MOBILITATE

Post-Mortem for the R2000 Rehabilitative Exoskeleton

PROJECT TEAM	Chantal Osterman	CEO
	Lucia Zhang	CFO
	Jialiang Ou	CTO
	Ryan Villanueva	COO
CONTACT	Chantal Osterman	chantalo@sfu.ca
SUBMITTED TO	Dr. Andrew Rawicz	ENSC 440
	Steve Whitmore	ENSC 305
	School of Engineering Science	
	Simon Fraser University	

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Table of Contents

Table of Figures

List of Tables

1.0 Introduction

Mobilitate's R2000 is an attachable exoskeleton to aid in leg rehabilitation, particularly with a torn ACL, PCL, or arthritis. The product was designed to be used in conjunction with pre-purchased knee braces, as many of them can cost upwards of $500. By simply inputting parameters, such as degree of extension and number of repetitions, the R2000 will provide the power and assistance required for the user to reach their rehabilitative goals. It can be difficult for injured people to rehabilitate on their own, due to lack of motivation, convenience, and strength. As the R2000 is designed for home usage, it allows users to exercise on their own time and not rely on clinic personnel.

There are three main motivations behind the development of the R2000. The first is the fact that the increasing ratio of patients to physicians and physiotherapists is placing a strain on our healthcare sector, so other methods of rehabilitation must be considered in the near future. We aimed to provide a convenient, intuitive manner for those who suffer from knee injuries to rehabilitate at home without the need for a supervisor.

The second reason builds on the first. A study done by Frobell [1] shows that 60% of a control group that delayed reconstruction surgery in the knee in favour of rehabilitation no longer needed surgery. These results stress the importance of rehabilitation. If less people resort to surgery, the healthcare money used to subsidize knee surgery can be allocated to other areas.

The final reason is a personal one. This project provides experience in a number of engineering fields: biomechanical, software, electrical, and mechanical. By gaining hands-on experience in these fields individually, as well as integrating them together, we hope to build a strong skillset for future projects.

2.0 Project Overview

Figure 1 presents a high-level system diagram of the R2000.

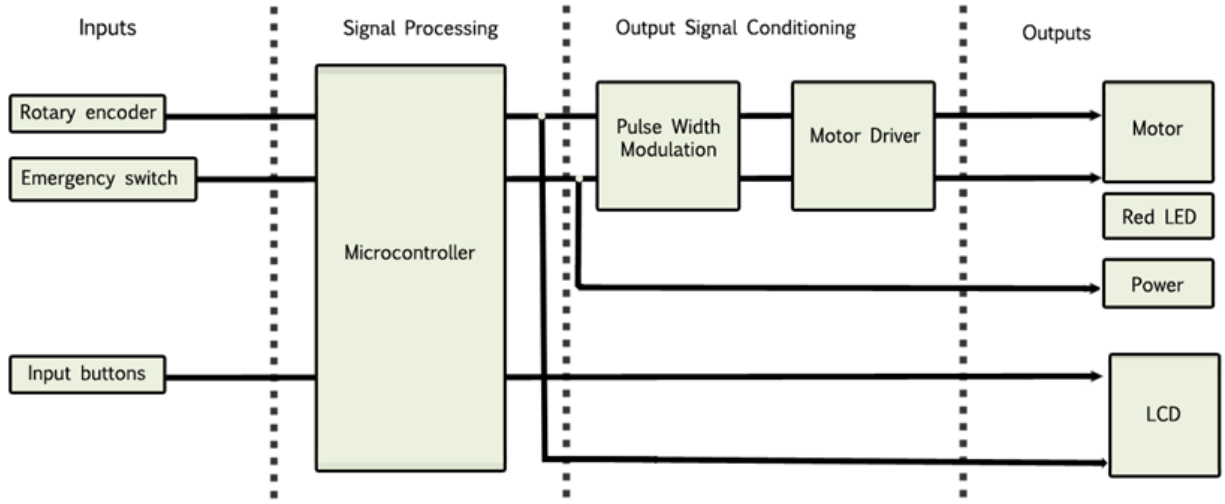

Figure 1: High-level system diagram

2.1 User Interface Unit

The UI unit is composed of both software and hardware.

2.1.1 Software

The software was implemented entirely under the Arduino environment. The user is prompted to make selections from the first menu, with the selections being:

- Input exercise parameters
- Calibration to set neutral position
- Current battery level
- Test input buttons

As shown above in Figure 1, the Arduino receives all user input, manipulates the data, and sends it to the corresponding outputs. For example, choosing the "input exercise parameters" prompts the user to enter the desired extension angle and the number of repetitions. The Arduino then generates and sends the corresponding PWM signals to the motor driver to control speed and direction of rotation.

"Calibration to set neutral position" is required as we implemented the R2000 with speed and directional control, not positional feedback, so there is no way for the motor to detect its current position. This is especially an issue if the exercise stops midway due to the user disconnecting power, or the distance sensor halting exercise due to obstacles. In this mode, the user turns the rotary encoder to control the motor and rigid bar to a comfortable position.

2.1.2 HARDWARE

The hardware of the UI is all mounted on a printed circuit board. The components are as follows:

- Arduino Uno
- LCD Shield and pushbuttons
- Rotary encoder
- Red LED
- Power and emergency switch
- Buzzer
- 9V battery

The pushbuttons and rotary encoder are used to input exercise information and traverse through menus. The LCD displays the menus as well as elapsed time and current repetition during exercise. The red LED will light up when the current battery level is under 50% of the maximum battery level. Audio feedback is also given through a buzzer, which emits a sound when the battery level hits 50%.

