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Project Proposal

Introduction

Knee injuries are prevalent in today's society. For example, over 200,000 ACL tears occur each year (1). In order to return to daily and recreational activities, ACL patients first have to go through an exercise rehabilitation program. These programs include stretches and exercises for the patient to complete every single day. Each week, the program outlines goals that the patient should try to reach. However, a huge problem with these rehab programs is that they are not geared towards the specific individual recovering from injury. Everyone recovers at a different pace. Some people make faster progress and are ahead in schedule in their rehabilitation process. On the other hand, others take a longer time to reach the weekly goals. This raises the question: Is there a way to track how a person is progressing during their rehabilitation program, so they can alter their workout plan accordingly?

Proposed Project

To fix this problem, I have come up with the Smart Brace. This wearable knee brace will have sensors to measure the range of motion and acceleration of the user's knee during rehab exercises. Regaining full range of motion is very important and is one of the main goals in an ACL rehabilitation program (2). In addition, acceleration and speed strengthening of one's knee is also a main component in recovery programs (3). Through Bluetooth, the Smart Brace will transmit data to a smartphone app for storage and analysis. By analyzing this information over a period of several days, the user can determine if they are progressing at a good pace, or if they are not progressing at all. Subsequent changes to their workout plan can be made accordingly.

Design Requirements

The development of a wearable smart brace will allow people to be able to measure a user's knee joint using a potentiometer. This measurement is used to quantify range of motion. In addition, the smart brace will also monitor the acceleration of the user's leg when they bend their knee using an accelerometer sensor. During rehab exercises, the potentiometer, accelerometer, and a microcontroller will be used to constantly take samples of the angle of the user's knee joint and acceleration of their leg. Through Bluetooth, the Smart Brace will be connected to an Android app. The microcontroller will send the taken data to the user's smartphone. The smartphone app will constantly update the values of the angle of the user's knee joint and acceleration of their leg. These values will be displayed to the user and stored for analysis.

Since we are attaching the system to an existing knee brace, there must be constraints on dimensions. The accelerometer, potentiometer, and microcontroller all have to be small enough to fit the knee brace, and not interfere with the user's movements. As a result, we will use an accelerometer that has a diameter of 20mm. In addition, the potentiometer has a diameter of ¾", and the microcontroller has a diameter of 50mm.

It takes roughly 20 minutes to do a rehab exercise of bending and straightening the knee. A typical exercise consists of a person doing 10-15 reps for 3-5 sets. Each set takes approximately 2-3 minutes. In between sets, a person usually rests for a couple of minutes. In addition, a person will bend and straighten their knee at a normal, constant pace. As a result, the microcontroller will take 100 samples per second. This value was chosen, since the angle of the knee joint and acceleration of the user's leg will constantly be changing. Taking 100 samples per second will virtually guarantee that we will not miss taking a sample of all the values. The microcontroller will have 32 KB of flash memory, and 2.5KB of SRAM. Since the microcontroller will only be taking values while the person is actually doing the exercise (2-3 minutes), this memory is more than enough to capture all the data. The user will not have to worry about the microcontroller running out of memory mid exercise.

The microcontroller will be charged using a micro USB connection. When the Smart Brace is not in use, it can be plugged in and charged. Therefore, it can be used for the entire exercise without the fear of it running out of battery.

The user will be able to see a nice graph of the results on their smartphone app, similar to a stock market ticker. In addition, the user will be able to view the results from past exercises.

Design Approach

The goal of this project is to make a prototype where the microcontroller correctly obtains data from the accelerometer and potentiometer, and sends it to the smartphone app. As the data is coming in, the smartphone will update the angle of the knee joint and acceleration, and display it to the user. A block diagram of the overall project can be seen below.

Figure 1: Model of Overall Project

The accelerometer sensor and potentiometers will be attached to a Breg Fusion Knee Brace (4). The accelerometer will be sewn on, while the potentiometers will be attached with high strength gorilla glue. We chose this brace, because this is the style of brace given to patients who are recovering from an ACL injury.

