

Measurement of Baseball Glove and Hand Dynamics

by

Brian A. LaCrosse

Submitted to the Department of Mechanical
Engineering in Partial Fulfillment
of the Requirements for the
Degree of

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Signature of Author: _____

Department of Mechanical Engineering

May 10, 2007

Certified by: _____

Dr. Kim B. Blair

Sports Innovation @ MIT

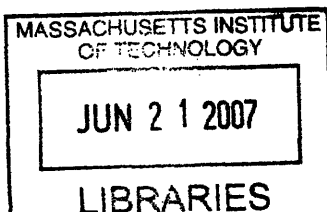
Thesis Supervisor

Accepted by: _____

Professor John H. Lienhard V

Professor of Mechanical Engineering

Chairman, Undergraduate Thesis Committee



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Submitted to the Department of Mechanical Engineering
on May 11, 2007 in Partial Fulfillment of the
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ABSTRACT

An apparatus was developed that provides a dynamic representation of the hand-glove interaction inside a baseball glove during catching situations. Until recent history, baseball manufacturers relied primarily upon player input and practical necessity to develop their technology; the use of scientific exploration was minimal. To add scientific technology to the design of baseball gloves, the project consisted of a sensor glove component and a visual interface, developed to better understand the hand-glove interaction. The sensor glove was created by attaching FlexiForce A201 sensors to a golf glove to fit inside a baseball glove. The sensors measure the forces in a variety of locations on the back and front of the hand. The project resulted in a simple user interface that presents a better representation of the hand-glove interaction and provides a means to better identify characteristics of glove use.

Thesis Supervisor: Dr. Kim B. Blair

Title: Sports Innovation @ MIT

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1. Introduction

1.1 Historical Overview

Baseball glove design has seen an interesting history, affected mostly by improved hitting and the development of efficient fielding. The evolution in glove manufacturing has largely been due to the desire to create a glove that not only protected the hand, but also aided in fielding and catching. As shown below in Figure 1, baseball gloves have made a very dramatic transition from the days of no gloves to current models that have been designed with particular positions in mind and to some degree even different players.

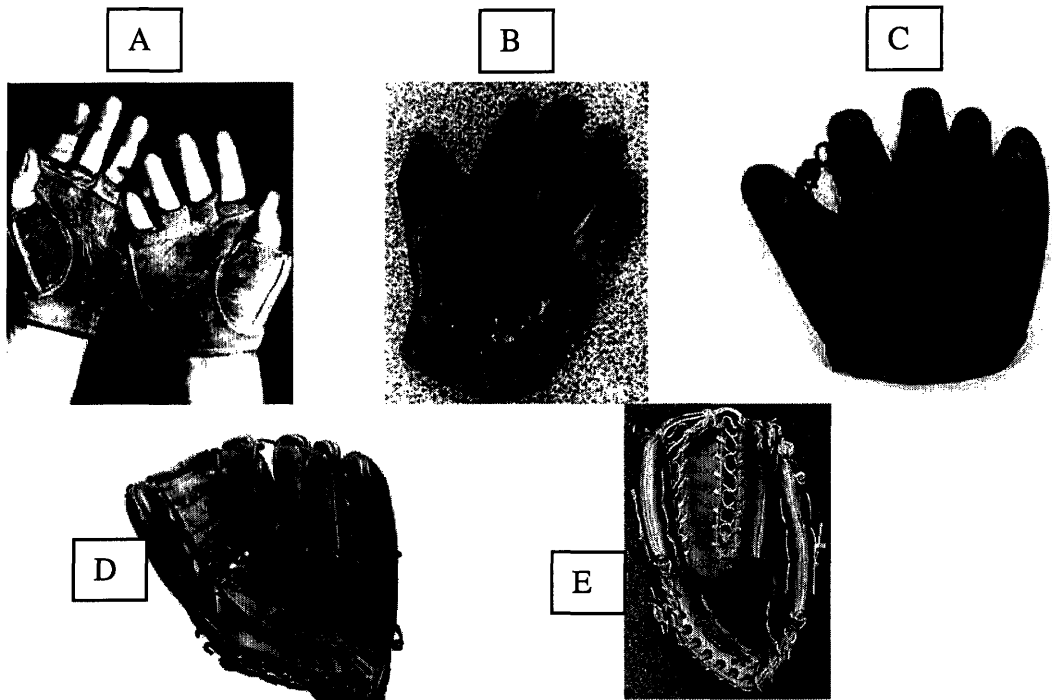


Figure 1: Evolution of baseball gloves. A is a photograph of a 1870 fingerless glove, B is a 1893 fielders glove, C is a 1910 Walter Johnson glove, D is a 1960 Macgregor glove, and E is a 1970 Rawlings Gold Glove Pro.¹

