Temperature Sensors For Veterans With Paralysis

DESIGN DOCUMENT

Senior Design Team 16
BAE Systems
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Team Member: Role
Evan Rosonke: Project Lead
CJ Reitz: Test Lead
Ethan Houts: Software Lead
Thomas Kivlahan: Hardware Lead
Mensanh Namessi: Hardware Lead

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Executive Summary

Development Standards & Practices Used

List all standard circuit, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

- We will need to use a communication standard, most likely Bluetooth
- Commenting code for the application for others to read easily
- Document hardware as it is implemented, as well as document hardware changes
- Standardize among hardware for an easier pairing of devices and one location for purchasing

Summary of Requirements

List all requirements as bullet points in brief.

- Temperature sensors that read body and air temperature
- Means of attaching the sensor to the body
- Phone application that uses data from the sensor to alert the user if the temperature is too extreme
- Data control center to store historical data

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

- EE285
- CPRE288
- EE330

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired that was not part of your Iowa State curriculum in order to complete this project.

- Project Management
- Communication among a large team
- IOS Development

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1 Team

1.1 Team Members

Evan Rosonke, Thomas Kivlahan, Ethan houts, CJ Reitz, Mensanh Namessi

1.2 Required Skill Sets for Your Project

Electronic system integration and software development. Understanding of microelectronics and their uses within temperature sensors with Bluetooth compatibility.

1.3 Skill Sets Covered by the Team

(for each skill, state which team member(s) cover it)

Project Management- Evan Rosonke

Testing- CJ Reitz, Ethan Houts

Hardware Design- Evan Rosonke, CJ Reitz, Thomas Kivlahan, Mensanh Namessi

Software Development- Ethan Houts

1.4 Project Management Style Adopted by the team

Our team is adopting a single project manager role with leaders for each division of the project, including but not limited to a software lead, a hardware lead, a test lead, and an overall project management lead.

1.5 Initial Project Management Roles

Overall Project Management - Evan Rosonke

Software Lead - Ethan Houts

Test Lead - CJ Reitz

Hardware Leads - Mensanh Namessi and Thomas Kivlahan

2 Introduction

2.1 Problem Statement

The goal of this project is to implement a series of temperature sensors to allow individuals with paralysis in the limbs to know if their body temperature is too cold or too hot in the areas without feeling. We will then use the sensors to alert the user of any abnormality in their body temperature through a phone application.

2.2 Requirements & Constraints

Hardware Requirements

- The sensor **shall**[1] fit comfortably inside a boot
- The sensor **shall**[2] communicate via Bluetooth to a phone
- The power supply **shall**[3] last 12 hours on a charge
- The moisture sensor **shall**[4] alert the user when water is present on skin

Software and UI Requirements

- The user interface shall be simple
- the phone application shall have a notification sensor
- the application shall be able to voice-activated
- The application shall have multiple warning levels (LOLO, LO, HI, HIHI)
- The LO and HI warning levels shall be user-defined within a range
- The application shall alert users when outside acceptable temperature range
- The application shall alert instructor when users temperature is outside acceptable range
- The application shall notify a user when low battery level

Aesthetic Requirements

- The sensors shall be embedded in an insole
- The insole shall be comfortable to walk on
- The insole shall not irritate the skin
- the insole shall not interfere with sweat productions
- the power supply shall attach to the leg above the boot
-

Performance Requirements (Data rate and frequency of data collection and upload)

- Data shall be collected from the sensors once every minute
- Data shall be sent to the phone application as it is collected

Quantifiable Metric	Number needed
Sensors	6/leg
Data collection Rate	1/min
Battery Life	8 Hours

2.3 Engineering Standards

Skin Interfaced Electronics

FDA has a list of allowable chemicals that can be used in contact with the body for microelectronics

Wearable electronics (IEEE 360-2022)

Personal health devices (IEEE 11073)

2.4 Intended Users and Uses

Our project will mainly impact those with limb paralysis or loss of feeling within limps. The idea behind this is to allow these people to do the things they love without having to worry about running the risk of the body becoming too hot or too cold. One example of people would be people who go adaptive skiing and run the risk of frostbite in their toes and would not be able to feel it. This will allow them not to worry because if this were to come close to happening, they would receive an alert beforehand to know something needs to change.

