Indoor Training: How well are we mimicking the movements?

Project Proposal

SYSC 4907

Fall 2021/Winter 2022

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1 Objective

Hockey is a national sport that provides entertainment as well as exercise. Training for hockey occurs year round and contains both on ice and off ice training periods. The key objective is to observe how well off season training (i.e. rollerblading, dryland training) mimics the movements of ice hockey skating. The goal is to generate a system that is able to record the various movements of key muscles while also monitoring the skater's acceleration and speed and weight distribution.

2 Introduction

This document contains the project proposal for the group's fourth year engineering project. Over the next two semesters the group will work towards creating a product that can evaluate if a person off ice training is accurately depicting their on-ice work. Following the introduction section, the proposal contains background research. This section contains some relevant information about training, electronics and muscles. The background is followed by a project description which contains what the plans for the project are. Following this section is the program relations where it will be discussed how this project relates to each person's degree and how the team's collective knowledge and skills will help complete the project.. Then the problem solving methods for potential issues in the project are discussed. Following this, is the group timeline that was set for the year and then the risk mitigation section will discuss potential hazards and mitigation techniques. Electronics, software and facilities required for the project will be discussed in the Electronics, software and facilities requirements section. Finally the Roles and references where the member rolls are defined and the resources accessed in the document are referenced.

3 Background Research

Hockey is a one/two season sport, and generally the league season lasts for around half a year. This leaves the players with a lot of off-season time. During this off-season time, the players must keep in shape for the following season, hence why dryland and off-season training is so important. There are two different forms of dryland training, one is off-season and two is in-season [1]. The difference is the off-season training will be when the season is finished and the in-season is when the season has started. Along with the time of these training sessions being different, also comes the training itself being different. During the off season, the foundation of the dryland training is preparing one's body and skills for the following season. To do so, a lot of core strength, stability, balance, and speed will be the main focuses of the training [2]. While during the season (in-season) the workouts will be more about maintaining the player's strength and fitness, however not at a high enough level where it will exhaust the players. This is because the players will also be working hard in practice and during the game, so they will already maintain a certain level of fitness through doing so. In the off season however, the players will challenge themselves far more, as they do not have the games and as many practices. Overall, this training is very important as if the players are not in top shape come the next season of hockey, then they will not be ready for the season.

The group's project is focusing on assessing the movements associated with hockey and comparing on-ice hockey to dryland hockey training. During the season games and practices, players can only maintain their strength, balance and fitness to a certain extent. So, when they are working off the ice (dryland training), the exercises the players are performing must be properly targeting the muscles that the players need during the game and mimicking the movements that the players are using during their games as well [1]. This comes in many different forms of workouts including off ice rollerblade hockey and many different exercises in the gym. The same applies to off season training, the proper muscles must be targeted, and the proper movements must also be targeted, to be able to exploit weaknesses where the player needs to work, preventing injuries as those muscles will be strong and will have been used and strengthened all off season and overall improving performance [2].

There are multiple ways of evaluating the effectiveness of the training with sensors. Arduino circuit boards are compatible with a variety of sensors and programming libraries that can aid in data collection. The main Arduino board is an Arduino uno rev 2. This board has many built in useful features like an accelerometer, gyroscope, and Wi-Fi connection [3]. The accelerometer and gyroscope will be important for testing as they can take readings on the movements of the board. These readings will include the direction of moment and changes in the board position. The gyroscope and accelerometer readings will be used to compare the speed and direction that a specific body part is moving. The board's Wi-Fi capabilities allow wireless upload of the data to a database. One of the sensors is an electromyography sensor or EMG. This sensor measures small electric signals created in muscles when they are moved or contracted [4]. Using these sensors on targeted muscle groups, their activation over different exercises can be compared. In addition to the EMG sensor, there are sets of pressure sensors in the skates. Using two smaller sensors for the front of the foot and a large one for the heel a player's weight distribution can be evaluated and compared.

