WiiHopp

Sponsored by JumpSport

Team Members:

Jeff Christian
JtChrist@CalPoly.edu

Ben Hoselton
BHoselto@CalPoly.edu

Derek Simon
DeSimon@CalPoly.edu

Revision: 12/6/2011

Table of Contents

Introduction

Childhood obesity is becoming a growing problem in the United States. According to the CDC, childhood obesity has more than tripled in the past 30 years [7]. It can lead to health problems previously reserved for adults, such as diabetes, high blood pressure, and high cholesterol. For the team WiiHopp project, we plan to turn a JumpSport mini-trampoline into a controller for the Nintendo Wii console. The hope is to help turn the problem of video games and the laziness surrounding them into an active solution to combat the problem of childhood obesity.

Our goal is to produce an add-on device for a mini-trampoline capable of interfacing with a gaming console. The device should be able to recognize typical trampoline motions, such as bouncing, stepping, and running along with bounce frequency and height. This will be done by integrating a series of sensors designing to interpret these motions. The device will then produce an output recognizable by the gaming system, thus allowing the user to use their trampoline to play their video games.

Background

General System Design

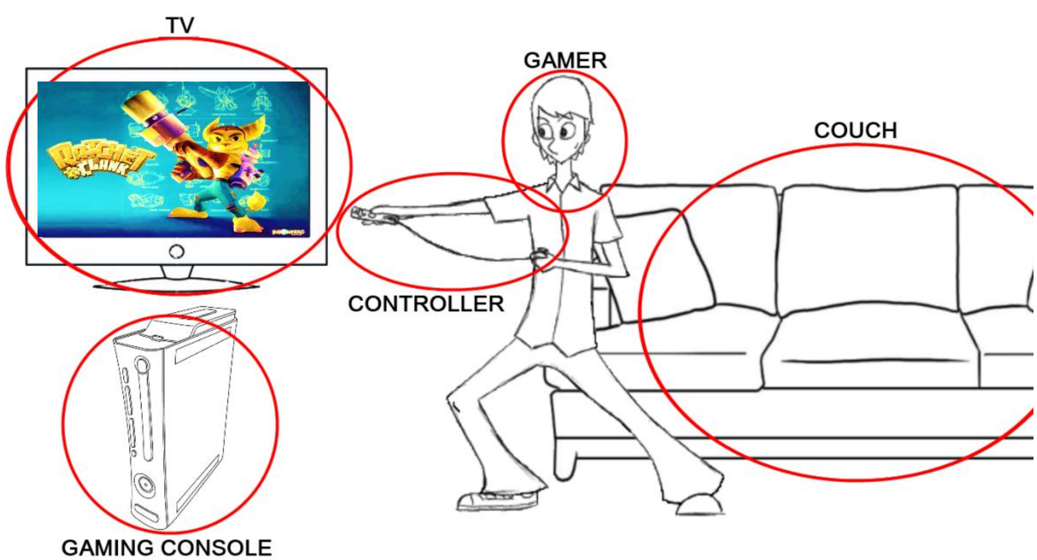


Figure 1. Diagram of essential gaming components: gaming console, controller, TV, gamer, and couch.

Gaming Console

The game console is the piece of electronic equipment that does all of the processing and graphics computations necessary for the user to play a game. Its layout typically resembles that of a modern computer, consisting of a CPU, GPU, and RAM mounted to a motherboard. The console receives input from a controller and displays output on a TV. Nowadays, the controller-console connection is usually wireless. However, the console-TV connection is always wired. See the TV section below for more on the console-TV connection.

Consoles are categorized by their generation, with the latest being the 7th generation. The three current generation consoles are the Nintendo Wii, the PlayStation 3, and the XBOX 360, as seen below in Figure 2. For clarity, the terms gaming console and gaming system are interchangeable.

Figure 2. Current generation gaming consoles, from left to right: XBOX 360, PlayStation 3, and Nintendo Wii. [3]

Controller

Figure 3. Typical video game controller consisting of buttons and joysticks. This controller is for the XBOX 360 [4].

The controller is the link between the gamer and the console. All game consoles utilize some sort of controller. Older consoles had wired controllers, but as of the current generation (7th) all major consoles now have wireless controllers. These are powered by either a pair of traditional AA batteries or a rechargeable battery pack [1]. PS3 and Wii use Bluetooth to connect wirelessly to their consoles, while XBOX 360 uses a proprietary radio frequency technology. The Bluetooth chip is the Wii controller is a Broadcom BCM2042 [2].

Each of the three modern consoles also has its own means of motion control. For the Wii, the motion sensing is built in, but for the other systems it is sold as an add-on (pictured below). They are called the PS3 Move and XBOX Kinect. In this document, the term "remote" will refer to a handheld motion-sensing device, while the term "controller" will refer to a device using buttons and joysticks to communicate.

Figure 4. Current motion sensing systems for different consoles. From left to right: PS3, Wii, Xbox360.

New motion sensing control systems, as can be seen above, show that the PS3 and Wii use very similar systems consisting of a controller in one hand (left) and a motion sensing remote in the other. The remotes both contain 3-axis accelerometers. The Wii in particular uses an Analog Devices ADXL330 3-axis accelerometer[1] [2]. The Wii Mote (Wii remote) detects its position through the use of a sensor bar. The sensor bar is placed above or below the TV and contains a series of infrared LEDs at a fixed spacing. Contained in the front of the Wii Mote is an infrared detector. Based on the orientation of the LEDs and the perceived distance between LEDs, the Wii Mote can determine where it is pointing. Note that this means of sensing only works when the Wii Mote is pointed towards the TV. Otherwise it must rely on its accelerometers for position detection.

The PS3 uses a similar yet more advanced system to accomplish the same goals. It uses a camera, called the PlayStation Eye, placed above the TV (in place of the sensor bar). Each remote has a glowing orb at the tip. The camera is used to locate the orb and can determine depth based on the orb's size. Because the orb can be seen at all angles, this system allows the PS3 to maintain accurate position detection regardless of the orientation of the remote. In addition to a 3-axis accelerometer, the PS3 remote also contains a gyroscope to determine its rotation, as well as a magnetometer to determine its rotation relative to magnetic north. Data from all of these sensors is analyzed to determine the remote's position and orientation in 3D space to within a millimeter.

The XBOX Kinect works quite differently. It utilizes two mounted cameras to identify the human body. The data from the two cameras is combined to create a 3D model of your body and the room in which you're playing. It also has a RADAR system to determine your distance from the TV. Advanced

[1] ADXL330 data sheet can be found at http://www.analog.com/static/imported-files/data_sheets/ADXL330.pdf

software is used to interpret this data and create a 3D skeleton of your body. This allows it to track your motions which are then used to control the game.

TV

In order to play a console, one must have a television or monitor to display the game. The TV is the primary means through which the gaming system interacts with the user. The user primarily interacts with the gaming system by pressing buttons, moving joysticks, and recently through certain full body motions recognized by the new motion control systems.

Consoles typically connect to a TV through composite-video cables, component-video cables, or HDMI (High Definition Multimedia Interface). Any display device, be it analog or digital, TV, monitor, or projector, will work with the console. The connection used depends upon user preference and the available connection types on the user's TV. See Appendix A for a description of these connection types.

Couch

Sitting on a couch is the classic position for playing video games. However, as the new motion systems mature, household gaming is becoming more and more active. We hope that our trampoline controller will get players on their feet and bouncing, making the gaming experience more fun, more interactive, and healthier.

Arduino

Concept Selection

Our first choice for interfacing our controller with the Wii was through the Wiimote expansion port. This is a port in the back of the Wiimote into which extension controllers can be plugged, such as the Wii Nunchuck, classic controller, or Guitar Hero guitar. Our other options for interfacing with the Wii were to use the Gamecube ports or to create our own Bluetooth compatible device. The expansion port, however, has many advantages:

1. Maintains wireless – as opposed to using the Gamecube ports which are wired
2. Wiimote already has bluetooth built in – this simplifies our product and eliminates redundancy
3. Wiimote expansion port communicates through I2C, a simple and well-known protocol.
4. Possibility to power our extension from the Wiimote, thus eliminating the need for a battery pack.
5. For development purposes, we can have our extension controller disguise itself as different pre-existing controllers, allowing us to use it to try it out different games without having to develop our own software. This could not be done through the Gamecube ports.

Choosing Arduino

We decided that the best way to convert our inputs (accelerations and buttons presses) to an output recognizable by the Wiimote, was to use a microcontroller. We've chosen to work with an Arduino Uno (Figure 35). Arduino boards are open source electronics prototyping platforms. They are cheap, fully programmable (in C), and widely used. In fact, much progress has been made towards using an Arduino with Wii controllers, and all of the code is readily available online, so we decided this was a good place to start.

We began by familiarizing ourselves with the Arduino IDE (Integrated Development Environment), programming language, and the use of buttons, LEDs, and sensors. We extended this into communicating between the Wii nunchuk and Arduino. The Arduino could read the Nunchuck's acceleration and button values and perform calculations on them.

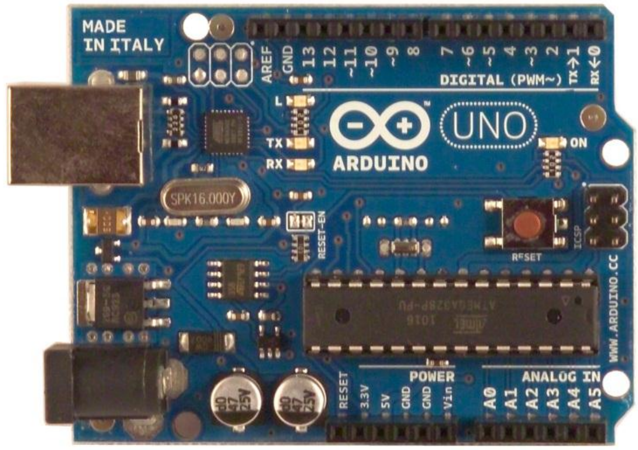


Figure 5. Arduino Uno

Similar Products

Fitness Trampoline

While we plan to integrate a fitness trampoline into our product, we are still in competition with existing mini trampolines. Trampolines like the JumpSport Rebounder, shown in Figure 5, are most commonly used for working out, either in a fitness class or with a workout video. We hope to maintain these uses while adding the ability to use the trampoline as a game controller.

Figure 6. Fitness Trampoline. The model pictured is a JumpSport Rebounder [6].

DDR Pads

Dance Dance Revolution (DDR) was a video game released in 1999. It began as an arcade game and grew in popularity once the game and the required dance pads were released for home game consoles. The DDR Pads are the simplest controllers we've examined, containing only buttons as input devices. Underneath the colorful surface of the gamepad exist three distinct layers: a top and bottom layer of conductive sheeting with a middle layer of foam.

Figure 7. Dance Dance Revolution game pad.

The foam has holes cut throughout it, so that when it is compressed by stepping on it, the top and bottom layers complete a circuit (button press). See Testing for details on the DDR Pad we disassembled.

Many people applauded the game's incorporation of physical activity into gaming, as people playing at the higher difficulties can easily work up a sweat in a matter of minutes. Unfortunately, these gamepads are only usable with actual DDR games.

It should be noted that the DDR controller connection is the same as that of a Nintendo GameCube controller, which is also compatible with the Wii. This allows us to play any game on the Wii that can be played with a GameCube controller or a DDR pad.

Wii Balance Board

Figure 8. Wii Balance Board

The Wii Balance Board was introduced in 2007along with the game Wii Fit. It is an attempt to incorporate more physical activity into gaming, with categories such as yoga, strength training, aerobics, and balance. While these are certainly healthy activities, we feel the balance board falls short in being able to deliver any type of full workout. Additionally, it is limited in the games with which it can be used. The balance board uses four strain gages, one in each corner, to measure the user's weight and determine their distribution of weight. See Research for more information on the internal workings of the Wii Balance Board.

Although we have not been able to find another instance of a trampoline being used with a video game console, we have identified certain of its competitors. We hope that our product, when used in conjunction with a Wii, will replace a regular mini-trampoline used with a workout video. Other products, such as the Wii Balance Board and Dance Dance Revolution dance pads are designed to meld activity with gaming. Our product will accomplish this same goal through the arguably more fun medium of a trampoline.

Table 1. Pros and Cons of Similar Products

	Fitness Trampoline	DDR Pads	Wii Balance Board
Disadvantages	Doesn't appeal to kids Workout oriented	Doesn't appeal to adults Can only be used with one type of game	Not very intense (can't jump or run) Limited use with other games Only single player
Advantages	Rugged design	Multi-player Variable intensity	Precise control

Objectives

The overall goal of the project is to make a market ready trampoline that connects to a gaming console to give real time feedback of movement. The initial goal will be to get the trampoline to work with some existing games. Once this is completed, the trampolines outputs can then be used by software engineers to make games designed for trampoline jumping. The final product should meet the following engineering specifications.

I. Length of Assembly

We want the user to be able to pull the unit out of the box and have it ready to play within 30 minutes. This gives enough time to pull everything out of the box, bolt the legs of the trampoline together, and mount the sensory equipment. The final step will be to hook up the Wii trampoline to the Wii console which will be as easy as the press of a button.

II. Customer Survey on Use

We are requiring that all aspects of the device receive at least 80% positive feedback on use. We do not want to market an item that users do not want to use on a regular basis. The device should satisfy all customers in the customer description.

III. Customer Survey on Fun

We require that we have at least a 90% positive feedback on a survey of how fun the item is. We want our customer to be satisfied with the product.

IV. Energy Used by User

We want to regulate the amount of energy needed to use the device. The average user may not want to get an extreme workout every time they use the device so we want to be able to limit the input of the device. Also, since the device will be used by children and adults we must set the limits accordingly. We set the maximum value for this specification based on the average amount of energy to play basketball. The lower limit would be as low as possible so that anyone from any skill level can play with the device whether it is for fitness or fun.

V. Price

The price of the unit should be around $50 for the sensory equipment and the mounting system. This price does not include the price of the $300 dollar trampoline or the price of the $200 dollar Wii. The Wii Fit costs $100 which is like just having our sensory equipment and mounting system. The Wii and the trampoline already cost so much that a $50 add on is not a huge investment to mesh the two together

VI. Response Time

We need the device to be able to accurately relate input motion to a visual display as quickly as possible. The value of the upper limit came from the Wii Remote response time.

VII. Test Games

All devices testing should pass with at least 50% effectiveness on current games produced. We want the user to be able to use their current game collection with the device.

VIII. Test Movements

Since the device is going to be used by a wide range of users, our inputs must work accordingly. The device should be able to pick up all movements from our user range with 95% effectiveness.

IX. Customer Survey on Aesthetics

The device must produce 90% positive feedback for its looks. We want the customer to be able to leave the device in the living room or gym area all the time without the embarrassment of it looking sloppy.

X. Pass/Fail

Some requirements can only be either pass or fail. These include, wireless capabilities and power source effectiveness. For instance we want to require that the device be wireless. Its either pass meaning it is wireless, or its fail meaning it isn't wireless. We also want to be able to run the device by two double A batteries.

Table 2. Project WiiHopp Formal Engineering Requirements
For Risk L = Low, M = Medium, H = High
For Compliance A = Analysis, T = Test, S = Similarity to an Existing Design, I = Inspection

Spec #	Parameter Description	Requirement or Target (Units)	Tolerance	Risk	Compliance
1	Length of Assembly	30 minutes	Max	L	T
2	Customer Survey on Use	80% positive	Min	H	A
3	Customer Survey on Fun	90% positive	Min	H	A
4	Energy Used by User	13 Calories/Min	Max	M	T, S
5	Price	$50	+/- $10	L	A, S
6	Response Time	16 ms	+/- 2	H	A, T, S
7	Test Games	50% effective	Min	M	T
8	Test Movements	95% effective	Min	H	T
9	Customer Survey on looks	90% positive	Min	H	A
10	Pass/Fail	Pass		M	A, T, I, S

In summary, we hope to build on this newer generation of motion sensing controllers. We plan to use some of this latest generation motion sensing technology and adapt it to a trampoline. This will bring video games controllers and workouts to an all new level of interactivity.

Concept Generation

Single Accelerometer

This design uses a single accelerometer to take data then transfers it to the interface device which processes the data then sends a signal to the Wii via Bluetooth. This would allow for the jumping interface between the user jumping on the trampoline and the Wii game. We can also satisfy leaning, directional jumping, light and heavy jumping, as well as running with this one sensory device.

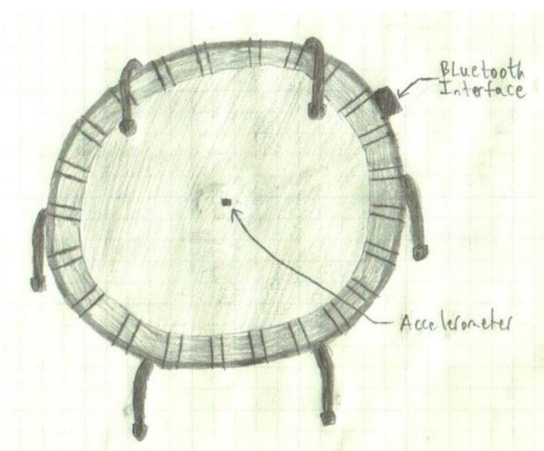


Figure 9. Single accelerometer

Pros

- Doesn't interfere with jumping
- Light weight
- Cheap

Cons

- Hard to process data
- Mounts to mat
- Requires intense software and electronics

Nunchuck as Accelerometer

This design utilizes the equipment already made for Nintendo interface. The user would strap the Nunchuck to the underside of the trampoline then slide the Wii Mote into the remote holder. The Wii Mote is already set up to read the accelerometer data and interface with the Wii. This would satisfy all the same design requirements as the singular accelerometer would.

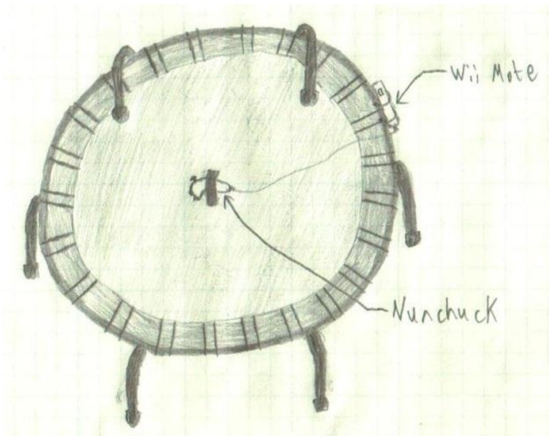


Figure 10. Nunchuck

Pros

- Uses a common Wii accessory
- Easily unstraps
- Cheap
- Interface is already set up

Cons

- Interferes with jumping
- Can cause damage to the Nunchuck
- Could fall out if not mounted correctly

Multiple Accelerometers

This design uses a multiple accelerometers located at different points on the mat. It would allow us to analyze the accelerations relative to other mat positions. With this we could map where the user is on the mat and potentially where they are in the air. This would satisfy the design requirements in the precious two concepts but allow for more accuracy.

