Boston University
Electrical & Computer Engineering
EC464 Capstone Senior Design Project

User Manual

Augmented Reality Climbing Wall

by

Team 14
Augmented Reality Climbing Wall

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Executive Summary

Our project focuses on optimizing the current augmented reality climbing walls by creating a smoother, mistake-free gaming experience for the user. To accomplish this, we plan to take the skeletal tracking system that most augmented reality climbing walls already use and couple it with our own active sensors that would be attached to the climbing holds already on the wall. Doing this would remove the reliance on the inconsistent skeletal tracking system and add a second element that can actively sense which climbing holds the user is exerting pressure on while hanging from the wall. In addition to providing users a smoother experience, we also plan to develop our own augmented reality climbing wall games such as Simon, a pattern matching game, that the user will be able to enjoy without error or delays while on the wall.

Introduction

Recently, augmented reality has seen a huge popularity spike in the world of gaming. Since augmented reality consists of real objects being overlaid with digital elements, this dynamic creates the potential that regular situations in life can be turned into an exciting game. One such situation is climbing a rock wall at a climbing gym. Augmented reality is perfectly suited for the world of rock climbing because it can create an incredibly immersive gaming experience, and unlike virtual reality, no overburdensome equipment is necessary. Augmented reality climbing walls do exist today and are done using a projector to project the game onto the wall, a game engine running the actual game being played, and a skeletal tracking system that estimates where a user is on the wall. However, this is not exactly a mistake-free system. Skeletal tracking can prove to be unreliable at times such as if a person's body comes in between the skeletal tracking system and a hand that is on a hold, leading to the system being unable to track where that hand is and resulting in a flawed gaming experience.

This is the problem that our team was tasked by our client asked our team to solve. Our objective is to provide climbing gyms with an augmented reality bouldering experience that can create a smooth and error-free game for the user. How we plan on accomplishing this is by creating pressurized sensors that can be placed between the climbing wall and the holds, allowing for accurate knowledge of where the user is on the wall. The main metric of this project is that by the end of the year, we hope to have an augmented reality climbing wall that outperforms the current AR walls on the market.

In addition to creating the pressurized climbing holds, we also plan on creating our own augmented reality game to be played on the wall. This was an idea from our client, with most of us being computer engineers, the idea of creating a game was very exciting. Currently, we have created a pattern matching game as well as a missile dodging game; both of which are specifically programmed to work with our sensors and wall. We plan on providing this game plus the pressurized climbing holds and the rest of the system involved in making the AR wall operational, such as the microcontroller processor, projector, and skeletal tracker, as our main deliverables for this project.

Pairing augmented reality with rock climbing walls is an optimal combination with incredible potential to create amazing gaming and climbing experiences for the users. However, that potential has never been fully realized as the modern way of pairing the two leaves much to be desired. For our project, by taking the skeletal tracking system that is the cornerstone of how augmented reality climbing walls are currently done and combining it with our own pressurized climbing holds, we plan to fully reach that potential and allow climbing gyms to offer their customers an error-free gaming experience.

