MOBILITATE

September 28, 2015

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

RE: ENSC 305/440 Project Proposal for an Attachable Exoskeleton Device to Aid in Leg Rehabilitation

Dear Dr. Rawicz,

Enclosed is our document entitled "Project Proposal for an Attachable Exoskeleton Device to Aid in Leg Rehabilitation", which serves as the foundation for our ENSC 305/440 Capstone project. We endeavor to design, prototype, and test a rehabilitative, lower-body exoskeleton, codenamed R2000, that enables users with weak and degenerative leg muscles to perform exercises and stretches in lieu of surgery.

The proposal will highlight our proposed design, including the system's functionality, safety, and budget. The overall risks, benefits, and current industry competition is considered as well. A brief overview of the project schedule and team members undertaking this project is included as well.

Mobilitate consists of four inventive engineers from Simon Fraser University's School of Engineering Science: Kevin Ou, Lucia Zhang, Chantal Osterman, and Ryan Villanueva.

If you have any questions or concerns regarding our company, product, or proposal, please feel free to contact us at chantalo@sfu.ca.

Sincerely,

Chantal Osterman
CEO

Proposal for an Attachable Exoskeleton Device to Aid in Leg Rehabilitation

PROJECT TEAM	Chantal Osterman	CEO
	Lucia Zhang	CFO
	Jialiang Ou	CTO
	Ryan Villanueva	COO
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SUBMITTED TO	Dr. Andrew Rawicz	ENSC 440
	Steve Whitmore	ENSC 305
	School of Engineering Science	
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REVISION 1.1

ISSUED September 28, 2015

Executive Summary

Every year, millions of Canadians are inhibited by injuries targeting their leg muscles. While many of these injuries require surgical intervention, studies show that a majority of these injuries would benefit from active rehabilitation through strength conditioning and stretching, eventually leading to not having to need surgery at all. However, many people refuse to start the initial strength conditioning program which causes them inconvenience in their busy schedules.

Mobilitate intends to encourage convenient and accessible rehabilitation by the use of an attachable exoskeleton called the R2000 which will assist users with their exercises and stretches. A set of stepper motors and springs will help alleviate the strain on the injured leg while exercising by assisting with rising, crouching, or stretching motions. Selectable, preprogrammed exercises with limiting leg motion parameters will enable users to condition themselves below their pain threshold and will assist in keeping track of their progress.

The team at Mobilitate consists of four senior Simon Fraser University engineering students. Their expertise in a wide variety of fields, such as software engineering, mechanical design, biomedical imaging, and telecommunications establishes an innovative project dynamic. This versatility is also crucial to the project's successful culmination.

With careful design, Mobilitate's R2000 is projected to incur expenses of $908.40. Funding will be provided through the ESSEF, SFU School of Engineering, and the Wighton Fund. The expected project completion date is December 8, 2015.

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Introduction

In 2009, approximately 4.27 million Canadians over the age of 12 suffered injuries that inhibited their normal life [1]. Of these people, approximately 51% suffered a sprain or strain [2], and for 37% the injury occurred in their legs [3]. While reconstruction surgery is only required for Grade III tears in the anterior cruciate ligament (ACL) or posterior cruciate ligament (PCL) in the knee [4], many people still opt to skip the initial rehabilitation in favour of it.

However, according to a 2010 clinical trial conducted in by Frobell at the University of Lund [5], this may be the wrong approach. He suggests that rehabilitation should be the first step, and surgery should only be used until the need for it is obvious. His findings support this, as 60% of the control group that delayed ACL surgery in favour of exercise found that they no longer needed an operation [6]. An important factor in this recovery is that mild stretching and exercise occurred shortly after the injury was received.

R2000 aims to help users with the strength training through rehabilitation. The exoskeleton is to be attached to pre-purchased braces, meaning users do not have to purchase an entirely new customized brace after previously spending up to $1000. The accompanying controller allows the customer to select from pre-programmed exercises and input details such as bending angle and number of repetitions, providing a customized experience.

