PINNACLE BIOMETRICS

February 15, 2016

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 305W/440W Capstone Project Functional Specifications for *Floe*: the Athletic Balance Monitoring System for Skiers

Dear Dr. Rawicz,

Please find the functionality specifications document for our Capstone project, *Floe*: the Athletic Balance Monitoring System for Skiers, enclosed herein. Our objective with this project is to design and build a system that can assist skiers in furthering their abilities by collecting quantitative data on their performance and converting it into useful real-time feedback.

This document consists of a functionality breakdown of our project, a thorough requirements analysis, and definition of production stages. The requirements analysis will encompass areas of concern, including physical, electrical, environmental, reliability, sustainability, usability, performance, and safety, for each system component. This document will be referenced throughout the project.

Pinnacle Biometrics is comprised of four Simon Fraser University engineering science students: Kurtis Bohlen, Eric Raposo, Louis Roux, and Clara Tsang. Specializing in systems and electronics, we are motivated and passionate about our fields of study and the use of technology to help athletes meet their true potential.

Please do not hesitate to contact me at clarat@sfu.ca if you have any questions or concerns in regards to this submission. On behalf of my team at Pinnacle Biometrics, I thank you for your time and consideration of our project's functional specifications.

Sincerely,

Clara Tsang
Project Manager, Pinnacle Biometrics

Enclosed: Functional Specifications for *Floe*: Athletic Balance Monitoring System for Skiers

PINNACLE BIOMETRICS

ENSC 304/440W

Functionality Specifications

for

Floe: the Athletic Balance Monitoring System for Skiers

Contact Person: Clara Tsang
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Date Issued: February 15, 2016

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PINNACLE BIOMETRICS

Executive Summary

Today's skier is bounded by the limitations imposed by feedback that is exclusively qualitative. Although qualitative analysis is most beneficial to a user when they first face the task of learning a new skill, quantitative analysis is what will drive the learner to most effectively further their skills after they have grasped the basic concepts. The market for performance analysis technology currently lacks a device capable of attaining balance metrics in an athletic environment, let alone provide a user with real-time feedback.

Floe: the Athletic Balance Monitoring System for Skiers will provide the amateur and professional skier, as well as their trainers, with quantitative augmented feedback and allow them to further their skills more efficiently. Using force-sensitive insoles and the readily available gyroscope and accelerometer on the user's mobile or HUD device, *Floe* will be able to compare the balance of the user to characteristics corresponding to skiing with proper form. With such information, the user can receive real-time quantitatively gathered feedback during their performance, as well as view a summary of performance statistics post-run.

Floe is comprised of three sub-systems: the pressure-sensing insoles, the boot-mounted hardware, and the software application. Weight distribution data is taken by the pressure-sensing insoles, which are wired to the boot-mounted hardware. The boot-mounted hardware then converts the analogue signal received from the insoles into a digital signal to be transmitted wirelessly to the software application. Finally, the software processes the received data and converts it into usable graphical information for the user.

The development of *Floe* is divided into three stages. The first stage features our proof-of-concept model, focusing on the ability to display the user's weight distribution under real-time constraints and alpine sport conditions, as well as saving such data onto a mobile device for later review. Due to the budget and time constraints imposed by this project, the real-time feedback function our proof-of-concept is rather limited, but ultimately, will prove the concept of *Floe*. The second stage features our prototype model, upon which a HUD is integrated and the real-time feedback functionality is realized. The third and final stage features our final product model, presenting fully functioning prescriptive feedback and advanced performance analysis through the incorporation of gyroscope and accelerometer sensing.

This document will outline the functional specifications of *Floe*, and will be referred to as a guide for product design as well as testing. Such specifications and requirements will be organized into categories corresponding to the subsystems. Furthermore, this document will describe the details pertaining to each stage of development. Lastly, this document will address the sustainability and safety concerns potentially imposed by *Floe*.

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Glossary

Anteroposterior: relating to front-to-back motion

Augmented feedback: performance feedback received from an external source; for example, a coach, video, biometrics, etc.

BLE (Bluetooth LE): Bluetooth Low Energy; a low-energy wireless data transmission protocol

BMH: Boot-Mounted Hardware; system component of *Floe* pertaining to the ski boot-mountable enclosure containing the SoC, signal-conditioning circuit, and power supply

CoP: Centre of Pressure; single point on a body at which summarizes the total net force induced by several forces

FSR: Force-Sensitive Resistor

GUI: Graphical User Interface; type of interface that bases user interaction with an electronic device on visual indication/graphical controls

Hallux: big toe

HUD: Heads-Up Display; transparent display that allows user to interpret shown data without the need to divert vision

Mediolateral: relating to side-to-side motion

SMD: Surface Mount Device

SoC: System-on-Chip; single chip with integrated circuit that gives it all components of computer/electronic system

UI: User Interface

1 Introduction

At Pinnacle Biometrics, we are working to assist athletes in meeting their true potential by relieving them of learning limitations imposed by performance analysis that is exclusively qualitative. *Floe*: the Athletic Balance Monitoring System for Skiers will provide the amateur and professional skier with accessible quantitative analysis on their performance. The concept of *Floe* is shown in Figure 1.1 below.