3 Project Plan

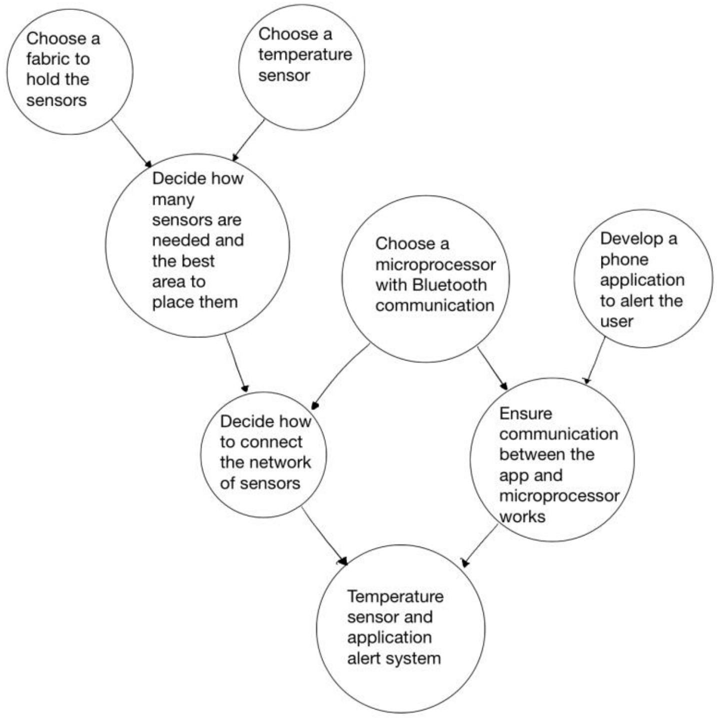
3.1 Task Decomposition

Hardware

- Temperature Sensor
  - Researching functionality
  - making sure it falls within the constraints of the project
  - has Bluetooth functionality
  - connecting sensors together
  - Power sensors
  - Test that sensors work and can last long enough
- Bluetooth device
- Attachment
  - Get design specs and see if there is a preferred method of attachment
  - Figure out the best fabrics for this method of attachment
  - research how it will interfere with the body

Software

- IPhone application
  - Bluetooth communication
  - UI design
  - Back-end
  - Optional Communication to instructor's device
  - Apple watch compatibility - tbd with pending research
- Android application
  - To be done after iOS is complete.
  - Bluetooth communication
  - UI design
  - Back-end
  - Optional Communication to instructor's device
  - Wear-OS compatibility - tbd with pending research
- Microcontroller program
  - Bluetooth communication
  - Collect sensor signals
  - Battery percentage indicators
  - Convert signals into usable forms for transfer



3.2 Project Management/Tracking Procedures

Waterfall+agile is the best option for our team as our project consists of a software application and hardware implementation. because both of these teams will need to be working forward simultaneously, we will work as an agile project management style between them but also try to follow a waterfall approach within each team to continue completing tasks in a forward manner.

Our team will be utilizing a combination of GitLab and Discord for project management. We will be using Discord for quick communication, meeting reminders, quick discussions, etc. We will be using GitLab to delegate tasks to individual team members as well as track progress.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Hardware

1. Get a list of design specs.
    a. What are the functionalities they want?
    b. What are our constraints?
2. Start researching hardware components that fall within these constraints
    a. Temp Sensor with Bluetooth transmitter
    b. Data collection and control board.
    c. Wire to string together sensors

d. Power supply/battery pack with recharging capability
e. enclosures for hardware that needs it and ways to attach to body the parts that need it

3. Start designing layout
    a. integrate sensors together
    b. connect sensors to the power supply
    c. connect to the data control board or application
    d. make sure everything will work together
        i. power consumption
        ii. aesthetics (not too large and easily maneuverable).
        iii. The components are all within standard of skin interfaced electronics
4. Order hardware components, enclosures, and fabric once research and design are complete.
5. Start integrating sensors together and creating the circuit for all sensors and power supply.
6. Test the functionality and power of the system.