Many exoskeletons on the market are incredibly expensive, large, and complex, meaning their usages are mostly limited to hospitals and clinics. This increases the ratio of patients to therapists, and subsequently appointments may be difficult to book. The resulting infrequent rehabilitation may cause muscle fibers to shrink, in some cases by 20% in just two weeks [7].

A large factor that prevents people from exercising and healing injuries on their own is inconvenience. It is a more lengthy solution than surgery, and requires the patient to travel to and from a clinic, decreasing motivation. R2000 will provide a safe, convenient means for users to exercise in the comfort of their own home. An intuitive interface will allow anyone to use it without fear of injuring themselves or damaging the product, and a number of safety features will be included to ensure the user's well-being.

System Overview

Functionality

Figure 1 below details a general overview of the system.

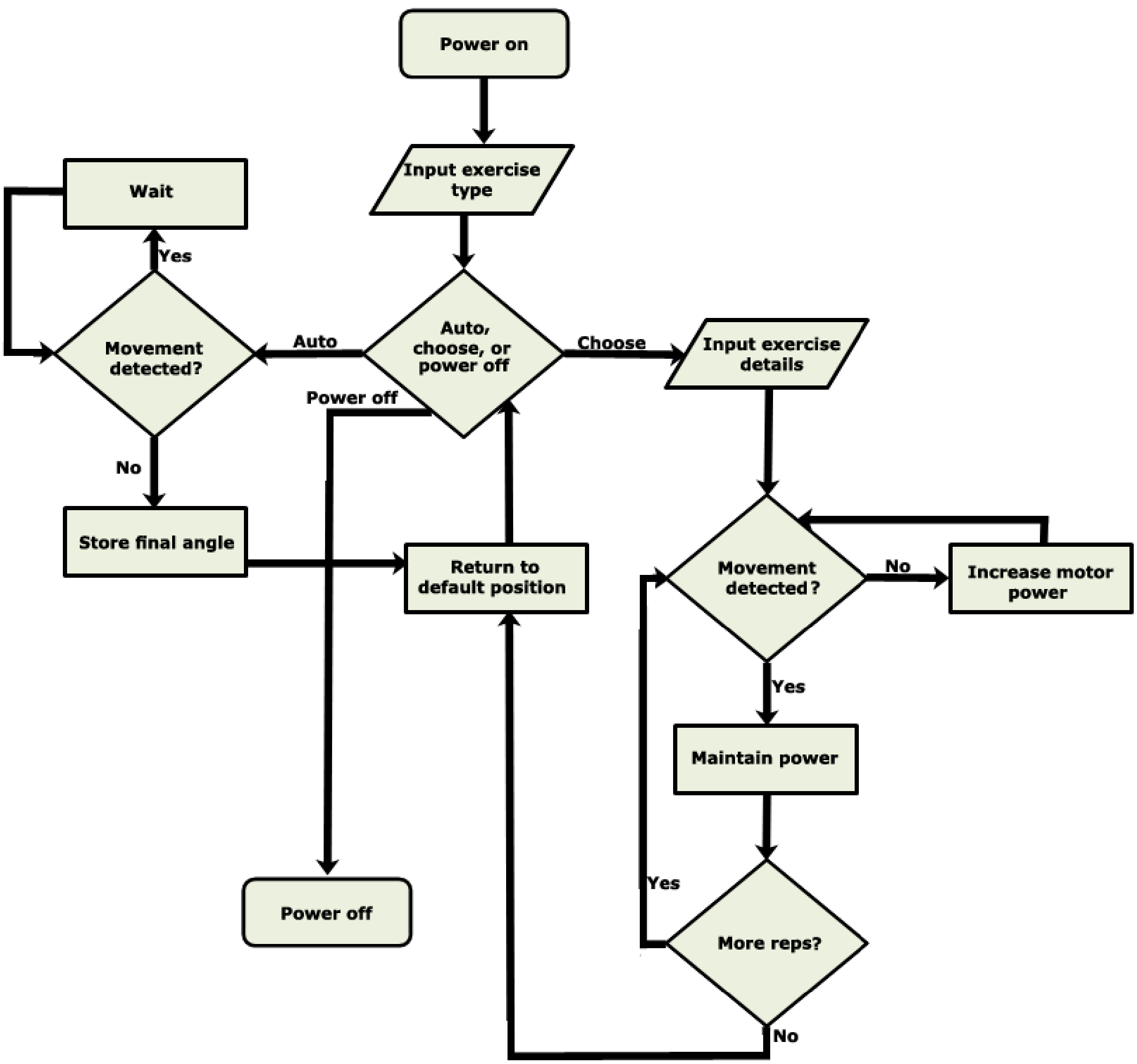

Figure 1: Flowchart for the General Overview of the R2000

The user first chooses the type of exercise he wants to perform, for example knee extensions or squatting. Next there is a choice of whether the angle of exercise, an example of which is given in Figure 2, should be entered manually, or found through the auto-calibration method.

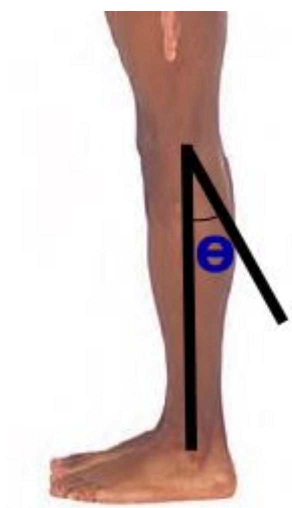

Figure 2: Example of knee angle, perpendicular to direction of motion [8]

If auto-calibration is chosen, the user will then be prompted to perform the selected exercise as far as they can. No movement detected translates to the user reaching his maximum angular displacement, so at this point the angle is stored and the exoskeleton returns to its default position. If the user is happy with this final angle, it can be used for the next step. If not, he can re-calibrate or simply enter his own angle. Other details, such as the number of repetitions, will then need to be entered.

At this point the exercise will begin. The user will first attempt to perform the exercise on his own. If the muscle sensors pick up muscles tensing but no movement is detected, the motors will turn on and provide assistance. If there is still no movement, the motor power will increase slightly. This loop continues until movement is detected, at which point the motor power will be held steady either until movement ceases or the number of repetitions is over.

