Temperature Sensor for Veterans
Final Report

<u>Developers/Roles</u>

Bridget Schmitt – Frontend Developer

Caleb Arnold – Hardware – Temperature Sensing and Physical Design

Jared Cox – Hardware – Bluetooth Communications

George Makhali –Software – Bluetooth Communications

Max Berthold – Hardware - Radio Frequency Communications

Michael McDonough – Hardware - Power Control and Optimization

Jamie Anderson – Backend Developer

1 Introduction

1.1 Problem statement

The goal of our project was to create a system that would allow any individual who deals with loss of sensation to body appendages, bad circulation, or amputations to monitor their body temperature while performing various activities in extreme weather conditions. Our team created a system in which a controller will collect data from a temperature sensing device and transmit the data to an application on the user's phone and/or supervising individual's phone. The user and supervising individual will be alerted as to when the user's temperature is approaching and/or has approached dangerous temperature levels.

1.2 Requirements and Constraints

Functional Requirements:

1. The temperature sensor can be applied to multiple areas of the body
2. The sensor can be used multiple times (not a one-use product)
3. The temperature sensor can withstand daily usage, including sweat and mild pressure
4. The temperature sensor communicates with an Android application running on both the client's phone and the instructor's phone
5. The application and the sensor have a line of communication (app-to-sensor: connection issues, sensor-to-app: body temp, battery, etc.)
6. The application and/or temperature sensor must be able to communicate to the user if there is loss of connection
7. The application must display body temperature measurements within +/- 2 degrees Fahrenheit
8. The phone application must be simple / easy to navigate for a new user
9. The device's battery must last for at least 8 hours

Resource Requirements:

1. The project has a maximum budget of $5,000
2. The sensor must be reusable

Physical Requirements:

1. Maximum size of device: 4" x 6"

2. The temperature sensor and accompanying hardware must be able to withstand temperatures between 10F to 100F
3. The temperature sensor and accompanying hardware must not produce any damaging pressure to any area of the user’s body
4. The temperature sensor and accompanying hardware must not produce any friction or skin irritation to the user’s body
5. The temperature sensor and accompanying hardware must be able to withstand temperature cycling
6. The temperature sensor and accompanying hardware must be water resistant

1.3 Engineering Standards

1. IEEE Standards
    a. Our group utilized IEEE standards for the use of designing consumer technology. These standards help to determine certain design constraints and considerations in relation to electrical hardware.
2. ANSI Standards
    a. Our group utilized ANSI standards in regard to the design, process, testing methods, and other aspects of our design process.
3. ISO Standards
    a. Our group utilized ISO standards in conjunction with ANSI standards in order to dictate the best course of action for our design constraints and procedures.

1.4 Intended Users and Uses

Intended Users: Any individual suffering from a disability or injury that prevents sensation or circulation of various body parts, as well as supervisors of these individuals.

Key Characteristics of People Suffering with Disabilities:

1. Active outside in cold/hot weather
2. Loss of sensation to areas of the body
3. Bad circulation to various appendages due to paralysis
4. Limited movement of appendages

Key Characteristics of Supervisors:

1. Monitor the safety of individuals with disabilities
2. Trained to respond to various harmful conditions

3. Maintain communication with individuals while performing activities
4. Familiar with technology related to providing safety to disabled individuals

2 Design

2.1 Design Context

2.1.1 Broader Context

Table 2: Broader context of our project

Area	Description	Examples
Public health, safety, and welfare	Protects users against various extreme temperature conditions.	Frostbite, hypothermia, heat exhaustion, etc.
Global, cultural, and social	Development or operation of the solution directly coincides with the values, practices, and aims of the cultural groups it affects.	Ability to spend more time with family, ability to be active outdoors, ability to have courage and freedom outdoors.
Environmental	Radiation to the environment, increase in carbon footprint.	Increase in radiation to the environment due to Bluetooth and RF frequency transmission. Increase in carbon footprint due to the addition in manufacturing of batteries.
Economic	Minimal development cost, affordable final product for users.	Our team's goal is to produce a final product that incorporates all desired functionality and usability constraints in the most cost-effective manner possible.