The accelerometer will have a 0.8mm printed circuit board. In addition, it will be made out of a wearable electronic textile (5). Having an accelerometer sensor this size and made out of this material is necessary, because it will allow us to attach it to the knee brace easily. Furthermore, it will not affect the performance of the brace.

The potentiometer will have a diameter of ¾" (6). Similar to the accelerometer, we chose this size potentiometer because it will allow us to attach it to the knee brace easily.

Both the accelerometer and potentiometer will be connected to a LilyPad Arduino USB microcontroller using jumper breadboard wires. This microcontroller that we will use will have 9 digital input/output pins and a micro USB connection. Furthermore, it will have a 0.8mm printed circuit board as well (7). The LilyPad Arduino USB microcontroller was chosen over the Arduino Uno because of the size and material. Just like the accelerometer, this microcontroller will be made out of a wearable electronic textile. Unlike the Arduino Uno, we will be able to sew the LilyPad Arduino onto the knee brace easily.

A Bluetooth mate will be soldered to the microcontroller. The size of it will be 1.75"x0.65". It will work as a serial pipe, and can pass a stream from the microcontroller to the smartphone. This Bluetooth mate was chosen because it is designed specifically to be used with the LilyPad Arduino USB microcontroller (8). With the combination of the 6-pin female header (9), the Bluetooth mate will lay horizontal when connected to LilyPad Arduino USB. This will allow us to attach the LilyPad Arduino USB easily to the knee brace.

The phone used to test the app will be a Samsung Galaxy 4S. We will design the app to have a button on the smartphone screen saying "Start". The user will press this when they start their exercise. As each value comes in, the microcontroller will send it over to the smartphone. The smartphone app will then constantly update the angle of the knee joint and acceleration. These values will be displayed to the user. When the user's exercise is over, they will press a "Stop" button, and the max values will be stored.

After obtaining the parts, we will focus on the hardware portion of the project. We will take the first three weeks to correctly wire the accelerometer sensor and potentiometer to the LilyPad Arduino microcontroller. Once this is complete, we will test them to make sure they are properly gathering the data. To test the accelerometer, we will hold it in our hands and repeatedly do a "bicep curl" motion. This is because this motion is a very similar to the one when a person bends their knee. To test the potentiometers, we will physically rotate them ourselves and see if we obtain the correct measurements. As soon as both devices pass the tests, we will attach them to the knee brace. The following two weeks will involve testing these components with the knee brace on me. With the knee brace on, I will bend and straighten my knee. This is the same rehab exercise that patients do while rehabbing from an ACL injury. Finally, I will spend the remainder of the weeks continuing to work on developing and finishing the app.

Anticipated Outcomes

Testing the final product will show us if we need to improve the accuracy of the accelerometer and potentiometer, as well as making changes to any bugs in the app. However once the project is complete, it is anticipated that the Smart Brace will be a useful tool to improve a person's rehab. After each day of doing rehab exercises, the user can compare their max angle of their knee joint as well as their max leg acceleration to the values from the day before. By comparing these values, the user can check how they are progressing throughout their recovery. Changes can be made to their workout plan if they are not pleased with the results.

Reason Funding is Necessary

Funding will be necessary for this project in order to purchase the component for measuring the acceleration of the user's leg when they bend their knee. In addition, it is necessary for purchasing the microcontroller, its charger, and parts needed to connect it to the smartphone app.

References

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3 "Accelerated ACL Reconstruction Rehabilitation Program." *Chester Knee Clinic*. N.p., n.d. Web. 23 Sept. 2015. <http://www.kneeclinic.info/rehab_markdecarlo.php>.

4 "Fusion Knee Brace." *Breg Inc.* N.p., n.d. Web. 22 Sept. 2015. <http://www.breg.com/products/knee-bracing/functional-ligament/fusion-knee-brace>.