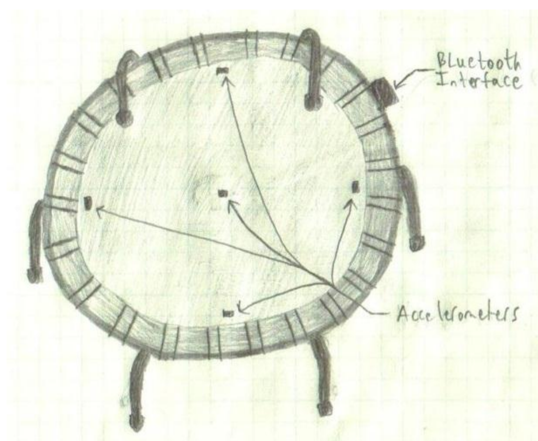


Figure 11. Multiple accelerometers

Pros

- Accurate mapping
- Light weight
- Doesn't interfere with jumping

Cons

- Super intense software and electronics
- Difficult to calibrate
- Hard to process data
- Mounts to mat
- Expensive

Strain Gages

This concept attaches strain gages to the legs of the trampoline. It would allow us to map the user's position on the trampoline. This concept is very similar to the way the Wii balance board is made. Strain gages would be easily mounted but this could not be a standalone concept because we would not be able to correlate jumping to an output very easily.

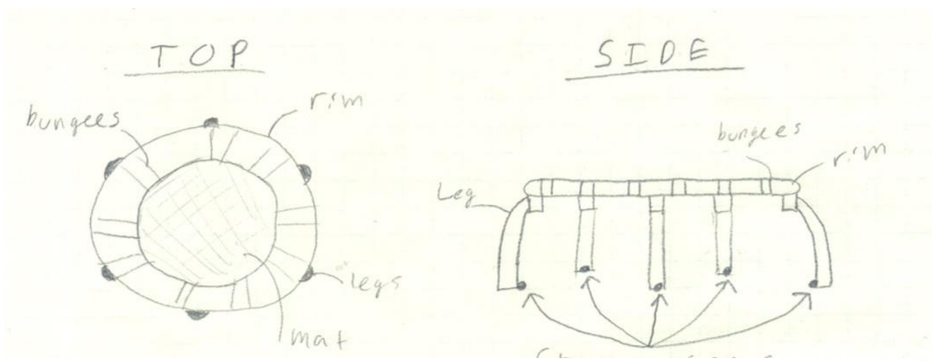


Figure 12. Strain Gages

Pros

- Easily mounted
- Doesn't interfere with jumping

Cons

- Hard to process data
- Expensive
- Difficult to calibrate
- Doesn't pick up jumping very well

Buttons

This concept adapts buttons to the surface of the trampoline mat. It would follow a similar construction to that of the DDR Pad, using conductive pads separated by a foam pad. However, it is a simple, straighforward, and cheap solution and allows the user to do a wide range of controlling.

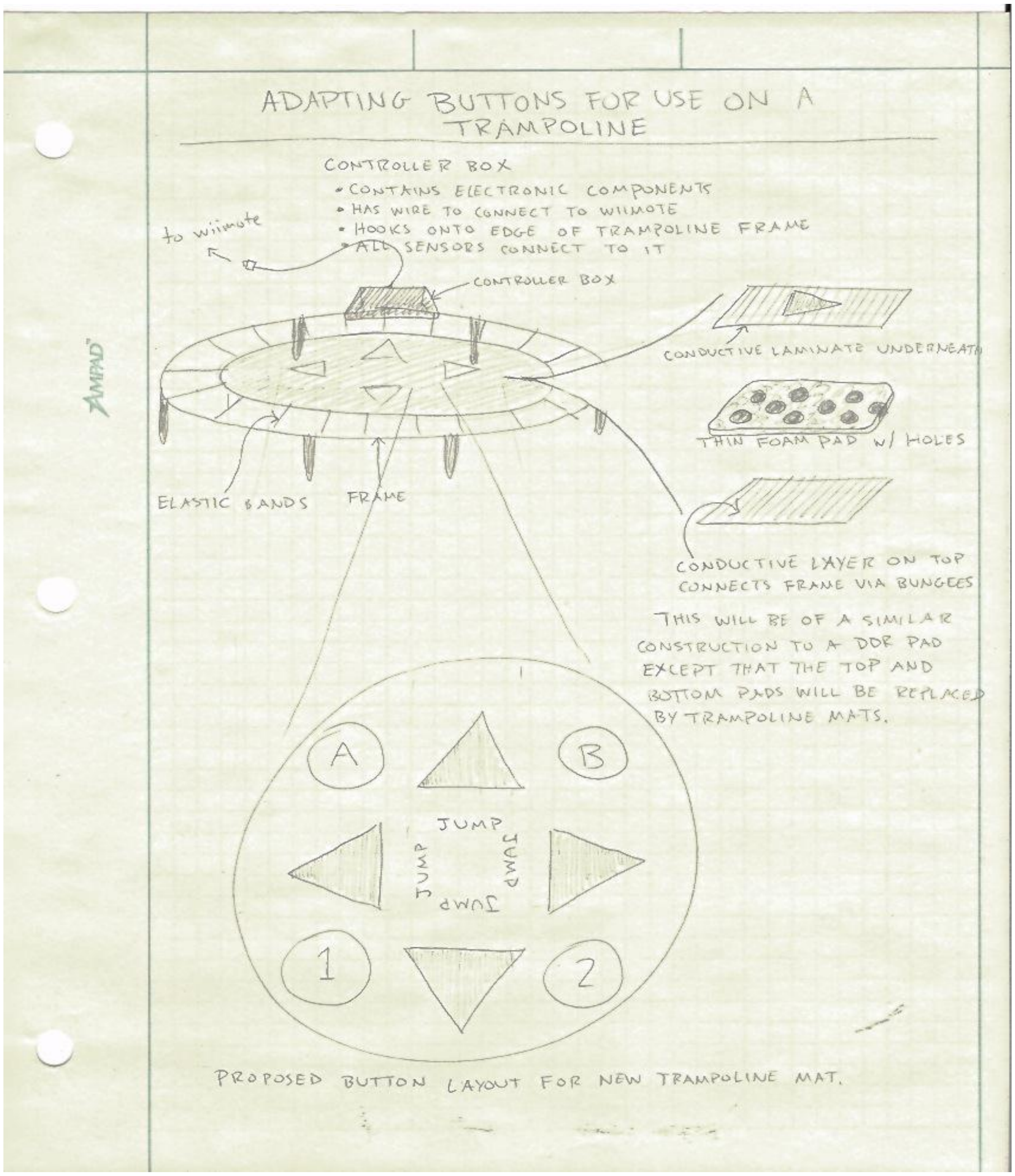


Figure 13. Buttons adapted to trampoline

Pros

- Simple electronics
- Already compatible with DDR games
- Wide range of controls

Cons

- Doesn't take full advantage of bouncing
- Complicates the trampoline mat
- May make the mat less comfortable for regular bouncing

Concept Selection

After brainstorming for design concepts we must narrow our ideas down to the most feasible options. To do this we used a decision matrix with a list of the important requirements to our system. Please see table 3 below.

Table 3. Project WiiHopp Concept Selection Decision Matrix

	Concepts				
Selection Criteria	**A Single Accelerometer**	**B Nunchuck as Accelerometer**	**C Multiple Accelerometers**	**D Buttons**	**E Strain Gages**
Ease of testing	0	+	-	+	-
Ease of integration	0	+	0	-	+
Manufacturability	0	+	0	-	+
Readability of Outputs	+	+	+	+	0
Range of Controls	0	0	+	+	0
Software Intensity	-	0	-	+	-
Electronics Intensity	-	0	-	+	-
Trampoline Interference	0	-	0	-	+
Cost	+	+	+	0	0
Sum +'s	2	5	3	5	3
Sum 0's	5	3	3	1	3
Sum -'s	2	1	3	3	3
Net Scores	0	4	0	2	0
Rank	3rd	1st	3rd	2nd	3rd
Continue?	No	Yes	No	Yes	Revise

Based on the decision matrix we found that the Nunchuck as an accelerometer and the button concepts definitely satisfied most of our requirements. Then, the other three concepts tied for third with a net score of zero. Concept A and C are similar to the ideas produced in concept B. Meaning they basically satisfy the same design requirements. Concept C provides slightly more accuracy than the other two options, but intensifies the problem. So based on this we are not going to pursue concepts A and C. Concept E is different than any of the other concepts and may satisfy some design requirements that the other concept might not be able to satisfy. For these reasons we do not want to throw this idea out just yet. We are going to continue research and development on this concept in anticipation of revising the decision matrix.

Table 4. Project WiiHopp Console Selection Decision Matrix

Criterion	Weight	Current Generation Consoles					
		Nintendo Wii		PlayStation 3		Xbox 360	
		Rating	Score	Rating	Score	Rating	Score
Price	3	10	30	5	15	4	12
Total Sales	7	10	70	5	35	6	42
2009 Sales	8	10	80	5	40	5	40
Audience Range	10	7	70	9	90	9	90
Sensory Equipment	4	5	20	10	40	7	28
3rd Party Compatibility	8	6	48	6	48	3	24
Fitness Oriented	6	8	48	3	18	6	36
Current Potential	8	7	56	7	56	2	16
Future Potential	8	10	80	8	64	5	40
Total	62	**73**	**502**	**58**	**406**	**47**	**328**

Table 4 is a decision matrix that we used to help us choose which console would be our primary focus to develop for during this project. The criterion weights vary from 1 to 10 and the ratings for each criterion also vary from 1 to 10. The higher the number, the better the console fulfills the criterion. The console with the highest score is the Nintendo Wii, followed by the PlayStation 3. The Xbox 360, according to our decision matrix, is the least desirable platform for development.

Method of Approach

In order to produce a video game controller, we plan to start by examining existing controllers. We are going to start with one of the oldest and simplest gaming systems, the Nintendo Entertainment System, and take it apart to figure out how its controller works. We then plan to move up to current generation controllers, such as the Wii Guitar. We'll also examine our competitors' products, like the Wii Balance Board and DDR dance pad to learn how they've used sensors with the Wii console.

Once we have an understanding of the controller interface and the sensors used, we will go about designing our product. We plan to build our product in baby steps, first getting the basic sensors to work with a NES and then expanding on them. As all Nintendo controllers are backwards compatible we'll know that our early prototypes will work with the Wii. Once we move to the Wii and get the basics working, we can possibly take advantage of the Wii's more dynamic controller interface.

I. Research
    a. Disassemble
II. Design
    a. Decide on Basic sensors
III. Prototype (adjusting design based on how well the sensors work)
    a. Adapt to Wii
    b. Get working on NES
    c. Get working on Wii
IV. Test
    a. Add more advance sensors (time permitting)

Research

Wii Balance Board

We disassembled the Wii Balance Board and discovered that it uses four strain gages to measure weight. One is located in each corner of the board. In addition, the strain gages are placed on finely machined steel bars which are put in bending in order to increase strain.

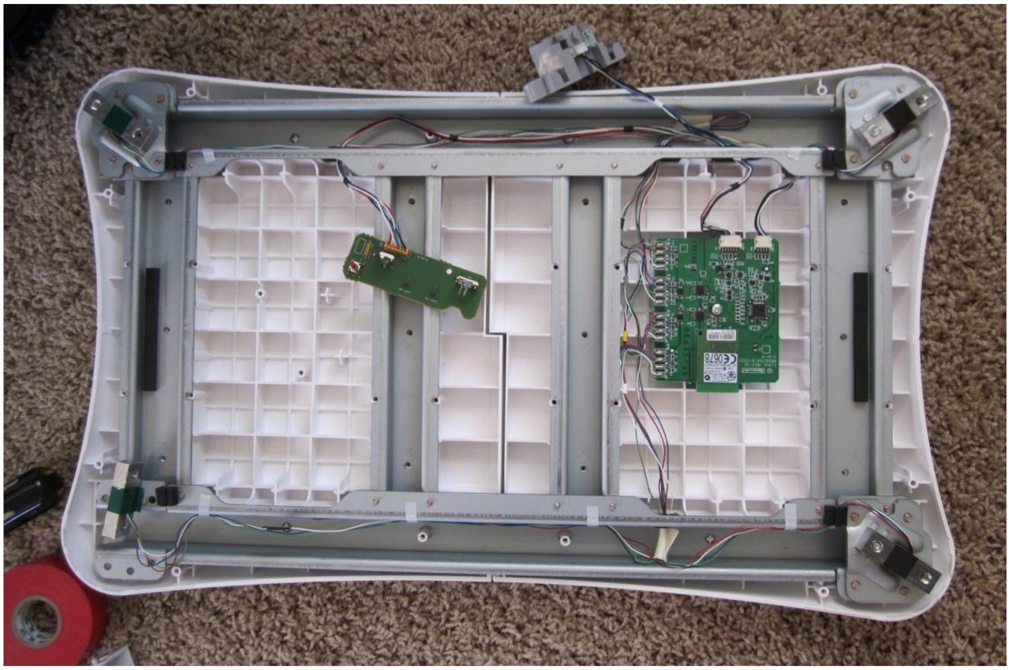


Figure 14. Wii Balance Board disassembly

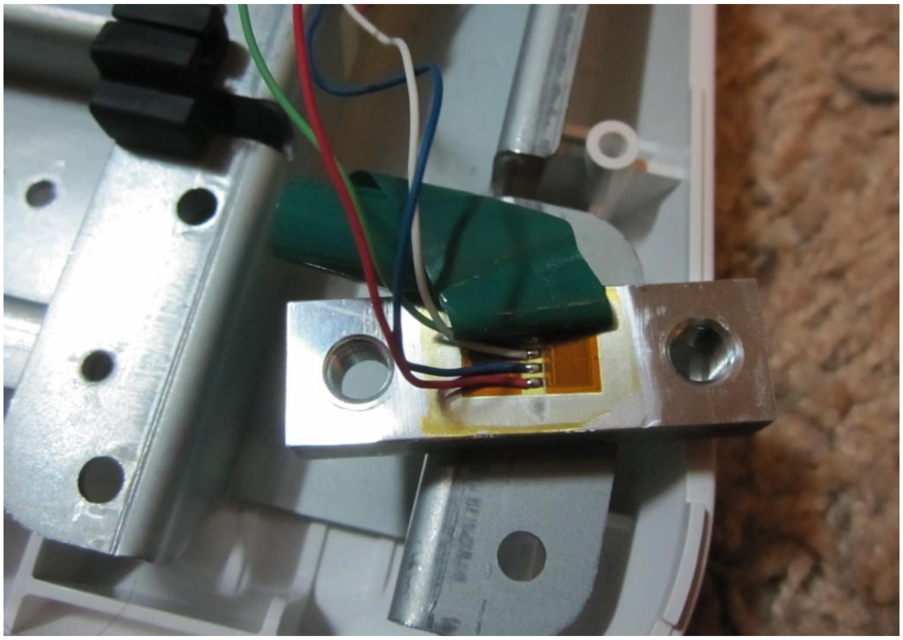


Figure 15. One of four strain gages in the Wii Balance Board

Table 5. Voltages measured between different wires on one of the strain gages. All values are in V_{DC}. All measurements made with an Omega multimeter.

	White (V_{DC})	Green (V_{DC})	Blue (V_{DC})	Red (V_{DC})
White	-			
Green	1.590	-		
Blue	1.590	0.000	-	
Red	No Value	1.590	1.590	-

There seemed to be no readable signal between Red and White. The multimeter just read "1" or "-1." All other values were simply the voltage of a single AA battery (~1.5V) in the range 1.590±0.001 V_{DC}. With Derek (148lb) standing on one of the strain gages we could measure a voltage increase of 0.002V_{DC}.

DDR Pad

We cut open a DDR Pad to examine its internals and take some measurements. Our test setup can be seen below in Figure 15.

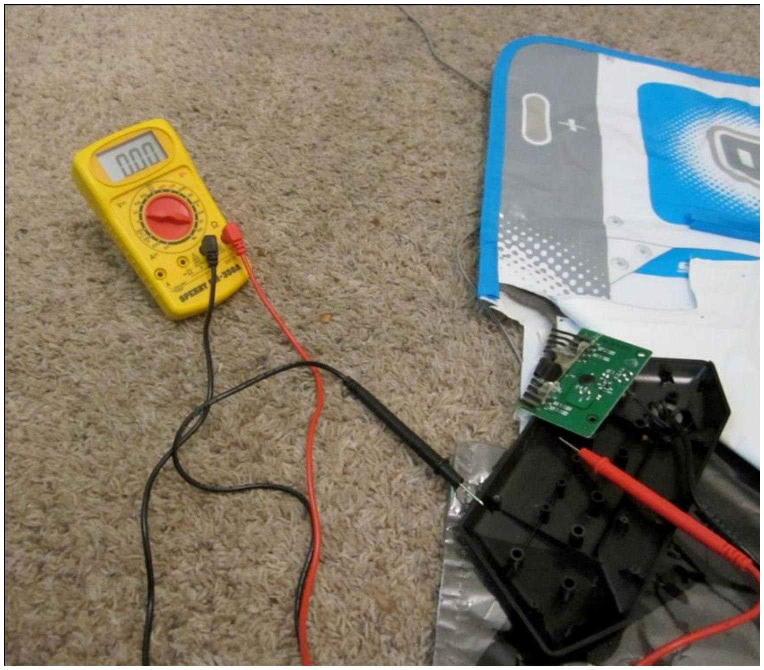


Figure 16. DDR Pad test setup

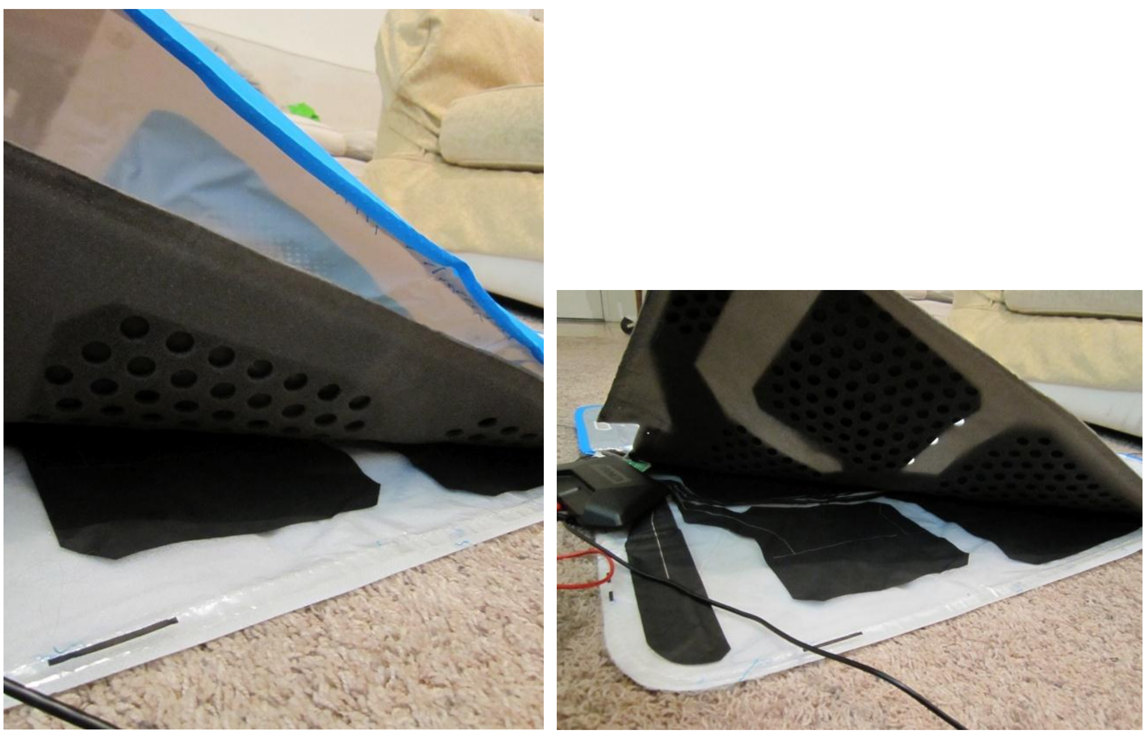


Figure 17. DDR Pad layers

Seen in Figure 16 are three of the DDR Pad's internal layers. The top is the colorful protective coating. The middle layer consists of the upper conductive sheet connected to a 4mm thick foam pad. (Foam thickness varies from manufacturer to manufacturer.) The bottom layer is the lower conductive sheet with a protective rubber pad below.