2.1.2 User Needs

Needs Related to Project for People Suffering with Disabilities:

1. Ability to monitor vitals while performing various activities in cold/hot temperatures
2. Ability to be alerted when vitals are at dangerous levels
3. Ability to maintain contact with local hub or supervisor
4. Ability to examine data related to previous experiences
5. Ability to utilize the product on various areas of the body without the purchase of additional products
6. Ability to put on the product without help
7. No irritation to areas of the body the product is used upon (friction caused by the product, etc.)
8. Water and Heat resistance
9. Easy to understand application paired with the product
10. Ability to customize alert settings for various temperatures (i.e., soft alert when within 10 degrees of threshold, medium alert at 3 degrees, hard alert when past threshold)
11. Ability to be alerted when loss of connection between the product and application occurs
12. Ability to be alerted when product is outside the range between them and supervisor
13. Ability to utilize product more than once (i.e., rechargeable)
14. Ability to remain comfortable when utilizing the product (i.e., wireless, frictionless)
15. Ability to receive alerts without auditory devices placed in ears
16. Ability to be alerted when the device is at a low level of battery
17. Ability to confirm the product is retrieving correct data from the user
18. Ability to place sensors within various forms of clothing (i.e., ski boots, rash guards, socks, sleeves, etc.)

Benefits for Individuals Suffering from Disability:

1. Ability to feel safe when performing various outside activities
2. Ability to enjoy more time with family members
3. Ability to examine data from previous experiences to make corrective adjustments for future
4. Ability to perform activities outside without the need for constant supervision

User Needs of Supervisors:

1. Ability to monitor vitals of individuals in real-time
2. Ability to historize data to examine past experiences
3. Ability to be alerted for loss of connection to individual
4. Ability to be alerted when vitals are approaching/approach dangerous levels

5. Ability to monitor vitals over long distances to allow for the performance of various activities
6. Ability to confirm the product is retrieving correct data from the user
7. Ability to contact/alert the user at any point

Benefits of Supervisors:

1. Ability to provide better care and supervision for users
2. Ability to allow users more freedom
3. Ability to examine past experiences to provide better future experiences

2.1.3 Technical Complexity

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles.
    a. Instrumentation
        i. The temperature sensors we used required knowledge of circuit design and how analog values can be used with I/O
    b. Microcontroller
        i. We embedded a microcontroller. We needed to understand I/O, registers, high-level programming, and analog to digital conversions to make this work
    c. Wireless Communications
        i. We used both RF and BLE for communication with our devices. An understanding of wave propagation, receivers and transmitters was necessary.
    d. App development
        i. We developed an android app for this product. Software knowledge, in both front and back-end development, is necessary. along with an understanding of receiving and transmitting wireless data.
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.
    a. Although the technology needed to complete this product is not revolutionary, the challenge lies in making a useful easy to use product that is:
        i. Easy to wear
        ii. Does not create abrasions for the user
        iii. Accurately measures key locations on the body
        iv. Cost efficient
        v. Easy to use phone application for user interface
        vi. Transfers data over long distances
        vii. Works in extreme conditions

2.1.4 Related Products

With cursory research, we were able to find some products such as the CORE Body Temperature Sensor (https://corebodytemp.com/) that are used to monitor core body temperature for athletics. This is similar to our product, but the key difference is that we are tracking temp at extremities rather than at the core. Temperature at extremities is often measured in a medical setting, but those settings rarely require battery power, radio communications, or a handheld application. Compared to the CORE Body Temperature Sensor, an advantage of our design is that it is more robust. The biggest disadvantage is that our product is somewhat bulkier.

2.2 Design Details

2.2.1 Design decisions

1. Decision to have an RF Gateway
   a. This was important to the project's success because without having an RF Gateway, there is no way to get the desired range.
2. Decision to use Arduino MCU
   a. This was an important design decision because the Arduino MCU is easy to understand, and members of the group have experience with Arduino Boards.
3. Decision to have an external case that houses the battery, MCU, and RF Modules
   a. This was important to the success of the project because we could not find a good option to have the battery, MCU, and RF Module inside of a ski boot. These components are too large and would cause discomfort/pressure inside of the boot.
4. Decision to create an Android based phone application
   a. This was important since members of the team had prior experience with Android application development.
   b. Android has a less rigorous process for making the application available on the store as well as greater ease in installing application files directly to the phone.