2.2 EXOSKELETON

The exoskeleton consists of the motor driver, motor, and rigid bar.

2.2.1 MOTOR DRIVER

The original motor driver is the jrk 21v3, which provides the option of position feedback. However, due to issues explained under "Challenges", we had to resort to a regular DC driver. The motor driver consists of an L298 H-bridge designed to deliver high current power to the exoskeleton, and can reverse the direction of rotation depending on what pulse-width modulated signal it receives from the Arduino.

2.2.2 MOTOR

A servo motor was chosen, primarily due to its high torque and position feedback. Using methods detailed in the functional and design specifications, we approximated the required torque to be 100kg-cm with a 10% safety contingency, resulting in a torque of 110kg-cm. The motor used was i00600 Torxis, which provides 115kg-cm.

2.2.3 RIGID BAR

The final rigid bar design is a slightly modified version of what was presented in the design specifications. It features a scooping feature to lift the user's calf, while not requiring dynamic length adjustments during the exercise. The scooping feature also provides a reliable and safe way to move the user's calf, as it places no strain on the user and ensures that the lifting motion is spread across the entire leg evenly.

3.0 Cost Breakdown

Table 1 contains the both the estimated and actual costs of the project.

Table 1: Estimated Cost vs Actual Cost

Component	Estimated Cost ($CAD)	Actual Cost ($CAD)
Servo Motor	482	509.16
Motor Enclosure (wood boards, joints, etc.)	N/A	Donated
Distance Sensor	20	12.32
Arduino Uno	Borrowed	Borrowed
Arduino LCD	35	33.60
Power Source	40	Borrowed
Rigid Bar (material and fabrication)	40	364
UI enclosure	N/A	90
Misc components (wires, gears, other sensors)	80	Donated
Contingencies	151.40	N/A
Total	908.40	1009.08

Changes in design are the main reason for the differences between estimated and actual cost. The estimated cost for the rigid bar was significantly lower than the actual cost, as we initially thought to purchase the material and fabricate it ourselves. However, the final design was much more complex than our initial design, and therefore had to be fabricated professionally.

Furthermore, we neglected to budget money specifically for the motor and UI enclosures, instead including these costs in the contingencies. We were, however, able to reduce costs by borrowing components from team members, as well as fabricating the motor enclosure by hand.

4.0 SCHEDULE

Figure 2 presents the original and actual project timeline.

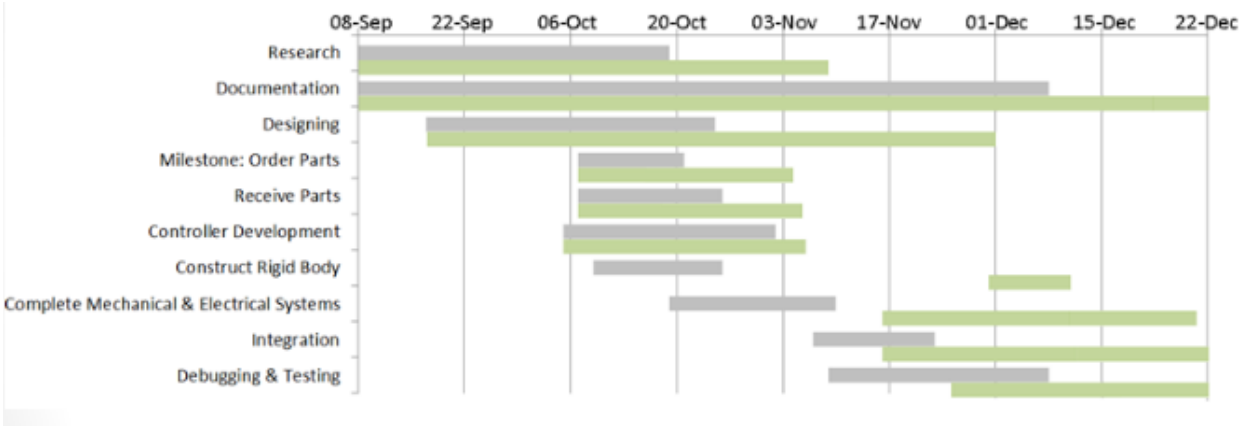

Figure 2: Gantt chart of the original (grey) and actual (green) project schedule

The main reason for our delay is because we were too cautious when purchasing parts, in particular the servo motor. As we did not have much experience with motors, we did a lot of research and gathered the opinions and experiences of past professors. Taking too long in acquiring parts caused major delays in other aspects of the project.

5.0 CHALLENGES

The main challenge faced was controlling the motor to rotate accurately. This issue was amplified when, a few days before the demo, the motor driver was bricked. To ensure a functioning product, we purchased a regular DC motor driver while also emailing motor support to see if we could salvage our original driver. Because of this change in drivers, we could no longer use position feedback, which would be much more accurate than speed and direction control. This also meant that the product would be less robust, as the user would have to manually calibrate the neutral position each time an exercise is stopped.

The scope of the R2000 has also been significantly narrowed. Rather than targeting both legs and allowing the user to perform a number of exercises, we focused only on the left leg and a simple extension and flexion exercise from 90 to 180 degrees. This is depicted below in Figure 3.

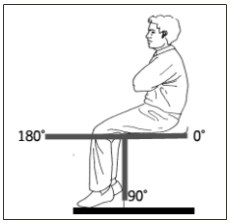

Figure 3: Angle diagram for R2000 usage [2]

Other challenges included having to continuously redesign components such as the UI enclosure, motor enclosure, and rigid bar. The rigid bar was the most important design, as it would be lifting the user's leg with a torque of 115kg-cm. Any errors and neglect in design could further injure the user.

