PINNACLE BIOMETRICS

April 15, 2016

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

Re: ENSC 305W/440W Capstone Post Mortem for *Floe*: the Athletic Balance Monitoring System for Skiers

Dear Dr. Rawicz,

Please find the post-mortem 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 review of our product design and implementation, as well as an overview on project dynamics, including summaries on: project materials and costs, deviance from the initial project schedule, work distribution among members, and technical challenges encountered during the course. A conclusion regarding the state of the project will be discussed, and a personal reflection from each team member will be provided. Lastly, agendas and meeting minutes for team meetings throughout the project course are attached for your reference.

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 post-mortem.

Sincerely,

Clara Tsang
Project Manager, Pinnacle Biometrics

Enclosed: Post-Mortem for *Floe*: Athletic Balance Monitoring System for Skiers

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ENSC 305W/440W

Post-Mortem

for

Floe: the Athletic Balance Monitoring System for Skiers

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

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Submitted to:

Dr. Andrew Rawicz
Steve Whitmore
SFU School of Engineering Science

Executive Summary

Floe: the Athletic Balance Monitoring System for Skiers is designed to provide the amateur and professional skier, as well as their trainers, with quantitative augmented feedback and allow them to further their skills more efficiently. The final marketable version of *Floe* will use force-sensitive insoles and the readily available gyroscope and accelerometer on the user's mobile or HUD device 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.

This document will outline conclusions regarding several aspects in the course of this project. It will first recapitulate the background and scope of the project, as well as discuss its corresponding business case and place in the market. Summaries on final financial matters and scheduling with respect to the initial plan will then be discussed, followed by technical challenges that were encountered during the project and their resolutions. This document will also describe the group dynamics and task distribution between team members, and finally, discourse the future plans of the project.

Lastly, personal reflections of each team member, as well as the minutes to each meeting are attached at the end of the document.

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Glossary

Anteroposterior: relating to front-to-back motion

API: Application Program Interface; set of routines, protocols, and tools used for software application development

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

NUS: Nordic UART Service; includes BLE service

Op-amp: operational amplifier

SAADC: Successive Approximation Analogue-to-Digital Converter

SDK: Software Development Kit

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

UART: Universal Asynchronous Receiver/Transmitter

UI: User Interface

1 Introduction

1.1 Background

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.

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. A high-level depiction of *Floe*'s concept can be seen in Figure 1.1 below.

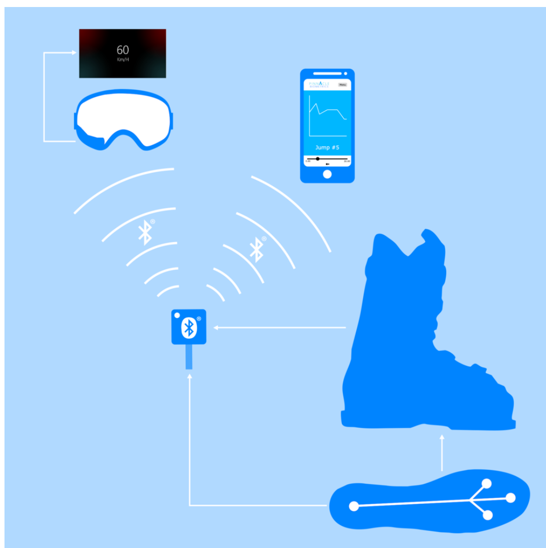

Figure 1.1 – High-level concept of *Floe*

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.

1.2 How Floe Fits in the Market

Floe, with its prescriptive feedback technology, is uniquely placed to make learning the sport of skiing easier, thus help the market grow further. Ski schools could use our product to turn more new skiers into returning customers quicker, thus growing their business at an accelerated pace. At a price point of around $200, once economies of scale from mass production and some markup to account for our own business expenses are taken into account, our product would be affordable enough for ski centers to purchase multiple units for use in their ski schools, and for dedicated members of the public to acquire for themselves. This price point would also be competitive with rival performance tracking devices, details of which can be found in our Project Proposal document [1].

To further the business case for *Floe*, upon completion of *Floe's* product design development and, therefore, long after the conduction of market research, a campaign for the product *Carv* commenced on Kickstarter [xx]. *Carv*, essentially *Floe* at a stage of further development, claims to allow its user to analyze physical metrics at a high level with a retrofitting device, and has currently raised $275,000 on their campaign.

Floe is poised to make a good entry onto the performance tracking device market with its unique real-time, prescriptive feedback and progress tracking features. Furthermore, future designs could easily incorporate more common metrics, which would allow us to capture an even larger part of the market by offering a product that encompasses all areas of performance tracking for that sport.

2 System Overview

This section will outline the overall functionality of *Floe*, as categorized by its three main components: the pressure-sensing insoles, BMH, and mobile application 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. The system then relies on the software to interpret the received data and 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.

