Senior Project - Final Design Report
Motion Sensing FIFA Controller

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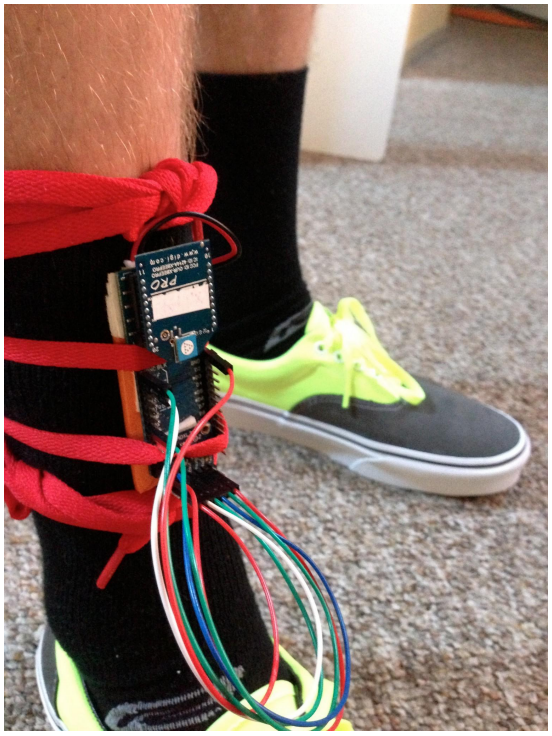


Table of Contents

Introduction

Project Overview:

Our Senior Project was designed to control the XBOX 360 video game FIFA Soccer by different kicking motions made by the user. This system consists of two pieces: the microcontroller attached to the XBOX 360 controller and the foot piece that is attached to the users foot in order to read all of the movements needed to control the game. The intended gameplay of FIFA Soccer was to be controlled by a typical handheld XBOX 360 controller and the pressing of different buttons results in the game avatar performing different movements. Our project brings the soccer game to life by forcing the users to actually perform the different kicking motions that they want their game avatar to copy on the game. This project was designed for those who want to be more active during gaming as well as fans of soccer that want to see their movements replicated on the video game system.

The current prototype that we have completed can sense the three main movements used in both real life soccer as well as the FIFA Soccer video game, which are pass, shoot, and cross. The foot piece attached to the users ankle has an accelerometer, a microcontroller, and a radio broadcast device on it. The accelerometer is used to capture data on user motions and then send that information to the microcontroller. The microcontroller then process' the data and decides which movement had been performed by the user. This movement is finally sent over the radio device to the microcontroller attached to the XBOX 360 controller and this then mimics the corresponding button press leading to the game avatar performing the movement on the game.

Stakeholders:

People who are affected by the outcome of this project include the creators (Anthony Agius and Jake Troychak), our advisor (Lynne Slivovsky), and any FIFA Soccer fan. As creators we have put in a lot of our time and money into this project to make it the best experience as possible. A successful product will be the main goal of our team and by reaching this we will feel very accomplished. Our advisor, Lynne Slivovsky, is also a soccer fan and we are sure she wants to see this project be a success so she could play virtual soccer anytime she wants. As for the casual FIFA Soccer fan, a successful product will result in a new and engaging way to play the game they love. We chose to take on this project because we are also huge fans of the game and we are excited to not only control the game, but also feel like we are a part of it by using our motion-sensing controller.

Need Statement:

People who play video games are often thought of as lazy and unathletic. As two computer engineers who like playing video games, but also like being active and playing sports we wanted to combine the two and create a device that would allow the user to control a soccer video game by making different kicking motions representing different button presses and movements made by the video game avatar.

Project Goals and Objectives:

The following sections outline our initial goals and objectives regarding our project.

Goals:

- Create a device that can wirelessly control FIFA Soccer by kicking motions.
- Change the unathletic stereotype of people who play video games.
- Be able to read and distinguish between several different soccer moves.

Objectives:

- Purchase all of the parts necessary.
- Be able to communicate between two microcontrollers wirelessly.
- Trigger button presses on the XBOX 360 controller through a microcontroller.
- Read and analyze accelerometer data of different soccer movements.
- Run several noise cancellation functions to determine which is best for our data.
- Distinguish different trends and correlate data graphs with kicking motions.
- Combine all of the above and control FIFA Soccer by user kicking motions.

Project Outcomes and Deliverables:

If all of our goals and objectives are completed the deliverable of our project will be two devices: The first will be a device that is connected to a XBOX 360 controller that can trigger all of the button presses, and the second will be a device that is connected to the user's leg which will read all of the movements and send the corresponding button press to the first device wirelessly.

We hope that this outcome can be used in order to control a game of FIFA Soccer for the XBOX 360 and that any of the game movements we have coded into the system will be able to be done by the user and replicated on the game screen by the avatar.

Team Mission and Objectives:

The following mission statement and objectives will help us stay on track and complete our goals stated above.

Mission Statement:

Our mission for this project is to make a device that enables us to be more interactive while playing FIFA Soccer on the XBOX 360.