System Overview and Installation

2.1. Overview block diagram

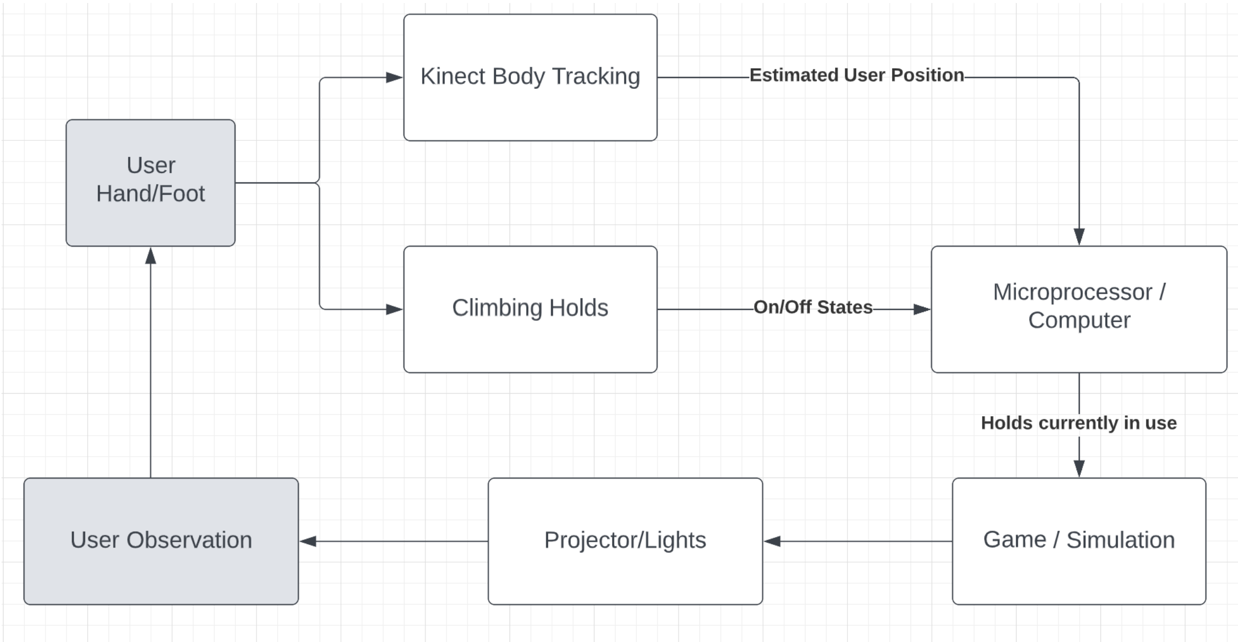

Figure 2.1: System Overview of the Ecobi

Here is a block diagram featuring the various inputs that the sensors will receive and how that data is passed throughout our entire system, composed of the sensors, Raspberry Pi, the game software, and the projector, until it is displayed for the current user to see on the wall.

2.2. System Components

Our system consists of three major components: the holds, the computer and the game. The holds we attached to our apparatus which will be what detects where a player is on the wall. The computer intakes the data of which holds are being held at the time. The computer transcribes this information to the game that is being played. This identifies the position of the corresponding holds where the player's body is from the data that the computer is importing to it. For our original game, a virtual quadrilateral will be created as a “collision box” for where the player is. The game will update according to the rules of the game and continue until the game has reached an end state whether that is completing the game or reaching a “game over” condition

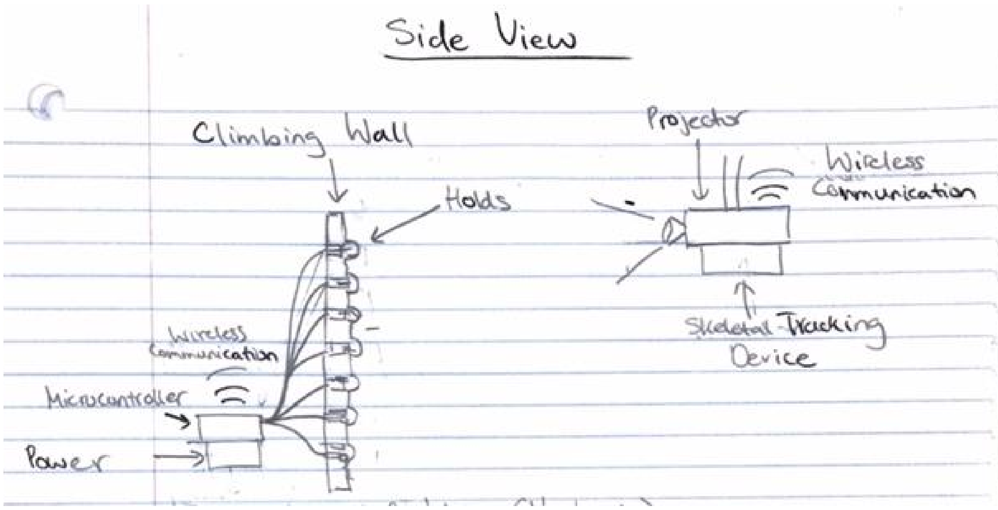

Figure 2.2: Complete Visualization of our AR Climbing wall system

2.3. Installation, setup, and support

To install the apparatus (see *Figure 2.3.2*)to the hold do the following:

1) Place the apparatus between the hold and the where on the wall you would like to place the hold on.
2) With the screw through the hold, insert the hold inside of the apparatus and drive the screw through the wall with a screwdriver or drill until the screw is tightly secured in the wall. This can be seen in *Figure 2.3.1*
3) Do the same for each of the holds.

Figure 2.3.1: Front view of the apparatus properly place between the hold and the climbing wall