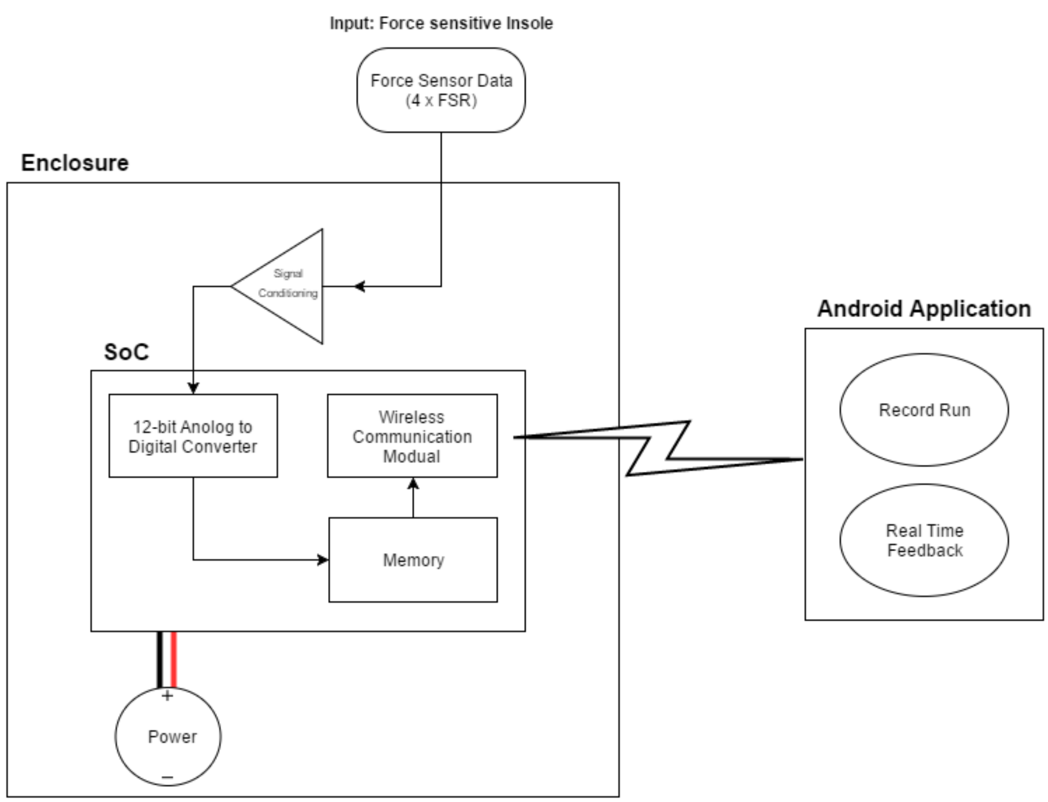

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Figure 2.1 – System overview of *Floe*

2.1 Pressure Sensing Insoles

The system receives its input from the pressure-sensing insoles, in which it uses to calculate the centre of pressure exerted by the skier at any instance. A diagram presenting the sensor layout and corresponding target points on the user's foot is shown in Figure 2.2 below. This formation was found to be the minimum amount of sensors needed in providing sufficient data to calculate the user's centre of pressure.

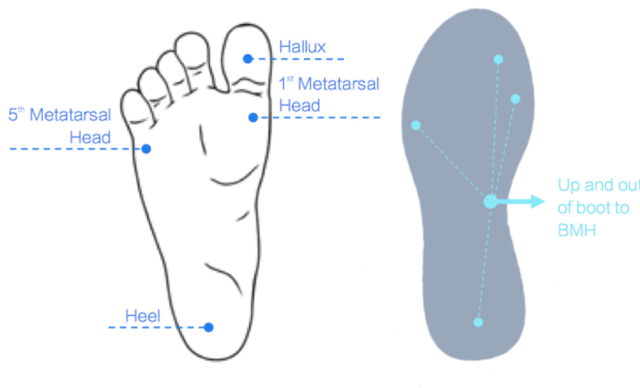

Figure 2.2 – Insole FSR array

2.2 BMH

. The BMH is a crucial component of *Floe*, comprised of a SoC, signal-conditioning circuit, and power supply. Containing the heart of the system, it is responsible for collecting analogue data from the pressure-sensing insole and converting it into a digital signal to be transmitted via Bluetooth LE to the user's mobile device. The physical design of the enclosure can be seen in Figure 2.3 below. The technical breakdown and signal path in the BMH can be found in Figure 2.1.

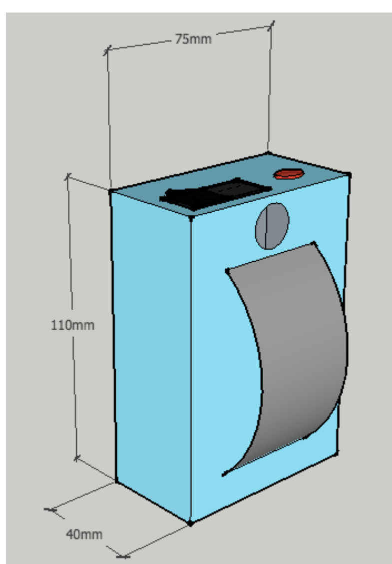

Figure 2.3 – BMH physical design

2.3 Mobile Application

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. Due to budget and time constraints of this project, we did not implement the HUD component of the UI, and instead implemented a proof-of-concept application for the real-time feedback on the mobile device. Within the proof-of-concept model as specified in the Functional Specifications document [2], the user will be able to receive real-time feedback on their centre of pressure, as well as record, save, and review "runs".

A screenshot of the real-time feedback functionality can be seen in Figure 2.4. The blue ball shows the user's instantaneous centre of pressure, whereas the lines act as indicators and appear when the centre of pressure of the user crosses a specified threshold; as can be assumed, red indicates a threshold more severe than yellow.

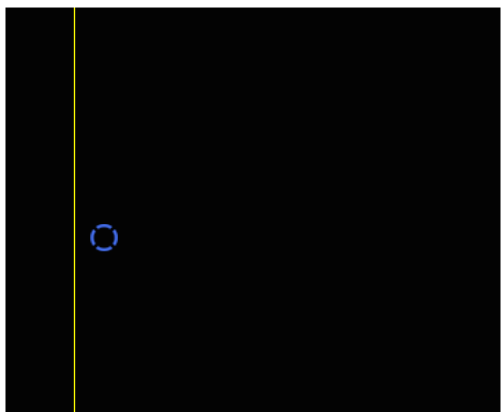

Figure 2.4 – Application screenshot showing real-time feedback functionality

A screenshot of the run review functionality can be seen in Figure 2.5. Our design for the post-run analysis consists of two line graphs depicting the user's CoP deviation from their balance origin against time; the first corresponds to the anteroposterior CoP, and the second corresponds to the mediolateral CoP.