An interesting component of this evolution has been its reliance on players' input for glove design rather than scientific data and quantitative experimentation. For example of a way in which players influenced change in baseball technology, consider Hall of Fame second baseman and broadcaster Joe Morgan. During his career, Morgan realized that for

his position, the padding in the heel of the glove was largely unnecessary. He began to remove padding from the heel of his glove. His actions resulted in many manufacturers reducing the amount of padding in the heel. He also started a trend toward smaller infield gloves that has become the norm in infield glove manufacturing. Other recent changes have been the thinning of the thumb, using 1.5 mm plastic stays rather than 2 mm plastic stays, and the use of softer leather, both of which have been the result of requests by players.¹ This characteristic is not surprising in baseball, known for its often practical philosophy, but with today's technology, many corporations are looking to use science and technology to improve the quality of their baseball glove products.

1.2 Motivation

Baseball glove technology has been progressively improving since the 1880s when the overhand pitch rule was adopted. At that time, no gloves were used, but with this rule change in professional baseball, different glove designs began to develop and since have not stopped evolving. Even with the continual evolution in glove design, very little scientific research and engineering has been done to study how the hand to glove interaction works and how different players interact with different types of gloves. Companies, such as Rawlings®, have been introducing new glove models for the past century that have enhanced the efficiency of catching by creating different gloves for the outfield, infield, and different types of players. These improvements have been done primarily by users and designers realizing potential changes to the glove configuration for each position, but few of these changes have been realized through scientific exploration. A better understanding of the hands dynamic movements and forces within the glove could even further advance the technology.

1.3 Objective

The objective of this project was to develop and design a system capable of measuring the forces in the hand in a variety of areas during the process of squeezing a baseball glove while catching a ball. This system can be used to analyze and compare the results of a number of different glove types, hand sizes, and different aged gloves. By producing this system, scientific insight can be used in conjunction with practical application to better baseball glove technology.

2. Technical Approach

The system was designed to measure the forces associated with the hand-glove interaction inside a baseball glove. Through the development of an interface to easily view the resulting interaction, characteristics of the hand-glove interaction are more identifiable. By discovering these characteristics, new glove design and technology can be improved.

2.1 Apparatus Description

The system is made up of two tight fitting gloves, one equipped with sixteen pressure sensitive sensors on the front and one equipped with sixteen pressure sensitive sensors on the back. Each of these sensors measures a voltage that is transmitted through a complex op amp circuit to a data acquisition hub and LabView.

2.2 Experiment Description

The experimental set up begins, if necessary, with the appropriate conditioning and calibration. This is necessary if the apparatus has not been used for a good length of time. A number of human subjects will insert their hand into the sensor glove component after which they will use a series of gloves ranging from new to old and for a variety of positions and sizes.

2.3 Measurement Description

The data is presented in a very user friendly interface designed to not only give the user the concrete data, but to also give a colorful representation of what is occurring in the hand-glove interface. Through this type of data presentation, specific characteristics of an individual's hand-glove interaction are more easily identifiable. The interface indicates the forces by showing a hand with colors at each sensor node ranging from green, the weakest force, to red, the strongest force.

3. Experimental Design

3.1 Apparatus

The experimental setup includes 2 different tight fitting golf gloves, each equipped with sixteen FlexiForce® A201 Sensors, an op amp circuit, a data acquisition hub connected to a computer with LabView, and 2 Mastech HY3005 DC power supplies used to drive the op amp and sensors. The data is opened in a GUI designed to visualize the information more clearly. The experimental set up is shown in Figure 2.