Objectives:

- Communicate effectively between each other on project decisions.
- Weekly meetings with our advisor and communicate with her on a weekly basis.
- Work together on all aspects of the project for us both to get a full understanding.
- Develop progress objectives and due dates to keep on track with the large project.
- Create a budget plan to keep our expenses within our group's budget.

Team Membership and Roles:
Below is a list of the members and their designated roles:

- Anthony Agius - Liaison
    - Anthony was the main point of contact on our group for our advisor, and made sure to keep everyone updated on project progress.
- Jake Troychak - Project Manager
    - Jake made sure that all the tasks were being completed and planning outside of meetings.

While we both had our own roles we each also spent the whole project working together on development of the devices as well as testing and budgeting.

Related Work

This list of websites and videos gave us inspiration and direction to help complete our project:

How to Mod a Xbox 360 Wireless Controller with CG Board using A 20 mod chip
http://www.youtube.com/watch?v=MPzbmDVJAZU

This Youtube video was used to help us get a better understanding of how we should disassemble and wire up our XBOX 360 controller in order to control it using a microcontroller. This video was very helpful to us when trying to understand the hardware schematic diagram of the different types of configurations on the XBOX 360 controllers.

Xbox 360 wired pad hack tutorial
http://teapotskingdom.blogspot.com/2010/08/xbox-360-wired-pad-hack-tutorial.html

This website was used to better understand the different components of the XBOX 360 wired controller that we used in order to communicate between the Arduino Uno microcontroller and the XBOX 360 system.

Linear Discriminant Analysis - A Brief Tutorial
http://www.music.mcgill.ca/~ich/classes/mumt611_07/classifiers/lda_theory.pdf

This pdf isn't directly related to our project but it gave us a pretty good understanding of different types of algorithms that we could use in order to distinguish between different types of movements.

XBOX 360 Controller Mods
http://www.youtube.com/watch?v=FbF-pZY12z4

This Youtube video was our original inspiration to use the XBOX 360 controller as a "middleman" to communicate with the XBOX 360 when we were unable to send the RF signals directly to the XBOX 360 system from the Arduino Fio.

Formal Project Definition

Marketing Requirements:

The marketing requirements we developed for our senior project were developed around what we wanted the user to experience while using our project. Our project's performance and success will be determined by the user's experience with our project. We would like the user to have the experience of feeling like they are playing soccer and having their movements determine gameplay.

1. Motion controlled "shin-guard" attachment to play the Xbox game FIFA with soccer based kicking motions
2. Motion controller can trigger the 3 main button presses for the game.
3. Controller works for people with no experience player soccer as well as seasoned soccer veterans.
4. Does not require software update or a patch to the game FIFA to use
5. Device will be safe and easy to use.
6. Device will work for a wide-range of movements so gameplay feels like natural soccer motions
7. The device will identify user motions of "crossing", "shooting", and "passing".

Engineering Requirements:

Marketing Requirements # and (Engineering Requirements Category)	***Engineering Requirements***	***Justification***
(Performance)	**The device will detect and process user movements and signal when a move has been completed to the Xbox within 1 second**	**If the device doesn't trigger the button presses within a reasonable amount of time otherwise gameplay will be ruined for the user**
(Performance)	**The accelerometer must sample at a rate of 1 sample every 5ms**	**It the accelerometer doesn't sample fast enough movement data would be lost**
(Performance)	**The device must be able to store at least one movement worth of data (1 second of accelerometer readings)**	**If the device cannot store enough data to process a movement the device will not function properly**

(Functionality	**The device will correctly identify the user's movement (if performed correctly) 100% of the time.**	**If the device cannot identify movements correctly the user will not enjoy using the device and will not use it**
(Functionality)	**The device will be useable for people of various levels of athleticism, size, and skill.**	**The device needs to work for a wide variety of users otherwise the market for it would be too narrow**
(Economic)	**The device will cost $50. That is the cost of 1 Xbox controller.**	**The controller should not cost more than current price of an Xbox controller.**
(Economic)	**The device will not need a special version of FIFA to function.**	**User should not need a special version of FIFA to use the device. They should be able to use the device with the game they already have.**
(Environmental)	**The device will use rechargeable, recyclable polymer lithium ion batteries.**	**Batteries are toxic to the environment and difficult to recycle. Polymer lithium ion batteries are the most sustainable option.**
(Energy)	**The battery charging the device must provide a voltage between 3.3V and 7V**	**The Arduino Fio microcontroller requires an input voltage of 3.3V - 7V to charge**
(Health and Safety)	**The device will be cased in a secure manner such that it will not come detached from the user and hit anyone nearby.**	**The use of the device requires fast, powerful movements. If the device cannot be securely attached it could fly off and injure someone nearby.**
(Health and Safety)	**The device will have a minimal profile (1" x 5" x 2") and weight (18oz.).**	**The device should not force the user to alter their movement in a way that would harm their body. The device should not add any additional strain to the user's movements.**