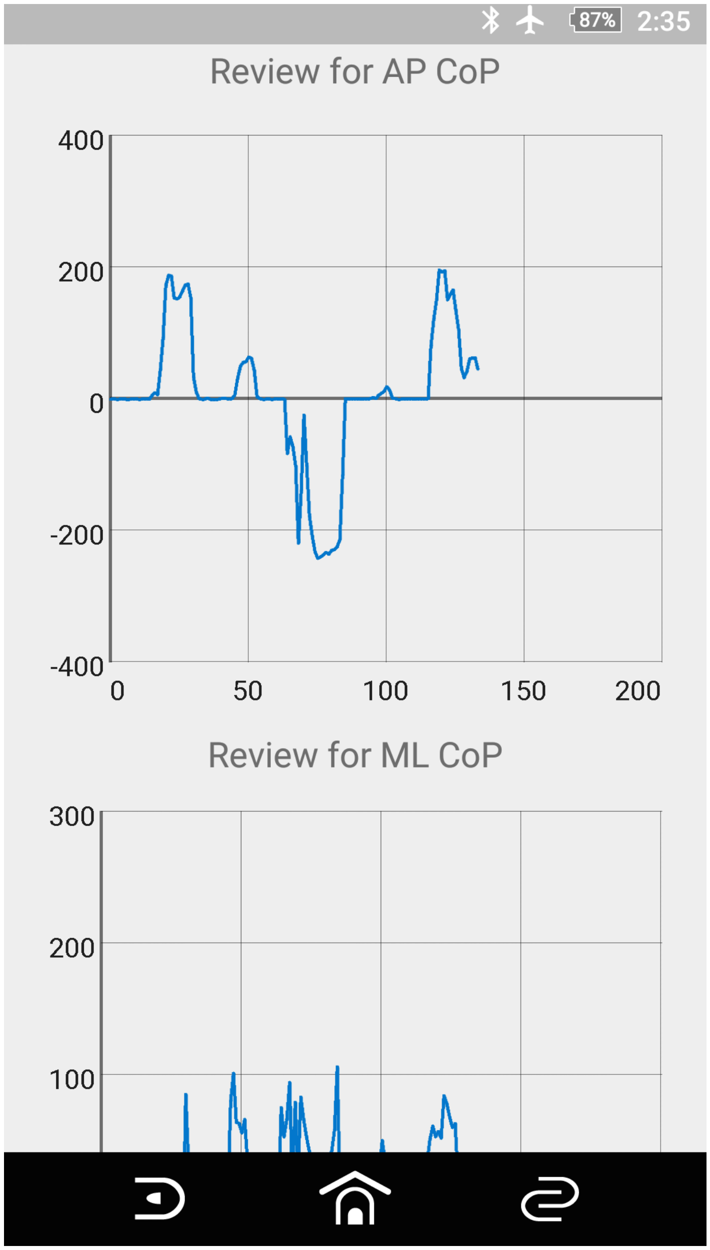

Figure 2.5 – Application screenshot showing run review functionality

3 Materials & Costs

This section describes the materials and costs accumulated in the project. The final project expenditures will be compared against the initial projected costs and budget, followed by reasoning behind the deviation.

3.1 Estimated Costs vs. Actual Costs

The initial projected costs and actual project expenditure can be seen in Table 3.1 and Table 3.2 below, respectively.

Table 3.1 – Initial projected costs

Item Description	Quantity	Unit Cost	Total Cost
Bluetooth Low Energy SoC (nRF52-DK)	2	$115.00	$230.00
Piezoelectric FSR (Flexiforce A201)	16	$21.25	$340.00
Recon Instruments Snow2	1	$580.00	$580.00
Power Electronics	1	$50.00	$50.00
Signal Conditioning	1	$20.00	$20.00
Circuit Components	1	$10.00	$10.00
Physical Housing	1	$10.00	$10.00
20% Contingency			$248.00
Total Budget			$1488.00

Table 3.1 – Project expenditure

Item Description	Cost
2 x Nordic nRF52 Development Kits	171.31
8 x Flexiforce A201 FSR Sensors	165.27
9 x Interlink 402 FSR Sensors	65.00
4 x MCP6004 Opamps	2.64
10 x 3296 1MOhm Trimpots	32.93
3 x TL7660 Voltage Inverters	6.60
Tax and Shipping	80.71
Total	524.46

Pinnacle Biometrics received insufficient funding to compensate the initial projected projects costs and was forced to make cutbacks to meet the funding allocated by the ESSEF. Cost reduction was accomplished by dismissing the heads-up display feature of *Floe* and opting for a mobile phone GUI and feedback as a proof-of-concept model. Research was also conducted on the measurement and calculation of the center of pressure and it was deemed that only four sensors would be required for *Floe*'s proof-of-concept. These cutbacks were enough to reduce the budget to the amount of funding Pinnacle Biometrics received from the ESSEF.

Floe underwent a hardware design update halfway through its design process, cutting into the remaining funding. The Flexiforce A201 sensors had too large of a sensing range for Floe's application. It was attempted to fix this range by implementing a more complicated signal conditioning circuitry, using op-amps to amplify the values measured. Unfortunately, this amplified the noise to indistinguishable levels. Switching to the Interlink 402 FSRs solved the sensing range problem, but this action in turn discarded the need for the complex signal conditioning circuitry. As a result, the A201 FSRs, 3269 trim-pots, and TL7660 voltage inverters were unused and therefore sunk costs. Pinnacle Biometrics is trying to recover as much of these sunk costs as possible by returning or reselling these materials.

3.2 Summary

Even with these unexpected costs, upon termination, the project was essentially on budget with a total expenditure of $524.46. Currently the members of Pinnacle Biometrics are $11.46 out of pocket, dividing into individual costs of $2.87. Once sunk costs are recovered, the members will be reimbursed their share of the cost.