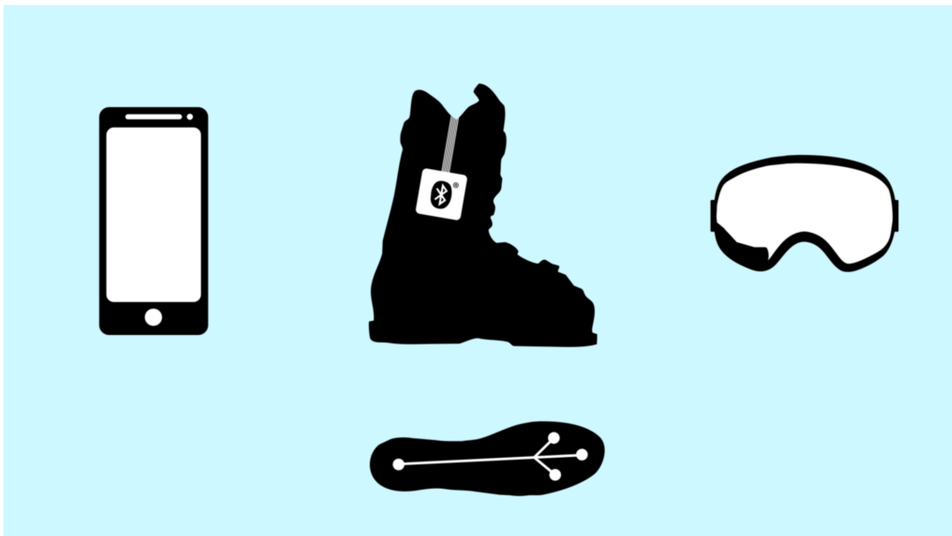

Figure 1.1 *Floe* conceptual component breakdown

Through the use of force-sensitive insoles and Bluetooth technologies, *Floe* will collect weight distribution data during a skier's performance and convert it into useful information to be displayed as real-time prescriptive feedback in a heads-up display or post-run performance statistics on a mobile device. The objective of *Floe* is to assist its user in furthering their abilities through the concept of augmented feedback. Once a learner grasps the basics of a new skill, the use of augmented feedback enables them to progress more effectively by allowing them to analyze their own performance from an external standpoint [1]. The market for sports performance analysis currently does not offer a product that can provide the user with real-time performance feedback, nor does it offer a product featuring weight distribution analysis suitable for alpine sport conditions; *Floe* will have both of these features. Furthermore, *Floe* will not only allow users to learn more effectively with the addition of consistent, quantitative augmented feedback, but it will enable instructors to review and analyze their students' progress more effectively. *Floe* is not intended to replace the role of the ski instructor; it is intended to enhance the benefits of independent training as well as increase productivity in a student-instructor environment.

To be able to provide a user with effective prescriptive feedback and performance analysis, *Floe* uses data concerning the user's instantaneous weight distribution and instantaneous motion. The proper form of skiing requires the skier's weight distribution to vary with the movement they are conducting. The generalized CoP points corresponding to different movements in skiing are shown in Table 1.1 below [2]. The most notable movement requiring CoP analysis is turning, which is comprised of three stages: initiation, control, and completion [2].

Table 1.1 – CoP corresponding to varied movements in skiing

Movement	Anteroposterior Location of CoP	Mediolateral Location of CoP
Traveling straight	Centered	Centered
Jump Landing	Centered	Centered
Turn: Initiation Stage	Forward	Centered
Turn: Control Stage	Centered	~80% Downhill Ski
Turn: Completion Stage	Slightly Backward	~80% Downhill Ski

A system overview of *Floe* is shown in Figure 2.1 below. The system is comprised of a SoC, attachable to the boot, receiving data from force-sensing insoles and sending it to the user' s mobile device or heads-up display device via Bluetooth LE. *Floe* employs the use of the gyroscope and accelerometer within the user' s mobile device or HUD to calculate the user' s movement that it then uses to determine the CoP at which the user should be focusing their weight. The user' s actual CoP calculated from data taken from the insoles is then compared to the aforementioned value and feedback is given accordingly, either displayed as a summary of performance statistics assistive to the user or real-time feedback through a GUI conveying the user' s CoP.