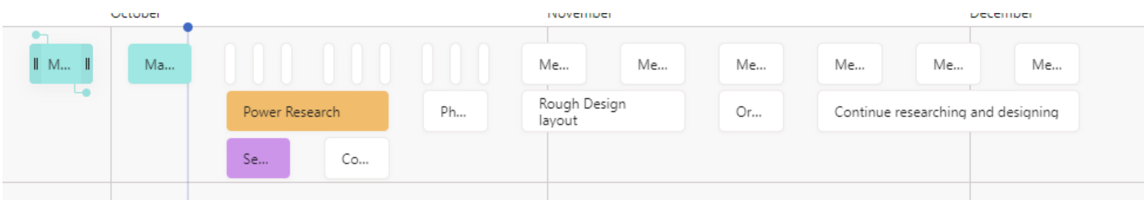
Software

1. Start development for iOS
    a. UI development
    b. backend development
2. Create a round trip to connect microcontroller to phone
    a. create basic program on chosen microcontroller to create a data transfer
    b. implement integration for bluetooth on app
3. Capture sensor data
    a. implement sensor data collection on microcontroller
    b. implement ui functionality to display recorded sensor data
4. Communication functionality
    a. some form of messaging to another nearby device
5. Create Android version
    a. Do 1-4 with the relevant portions for android development
6. Watch OS companion app
    a. A version of the app that has another way to alert the user
7. Wear OS companion app
    a. same as Watch OS but for android

Combined - After completing hardware and software pieces individually

1. test that the sensors are reading data over Bluetooth
2. calibrate the sensors
3. check for errors in hardware or software
4. fix the issues
5. repeat until correctly functioning project

3.4 Project Timeline/Schedule



First Semester

Second Semester

3.5 Risks And Risk Management/Mitigation

Hardware

- Temperature Sensor
    - Researching functionality .2
    - making sure it falls within the constraints of the project .4
    - has Bluetooth functionality .3
    - connecting sensors together .3
    - Power sensors .3
    - Test that sensors work and can last long enough .3
- Attachment
    - Figure out the best fabrics for this method of attachment .3
    - research how it will interfere with the body .2

Software

- IPhone application
    - Bluetooth communication
    - UI design
    - Back-end
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- Microcontroller program
    - Bluetooth communication
    - Collect sensor signals
    - Battery percentage indicators
    - Convert signals into usable forms for transfer

3.6 Personnel Effort Requirements

Overall, this project should count for roughly 340 total man-hours of meetings, which will be conducted on Mondays for 30 minutes, Wednesdays for 1 hour, and Fridays for 1 hour with our TA, Faculty Mentor, and Client, respectively. In these meetings, we will be discussing our weekly milestones

This project will also consist of hardware and software research, design, implementation, and testing. We estimate this will take roughly 480 total man hours averaging 20 man hours per week, roughly 4 man hours per person per week.

Research should take us around 4 weeks to complete thoroughly to where we are able to make decisions on the specifics such as what sensors and microprocessor to use which comes out to about 80 man-hours for research.

Designing should take us around 6 weeks to complete to the point where we have a very solid idea of what the final product will look like with more specific constraints. This comes out to around 120 man-hours.

Implementation and testing will go hand in hand for the most part because as we are able to implement our design, we will need to test the results to ensure that they are staying within our requirements and no problems arise. These together should take about 14 weeks, which is around 280 man-hours.

Task	man-hours
Meetings	340
Research	40
Design	120
Implementation	120
Testing	60

3.7 Other Resource Requirements

- Software to develop an application
- Temp Sensor with Bluetooth capability
- Wiring to string together sensors
- Rechargeable battery pack to provide power
- charger for the rechargeable battery pack
- Cloth or strap to attach to the body

4 Design

4.1 Design Content

The aspect of this project that requires design will be broken up into hardware and software.

Hardware

- We will need to design a high-level layout of the sensors, power supply, and control board of how it interfaces with the body
- we will have to potentially design a microcontroller chip
- We will have to design a way to attach this system to the body including the sensors and the power supply and control board.

Software

- UI screens will need to be designed and created to be user-friendly
- We will have to design a notification center that can show up on the home screen of the phone
- We will have to complete the software design as it pertains to data collection of the electrical system

4.2 Design Complexity

1. The design is composed of multiple components that each make use of scientific/mathematical/engineering principles. The temperature sensors use the fact that voltage across a PN junction is dependent on the ambient temperature. The communication between the sensors and the user's phone is done with Bluetooth. Bluetooth has applications in audio streaming, data transfer, device networks, and more.

2. The scope of the problem has multiple requirements that currently don't have standard industry solutions. The goal of the project is to greatly reduce the probability of someone getting frostbite or other temperature-related problems despite having limited or no feeling in one's feet/toes. This goal would have to be accomplished in cold conditions while the user is skiing or enjoying some other outdoor activity in the winter.

