Design of a Dry-Land Skating Athletic Performance Measurement System

ECE4600 Project Proposal

Faculty Advisor: Dr. Douglas Thomson
Industry Advisors Mr. Ron Bulloch and Mr. Peter Twist

Group 08:
Xiang Li
Rhema Prathipati
Bryce Englot

Department of Electrical and Computer Engineering
University of Manitoba
Winnipeg, Manitoba, Canada

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1. Introduction

The purpose of this project is to integrate an electronic measurement system into two similar varieties of a dry-land skating machine developed by Powering Athletics LLC: the Power Skater and the Pro Skater. The measurement system will be used to capture and analyse a user's athletic performance for training and rehabilitation purposes.

The Power Skater and Pro Skater were designed to provide a means of “developing the motor skills and muscular strength needed to be a superior skater in an off-ice environment” [1]. The machines have been successfully marketed to families and amateur skating clubs across the United States and Canada, but their utility as strength-training and rehabilitation tools has also gained the product support from several training organizations within the NHL. Powering Athletics believes the machines have the potential to become industry standards in the highest levels of skating training. Currently, the Power and Pro Skater are purely mechanical and do not offer any way to easily quantify, store, or analyse a user's athletic performance; therefore, an electronic athletic performance measurement system will be designed and integrated into the existing mechanical body of the Pro and Power Skater dry-land skating machines to maximize training efficiency.

Three designs involving optical sensors and potentiometers will be tested against several criteria including system accuracy, durability and cost. The system must be non-intrusive to the user. The design that is selected will be interfaced with a microcontroller into a PC for data analysis, data storage, and data display.
2. Product Description

The PowerSkater (Figure 1.) and ProSkater (Figure 2.) systems are similar but for a few key differences. Both systems consist of two metal trucks that move along straight, rigid metal tracks. The trucks are set on a wheel system designed to minimize friction and simulate gliding. The user stands on the trucks and kicks out to simulate a skating stride. Rubber weaved tension cords (Rhino Cords), which are fastened to the machine body and attached to the trucks through a series of pulleys, are meant to offer an adjustable level of resistance for strength training.

The Power and Pro Skater differ in configuration: the tracks of the Power Skater are fixed and orthogonal while the angle between the tracks of the Pro Skater is adjustable. Additionally, the PowerSkater contains a patented locking system that holds the glide leg truck in place between a user's strides; the ProSkater does not.

Figure 1. PowerSkater Setup

Figure 1. ProSkater Setup
3. Project Design Requirements

This project will be broken down into three components:

- Designing a measurement system using electronic sensors and integrating the sensor hardware into the bodies of the Power Skater and Pro Skater
- Collecting and analysing data from the sensing system
- Creating a graphical interface for data display

The components will be integrated as illustrated by Figure 2.

![Figure 2. Design Block Diagram](image)

3.1 Hardware Requirements

3.1.1 Overview

The selected sensors used to measure stride length, power, and frequency must not only be accurate, but also durable as they will be attached to the machine bodies and subjected to considerable stress. Table 1. details the hardware specifications.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Sensor Resolution</td>
<td>+/- 0.5 cm</td>
</tr>
<tr>
<td>Force Sensor Capacity</td>
<td>300 kg</td>
</tr>
<tr>
<td>Hardware Durability</td>
<td>10’ stride cycles</td>
</tr>
<tr>
<td>Processing Delay</td>
<td>&lt;1s</td>
</tr>
</tbody>
</table>

A design that is non-intrusive to the user is also highly desirable.

Three preliminary design options are being considered by the team and will be tested and evaluated as to how well the hardware system requirements are met. The winning design will be developed further as a prototype. The three designs are as follows:
3.1.2 Optical Rotary Encoder and Pulley Design (Figure 3.)

The first design involves installing two extra pulleys on both ends of each track. The pulleys will be connected by a tight belt. The belt will also be run through the truck. As the truck moves, the pulleys will be rotated by the belt. A digital rotary encoder will be attached to one of the pulleys and will rotate accordingly. The encoder will send two digital signals offset by 90 degrees to the microcontroller. Using these signals, the microcontroller will be programmed to recognise and decode the distance and direction the truck has travelled.