2.2.2 Design Evolution

Our design evolution since the end of CprE 491 has largely been in the form of streamlining planned features to better meet project specifications, though there have been some features added as well as removal/reworking features that didn't make a meaningful contribution to the users' needs. Notable changes are listed below.

- Addition: Device battery level monitoring
    - This feature was implemented as a quality-of-life change for the user. We added an additional high-resistance voltage divider to monitor the battery level, use the battery's charge-voltage characteristic curve to estimate capacity, and send that data to the user.
- Change: Non-removable batteries
    - This change was implemented to make the device both more convenient and safer to use. Our original plan in CprE 491 was to use lithium-ion cells that could be removed and charged independently from the device. After feedback and further consideration, we determined that the removal of lithium-ion batteries could prove hazardous to the users. Removing these batteries was also inconvenient. We re-evaluated and decided to change to a two-cell lithium-ion battery package with a charging cable. We then embedded the end of this cable in the side of our enclosure to create a functional charging port that can be adapted to USB.
- Change: Pre-existing enclosure
    - Our original plan presented in CprE 491 was to design and 3D print an enclosure to match our internal hardware design. Feedback from our presentation included concerns that a 3d-printed enclosure may sacrifice some of the durability and resistance to water ingress that our project required. We then shifted our design philosophy to prioritize finding a suitable enclosure, then designing our internal systems to fit that enclosure. We found a polycarbonate enclosure that meets NEMA-4X specifications (watertight and corrosion resistant). The polycarbonate design also allows for functionality in a wide range of temperatures and moderate impact resistance, meeting all physical requirements for the enclosure. We then designed our PCB and component organization to fit within this enclosure.
- Removal: Auditory alert system
    - During meetings with the user, we determined that the device would potentially be worn under a blanket, or that the ambient noise in the environments that the device could be used in would drown out most noise. Users also indicated that they were comfortable with receiving alerts through phone vibration or audio alerts through the app (which could optionally be connected to earbuds or headphones). We determined that implementing this alert to the device itself would therefore be redundant and axed the feature in favor of customizable alerts through software.

2.2.3 Functionality

This device is designed to obtain real-time temperature measurements of any area of an individual's body. The user will strap the housing enclosure in near proximity to the desired area, place the temperature sensor on the desired area, push the power button to initialize the hardware, connect to the device using the application, and begin obtaining real-time temperature measurements with ease. The device will handle obtaining the temperature measurement and communicating the results to the local application and global hub.

2.2.4 Design Visuals and Descriptions

Software

The most important aspect to think about when it comes to user interface design is the user of the application. From discussions with the client, the team determined that the primary audience of the application is people over the age of 60. To accommodate the primary audience in the user interface design, the team decided that the application should be easy to navigate with large text and very few options that could confuse the user.

The application initially opens to a basic login screen with only two options, fill in account credentials and press login, or press button to proceed to a create account screen. If a user navigates to the create account page, the user is asked for basic profile information and creates a password. The create account and login pages are visually the same, with an image of an individual skiing containing a text overlay of “Adaptive Adventures”. The image and text on the login and create account pages are not only visually appealing but also give information to ensure that the user understands what they are logging into.

When the user gets logged into the app, the application navigates to a page with images of snow sport with the text “Welcome to Adaptive Adventures”. This initial page is designed to be very basic to guide the user to click the triple bar icon on the top left corner of the screen to access a popout menu. All the pages in the application are listed in a single menu to make the application easy to navigate with everything in one place.

The first link listed in the menu takes the user to the temperature sensor page. The temperature sensor page represents the data sent by the temperature sensing device. To make the page easy to read, the temperature sensor page shows a half circle progress bar that is bound by two editable values, a maximum and a minimum temperature. The skin temperature value found by the device is shown in the middle of the half circle progress bar, and the half circle is cut to represent how close the value is to the maximum or minimum values. If the user’s skin temperature is higher than the maximum value or lower than the minimum value, the application shows a popup and a notification to warn the user of an unsafe skin temperature. In addition to the temperature sensor bar, the page includes a battery visual to show the amount of battery left on the hardware device. The battery indicator produces a popup and notification when the battery level drops below 20%.