4.3 Modern Engineering Tools

Several modern engineering tools are being used for this design and more will be used. Several types of CAD softwares have been used so far with more to come. Some examples of these include AutoCAD and KiCad. AutoCAD is a software used to make technical drawings in both 2D or 3D. It will be very useful when designing enclosures for electronic components. KiCAD will be used to design PCBs. Some other tools include MATLAB and SPICE simulations. SPICE simulations will be very useful when designing circuits.

4.4 Design Context

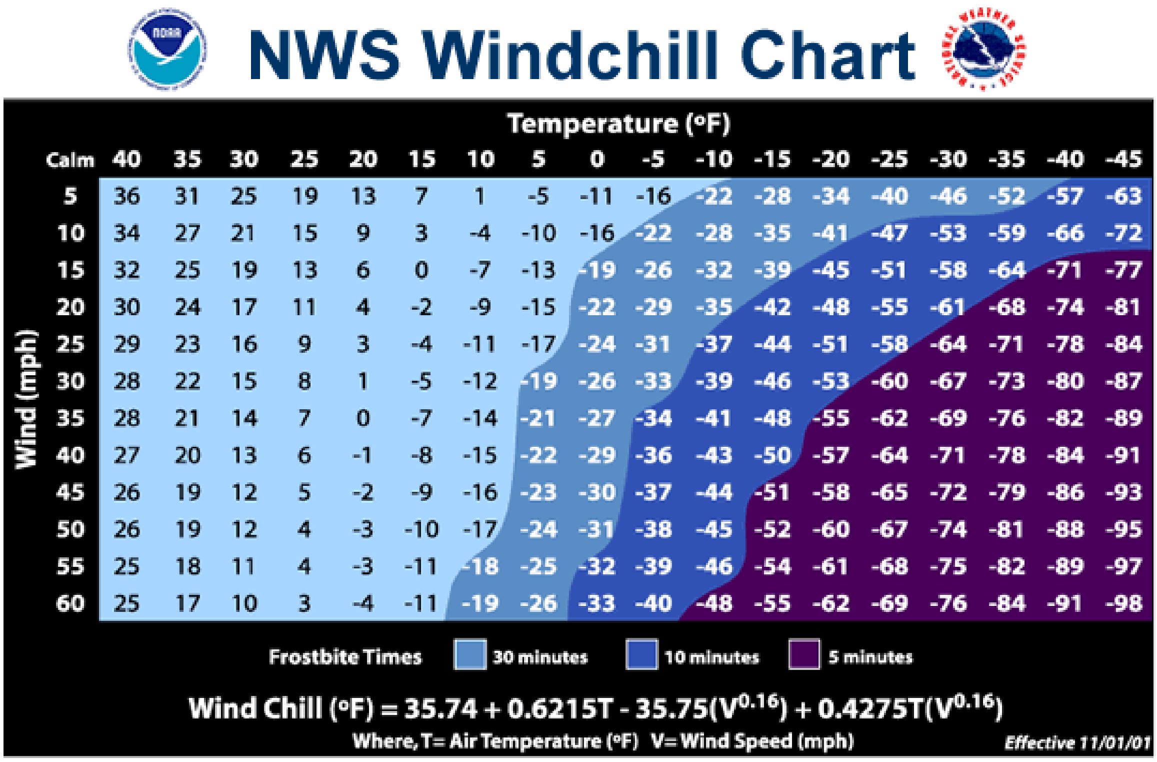
The primary community for whom the project is intended to help is the handicapped veteran community; more specifically, those veterans who suffer from paralysis. The project has the potential to make outdoor winter activities safer without taking away from the experience. Taking care of the veterans is always a societal need and this project can contribute to the quality of their lives.

Area	Description	Examples

Public health, safety, and welfare	This project makes skiing and other outdoor activities safer for those with limited nerve function in their lower extremities.	Someone with the inability to feel the sensation of cold in their feet becomes way more vulnerable to frostbite and hypothermia. A warning system can give these individuals a chance to find warmth before suffering permanent damage to their bodies.
Global, cultural, and social	The project is definitely aligned with the values of the handicapped veteran community. Although being a veteran is not an ideology, it can be safely assumed that they want the best for each other and providing tools that allow them to enjoy more experiences will undoubtedly receive support.	The project can lead to a more diverse skiing clientele. It can also lead to more awareness of pastimes that have been unavailable to persons with paralysis in the past.
Environmental	It's hard to imagine this project having any substantial environmental impact. There's always a carbon footprint associated with the production of anything but it will be negligible in the big picture.	The biggest potential environmental impact from the project comes from the use of disposable batteries. The proper disposal of those will be the responsibility of the consumer.
Economic	This product has the potential to increase the number of customers in ski resorts and other cold outdoor activities. This can lead to increased revenue at those resorts and increase the demand for ski gear also.	There is no reason that the end product should be unaffordable. It uses materials and components that are commonly used in other applications.