4 Schedule

This section compares the original schedule designed for the project with the actual progress timeline.

4.1 Original Schedule vs. Actual Progress Timeline

The projected project deadlines and actual progress timeline can be seen in Figures 4.1 and 4.2, respectively.

Deadline	Item
Jan 18	All development teams commence research
Feb 1	Part arrive, development starts (mobile app, hardware, firmware)
Feb 28	First prototype completed (Single BMH and and mobile application)
Mar 13	Integration of the second BMH, real-time feedback functionality completed (Heads up display)
Mar 28	Fully developed prototype, fine tuning and testing commences
Apr 4	Project Deadline

Figure 4.1 – Initial project deadlines

Deadline	Item
Jan 18	All teams commence research
Feb 1	Parts arrive, start development (mobile app, hardware, firmware)
Feb 19	Firmware team BLE data transmission working for one pin
Mar 20	Software database working
Mar 21	Hardware team signal conditioning completed
April 6	Hardware team physical housings complete
April 8	Hardware team both insoles are completed, software team UI working
April 10	Firmware team reading and transmitting all sensor values
April 12	Both insoles are integrated with the BMH, software team BLE working
April 13	BMH and Android application integration
April 15	Software team Android application working with two boots, testing commences
April 19	Project due

Figure 4.2 – Actual project timeline

Many major design changes occurred throughout the duration of the project, which caused our original deadlines to be re-evaluated and pushed back. The first design change was due to lack of funding and support. *Floe* was designed to work with the Recon Snow2 HUD interface placed within the user's ski goggles. The team was unable to raise enough money to purchase the HUD and thus cut it from our design. Additionally, the amount of time needed to develop an Android application for both mobile and HUD platforms was unreasonable for the given project deadline. Thus the whole design was scaled back to include only an Android mobile application.

The firmware team originally planned to develop a custom BLE service but concluded that it was unnecessary due to pre-existing services having the required functionality. Firmware development shifted, and all custom service development was abandoned. Near the end of the project timeframe, the firmware team encountered a SoC hardware/SDK bug causing unexpected behaviour. Due to this bug, firmware development was halted and a work around was developed to circumvent the problem. The hardware team encountered sensor sensitivity issues and thus the type of FSRs was changed. The signal conditioning circuitry then had to be redesigned, causing some delays in development.

Software development had a major scope change near the start of the project. Machine learning and prescriptive feedback algorithms were planned to be completed for the prototype application. Further research in the subject proved that it would take large amount of time and existing data to create functional algorithms. Since this could not be completed within the project timeframe, the software scope was redesigned and simplified. The most time consuming aspect of the revised software development was the implementation for Bluetooth communications. Due to its complexity, it delayed software development.

5 Encountered Challenges & Resolutions

This section outlines the challenges that were encountered during the course of the project, categorized as issues pertaining to hardware, firmware, and software.

5.1 Hardware

Most of the hardware challenges and their resolutions were mentioned earlier in Section 3.1, regarding the change of the sensors and the resulting change of the signal conditioning circuit. Another issue occurred during the first testing of the signal conditioning circuit connected to the insoles. It was observed that the output of two sensors did not reach their full range, and generated an output when a different sensor was pressed. This problem occurred across both signal-conditioning PCBs with a slight variation. On one board, the output halved expected value and changed when two of the four sensors were activated. On the other board, the output was a quarter of what was expected and activated when any sensor were pressed. Testing revealed that the sensors were shorted together on the PCB from remnant copper traces leftover by manufacturing and were not detected in the inspection. The solution to this problem was to simply scrape away the thin remnants of copper on the PCB that caused the sensors to short together.

5.2 Firmware

During firmware development, many different challenges were overcome. Initially, research was conducted prior to development in order to fully comprehend the BLE protocol and Nordic's NRF52 SDK. Once the team had a sound understanding of each component, the application's structure, including all necessary services and peripherals, was created.

The next hurdle was configuring the C development environment. Since the NRF52 DK had been recently been released, documentation for setup was limited. A few days of troubleshooting were needed in order to install all the correct drivers and source files as well as set up a working environment that could flash code to the SoC. In the initial planning phases, the main application was designed to utilize a custom BLE service to transmit the data in real time. As the team was researching the creation of a custom service, it was concluded that it would take too much time to develop and implement a custom service and unnecessary due to an existing better, quicker alternative.

Nordic's UART over BLE service was used in order to implement bidirectional real time wireless communication between the BMH and Android application. The team encountered two major bugs regarding SAADC voltage sampling and storage. The first bug caused the maximum value sampled to be lower than the maximum ADC resolution at 12 bits. It was later discovered that it was due to improper initial analog pin reference and gain configuration. Once resolved, the application was able to receive the full range (0 – 4095).

The last bug was unexpected and due to an internal error with the SoC hardware and SDK. It limited the SAADC to sample on only two of the four analog pins used. Nordic's specification states that the SAADC is able to sample up to 8 channels successively. Because of this external bug, a workaround was needed in order to circumvent the problem. The firmware team was able to implement a fix that only sampled two pins at a time at a higher frequency in order to fulfill all four sensor samples per 100ms.

5.3 Software

Software development for Floe was entirely encompassed by the development of the companion app for the Android platform. The main goals of development were that the app be capable of communicating with the two separate BMH units simultaneously, and that it could either display the user's balance data in real-time or record it for later review. The user should be able to review their performance from within the app, or to export the data to a desktop computer for further analysis.