(Legal)	**The device will contain a warning about be observant of one's surroundings and having at least a minimal area of free space.**	**The user should have at least a minimal distance where there are no object that their motion would cause a collision**
(Legal)	**All the necessary permissions from Microsoft (Xbox) and FIFA would be obtained before manufacturing the device**	**The device will work alongside the products these companies manufacture.**
(Operational)	**The device will identify characteristics, patterns, and features unique to the movements in order to identify movements.**	**The device needs to have a means to identify and characterize movements for all types of users.**
(Operational)	**The device will have a wireless range of at least 10 ft.**	**The user needs adequate space to perform the necessary movements.**
(Reliability and Availability)	**The device will function for all Xbox models and versions of FIFA.**	**The device needs to be available on all platforms of Xbox and versions of FIFA for commercial use.**
(Social and Cultural)	**Our device will use Gamer's blogs and magazine to advertise the product**	**To get the device know it will be advertised through media that the target audience uses**
(Usability)	**The user will be able to simply strap the device to their leg and be able to play**	**If the device requires too much setup to use, users will not use the device.**
(Usability)	**The movements used to play should be feel natural and like real soccer moves**	**The main attraction of the device will be that it allows the user to play FIFA like they are playing**

Constraints:

We added the following constraints to our project.

- The device will have a warning that it should not be used if:
    - the user feels muscle strain.
    - there is not a 10ft radius of free space for the user to play.
    - if the user possess any medical condition that would not let them use the device.

Criteria:

Accuracy: The percentage of valid movements that are correctly registered by the device.

Response Time: The time from which the movement was executed and the move is performed in the game.

Battery Life: The amount of time the device can be used before it needs to be recharged.

Compatibility: The number of users that the device works correctly for.

Range: The distance (in feet) from the receiver and Xbox, that the device can be used.

The User Experience

Overview:

The user of this product should have a very enjoyable and easy time throughout the entire game from startup to shutdown. The user should be able to very easily put on the foot piece, setup the controller piece, and play the game within minutes after reading the user manual. We wanted to make that all of our moves were easily distinguishable from each other as well as easy to learn for any person, whether or not they have any soccer background. One of the main reasons we wanted to move forward with this project is because of the active aspect and to promote everyone to stay healthy and active. Because of this we want our users to feel like they have received a genuine workout after using our device, but at the same time we don't want the users to get too tired within a short amount of time otherwise they will be unable to finish any games. It is up to us to control the power and types of movements the user has to make in order to find the happy medium between active users and tired users.

The game FIFA Soccer is designed for people with varying soccer knowledge, from people who have never seen the game to professional international superstars. We want our device to go along with this wide variance and make the movements very easy to understand and "master" in order to easily control the game's avatar. We also want the setup to be very easy to make the user experience a positive one, from turning on the controller device to strapping on the foot piece the user should be ready to play the game in under a minute from starting. The reason for this is that we do not want it to be too difficult to use our device otherwise people will be more likely just to use a regular controller in the place of our motion sensing controller.

Personas:

Two personas were created as the typical users of our project. One is an experienced soccer player and the other is a gamer with no previous soccer experience. These personas cover the different ends of the spectrum that we expect will use our device.

Name: Cristiano Messi
Age: 27

Background: Cristiano is an international soccer superstar who has played soccer since before he could walk. Cristiano is considered the best player of his generation and has won numerous

awards during his career. During the offseason when he is not conditioning and training, Cristiano likes to play as himself on his favorite video game, FIFA Soccer. Cristiano is able to use the game to both strategize for his real matches as well as relax from long practices with his club team.

Environment: Cristiano Messi lives in a beachside resort in Barcelona, Spain.

Skills: Considered by many as the best soccer player alive. He is also known for being one of the best FIFA Soccer players on online play.

Attitudes: Cristiano is always ready for a good work out and takes very good care of his body. He is also very competitive and will never back down from a challenge.

Goals: Cristiano wants to win numerous FIFA World Cups in real life as well as reach the #1 spot on the FIFA Soccer Online XBOX 360 leaderboards.

Blog Entries:

"Today I was introduced to a new device that allows me to control FIFA Soccer on the XBOX 360 by doing the moves in real life. This is a lot of fun and combines two of my favorite things: getting a good work out from playing futbol and being able to get closer to the #1 spot on the XBOX 360 leaderboards!"

Name: Susan Lazy
Age: 18

Background: Susan just graduated High School and loves to do one thing, play video games. Her favorite types of games include strategy and first person shooters. All of her friends from home play video games as well and every night they get together online to challenge each other. Susan is not a fan of sports because she does not play well with others, the only sports she plays are individual ones like golf and bowling, but only if she is the only one there.

Environment: Susan Lazy lives on her parents farm in Omaha, Nebraska.

Skills: Susan is very good at strategy video games and is a whiz when it comes to modifying video game controllers.

Attitudes: Susan hates working out and doesn't like to go outside much. After Susan has breakfast she always goes straight to her room where she puts on her headphones and plays video games until it is time for bed.

Goals: Susan wants to one day be a video game tester for any of the major video game creators. Susan also would like to start her own company that creates different types of controllers for different video game systems.