Hockey is a full body workout, but the focus will primarily be looking at the lower body for skating. To pick the specific muscles that will be compared, it is first needed to test the EMG sensors to see what muscles provide the most useful data. In the initial testing the targets are going to be the calf, quadricep, hamstring and glute muscle groups[6]. In the back of the leg, the calf has the soleus and the gastrocnemius. These muscles are the main plantar flexor of the ankle. They allow one to push the foot out. On the shin there is the tibialis anterior muscle. This is the strongest dorsiflexor for the foot and is responsible for pulling the foot in. On the front of the thigh there are four quadricep muscles, the rectus femoris, vastus intermedius, vastus lateralis and vastus medialis. The rectus femoris is a muscle that passes from the knee to the hip acting as a hip flexor and to extend the knee. The vastus intermedius is covered by the rectus femoris so an EMG will be unable to read it. The vastus lateralis and vastus medialis are located on either side of the vastus intermedius and rectus femoris. The lateralis is the exterior and the medialis is the interior. These muscles also work together to extend the knee. In the back of the thigh there are the three hamstring muscles the biceps femoris, semitendinosus and semimembranosus. These muscles work to flex the knee joint. The last section is the glutes. They contain the gluteus medius, gluteus minimus, gluteus maximus and the lateral rotators. The gluteus minimus and the lateral rotators are located under the gluteus maximus so they cannot be read by an EMG. The gluteus maximus controls the external rotation of the thigh at the hip. The gluteus medius is responsible for the abduction of the hip joint. [5]

4 Project Description

The project will focus on two different ways to play hockey. The first focus being traditional on-ice hockey, and the second focus being off-season dryland hockey. The on-ice hockey will be analyzed using ice hockey skates, whereas the off-season dryland hockey will be analyzed using rollerblades. Through observation of these two approaches, results will be taken according to how the participant shoots and skates. The various muscles that are involved in those activities will be recorded. These two different movements will then be compared to observe how well the dry land movements compare to one's on ice movements. This will be completed using accelerometers to determine the speed and acceleration. Another apparatus that will be used are pressure sensors. These pressure sensors will be placed on the balls and heels of the feet, which in turn will allow us to determine the amount of force that is applied when the skater uses their feet to push off of the ground and how their weight is being distributed during various actions. Finally, muscle sensors will be used to help determine which muscles are working during certain activities. The muscle sensors that will be used are EMG sensors. A conditioning circuit will need to be created in order to reduce the noise that the EMG sensors will create from the raw data. The conditions that will be in the circuit are for signal analysis. Three main muscle groups will be focused on, the quadriceps, calves, and hamstrings. As displayed below in figure 4.1 and 4.2, the muscles within the three muscle groups can be observed.

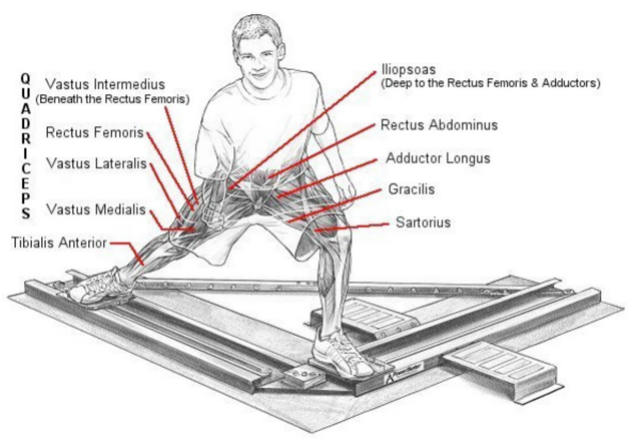

Figure 4.1: The Anterior view of a Diagram of the Main Muscles that are used while Playing Hockey [6]

Through experimentation of placement of the EMG sensors, the specific muscles within these groups will then be decided according to the most active. Each of the de-

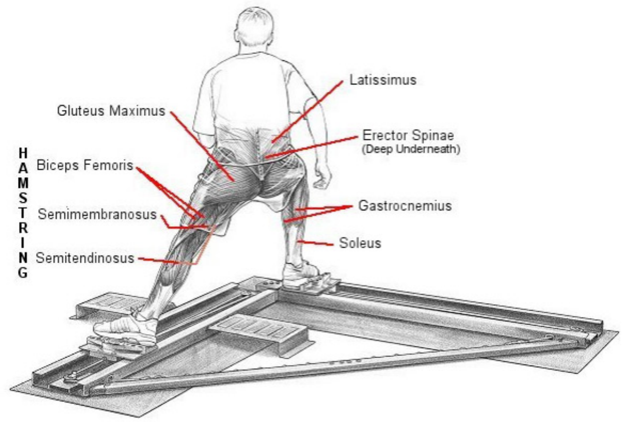

Figure 4.2: The Posterior view of a Diagram of the Main Muscles that are used while Playing Hockey [6]

vices will be implemented using electrical circuits and the Arduino Uno microcontroller board. An electrical circuit will be constructed and will contain attachments to each of the instruments. There will be a separate circuit for each instrument, the accelerometer, pressure sensors, and the EMG muscle sensors. The data will be compared using the real experimental numbers, as well as compared using a Picoscope to observe the signal through a scope.