5 "LilyPad Accelerometer ADXL335." - *DEV-09267*. N.p., n.d. Web. 22 Sept. 2015. <https://www.sparkfun.com/products/9267>.

6 "3856A-282-502AL Bourns | Mouser." *Mouser Electronics*. N.p., n.d. Web. 23 Sept. 2015. <http://www.mouser.com/ProductDetail/Bourns/3856A-282-502AL/?qs=sGAEpiMZZMtC25l1F4XBU4LIzrlRxKBZv7B806NHoYY%3D>.

7 "LilyPad Arduino USB - ATmega32U4 Board." - *DEV-12049*. N.p., n.d. Web. 23 Sept. 2015. <https://www.sparkfun.com/products/12049>.

8 "SparkFun Bluetooth Mate Gold." - *WRL-12580*. N.p., n.d. Web. 23 Sept. 2015. <https://www.sparkfun.com/products/12580>.

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Budget Breakdown

The costs of the components can be found below in Table 1. The project will not require the purchase of a knee brace. We are using the knee brace I received when I tore my ACL. However, the project will require the purchase of three accelerometers. Three accelerometers are necessary in order to consider acceleration in all three axes. The LilyPad Accelerometer ADXL335 was chosen for its size, ability to detect joint movement, and ability to be attached to the knee brace. Also, five potentiometers will need to be purchased. These potentiometers were chosen because of their sturdiness to withstand frequency rotation. In addition, it will require the purchase of a LilyPad Arduino USB – Atmega32U4 Board. This microcontroller was chosen for its small size and ability to be attached to the knee brace as well. In order to charge and program the LilyPad Arduino USB, the USB microB Cable will be needed as well. Finally, we need a way for the Android app to receive data from the Lilypad Arduino USB. Thus, the SparkFun Bluetooth Mate and 6-pin female header are needed for the successful completion of this project. The total amount of funding requested from the Student Research Grant Program is $180.45 plus the cost of shipping the components. This makes the total $215.45. The student, Taylor Ellsworth, and the Electrical and Computer Engineering Department will supply any additional funding.

Table 1: List of components for the Smart Brace. The * indicates the item will be covered by the student, Taylor Ellsworth. The ** indicates the item will be covered by the ECE Department.

Stage:	**Part:**	**Purpose:**	**Price:**
Knee Brace:	1 Breg Fusion Knee Brace	Serves as the knee brace	*
Components to collect data:	3 LilyPad Accelerometer ADXL335	Sensor needed to capture acceleration of leg when knee is bent	$44.85
	5 Rotary Potentiometer 5k Ohm, Linear	Needed to measure the angle of knee joint	$69.80
	Jumper Breadboard Wires	Needed to connect sensor/potentiometer to microcontroller	**
Microcontroller:	1 LilyPad Arduino USB – Atmega32U4 Board	Serves at the microcontroller. Used to collect data from sensor/potentiometer and send to smartphone	$24.95
	1 USB microB Cable – 6 Foot	Needed to connect LilyPad Arduino USB to computer to program and charge it	$4.95
	1 SparkFun Bluetooth Mate Gold	Needed to attach to Lilypad Arduino USB in order to connect to smartphone app	$34.95

	1 SparkFun Bluetooth Mate Gold	Needed to attach to LilyPad Arduino USB in order to connect to smartphone app	$34.95
	1 Header – 6-pin Female (0.1”, Right Angle)	Needed so SparkFun Bluetooth Mate can lay horizontal when connected to LilyPad Arduino USB. Necessary to attach LilyPad Arduino USB and SparkFun Bluetooth Mate properly to knee brace	$0.95
Smartphone:	1 Samsung Galaxy S4	Smartphone used to create app to obtain data from LilyPad Arduino and display to user	*
			Total: $180.45 + $35.00 (shipping) **$215.45**