Safety

As the R2000 will be physically attached and used by those with injuries, a number of safety precautions will be required. First and foremost will be an emergency stop button, which will immediately stop all processes and return the exoskeleton to its default state for easy removal.

Another idea is an optional e-mail or text alert to be sent to a specified recipient in case of product malfunction. This will alert a third party that the user may need assistance. Feedback systems will also be in place to ensure motors do not overheat, and that the R2000 will be in a safe position for removal if the power source need to be recharged or replaced.

Scope

Risks

First and foremost is having movements that do not mimic the leg's natural motions. Stretches and flexes done at improper angles or performed past the user's limits could occur. Furthermore, the weight distribution of each component could be sub-optimal and introduce more pain for the user. To avoid this, characteristics like the structure and natural motions of the leg and hip must be researched. A number of tests using different tests and conditions will also be conducted to pin-point any unforeseen burdens.

As there are many components involved, they must all be tested and regulated carefully. The rigid structure could break, either due to insufficient strength or due to the motor movements. If the rest of the system still functions and there is no secondary safety mechanism, the user and product could suffer damage. The motors and controller must also be precise and stable. Malfunctioning motors or code with errors could break the device and further injure the user. As mentioned before, features to avoid this include an emergency stop button and a number of quick, responsive feedback systems.

Benefits

There are two main draws to our product, the first being that it offers convenience and can be easily used. The attachment process will only require using straps and simple adjustments to the support bar lengths to fit each person's leg. The product will also be designed to be small and lightweight enough that the user can walk around or perform tasks, such as washing dishes, without having to remove it. Having an easy to use device means less direct supervision is required, so the user can operate it at home instead of going to a clinic for rehabilitation.