![Figure 3. Rotary Encoder Setup](image)

3.1.3 Optical Sensor (Figure 4.)

The second design has a similar concept: an optical sensor will be fixed to each truck and a transparent strip with a series of equal spaced opaque bars will be installed along each track. As the truck moves, the optical sensor will trigger the microprocessor once the light signal is interrupted by the opaque pars. By counting how many bars the sensor has passed by, the microprocessor is able to calculate displacement of the truck.

![Figure 4. Optical Sensor Setup](image)
3.1.4 String Potentiometer (Figure 5.)

The final method involves a string potentiometer. The potentiometer body will be fixed and centered at the end of each track with the string attached to the truck. This device will give the exact displacement directly to the microprocessor in digital form. Based on instantaneous displacement, a microprocessor is able to recognize which direction the trucks are moving along the track.

![String Potentiometer Setup](image)

3.1.5 Power Measurements

The Rhino Cords will be used to determine the force of a user’s stride according to the expression:

\[ F = -kx \]

Where \( F[N] \) is the force, \( x[m] \) is the displacement of one end of the Rhino Cord from its equilibrium position, and \( k[N/m] \) is the linear rate spring constant.

As the Rhino Cords are stretched with each stride, \( k \) can be determined by measuring \( F \) (using a tension link load cell) exerted on the Rhino Cord at varying \( x \). The tension link load cell will provide a voltage output that can be scaled to determine \( F \) acting on the cord. From this data, the average power, \( P_{\text{avg}}[\text{W}] \), can be derived from the expression:

\[ P = F \frac{x}{t} \]
3.2 Software Requirements

The programming aspect of the project will involve configuring the microcontroller to calculate the displacement of a truck (the stride length). The data received from the sensors will be sent to a computer for display in near-real time. The microcontroller should be able to calculate the stride frequency of each leg through the use of an on-board clock.

Software that allows the user to input personal data such as name, age, mass, leg length, and cord resistance must be written. From these input data, the software will calculate the best theoretical stride length and stride power, for an individual user. These numbers will be compared to the values detected from user’s performance. Both sets of data will be displayed on the computer, with the option to save for further long term analysis.

Various parameter formulas will be provided by Powering Athletics LLC.
4. Tasks, Milestones and Division of Work

The team will be applying a progressive process. The hardware component will be focused on first, which involves trying different design schemes and finding the one that best meets this project’s design goals. Once the hardware scheme has been finalized, software will be written to capture and analyse the data measured by the hardware. Table 2 describes the team’s tasks, milestones and division of work.
Table 2. Tasks, Milestones and Division of Work