6.0 Group Dynamics

For the most part, everyone was involved in almost all aspects of the project. However, for the sake of organization and leadership, team leads were assigned to the major projects as follows:

- Lucia: Mechanical lead
- Jialiang: Software lead
- Ryan: Electrical lead
- Chantal: Integration and testing lead

Having each member involved in all aspects was important, as we could all contribute to make informed decisions. Furthermore, if one person needed help, the others had enough context to quickly understand the problem and offer solutions.

Most tasks were initially designated according to previous experience. For example, Chantal performed the torque calculations and researched with Ryan and Lucia to determine the best method to implement the system. After sifting through hydraulics and pneumatics, particularly pneumatic artificial muscles, they settled on servo motors. At this point, Lucia began mechanical design and Ryan began electrical design. Jialiang started software development early on, as he has abundant experience with programming. Chantal acted as support for the other group members, as she had a good general understanding in all of these systems.

One of the major issues faced were due to miscommunication. On a few rare occasions, changes were made to designs without consulting other group members. Furthermore, some people had simply forgotten or were unaware of changes that had been made. These issues were quickly remedied through group meetings. At other times, rapid decisions had to be made concerning whether to include a certain feature, for example the distance sensor which would detect obstacles during exercise. The reason for choosing system leads was to address these problems. After each member presented their opinions, the system lead would have the final say, as they were the most involved.

Having only one motor also caused a few minor issues, as the motor was required for all system designs and implementations. When Lucia needed the motor to fabricate the rigid bar, Jialiang needed it to test the user interface. When Chantal needed the motor to create the enclosure and mounting shelf, Ryan needed it to test the electrical connections. While this was mostly solved by having everyone work in the lab at the same time, some members required days to complete some of their tasks, so this was another cause of delay. While we did face some issues, they were all resolved fairly quickly through clearer communication and sacrifices.

7.0 REFLECTION

7.1 WORKLOAD DISTRIBUTION

Table 2 presents the major technical, administrative, and support tasks required for R2000 development, as well as the level of involvement of each member.

Table 2: Workload distribution chart.

Task	Chantal	Jialiang	Ryan	Lucia
Documentation	XX	X	XX	X
Research and Design	X	X	X	X
Ordering Parts	X	X		X
UI Development (Software)	X	XX		
PCB Design	X	X	XX	X
Motor Enclosure	X			
UI Enclosure		X		XX
Rigid Bar Design	X		X	XX
System Integration	X	X	X	X
Testing and Debugging	X	X	X	X

x = some or equal responsibility

xx = primary responsibility

7.2 Chantal Osterman: Chief Executive Officer

The past four months have definitely provided me with a lot of hands-on experience. It's been very different from co-op, as with co-op you are usually given a set of tasks, a goal to achieve, and a few rules you must adhere to. For example, make a program in Ruby that achieves a certain functionality, and have monthly progress reports to a supervisor to ensure correct progress. With capstone, our team was in charge of everything from start to finish: the idea, design, implementation, and end goals. And this was both daunting and, in the end, rewarding.

As with most teams, we started off with an ambitious project: a portable leg exoskeleton that can perform a number of exercises to aid in patient rehabilitation. It would be mounted to the user, be minimal in design, and have a wireless user interface to enter exercise parameters. But after a few weeks of research and design, reality quickly set in with the first major reason of scope change: the size of the motor. With dimensions of 14x6x12cm and a mass of 1kg, there was no way we could safely mount this to the user. This issue also meant that we had to limit the range of available exercises to one: a 90-180 degree extension and flexion depicted in Figure 3.

Being involved in the entire lifecycle of product development also allowed us to see the consequences of all of our choices, and forced us to really think out our design choices. This was especially evident with the UI enclosure and PCB. We neglected to design in 3D, and therefore the end result had some components not flush against the lid or completely lined up with the holes that provided access to the pushbuttons.

As the CEO, it was my responsibility to ensure everyone was on the same page and on track. This was mostly achieved through the monthly documents required for capstone, as when they were completed everyone could reference these documents for Arduino pin connections, rigid bar dimensions, etc. But being the team leader meant having a careful balance between being strict and flexible without being a "hover parent". I also had to make sure that design choices for mechanics would not conflict with design choices for electronics, as I did not specialize in one system, but rather acted as the bridge between mechanical, electronic, and software.

This project definitely taught me the importance of documentation, communication, and teamwork. While documentation was incredibly time-consuming, it provided a solid reference for us to refer back to and ensure everyone was on the same page. Likewise, communication and teamwork were key components to ensure a successful project. This was a hands-on learning experience for us all, and not taking the time to properly explain any concepts to other members would have proved detrimental in the long run. That being said, I'm very pleased with how we worked as a team. We were able to debate issues without becoming offended, which to me is a successful sign of working as a team.

7.3 JIALIANG OU: CHIEF TECHNOLOGY OFFICER

By doing a capstone project, I have a deeper understanding of how engineer build things: trim down the impractical branches by trial and error, then leave in the main and the correct way to work. We have tried a few design ideas, but later on they were not doable so we had to give up on them even though the idea may sound nice. One example is pneumatic artificial muscles, which are lightweight and attach close to the patient's body. However, due to the inaccuracy of PAM control and the incapability of providing huge torque, we gave up on this cool idea and chose motor control in the end.