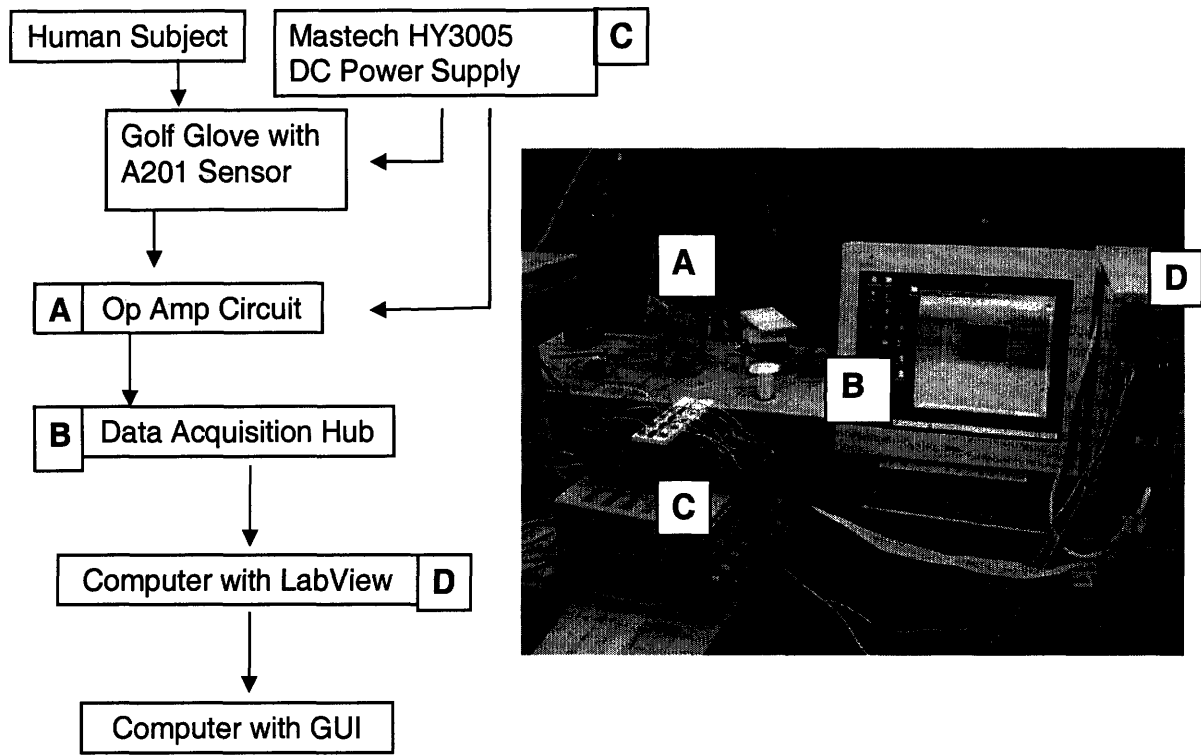


Figure 2: Experimental setup for computing the force on the glove sensors. On the left is a block diagram of the basic flow of information. On the right is a picture of the individual components within the block diagram. A represents the op amp circuit, B represents the data acquisition hub, C represents the 2 Mastech HY3005 DC power supplies, and D represents the computer equipped with LabView.

3.1.1 Fitted Glove and FlexiForce® A201 Sensors

To measure force data across the hand, sixteen individual FlexiForce® A201 sensors were applied to the front of a golf glove and sixteen individual sensors were applied to the back of a golf glove. Each sensor is a printed circuit designed for force ranges from zero to twenty five pounds. An example is shown in Figure 3. The sensors were harnessed using a strap around the arm.