5 Team Background

For this project it relates to Drake's degree of computer systems engineering very heavily as it will be relying on arduinos, and various sensors to observe muscle movements of the skater, accelerometers to track the speed and pressure sensors to see how well the skater is skating. The project relates to the program on the software side as well with the setting up of these sensors and potentially sending the data to cloud based data collectors.

The project relates to Kate's program of Biomedical and Electrical Engineering. Various aspects within the project relate to courses that she has taken throughout her years at Carleton University. The biomedical aspect of her program relates to the project due to the movements of various muscles that will be analyzed using EMG muscle sensors, as well as the pressure sensors and the placements of them. As well, there are various electrical aspects relating to her program that will be used to achieve the objective such as circuit building and usage of an Arduino Uno.

This project is related to Mario's program in Computer Systems Engineering because of the importance of combining the usage of computer hardware with software in data gathering. The program involves learning a mixture of hardware and software and the interactions between the physical realm of hardware and the digital realm that software inhabits and their communication.

This project relates to Braden's program of Computer Systems Engineering as in this project there will be a very prominent software component. In Braden's program there is a great emphasis on the software side of projects. He has learned many different coding languages (one being python extensively) and has also worked with a variety of boards (raspberry pi and arduino) as well. Because of this, the arduinos that will be used in this project are ideal for him. In Braden's 3rd year project (Sysc 3010) he had to use multiple sensors including a sound sensor, motion sensor and a photoresistor, so he has experience with various sensors as well.

This project relates to Marko's program of Software Engineering as it encompasses many aspects of the software development cycle as well as various types of software development. The project includes embedded systems development where software used to control the arduino microcontroller and all accompanying hardware needs to be developed and tested. The project includes real-time concurrent systems development, and database management as the arduino and python application will be concurrently communicating with the database in real-time. Then a python application with a back-end and front-end that will pull the data, parse and analyze it, and display it in an intelligible way to the end-user in real-time also needs to be developed and tested. Further, all the software being developed will need to go through the requirements engineering process, architecture and design, and validation and verification - all of which has been covered during his program. Thus, this project provides applied exposure to different types of software development for different purposes, as well as the opportunity to exercise the software development lifecycle.

This project relates to Connor's Program of Electrical Engineering through its use of microcontrollers and sensors. Connor has experience with microcontrollers from his third year project and the ELEC 4601 class. This project will allow for an expansion on the understanding and utilization of microcontrollers and their sensors. In addition the programming language for the arduino microcontroller is C++ which was taught in ECOR 1606. This project will increase the understanding of the programming language.

5.1 Group's Collective Ability to Accomplish Project Objectives

The project group, with six total members, contains a wide variety of technical backgrounds - 3 Computer Systems engineering students, 1 Software Engineering Student, 1 Biomedical Electrical Engineering Student, and 1 Electrical Engineering Student. The project being pursued spans multiple technical fields in which assets with specialization in many fields are required to successfully accomplish the objectives of the project. The physical construction, operation, and interfacing of complex hardware components require the expertise gained in an Electrical Engineering Degree. However, determining use cases for the hardware components, proper application of hardware components, and interpretation of collected data require knowledge of human biology in the context of electrical engineering in which the expertise gained in Biomedical Electrical degree is an asset. In order to develop the critical embedded software to run the hardware and collect data requires expertise in Computer Systems Engineering, and Software Engineering. When the data is collected, it needs to be efficiently and effectively communicated wirelessly to the database, pulled from the database, analyzed and outputted in an intelligible format all in real-time, which requires, again, expertise acquired in Computer Systems Engineering, and Software Engineering. Additionally, the software needs to be put through stringent testing and quality analysis to ensure its soundness which requires knowledge acquired in Software engineering. With members of the team covering all these needed technical areas, the team has a robust foundation on all fronts, and a proven exceptional ability to collaborate with one another, which is a strong indication that the team is capable of successfully carrying out the project to completion.

6 Problem Solving Methods

Given that the group is fairly big in size, there are many resources that the team has. If the team happens to become fixed on a problem, collective problem solving is a good first step as there are a wide array of skills in the group. If the problem is not something the group can overcome, the team has a wide variety of resources from previous coursework to online resources and forums available for programming and hardware along with a host of documentation available for Arduino, Python, MySQL, etc... There are also websites such as github where open-source code can be viewed and analyzed in an attempt to solve a problem in the team's own system. For the biomedical side, there are various resources from courses that Kate has taken that can be an asset such as Bioelectrical Systems (SYSC 3203), Bioinstrumentation and Signals (SYSC4203), and Biomedical Systems, Modeling, and Control (SYSC 3610). As well, there are many biomedical studies that can be found through research of accredited online journals.