The most exciting learning experience is to comprehend the structure of servo motor and its control methods. In order to reach precise position control we have chosen a servo motor as our motor choice. Then we started to learn the way of controlling the motor, such as analog voltage and PWM signal control. Unlike a regular DC motor, a PWM signal is used to control position instead of speed. Later on, we actually disclosed our servo motor shield and tried to configure the parameters of motor drivers like angle limits, feedback, acceleration, current limit and PID calculation. During the process of configuration, many unexpected accidents occurred. One of the examples is the breaking of USB port. We actually had to order a new port and solder it back on the driver board so that the board can still communicate with the computer. All our team members contribute the greatest effort on making the motor to function properly and precisely.

In addition, I was new to the develop environment of Arduino before. This project gave me a chance to have a look at this open source platform. I got a lot of help on this friendly and generous community during the development of the first user interface of my life. The community provides abundant resources on control method such as button implementation, rotary encoders, LCD screen display and etc.

It is a great fortune that I worked in a team that devoted ourselves a lot to capstone project. I really enjoy working with our teammates, especially our CEO Chantal, who pushed us and encouraged us to move forward and worked the hardest . Also deepest thanks to our TAs and professors since they provide useful advice, guided us onto the right way, and showed us what a professional engineer should do.

7.4 Ryan Villanueva: Chief Operating Officer

In this Capstone project, I learned a lot of technical skills. The technical skills were by far the most aggravating, but they were rewarding to see when working. Getting the i00600 Torxis to finally move, after weeks of banging our heads against the wall, was amazing to see. Linking the servo to the Arduino, was even more exciting to see. It was a good introduction to PWM motor control and speed motor control that I hope to continue to hone in the future for projects. I think the most stressful part for me was the PCB as it had to be developed very shortly before the presentation date. In hindsight, I would have developed the PCB first, then developed the UI enclosure, as the UI enclosure did not quite fit with all the components inside. It feels good to know that our technical knowledge was being applied so that someday, someone might benefit from it while suffering from a leg injury.

This project also exposed my teamwork capabilities, whether good or bad. I'm glad I had Kevin, Chantal, and Lucia as my teammates. I think we worked well, and did our best to make sure we were always on the same page. However, it was hard for me to always stay focused on the task at hand because I view them as friends first (even though it might not be reciprocated). That's probably a reason why the Capstone instructors tell people not to form a group with friends. The lesson I took out of this was to learn where to draw the line between co-worker and friend.

This Capstone project was a quite a different experience. I've done term-long projects at BCIT, but nothing of this magnitude. I felt like at BCIT, they sometimes limit crazy project ideas, whereas SFU almost encourages crazy projects, which is definitely not a bad thing. It's almost like running your own business at SFU. However, setting the bar that high requires much more creative solutions in order to get a functioning project at the end. This is where having diverse team members had such a dramatic effect. Everyone has such different engineering backgrounds at SFU that it's almost impossible to run out of ideas.

I would like to personally thank the following people for their ongoing guidance during the project: Professor Andrew Rawicz, Professor Steve Whitmore, Lukas Mehri, and all the other TAs who helped give valuable feedback for if we ever wanted to take our product to the market.

My parting advice to students about to take ENSC 305/440 is to choose a project that interests you, give it your all, have fun, and don't stress out too much. Make sure you start integrating the project together early!

7.5 LUCIA ZHANG: CHIEF FINANCIAL OFFICER

Capstone gave us a great opportunity to apply our knowledge to a real project. It also provided us the experience of teamwork. Capstone project teamwork is not like writing lab report or making slides for a presentation together as a team. I am appreciated to work with Chantal, Kevin and Ryan. Capstone teamwork made us a group of 8 hands and only one mind.

Our group started with several project ideas and we did lots of researches for all of the ideas. Eventually, we chose the idea of rehabilitation exoskeleton for human leg. However, due to the time constraint, we only finished the motion for knees. Since the knee exercise requires a large torque, the first challenge of R2000 is the motor selection. The motor was supposed to be high torque with compact size. Moreover, the motor was also required to move with precise angles or positions, in order to achieve our goal which is to lift leg in difference angles. Stepper motor, servo motor, pneumatics air muscles and hydraulic motors were chosen as options. For the stepper motor, there has not enough torque for a single stepper motor, which means a motor synchronization would be needed. The worst case of pneumatic artificial muscles would be that when there was not enough air in the tube, the muscle would bend and there will be no support for the user. Hydraulic motor provides better support and the torque performance is satisfied; however, it could not help the user to reach the certain angle accurately. The issues with servo motor were size and price. A servo motor with a high torque weighs around 2.36 lb which is a lot of weight for a knee. Another idea to increase the torque of the motor is to design the gearbox by ourselves, which is a time consuming task and is not a good idea for a short-term project.

At this point, a servo motor was chosen and the rigid bar was redesigned several times. I learned about gears, pulleys and other mechanical design components. The strength, weight and thickness were the main concerns for fabrication. When we put the design into SolidWorks, we need to consider the thickness and strength of the material that we were going to use for the bar. Extrusion cutting helped with the weight reduction of the bar.

Our UI enclosure required a compact and ergonomic structure. We chose to use 3D printing for the enclosure. For 3D printing, we chose PLA to reduce our cost. During the design, the resolution, material strength, and printer allowance presented the most concerns for us. Since I had no experience with 3D printing, it was not easy to decide the size of each hole or block on the UI box, and we also need to ensure the sizes of screws or other components we are going to use can be found in the market. Due to the 0.75mm allowance of the 3D printer, our original UI enclosure was scale up the upper piece by 0.5mm.

Detecting obstacles in the path of the exercise motion is a good feature for this project, as we needed to make a decision when to detect and how to stop the motor after any object is detected. Before this semester, I have never heard of Arduino. In this project, I learned a bit about how Arduino works with sensor and how the sensor controls the motor via Arduino. The Arduino playground is a friendly community for users to learn and share their experience. I am willing to learn more about Arduino in the future.