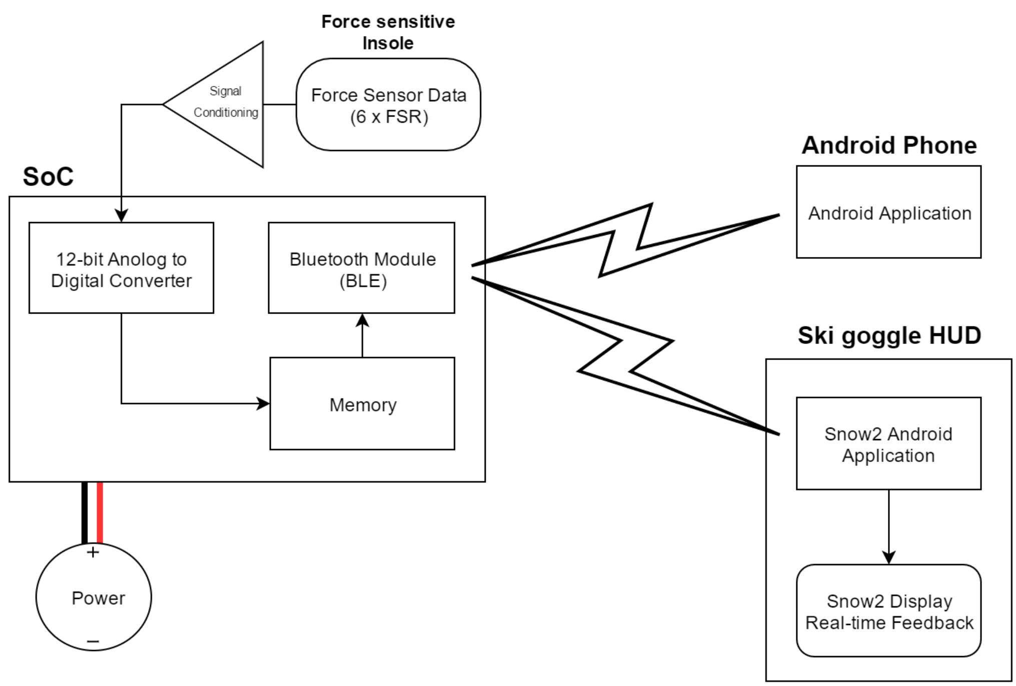

Figure 1.2 – Technical system overview

1.1 Scope

The objective of this document is to define and organize the necessary functional requirements of *Floe* to ensure its performance, usability, reliability, and safety. Aside from general requirements, the functionalities of the system are broken down and categorized in the three system components: the pressure-sensing insoles, BMH, and user interface. Details and justifications are given for the requirements, as this document will be used as a reference guide when designing and building the product. Furthermore, this document will outline the features and functionality of the product at its different stages of development.

1.2 Intended Audience

The functional specifications made in this document are intended for the use of all members of Pinnacle Biometrics. As mentioned, this document will be used as a reference guide during design and implementation of the system to ensure the product's overall quality. The requirements in this document can also act as testing guidelines upon completion of development.

1.3 Classification

Throughout this document, functional requirements will be represented in the following convention:

[R*xx*-*p*] *Requirement description*

where *xx* represents the requirement number and *p* is the priority of the requirement, as defined in Table 1.2.

Table 1.2 – Requirement classification priority definition

Priority *p*	Definition
i	High priority; essential to functionality and concept of product; present in all stages of product
ii	Intermediate priority; requirements that will allow product to be used effectively in its designated environment; present in the prototype and further
iii	Low priority; requirements that will enhance the usability and value to the user; present in the final product

2 System Requirements

This section will outline the general system requirements and functional specifications of *Floe*. Furthermore, the stages of development will be defined, in which the objectives and corresponding capabilities of each model are described.

2.1 System Overview

As opposed to the more technical system overview shown above in Figure 1.2, a more user-oriented overview can be seen in Figure 2.1 below. *Floe* can be broken down into three components: the pressure-sensing insoles, BMH, and user interface. As shown in

Figure 2.1, the BMH is wired to the insoles to receive analogue sensor data, in which it then converts into digital data to transmit via BLE to the paired device. Gyroscope and accelerometer data is taken from such components of the user's mobile device or HUD to be able to calculate the user's instantaneous movement. The system then relies on the software to interpret the received data, and in combination with the gyroscope and accelerometer data, convert it into information that is useful to the user, in which it will be displayed in a manner intuitive to the user under real-time constraints.