7 Proposed Timetable

Order Electronics completed	October 18
First Draft Proposal	October 20
Project Proposal Submission	October 22
Initial Hardware Order Tested, Remaining Hardware Ordered	November 8
Forms for test subjects (check name)	November 8
Progress Report First Draft	November 27
Oral Presentation Form style determination	December 7
Oral Presentation Form	December 10
Progress Report Submission	December 10
Hardware prototype + embedded software iteration	December 17
Python application sprint	January 1-9
Primary Data collection	January 10-14
Poster Fair Demo Form	January 10 - March 1
Oral Presentations	January 24 - January 28
Final Data collection	February 7-February 11
Deadline for special software/hardware needs Poster Fair	February 15
Final Report Draft Submission	February 28
Poster Fair	March 18
Final Project Report Submission	April 12

Table 7.1: Proposed Time Table, A Gantt Chart variant is in Appendix as figure 10.1

8 Risk Mitigation

Due to the nature of the project there are a variety of risk factors that the team has acknowledged and will be designing the project tests around. The project involves ice hockey and roller blading and due to this, any test subjects will be required to be wearing proper safety equipment to minimize injuries while on the ice or flooring. Outside of the usage of proper safety equipment the subjects that will be used were chosen due to their experience with skating. As only the skating element of hockey is being analyzed there will not be physical contact or interference of skating by hockey sticks or hockey pucks/balls. Furthermore, by using indoor hockey rinks some of the safety risks that are present with outdoor ice hockey are avoided. This includes less well kept ice and highly decreases the risk of hardware malfunction due to temperature and weather. The roller blading being done in a gymnasium will also mitigate some of the risks that rollerblading outdoors on a road or cement would have. While the data being collected is done at a controlled location separate from anyone's house, mitigations of privacy risk will be conducted by not identifying in the software or report whose data was being gathered at any given time.

To mitigate the risk of inadequate datasets, and get a representative model a large sample of data will be collected from as many as 5 test subjects.

To address the risk of software or hardware defects, stringent testing will be put in place both during the development process, as well as once the system is complete and ready to use, but prior to data collection.

9 Requirements

9.1 Hardware Requirements

9.1.1 Arduino

The Arduino Uno Microcontroller unit will be used to read inputs from a vast array of hardware components and sensors and convert it to output that will be used by the software end to analyze and display data in real-time. The arduino unit along with the corresponding hardware and sensors will be mounted to the test subject and wirelessly transmitting data to the database.

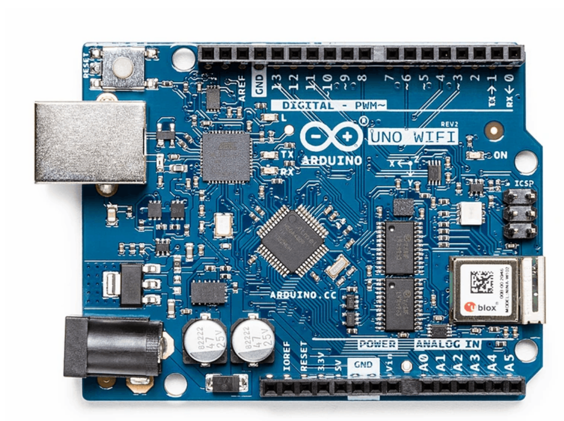

Figure 9.1: The Arduino Uno Microcontroller Unit [3]

9.1.2 EMG Sensors

Electromyography (EMG) sensors measure electrical signals generated by a person's muscle movements. These sensors will be used to collect data on a subject's muscle movements during the execution of a certain movement.

Figure 9.2: The Electromyography Sensor [7]

9.1.3 Force Sensitive Resistors

Force sensitive resistors are sensors that measure applied force or pressure. These sensors will be used on the bottom of the subject's foot to measure the amount of force being applied during certain movements.

9.1.4 Accelerometer

Accelerometers are sensors that measure proper acceleration. These will be used to measure a subject's acceleration, which will be integrated over time to obtain the speed of a subject.

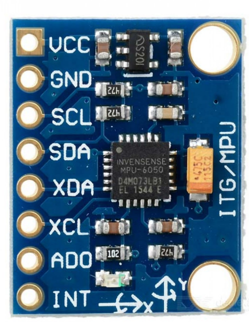

Figure 9.3: The Accelerometer Gyroscope Sensor [8]

9.1.5 PicoScope

A PicoScope is a device that measures real-time signals and operates as an advanced oscilloscope and spectrum analyzer. The PicoScope will be used to measure the output of each of the sensors, allowing the data to be visually observed as a waveform.