Significant challenges were faced by the software development team at the beginning of app development in learning the structure of Android apps and the methodologies behind their development. External help from an Android development expert, along with extensive and ongoing research helped the team overcome the initial development difficulties. Implementing the BLE communication functionality was a significant challenge faced by the team. Again, inexperience made initial progress slow, and a lack of literature made learning difficult. The successful implementation of wireless communication between the app and the BMH units required some deviation from the initial software structure design as it was presented in the Floe design specifications document [X1]. The original software structure plan was drafted based on incomplete knowledge of the asynchronous nature of BLE communications; therefore, deviations from the plan were unavoidable. The shift to asynchronous coding techniques was the main factor that allowed the team to implement a reliable data acquisition system. Contrary to what was initially expected, connecting the mobile device to two separate boots simultaneously was not much more difficult than connecting to a single boot.

Another problematic area was the implementation of the real-time visual feedback functionality. Issues arose specifically when dealing with image generation and display updating. Initial attempts at generating an image and displaying it on the mobile device screen were unsuccessful, for reasons that research and debugging were able to uncover. The solution involved completely changing the manner in which the image was generated and displayed, using a more direct, though less elegant, method.

The mathematical process of data processing was, in itself, not a significant software challenge. However, its implementation was facilitated by a change in the data flow through the app. The work that was projected to be done by multiple successive application components was instead implemented within a single application component without a significant performance cost. The design change brought greatly improved stability and simplicity to the app, facilitating the implementation of other application components relying on the data processing systems to operate properly.

6 Work Distribution

This section describes the project team dynamics and distribution of work between team members.

6.1 Task Organization

The organization and distribution of project tasks between team members can be seen in Table 6.1.

Table 6.1 – Project task distribution

Category	Task	Kurtis	Eric	Louis	Clara
Technical	Hardware	x			
	Firmware		x	x	
	Software (Back-end)		x	x	
	Software (Front-end)				x
	Physical	x		x	x
Admin	Scheduling/Document Submission				x
	Meeting Agendas/Minutes				x
Other	Financial	x			
	Documentation	x	x	x	x
	Branding/Graphic Design		x		

Each team member mainly worked within his or her originally assigned technical fields as specified in the Project Proposal document [1], and made major contributions to the project documentation.

Kurtis designed and implemented all hardware aspects of *Floe*, constructed the pressure-sensing insoles, as well as worked assisted Clara in constructing the physical design of the BMH housing. He was also responsible for all of the project's financial matters.

Eric designed and implemented all firmware development of *Floe*, as well as assisted Louis in implementing some back-end software aspects.

Louis designed and implemented all back-end software development of *Floe*, as well as assisted Eric in firmware development. He was also involved in the physical design of the insoles and BMH housing.

Clara designed and implemented all front-end software development of *Floe*, constructed the BMH housing, as well as worked with Louis in physical design. She was also responsible for administrative tasks including overseeing project documentation, project scheduling, and meeting agendas and minutes.

6.2 Problems/Challenges

Few and insignificant conflicts and challenges rose between team members. Among the few, the most significant involved time dependencies between firmware and software. Task deadline conflicts arose due to the software depending on the firmware to be sound. Due to incomplete testing, firmware progress lagged, causing a delay the software team's development. This issue was resolved through the firmware team assisting software in debugging their code subsequent to the completion of firmware development.

7 Conclusion

For the team at Pinnacle Biometrics, the development of Floe was an enriching and stimulating experience. All members of the team had an occasion to strengthen pre-existing bonds of friendship, as well as improve their own skills in their chosen area of development. The flat organisational structure fit the team very well, and no team dynamics issues arose.

From this we can conclude that the team at Pinnacle Biometrics did achieve its goals in the development of Floe. The working proof-of-concept version demonstrated to faculty, family and friends on 18 April, 2016, featured all the important functions of Floe, as prescribed in earlier Pinnacle Biometrics documentation.

7.1 Project Summary

At its inception, the idea behind Floe was to create a device able to provide valuable data to its user about their performance, thus enabling them to improve their skill further without the need for costly solutions such as personal instructors.

The original concept for Floe called for pressure-sensitive insoles to be connected wirelessly to a mobile device and a Snow2 heads-up display. The mobile device could record data sent out by the boot-mounted hardware, while the heads-up display could display real-time balance data and provide prescriptive feedback on the user's performance. As noted in previous sections, not all of these ambitious features are available in the proof-of-concept, for a variety of reasons.

The first major revision in scope came with the decision to remove the heads-up display from the proof-of-concept version of Floe, due to budget constraints. Another significant change was the change in FSRs used as well as the number of them placed in each insole, due to technical considerations. Next, issues specific to the version of the SoC used for development posed some challenges in data acquisition, leading to some delay in the completion of firmware development. The development of the companion app for mobile devices also experienced some delays, especially in the implementation of communications over BLE and the real-time graphical display of balance data. Early expectations for predictive feedback on the user's actions had to be scaled back to simple real-time display of data, due to computation speed considerations as well as development time and resource limitations.

Our proof-of-concept version of Floe has thin, flexible pressure-sensing insoles, which are connected through signal-conditioning circuitry to a BLE-capable SoC. The SoC uses a custom-developed BLE UART service to send the digital sensor data to an Android mobile device running the Floe companion app. Through the app, a user can visualize their centre of pressure in real-time, record their balance data over time, as well as review previously recorded events with the help of graphs generated by the app. The components of the system are able to interoperate reliably to produce a consistently positive experience for the user.

The planning underpinning the development of Floe was mostly well executed. Documentation drafted early and continuously updated helped the team stay on track throughout the development process. The financial aspect of development was well planned and allowed the team at Pinnacle Biometrics to develop Floe without exceeding the budget, despite unexpected costs. The original time-frame for development was less well respected, despite including a fairly large amount of time for contingencies. In particular, the slow start to software and firmware development limited the time available for system-wide testing of Floe. Due to the late date at which full system interoperability was completed, testing Floe on the slopes was not a possibility. Such testing might have exposed flaws in the design or implementation of Floe that in-lab testing could not uncover.