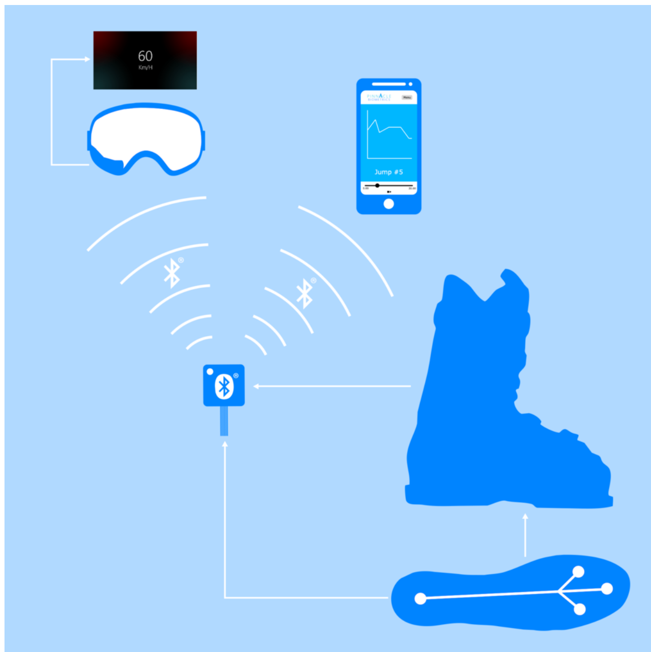

Figure 2.1 User-oriented system overview

The pressure-sensing insoles are composed of an array of four FSRs, as can be seen in Figure 2.1 above. For each foot, a FSR is placed to be underneath the hallux, first and fifth metatarsal heads, and the heel. The FSRs corresponding to the hallux and heel are to sense change in anteroposterior pressure, whereas the FSRs corresponding to metatarsal heads are to sense change in mediolateral pressure [3]. The CoP and weight distribution of the user can then be calculated using this data and displayed to the user in a two-dimensional array.

2.1.1 Stage 1: Proof of Concept

The objective of this first model is to display weight distribution and CoP information to the user under real-time constraints, as well as save information onto a mobile device to be displayed to the user post-run. This entails the implementation of one SoC and insole connection per boot, with both SoCs paired to the mobile device via BLE during operation.

Due to budget constraints, the system will display the real-time information on a mobile device using a GUI designed for the projected integration of a HUD. Therefore, this restriction imposes the infeasibility of employing the real-time feedback function in the environment of intended use.

Furthermore, it is not in the scope of this model to provide the user with real-time prescriptive feedback, as such functionality would require the incorporation of additional sensing using gyroscope and accelerometer data, extensive test sampling, and applications of pattern recognition. Such a procedure must be followed, as balance feedback varies according to the user’s instantaneous movement. As a proof-of-concept, this model will give feedback assuming the conditions pertaining to a user of amateur-level with competent parallel skiing skills travelling straight on groomed terrain.

Lastly, product requirements regarding the alpine environment will be addressed starting in this stage of development. These considerations include the system’s overall susceptibility to cold, moist conditions, as well as potential impact it may face upon the user’s physical motion and interaction with his surroundings.

2.1.2 Stage 2: Prototype

The most significant progression made in the second stage of development involves the integration of a HUD. This advancement relieves the restriction on testing the real-time feedback function imposed by the previous model. This stage prompts us to thoroughly consider the safety concerns brought forth by augmented reality. The rest of the hardware remains very close to that of the first model.

2.1.3 Stage 3: Final Product

The final product will incorporate the technology and processes mentioned as out-of-scope actions in Section 2.1.1 to allow the model fully functioning capabilities of prescriptive feedback and specific run statistics, such as turn and jump counts, and turn and landing ratings. This model will be modular, allowing the user to select feedback according to the type of terrain (such as groomed or moguls) and style of skiing (such as race or amateur). Moreover, sensing between the two ski boots for their relative positioning will be implemented to further improve the accuracy of the feedback.

The hardware concept remains similar to that of the proof-of-concept model, except for obvious improvements on specific components. The most significant development in the hardware would be the replacement of the development board with a custom printed circuit board, and the implementation of SMD circuit components to reduce costs, size, and power consumption.

2.2 General Requirements

[R1-i] The system must allow two SoCs to connect wirelessly to a mobile device.

[R2-i] The system must be able to be turned on and off.

[R3-i] All performance data collected by the system must be exportable to external programs.

[R4-i] The system must collect sufficient data for effective data processing and feedback.

[R5-ii] The product should be compatible to any ski boot.

[R6-ii] The system must be able to transmit data wirelessly to a HUD.

[R7-iii] The product should not exceed the market price of $300 USD.

2.3 Physical Requirements

[R8-i] The system must not hinder the user's movement or balance.

[R9-i] The system must not exceed 1lb per foot.

[R10-iii] The system should be minimalistic and aesthetically attractive.

2.4 Electrical Requirements

[R11-ii] The system must be battery operated.

[R12-iii] The system must last 8 hours of continuous usage at its highest power consumption.

[R13-iii] The system should have multiple power conservation levels.

[R14-i] The system must not operate on voltages exceeding 9 V.

2.5 Environmental Requirements

[R15-ii] The system must be able to operate within an elevation range of sea level to 4000m above sea level.

[R16-ii] The system must be able to operate within the temperature range of -30° C to 30° C.

[R17-i] The system must be waterproof.

2.6 Standards Requirements

[R18-iii] The boots onto which the BMH is mounted must comply with the ISO Standard 5355:2005 on requirements for alpine ski boots [4].