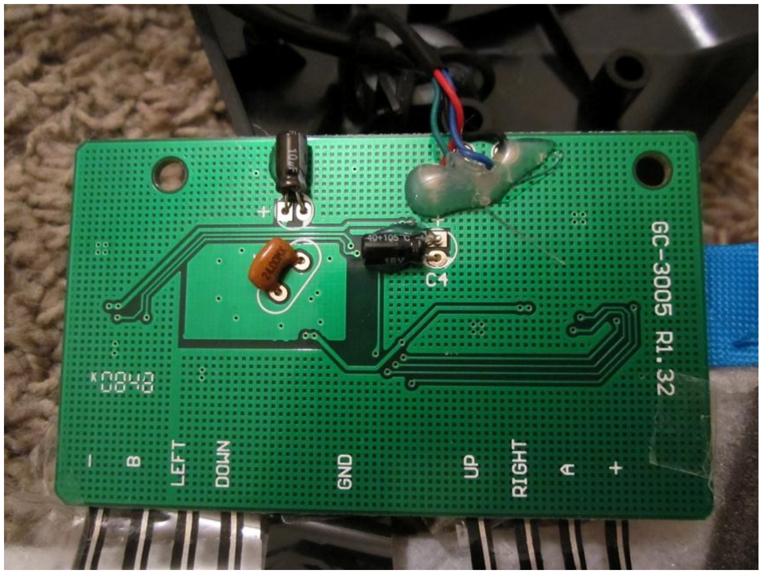


Figure 18. DDR Pad circuit board

The DDR Pad consists of 8 buttons: Plus, Minus, A, B, Up, Left, Right, and Down. These were conveniently labeled on the DDR Pad circuit board. We discovered that when any of the buttons are connected to the ground it responds as a button press. We measured $3.31V_{DC}$ and 15mA between each of the buttons and ground. This voltage is reasonable, as the DDR Pad is supposed to receive an input voltage of $3.3V_{DC}$ from the Wii.

Accelerometer

To test the feasibility of using an accelerometer to sense trampoline motions, we attached a Wii Nunchuck to the bottom of a trampoline mat. We did this by threading string between the holes in the net and looping it around the Nunchuck controller until it seemed sufficiently secure. Our test setup can be seen below in Figure 18.

Figure 19. WiiHopp team member Derek Simon displaying accelerometer test setup

Figure 20. Close up of Wii Nunchuck attachment to trampoline

After attaching the Nunchuck to the trampoline mat, we measured the acceleration while performing different actions on the trampoline. Acceleration results can be seen in the graphs below.

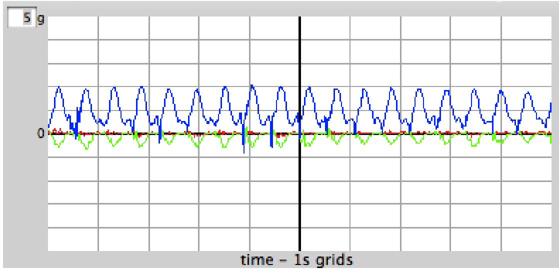


Figure 21. Light bouncing

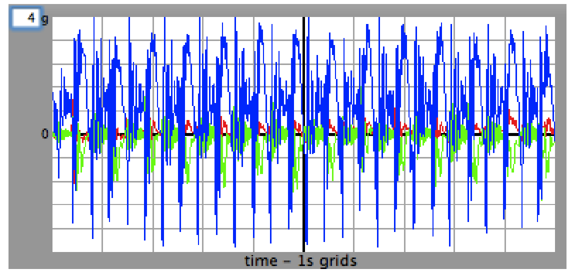


Figure 22. Heavy bouncing

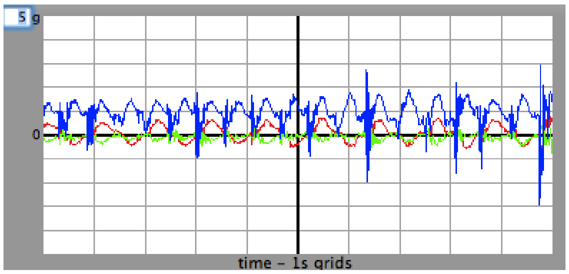


Figure 23. Walking

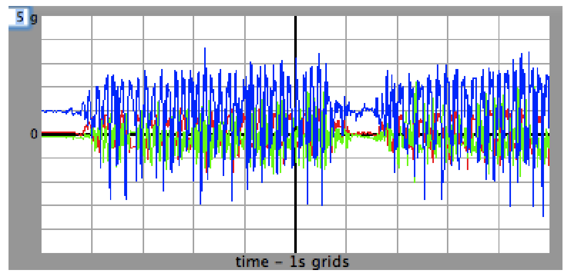


Figure 24. Running

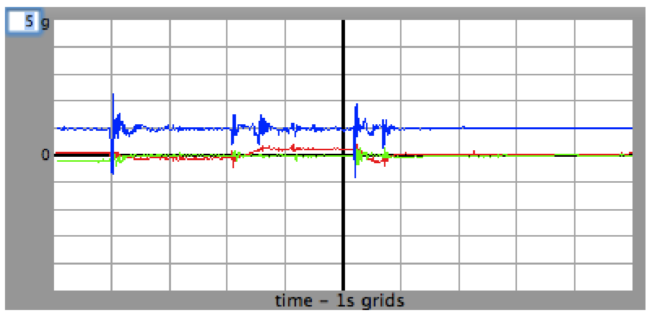


Figure 25. Leaning: front, back, left, right

We were thrilled with these results, as it seems that one can clearly distinguish between different motions simply based on data from a single accelerometer. Each type of motion appears to create its own unique acceleration pattern. We are even able to sense leaning to a degree. When the gamer leans in one direction, he tilts the accelerometer. Although this does not change the magnitude of acceleration, it changes the relative direction of gravitational acceleration. This leads us to believe that we could possible sense leaning as well as bouncing with an accelerometer.

Management Plan

In order to stay on task in the design process we have put together a management plan that defines the responsibility of each team member.

Derek Simon is in charge of:

I. Gathering information about:
   a. JumpSport Trampoline
   b. Gaming Systems
II. Documentation of progress on
III. Managing the sensory mounting system

Ben Hoselton is in charge of:

I. Gathering information about:
    a. Sensory equipment
    b. Games
II. Manufacturing considerations
III. Prototype fabrication
IV. Managing the sensory equipment system

Jeff Christian is in charge of:

I. Gathering information about:
    a. Software
    b. Modding
II. Testing plans
III. Managing the software system

Also, in order to stay on track, we have a schedule that we are striving to fulfill.

Winter Quarter

Finalize Problem Definition……………………………………………………………………………Jan. 25th

Design Specifications……………………………………………………………………………………Feb. 1st

Project Objectives…………………………………………………………………………………………Feb. 3rd

Concept Generation……………………………………………………………………………………Feb. 8th

Concept Selection…………………………………………………………………………………………Feb. 10th

Concept Design Review…………………………………………………………………………………Feb. 15th

Measure Sensory Outputs of Wii Mote……………………………………………………………Feb. 17th

Measure Sensory Outputs of Balance Board……………………………………………………Feb. 22nd

Measure Sensory Outputs of DDR Pad……………………………………………………………Feb. 24th

Static Calculations on Legs for Strain Gauges…………………………………………………Mar. 1st

Acceleration Measurements on Trampoline……………………………………………………Mar. 1st

Design Specifications for Strain Gauges, Accelerometers, Etc……………………………Mar. 3rd

Buy Strain Gauges, Accelerometers, Etc…………………………………………………………Mar. 3rd

Conceptual Design Report………………………………………………………………………………Mar. 4th

Conceptual Design Review………………………………………………………………………………Mar. 11th

Spring Quarter

Implementing DDR Type Buttons onto Trampoline……………………………………………Mar. 30th

Mounting Accelerometers onto Trampoline………………………………………………………Apr. 6th

Testing DDR Type Buttons (ongoing)………………………………………………………………Apr. 6th

Testing Accelerometers (ongoing)……………………………………………………………………Apr. 13th

Writing PC code to analyze DDR Type Button Input (ongoing)……………………………Apr. 20th

Writing PC Code to Analyze Accelerometers (ongoing)……………………………………Apr. 20st

Calibrating/fine tuning DDR Type Buttons for Use on Trampoline………………………Apr. 27th

Design Report…………………………………………………………………………………………Apr. 28th

Get Accelerometer working with Arduino…………………………………………………May 4th

Try fabric samples and tape……………………………………………………………………May 4th

Integrate DDR Type Buttons hardware to Arduino……………………………………May 11th

Get emulator program working with button design…………………………………May 11th

Mounting single Accelerometer to mat………………………………………………………May 18st

Integrating single Accelerometer hardware to Arduino……………………………May 18th

Writing PC code to analyze single accelerometer (ongoing)………………………May 18th

Get emulator program working with accelerometer design………………………May 18th

System Integration (Accelerometer and Buttons connected to Arduino)…………May 25th

Writing PC Code that Analyzes all Systems Simultaneously (ongoing)……………May 25th

Get emulator program working with system………………………………………………May 30th

Critical Design Review…………………………………………………………………………May 31st

Project update report…………………………………………………………………………June 2nd

Fall Quarter

Writing Homebrew Application for use with the Wii……………………………………Sept 21st

Testing buttons complete………………………………………………………………………Sept.28th

Testing accelerometer complete………………………………………………………………Sept. 28th

Start laying out manufacturing process…………………………………………………Sept. 28th

Test sensory equipment with current games (homebrew?)…………………………Oct. 4th

Finalize Manufacturing Process………………………………………………………………Oct. 19th

Testing

Accelerometer

Testing with the Nunchuck's accelerometer has proved it is a worthy sensory device for use on the trampoline. We decided to mount the Nunchuck in a permanent location on the bottom of the mat so we could take more data and compile some programs to test its sensitivity in measuring jumping and leaning motions. A picture of the setup is shown below.

Figure 26. Accelerometer setup

The system consists of a stretchy neoprene holder for the Nunchuck to keep it from slipping out, moving around, or getting crushed from a giant jump. The neoprene holder was then sewed to the bottom of the mat so that the accelerometer was in the middle of the mat. The Nunchuck is inserted into the neoprene holder and the extension is plugged into the Wii mote's expansion port. The Wii mote interfaces wirelessly through Bluetooth communication to a computer. The computer can then run a program that accepts info from the Nunchuck and does a task. A schematic of the system is shown below.

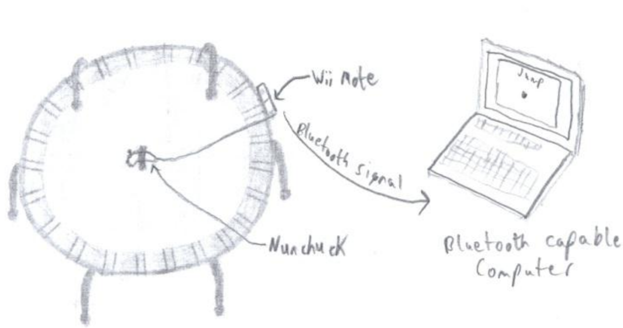


Figure 27. Nunchuck Schematic

We decided to use MatLab to write a test program since we found an existing interface online between the Wii mote and a PC running MatLab. Also, the MatLab language is widely used by mechanical engineers.

Using our initial data from the research section, we found that the *X*-axis of the accelerometer would be our jumping axis, the *Z*-axis would be our right and left directions (positive ΔZ would be left and negative ΔZ would be right), and the *Y*-axis would control our forward and reverse (positive ΔY is a forward motion and negative ΔY is a reverse motion). With this we developed a three dimensional interface between walking around on the trampoline and moving a ball on the screen. A screenshot of the play surface is shown below.

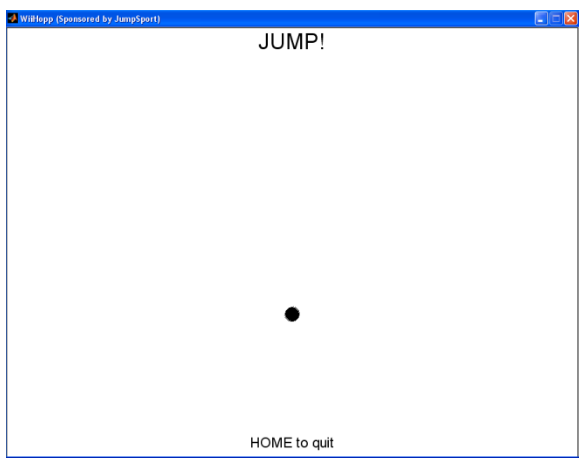


Figure 28. Screenshot of PC play surface

The details of the directional controls of the system are relatively simple. Basically, if the directional control acceleration is greater than the initial accelerations it moves in that direction (when you stand on the trampoline near an edge of the mat, gravity will act on the axis of the directional motion).

The first step is to get the initial accelerations while off the mat.

```
% Calibration
    Wiimote.GetNunchukAccelState(); %gets initial accel state
    X1 = Wiimote.NunchukAccel.X %show in command window
    Y1 = Wiimote.NunchukAccel.Y
    Z1 = Wiimote.NunchukAccel.Z
```

Then we can relate the change in the accelerations to the initial accelerations.

```
while (~isButtonPressed('HOME'))%exit program if HOME button pressed
        Wiimote.GetNunchukAccelState();%continues to get accel state
        X = Wiimote.NunchukAccel.X;
        Y = Wiimote.NunchukAccel.Y;
        Z = Wiimote.NunchukAccel.Z;

 %Bi directional controls
        if(Z>Z1+tolerance && Y>Y1+tolerance)%move left and up
            %controls to make ball move up and left
        else(Z>Z1+tolerance && Y<Y1-tolerance) %move left and down
            %controls to make ball move down and left
        else %accels to move in another direction...
```

This process is done throughout the other directions from hardest directional condition (bi-directional) to easiest directional condition (singular directions). So that if the user trips a bi-directional control first it registers as a bi-directional control, but if a singular directional control came first in the order it would trip that control first and move in a singular direction.

The tolerance value is to set the sensitivity of the acceleration values. The difference has to be greater than some tolerance value. This allows the programmer to change how easy it is to make the ball move in the desired direction. A small tolerance means the user only needs to apply a small force to the mat to get the ball to move directionally, a large tolerance means the user has to jump on the mat to get the program to pick up a directional movement.

Now that we have covered the two dimensional directional controls we can introduce a jump to the system using the *X*-axis.

```
if(X < jump) % jump is the acceleration required for a jump (-20 m/s)
      hide(obj); % hides previous circle
      obj = drawCircle(l, s+j, p); % draws new circle a location j
      above the initial location and increases the size of the ball to
      give a 3 dimensional effect
      pause(jumppause); % Air time
      hide(obj); % hides in air object
      obj = drawCircle(l, s, o); % draws initial object
      pause(0.001);
else
      % continue with next statement
end
```

Basically what happens is when the ball jumps it moves up slightly and increases in size as if it were jumping out of the screen towards the user. This allows for a three dimensional feel in game play. Jumping can be smoothed out to be a gradual increase from the initial object to the jumping object but the example just shows a basic jump.

The jump statement can now be placed into each directional flag so that if a directional flag is raised, it will also check to see if a jumping flag is raised. This will allow for directional jumping. An example of this will not be shown (see the .m file in Appendix E for code).

The final step is to complete the program with a jumping flag so that if there are no directional flags raised, the object will still jump if a jumping flag is raised. Testing is simplified by increasing the tolerance to an unreachable amount and the accelerometer will only flag a jump. Testing of the directional controls can also be simplified by increasing the jump value to an unreachable acceleration and decreasing the tolerance to a value seen while leaning on a side of the mat.

The program will continue to run until the HOME button on the Wii mote is pressed.

Pros

- Works great for directional controlling and jumping
- Doesn't get stuck in loops
- Allows user to set different tolerances for directional or jump movements

Cons

- Uses a simple flag system that allows a left before a right
    - This causes problems with ball motion when jumping too hard on the trampoline because initially a right jump is read as a left jump. This is due to the swinging motion of the mat as the accelerometer moves down.

The accelerometer test program is able to reliably interpret the user's motions. Upon jumping or leaning, it will consistently respond by moving by ball (as seen in Figure 29) in the intended direction. Overall, our testing demonstrates that a mounted accelerometer will allow directional and jump controls.

Future Additions to Code

- Calorie values could be calculated from the users mass and acceleration values. We can introduce a calories burned in game play to see if we can get accurate measurements.
- Stopping at screen limits
    - As of right now the ball will continue infinitely off the screen once it leaves the window
- Smoother jumps and directional movements

Next Step with Accelerometer Design

Incorporate accelerometer with Arduino in order to interface the accelerometer system with the button system. This may require the use of an off board accelerometer that isn't built into the Nunchuck circuit board because the Arduino can't accept Nunchuck information and send information to the Wii. It cannot act as a Wii mote that both inputs and outputs data from Nintendo hardware. We are going to try to mount an accelerometer circuit board onto the bottom of the mat in a similar design to our first concept in the concept generation section. This will allow the Arduino to sense accelerometer data while outputting data to the Wii.

Buttons

Through further testing and concept generation, we have modified and improved our original button design. At first, the buttons were going to be placed on the mat, or jump surface itself, as shown in the concept generation section. After further consideration to the function of the system we are designing, it was decided that we would try and preserve the jump surface as much as possible. At first our idea was to move the buttons to the edge of the mat and arc them according to the mat's circumference. In this design, the buttons appeared too small and hard to distinguish and they were still on the mat itself. This led us to our final design concept: placing the buttons off the mat and inserting them into the dense foam pads that cover the trampoline's bungees. In this way the buttons will be large, clear, easy to step on, and the mat surface is perfectly preserved for the ultimate jumping experience.

The button assembly consists of a lower layer of very dense thick foam (trampoline bungee cover), a flexible plastic sheet used to hold the lower conductive layer, a thin foam of medium density with holes in it to allow contact between the upper and lower conductive layers, and a top conductive layer attached to another flexible plastic sheet for stability. This layered sandwich is what is inserted into the canvas flaps that cover the bungees of the trampoline. When stepped on, the two conductive layers connect and send a signal in the form of a button press to the Wii, Arduino, or computer.

Figure 29. Cutting out the buttons

This eventual button configuration sounds simple enough, but a great deal of testing went into material selection. The dense foam came with the trampoline and is almost ideal for the button design, so it has remained unchanged. The conductive layers took much iteration to come up with a final design. At first we considered using conductive cutouts from our DDR pad but we did not like the cheap and flimsy feel of the material, as well as the crinkling sound it made. Next, we tried using aluminum screen. This not only was not a very good conductor, it was very difficult to attach to the button assembly. It had trouble connecting through the holes, and it permanently deformed after repeated use. We have narrowed the material down to either a conductive copper tape or highly conductive EMF shielding fabric. These materials have extremely low resistance, are flexible, and are easy to attach to other materials. We first tested all of these conductive layer designs on the floor and connected their leads to LEDs. We chose our design based on which material types most consistently and stably lit up the LED. We discovered the need to keep the conductive material from creasing and sliding around. We settled on a linoleum type material that is tough, flexible, won't fray or crack, and holds glue very well.