<table>
<thead>
<tr>
<th>Tasks/Milestones</th>
<th>Individual in charge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Literature Review</strong></td>
<td></td>
</tr>
<tr>
<td>Displacement Sensors</td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td>Force Sensors</td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td>Micro-controllers</td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td><em>Project Acceptance Form</em></td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td><strong>2. Paper Design</strong></td>
<td></td>
</tr>
<tr>
<td><em>Project Proposal</em></td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td>Design 1: Incremental Optical Rotary Encoder</td>
<td>Rhema</td>
</tr>
<tr>
<td>Design 2: String Potentiometer</td>
<td>Rhema</td>
</tr>
<tr>
<td>Design 3: Linear Magnetic Encoder</td>
<td>Bryce</td>
</tr>
<tr>
<td>Design 4: Variable Resistor</td>
<td>Bryce</td>
</tr>
<tr>
<td>Design 5: Optical Photo Interrupter</td>
<td>Xiang</td>
</tr>
<tr>
<td>Choose 3 designs to implement and test</td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td><strong>3. Prototype Build/Test</strong></td>
<td></td>
</tr>
<tr>
<td>Implement and test Design 1</td>
<td></td>
</tr>
<tr>
<td>Hardware</td>
<td>Rhema</td>
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<tr>
<td>Software</td>
<td>Bryce and Xiang</td>
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<tr>
<td>Implement and test Design 2</td>
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<td>Hardware</td>
<td>Rhema</td>
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<tr>
<td>Software</td>
<td>Bryce and Xiang</td>
</tr>
<tr>
<td>Implement and test Design 5</td>
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<tr>
<td>Hardware</td>
<td>Rhema</td>
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<tr>
<td>Software</td>
<td>Bryce and Xiang</td>
</tr>
<tr>
<td><em>Informal Oral Progress Report</em></td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td><strong>4. System Build/Test</strong></td>
<td></td>
</tr>
<tr>
<td>Choose 1 final design and implement</td>
<td>Bryce, Xiang and Rhema</td>
</tr>
<tr>
<td>Choose micro-controller and programming language and implement</td>
<td>Bryce, Xiang and Rhema</td>
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<tr>
<td><strong>5. Final Completion of the Design</strong></td>
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<tr>
<td>Complete final design implementation (hardware)</td>
<td>Rhema</td>
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<tr>
<td>Complete interfacing with the micro-controller (software)</td>
<td>Bryce and Xiang</td>
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<tr>
<td>Test final design for any glitches (trial period)</td>
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<tr>
<td><em>Formal Written Progress Report</em></td>
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<td><strong>6. Final Report Organization</strong></td>
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<td><em>&quot;Official Title&quot;</em></td>
<td>Bryce, Xiang and Rhema</td>
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<td><em>Final Report Draft</em></td>
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<td><em>Final Report</em></td>
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<td><em>Project Presentation Day</em></td>
<td>Bryce, Xiang and Rhema</td>
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</table>
Figure 6. Gantt Chart as of 25th Sept. 2012

1. Literature Review
   Displacement Sensors
   Force Sensors
   Micro-controllers
   Project Acceptance Form

2. Paper Design
   Project Proposal
   Design 1: Incremental Optical Rotary Encoder
   Design 2: String Potentiometer
   Design 3: Linear Magnetic Encoder
   Design 4: Variable Resistor
   Design 5: Optical Photo Interrupter
   Choose 3 designs to implement and test

3. Prototype Build/Test
   Implement and test Design 1
   Implement and test Design 2
   Implement and test Design 5
   Informal Oral Progress Report

4. System Build/Test
   Choose 3 final design and implement
   Choose micro-controller and programming language and implement

5. Final Completion of the Design
   Complete final design implementation (hardware)
   Complete interfacing with the micro-controller (software)
   Test final design for any glitches (trial period)
   Formal Written Progress Report
   Formal Oral Progress Report

6. Final Report Organization
   "Final Title"
   Final Report Draft
   Final Report
   Project Presentation Day

Key:
- Main section
- Subsection
6. Proposed Budget

Table 3. Proposed Budget

<table>
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<tr>
<th>Product Name &amp; Model Name</th>
<th>Supplier &amp; Part Number</th>
<th>Quantity</th>
<th>Cost (CAD)</th>
<th>Cost (EUR)</th>
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</thead>
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<tr>
<td>Photomicrosensor (Reflective) EE-SY310, 410</td>
<td>Digi-Key Part Number OR525-ND</td>
<td>4</td>
<td>$4.32 each</td>
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<td>Reflective Photomicrosensor with Sensitivity Adjuster EE-SY671/672</td>
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<td>Transmissive photo interrupter GP1A57HRJ00F</td>
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<td>Miniature Low Profile Tension Link Load Cells LC703-750</td>
<td>OMEGA ENGINEERING LC703-750</td>
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<td>Timing Belt 3060-5M-25 Synchronous Timing Belt</td>
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<td>12 Tooth timing pulley Alum.-12-5M15-6FA3</td>
<td>Global Industrial Canada Inc T9FB376957</td>
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<tr>
<td>Rotary optical encoder ENS1J-B28-L00256</td>
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<td>-</td>
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<td>Arduino Uno USB Microcontroller Rev 3</td>
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<td>Total</td>
<td>$1120.89</td>
</tr>
</tbody>
</table>
7. References

[1] What is the story behind the PowerSkater Available at
http://www.poweringathletics.com/powerskaterstory.html


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