[R19-iii] The electrical components of the system must comply with the IEC Standard 60950-1:2005+A1:2009+A2:2013 on the safety of information technology equipment [5].

[R20-iii] The insole force sensors must comply with the CAN/CSA-C22.2 NO. 61010-1-12 standard on the safety of electrical equipment for measurement use [6].

[R21-iii] The transmission of data between the BMH and the HUD or mobile device must comply with the IEEE Standard 802.15.4-2011 for low-rate wireless personal area networks [7].

[R22-iii] The power state indicator must comply with the IEEE Standard 1621 for user interface elements in power control of electronic devices [8].

[R23-iii] The power supply must comply with the IEEE Standard 1625 for rechargeable batteries for multi-cell mobile computing devices [9].

2.7 Reliability & Durability Requirements

[R24-iii] The system must use rechargeable batteries.

[R25-iii] The system must be shock resistant up to a force of 1000N.

2.8 Safety Requirements

[R26-i] The system must be physically unobtrusive to the user during the duration of operation.

[R27-ii] The system must not cause distraction to user by diverting their attention from their surroundings.

2.9 Usability Requirements

[R28-ii] The system should be easy for the user to integrate into their ski boots.

3 Pressure-Sensing Insoles

The pressure-sensing insole is the part of *Floe* that is most susceptible to damage or failure, due to its constant contact with the user's foot. Therefore, it must be designed with durability and ease of replacement in mind. The insole is also the component most likely to inconvenience the user. Because it touches the user's foot directly, any sharp points, hard spots or variations in thickness will be felt by the user and cause discomfort, which could degrade the quality of the skiing experience. Any electrical malfunction in the insole will also be felt directly by the user. Another important design consideration is that the sensors be able to accommodate users of a wide range of body weights.

3.1 General Requirements

[R29-i] The insoles must be able to measure the CoP of a user ranging in weight from 70lb to 250lb.

[R30-i] The insoles must be able to be connected to the SoC via wires.

3.2 Physical Requirements

[R31-i] The insoles must not exceed 2mm in thickness.

[R32-i] The sensors for the insoles must be housed in a flexible film.

[R33-ii] The wires connecting an insole to the SoC should be a flat cable, not exceeding 24AWG in diameter.

[R34-ii] The bottoms of the insoles should be a non-slip surface.

[R35-iii] The insoles should be produced to multiple sizes to accommodate different foot sizes.

3.3 Usability Requirements

[R36-iii] The insoles should have a detachable connection to the SoC for easy replacement.

[R37-ii] The insoles should be easy to slide in and out of the user's ski boot.

3.4 Safety Requirements

[R38-i] The insoles must not have any sharp or pointed segments.

[R39–i] The voltage used by the insoles must not exceed 9 V.

[R40–i] The power used by the insoles must not exceed 0.5 W.

3.5 Environmental Requirements

[R41–ii] The insoles must be able to operate within a temperature range of 10° C to 35° C.

[R42–i] The insoles must be susceptible to and operate under moist conditions.

3.6 Sustainability & Reliability Requirements

[R43–i] The insoles must withstand deterioration due to usage of at least three ski seasons.

4 BMH

A breakdown of the BMH can be seen in Figure 4.1 below.