Lastly, we needed a foam layer with holes in it to allow the conductive layers to make contact. We tried using the foam from the DDR pad, but it was too thin and flimsy and would give us false connections. Next, we tried a car wash sponge but found it to be too thick, dense, and difficult to test. We have narrowed down our foam selection to two types: ½ inch craft foam of fairly low density and thin rubbery foam of medium density used to line toolboxes. Both foams work so we have not yet decided between these two foam types and are currently testing both. For the holes in the foam, we are using a ½ inch leather punch to make rows and columns of holes in the foam. Each hole is about 1" apart in each row (edge to edge distance) and the columns are spaced in the same fashion.

Figure 30. Foam test sample with holes

We have successfully used these buttons on the trampoline and to play emulator games on the computer such as SNES' Mega Man X and classic Super Mario Bros on the Wii.

Next Steps

The next step for the buttons is to finalize our material choice and build a complete set of 6 buttons. Once this is done we will run the wires around the trampoline and clean up the connection to the Arduino by soldering them to pin headers or using a known type of data connection such as USB. We have yet to decide on a suitable method for sealing the buttons. For our prototypes we have been taping the layers together, but we would like to sew them together for our final product.

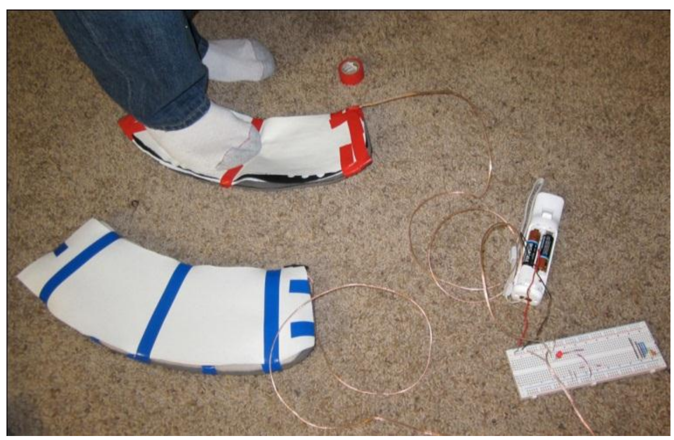


Figure 31. Testing two different button constructions

We also plan to conduct static and dynamic tests of our different button designs in order to quantify their reliability. For static tests, we will attach each button to an LED that will turn on when the button is pressed. We'll then load the button with weight, increasing the weight until it registers a button press. For a dynamic test, we will have one person play a DDR game while another person watches and tracks the accuracy of their dance steps. DDR games classify each step as either "perfect," "great," "good," or "miss." After a large number of button presses (~100) we'll examine the data to see if certain buttons have a higher hit rate than others and use that design in the rest of our buttons.

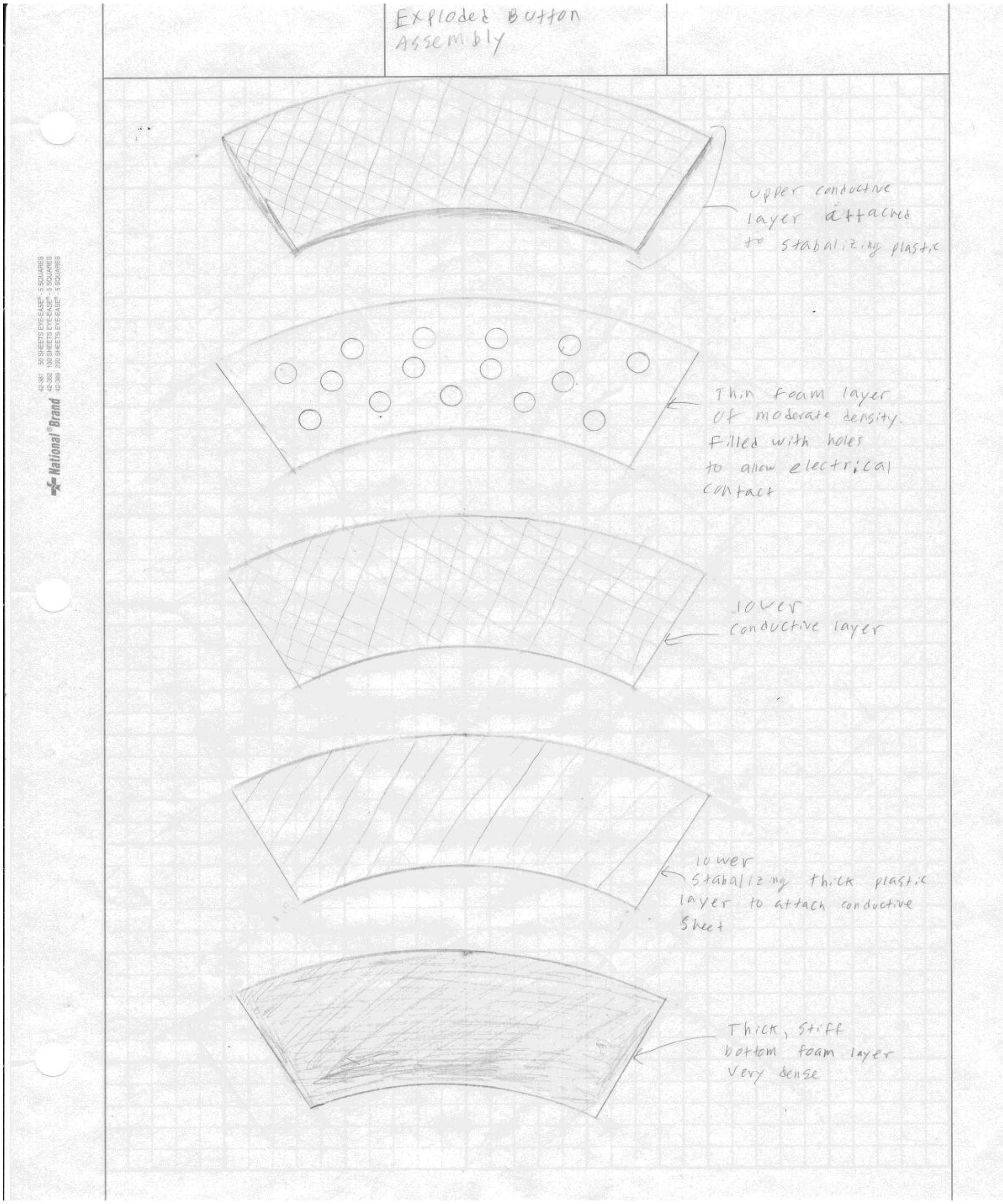


Figure 32. Conceptual design sketch of button layer diagram

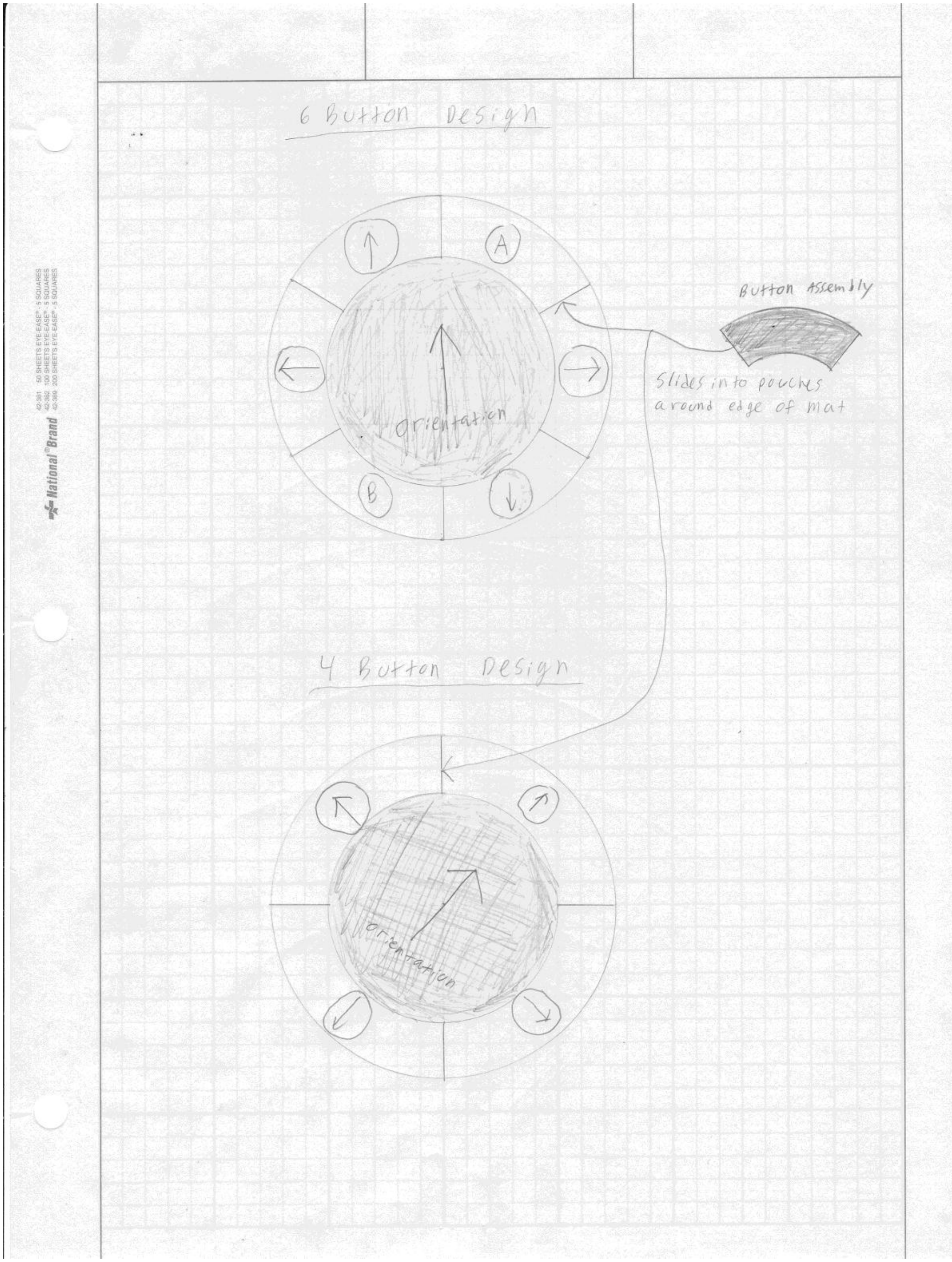


Figure 33. Conceptual design sketch of button layout

Arduino

We began specifically developing the Arduino as a Wiimote extension. We purchased an extension cable, cut it in half, and soldered it to a pin header in order to connect the Arduino to the Wiimote (Figure 36). We rewired the Arduino's circuit board to contain 6 buttons (Figure 37). Once this was done, we made some modifications to existing code online until the computer was able to recognize the Arduino as any type of existing extension controller. Which type of extension controller is determined by certain variables in the Arduino code.

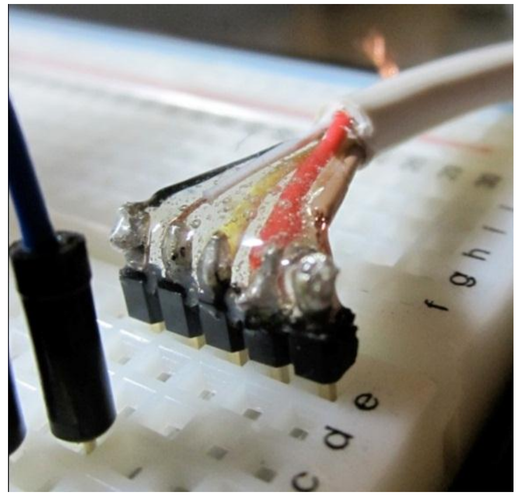


Figure 34. Arduino to Wiimote connection cable

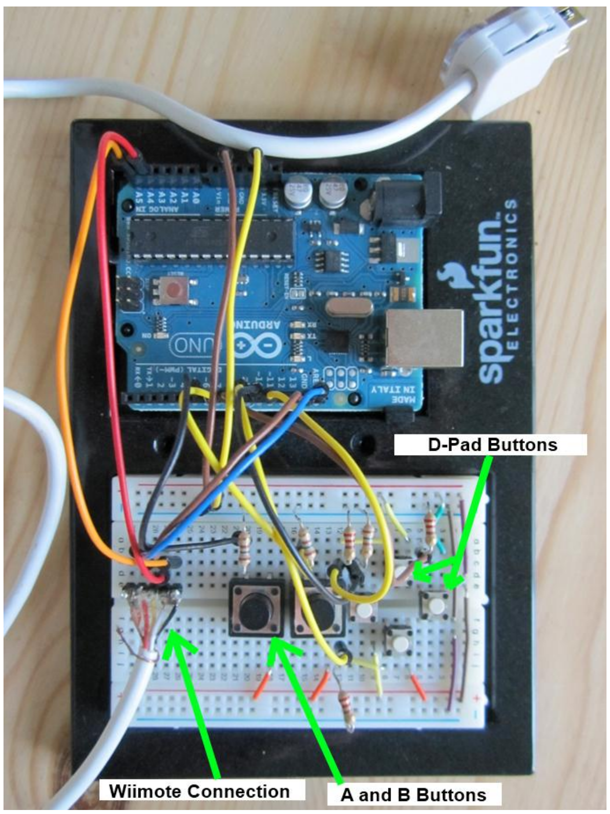


Figure 35. Arduino with buttons and extension cable

The Arduino code maps Arduino buttons to certain Classic Controller buttons. Using a Mac program called DarwiinRemote, we've been able to get a computer to connect to the Wiimote via Bluetooth and recognize the Arduino as a Nintendo Classic Controller extension. DarwiinRemote is a Mac program that allows one to connect a Wiimote (with extensions) to a computer over Bluetooth. It then maps the extension controller buttons to specific keyboard keys allowing the Wiimote to be used to play games on the computer. We've also used a Snes9x, a Super Nintendo emulator, to play SNES games using the Arduino. Snes9x maps keyboard keys to SNES controller buttons. Thus, in this setup, the Arduino buttons correspond to Classic Controller buttons, which are mapped to keyboard keys, which are mapped to SNES controller buttons.

Once all of these are set properly, play goes quite smoothly. There is no detectable lag in the Arduino's output and all button presses are consistently recognized. We have tried this setup on an actual Wii but have had limited success. The Wii will only recognize the Arduino as Nunchuck extension, regardless of how it's programmed to be recognized. As a Nunchuck, we can successfully send button and joystick values, but not accelerations. We plan to continue testing our controller on a computer and developing it for use with the Wii.

See Appendix F for details on the Wiimote expansion port, Wiimote extension signals, and I2C protocol.

Static Button Testing

In order to asses our different button designs, we designed a set of static and dynamic tests. For the static test, we wanted to measure the force required to activate a button press. The static test consisted of wiring each button to an LED and placing it on a scale. We slowly added weight to the button until the LED turned on, indicating a button press.

We repeated this process processing each button in both a forward foot position and a sideways foot position (Figure. 36 below), since these are the two ways in which we expect the buttons to be pressed, depending upon their position on the trampoline mat. We used actual human feet in order to most accurately simulate an in-game setup.

Figure 36. Static button test setup. Left: Forward foot press. Right: Sideways foot press.

The results from these tests are seen below in Figures 37-39.

The most significant differences in the buttons we tested were in hole size and spacing of the foam layer. We tested combinations of large and small holes with sparse and dense spacing as defined below.

Table 6. Quantified button parameters

Small Hole Diameter	Large Hole Diameter	Sparse	Dense
.375 in	0.50 in	1.5 buttons/in^2	2 buttons/in^2

It is worth noting that we had been using all of these buttons ahead of time, so we knew that all of the designs worked. With this test we sought to quantify what made certain buttons better than other

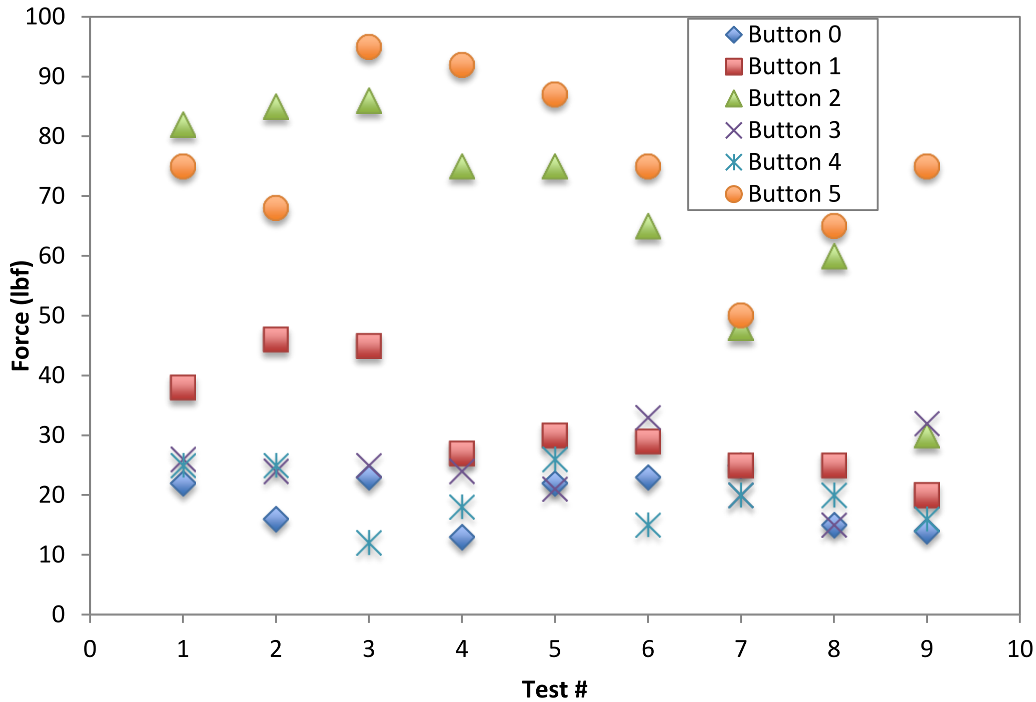


Figure 37. Static button force test results (forward foot placement)

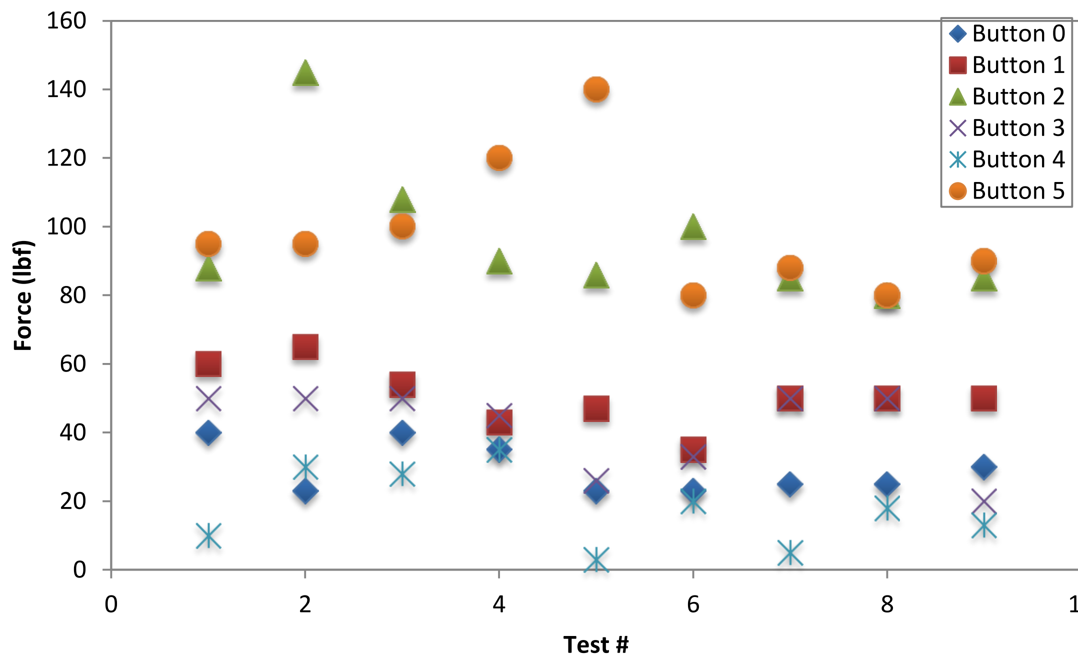


Figure 38. Static button force test results (sideways foot placement)

Based on these test results, the each button appears to perform consistently. In other words, Button 1 is consistently requires the third greatest amount of force to activate. We decided to plot the average force required to activate each button, as seen below.