Blog Entries:

"Today one of my friends online told me about this soccer video game and a way to control it by making kicking motions. I've never played soccer before, but after reading the user manual I think I got it down pretty good. I've never exercised before so I am pretty wiped out, but I think I'll keep using this to get more healthy as well as reach the top of the FIFA leaderboards online!"

Use Cases:

The following are common use-cases that users of our product will be more than likely to experience. These short situations outline the details of interaction between the user, the foot device, and the controller device.

Use-Case	Setup - Turning on the system
Actors	User, foot device, and controller device
Description	The use-case occurs when the user straps on the foot device and then turns on both devices as well as the XBOX 360 system.
Stimulus	User wants to play FIFA Soccer using our device.
Response	Both devices start up, Arduino Fio device captures the initialized values for all three axes based on the accelerometer values while the user is standing still for 5 seconds.

Use-Case	"Shoot" movement executed
Actors	User, foot device, and controller device
Description	The use-case occurs when the user wants their avatar on the game to perform the shooting action and hopefully score a goal!
Stimulus	User brings foot straight back then drives forward in a kicking motion pretending to contact the imaginary ball with the laces of their shoes.
Response	Accelerometer collects movement data and passes data to Arduino Fio. The Arduino Fio then determines the shooting motion was performed and sends an 'B' over the XBEE interface to the Arduino Uno. The Arduino Uno then triggers an B-Button press on the XBOX 360 controller, which makes the avatar shoot the ball.

Use-Case	“Cross” movement executed
Actors	User, foot device, and controller device
Description	The use-case occurs when the user wants their avatar on the game to perform the crossing action and set up a perfect opportunity for their teammates to score on a header.
Stimulus	User brings foot straight back then drives forward in a similar motion to the kicking motion, but instead pretending to contact the imaginary ball with the inside of their foot and following through in the same way.
Response	Accelerometer collects movement data and passes data to Arduino Fio. The Arduino Fio then determines the crossing motion was performed and sends an ‘X’ over the XBEE interface to the Arduino Uno. The Arduino Uno then triggers an X-Button press on the XBOX 360 controller, which makes the avatar perform a cross.

Use-Case	“Pass” movement executed
Actors	User, foot device, and controller device
Description	The use-case occurs when the user wants their avatar on the game to perform the passing action.
Stimulus	User keeps their foot parallel to the ground and drives the ball forward with the inside of their foot.
Response	Accelerometer collects movement data and passes data to Arduino Fio. The Arduino Fio then determines the passing motion was performed and sends an ‘A’ over the XBEE interface to the Arduino Uno. The Arduino Uno then triggers an A-Button press on the XBOX 360 controller, which makes the avatar pass the ball.

Design and Justification

Overview of Team Process:

The process in which we went about this project was very team oriented. We both wanted to learn every little detail and every new technique that went along with this project and the only way we were going to be able to do that is if we both worked together on every part. This also helped during coding because it was much easier to catch any mistakes with four eyes watching instead of just two.

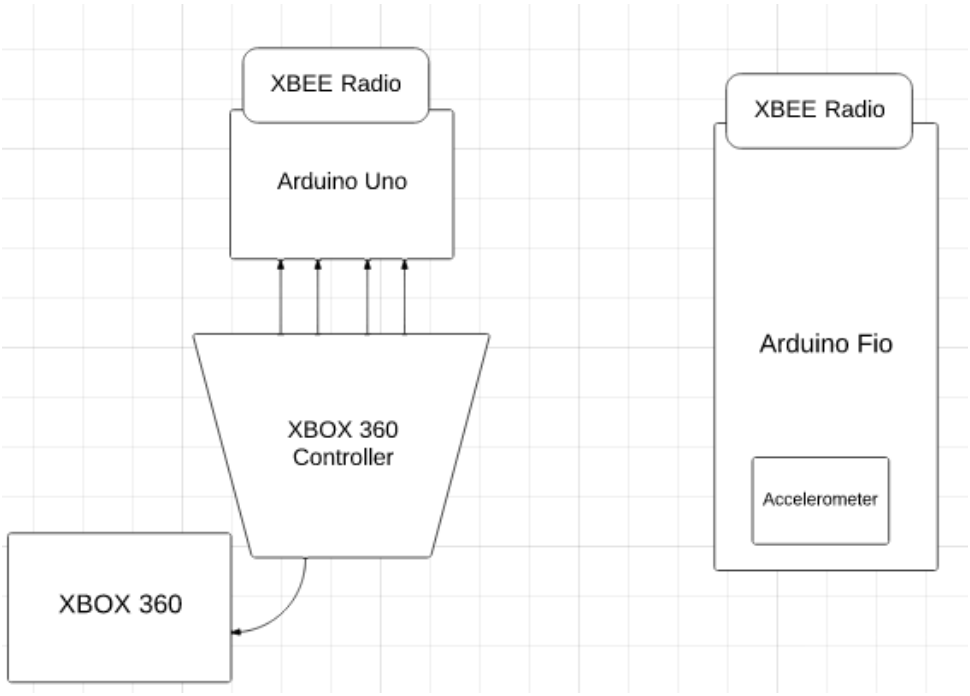
At the beginning of the project we sat down together and planned out our timeline for when we wanted to get certain milestones done in order to have enough time to test and complete the project before the end of the year. We also used this planning time to figure out which parts we needed and budget out how much money we would have to spend on this

project. All throughout this process we held a good communication with each other for when we wanted to get certain pieces of the project done and this communication really helped us complete our goals and successfully complete the project.