The additional pages on the menu are profile, settings, instructor view, Bluetooth, and log out. The profile and settings pages are very basic pages with a large title and a few lines of text. These pages were created to be very functional and easy to read. The instructor view page shows a list of devices that an instructor can look at to monitor different users' skin temperature. Visually, this page is very basic with only text. The Bluetooth page is purely functional so may require a greater knowledge of the application's functionality. Finally, the log out button logs the user out upon being pressed.

The visuals on the application were planned out to make the application easy to read and navigate. The software visuals are shown in Figure 1.

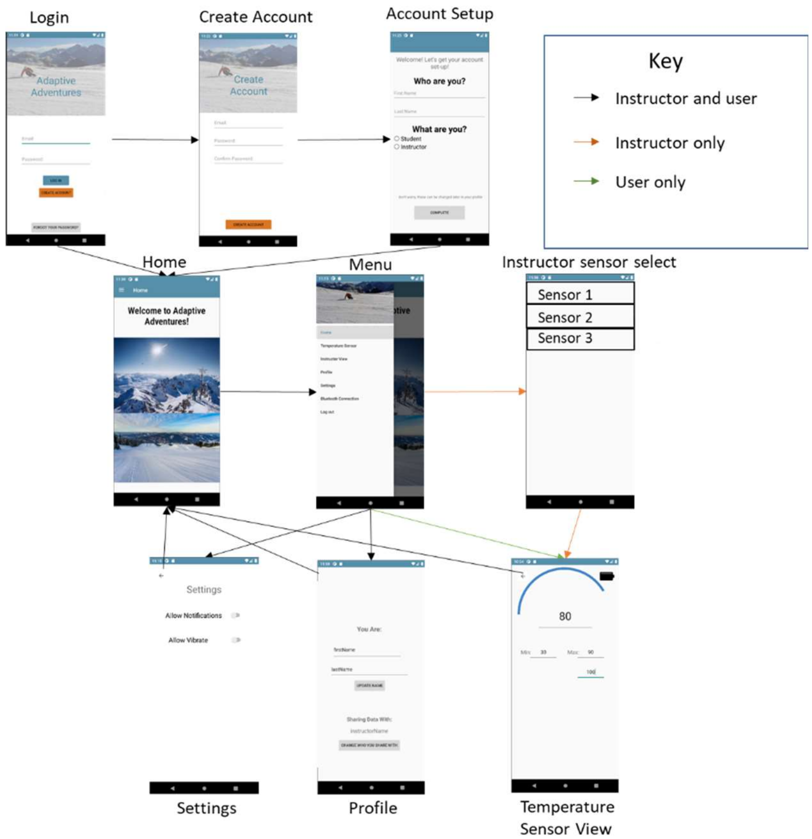

Fig. 1: Software Visual Flow Chart

Hardware

Fig 2: Completed hardware design

Our device consists of the following components:

- Temperature Sensor
- Arduino Nano 33 BLE
- PCB with integrated resistors
- 7.4V Battery Supply with integrated charger
- Radio frequency module
- Velcro straps
- NEMA 4X enclosure with gasketing and clear top plate
- (3) Onboard LEDs
- Jumper Wires
- Latching Push Button

2.3 Technology Considerations

Hardware

For the hardware responsible for temperature measurement and data communication, one of the big technological aspects of the design is the microcontroller. The Arduino Nano 33 BLE provides a compact design to provide comfortable use of the device and Bluetooth capabilities in order to locally communicate data to the user's phone application. In addition, the Arduino ecosystem is extremely user friendly.

Another important consideration was what radio frequency module to use to reach the desired communication range for the gateway or local hub. We chose to use a LoRa radio frequency module because of the low power consumption and long range of the module in comparison to basic 433 MHz modules or HC12 modules.