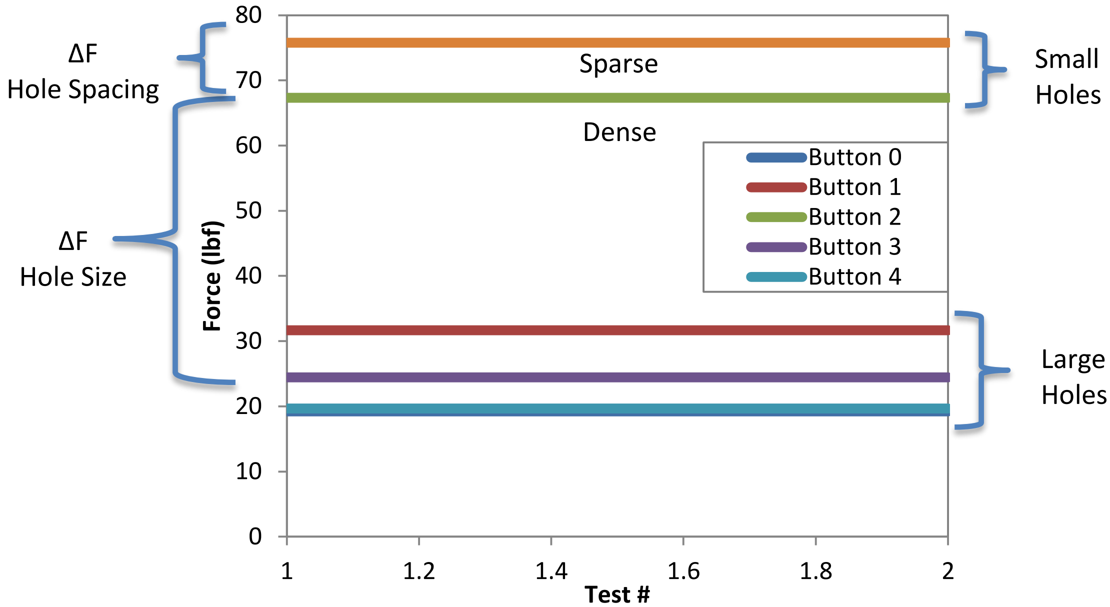


Figure 39. Analysis of static button tests. Each line represents the average value of force required to make each button connect

The results of this test were fascinating. It is clear that the buttons fall into two distinct groups. However, once we actually labeled each button with its appropriate hole layout, we arrived at an interesting result. The buttons with small holes took significantly more force than those with large holes. This is expected. But, this force paled in comparison to the force difference as a result of spacing between the holes.

In comparing, sideways and forward button presses, we found that the relative ranking between buttons was consistent. This was a reassuring result. However, the forces were not the same. On average, it took 1.4 times as much force to press the button when stepping sideways than when stepping forward. We attribute this difference to the fact that a sideways step is distributed over a greater surface area than a forward step (one's heel is contacting the button in addition to the ball of their foot). This increase in surface area means that more force must be applied to achieve the same amount of pressure.

From these results, we conclude that while hole size is very significant, hole spacing is much less significant. They can be used together as coarse and fine adjustments to tune the buttons to the desired activation force. In our case, we decided a button sensitivity of 25 lbf was most desirable, and tuned the buttons accordingly.

Dynamic System Testing

Dynamic button tests were performed using a sample size of 9 players. We chose two different games to play, each of which highlighted a different component of the controller. The game Dance Dance Revolution (DDR) used all of the buttons on the trampoline while Mario Kart 64used the accelerometer.

Mario Kart 64

For Mario Kart, each player raced one time with a traditional controller and then again using the trampoline. The time differences, in favor of the traditional controller, are displayed in the table below. The testing results confirm that the trampoline is a competitive and viable controller option.

Table 7. Increase in Mario Kart lap times while using trampoline as the controller. Since time differences are small, we see that the trampoline is a competitive alternative to a traditional controller.

Δt_{ave}	**1.73**	seconds/lap
Last Lap Δt_{ave}	**2.24**	seconds/lap

On average, users raced 1.73 seconds slower per lap when playing on the trampoline than they did with a traditional controller. However, we attribute much of this difference to adjusting to the new controller scheme. Most people all familiar with a traditional video game controller, but no one has used the steering mechanism implemented in our trampoline, and thus, we expect a learning curve.

On average, players lap times decreased throughout the race. This was true with both the trampoline and traditional controllers. However, in comparing the time differences for only the last lap, we found that the trampoline produced times that were slower by 2.24 seconds. This is greater than the average difference for all laps. From this we conclude that improvement with the trampoline is slower than with a traditional controller. In other words, it takes longer to learn and adjust to the trampoline's controller layout than to the traditional controller. However, we believe that with enough practice, the trampoline will prove to be a controller that is competitive with traditional controllers. As it is, the difference is on the order of a few seconds, which is minor enough to demonstrate that the trampoline is a viable controller alternative.

Dance Dance Revolution

For Dance Dance Revolution (DDR), each person played a song and their game statistics were recorded and graphed.

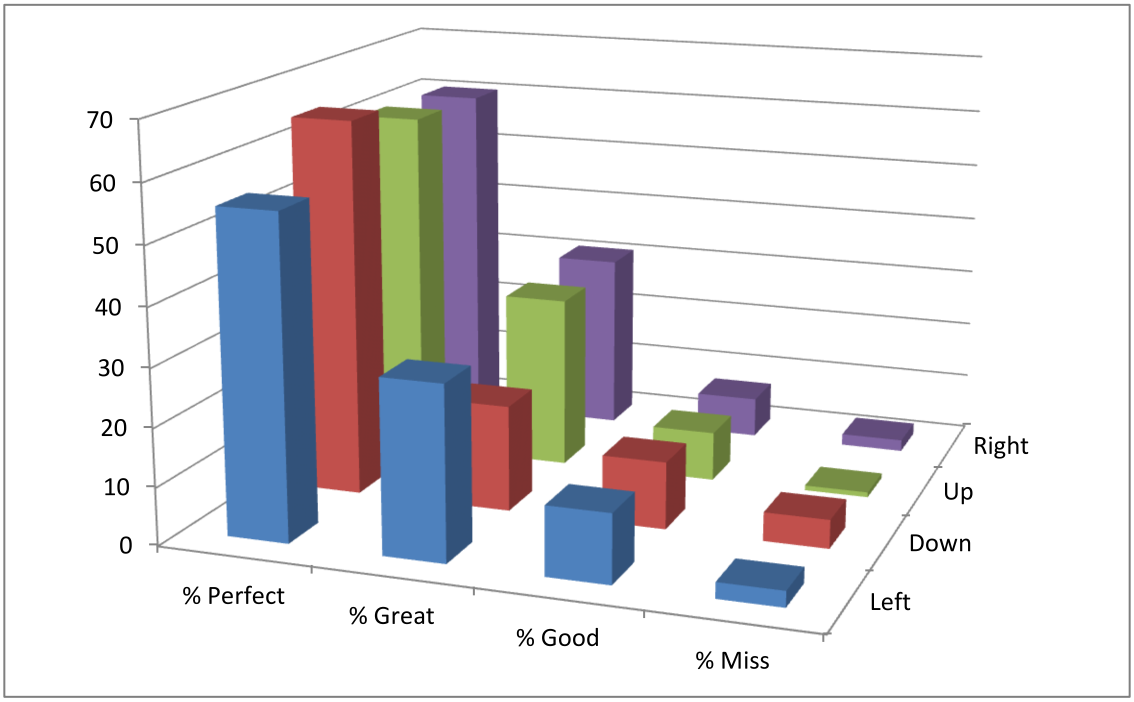


Figure 40. Button accuracy for trampoline directional pad in DDR. Since accuracy is similar for each button, we conclude that all buttons are performing equally well.

Because the distribution of accuracy is very similar for each of the directional buttons, we conclude that all of the buttons are performing equally well. Additionally, below we have compared the percentage misses for each button. (Perfect, great , and good all qualify as hits with varying accuracy).

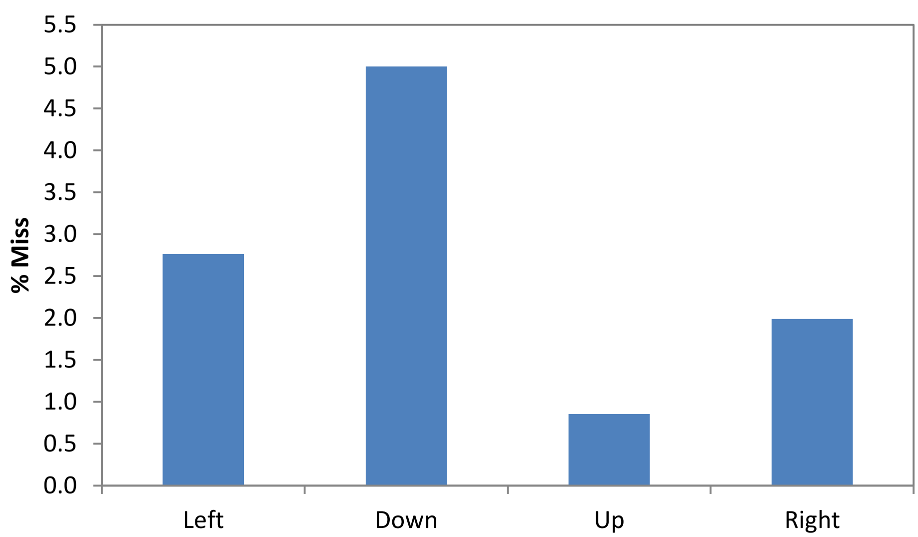


Figure 41. Percent of missed button presses in DDR. Since percentage misses is 5% or less for each button, this indicates that all buttons perform reliably.

This graph indicates that users were able to successfully press all buttons at least 95% of the time. Additionally, with numbers this small, we assume that most, if not all misses are due to user error and not the malfunctioning of our buttons.

We believe that button placement can explain the difference between the % Misses for each button. The Up button, with the lowest miss rate (<1%) is placed directly in front of the user and is easily visible to the player. The Left and Right buttons are also easily accessible, but are more in the player's peripheral vision. This results in similar miss rates that are higher than that of the Up button. The Down button is located behind the player, making it difficult for him/her to see the button and know where he/she is stepping. Thus, the Down button produced the greatest number of misses.

The results of these tests lead us to believe that our trampoline controller functions reliably. Users are able to play various games with the controller and to achieve similar results to the traditional controller.

User Feedback

We prepared a survey for all users of our system. The results from the survey were generally very positive and we gained some valuable suggestions for future modifications. A summary of the quantitative results can be seen below. The entire survey can be seen in Appendix G.

Table 8. Average feedback scores from users. Scores are on a scale from 1 to 10, where 10 is best.

	Average
Overall Functionality	7.3
Lag/sensitivity	7.3
Ease of Use	7.2
Overall Enjoyment	8.9

Building

Our final product will consist of a trampoline outfitted with buttons and an accelerometer in the center of the mat. The buttons will be labeled on the pad surrounding the trampoline. Both the buttons and the accelerometer will connect to the Arduino which will interface with a Wiimote.

Accelerometer

We decided to use a single accelerometer in the center of the mat. However, due to limitations of the Arduino, we could not have it communicate with both the Nunchuk and the Wiimote. As a result, we decided to use a bare accelerometer. This simplified many parts of our design, including communication with the Arduino and mounting to the trampoline mat. It also reduced the danger of bottoming out and crushing the accelerometer, since the bare accelerometer is much slimmer than the Nunchuk.

In order to attach the accelerometer to the Arduino we have run a wire out to the center of the trampoline mat. The wire is threaded into the mat at 3 support points. The connection must be solid enough to withstand heavy bouncing without transferring any extra vibrations to the accelerometer. We have also given it enough slack (~4 inches) at the transition across the bungees in order to absorb bounces without being put in tension.

By default, the Arduino reads in XYZ accelerations as integers from 0 to 1023. In order to adjust for any offset in initial accelerations, we have added a button to zero the values. After the button is pressed, all accelerations are read relative to this zero reference point.

In order to send the accelerations as joystick values, they must be converted to integers between 0 and 63 with 31/32 being the center (no movement/no acceleration). We multiply the accelerations by the factors necessary to both reduce it to this range and ensure that the range of accelerations experienced on the trampoline spans the range of joystick values. With this conversion, the Arduino is plugged into the Wiimote disguising itself as a Classic Controller. The Wiimote is then connected to the computer through Bluetooth using a program called Wiiji. While there are many computer programs that can be used to simply connect a Wiimote, this one is unique in that it recognizes the Classic Controller's joysticks as computer joysticks. The Wiimote-Arduino-accelerometer combination can then be used to play any game that will run on a computer. However, in order to simulate Wii games, we have been testing with games on a Nintendo64 emulator. Nintendo64 is an older generation gaming console from Nintendo. An emulator is a program that runs programs or games designed for a different system, thus allows use to test N64 games on a computer.

Using the accelerometer as a joystick only uses the X and Y accelerations. This leaves the Z acceleration to be mapped to another button. For example, when the user exceeds a certain value by jumping, the player's character could be made to jump. This action could be changed to suit different games.

Mounting the accelerometer was a difficult task for us because the accelerometer is just a one inch by one inch by two mm circuit board with a little accelerometer mounted in the center. There are no holes or mounting points manufactured into the circuit board. For testing, we glued a brass rod to the back of the circuit board so that it hung over the edges of the board, then we sewed it to the center of the mat. This worked well because it mounts the accelerometer firmly to the bottom of the mat so that it cannot change its axis while in game play. See Figure 38 for the current setup with the brass rod sewed into the mat and the three wire support points.

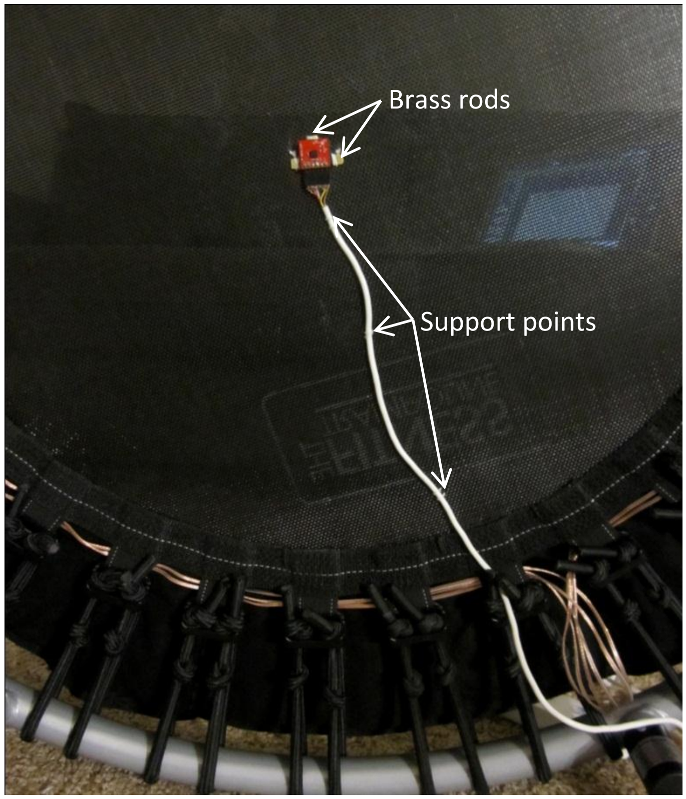


Figure 42. Mounted accelerometer with brass rods sewed into mat

For final manufacturing we are going to use a glue that cross threads into the trampoline surface then cover the accelerometer with a polypropylene surface. So the accelerometer would be glued then sandwiched into place so that it was protected from moving and from users. The next step would be to add some protection for the circuit board. Since the accelerometer is in the center of the mat, it is in danger of being crushed if someone bottoms out the trampoline. To protect the accelerometer we are going to add a foam donut that goes around the circuit board. When bottomed out, the accelerometer will not experience pressure because the force will be absorbed by the foam pad surrounding the accelerometer.

Accelerometer Protector

When bouncing on the trampoline, it is quite easy to bottom it out when jumping in the middle of the mat. The problem with this is the accelerometer has to be mounted directly in the center of the mat in order to detect leaning in all directions equally. We decided to make a foam ring to surround the accelerometer that protects it when the trampoline is bottomed out. This assembly can be seen in Figure 37. The ring is attached to the mat using a standard hot glue gun which worked unexpectedly well. After the ring was secured we tested it by jumping on the trampoline hard enough to bottom out the mat on a hard wood floor. We did this multiple times and the accelerometer remained unharmed, validating our design.

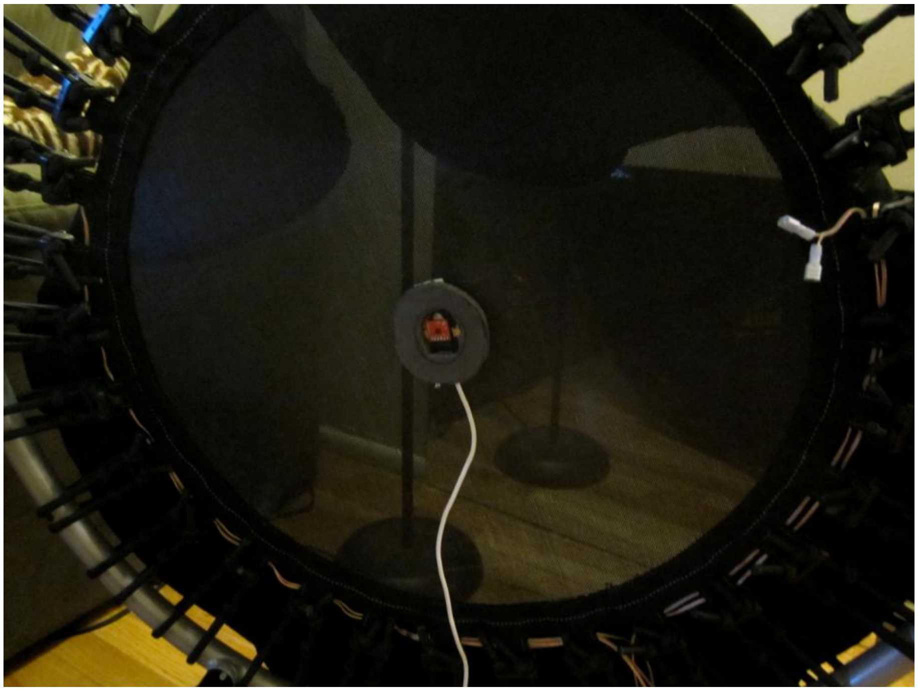


Figure 43. Mounted accelerometer with brass rods sewed into mat

Because the hot glue worked so well in attaching the protection ring, this gave us the idea that the accelerometer itself may be able to be hot glued directly to the mat as well. Our idea was to use super glue (which attached better to the accelerometer board than hot glue) to attach a thin foam pad directly to the accelerometer. Then we would use hot glue to glue the foam/accelerometer assembly to the mat itself in the same way we attached the protector ring.