The second main benefit ties in with the first. Because it is easy and convenient to use, it encourages rehabilitation, both before and after surgery. If more people have the means to rehabilitate on their own, they may not, as Frobell's study [6] shows, need surgery. Subsequently, those who are able to rehabilitate in lieu of surgery save money. Furthermore, health care money allocated to subsidize this surgery can be used elsewhere, therefore providing more funding to other sectors of health.

Market Research

Competition

Most of the powered exoskeletons on the market are designed for military purposes. Based on the budget and accessible resources, we decided to focus on medical usage. Japanese company Cyberdyne has developed a whole lower-body structure to fully support patients, enabling them to walk again [9]. However, the full support system inevitably leads to a high cost of the solution. Otherwise, recovering patients need specific tutors or nursing aides to assist in learning how to walk again.

We want to focus on rehabilitation for home use and also to reduce our product size as much as possible to discourage the increased expense for our product. Therefore our goal is to modularize our product to several specific joints on human lower-body. Patients have options to choose which specific part they need instead of using the whole structures. Comparing to other rehabilitation exoskeletons, we intend to have a more compact size that is more patient-oriented and provides greater flexibility available to customers.

Project Schedule

Figure 3 depicts the project's start and end date, and the timelines of the major tasks. Figure 4 denotes several project milestone dates regarding documentation. The expected project end date is December 8, 2015.