4.5 Prior Work/Solutions

There have not been any widely published attempts to provide a warning about concerning temperatures in areas of one's body for those with limited or no nerve sensation. Because of this, this project will require research about frostbite in all patients. Below is a chart made by the National Weather Service that can give a baseline for temperatures that warrant a warning.



NWS Windchill Chart

Temperature (°F)

Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
	5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
	10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
	15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
	20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
	25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
	30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
	40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
	45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
	50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
	55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
	60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Source: https://www.weather.gov/bou/windchill

As far as similar products go, there are a few examples of devices with a similar build. One example is the CARV. It is a device that goes in one's ski boot to monitor pressure points so that the skier can get feedback on his/her technique.

Source:https://d3t7modobimpp4.cloudfront.net/uploads/carv-sizes_2022-10-03-091206_chvv.jpg

This product can set a precedent for durability and it shows that there have been other electronic insoles that have been successfully implemented in the past. This is not in any way potential competition for the project's final product because it does not monitor temperature and it's only used by those with full use of their feet.

4.6 Design Decisions

One key design decision we have made is how to attach the system to the body to make it the most comfortable, agile, durable, and easily usable. Our initial thought was to use a sock-like feature, but the client let us know there had been previous groups that had tried this and had issues with the sock falling off the foot and bunching up, as it is not a one-size-fits-all. We have since switched to a gel insole-like feature that will fit inside a person's sock and will attach directly to the skin, and get a better temperature reading. There will be multiple sensors in the insole to read temp at various locations on the foot.

Another key design feature we are working on is an attachment of the power supply, control board, and Bluetooth transmitter to the person. Again we had an initial thought which has since changed once we did our detailed initial design. Our initial thought was to have the wires run up the leg to a small box that would fit inside the pocket. We have since changed our mind due to loss of power over long wires and decided to run the wires just above the boot and attach all of the control and power in a small enclosure to the leg using a velcro strap.

Our third key design decision includes our software/UI. With our system having two levels of alarms such as a warning level and a critical warning level, we have decided to allow the user to define a specific temperature for the warning level so they can adjust the amount of time they need to get inside or find a way to warm their extremities based on current weather conditions, their mobility, and their preference.

4.7 Proposed Design

So far, we have a systems design drawn up and have started implementing small portions of our UI and phone application. Our overall system design consists of multiple sensors in a shoe insole-type layer. The sensors embedded are primarily temperature sensors with the possibility of adding moisture sensors. These then run up to an ankle bracelet attached by a velcro strap. The anklet has a power supply and a control chip for Bluetooth.

4.7.1 Design 0 (Initial Design)

Design Visual and Description

Our design is broken into hardware and software components.

The hardware consists of two main areas: the control and power box and a sock-like feature containing temperature sensors. The power and control box consists of a power supply to our sensors, microchip, and Bluetooth chip that relays the data to the phone application. This will run up the leg and be able to go inside the pocket of the pants. The second part is the sock-like feature, which will slide onto the leg and have a layer of sensors that will run through wires to the control box.

The software side of things consists of two main portions: user interface and logic. On the logic side of things, the main focus is paying attention to the proper parameters ie. temperature, and making sure we can warn people if their body temperature is getting to a dangerous level. From there we will look at the user interface, which will show the warnings and current temperature and be easy to use.