Buttons

The system of buttons, as can be seen in Figure 34, was successfully implemented into the actual trampoline and used to play a DDR game. There are 6 buttons on the trampoline which are up, down, left, right, A, and B. The "up" button corresponds to the forward facing direction of the trampoline and is the button that the user will orient themselves with while playing a game. The bottom foam layer describes in Figure 33, which comes with the trampoline, actually has an orientation itself and dictates the way the button is assembled and inserted into the pouch. The pad has one square edge and one round edge. The square edge is meant to be inserted first into the pouch because of the shape of the pouch. Each button is then connected to the Arduino using speaker wire. The wires are run around the inside edge underneath the mat and are given enough slack so that they are not pulled or jerked when the user jumps on the trampoline. In order to quickly insert or remove pads, a quick release mechanism is going to be added to each button so that the buttons can be taken out of the pouch without redoing the wiring. With this button setup we were successfully navigate game menus, select things on screen, and play DDR completing songs with reasonable scores. Our DDR skills being the only thing keeping us from scoring higher. See the figure below for the current control layout.

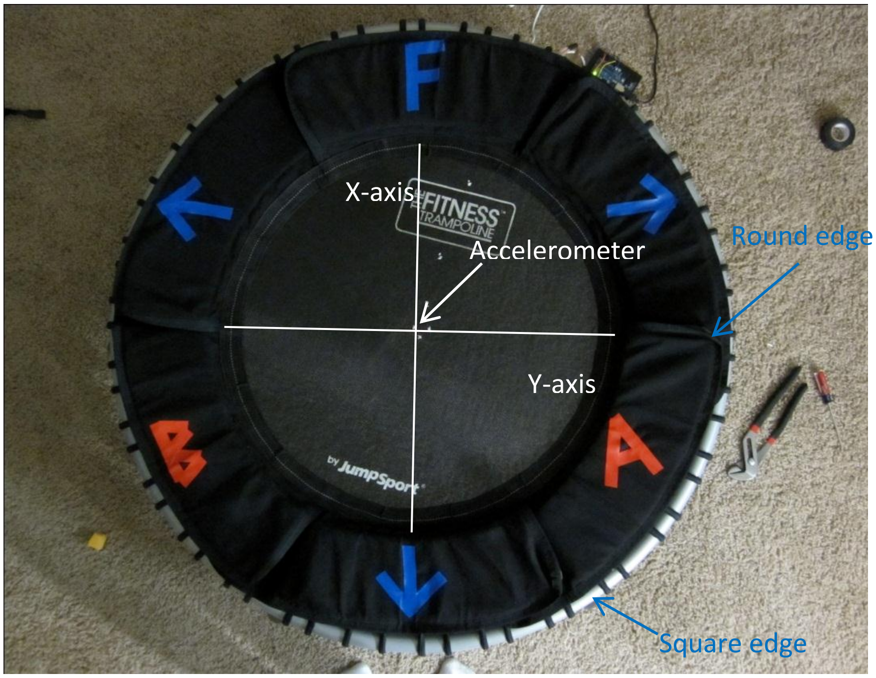


Figure 44. Current trampoline control layout.

Now that we have a few buttons that work relatively well, we need a way to quantify the quality of each button design so that we can choose the best design for our project. We came up with a couple of different tests for static and dynamic testing of the button assemblies. The static test can be accomplished with a shoe sole and some weights. We will place the button on a hard surface and connect it to our Arduino circuit that can read a button press. Then we will place the shoe sole on top of the button in different orientations and then place weights on the shoe sole until we received a button press through the Arduino.

The dynamic testing will be completed using the trampoline and a DDR game. We will play the DDR game with a certain button configuration then tally up the number of good and bad button presses. This will be done through the DDR game itself. At the end of the song the DDR game tells the user how many good and bad button presses they had. We will record this data with multiple users in order to get a fair reading of each button configuration. The DDR statistics window is shown below.

Figure 45. DDR statistics shows perfect, great, good, ok, bad, and missed button presses.

Final Button Design

After reviewing the data from our static button test we rebuilt all of the buttons in a consistent manner using the top test result of densely spaced large holes. During the rebuild we also added electrical quick-releases to each button for ease of removal or repair. This was done not only so we could investigate a button problem but also so we could try different buttons in different positions on the mat to verify their sensitivity. Afterwards we tested all of the buttons again to make sure they were of the appropriate sensitivity. These results were then validated during our dynamic testing session where all buttons performed excellently and users did not notice any button performing worse than any other.

Recommendations and Conclusions

Button Size

Feedback from users at the dynamic button testing review suggested a new layout of the buttons. The major concern by most users was the size of the buttons. Along the same lines as this issue, a lot of users at the expo were hitting their heels on the back button while playing DDR. Most users were stepping on the buttons with the ball of their feet so the heel tends to overhang the back button. While bouncing the button gets pressed down and the heel strikes the trampoline frame. We suggest that either the outer ring of the trampoline frame be a larger diameter or the buttons overlap the mat a bit to allow for a larger button. We also found that most button misses were due to users pressing slightly off the side of the button because they couldn't see it while playing DDR. Larger buttons would decrease the amount of button misses due to the larger surface area.

Button Layout

Another suggestion we got from our users at the dynamic button testing was on the location of the buttons. DDR pads have users stand directly in the center of the mat, and directional buttons are directly in front or to the side of the user. D-pad and joystick controllers work the same way. Our controller has left and right in front of the users side (Refer to Figure 44). This button layout is not intuitive to most people and the DDR game involves constant looking at the screen. We found that most users did adjust accordingly as there is a learning curve to all new controllers but it was slower than we would have liked to see. We designed the button layout based on the existing pads in the trampoline we received from JumpSport, so we weren't left with a whole lot of options with our lack of sewing skills. Our suggestion is to redesign the button layout to have left and right parallel with the TV and centered with respect to the user. This will give the user the most intuitive button layout. The A button could then be placed in between up and right, B button between up and left, 1 button between down and right, and the 2 button between down and left. This would allow for a lot of available buttons for menu selection and scrolling. Then game play could be achieved with the larger directional buttons or an occasional tap on a smaller A button. Figure 13 gives an example of a possible setup.

Accelerometer Mount and Gyroscope

We ran into issues with trying to mount things to the mount without inhibiting the use of the trampoline or damaging the material. Initially we sewed the accelerometer into the mat to hold it securely in place. This worked great for our proof of concept but we had trouble coming up with a mount design that could be easily manufactured. The hot glue on the accelerometer protector seemed to work well but we were not able to test this method. Hot glue may be a viable option for mounting but would have to be further analyzed.

A gyroscope may be a beneficial piece of hardware for the controller. An accelerometer works great for getting the jumping accelerations to figure out if the user is jumping, running, walking, etc., but a cheap accelerometer doesn't allow for a large range while leaning on one side of the trampoline. A gyroscope may be a better piece of hardware for this aspect of the controller. If the user were jumping on the left side of the trampoline, the accelerometer outputs would make it hard to figure out that left were being pressed. A gyroscope on the other hand would show a rotation to the left then back to center. It would clearly show that the user was trying to control to the left.

Get Working With Wii / Package Electronics

Our project involved quite a bit of software engineering that our background in mechanical engineering did not prepare us for so we were not able to get the product working with the Wii. We used a microcontroller to fake a classic controller that worked on an emulated gaming system. It is crucial for the project to have it working on a gaming system in order for it to be a viable option as a controller. We proved the concept of it by getting it working on the controller but we do not possess the abilities or time to get it working on the Wii. We suggest writing a Wii Homebrew application in order to test the controller then eventually getting it to work with current games or even making new games specifically for the controller.

We used an Arduino microcontroller which is considered a general purpose microcontroller. We are not experts on microcontrollers and don't know where to start in order to find a microcontroller that satisfies exactly what we need it to do. This would be a crucial step to minimize costs on the product. The circuit board and wiring could also be minimized in order to save manufacturing costs as well as the total size of the unit. It would be nice to have the controller completely wireless, either by plugging the unit into a Wii mote or by incorporating Bluetooth into the device so it communicates directly to the Wii. We didn't look into power use of the unit either. The final unit should be battery powered and be able to power the device for as long as a Wii mote. The device could be powered by the Wii mote itself just like any other Wii extension.

Users told us that the stability bar was a must have for the controller. It allowed users to shift their weight faster in reaction to game motions. One suggestion for the bar is to add buttons directly to it so that the user does not need to hold the Wii mote for gameplay. For instance, the acceleration and brake buttons for Mario Kart could be incorporated in the bar so the user can keep a firm grip on the stability bar.

Manufacturing Process

Another important step in developing the product further is thinking towards the manufacturing process of the controller. The buttons need to be designed in a way that's cheap and easy to manufacture. Manufacturability should be taken into consideration for the mounting of the hardware and the packaging of the electronics. The whole product needs to be streamlined for manufacturing. One suggestion for the button design is the conductive material could be a conductive paint that could be sprayed or brushed on. The accelerometer and any other hardware mounted to the mount could be adhered with some type of hot glue.

The final step in the controller design process would be to get some kind of license agreement with Nintendo. This will help with marketing the product and interfacing with current and new games. Game designers may be more interested in developing games for the controller if it were licensed by Nintendo.

Engineering Conclusions

After completion of a project it is important to re-evaluate the original design specifications. Table 2 is partially reproduced below for reference.

Table 2. Project WiiHopp Formal Engineering Requirements

Spec #	Parameter Description	Requirement or Target (Units)	Tolerance
1	Length of Assembly	30 minutes	Max
2	Customer Survey on Use	80% positive	Min
3	Customer Survey on Fun	90% positive	Min
4	Energy Used by User	13 Calories/Min	Max
5	Price	$50	+/- $10
6	Response Time	16 ms	+/- 2
7	Test Games	50% effective	Min
8	Test Movements	95% effective	Min
9	Customer Survey on looks	90% positive	Min
10	Pass/Fail	Pass	

Upon evaluation of our final product we can conclude that some requirements were met, some were not, and some were found to be irrelevant, not available, or negligible.

Specification 1

This specification is irrelevant to our project as we did not focus on the manufacturability or packaging of a final design, but more on a proof of concept. We do believe, however, that this requirement can be met if our project continues along the same development path.

Specification 2 and 3

These requirements were met.

Specification 4

In our project testing we did not asses heart rates of direct energy during the dynamic testing session, however, we proved that the product could be variable intensity and therefore can say that we met this target.

Specification 5

For the same reasons as Specification 1, we believe that this requirement can be met.

Specification 6

This specification is met because our target is the response time of the Wii Remote and we used the Wii Remote to communicate with our various devices in our product.

Specification 7

Our system was designed to work with several games but can be made compatible with any game through software. We did not focus our project on software development so this requirement does not apply to our project.

Specification 8

As shown in our Dynamic system testing of buttons, users performed with an average missed button hit of only 5%. We can safely attribute this to user error though and state that this requirement is therefore satisfied.

Specification 9

This specification is irrelevant as we did not design our product to involve aesthetics or survey users on the overall system appearance.

Specification 10

The previously specified pass/fail requirements of wireless capabilities, and battery powered were achieved.

All of these engineering requirements were also validated through overall product functionality and user enjoyment.

Final Comments

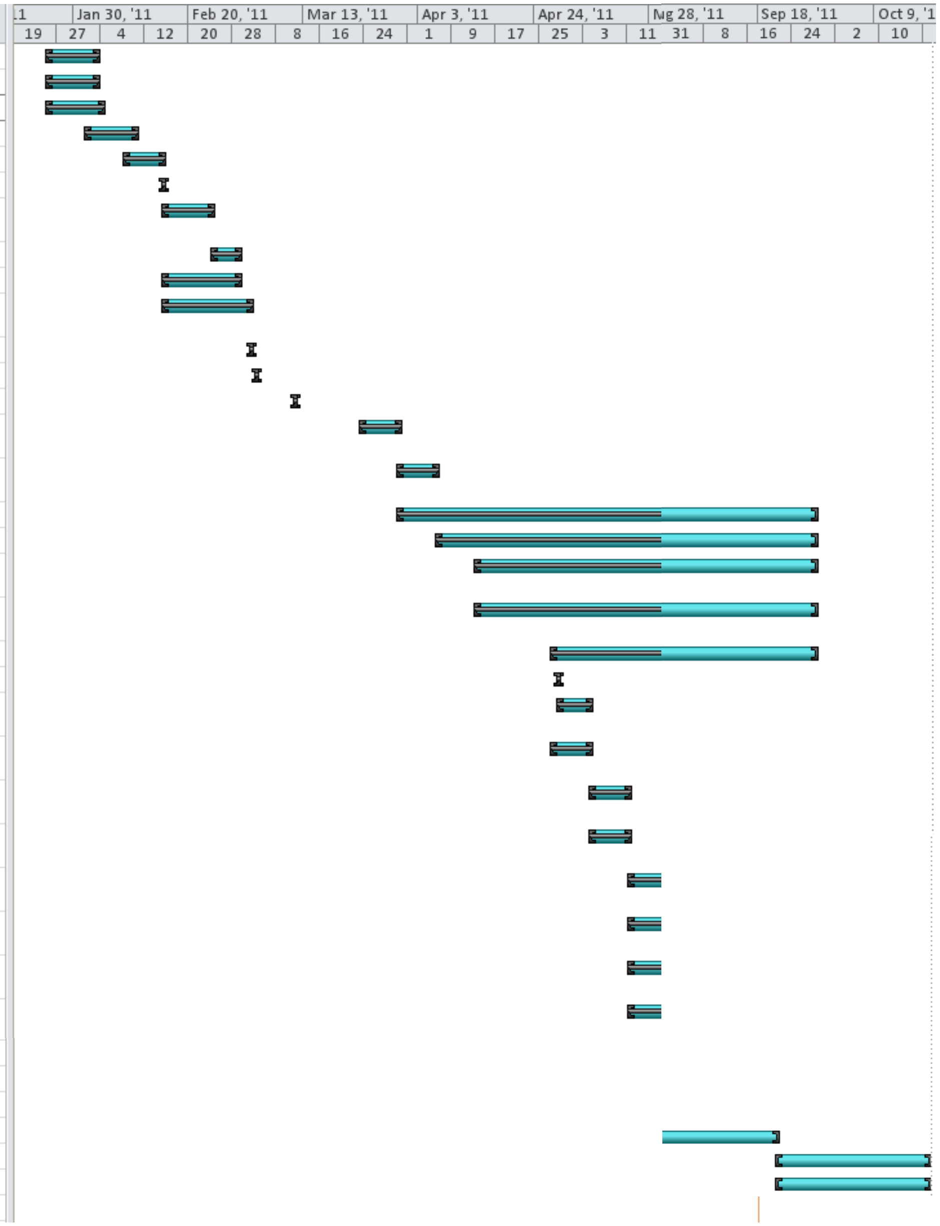
The project was a total success! Based on the results from our user feedback, and our own use of the system, we believe that we have demonstrated and built a viable design for integrating a trampoline with a video game console. We receive user feedback such as, "Tons of fun!," "great for the casual gamer," and "Flat ground will never be good enough again!"

We would like to thank our dedicated advisor, Professor Kim Shollenberger, and our sponsor, JumpSport, Inc. for their great idea and support.

References

1. http://electronics.howstuffworks.com/xbox-three-sixty5.htm
2. http://wiire.org/Wii/Wiimote
3. http://internetgecko.com/sony/gaming-consoles-battle-news-xbox-360ps3wii
4. http://www.modchip-wizard.com/images/xbox-360/Xbox-360-controller.jpg
5. http://www.crutchfield.com/S-K9s8Lnd5hbA/learn/learningcenter/home/TV-connections.html
6. http://www.fernsnutrition.com/jump_sport_fitness_trampoline_350.html
7. http://www.cdc.gov/HealthyYouth/obesity/
8. http://todbot.com/blog/wp-content/uploads/2007/11/bionic_arduino_class4.pdf
9. http://wiibrew.org/wiki/Wiimote/Extension_Controllers
10. http://www.esacademy.com/en/library/technical-articles-and-documents/miscellaneous/i2c-bus.html

		Task Mode	Task Name	Duration	Start	Finish
1	✓		Finalize Problem Definition	8 days	Tue 1/25/11	Thu 2/3/11
2	✓		Design Specifications	8 days	Tue 1/25/11	Thu 2/3/11
3	✓		Project Objectives	9 days	Tue 1/25/11	Fri 2/4/11
4	✓		Concept Generation	8 days	Tue 2/1/11	Thu 2/10/11
5	✓		Concept Selection	6 days	Tue 2/8/11	Tue 2/15/11
6	✓		Concept Design Review	1 day	Tue 2/15/11	Tue 2/15/11
7	✓		Measure Sensory Outputs of Wii Equipment	8 days	Tue 2/15/11	Thu 2/24/11
8	✓		Statics Calculations on Legs	4 days	Thu 2/24/11	Tue 3/1/11
9	✓		Acceleration Measurements	11 days	Tue 2/15/11	Tue 3/1/11
10	✓		Design Specs for Sensory Equipment	13 days	Tue 2/15/11	Thu 3/3/11
11	✓		Buy Sensory Equipment	1 day	Thu 3/3/11	Thu 3/3/11
12	✓		Conceptual Design Report	1 day	Fri 3/4/11	Fri 3/4/11
13	✓		Conceptual Design Review	1 day	Fri 3/11/11	Fri 3/11/11
14	✓		Implement DDR Type Buttons onto Trampoline	6 days	Wed 3/23/11	Wed 3/30/11
15	✓		Mount Nunchuck Accelerometer onto Trampoline	6 days	Wed 3/30/11	Wed 4/6/11
16			Test DDR Type Buttons	131 days	Wed 3/30/11	Wed 9/28/11
17			Test Accelerometer	126 days	Wed 4/6/11	Wed 9/28/11
18			Write PC Code to Analyze DDR Type Buttons	121 days	Wed 4/13/11	Wed 9/28/11
19			Write PC Code to Analyze Accelerometer	121 days	Wed 4/13/11	Wed 9/28/11
20			Calibrate/Fine Tune Buttons	111 days	Wed 4/27/11	Wed 9/28/11
21	✓		Design Report	1 day	Thu 4/28/11	Thu 4/28/11
22	✓		Accelerometer Working with Arduino	5 days	Thu 4/28/11	Wed 5/4/11
23	✓		Test Conductive Fabrics for Buttons	6 days	Wed 4/27/11	Wed 5/4/11
24	✓		Integrate DDR Type Buttons with Arduino	6 days	Wed 5/4/11	Wed 5/11/11
25	✓		Get Emulator Working with Button Design	6 days	Wed 5/4/11	Wed 5/11/11
26	✓		Mounting Single Accelerometer onto Mat	6 days	Wed 5/11/11	Wed 5/18/11
27	✓		Integrating Singe Accelerometer Hardware to Arduino	6 days	Wed 5/11/11	Wed 5/18/11
28	✓		Writing PC Code for Single Accelerometer	6 days	Wed 5/11/11	Wed 5/18/11
29	✓		Get Emulator Working with Single Accelerometer	6 days	Wed 5/11/11	Wed 5/18/11
30	✓		System Integration	11 days	Wed 5/18/11	Wed 6/1/11
31	✓		Get Emulator Working with System	11 days	Wed 5/18/11	Wed 6/1/11
32	✓		Critical Design Review	1 day	Tue 5/31/11	Tue 5/31/11
33			Project Update Report	1 day	Mon 6/6/11	Mon 6/6/11
34			Writing Homebrew Application	78 days	Mon 6/6/11	Wed 9/21/11
35			Manufacturing Process	21 days	Wed 9/21/11	Wed 10/19/11
36			Test System with Current Games	21 days	Wed 9/21/11	Wed 10/19/11