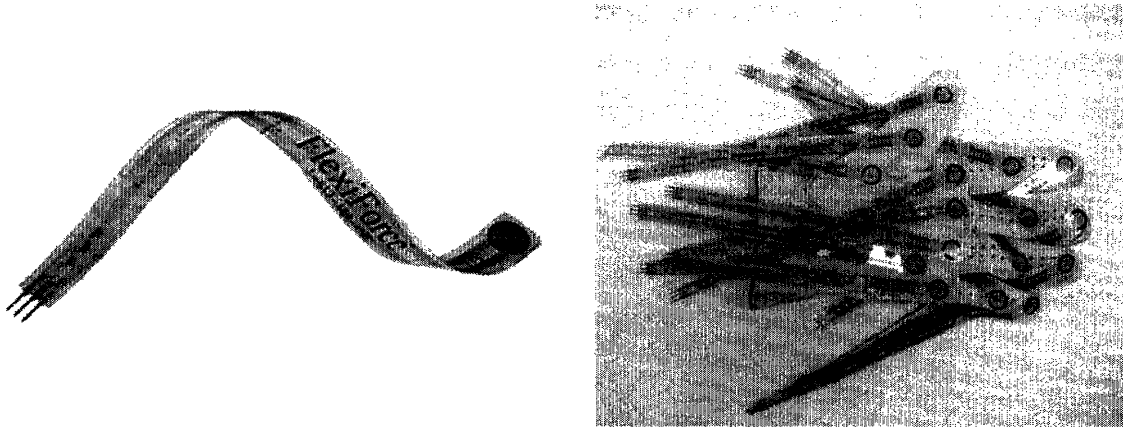
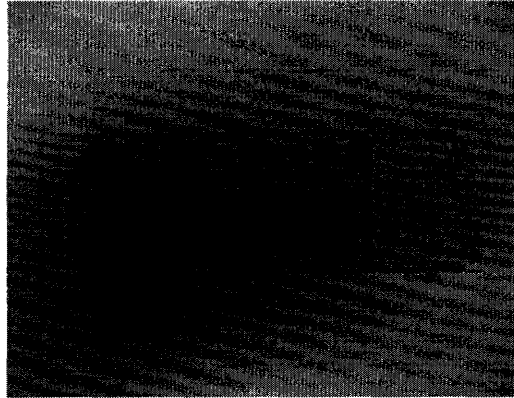


Figure 3: Experimental setup for the sensor glove. The left picture represents an individual FlexiForce® A201 sensor.² The right figure is a picture of the golf glove equipped with sixteen sensors on the front.

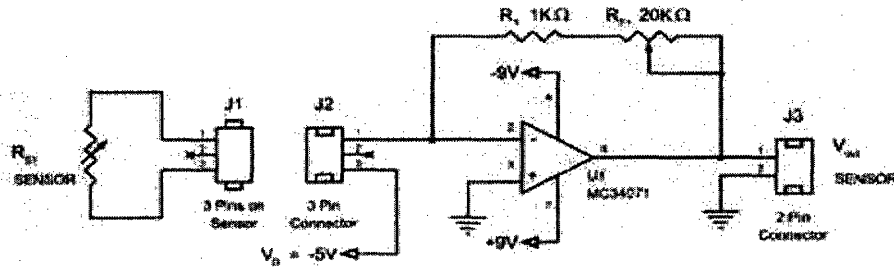
Two sensors were placed on the thumb and each finger, one was placed beneath the thumb and one sensor was placed directly below each finger, with an additional sensor placed near the pinky and ring finger on the open palm.

3.1.2 Op Amp Circuit

In order to appropriately convert the sensors output into force, a force-to-voltage circuit was incorporated into the circuitry. The op amp circuit was constructed as shown in Figure 4.



$$V_{out} = -V_D * (R_f / R_{S1}); \text{ where } R_f = R_1 + R_{F1}$$



U1: MC34071AP (Plastic Dip Package)
 or
 U1: MC34071AD (Surface Mount Package)

- Max recommended current: 2.5 mA
- No-Load Resistance = Approximately 20 MΩ
- Full-Load Resistance ≥ 20 kΩ
- Possible Overload Resistance ≥ 5 kΩ
- The two supply voltages (+9V and -9V) and V_b (-5V) should remain constant

Figure 4: Op Amp Circuit configuration. The top figure is a picture of the actual constructed circuit. The black pieces are a double op amp. There are sixteen different sensor inputs and sixteen voltage readings connected to the data acquisition hub. The bottom figure is a diagram of the circuit used. +10 volts and -10 volts were supplied rather than +9 volts and -9 volts.³

Sixteen analog outputs were created through the use of this circuit. Each circuit consisted of an inverting operational amplifier and a fixed reference resistance of

22kOhms in addition to two supply voltages of +10 volts and -10 volts. The output was based on the sensor resistance and its sensitivity was determined by the reference resistance. Additional calibration was conducted on the sensors and within the computer interface.

3.1.3 GUI

The data is collected in LabView in the form of analog voltage input. A GUI system was created to present both the numerical values and to enhance the graphical representation. LabView's graphical format was inaccurate and poorly presented the data in a hard to read line graph form. As shown in Figure 5, the GUI shows the force data through the use of a color spectrum.