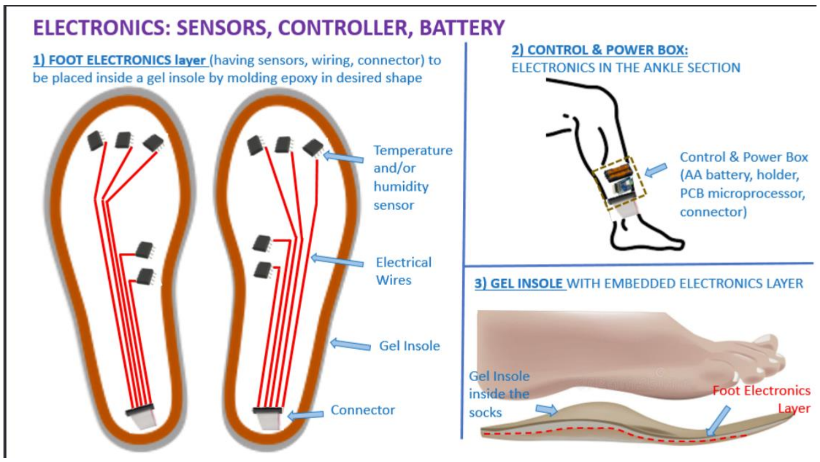
Functionality

Our design is intended to be as simple as possible. We use a sock-like feature that will read in body temp and be sent to a control box that is in the pocket of the user. We will run wires to a small yet effective control and power box that fits inside the user's pocket. The person will then be able to connect to the sensor system via Bluetooth using their phone. This will have a simple user interface that will show warnings and body temperature.

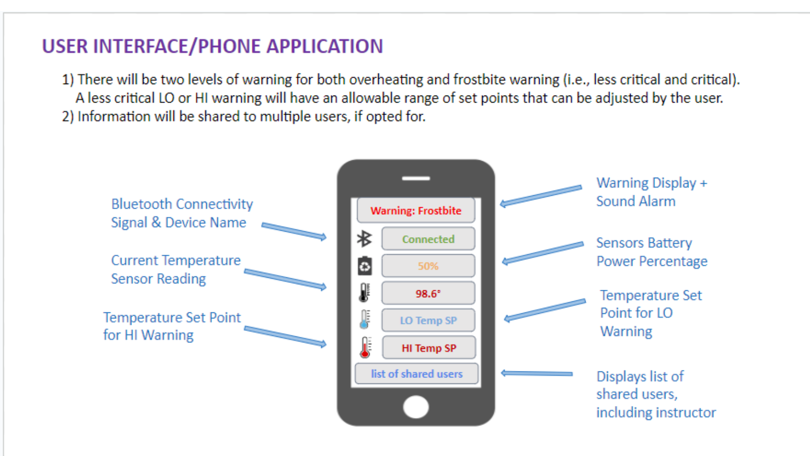
4.7.2 Design 1 (Design Iteration)

Design Visual and Description

Our design is broken out into hardware components and software components.



The hardware consists of two main areas: the control and power box and the shoe insole with an embedded electronics layer. The power and control box consists of a power supply to our sensors and microchip, as well as the microchip and Bluetooth chip that relays the data to the phone application. This will be attached to the person's lower leg via a velcro strap. The second part is the foot electronics layer and gel insole. The gel insole contains sensors, mainly temperature sensors, but also a potential for moisture sensors. This insole will go inside the sock and attach to the bottom of the foot to read the data. There will then be wires running toward a connecter where all sensors are connected to a ribbon cable that runs to the control box.



The software side of things consists of two main portions, user interface and logic. On the logic side of things, the main focus is paying attention to the proper parameters ie. temperature and making sure we can warn the people if their body temperature is getting to a dangerous level. From there, we have decided to implement two levels of warnings, one being a low-level warning and the other being a critical warning. The less critical level of warning is going to have an allowable range of set points for the user to define if they want a longer time before they need to get attention or if they are fine with a shorter time. On the other side of things the biggest goal with the user interface is simple yet effective. We are going to have the basic functionalities shown above which include the requirements of Bluetooth connectivity, HI and LO user-defined temp setpoints, a notification center, and the battery life of the system. as well as showing the current temperature being read in by the sensors.

Functionality

Our design is intended to be as simple as possible. We are using a shoe insole-like feature with temperature sensors to read body temperature. From here we will run wires to a small yet effective control and power box that attaches simply to the ankle and fits inside the pants without compromising the warmth of the pants. The sensors will read the data transmitting it over Bluetooth to the phone application. In the phone application, there will be logic running in the background that compares the data being read to set points for hypothermia warning and frostbite warnings that make sure the user is not at a critical level for any of those conditions. There will be two levels of warning and the lower level of warning will be allowed to be set by the user in the application within an allowable range. If this set point is hit they will receive a notification saying they need to do something differently. Once they hit the second warning level, they have very short time before either hypothermia or frostbite is setting in. We currently do not have anything implemented.

NOTE: The following sections will be included in your final design document but do not need to be completed for the current assignment. They are included for your reference. If you have ideas for these sections, they can also be discussed with your TA and/or faculty adviser.

4.8 Technology Considerations

Highlight the strengths, weaknesses, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

4.9 Design Analysis

We have not yet implemented our design to be able to test any thing