The alert system on the device itself was a major point of consideration. Initially, the team wanted to have both visual and auditory indications of when the temperature readings reach or approach dangerous levels. After testing auditory alerts, we discovered that we would not be able to make a loud enough auditory alarm for the environmental conditions that the users will be in. In the end, the final decision was to use LED indicators on the device and vibratory alerts from the phone application.

The way in which the user applies the device was one of the most important technological considerations for our device. Simplicity does not always mean inadequacy. Our team elected to integrate Velcro straps with the device in order to meet a variety of vital constraints. Velcro straps allow our device to be utilized by individuals of nearly any body type through the ability to modify loop length of the straps. It also allows the highest level of comfortability with users being able to modify the strength of the loop at their will. Lastly, and most importantly, it provides users with the easiest form of application. Users do not want to rely on others to utilize our device, and using Velcro straps allows the highest level of self-sufficiency.

The longevity of the device required an immense amount of technological consideration as numerous factors played a role. The types of activities desired to be performed when utilizing the device developed the requirement that the device must be waterproof, dustproof, and impact proof to the highest degree possible. Therefore, our team utilized an enclosure that provides extreme robustness, rubber seal gasketing between the top plate and device housing, and sufficient size for all device hardware. Amongst these requirements, other requirements included battery life, which our team accounted for by calculating overall power consumption of device components and adequately sizing the device power supply, as well as, providing users the ability to recharge the battery at their convenience.

Phone Application

For the phone application, the software development team focused on the Android system, using Java in Android Studio to develop the app. A focus on the Android system was decided as opposed to splitting development into two platforms. Accounting for iPhone and Android systems would increase workload without major payoff. Furthermore, the team has a considerable background with Java and Android development, allowing focus on implementation of key features rather than learning new software and systems.

A key feature within the application is the use of a cloud database, which holds login details, user information, and other features necessary for the functionality of the project. Amazon Web Services (AWS) has been selected as the cloud database provider, as it is compatible with Android Studio and has become an industry standard as of late.

2.4 Design Analysis

Our device was able to meet the key requirements of temperature sensing and handling that data within the application. While there is future work to be done in optimization of the device and strengthening connectivity, we have successfully created a prototype that can be polished to meet and even exceed our user's needs.

2.5 Design Overview

Hardware

Our device consists of the following components:

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- NEMA 4X enclosure with gasketing and clear top plate
- (3) Onboard LEDs
- Jumper Wires
- Latching Push Button

Phone Application(android):

As previously stated, the main audience for this device is people 60+ with disabilities, so it is imperative that the phone application be easy to navigate and use. To achieve this, lettering is large and to the point, clearly indicating how and where certain things are. Buttons are also large, with bright coloring and text to indicate what they do.

Account registration has been narrowed down to the most important pieces, to make the process easier to understand and set up. Only information that is required to get the system working is necessary to provide and is clearly labeled during the process.

The main body of the application, the temperature sensing home page, is easy to understand. There are few interactions on the page (those for leaving the page or changing the desired temperature range), and there is a clear indicator of where the current temperature sits, both visually in the form of the progress bar and readable in the form of a current temperature in numbers between the minimum and maximum.

3 Testing

See attached Testing Document - "Test Document Report"

4 Implementation

Hardware:

The hardware of the device was implemented using the following components:

- Microcontroller: Arduino Nano 33 BLE
- On-board Alerting: (3) LEDS providing alerts for low battery life, temperature range exceedance, and loss of connection between the phone application and the device
- Power Control: Latching push-button switch with built-in LED for confirmation of power
- Power Supply: 7.4V battery pack with integrated charging through JST connector port
- PCB with integrated resistors for voltage dividers and LEDs
- Temperature Sensing Element: NPT Thermistor Probe
- Radio Frequency Module: LoRa 915MHz Radio Frequency transceiver
- Hardware Enclosure: 4"x2.5"x1.5" enclosure with clear top plate and rubber seal gasketing

Software:

- The android app used many integrated parts under the constructing platform of android studio which is compiling all these parts to come out with the final app.
- For data base profile and data storage, we used amazon (AWS) to be our backend stage since it is easier and more flexible to use.
- For the front end, we created a login page where the user specifies if he is an instructor or not and login with his existing account or to sign up for one.
- There should be a temperature page where the temp is sent from the Arduino board to the Android app and display it.
- The Bluetooth connection is set up on the Arduino side using BLE since we are using nano 33 which is using bluetoothGattCharachteristics on the android side.
- The Bluetooth is connecting to the board and can send characteristics to it but we couldn't format it to display the actual temp.
- The Bluetooth and the app when integrated together were crashing at launch at first or showing blank activities. After lots of Debugging, it had some technical bugs that slightly improved the overall performance but still the crashing happens at random times.