7.2 Future Plans

Future development of Floe would be aimed at performance optimization, as well as aesthetic improvements and implementation of additional sensor information. Given the size of the alpine sports market, such development could be worthwhile from a financial point of view. However, such development would necessitate large time commitments from members of the team, which may be difficult to achieve because of other, prior commitments. Furthermore, as noted above, a product called Carv was publicly announced in February 2016, more than a month into the development of Floe. Carv features similar functionality to Floe, and has been in private development for two years. It recently raised more than 200 thousand dollars through crowd-funding. The existence and apparent success of Carv show that Floe could have been a profitable business opportunity; however, the release of Carv makes continuing development of Floe unlikely to be a financially profitable venture.

8 Personal Reflections

8.1 Kurtis Bohlen

My Capstone experience was thoroughly enjoyable. Over the past semester I have put my engineering skills that I have developed over the past 4 years to work. I have learned lots of important things both technically and interpersonally, and I am glad that I was able to have the opportunity to work on *Floe*, with the other members of Pinnacle Biometrics.

I am appreciative that I was able to work on the hardware of *Floe* as it is the closest component to my electronics engineering degree and suits my interests. I was able to efficiently apply my electronics knowledge and gained other valuable experience from working on *Floe's* hardware. I had previous experience with a couple of the materials used to design Floe. One of these was the Nordic Semiconductor nRF Bluetooth Low Energy System on Chip. I used this IC before to do a special projects laboratory earlier during my time at SFU. I had also worked with the Interlink 402 FSRs before in my ENSC 100 first year project. Having worked previously with these materials, it leant a certain familiarity and ease in designing *Floe*.

I was also able to expand my electronics knowledge by designing and fabricating a PCB for the signal conditioning for *Floe*. This was the most rewarding part of the project that I got to work on. I had little previous knowledge of signal condition circuits, and why they were required to lower the output impedance of sensors. Being able to design a circuit, design a board layout, and get it fabricated was very satisfying. I had experience using Eagle before for schematic design, but I had never gone into the level of detail that was required for *Floe*. I foresee myself using Eagle in the future and being able to apply the skills that I developed working on *Floe*. It was also extremely beneficial for myself to be able to work on a professional System on Chip and get to familiarize myself with the complexity and scale of an industry grade device.

From working on *Floe* alongside three of my peers I was able to gain great interpersonal experience. I have worked in a professional business environment before, but never only with other people who are my equal. Additionally I had never participated in a startup environment where we had to come up with an idea, design it and manufacture the product. Working alongside my peers was not without its challenges, but that is where the learning experiences came from. Being able to overcome the challenges through clear communication and reasoning was a valuable skill to develop further.

Being a part of Pinnacle Biometrics has been a great experience and I have learned a lot. Working with my engineering peers who are also my friends only strengthened our relationship and my own personal skills. It was humbling to work alongside people with the same technical knowledge as me and understand everything that was happening in the project. At the same time, everyone had something that they specialized in, and as such I had to rely on my peer's judgment to make executive decisions for their sections of *Floe*.

My time at Pinnacle Biometrics has been invaluable and I am glad that I had to be a part of the team that created, designed, manufactured, marketed, and documented *Floe*.

8.2 Eric Raposo

I have always looked forward to the Capstone engineering project. Since my first year at SFU, I have been excited for this opportunity to design and create an interesting innovative product. Looking back to when I had little to no experience in any kind of engineering development, I can really appreciate the accumulated wealth of knowledge and experiences I have gained from ENSC courses and coop work terms. As the end of my 2015 fall semester approached, the reality of the amount of hard work and dedication needed for this project set in. Nevertheless, I was ready for the challenge and eager to work with my team to develop a product from the ground up and have fun at same time.

Throughout this whole experience I have learned a lot about product development and group organization through the many challenges my team and I faced. Brainstorming for project ideas seemed like an overwhelming task at first since the possibilities were endless. After a few days of consistent thinking, ideas started to form. We were able to limit our scope and categorize all the problems we discovered, which aided in narrowing our search. Once we finally decided on our idea for floe we had many different visions for its product development. Ultimately our passion for the future of the product created very ambitious goals, which were impossible to complete within the 4-month timeframe. This was my first lesson in project organization, limiting the scope of the project so it is viable within a specific deadline. We had to prioritize all our ideas to define the core features of our product for the prototype phase; our initial visions had to be scaled back. From my work experience at Point Grey Research, I knew that organization was key in product development, as it prevents problems in the future that were likely to be due to improper structure. Writing all our ideas down and creating flow charts allowed us to objectively look at everything and structure it appropriately.

My passion for low level code and experience as a firmware engineer in previous coops made me an ideal candidate for SoC and BLE firmware development. The most challenging step in development for me was developing the SoC application for floe’s real time wireless data transmission. I had no previous experience working with Nordic SoC development kits or BLE Protocol. My interest drove me to utilize all resources until I had a sound understanding of BLE protocol and SoC firmware. Setting up the development environment was tedious and took a lot of trial and error since the development kit had just been released and tutorials had been limited. At first I was set on creating my own BLE service but I soon realized the time and effort needed to develop one from scratch was pointless, as pre-existing services could be utilized instead. By analyzing the many examples provided in the SDK, i was able to implement my own application.

Near the end of my development I had encountered unexpected behaviour due to a bug within the hardware and SDK itself. I was caught off guard as deadlines were approaching and had to redesign my application in order to bypass this problem. Luckily all my final exams had been completed and I was able to fully divert my attention to the firmware. After two days of troubleshooting and coding I was eventually able to circumvent the problem and successfully transmit data in real time. I learned that realistically when developing a project like this one I work best when focusing fully on the task at hand. It was a major struggle to balance both classwork and capstone development. Homework, midterms and finals got in the way of development and made it hard to work on firmware for long periods of time. I know that I work best when my attention is undivided, as once I get into the “zone” I am able to make significant progress.