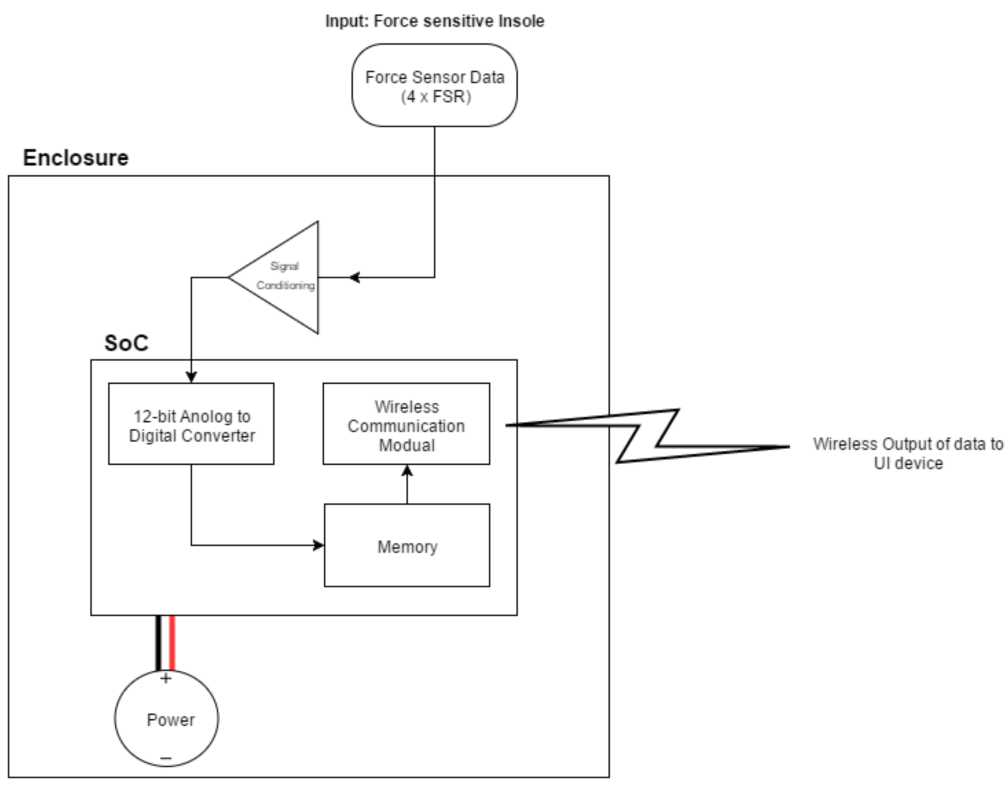

Figure 4.1 – BMH breakdown

The boot-mounted hardware is a crucial part of *Floe*, collecting analog data from the pressure-sensing insole and converting it to a digital signal, before transmitting it to the HUD or mobile device. The BMH must accomplish this task at a rate rapid enough for the purposes of real-time visualization and data recording, and must be able to stay reliably connected with the device to which it is sending the data. For *Floe* to be a useful alpine skiing tool, the BMH must also be able to function for extended periods of time on battery power, and be resistant to the hostile environment that will surround it. Additional care must be taken to ensure that the BMH does not impact the usability of the ski boot or its safety features, while remaining securely attached to it. For the final product version of *Floe*, the power state of the BMH must be readily visible, and the user must have a clear and simple way to control it, in order to facilitate the use of the product.

4.1 General Requirements

[R44-i] The SoC must be able to interface wirelessly with a mobile application within the distance of 2m.

[R45-ii] The board must be able to interface wirelessly with a HUD within the distance of 2m.

[R46-i] Input data received from the insoles must be scaled in a signal-conditioning circuit before being transmitted to the SoC.

[R47-i] The SoC must convert the analogue input data into a digital signal before transmission to the mobile device or HUD.

[R48-i] The signal-conditioning circuit must create a low impedance load of under 10kΩ to the ADC on the SoC.

4.2 Physical Requirements

[R49-ii] The BMH must be able to be securely mounted to the user's boot without an invasive procedure.

[R50-iii] The BMH should be less than 5cm x 5cm x 2cm in size.

4.3 Electrical Requirements

[R51-i] The BMH must have a power supply sufficient in supplying the pressure-sensing insoles as well as for wireless transmission.

[R52-iii] The BMH must be battery-powered and endure 8 hours of constant operation.

[R53-iii] The signal-conditioning circuit must use SMD components to reduce physical size and power intake.

4.4 Usability Requirements

[R54-i] The BMH must have an ON/OFF toggle available to the user.

[R55-iii] The ON/OFF toggle should be the only control visible on the BMH to the user.

[R56-ii] The power toggle must be easily accessible to the user.

[R57-iii] The power toggle should require the user to hold down a button for three seconds to take effect.

[R58-i] The BMH should have an LED indicator in place to signify state of power.

4.5 Performance Requirements

[R59-i] The BMH must be able to read sensor data at least 10 times/sec.

[R60-iii] The BMH shall be able to read sensor data up to 30 times/sec.

[R61-i] The wireless data transmission of the BMH must follow Bluetooth protocol standards.

4.6 Safety Requirements

[R62-i] The BMH must remain secured on the user's ski boot at all times.

[R63-i] The BMH must not have protruding elements in its structure.

4.7 Environmental Requirements

[R64-iii] The BMH must be shock resistant up to a force of 1000N.

[R65-i] The BMH must be waterproof.

[R66-ii] The BMH must be operational in a temperature range from -30° C to 30° C.

4.8 Sustainability & Reliability Requirements

[R67-iii] The housing of the BMH shall be made of recyclable materials.

[R68-iii] The battery must be able to last at least a year of charges and discharges.

5 User Interface

The user interface of *Floe*, comprising the HUD and the app for mobile devices, is the component with which the user will be interacting the most. For that reason, the appearance of the UI must be aesthetically pleasing to the user, and its use must be simple and intuitive. The software application must be able to process the data received from the BMH rapidly enough to produce a smooth real-time display of the weight distribution data on the HUD during performance, and must also be able to save the data in a mobile device's memory at the same rate for later review. To allow the user maximal flexibility in the use of their collected data, the mobile device app must let the user perform a variety of operations on the data on the mobile device, as well as allow the data to be exported in raw form to other devices for further analysis. Because of the rapid reactions required in alpine skiing, care must be taken to avoid distracting the user during performance. To achieve this, the HUD must present the real-time weight distribution data in an intuitively informative fashion that is not distracting to the user, allowing him to view data when desired and to concentrate fully on his performance when necessary. The control flow for the software application can be seen in Figure 5.1 below.