As a team we also set up bi-weekly meetings with our advisor, Lynne Slivovsky, for the first quarter and weekly meetings for the second quarter. This helped our overall process because we were able to get feedback on the direction we were going as well as have any questions answered along the way. The overall process we used for this project was very successful and was backed by a lot of communication, and I believe that is the main contributing factor to our successful project.

System Architecture:

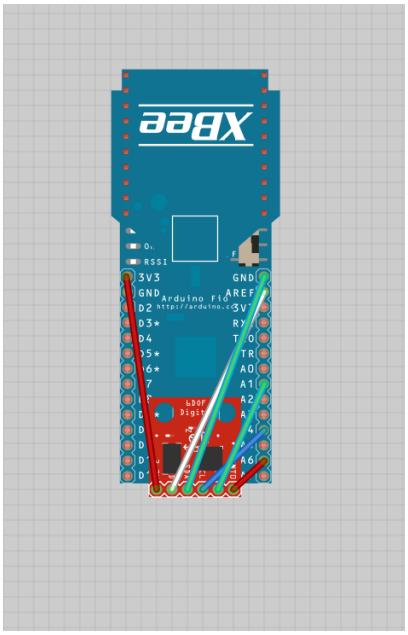
The following is a general diagram of our entire system including the foot piece on the right with the Arduino Fio, Accelerometer, and XBEE device as well as the controller piece on the left connected to the XBOX 360 controller which is connected to the XBOX 360 system.



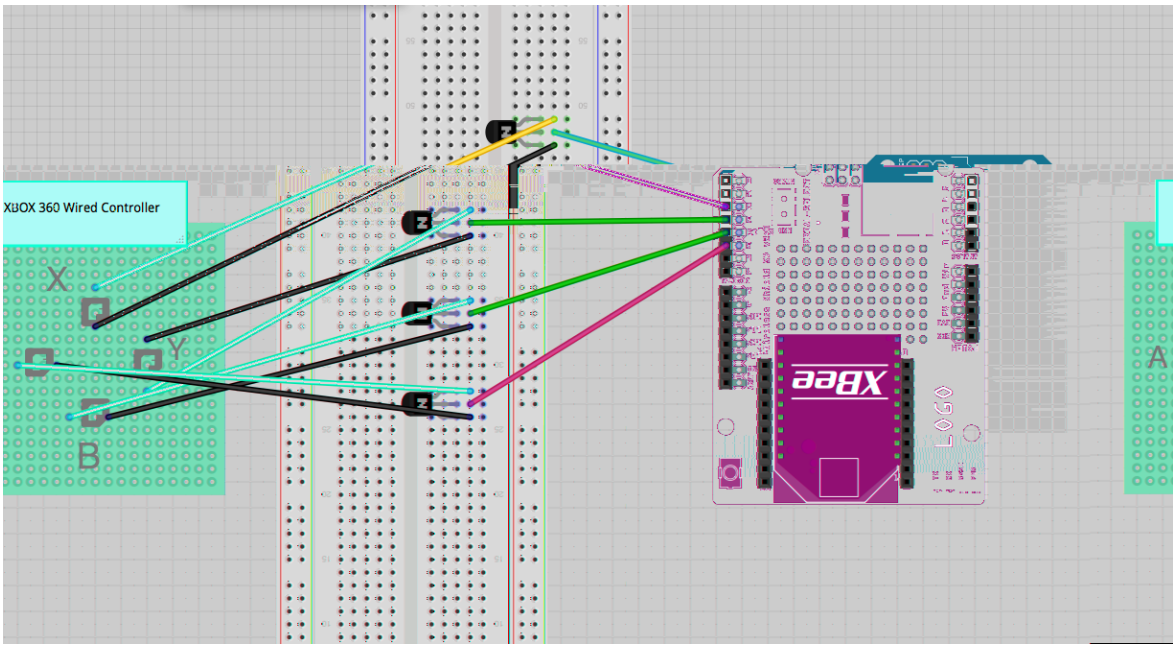
System Architecture Diagram

Hardware Block Diagrams:

The following Block Diagrams are a more in depth look into each piece and how they are connected to each other in order for the whole project to work as one.