Figure 9.4: The PicoScope [9]

9.2 Software Requirements

For the project's embedded development, Arduino's integrated development environment (IDE) will be used, in conjunction with Arduino's programming language which is based on the C programming language. This will be used to write all the embedded code that will control the hardware, collect the data and subsequently send it to the database.

Once the data is collected by the hardware, the arduino will send this data wirelessly to a MySQL database using phpmyadmin. MySQL is an open-source relational database that will permit high-speed fetching of data using SQL queries such that the data can be displayed in real-time. The python application will be able to access the MySQL database to acquire the data.

In case implementing the MySQL database and Arduino connection proves to be too difficult or inefficient, the plan will pivot to using Matlab's ThingSpeak software for data storage/management, and analytics. ThingSpeak is an Internet of Things API that allows data to be collected, stored, analyzed and graphically represented in the cloud, in real-time [10]. Using Thingspeak's Arduino API, the Arduino board will be able to seamlessly send data to Thingspeak.

On the front-end, a cross-platform Python application running on a local machine will pull down the collected data from the database in real time, process and analyze the data, using a variety of Python mathematical, data analytics and machine learning libraries, and present it on a user interface dashboard. This dashboard will allow the team to monitor select data and results as they are collected in real-time, and allow for adjustments to be made as needed. Python is an adept tool for these tasks as it is widely used in the data science world due to its abundance of library offerings such as NumPy, Pandas, Matplotlib that make data cleaning, analysis and visualization much more efficient and simple [10]. Further, Python offers many frameworks for building graphical user interfaces which allows the team to maintain a consistent language for all front-end needs, while maintaining cross-platform capabilities. As python is such a widely used language on the data science and UI front, there is an abundance of documentation and information online that will help the team in successfully developing and testing the application.

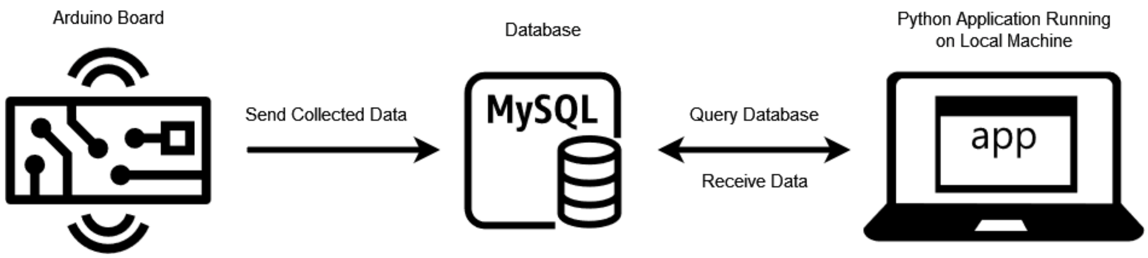

Figure 9.5: Diagram of the Software Process

9.3 Facility Requirements

In order to accomplish data collection and testing for the ice skating portion of the project, an indoor, controlled and maintained ice skating rink will be needed. For this rink the team will be using the Ice House at Carleton University. For the roller blading portion of data collection, an indoor, controlled and maintained gymnasium will be required. The gymnasium that will be used will be Norm Fenn at Carleton University.

10 Roles

10.1 Roles

Braden Hayes - Software (Front-end, Back-end, Embedded, Quality Assurance)

Mario Shebib - Hardware (Implementation), Software (Embedded)

Drake Mcgillivray - Hardware (Pressure Sensors)

Kate Delaney - Activity of Muscles, Hardware (EMG Sensors), Visualization of Data (Hardware - Picoscope)

Connor Judd - Hardware (Arduino Coding and Implementation, Hardware construction)

Marko Majkic - Software (Front-end, Back-end, Embedded, Quality Assurance)

Appendix

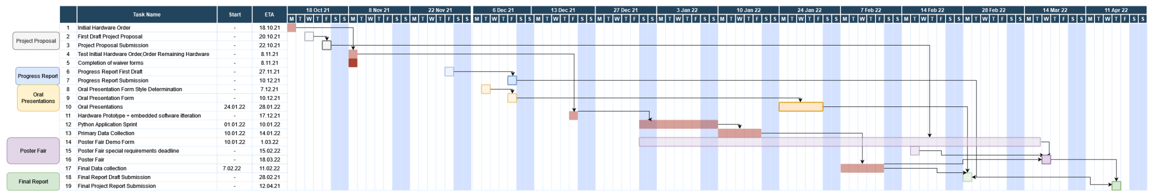

Figure 10.1: A Gantt Chart visualization of the timetable 7.1

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