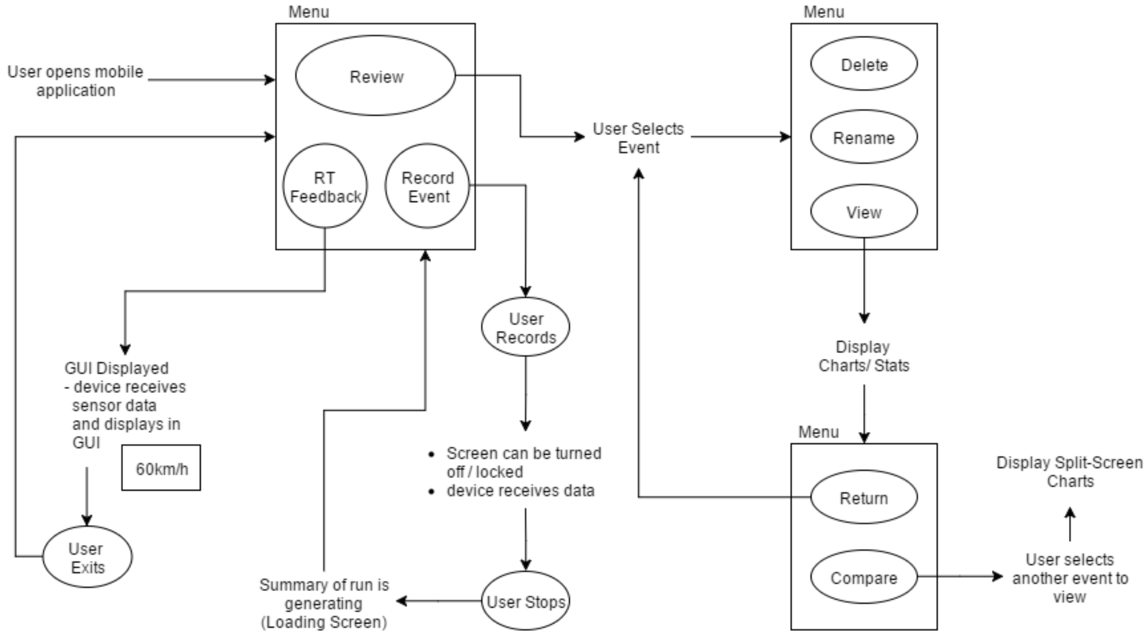

Figure 5.1 – Software control flow

5.1 General Requirements

[R69–i] The software application must be able to receive and process data from the board under real–time constraints.

[R70–i] The software application must produce data exportable to external programs.

[R71–i] The software application must process received data into real–time GUI conveying the user's weight distribution.

[R72–i] The software application must process received data into post–run analysis conveying the user's weight distribution to be saved and displayed on mobile.

[R73–ii] The software application must process received data into real–time GUI conveying the user's weight distribution to be displayed on a HUD.

[R74–iii] The software application must process received data with device's gyroscope and accelerometer data to produce prescriptive feedback and advanced post–run analysis.

5.2 Usability Requirements

[R75–i] The software application must display data in a manner intuitive and aesthetically pleasing to the user.

[R76–ii] The software application must have an intuitive and graphically–based control flow.

[R77–ii] The HUD software application must operate with minimal interaction between the user and device.

5.3 Safety Requirements

[R78-i] The real-time feedback function of the application must be minimal and not distracting to the user.

5.4 Performance Requirements

[R79-ii] The screen refresh rate for the HUD should be at last 30Hz.

6 User Documentation

[R80-iii] The user manual should include system set-up instructions.

[R81-iii] The user manual should describe all features of the system and include different mode operation protocols.

[R82-iii] The user manual should include liability and safety information.

[R83-iii] The user manual should be written in minimally technical, user-oriented language.

[R84-iii] The user manual should be available on the company website.

7 Sustainability/Safety

7.1 Sustainability

Given that *Floe* is intended for use in the great outdoors, it is logical that Pinnacle Biometrics should be committed to keeping the snow white and the air clean. As avid practitioners of the alpine sports, we keep environmental sustainability concerns in mind at every step of the design process.

This is reflected in our choice of recyclable materials for the construction of the pressure-sensing insole substrate and the BMH casing. Ensuring that those components are as durable as possible and that they can operate in a wide variety of situations and environments minimizes the additional manufacturing costs of replacement parts. Should replacement parts be needed, we designed the BMH with such a possibility in mind. Replacing an insole is as simple as removing the damaged one and connecting a new one to the BMH. This simple and intuitive design allows our users to replace a damaged product without having to wastefully purchase and an entirely new *Floe*.