5 Closing

5.1 Conclusion

Overall, this project was an immensely valuable opportunity to practice the knowledge we have learned at Iowa State to develop a device and phone application that truly better the lives of individuals struggling with physical disabilities. While our team had areas in our development that can be improved upon and have documented future work for this application, we were able to achieve substantial progress and provide a device that can obtain temperature data measurements, alert users of low battery life, temperature range exceedance, and loss of connection between receiver and transmitter, and communicate temperature data of the user to the supervising individual. All in all, we believe we were able to truly improve the lives of our users, and for that, we are grateful.

5.2 References

Development References:

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2M NTC 10K 3950 Temperature Waterproof Probe, diymore 3PCS 1% 3950 NTC Thermistor Temperature Sensor: Amazon.com: Industrial & Scientific

6 Appendices

6.1 Appendix 1: Operation Manual

Overview: This manual is intended to provide a step-by-step guide on how-to utilize the temperature measurement device. This manual will describe the step-by-step process for both users and supervising individuals.

<u>User</u>

Step 1: Using the velcro straps on the device, strap the device to the desired location of the body. For foot measurement, the recommendation is to strap the device to the mid-thigh. For hand measurements, the recommendation is to strap the device to the top or side of the bicep, whichever provides the highest level of comfort. To strap the device to the body, simply open the velcro straps, place the back of the device on the desired body location, wrap the strap around the arm/thigh through the loop, tighten as desired, and close.

Step 2: Now that the device is on the desired part of the body, grab the temperature probe (the metal cylinder on the end of the wire coming out of the device) and place it on the sticky side of an adhesive patch.

Step 3: Now that the temperature probe is ready to be applied to the body, remove any clothing or interference with the skin on either your foot or hand, whichever area is desired.

Step 4: Now simply, apply the patch to either the top of the foot or hand. Ensure the application is sufficient and will not slide around during activity. Allowing the adhesive patch to slide around during activity can cause unwanted friction to the skin, possibly leading to damage.

Step 5: Now that everything is ready, simply turn on the device using the push button on the side of the device. The ring around the push button will turn blue when the device is powered on and will be off when the device is off.

<u>To charge the battery of the device:</u>

We recommend charging the device at or below 30% remaining to ensure that the device does not die when being used, jeopardizing safety of the user. The device will indicate when it has reached 30% or below remaining battery life by lighting up the red LED on the device. In order to charge your device, follow the steps below.

Step 1: Turn off the device. This can be achieved by pressing the push button. The ring around the push button will no longer be lit up blue when the device is turned off.

Step 2: Remove the temperature probe from the body. This can be achieved by carefully removing the adhesive patch.

Step 3: Remove the device from the body. This can be achieved by unstrapping the velcro straps of the device.

Step 4: Use either a USB plug-in on a computer or use a USB wall-socket adapter (commonly referred to as a cube, brick, or charging block) and plug in the charger. The charger is properly connected when a blinking red light can be observed on the flat pad of the charger.

Step 5: Plug the device into the charger. This can be achieved by connecting the end of the charger to the charging port on the device. The charging port is on the side of the device and looks like a white rectangle. You can be sure that the device is properly connected when the red light on the flat pad of the charger is solid red and no longer blinking.

You can now let the device charge. When reapplying the device and powering it on, the red LED on the device should no longer be lit up. This represents that the device is above 30% charge.

Supervisor

The user will use what is referred to as the “transmitter” and the supervising individual will use the “receiver”. The transmitter will communicate the temperature of the user to the receiver for the supervising individual to observe using a laptop. To set up the receiver, please follow the steps listed below.