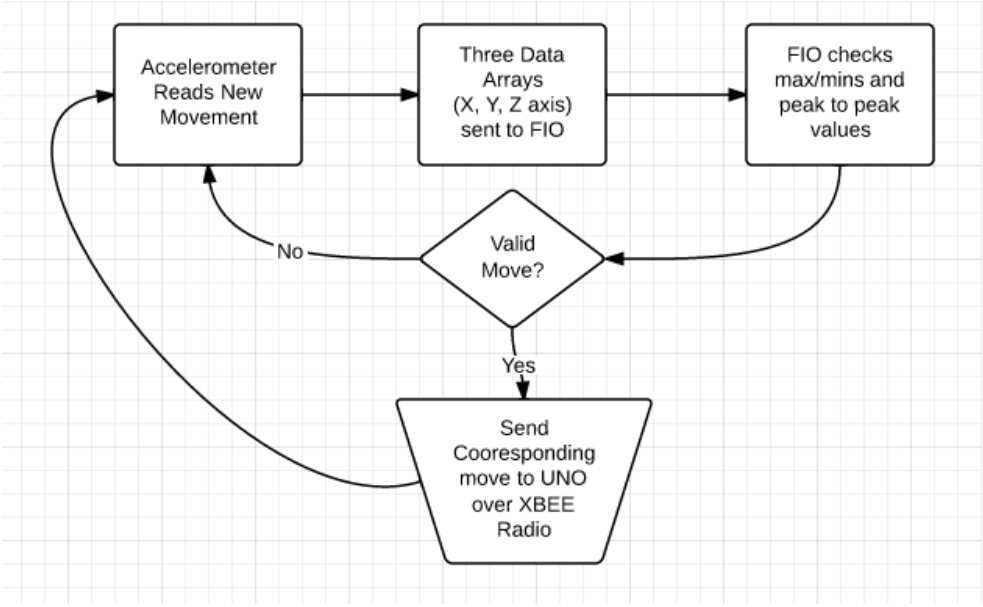
Foot Piece



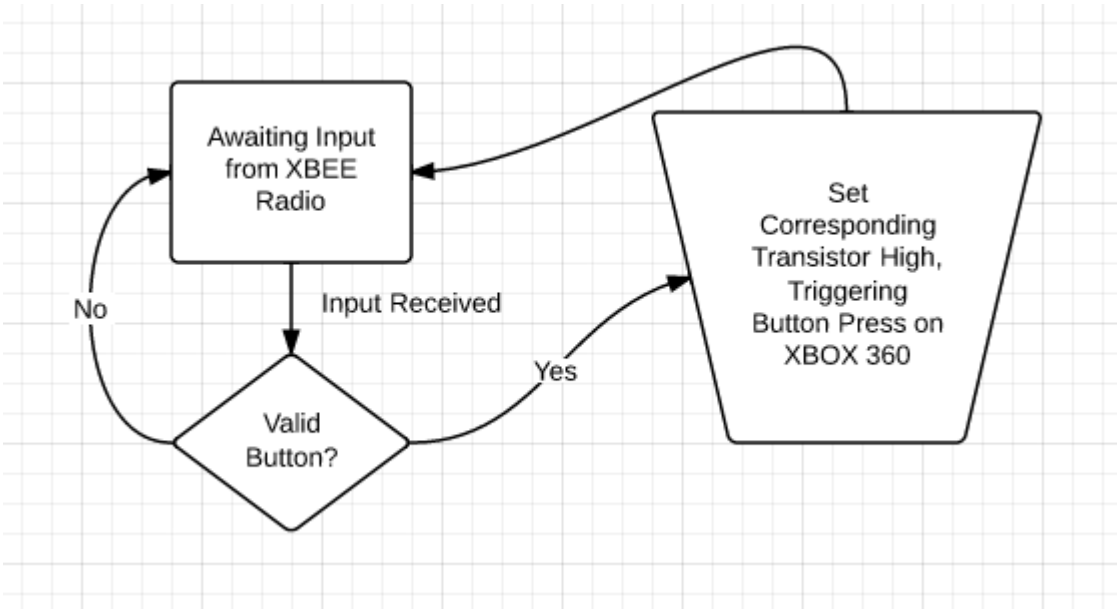
Controller Piece (Connected onto Breadboard)

Software Architecture:

The following flow charts demonstrate how our system software works and controls our system.



Software Diagram on Foot Piece

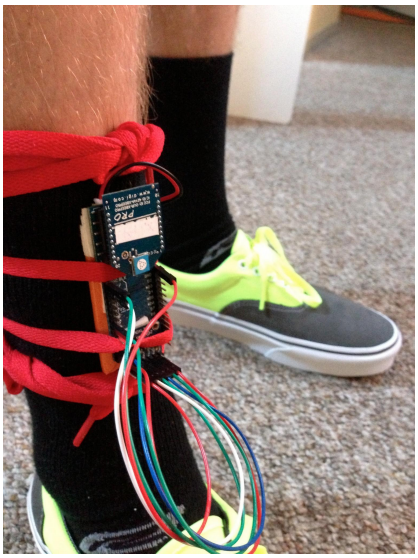


Software Diagram on Controller Piece

Mechanical Design:

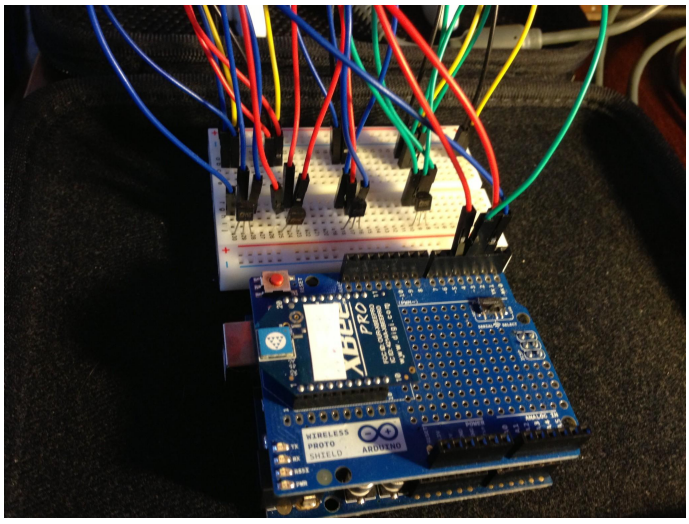
The following images show the mechanical design of our current prototype.

