 3V and 5V simultaneously. If the user wants to power the entire UI block from a USB port, we have to ensure that the current draw is less than 900 mA. The user can also power it from a wall with a block converter and then current won't matter. We need to ensure it stays below 900 mA as that is the max for the USB.

Input and UI Microcontrollers

These two microcontrollers are connected together via Bluetooth. The input microcontroller will collect the data and calculate decisions based on the data. It will then tell the UI microcontroller what it needs to do. The UI microcontroller will then display the correct data on the OLED, start/stop the fan or start the speech module. The output microcontroller talks to the OLED and Speech module via SPI and talks to the fan via general IO. The UI microcontroller can also send data back to the input microcontrollers. When the user changes parameters the UI microcontroller passes them back to the input microcontroller so it can make the correct decisions.

Requirements:
The input microcontroller must be able to handle N x M force sensors, the UI, and the temperature sensor. It must have enough ADC channels to handle all the inputs. It must also send data to the output microcontroller. The output microcontroller has to be able to send data via SPI to two devices. The GPIO from the microcontroller will control the fan as well as the chip-selects on the SPI devices. Both microcontrollers will have to run in a low power mode so we can last on our Li-ion battery.

2.3 Tolerance Analysis

The greatest risk to the completion of our project is the pressure sensor matrix and placement. One possible source of error is that the pressure sensors will not be able to accurately measure the exact quantitative pressure exerted on the chair's seat, since we are planning on using thin film pressure sensors that only require 20 grams of force to trigger and will adjust the placement based on trial and error before placing on a majority of the chairs bottom and back support. We've already bought samples of the pressure sensors to test their functionalities.

3. Ethics and Safety

Throughout the entire course of our project, we will keep ethics as one of our top priorities. Section I.1 of IEEE code states, "to hold paramount the safety, health, and welfare to the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others". Our main goal of this project is to ensure the safety and health of people that use our chair. To that end, our chair aims at users who sit for long periods of time, especially with improper posture. We are working to make sure that our chair correctly notifies the user when it's time to take a break from sitting for too long and to let them know if they are sitting unevenly or without proper back support.

A safety concern in our project is the power management system. Our project will involve lithium-ion batteries and utilization of high voltage. Higher voltages are more likely to have greater currents, which proposes an increased risk of injury and death. [2] We will use the one hand method and also make sure to check if anything is connected to power before touching.

Lithium-ion batteries are normally safe when they are used in the right operating conditions, but there have been over 25,000 overheating or fire incidents reported from consumer products in a five-year period [3]. Overcharging occurs when charging still continues when the battery is at full charge. This causes the battery to prematurely age and for current to continue flowing into the battery which can cause overheating, explosion, and fire. We will implement the proper overcurrent protection to ensure that the battery stops charging when it's full and to make sure that there is no way for the user or anyone around to get shocked.

Since our product is a chair, we consider our product as something that people would want to sit on. Our design is to add pressure sensors in a way that accurately captures the sitting data of the user, but also doesn't interfere with the user's comfort. Ideally, we want our project's users to not feel the pressure sensors, but depending on trial and error, it may be necessary for them to feel them but they will not cause any discomfort.

Section I.5 of IEEE describes working with honest criticism of technical work, to fix any potential errors, make accurate claims, and to properly give credit for people's contributions. We are always looking for areas to improve and are eager to receive feedback, whether it's positive or negative.

4. References

[1] Harvard Health Publishing, "The dangers of sitting" [Online]. Available at: https://www.health.harvard.edu/pain/the-dangers-of-sitting

[2] Division of Research Safety, "Electrical Safety In The Research Laboratory" Division of Research Safety Library [Online]. Available at: https://drs.illinois.edu/Page/SafetyLibrary/ElectricalSafetyInTheResearchLaboratory

[3] Occupational Safety and Health Administration, "Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices" [Online]. Available at: https://www.osha.gov/sites/default/files/publications/shib011819.pdf