Developing software that can be executed on existing HUD and mobile devices lets our customers use *Floe* with the devices they already possess, thereby reducing excess consumption. Our choice of board for the BMH also reflects our commitment to environmentally friendly technology. The system consumes a very low amount of energy, and uses a rechargeable battery as a power source, which greatly limits the environmental impact of *Floe*'s operation. Unfortunately, the current state of integrated-circuit and pressure-sensor technologies does not allow for the affordable manufacture of recyclable components, but the production model of *Floe* will comprise of specially designed sensors and a board, optimized for top performance while minimizing the amount of non-recyclable materials needed for their manufacture. The prototype models are designed and built with polyvalent and high-quality parts, to allow the team to use the same parts in many different ways if the product design should change.

To maximize customer satisfaction as well as sustainability, our production model will have a robust returns policy, entitling consumers to a fair treatment and allowing us to deal with the returned materials in an environmentally conscious way.

7.2 Safety

With its high descent speeds, potential obstacles and great number of variables to keep in mind, alpine skiing is a sport that carries with it a sizeable risk to the athlete's health. In creating a system that will operate in proximity to an individual practicing the sport, safety of the user must be the principal requirement at every step of the development process. This is why every part of *Floe* is designed with special care to ensure that our product does not endanger the user's health in any way.

The electrical components of *Floe* could pose a risk to the safety of the user, mostly for the potentially distracting effects of a shock. The voltages used in our circuits are very low, and therefore pose no real risk to the user's health by themselves, but we are nevertheless committed to follow international norms on the safety of electrical components. All electrical circuits and systems of *Floe* will comply with the IEC Standard 60950-1 and its amendments A1 and A2 for the safety of information technology equipment; all the sensors will be compliant with the CAN/CSA Standard C22.2 NO. 61010-1-12 for the safety of electrical equipment for measurement use; the battery used to supply power to the BMH will comply with the IEEE Standard 1625 for rechargeable batteries for multi-cell mobile computing devices.

The BMH, due to its volume, also has the potential to cause harm to the user. To minimize such risks, it is to be attached to the boot in a location that in no way hinders the movement of the user or impairs the user's ability to perform any task during a ski session. As mentioned earlier in the context of potential electrical shocks, distraction is the greatest risk that *Floe* poses to the user. When travelling very rapidly down a hill dotted with seen and unseen obstacles, it is crucial that the user be able to concentrate fully on the task of navigation when it is necessary. Therefore, the HUD component of *Floe* is designed to be intuitively informative, which lets the user assimilate the displayed information quickly without diverting too much attention away from the safe execution of the sport. The HUD is also designed to avoid distracting the user (for example, with bright flashes) from any other task they may be concentrating onto. This is intended to reduce the likelihood of distraction during a critical moment when the user's full attention is required for the proper execution of a maneuver.

8 Conclusion

This document has outlined the functional specifications of *Floe*: the Athletic balance Monitoring System for Skiers. It is meant to be a useful guide of the features a potential user or tester could expect to find in our product at different stages of development. The document will also help the team at Pinnacle Biometrics prioritize the development of important features of *Floe* throughout the development process.

The separation of our functional specifications into three stages of development will help ensure that the product is developed in a coherent way, and that it can operate with increasing levels of functionality as it is progresses through the stages. Our three main stages of development, as presented in greater detail in section 1.1 of this document, are as follows:

1. Proof of Concept – At this stage, *Floe* will be able to perform all basic functions required of the system. This includes acquiring, transmitting, analyzing (at a basic level), storing and reviewing weight distribution data. Real-time displaying of data will be done on the mobile device, in a GUI designed for the future implementation of a HUD. Prescriptive feedback will also be limited in scope to simplified use cases. The hardware will be usable on the slopes at this stage, with appropriate protection for the expected operating conditions.

2. Prototype – In the prototype stage, *Floe* will implement the HUD, which will allow use of real-time feedback by the user and more extensive testing of the GUI. A lot of research and testing will be invested into safety considerations relating to augmented reality. The hardware will remain mostly unchanged.

3. Final Product – At this final stage of development, *Floe* will improve the quality of the prescriptive feedback algorithms by including data from additional sensors present in the mobile device or HUD, as well as user-input data about the type of terrain and style of skiing. This will allow for advanced analysis of recorded data, including statistics on turns and jumps, among other features. The hardware in this stage of the design will be optimized for the specific requirements of *Floe*, and will include additional sensors to quantify the boots' relative positions, as well as a rechargeable battery to supply power to the BMH.

At all stages of development, great emphasis is put on the safety of the user, as it is the most important consideration of our design. Our product will conform to numerous international standards for the safety of electrical systems, and the design of the HUD is to be done with very careful consideration of the potential safety risks related to augmented reality. As detailed in section 7.1, environmental sustainability issues are taken into serious consideration every step of the way to ensure that the snow-capped mountains and blue skies that we so love remain that way for generations to come.

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