This image shows the foot piece attached to a user using strings. Future prototypes will have either Velcro straps or have the device connected to a shin guard in order for easy put on and take off. In this image you can see the XBEE radio (on top) directly connected to the Arduino Fio and the 3-axis accelerometer (on bottom) connected through multiple wires as well as double sided tape. On the back of the Arduino Fio is the rechargeable lithium polymer battery (orange).



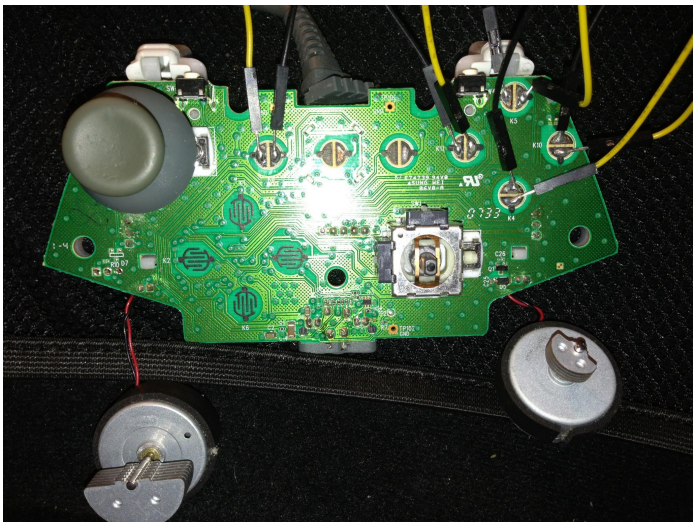
Foot Piece attached to users foot

This image shows half of the controller piece. In this image you can see the XBEE radio receiver connected to the Arduino Uno microcontroller using a XBEE shield (front). The four output wires coming out of the Arduino Uno are each connected to a N-type transistor, which is connected to one of the four main buttons on the XBOX 360 controller (A, B, X, and Y).



Arduino Uno connected to Breadboard

This image shows the other half of the controller piece. The wires seen soldered onto the board of the XBOX controller are coming from the breadboard connected to the N-type transistors. The yellow wires are high (3.3 V) and the black wires are low (0 V). In our current prototype the joystick on the left is used to control the direction the avatar is moving. In future prototypes we would like to either control the avatars direction using motions as well (running in place or moving the users head) or by detaching the joystick and having a handheld one for the user.



XBOX 360 controller

System Integration and Testing

Test Plan:

In order to test our product we both had many test kicks and collected enough data for each movement in all three axes (X, Y, and Z). These data graphs were all saved and compared to one another to see any differences and similarities between the movements. We used these data graphs (See Appendix C) along with the received data from the XBEE receiver on the Arduino Uno to see if the correct movements were being transmitted from the Arduino Fio to the Arduino Uno. To go along with these tests we also tested each piece of the project individually before putting it all together. From testing whether the Uno could trigger the correct button presses on the XBOX 360 controller to the Arduino Fio and Arduino Uno communicating over the XBEE radios, we wanted to make sure that every piece was working before we started putting them together.

I feel like this test plan really helped us isolate any problems we ran into and made it really easy for us to debug and move forward quickly with our project. After all finishing touches were made on our project we checked it against all of the engineering requirements and criteria that we set on ourselves (stated above) to make sure we designed the system for everything we planned for. Finally, we were able to test our system while playing FIFA Soccer on the XBOX 360 and were able to see our project in action!

Results and Analysis:

The results of our test were very positive with our project being able to successfully send all of the movements made by the user to the XBOX 360 and seen on the screen with the avatar replicating the movement. This test proved to us that all of our software and hardware was designed correctly and the flow of the system was a success. The one thing that we did notice after testing was there was a noticeable delay from the point when the kicking motion was made until it was seen on the screen. After analyzing this delay we have come to the conclusion that although there may be a delay caused in the processing of the accelerometer data and sending the button press across the XBEE radio, most of the delay stems from the difference between tapping a button on the controller and making a full kicking motion plus the same time it takes to press the button which is mimicked after the kicking motion is completed and sent over. In order to decrease this delay time seen during testing we may want to look into trying to determine what motion is being done in the middle of the motion, instead of always having to wait the full motion's duration before any processing is done on the axis array data.