Capstone project is a great opportunity which helps us to think like engineers. During the process, there are lots of details which can not be taught in textbooks or lecture notes. These little details built up a precious experience for my undergraduate life. I would like to thank all the TAs and professors who gave us suggestions and always kept us on the right track.

8.0 CONCLUSION

Overall, the R2000 exoskeleton was able to demonstrate the capability to potentially rehabilitate users with injured knee muscles by performing a lifting motion of the shank. Although we scaled back a lot of extra functionality, we were still able to retain the main rehabilitative purpose of the product. Despite the fact that we did not have an elegant enclosure or PCB during the demo, proper functionality for a proof-of-concept has higher priority than aesthetics, which can be modified easier at a later time.

Regarding the future plans of the R2000, the team feels that all development on the product should stop for the time being. As two members are leaving for co-op jobs next term, the amount of labor between the two remaining members to extend the exoskeleton into production would prove to be too much.

9.0 References

[1] R. Frobell et al. "A Randomized Trial of Treatment for Acute Anterior Cruciate Ligament Tears". N Engl J Med, 363., 331-342, July 2010.

[2] Assist Ireland. (2015). Choosing A Chair And Chair Accessories [Online]. Available: http://www.assistireland.ie/eng/Information/Information_Sheets/Choosing_a_Chair_and_Chair_Accessories.html, last accessed October 12, 2015

Mobilitate

AGENDA

September 17, 2015
13:00-14:00
Applied Sciences Building

Purpose of Meeting: To finalize project idea and begin designing.

Items for Discussion:

- Stick with exoskeleton for leg?
- What is the overall goal of our device?
- Will the product be worn in public and used intensively, or at home and less frequently?
- What makes the product marketable?
- Who is the target audience?

Mobilitate

MINUTES

September 17, 2015
13:00-14:00
Applied Sciences Building

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang

Absent: None

Purpose of Meeting: To finalize project idea and begin designing.

Minutes:

Chantal called the meeting to order at 13:00.

A. Approval of the agenda and minutes of the September 17, 2015 meeting

B. Finalizing the project idea

Discussion: Should the final project idea be an exoskeleton, or would more research be conducted for any other ideas such as the tennis robot or smart ingredient storage machine.

Action: All attendees agree with the exoskeleton, and unless incredible hardships are discovered within the next week, the exoskeleton will continue to be the project until the end.

C. Narrowing the project scope

Discussion: Ryan felt that the product should be used for increasing strength of normally healthy people. For example, allowing someone who could lift 50kg to lift twice that amount. Lucia and Chantal suggested rehabilitative purposes instead, for those who had weakened muscles due to injury or age.

Action: All attendees agreed that it should be used for rehabilitative purposes.

D. How and where the product would be used

Discussion: Chantal raised the issue of whether the product would be used in public, in which case aesthetics and portability would have a much higher priority, or in private. Other purposes such as helping with walking or hiking were discussed.

Action: The product will be used at home, therefore less intensively. This will also extend the types of power sources that can be used.

E. Extra functionalities and marketability

Discussion: Issues of defining features of the product were raised by all. Lucia recalled an airbag-like safety feature and presented a video showing an airbag jacket that deployed when a motorcyclist fell, and suggested something similar. Chantal also proposed an e-mail or text alert system in case of

product failure, similar to the Life Alert Emergency Response, Inc. service. A discussion of whether the product was to be marketed directly to end users, or through organizations such as clinics.

Action: The product will be marketed directly to end users. The functionalities issue was tabled until more research is conducted.

F. Next Meeting Date

The next meeting was arranged for September 18, 2015 at 10:30 in the Global Student Centre.

G. Other Business

None.

Mobilitate

AGENDA

September 18, 2015
10:45-12:00
Global Student Centre

Purpose of Meeting: To continue designing and brainstorming implementation of the product, as well as divide up proposal work.

Items for Discussion:

- What will the main power supply be: electrical power supply, hydraulics, pneumatics, or something else?
- Will the product be used for stationary or mobile purposes?
- Ideas for extra features?
- Relegating proposal work

Mobilitate

MINUTES

September 18, 2015
10:45-12:00
Global Student Centre

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang

Absent: None

Purpose of Meeting: To continue designing and brainstorming implementation of the product, as well as divide up proposal work.

Minutes:

Kevin called the meeting to order at 10:45.

A. Approval of the agenda and minutes of the September 17, 2015 meeting

B. Determining Power Source

Discussion: All raised the question of the main power source of the system. The three main ideas were a DC power supply, hydraulics, or pneumatics. Kevin raised concern over the price of hydraulics, as Lukas-Karim Merhi's project budget showed hydraulics would cost a few hundred dollars. However, Ryan mentioned he has experience with hydraulics. Chantal claimed a DC power supply would limit mobility of the product, but a retractable cord similar to a dog leash would prevent the cord from tangling.

Action: More research will be conducted over the weekend, and a preference will be decided by Sunday night before the ESSEF form must be sent in.

C. Mobile or stationary rehabilitation?

Discussion: The issue of what kind of exercise will be used was raised. Lucia and Kevin suggested walking (mobile), while Chantal proposed stationary such as squats and leg stretches.

Action: Stationary was chosen.

D. Extra features

Discussion: Kevin raised the issue that the product may not achieve the results desired, as the motor would contribute all of the strength and this may not help the user recover. Chantal recommended an auto-calibration feature. This would allow the user to attempt movement on their own first, and if no movement was detected, the motor would supply a small amount of power. This loop would continue until movement was detected, at which point the amount of power would stabilize. Other features include inputting an angle between zero and ninety measured perpendicular to the ground. This would train the user to be BLAH BLAH.