Lastly we needed to integrate all of our components from firmware, hardware and software. This posed numerous challenges that had to be overcome through teamwork and efficient troubleshooting. Tweaking on both the firmware and software side was needed in order for everything to mesh correctly. In the end, although getting very close to our final deadline, we were able to get everything functioning properly.

The entire experience has left me with a better understanding of the product development cycle. It has given me the experience of team dynamics and project planning needed to create a successful product. I now have a sound understanding of BLE protocol and SoC application development that can be used for future employment and personal projects. I really enjoyed the feeling of accomplishment I had after fully achieving my firmware development goals as well as working with my team members to develop something from merely an ambitious idea to a fully functional prototype. If I could go back, I wish that I could fully commit my attention to the project and possibly develop it further within the 4-month time span.

8.3 Louis Roux

Without a doubt, I can say that the realization of this Capstone project was one of the things I have done that I am most proud of. Until working on this project I had no real idea of how much I have actually learned from my four years of studying engineering at SFU. The work I did on this project, while it did not directly involve much of what I had learned from classes, really made clear to me the ability I have acquired to learn by myself whatever I need to accomplish a given task.

As part of Floe’s software development team, I had to learn to understand and use the Android Application Programming Interface (API), as well as the Java programming language, which underpins Android development. While I had some previous programming experience in the C++ language, which is very similar to Java, the subtle differences between the two were sometimes difficult to detect, assimilate and remember while writing the code for the companion app. Given that Java and C++ are two of the most popular programming languages, my experience in the development of Floe has made me a more versatile programmer. Working with the Android API has also greatly expanded my understanding of how larger programs work behind the user interface; this is likely to prove useful in future situations where I might have to write or maintain code that fits into a larger whole.

While programming the back-end of the companion app, I had to learn a lot about the asynchronous execution of methods to implement the BLE connection properly. This involved a lot of frustration in the first stages of development, when I was unaware of the asynchronous nature of the execution of different parts of the application. This new perspective on programming, along with the experience I now have with multi-threaded applications, has piqued my curiosity and renewed my interest in the realm of programming.

On a similar note, still on the subject of programming, working on the Floe companion app with a teammate was quite different from any previous programming experience I had. Indeed, the relative complexity of the program we were creating made writing the whole by oneself very impractical. Therefore, much discussion was required between the members of the software development team to coordinate the implementation of classes and methods, as well as the organization of the data structures and data flow through the program. I found this approach to programming very enjoyable and almost certainly more productive than single-person programming. Having to synchronize design decisions with another person made large systemic errors more difficult to create, thus saving much debugging time. Another interesting facet of team programming is that a lot of mutual trust is required between the team members. Because a single person cannot write the entire application, everyone has to rely on the code written by others for their own code to work properly.

Working with the team at Pinnacle Biometrics was a very agreeable experience. All members of the team were friends of mine before we started working on this project, and I am happy to say that, if anything, our friendships have only grown stronger. I have gained greater appreciation for my teammates' individual skills, and they have given me greater confidence in my own means. Our team worked very well as a unit, and I believe we are all satisfied with the amount of work the others contributed to the project. If I were to do this project over again, the only thing I would change is the speed of development. By starting serious development earlier, we could have found out about many of our programming issues sooner, and would have had more time to resolve them in an elegant way. Perhaps we might have even had the time to implement some of the features from our prototype model.

8.4 Clara Tsang

I remember first hearing about the Capstone project in my first year at SFU and thinking it a daunting, but comfortably distant, endeavor. Three years later, I thought it a daunting, and alarmingly near, endeavor. The experiences, skills, and knowledge gained from this project course deem it the most beneficial experience I have had in my undergraduate degree yet.

My personal learning outcomes of this project span between two main categories: technical skills and project management skills.

The software team consisted of Louis and myself; both of us were new to the Android API, or any API for that matter, as well as the programming language, Java. Without anyone with Android or mobile application expertise on our team, Louis and I took on the task to learn and implement the completely new concept. Weeks were spent researching and understanding the API before implementation commenced. This was my first time learning a language and highly technical skill outside of required course work. I was the main front-end software developer, and implemented the entire user interface of the application. Although my work was similar to programming that I had done in previous programming classes, what I was doing in this project had a much more realistic goal, rather than abstract theoretical practices, which I found to be inherently motivating – perhaps a motivation for future personal learning of technical skills. This project also allowed me to improve my coding style, as that was necessary in efficient implementation.

Lastly, it was refreshing to be able to apply rather abstract theories learned in my courses to the actual building of a project.

As a student aspiring to take on a project manager position later in my career, I took on the role of project manager within my team. I was able to employ and practice my organizational, communicative, and project management skills in this project – a rather limited opportunity in my usual school schedule. Several lessons were learned in managing this project. These included the importance in setting realistic goals within a given timeframe, the importance of persistent communication, as well as the effectiveness of the physical presence of team members as a productivity magnifier. The importance of timeframe-based realistic goals was a lesson learned from several scope scale-backs as listed in this document. The importance of persistent communication and physical presence was learned through the increase of productivity and morale when the topic and surrounding factors were more apparent to each team member.

Overall, I enjoyed the Capstone course and am grateful for the experiences and skills obtained through it. I am also grateful for being given the opportunity to work with the three talented individuals in my team. I look forward to applying both newly obtained technical and project management skill sets in my future coursework and career.

References

[1] *Project Proposal for Floe: the Athletic Balance Monitoring System for Skiers*, 1st ed. Pinnacle Biometrics, 2016, pp.5–7.

[2] *Functional Specifications for Floe: the Athletic Balance Monitoring System for Skiers*, 1st ed. Pinnacle Biometrics, 2016, pp.7–12.