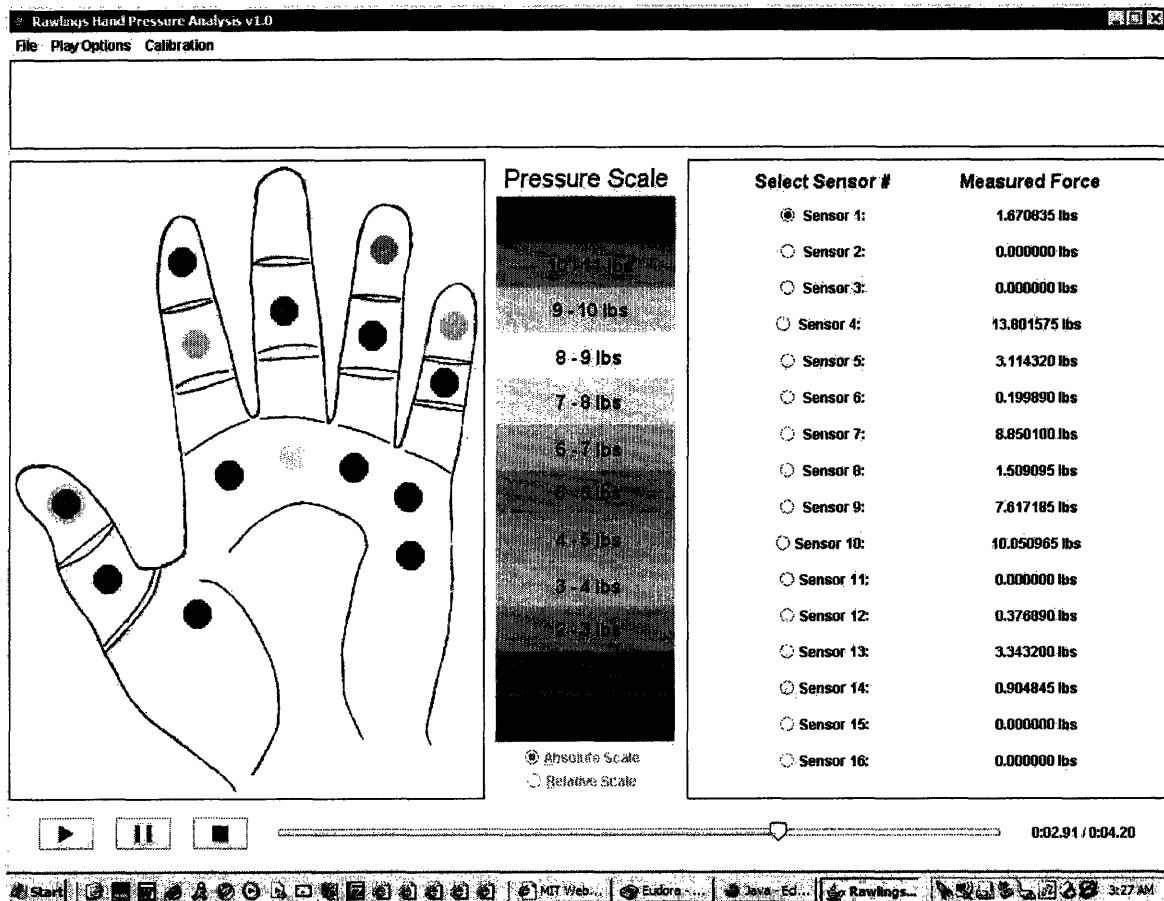


Figure 5: Picture of the GUI interface. The left portion of the picture provides a visual presentation of the forces at each hand. The middle portion represents the color spectrum and the right portion allows you to pick which sensor to highlight and each sensors measured force.

The interface indicated the forces by showing a hand with colors at each sensor location ranging from green, the weakest force, to red, the strongest force. As the forces at each location change, so do the colors at each location. To provide the actual numerical values of the forces at each location, there is a continuous feed that changes every second on the right side of the interface.

3.2 Experimental Procedure

3.2.1 Conditioning

To prepare the system for the experiment, the sensors underwent a basic conditioning as provided in the Tekscan FlexiForce® Sensors User Manual.³ The sensors were positioned under twenty pounds of weight with the use of a “puck” as shown in Figure 6.