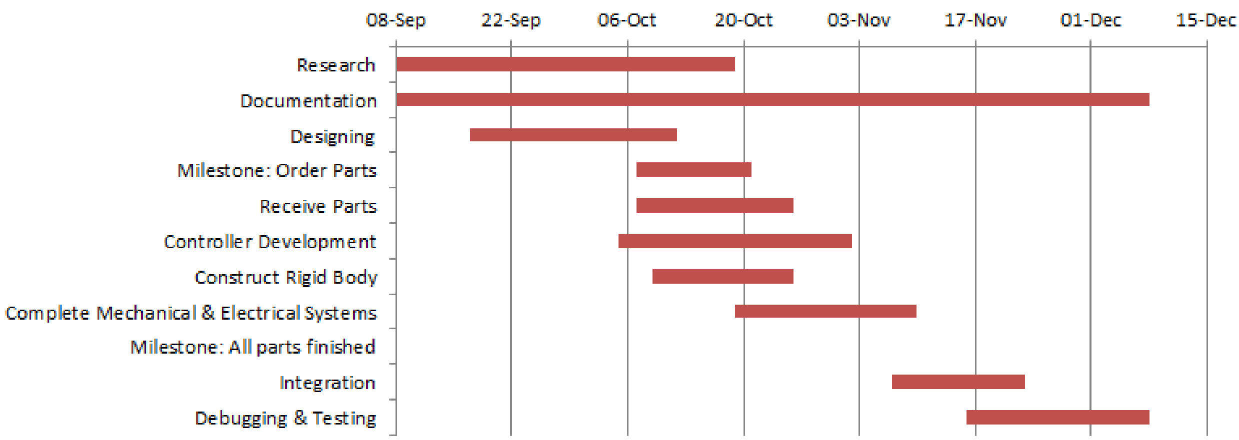

Figure 3: Project Gantt Chart

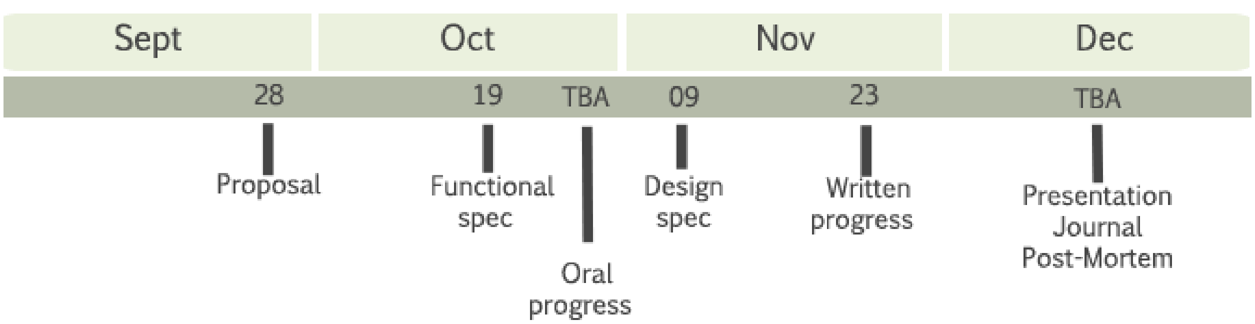

Figure 4: Project Milestone Chart

Cost Considerations

Budget

Table 1 below displays the projected cost to develop this product. Taking into account the US dollar to Canadian dollar conversion and leeway for contingencies, we expect this product to cost $908.40 to develop.

Table 1: Projected Costs

MATERIALS LIST	ESTIMATE
High Torque Servo Motor (1501MG)	$32.00
Muscle Sensor Kit V3	$60.00
Hybrid Stepper Motor (S9123M-S30HT) and drivers	$450.00
Battery	$40.00
4x16 LCD Display (TC1604A-01)	$30.00
Membrane 3x4 Matrix Keypad	$5.00
Alloy Metal	$40.00
Torsion Spring (TO-1119)	$20.00
Distance IR Sensor	$20.00
Misc gears, wires, sensors, etc.	$60.00
Total (including currency conversion and contingencies)	$908.40

Funding

Mobilitate's funding for this project will be generated through the generous support of the following groups: ESSEF, SFU School of Engineering, and the Wighton Fund.

Company Details

Chantal Osterman - CEO

I am a fifth year system engineering student at Simon Fraser University. During my two coop positions, I developed hands-on experience lab skills as well as worked through the entire lifecycle of program development and delivery. I believe I will bet fit in as the integrator between electronics and mechanics in this project due to my work tasks, knowledge gained through the electronic, robotic and control courses, as well as my experience with digital image processing and mathematical modelling in Matlab.

Jialiang (Kevin) Ou – CTO

As a fifth year undergraduate in Computer Engineering major at Simon Fraser University, I am experienced in objective programming, database queries, and basic shell implementation. Besides those, I love digital system design on FPGA boards including sound processing systems. I am also familiar with Solidworks. By contributing my knowledge to the project, I hope to ensure the success of our product with my teammates.

Lucia Zhang- CFO

I am currently studying at Simon Fraser University, majoring in Systems Engineering. I was working at SoYoung.Co., Ltd (Beijing) as an App Tester and I gained knowledge in the development of both smartphone apps and webpages. I have experience with HTML, C++, MatLab and LT Spice. I also have experience with lab equipment, such as oscilloscopes, DMMs and function generators. I am familiar with SolidWorks and also interested in mechanical design.

Ryan Villanueva – COO

I graduated from BCIT's Electrical and Computer Engineering Technology program in 2012, specializing in telecommunications. I am currently an ASTTBC Graduate Technologist and in my final year in the Systems Engineering program at Simon Fraser University. My primary interests include VHF radio design, embedded systems prototyping, and materials engineering.

Conclusion

Here at Mobilitate, we remain dedicated to providing lower body rehabilitation to people both awaiting surgery and after. The R2000 rehabilitative exoskeleton intends to provide safe, comfortable, and effortless leg conditioning and stretching in the convenience of the consumer's home. The ease of use and accessibility of R2000 encourages the self-development of injured leg muscles that will either render surgery nonessential to the consumer or promote healing pace. With a low-development cost, minimal market competition, and an enthusiastic engineering team behind the product, the R2000 will serve as a new beginning in lower-body rehabilitation.

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