Appendix A: QFD

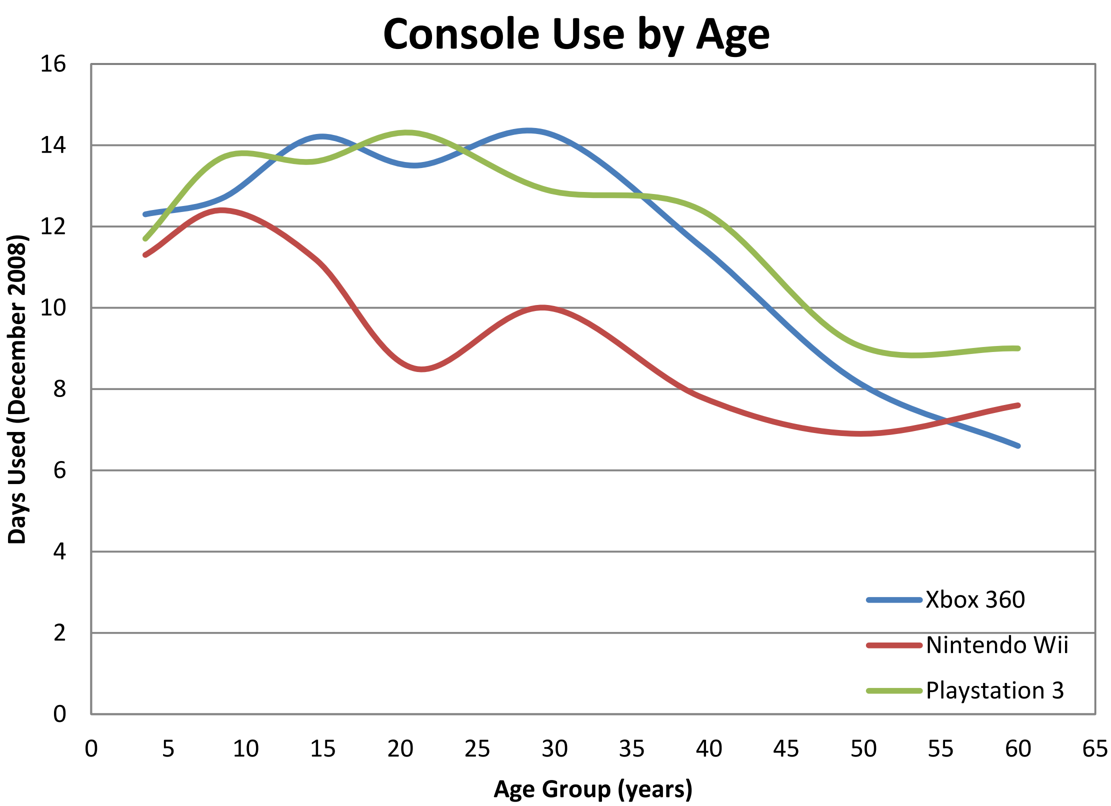
▲ Larger is Better
◉ Nominal is Best
▼ Smaller is Better

Customer Description	Grouping	Customer Requirements (Whats)	Item No.	Importance	A	B	C	D	E	F	G	H	I	J	K	1	2	3
					▼	▲	▲	▲	▼	▼	▲	▲	▲	◉	◉	Now		
					Length of assembly (min)	Costomer survey on use (%)	Customer Survey on fun (%)	Energy used (Calories/Min)	Price (dollars)	Response time (msec)	Test games (%)	Test movement (%)	Customer Survey on looks (%)	Is it wireless (yes/no)	Powered by Wii mote (yes/no)	WiiHopp	Wii Fit Balance Board	Fitness Trampoline
					Specifications													
1,2,3	Users	Easy assembly	1	5	◎	○										4	5	4
1,2,3	Users	Ease of use	2	10		◎										4	4	5
1,2	Users	Fun	3	15			◎									5	2	3
3	Users	Variable intensity	4	7				◎								5	1	5
1,2,3	Users	Cheap	5	5					◎							3	2	3
1,2,3	Users	Resposive	6	14		○				◎						4	3	NA
1	Users	Works with current games	7	10							◎					2	5	NA
1,2,3	Users	Reads multiple types of movements	8	14								◎				5	1	NA
1,2,3	Users	Asthetically pleasing	9	10									◎			4	3	4
1,2,3	Users	Wireless	10	5		○								◎		5	5	NA
1,2,3	Users	Powered by Wiimote	11	5		○									◎	5	5	NA
		Targets			30 minutes	80 % positive feedback	90 % positive feedback	13 Calories/Min +/- 3	$50 +/- $10	16 milliseconds +/- 2 milliseconds	50 % effective	95 % effective	90 % positive feedback	Pass	Pass			
		Weighted Importance			9	21	9	9	9	9	9	9	9	9	9	111		
		% Importance			8	19	8	8	8	8	8	8	8	8	8			

Relationship Strength:

Strength - 9 ◎
Medium-3 ○
Weak - 1 △

Appendix B: Console Research



The data in this figure is from the table on the next page.

US Next-Generation Video Game Console Usage, by Age and Gender, December 2008

	Male		Female	
	% of total minutes used	Average days of use	% of total minutes used	Average days of use
Microsoft Xbox 360				
2-5	2.3%	6.3	13.0%	6.0
6-11	8.3%	8.4	8.8%	4.3
12-17	31.3%	10.2	11.1%	4.0
18-24	24.6%	8.6	20.1%	4.9
25-34	22.0%	8.9	25.7%	5.4
35-44	8.0%	7.2	14.2%	4.3
45-54	2.8%	4.8	5.9%	3.4
55+	0.7%	4.4	1.2%	2.2
Nintendo Wii				
2-5	6.8%	6.3	7.8%	5.0
6-11	30.7%	7.5	20.0%	4.9
12-17	24.2%	7.0	18.5%	4.2
18-24	8.7%	5.4	5.2%	3.1
25-34	14.2%	5.5	17.9%	4.5
35-44	10.0%	4.2	14.7%	3.6
45-54	3.6%	3.5	8.6%	3.4
55+	1.8%	3.6	7.4%	4.0
Sony PlayStation 3				
2-5	2.9%	6.6	4.9%	5.1
6-11	10.3%	7.7	16.5%	6.0
12-17	20.0%	9.3	7.9%	4.3
18-24	28.0%	9.1	21.4%	5.2
25-34	22.3%	7.7	25.0%	5.2
35-44	13.3%	7.0	17.6%	5.4
45-54	2.0%	5.4	3.9%	3.7
55+	1.0%	6.1	2.8%	2.9

Note: numbers may not add up to 100% due to rounding
Source: Nielsen Media Research, "GamePlay Metrics" as cited on company blog, February 17, 2009

101818 www.eMarketer.com

http://www.emarketer.com/Article.aspx?R=1007055&AspxAutoDetectCookieSupport=1

Appendix C: TV Connection Types

Description of TV Connections. Article from http://www.crutchfield.com/S-K9s8Lnd5hbA/learn/learningcenter/home/TV-connections.html. [5]

The back panel of today's HDTVs may look intimidating, but we'll help you make the right connections for the most common video components.

Video connection types

HDMI

HDMI can carry both high-definition video and high-resolution multichannel audio. It's generally your best option for high-def video, since it can carry full 1080p signals, and it's your only option if you're connecting a 3D video source to your 3D TV. For an in-depth look at HDMI, see our HDMI connections article. For more info on 3D TV, see our intro to 3D, or check out our in-depth 3D TV FAQ.
Signal type: digital
Maximum resolution: 1080p

Component video

Component video is also high-def-capable, which makes it a good alternative when HDMI isn't an option. This three-jack connection splits the video signal into three parts (one brightness and two color signals). This analog connection delivers an extremely accurate picture with clearer color reproduction and less bleeding than S-video or composite video (below).
Signal type: analog
Maximum resolution: 1080p (however, many video components will only send video up to 1080i via component video)

S-video

This 4-pin connection usually provides a sharp picture by transmitting the chrominance (color) and luminance (brightness) portions of a video signal separately. The signals can then be processed separately, reducing interference. S-video connections generally outperform composite connections (below), but don't measure up to component video (above).
Signal type: analog

Maximum resolution: 480i

Composite video

This is the most universal video connector, found on most TVs made in the last 20 years. Picture quality is a big step up from RF (below), but typically not as good as S-video (above).
Signal type: analog
Maximum resolution: 480i

Coaxial or RF

Probably the most common way folks shortchange their TV's picture quality is through the overuse of RF-type connections. There's a reason the RF inputs on TVs are usually labeled "Antenna" or "Cable" — those are the signals they were designed for. RF-type connections should generally be limited to bringing signals into your A/V system from outside your house: TV antenna, cable TV jack, or satellite dish. If you find yourself tempted to use RF because it's a simple one-cable hookup, and that cable is usually included free in the box, remember that it's the lowest-quality type of video connection. Once the signal has reached your set-top box, use the highest-quality connection from the types listed above.
Signal type: analog
Maximum resolution: about 350i

Appendix D: Wii Mote Circuit Board

Wii Mote circuit board layout from http://wiire.org/Wii/Wiimote [2].

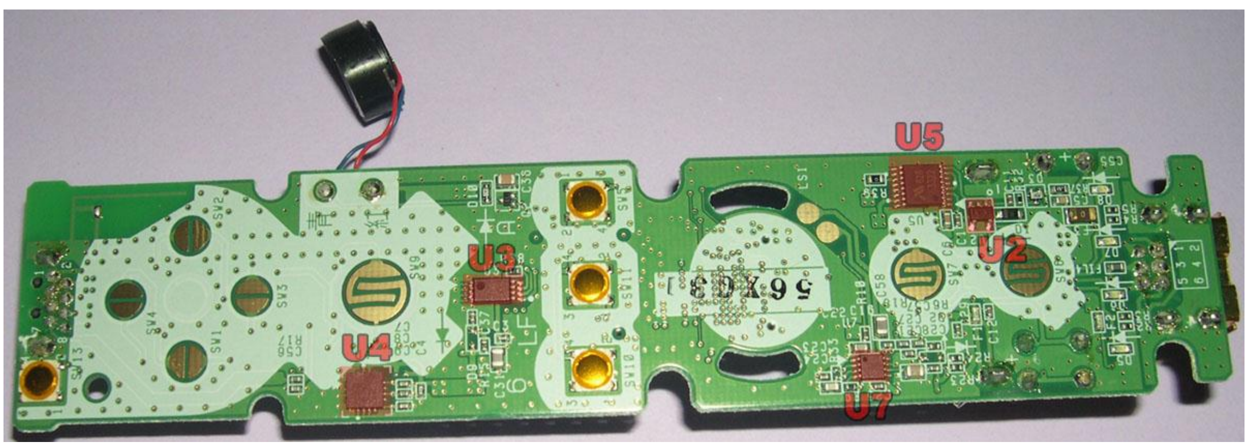


Figure 1. Wii Mote Printed Circuit Board, top view.

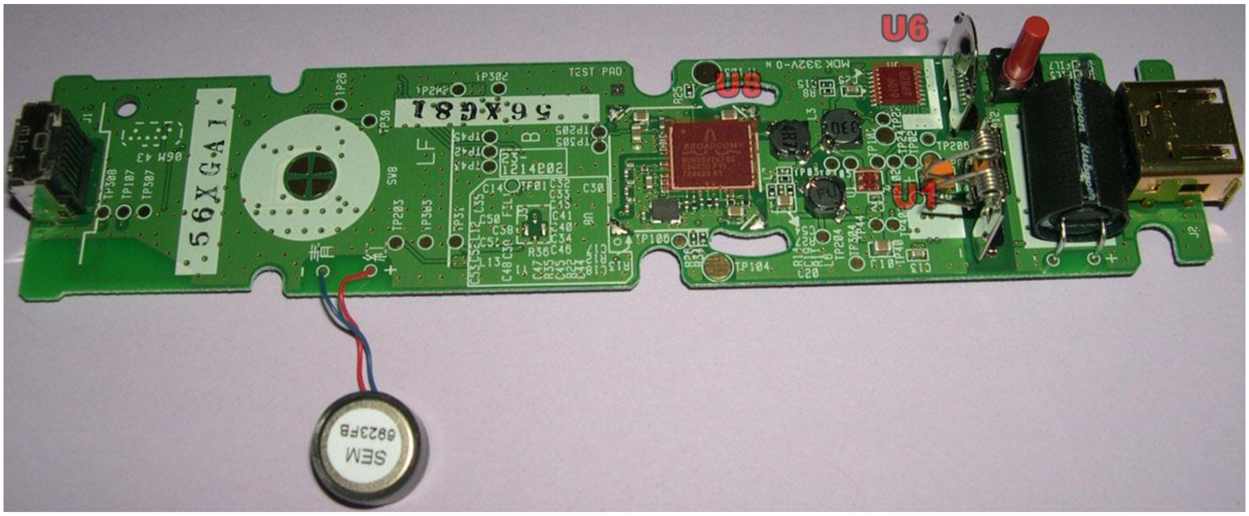


Figure 2. Wii Mote Printed Circuit Board, bottom view.

Chip listing:

- **U1:**
- **U2:**
- **U3:** ST Microelectronics M24128-BWP - "412A" "BWP" (128kbit I2C eeprom - tssop-8)
- **U4:** Analog devices ADXL330 - "XL" "330K" "#0614" "3464P" (accelerometer - 16 pin LGA)
- **U5:** suspected to be Microchip TC1027 - "628" "3322" (quad comparator -16 pin QSOP) - could possibly be a Mitsumi chip (the logo is similar)
- **U6:** Unknown manufacturer - "U7849" "6Q19" (Likely Audio DAC chip, due to proximity to U7 Speaker amp, and lack of another chip to perform this function - 16 pin tsop)
- **U7:** Rohm BH7824FVM - "H78" "2 4" "HN" (audio driver (speaker AMP) for mobile telephone - MSOP-8)
- **U8:** Broadcom BCM2042 - "BCM2042KF8C" "C80830 P13" "788899 N1" (Broadcom bluetooth & 8051 - probably 88pin FBGA)

Appendix E: Nunchuck Accelerometer Program

```
%JumpAndMove3D.m
addpath C:\'Program Files'\WiiLAB\WiiLAB_Matlab\EG111-H
addpath C:\'Program Files'\WiiLAB\WiiLAB_Matlab\WiimoteFunctions
addpath C:\'Program Files'\WiiLAB\WiiLAB_Matlab\WiimoteFunctions\...
    BouncingBallFunctions
addpath C:\'Program Files'\WiiLAB\WiiLAB_Matlab\WiimoteFunctions\...
    GraphingFunctions

clc
global Wiimote;
initializeWiimote();%Program to initialize the Wiimote
uiwait(msgbox('Wanna Play WiiHopp?'));
createWindow(900, 675, 400, 300);
setTitle('WiiHopp (Sponsored by JumpSport)');

%Stuff
center=200;%center of window
```

```matlab
l=200;%initial ball position
s=100;%y of ball
o=5;%object size
p=10;%jump ball size
x = [l l];
y = [0 155];
obj = drawCircle(l, s, o); %Initialize Object

if(isWiimoteConnected() > 0) %if the Wiimote is connected
    % User directions
    t1 = text(center, 290, 'Step Off Trampoline to Calibrate', ...
        'HorizontalAlignment', 'center', 'FontSize', 16);
    pause(1);
    t2 = text(center, 275, 'Push A when off trampoline', ...
        'HorizontalAlignment', 'center', 'FontSize', 16);
    waitForButtonPress('A');
    hide(t1);
    hide(t2);

    % Calibration
    Wiimote.GetNunchukAccelState(); %gets initial accel state
    X1 = Wiimote.NunchukAccel.X %show in command window
    Y1 = Wiimote.NunchukAccel.Y
    Z1 = Wiimote.NunchukAccel.Z
    pause(0.1);

    if (X1 == 0 || X1 == Inf || X1 == -Inf)%if Wiimote gives a false accel
        initializeWiimote();
        Wiimote.GetNunchukAccelState(); %gets initial accel state
        pause(0.001);
        X1 = Wiimote.NunchukAccel.X %show in command window
        Y1 = Wiimote.NunchukAccel.Y
        Z1 = Wiimote.NunchukAccel.Z
        pause(tiny);
        if (X1 == 0 || X1 == Inf || X1 == -Inf)
            close; %closes window
            Home;%errors out of program
        else
        end
    else
    end

    t3 = text(center, 290, 'Get back on trampoline', ...
        'HorizontalAlignment', 'center', 'FontSize', 16);
    pause(1);
    hide(t3);
    t4 = text(center, 290, 'Jump to move the ball.', ...
        'HorizontalAlignment', 'center', 'FontSize', 16);
    pause(1);
    hide(t4);
    t5 = text(center, 290, 'Ready?', 'HorizontalAlignment', 'center', ...
        'FontSize', 16);
    pause(1);
    hide(t5);
    t6 = text(center, 290, 'JUMP!', 'HorizontalAlignment', 'center', ...
        'FontSize', 26);
    t7 = text(l, 10, 'HOME to quit', 'HorizontalAlignment', 'center', ...
        'FontSize', 16);
    pause(0.1);

%Acceleration tolerances
    tolerance=1;%for directional accel's
    t=1;%for bidirectional accels
    jump=-40;%required accel to jump

%Pause time
    tiny=0.01;%pause time after moving

%Distance of Controls
    j=40;%height of jump
    d=4;%distance moved sideways
```

```
    c=4;%distance moved up and down

    while (~isButtonPressed('HOME'))%exit program if HOME button pressed
        Wiimote.GetNunchukAccelState();%continues to get accel state
        X = Wiimote.NunchukAccel.X;
        Y = Wiimote.NunchukAccel.Y;
        Z = Wiimote.NunchukAccel.Z;

%Bi directional controls
        if(Z>Z1+t*tolerance && Y>Y1+t*tolerance)%move left and up
            hide(obj);%hides ball
            s=s+c; %moving up
            l=l-d; %moving left
            obj = drawCircle(l, s, o);%draws new ball
            pause(tiny);
            %Jumping Controls
            if(X < jump)
                hide(obj);
                obj = drawCircle(l, s+j/4, (p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/2, (p+o)/2);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j, p);
                pause(0.1);
                hide(obj);
                obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/2, (p+o)/2);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/4, (p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s, o);
                pause(tiny);
            else
                % do nothing
            end
            pause(tiny);
        elseif(Z<Z1-t*tolerance && Y>Y1+t*tolerance)%move right and up
            hide(obj);
            s=s+c;
            l=l+d;
            obj = drawCircle(l, s, o);
            pause(tiny);
            %Jumping Controls
            if(X < jump)
                hide(obj);
                obj = drawCircle(l, s+j/4, (p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/2, (p+o)/2);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j, p);
                pause(0.1);
                hide(obj);
                obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/2, (p+o)/2);
                pause(0.05);
```

```
        hide(obj);
        obj = drawCircle(l, s+j/4, (p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s, o);
        pause(tiny);
    else
        % do nothing
    end
    pause(tiny);

elseif(Z>Z1+t*tolerance && Y<Y1-t*tolerance)%move left and down
    hide(obj);%hides ball
    s=s-c; %lateral moving
    l=l-d; %longitudinal moving
    obj = drawCircle(l, s, o);%draws new ball
    pause(tiny);
    %Jumping Controls
    if(X < jump)
        hide(obj);
        obj = drawCircle(l, s+j/4, (p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+j/2, (p+o)/2);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+j, p);
        pause(0.1);
        hide(obj);
        obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+j/2, (p+o)/2);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+j/4, (p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s, o);
        pause(tiny);
    else
        % do nothing
    end
    pause(tiny);
elseif(Z<Z1-t*tolerance && Y<Y1-t*tolerance)%move right and down
    hide(obj);
    s=s-c;
    l=l+d;
    obj = drawCircle(l, s, o);
    pause(tiny);
    %Jumping Controls
    if(X < jump)
        hide(obj);
        obj = drawCircle(l, s+j/4, (p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+j/2, (p+o)/2);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
        pause(0.05);
        hide(obj);
        obj = drawCircle(l, s+j, p);
        pause(0.1);
        hide(obj);
        obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
        pause(0.05);
        hide(obj);
```