Appendix A

Meeting Agendas/Minutes

Jan 15, 2016

Agenda
Purpose of Meeting: to determine project scope details and materials needed
Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Project Scope/Definition
    - Features:
        - 6 sensors/foot collecting weight distribution data
        - 1 SOC/foot processing data collected from sensors into data packet, packet sent to Jet via Bluetooth
        - App developed in Jet API:
            - Graphical display of where centre of weight is (real-time)
            - Recording and saving given time interval (record/pause functionalities)
            - Recorded playback of last event
            - Feedback for fall prevention/warning to stabilize
        - App developed in mobile Android API:
            - Storage of all recorded events
    - Design Constraints:
        - Weather/environment resistant (snow, low temperature, durability against physical impacts)
        - Small/comfortable
        - Real time constraints
        - Cost…
2. Project Funding
    - Materials Needed:
        - 2 SOCs
        - 12 FSRs
        - Recon Snow 2 installation
        - Power Supply (batteries)
        - Casing
        - Ski Boots
        - Insoles
        - Ribbon cabling
        - Electronic components

Jan 18, 2016

Agenda
Purpose of Meeting: to (properly) initiate project
Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Weekly Meeting Schedule, Communication
    a. Meetings
        i. Tuesdays 4:30-5:30
        ii. Fridays 10:30-12
    b. Communication Protocol
        i. Slack
        ii. Files uploaded to Google Drive
2. Project Schedule – tentative deadlines
    - Clara will make a detailed schedule on excel and upload onto the Drive
3. Research Topics – delegation
    - Bluetooth – Eric, Kurtis
    - Hardware specs – Kurtis
    - Data analysis/processing and biometrics – Clara/Louis

Jan 26, 2016

Agenda
Purpose of Meeting: to order materials and update on progress
Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Ordering Materials
    - Today:
        - 8-pack of FSRs
        - SoC
        - Cabling
2. Defining smaller goals:
    - Software
        i. First goal: Too far forward, too far back
    - Hardware
        i. Start circuit design

February 5, 2016

Agenda
Purpose of Meeting: updates, design spec breakdown
Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
    - Firmware
        - Environment set up
        - Research underway
    - Software
        - Pattern recognition not feasible
        -
    - Hardware
        - Parts arrived
        - Circuit design underway
2. Design Spec Breakdown
        - Sections split up on Google docs

February 12, 2016

Agenda
Purpose of Meeting: updates, redefine scope
Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
   - Firmware
     - Environment set up
     - Research underway
   - Software
     - Meeting with Gabi
       - Defined market to be: amateur/intermediate level skiers on groomed terrain
       - Post-run analysis more important than RT feedback
       - Turns are most important to track/analyze
       - Should we evaluate stance?
   - Hardware
     - Circuit design underway
2. Scope redefine
   - not implementing pattern recognition
   - implementing line charts, not run CoP playback
   - not implementing HUD display due to money

February 19, 2016

Agenda

Purpose of Meeting: updates

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
   - Firmware
     - One pin successfully sending data
     - Firmware dev - steady progress
   - Software
     - Research on Android API
     - Louis – research on implementing BLE services and implementing database in Android; design of classes for app
     - Clara – research on implementing UI, setting up Android Studio and GitHub for app dev
   - Hardware
     - Circuit designed
     - Meeting set up with past teacher to print PCB
     - Sensors tested

February 26, 2016

Agenda

Purpose of Meeting: updates

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
   - Firmware
     - One pin successfully sending data (no advancements since last time)
     - Firmware dev - steady progress
   - Software
     - Louis – classes defined and database dev underway
     - Clara – software program flow designed and all activities/services defined; main menu of app started
   - Hardware
     - PCB printed, circuit implementation underway
     - To do more testing

March 4, 2016

Agenda

Purpose of Meeting: updates, documentation scheduling

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
   - Firmware
     - 3 pins working – debugging/research
   - Software
     - Louis – database in progress, working on BLE service
     - Clara – main UIs done designing, working on app functionality
   - Hardware
     - Signal conditioning circuit built and tested – ready for connection
2. Design Specs
   - Deadline – using deadline extension
     - Sections split up on Google docs

March 11, 2016

Agenda

Purpose of Meeting: updates

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
    - Firmware
        - 3 pins working – debugging/research
        - 1 board set up and given to software for BLE development
    - Software
        - Louis – BLE service and database dev
        - Clara – app functionality (RT feedback, weight calibration, CoP calculation)
    - Hardware
        - Signal conditioning circuit built and tested – ready for connection
        - Sensors tested and must be replaced with 20lb-rated FSRs (100lb too much)

March 18, 2016

Agenda

Purpose of Meeting: updates, documentation deadlines

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
    - Firmware
        - No new updates
    - Software
        - Louis – working on BLE service
        - Clara – main UIs done designing, working on app functionality (mainly RT feedback GUI)
    - Hardware
        - Sensors switched and working better, tested with signal conditioning circuit
2. Documentation
    - Progress report – due March 28, sections split up on Google docs
    - Test plans – Clara will submit

April 6, 2016

Agenda

Purpose of Meeting: updates

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
    - Firmware
        - 4 pins working on 1 board, to instantiate other board
    - Software
        - Louis – BLE service ready to try connecting with working board
        - Clara – working on app functionality (linearization algorithm implemented to linearize received sensor data, RT feedback now working and ready for data receive)
    - Hardware/physical
        - Insoles set up and connected to signal conditioning, tested
        - BMH housing designed

April 14, 2016

Agenda

Purpose of Meeting: updates

Attendance: all present (Kurtis, Eric, Louis, Clara)

1. Updates
    - Firmware
        - Done, working on dev/debug with software
    - Software
        - Louis – dev and debugging for connection with board
        - Clara – all functions ready for receiving data, waiting on completion of BLE service, fine tuning UIs
    - Hardware
        - BMH housing built, insoles ready to be connected

READY FOR COMPONENT INTEGRATION – working together from now on