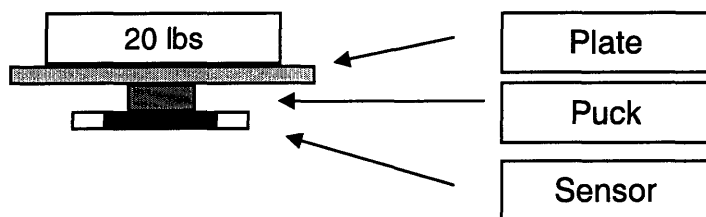


Figure 6: The figure shows the set up for the conditioning of all the sensors. The puck rested on the center of the sensor with a 20 pound load applied directly on the puck.

To appropriately condition the sensor, 110% of the test weight, or roughly twenty pounds was applied to the sensor. The sensor was allowed to stabilize and the weight was removed. This was repeated 3 times for each sensor. To prepare for calibration and testing, the conditioning is to be done with the same interface between the sensor and the test subject. The sensors were also subjected to the same 20 pound load while attached to the glove. Again, the sensors were allowed to stabilize, and the condition process was repeated 3 times for each sensor.³

The conditioning was important to prevent drift which was a characteristic very evident in the preliminary tests of the sensors prior to the conditioning. Conditioning

should take place prior to the first use with the system and also when the system has been unused for a length of time. After the conditioning, the drifting subsided and the sensors produced much more consistent results.

3.2.2 Calibration

The op amp circuit discussed in 4.1.2 created an analog output that aided in converting the measured voltage difference determined in the sensor to a readable force, but it did not completely convert the voltage output to the correct force. To complete the conversion to a force output, a range of forces from 0 to 15 were applied to three different conditioned sensors in order to calibrate the system. Figure 7 indicates the results.

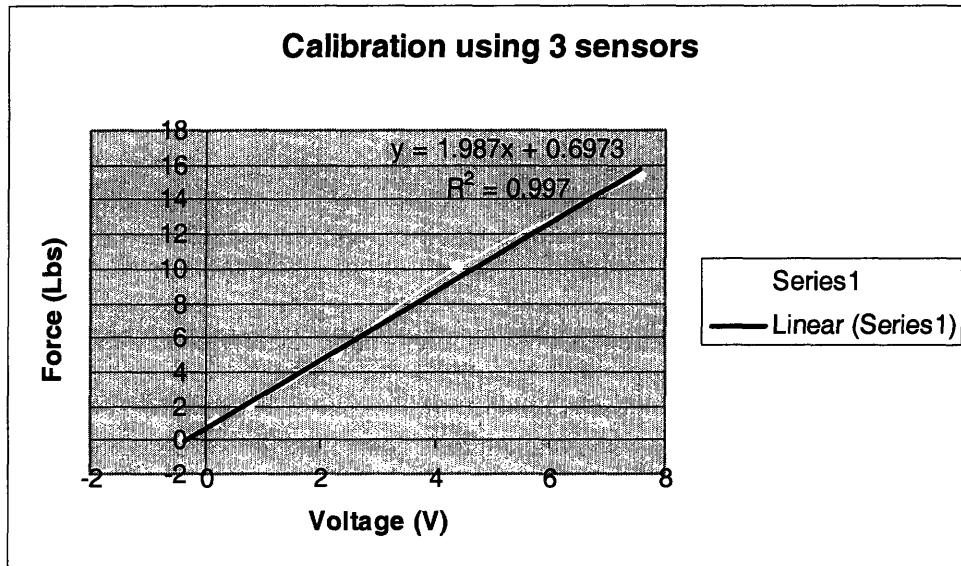


Figure 7: The figure shows the graph and equation that resulted from the calibration process. The lighter line represents the experimental data and the darker line represents the line of best fit.

Three different conditioned sensors were exposed to weights of 0, 1, 2, 5, 10, and 15. The voltage values recorded for each weight were averaged and the best fit line was determined. The equation for the best fit line is at the top of the graph and is $y = 1.987x + 0.6973$.

3.2.3 Testing

To prepare for testing, the inner golf glove is placed on the hand with the wires wrapped to the wrist to prevent any pulling on the sensor connections and to provide

mobility for the user. The baseball glove is then slipped over the hand and the system is prepared for testing. To switch between the two golf gloves, the sensors on the current golf glove are disconnected from the connection cables and the appropriate sensors on the new glove replace them.