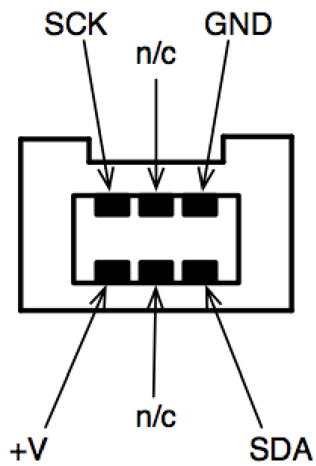
```
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s, o);
            pause(tiny);
        else
            % do nothing
        end
        pause(tiny);

% Directional Controls for right and left
    elseif(Z>Z1+tolerance)%move left
        hide(obj);%hides ball
        l=l-d;
        obj = drawCircle(l, s, o);%draws new ball
        pause(tiny);
        %Jumping Controls
        if(X < jump)
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j, p);
            pause(0.1);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s, o);
            pause(tiny);
        else
            % do nothing
        end
        pause(tiny);
    elseif(Z<Z1-tolerance)%move right
        hide(obj);
        l=l+d;
        obj = drawCircle(l, s, o);
        pause(tiny);
        %Jumping Controls
        if(X < jump)
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j, p);
            pause(0.1);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
```

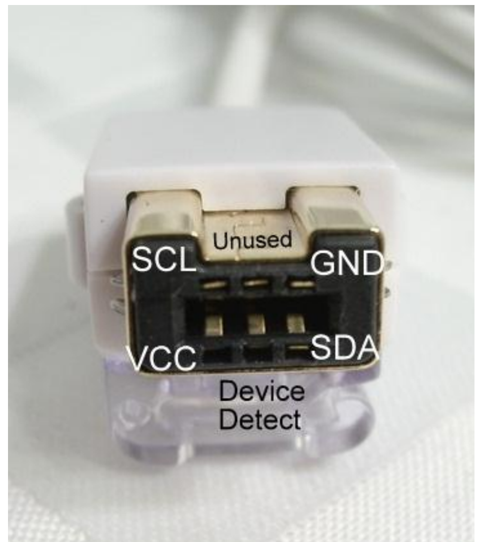
```
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s, o);
            pause(tiny);
        else
            % do nothing
        end
        pause(tiny);

% Directional Controls for up and down
    elseif(Y>Y1+tolerance)%move up
        hide(obj);%hides ball
        s=s+c;
        obj = drawCircle(l, s, o);%draws new ball
        pause(tiny);
        %Jumping Controls
        if(X < jump)
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j, p);
            pause(0.1);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s, o);
            pause(tiny);
        else
            % do nothing
        end
        pause(tiny);
    elseif(Y<Y1-tolerance)%move down
        hide(obj);
        s=s-c;
        obj = drawCircle(l, s, o);
        pause(tiny);
        %Jumping Controls
        if(X < jump)
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j, p);
            pause(0.1);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
```

```
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/2, (p+o)/2);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s+j/4, (p+o)/4);
                pause(0.05);
                hide(obj);
                obj = drawCircle(l, s, o);
                pause(tiny);
            else
                % do nothing
            end
            pause(tiny);

%If not moving directionally, just jump
        elseif (X < jump)%just jump
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j, p);
            pause(0.1);
            hide(obj);
            obj = drawCircle(l, s+3*j/4, 3*(p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/2, (p+o)/2);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s+j/4, (p+o)/4);
            pause(0.05);
            hide(obj);
            obj = drawCircle(l, s, o);
            pause(tiny);
        else

%If nothing is triggering than just sit still
        end
    end

    pause(0.1);
    close; %close window

else % If Wiimote not connected tell user
    text(center, 290, 'Wiimote is not connected.  Please try again.', ...
        'HorizontalAlignment', 'center', 'FontSize', 12);
    pause(1.5);
    close; %Close window
end
```

Appendix F: Wiimote Communication

Extension Controller Pinout





Left: Drawing of Wiimote extension connector from http://todbot.com/blog/wp-content/uploads/2007/11/bionic_arduino_class4.pdf [8]. Right: Picture of actual extension connection from http://wiibrew.org/wiki/Wiimote/Extension_Controllers [9].

The controller extension port contains 6 pins, two of which are not used. The serial data and serial clock handle data transfer in accordance with I2C protocol.

1. SCK – Serial Clock
2. N/C - No Connection
3. GND – Ground
4. SDA – Serial Data
5. N/C – No Connection (Note: some extension controls set this pin to high to signal that they are connected, but this is not needed)
6. +V – voltage input at 3.3 VDC

Nunchuck Data Format

(from http://wiibrew.org/wiki/Wiimote/Extension_Controllers [9])

The Nunchuk is identified by the 16-bit constant 0x0000 (0xFEFE encrypted) at register address 0xa400fe. It provides three-axis acceleration data, two digital buttons, and an X-Y analog stick.

The Nunchuk reports its information as 6 bytes of data, readable at 0xa40008 and streamable using Data Reporting Modes that include Extension bytes (unused bytes are filled with 0x00). The data is packed into the six bytes as follows (**after decryption**):

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	**SX**<7:0>							
1	**SY**<7:0>							
2	**AX**<9:2>							
3	**AY**<9:2>							
4	**AZ**<9:2>							
5	**AZ**<1:0>		**AY**<1:0>		**AX**<1:0>		**B**C	**B**Z

SX,SY are the Analog Stick X and Y positions, while AX, AY, and AZ are the 10-bit accelerometer data (in the same format as described in Wiimote#Accelerometer).

The values returned by the analog stick in the Nunchuk enclosure do not encompass the full possible range, but rather have upper and lower bounds. These bounds seem to be in the same range across Nunchuks, but there is some variation. Analog stick X returns data from around 35 (fully left) to 228(fully right), while analog stick Y returns from around 27 to 220. Center for both is around 128.

The accelerometer data uses the full range of 0-1024. However, the full range is only seen when moving or rotating the Nunchuk sharply. To measure still Nunchuk rotation in space, the following approximate bounds apply: X goes from around 300 (fully tilted left) to 740 (tilted right), turning further starts bringing the value closer to 512 (neutral position). Similarly, Y goes from around 280 (tilted backwards) to 720 (forwards). Z goes from 320 (upside-down) to 760 (right-side up).

BC and BZ are the state of the C and Z buttons (0=pressed).

Nintendo games calibrate the center position of the Analog Stick upon power-up or insertion of the Nunchuk. The mechanism for that is unknown.

I2C Protocol

(from http://www.esacademy.com/en/library/technical-articles-and-documents/miscellaneous/i2c-bus.html [10])

I2C (Inter-Integrated Circuit) Bus Technical Overview

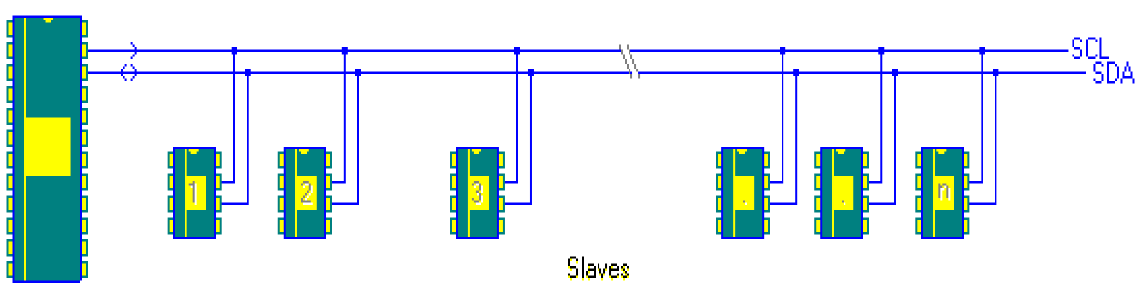
Based on the I2C FAQ by Vince Himpe

In the early 1980's, NXP Semiconductors developed a simple bi-directional 2-wire bus for efficient inter-IC control. This bus is called the Inter-IC or I2C-bus. At present, NXP's IC range includes more than 150 CMOS and bipolar I2C-bus compatible types for performing communication functions between intelligent control devices (e.g. microcontrollers), general-purpose circuits (e.g. LCD drivers, remote I/O ports, memories) and application-oriented circuits (e.g. digital tuning and signal processing circuits for radio and video systems).

All I2C-bus compatible devices incorporate an on-chip interface which allows them to communicate directly with each other via the I2C-bus. This design concept solves the many interfacing problems encountered when designing digital control circuits. I2C has become a de facto world standard that is now implemented in over 1000 different ICs and is licensed to more than 50 companies.

I2C Bus Protocol

The I2C bus physically consists of 2 active wires and a ground connection. The active wires, called SDA and SCL, are both bi-directional. SDA is the Serial DAta line, and SCL is the Serial CLock line. Every device hooked up to the bus has its own unique address, no matter whether it is an MCU, LCD driver, memory, or ASIC. Each of these chips can act as a receiver and/or transmitter, depending on the functionality. Obviously, an LCD driver is only a receiver, while a memory or I/O chip can be both transmitter and receiver. The I2C bus is a multi-master bus. This means that more than one IC capable of initiating a data transfer can be connected to it. The I2C protocol specification states that the IC that initiates a data transfer on the bus is considered the Bus Master. Consequently, at that time, all the other ICs are regarded to be Bus Slaves. As bus masters are generally microcontrollers, let's take a look at a general 'inter-IC chat' on the bus. Lets consider the following setup and assume the MCU wants to send data to one of its slaves (also see here for more information; click here for information on how to receive data from a slave).



First, the MCU will issue a START condition. This acts as an 'Attention' signal to all of the connected devices. All ICs on the bus will listen to the bus for incoming data. Then the MCU sends the ADDRESS of the device it wants to access, along with an indication whether the access is a Read or Write operation (Write in our example). Having received the address, all IC's will compare it with their own address. If it doesn't match, they simply wait until the bus is released by the stop condition (see below). If the address matches, however, the chip will produce a response called the ACKNOWLEDGE signal. Once the MCU receives the acknowledge, it can start transmitting or receiving DATA. In our case, the MCU will transmit data. When all is done, the MCU will issue the STOP condition. This is a signal that the bus has been released and that the connected ICs may expect another transmission to start any moment. We have had several states on the bus in our example: START, ADDRESS, ACKNOWLEDGE, DATA , STOP. These are all unique conditions on the bus. Before we take a closer look at these bus conditions we need to understand a bit about the physical structure and hardware of the bus.

Appendix G: Dynamic Testing/Expo Survey

Player name: ____.

DDR

Experience Level: 1 2 3 4 5

Easy Song Played: ____

Warm-up score: ____________________ Warm-up Letter Grade: ____________________

Test score: ____________________ Test Letter Grade: _____________________

	# of		% hit
perfects		Right	
excellents		Left	
goods		Up	
misses		Down	

Hard Song Played _______________________________________.

Score: ____________________ Letter Grade: _____________________

Hard Song Played _______________________________________.

Score: ____________________ Letter Grade: _____________________

Mario Kart

Time Trial
Level played: ____

	Traditional Controller	Trampoline Controller
Lap	Time	Time
1		
2		
3		
Average		

Race Course (Grand Prix/Verses)
Level played: ____

	Traditional Controller	Trampoline Controller
Lap	Time	Time
1		
2		
3		
Average		

Race Course (Grand Prix/Verses)
Level played: ____

	Traditional Controller	Trampoline Controller
Lap	Time	Time
1		
2		
3		
Average		

Survey

Overall Functionality and Usability

1 2 3 4 5 6 7 8 9 10

Pros?

Cons?

Possible improvements?

Additional comments or suggestions

Trends in buttons or accelerometer (Difficulty leaning in one direction or pressing certain buttons, etc.)

How much, if any lag do you notice in any component of the controller and please specify which component

0 1 2 3 4 5 6 7 8 9 10

What do you think of the button layout? Any suggestions?

Rate the ease of use/learning curve. Please explain.

1 2 3 4 5 6 7 8 9 10

Rate your overall enjoyment/fun. Please explain.

1 2 3 4 5 6 7 8 9 10

Would you buy it for yourself or someone else?

How much do you think the system should sell for?

Appropriate age range

Appendix H: Expo Poster

Wii Trampoline Controller

Jeff Christian
Ben Hoselton
Derek Simon

WiiHopp

"Tons of fun!"

"Great for the casual gamer"

Sponsored by JumpSport®

"Flat ground will never be good enough again."

"Bounce = Fun"

Problem Definition

To combat childhood obesity by integrating a JumpSport Rebounder with an interactive gaming system.

Project Objectives

- Integrate a sensory system into the trampoline
- Interface the trampoline sensory system with a gaming system
- Finalize a prototype that could eventually be taken to market

Design Specifications

- **Assembly Time**
  - Less than 30 minutes out of box
    - Put trampoline together
    - Mount Sensory equipment
    - Sync device with Wii
- **Price**
  - Less than $50 for the sensory equipment
    - Trampoline is $300
    - Wii is $200
  - Movement interface
    - All movements should be picked up with 95% effectiveness
- **Energy Use**
  - Variable intensity
    - 13 cal/min for a full court basketball game
    - 6 cal/min for EA Active
- **Response Time**
  - 16 milliseconds
    - Wii remote response time
- **Ease of Use**
  - Functions are clear
    - Distinct buttons
    - Room for user error
  - Movement interface
    - All movements should be picked up with 95% effectiveness
- **Interface with Existing Games**
  - Super Mario Bros.
  - Dance Dance Revolution (DDR)
- **Wireless**
  - The device must be wireless
    - Plug and play from Wii remote's external port

System Layout

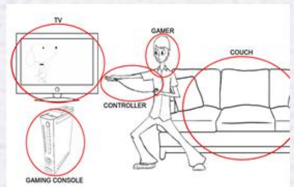


Figure 1. Overview of gaming system components. Our project intends to redesign the controller and eliminate the couch. Our controller consists of six buttons and an accelerometer, which interface with the Wiimote through an Arduino microcontroller.

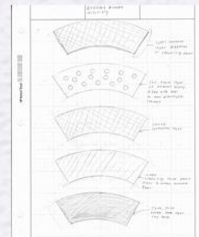


Figure 2. Conceptual design sketch of button layers.

Figure 3. Top view of different components of the trampoline controller

Figure 4. Our Arduino microcontroller plugged into a Wiimote. The accelerometer and buttons are all wired into the Arduino which acts as a Wiimote extension, similar to the nunchuk. This way, the Wii can communicate exclusively with the Wiimote.

Testing

Dynamic button tests were performed using a sample size of 9 players. For Dance Dance Revolution, each person played a song and their game statistics were recorded and graphed below. For Mario Kart each player raced one time with a traditional controller and then once using the trampoline. The time differences, in favor of the traditional controller, are displayed to the right. The testing results confirm that the trampoline is a competitive and viable controller option

Mario Kart 64

Table 1. Increase in Mario Kart lap times while using trampoline as the controller. Since time differences are small, we see that the trampoline is a competitive alternative to a traditional controller.

Δt_{ave}	**1.73**	seconds/lap
Last Lap Δt_{ave}	**2.24**	seconds/lap

Dance Dance Revolution

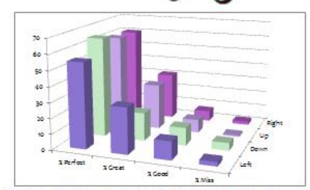


Figure 5. Button accuracy for trampoline directional pad in DDR. Since accuracy is similar for each button, we conclude that all buttons are performing equally well.

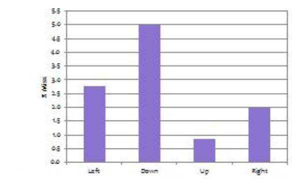


Figure 6. Percent of missed button presses in DDR. Since percentage misses is 5% or less for each button, this indicates that all buttons perform reliably

Analysis

Static Button Analysis

Static button tests were performed by placing each button on a scale and weighting it until it registered a button press. This test was performed with a forwards foot press and a sideways foot press to account for different button orientations

Figure 7. Static button test setup

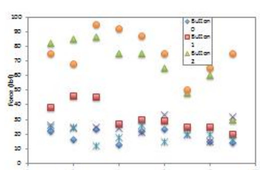


Figure 8. Static button force test results (forward foot placement)

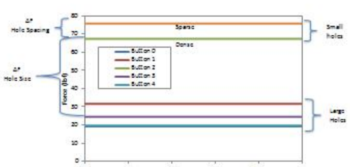


Figure 9. Static button analysis

Accelerometer Analysis

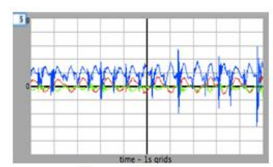


Figure 10. Walking

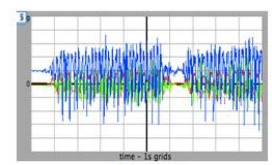


Figure 11. Running

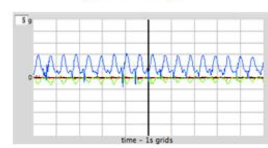


Figure 12. Light bouncing

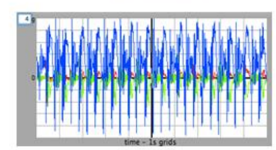


Figure 13. Heavy bouncing

In the above analysis a 3-axis accelerometer was mounted to the bottom center of the trampoline mat. Different motions were performed on the mat surface and the accelerations for each axis, represented in different colors, were recorded. It can be seen that the accelerometer is sensitive enough to distinguish between 4 different types of motion.

Special thanks to Mark and Valerie Publicover, Kevin Charles, Jon Hylbert, and Prof. Kim Shollenberger