Action: All agreed these features would be good, and more research will be conducted of how to achieve them. An Arduino was suggested for implementation.

E. Relegating proposal work

Discussion: With the proposal due in one week and the ESSEF form due in two days, the documentation work was divided amongst all people.

Action: Chantal is in charge of the introduction and ESSEF fund form. Kevin will write the scope, benefits, and risk. Ryan will do the executive summary and conclusions. Lucia will do the cost breakdown and budget. Everyone will contribute to company details and project planning. A draft for the proposal will be completed by September 22, 2015 at 17:00.

F. Next Meeting Date

The next meeting date has not yet been scheduled.

G. Other Business

None.

Mobilitate

AGENDA

September 25, 2015
11:00-12:00
Global Student Centre

Purpose of Meeting: To further discuss product design and how to implement controller

Items for Discussion:

- Will the battery be mounted on the product, or as a separate wired unit?
- How will the controller be implemented?
- What will the support diagram look like?
- How will power be regulated?

Mobilitate

MINUTES

September 25, 2015
11:00-12:00
Global Student Centre

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang

Absent: None

Purpose of Meeting: To further discuss product design and how to implement controller.

Minutes:

Lucia called the meeting to order at 11:00.

A. Approval of the agenda and minutes of the September 25, 2015 meeting

B. Will the battery be mounted on product, or treated as a separate wired unit?

Discussion: Chantal raised the issue. All agreed that, if using a battery as a power source, mounting it on the person would allow the product to be more mobile. That is, if someone was in the middle of exercising and needed to pause and get the phone or wash dishes, the product could still be worn while performing this chore. However, Ryan stated that if the battery was too heavy, it could hinder the user.

Action: Mounted on the product is preferred, but if the stepper motor chosen requires a large battery or a number of batteries, a separate unit will be used.

C. How will the controller be implemented?

Discussion: Kevin suggested that a cell phone could be used as the controller, and communicate with the Arduino via Bluetooth. Chantal suggested using two Arduinos, one in the controller and one on the product. Lucia said a wired connection would be easier and cheaper to implement, but would mean that the controller is mounted on the product when not in use.

Action: Kevin will conduct more research into app development and using a cell phone as the controller. He will report back his findings at the next meeting.

D. What will the support diagram look like?

Discussion: Chantal raised the issue that power may not be distributed evenly across the leg during movement. In other words, the outer side of the leg that has the rigid support will lift more than the inner side of the leg, resulting in a lack of comfort. Ryan brought up the torsion spring mentioned before, and said placing it under the knee would help. Chantal said the ankle is small, so power distribution should not be a problem there. Lucia brought up using joints at the knee and hip to allow for sideways movement.

Action: If using stepper motors, a spring would be good not only for power distribution, but would also be able to provide some torque. Lucia will look more into joints and present the information next meeting.

E. How will power be regulated?

Discussion: Chantal raised the issue of regulating power with the feedback mechanism. If more power is needed, how will the power source know how much to provide? She mentioned two possible ways: the first using a resistor ladder, switches, and one power source. The second used an Arduino and a digital pot, in particular the AD5171 which has 64 levels of resistance. It only uses 2 of the 6 analog pins, which might work with the project.

Action: Ryan will do more research into power regulation and report findings at the next meeting.

F. Next Meeting Date

The next meeting date has been scheduled for September 30 at 1:30.

G. Other Business
None.

Mobilitate

AGENDA

September 30, 2015
13:50-14:30
ASB Laboratory 4

Purpose of Meeting: To discuss progress with the design, especially to report findings from last meeting.

Items for Discussion:

- Controller progress
- Joints progress
- Power regulation progress

Mobilitate

MINUTES

September 30, 2015
13:50-14:30
ASB Laboratory 4

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang

Absent: None

Purpose of Meeting: To discuss progress with the design, especially to report findings from last meeting.

Minutes:

Chantal called the meeting to order at 13:50.

A. Approval of the agenda and minutes of the September 30, 2015 meeting

B. What is the progress on the controller?

Discussion: All decided that using a cell-phone as the controller would limit the market to only those who have Android phones, so a universal controller would be best.

Action: Chantal will give her Arduino and accompanying components to Kevin, who will familiarize himself with how to use an Arduino. He will also begin controller development. Lucia will purchased the muscle sensor kit from Lee's Electronics this weekend.

C. What is the progress on the joints?

Discussion: Lucia presented information on three types of joints. One can be bought, and the other two would be modeled in Solidworks and 3D printed.

Action: ???

D. What is the progress on the power regulation?

Discussion: Ryan found a stepper motor shield for the Arduino that can control up to two stepper motors. Chantal raised the issue that it will take up almost all of the pins for the Arduino, so another Arduino must be purchased if it is needed for anything else.

Action: The shield will not be purchased yet. Other ways to regulate power will be looked into as well.

F. Next Meeting Date

The next meeting date has been scheduled for October 2 at 11:00.

G. Other Business
None.

Mobilitate

AGENDA

October 6, 2015
11:50-13:10
SFU Laboratory 1

Purpose of Meeting: To discuss design issues

Items for Discussion:

- Issues with using motors
- Controller implementation
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Mobilitate

MINUTES

October 6, 2015
11:50-13:10
SFU Laboratory 1

Present: Kevin, Ryan, Chantal

Absent: Lucia (ankle sprained)

Purpose of Meeting: To discuss design issues

Minutes:

Chantal called the meeting to order at 11:50.