4. Discussion

The project resulted with a system capable of measuring the forces involved in the hand-glove interaction. The highlights of the system are the GUI presentation system and the sensor glove design. The GUI allows for enhanced ability of the user to understand and visualize the data collected. The LabView graphical representation was often both hard to read and lacked any real use. By producing this GUI, the project helped to aid in truly understanding how different people use their hand differently while in the glove.

Although the visualizations seen have been easy to read and have clearly represented the scenario being reproduced, there are still a number of different aspects of the system to consider for possible errors. A potentially major contributor to error in the data could be due to the conditioning performed on the sensors. The conditioning done on each of the sixteen sensors followed the same routine on each golf glove. The fact that each sensor was subject to the same routine and a number of repetitions should eliminate a large part of the error. The preliminary observations showed that there were some differences in the measured forces on different sensors with the same applied weight, but overall the results were close in their measurements.

The way in which the sensors were constructed could also play a role in any errors in data acquisition. The sensors are considered one contact point, which means that if the applied load is not evenly distributed across the sensing area, there are potential errors in accuracy and the system's repeatability may be affected. The edges of the sensor can also affect the data if it is aiding in supporting the load. Similar to the potential contributions to error evident in the conditioning of the sensors, these possible problems are unlikely and the effects of the sensors construction and inconsistent load distributions only vary the measurements slightly.³

Some further work that could be conducted to enhance this project would be to improve the sensor attachment to the glove and the gloves attachment to the wires coming from the op amp circuit. Currently, there is some awkwardness in having the glove on due to the fact that the sensors have not been most efficiently placed on the glove. Also, by producing an arm strap the awkwardness of the wiring would be reduced. The apparatus is completely functional, but by containing the wires and providing an arm strap, the apparatus would be improved.

The system provides an opportunity to investigate a number of characteristics of glove design. The major comparisons to be made would be between the gloves of different positions, different sized gloves, and how a variety of different people wear different gloves. Additional testing could be conducted to see how an experience player interacts with the glove as opposed to someone new to wearing a baseball glove. Lastly, a test that compares old gloves to new gloves would make significant headway in determining how best to break in a glove and where exactly certain forces in the hand are used.

5. Project Planning

5.1 Budget

The budget for this project consists of force sensors, golf gloves, and circuit components, as shown in Table 1. All other materials, including balls and gloves will be provided by Rawlings.

Table 1: Project Budget

Item	Cost
Force Sensors	\$200
Golf Gloves (2)	\$30
Circuit Components	\$30

5.2 Schedule

The schedule for IAP and the spring semester included primarily design and construction. The total schedule should take 18 weeks, with weekly meetings and monthly teleconferences with Rawlings. The main dates are shown in Table 2.

Table 2: Project Schedule

Dates	Tasks
January 6 - February 8 (IAP)	Experimental Design completion
February 8 – April 1	Project Construction
April 1 – May 8	Project Assembly and Debugging
May 1 – May 11	Report Writing and Submission
May 11 – May 18	Final Assembly and Testing

6. Conclusion

Glove technology and engineering is not a new concept, but the use of laboratory experimentation and scientific research in the generation of new ideas and products is a fairly new concept to baseball glove manufacturers. This project was created under the sponsorship of Rawlings® and the Sports Innovation @ MIT program to design a system capable of testing different gloves and players by measuring forces on the hand during baseball catching situations. The system created provided an easy to use sensor glove and a neat and interactive computer interface to better help understand the data and aid in identifying characteristics and problems in baseball glove technology.

7. Acknowledgements

During the course of the project, I worked closely with Jay Turner, a junior in Electrical Engineering and Computer Science. Jay played the major role in construction of the GUI aspect of the project with his experience in Java programming.

Rawlings® also provided a number of resources and funding that was used in our project. The help and guidance of Greg Williams and Brian Hoying provided great insight into the direction of the project.

Dave Robertson, Technical Instructor for the Department of Aeronautics and Astronautics, also provided extensive and helpful aid during the construction of our glove system. He also set us up with the appropriate instrumentation and software.

Lastly, Dr. Kim Blair provided regular assistance and advice on the project. The Sports Innovation @ MIT Program made this project possible and was extremely helpful throughout the year.

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