We also noticed the slow processing time could be due to the lack of memory on the Arduino Fio which has to not only hold information for the known movements as well as the three axis data arrays from the previously made movements. The Arduino Fio only has 2KB of SRAM, which gives us only 250 integers per data array to store. If we were able to store more data points per array it may be much easier to distinguish kicking motions and less time would be taken to process moves because they would be able to be determined before the user ended the motion. Overall we were both very proud of our current prototype and the progress we made over the past few quarters.

Conclusion

Over the course of this project we have learned to use many new tools that otherwise we would not have used during our undergraduate careers. These include the use of the Arduino Sketch software for developing Arduino based programs and the use of XBEE radio devices and programming them to communicate between each other. After the completion of this project we both feel much more confident reading hardware schematics because of all the XBOX 360 controller schematics we had to read to understand how to wire the controller to the Arduino Uno to control the mimicking of the button presses.

One of the main components of this project is the use of the accelerometer to pick up data from different motions and send them to the Arduino Fio microcontroller to determine which movement was performed. We both learned many techniques for collecting this data and cancelling out the noise in order for the data graphs we receive to be easily distinguishable from each other. Some of the different techniques we used to determine the different motions collected by the accelerometer were peak-to-peak difference on the X, Y, and Z axes and Linear Discriminant Analysis, which combines the X, Y, and Z data graphs into one vector and uses integration to "map" the vector to its corresponding movement. Another thing we both learned from this project was working with a partner on a large project and collaborating with our advisor once a week and trying to stay on track with hardly any intermediate deadlines other than the ones set on us by ourselves. Finally, we feel like we have really learned better time management as well as project planning techniques to finish a large project in a given amount of time.

Appendices

Appendix A: Budget Requests and Justification

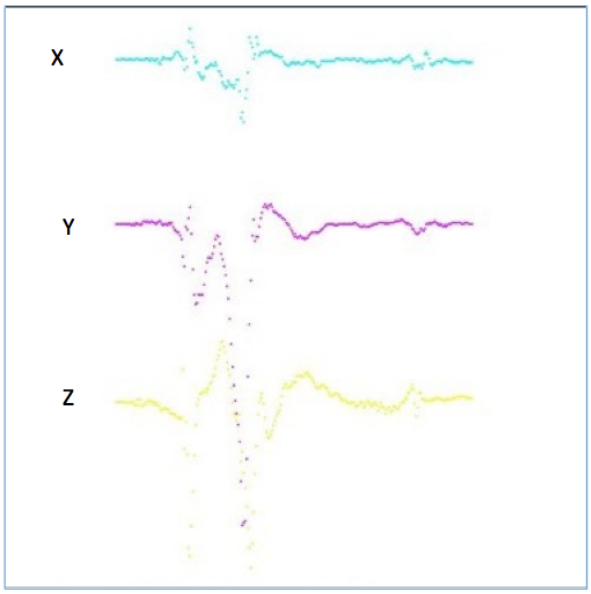
At the start of our project we estimated our project would cost around $100, which included the Arduino Fio microcontroller for the foot piece, an accelerometer to read the motions, a radio transmitter, and a few batteries to power the microcontroller to keep it wireless. This estimation was when we were still planning on sending the button signals directly to the XBOX 360 using the built in RF signals that the wireless XBOX 360 controllers used. However, we had to adjust our design since we were unable to use the built in RF signals on the XBOX 360 because Microsoft had encrypted their signals, which required us to purchases extra radio transmitter / receivers, an Arduino Uno microcontroller to control the XBOX 360 controller, a shield to connect the XBEE radio devices to the Arduino Uno and a specialized screwdriver to open up the XBOX 360 controller. These extra items combined with our original list of items brought our final cost of the project up to about $180.

Appendix B: Bill of Materials

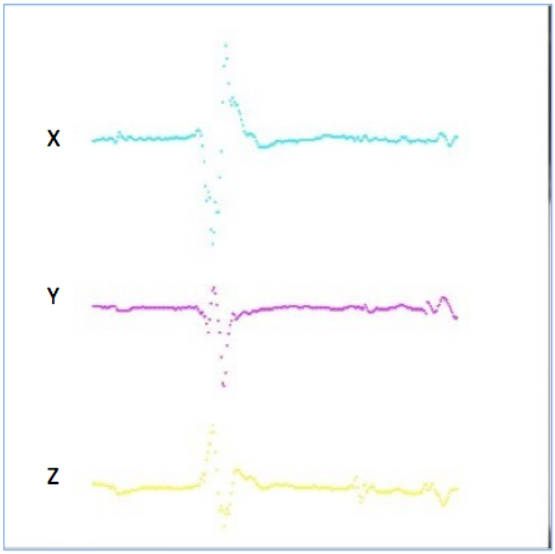
- Arduino Uno Microcontroller: $25
- Arduino Fio Microcontroller: $30
- (2) 3 – Axis Accelerometers: $40
- Arduino Xbee Shield for Uno: $12
- (2) XBEE Radio Devices: $40
- (2) Batteries for Arduino Fio: $28
- Torex T8 Screwdriver: $5

Appendix C: Accelerometer Data Graphs

SHOOT (B – Button)



PASS (A – Button)



CROSS (X – Button)