Step 1: Download Arduino IDE. This can be achieved by searching “Arduino IDE download” on a web browser. Select the link labeled “Download and install Arduino IDE”.

Step 2: Connect the receiver to the Arduino IDE using the proper port and board selection. This can be achieved by open Device Manager on your operating system, selecting ports, and observing which port lists USB Device. Once the port is known, go back to the Arduino IDE and open the tools tab, and select port and the port observed from the Device Manager. Then, select the Board option and select the Arduino Nano 33 BLE.

Step 3: Open the Serial Monitor. This can be achieved by open the tools tab on the Arduino IDE and selecting Serial Monitor. If an error pops up on the command console at the bottom of the screen saying the port is unavailable, repeat step 2 and try again. The Serial Monitor should then pop up on the screen and be available for data communication from the transmitter.

Application

Step 1: Open Temperature Sensor Application. The user should see a login page with a welcome message.

Step 2: User with account: Enter username and password onto respective lines and press the Login button. The user should then see a main welcome page with the text “Welcome to Adaptive Adventures” and Images.

User without account: Press the “Create Account” button on the login screen page. When the Create account screen appears, input an email and a password. Press the “Create Account” button. This will take the user to an additional information page. Input the information asked for and the find “verify account” email. After all of the information is included, the user will be on the main welcome page with text reading “Welcome to Adaptive Adventures” and images showing outdoor sports.

Step 3: Press the triple line icon on the top left corner of the screen to reach a menu screen with different page options. Select the page desired based on the descriptions below.

Temperature Sensor: The temperature sensor button takes the user to a page that shows the skin temperature of a user. The page uses a half circle progress bar to show how close the user’s skin temperature is to the minimum and maximum temperatures set by the user. This page also shows the total battery remaining on the temperature sensing device.

Instructor View: If the user is logged into an instructor account, the instructor view page shows a list of different users’ devices that the instructor can monitor.

Profile: The profile page shows the name, and email of the user currently logged on to the application. The user can go onto this page and change their name.

Settings: The settings page allows the user to set permissions for notifications and vibration.

Bluetooth Connection: Bluetooth connection page connects the application to Bluetooth.

Log out: Logs the user out. Opens login page.

6.2 Appendix 2

Initial design versions that were deemed not possible for this project after further consideration and communication with the client and users include the following:

- No external wires
    - This was deemed not possible because a wireless temperature sensor would not be able to fit inside of a ski boot without causing irritation excessive pressure
- Replaceable Batteries

  - This was deemed a vulnerability to waterproofness, dustproofness, impact resistance, and enclosure robustness if users were to be opening the enclosure in any fashion. Therefore, we implemented the ability for users to recharge the batteries using the charging port on the side of the enclosure.
- NEMA 4X Enclosure
  - Our initial design was to use an enclosure that is IP67 rated. This was a bit extreme as submersion of the device and high volume of dust or other contaminants is not to be expected when utilizing the device. The implementation of a NEMA 4X design allows for high level of impact resistance, robustness, waterproofness, and dustproofness, while also being rated for electrical hardware housing.
- Auditory alarms
  - We initially wanted to include auditory alarms in addition to the visual and vibratory alarms. This idea was scrapped because our users will be in an environment that would not allow them to easily and reliably hear the alarm. At first, we thought we could have the users wear headphones, but that was not possible because they need to be aware of their surroundings and they wear helmets.

6.3 Appendix 3

Lessons Learned

Some lessons that we learned throughout this project are as follows:

- "If I had an hour to solve a problem, I would spend 55 minutes thinking about the problem and 5 minutes thinking about solutions" - Albert Einstein
- Simplicity does not mean inadequacy
- Plan for problems
- Recognize accomplishments
- Communication is vital

These lessons show us that we need to spend time truly understanding the problem before rushing to solutions, finding solutions to the required problem without overcomplication, provide ample contingency to the schedule to account for issues that are to be observed during development, appreciate the progress completed, and most importantly, uphold a high level of communication at all times to ensure everyone is on the same page and all issues are being addressed.