A. Approval of the agenda and minutes of the October 6, 2015 meeting

B. Issues with using motors

Discussion: Chantal noted that a stepper motor might not provide enough torque to move the average person's knee, and presented her calculations. Kevin suggested using two smaller motors, and Chantal raised the issue that two motors may be too heavy or bulky. She also suggested using pneumatics instead, in particular PAMs, in lieu of stepper motors.

Action: A small-scale PAM would be constructed by Friday to test it usability to the current application. If successful with good reliability, the entire project may be done with pneumatics instead. However, the issue of non-smooth motion resulting from PAMs is still on the table.

C. Implementation of the controller

Discussion: Kevin suggested two manners of implementation: one is Arduino to Arduino, where the Arduino in the controller interfaces with the one on the product. The other is Arduino to android phones using an app and Bluetooth. The pro of the former is that it doesn't limit the market to people who only have android. The disadvantages are the cost and limited input method. Furthermore, both would need a shield for communication, and the Tx and Rx ports of the on-board Arduino are already used by the motor driver. The pro of the latter is it is less costly and easy to control, broadening the amount in input methods and providing a better display than an LCD. The cons are that it requires app development, which is not the same across android and apple devices.

Action: Issue was tabled until the team decides whether to use pneumatics, stepper motors, or a combination of the two. A wired controller may be defaulted to in the near future.

D. Next Meeting Date

The next meeting was arranged for October 9, 2015 at 10:30.

E. Other Business

Mobilitate

AGENDA

October 09, 2015
11:00-12:30
Parking Lot

Purpose of Meeting: To test pneumatic artificial muscles and discuss progress.

Items for Discussion:

- Will PAMs work?
- How will we divide up the functional specs?
- What should be done over the next week?

Mobilitate

MINUTES

October 09, 2015
11:00-12:30
Parking Lot

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang

Absent: None

Purpose of Meeting: To test pneumatic artificial muscles and discuss progress.

Minutes:

Kevin called the meeting to order at 11:00.

A. Approval of the agenda and minutes of the October 9, 2015 meeting

B. Will PAMs work?

Discussion: Ryan purchased the components for a small-scale PAM. Construction began, then testing was done with Ryan's air pump. The PAM was leaking from both ends and only slightly contracted.

Action: Ryan will continue to work with the PAM over the next week to try and solve the leaking problem. Further discussion about this will occur next week.

C. How will we divide up the functional specs?

Discussion: Parts for the functional spec must be assigned so that a draft can be completed by October 14.

Action: Chantal will do the general system and editing, Kevin the user interface unit (controller), Lucia the exoskeleton, and Ryan the summary, conclusion, editing, and formatting.

D. What should be done over the next week?

Discussion: Tasks for the next week, as well as deadlines for decisions, must be made.

Action: Chantal and Kevin will work on the UI unit. Ryan will continue to work with the PAMs. Lucia will do research into using motors in lieu of PAMs.

F. Next Meeting Date

The next meeting date has not been decided.

G. Other Business
None.

Mobilitate

AGENDA

November 06, 2015
11:30 - 13:00
ASB Laboratory 1

Purpose of Meeting: To finalize design specifications and share progress on individual parts.

Items for Discussion:

- Should the power supply in the proof-of-concept be battery (mounted) or external?
- What should the final exoskeleton design be, and what materials should be used?
- What will the UI interface enclosure be made of?
- Should we do PCBs or something else for the UI interface and motor controller?
- Discuss what changes need to be made to the Design Specifications.

Mobilitate

MINUTES

November 06, 2015
11:30 - 13:00
ASB Laboratory 1

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang (arrived one hour late due to a quiz)

Absent: None

Purpose of Meeting: To finalize design specifications and share progress on individual parts.

Minutes:

Kevin called the meeting to order at 11:00.

A. Approval of the agenda and minutes of the November 6, 2015 meeting

B. Should the power supply in the proof-of-concept be battery (mounted) or external?

Discussion: Chantal mentioned that a battery would be better, but depending on how much power is needed, portability of the prototype could be sacrificed. Ryan said that research he and Chantal had done on the motors shows a LiPo battery can be used.

Action: A LiPo battery will be used.

C. What should the final exoskeleton design be, and what materials should be used?

Discussion: Chantal and Lucia presented designs for the exoskeleton, including rigid bar design and motor mounting methods. Kevin and Chantal also suggested materials such as aluminium, titanium, steel, and plastic.

Action: More designs will be drawn up for the exoskeleton, with fabrication beginning within the next few weeks. Materials for the rigid bar will be researched by Lucia.

D. What will the UI interface enclosure be made of?

Discussion: All group members brought up the concern of heat dissipation, but realized that the Arduino Uno will not generate enough heat to warrant concern. Suggested materials are more broad for the UI enclosure versus the motor enclosure, and include metal, plastic, and wood.

Action: All group members will research materials, and come to a decision at the end of next week.

F. Next Meeting Date

The next meeting date has not been decided.

G. Other Business
None.

Mobilitate

AGENDA

November 20, 2015
10:30-11:30
ASB Laboratory 1

Purpose of Meeting: To discuss progress of each project component.

Items for Discussion:

- What is the progress with integrating the motor and UI?
- How should the motor be mounted to the user?
- Are there any other designs for the rigid bar system?
- How is the implementation of the distance sensor coming along?
- Designing the UI enclosure.

Mobilitate

MINUTES

November 20, 2015
10:30-11:30
ASB Laboratory 1

Present: Chantal Osterman, Kevin Ou, Ryan Villaneuva, Lucia Zhang

Absent: None

Purpose of Meeting: To discuss progress of each project component.

Minutes:

Kevin called the meeting to order at 10:30.

A. Approval of the agenda and minutes of the November 20, 2015 meeting

B. What is the progress with integrating the motor and UI?

Discussion: Ryan and Kevin are currently experiencing problems sending PWM signals to the motor driver via Arduino. One problem is that the motor senses signals between 50-100Hz, but the Arduino is between 500Hz-20kHz.

Action: Chantal suggested scaling the signal from the Arduino so it falls within the desired range. Ryan and Kevin will continue to work on integrating the UI and motor.

C. How should the motor be mounted to the user?

Discussion: Lucia and Chantal discussed designs for mounting the motor, also bringing up the concern that the user's thigh must remain stationary during exercise. Chantal suggested a wooden shelf placed on the chair and over the user's knee. While bulky, it would serve its purpose. Lucia suggested a more minimal design that included a curved triangle base that would be mounted on top of the knee with velcro, and the motor box would be secured on top of that.

Action: Chantal will begin construction of the box this week and provide her insight of which design is more doable and secure.

D. How is the implementation of the distance sensor coming along?

Discussion: Lucia reported her research done on the sensor, including an algorithm of how detecting obstacles can be achieved.

Action: Work on the distance sensor will be halted temporarily until the motor and UI are integrated, as the distance sensor must be connected to the UI.

E. Designing the UI enclosure.

Discussion: Chantal proposed a design for the UI enclosure, which includes a small slot for the battery if it does not share a battery with the motor.

Action: Lucia will create the design in Solidworks and look into 3D printing services at school.

F. Next Meeting Date

The next meeting will be held once the motor enclosure is completed.

G. Other Business

None.

Mobilitate

AGENDA

December 05, 2015
13:00-14:00
ASB Laboratory 1

Purpose of Meeting: To discuss and integrate components, as well as discuss the post-mortem.

Items for Discussion:

- Is the rigid bar sufficient for our uses, or will we have to redesign and refabricate?
- What is the progress regarding the UI?
- Where will the servo be placed on the leg?
- Where will the servo be housed?

Mobilitate

MINUTES

December 05, 2015
13:00-14:00
ASB Laboratory 1

Present: Chantal Osterman, Kevin Ou, Ryan Villanueva, Lucia Zhang

Absent: None

Purpose of Meeting: To discuss and integrate components, as well as discuss the post-mortem.

Minutes:

Kevin called the meeting to order at 13:00.

A. Approval of the agenda and minutes of the December 5, 2015 meeting

B. Is the rigid bar sufficient for our uses, or will we have to redesign and refabricate?

Discussion: Lucia presented the fabricated rigid bar. However, the bar is made specifically for the left leg, whereas development for the exoskeleton was initially set for the right leg.

Action: The exoskeleton will now have to be placed on the left leg. Any servo commands originating from the Arduino will now have to be remapped in order to compensate for relocation of the exoskeleton. No redesign or refabrication will be required at this point in time.

C. What is the progress regarding the UI?

Discussion: Kevin presented the UI. The main function of accepting input from the rotary encoder and outputting the angle to the motor has been accomplished. However, as pointed out in part B, the location of the exoskeleton has changed to the left leg. The code for the right leg will now have to be recalibrated for the left leg.

Action: Kevin and Ryan will recalibrate the code to allow the motor to turn properly when the exoskeleton is placed on the left leg. Kevin will also keep working on the software, as required by the test plan.

D. Where will the servo be placed on the leg?

Discussion: As discussed in previous meetings, the servo may lie on a shelf on a chair, or a curved triangle base that would be mounted on top of the knee with Velcro. Chantal has started work on the shelf, which looks structurally more stable than the curved triangular base.

Action: Team members all agreed that the shelf is a more feasable option rather than the curved triangular base. Chantal will continue to work on the shelf to ensure maximum stability when placed on a chair.

E. Where will the servo be housed?

Discussion: Chantal discussed options about where to house the servo. The most likely candidate would be to build a box out of wood in order to keep our costs low and allow flexibility in case the dimensioning changes.

Action: Chantal to start building wooden box to house the servo motor.

F. Next Meeting Date

The next meeting will be held once the motor enclosure is completed.

G. Other Business

None.

Mobilitate

AGENDA

December 17, 2015
15:00-16:00
ASB Laboratory 1

Purpose of Meeting: To discuss how to replace the motor controller.

Items for Discussion:

- How, if possible, can we recover the jrk?
- How will we replace the servo driver?

Mobilitate

MINUTES

December 17, 2015
15:00-16:00
ASB Laboratory 1

Present: Chantal Osterman, Kevin Ou, Ryan Villanueva, Lucia Zhang

Absent: None

Purpose of Meeting: To discuss how to replace the motor controller.

Minutes:

Kevin called the meeting to order at 15:00.

A. Approval of the agenda and minutes of the December 17, 2015 meeting

B. How, if possible, can we recover the jrk?

Discussion: Due to uploading the wrong software update, the jrk is no longer functioning. Applying power and inputs does not turn the jrk on. Chantal suggests to email Pololu to receive help. Ryan and Kevin opt to buy a locally available motor driver to power the motor.

Action: Chantal to immediately email Pololu for help. Kevin and Ryan to continue to try and revive board.

C. How will we replace the servo driver?

Discussion: Continuing with the last point, if Pololu does not respond within a day, critical time will be lost. Chantal suggests if there is no other way, we must buy H-bridge locally.

Action: Chantal and Lucia to immediately go to RP Electronics and find an H-bridge suitable for our purposes. Ryan and Kevin will continue to work on reviving the jrk and look for different H-boards online.

F. Next Meeting Date

The next meeting date is unknown.

G. Other Business
None.