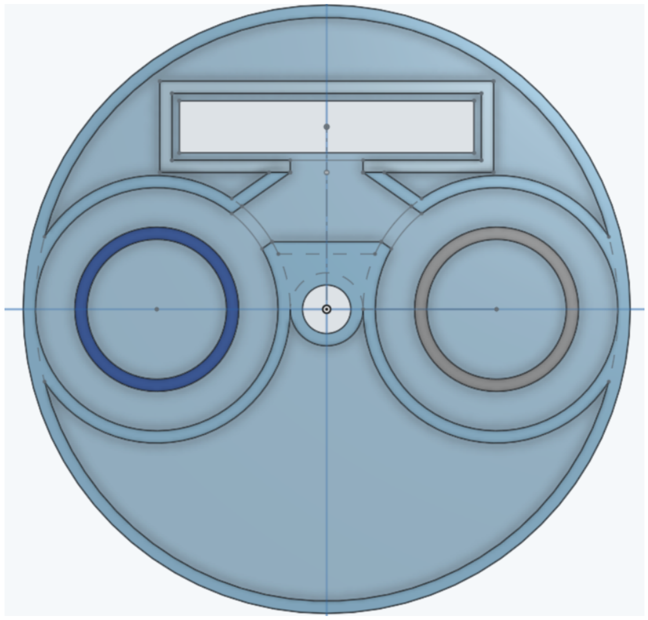

Figure 2.3.2 Overview of how the apparatus looks from the inside

To calibrate the game with the proper holds use the setup interface on the computer device.

1) Open the “AR Climbing Wall Setup” application on the device.
2) Click on the setting option in the menu.
3) Click on the calibration option in the next menu. You will now see a virtual depiction of the wall with an array of black dots depicting possible positions to place a virtual hold. At the bottom there should be a list of all the holds that can be placed on the wall. Each hold should have a number attached to it. Numbers are also printed on the apparatus of the corresponding real holds.
4) Drag a virtual hold to the position on the virtual wall.
5) Insert the corresponding hold into the corresponding position on the real wall.
6) Repeat this for all the holds that you will be using on your wall.

Figure 2.3.3: Preview of our interface application

Operation of the Project

3.1. Normal Operation

The expected operation of our system is as follows: The front insert we provide is placed between the hold and the wall, and the back insert is placed behind the wall, where the bolt is fastened. The front inserts and back inserts are all identical to each other, so no matching is needed when installing. After the holds are attached, the system is powered on, and the projector displays a menu of games. If the hold positions are new, the user will calibrate the system by pressing down on each hold and dragging a marker to that hold's position with a wireless mouse and keyboard. After the hold positions are properly calibrated, the user can select from a number of games that are compatible with different numbers of holds. When the game is started, the projector will display a game that the user can interface with using only the rock climbing hold buttons. When the buttons on the apparatus attached to the holds are pressed, a signal is sent to the Raspberry Pi. The Raspberry Pi is set on a timer to check the status of 1 of the 5 groups of holds and rotate through the groups in order. When a hold is not in the current group that is being checked, then it will hold the last state of the hold. The cycle at which the holds are pressed are within 50 milliseconds, so they are undetectable to the players. The signal is either a 1 or a 0, 0 denoting that the button is not being pressed and 1 denoting that a button is being pressed. When the hold is being read as "pressed, " then the game will update the position of the player and update the state of the game according to the rules. After the game ends, the user may interface with the menu using either the holds on the wall or the wireless mouse and keyboard.

3.2. Abnormal Operation

We have seen abnormal operations when a hold's state is misidentified. This phenomenon comes in two forms, false positives and false negatives. In the case of a false positive, the hold will always be detected as pressed, perhaps due to interference with nearby holds, sticky buttons, or a malfunctioning multiplexer. In the case of a false negative, the hold is being depressed but not being detected properly. This may be due to a lack of power during the wireless transmission, sticky buttons, or misaligned coils. In both cases, the insert would have to be replaced, which is not too much of an inconvenience given the number of inserts we expect a client to purchase. Apart from physical abnormalities, game bugs may also arise that cause disruptions in gameplay. Before a full product launch, it would be likely that software is provided that would automatically update as new bugs are found and patched.

3.3. Safety Issues

In our system, the primary safety issues are those associated with rock climbing in general. One issue that may arise is the deformation or destruction of our rock climbing hold inserts, which may create sharp corners or falling objects. In our final design, this would be unlikely to arise, since the inserts are made with a sturdy material, but any contact with enough force could still potentially damage the insert.

Technical Background

4.1 Mechanical Component

The manufactured parts portion is made up of 4 distinct parts: main coil enclosure, circuit button holder, button, and coil holder. The main coil enclosure is mounted on the front of the wall between the rock climbing hold and the wall itself. It has custom fit indentations for the two front side coils, the button holder, and button itself. The button and the circuit button holder are inserted between the main enclosure and wall in that order. They are built tightly enough to clearly lock into place, but they are mainly secured by the pressure between the wall and the enclosure. Lastly on the back side there is a coil holder piece which holds the two rear side coils into the correct position; this piece is also mounted on the standard bolt and requires no additional mounting hardware. Not used in the final product, but a key component of its assembly, is also a custom coil winding tool, which allows for the coils to be wound much more quickly and ensures they fit correctly.

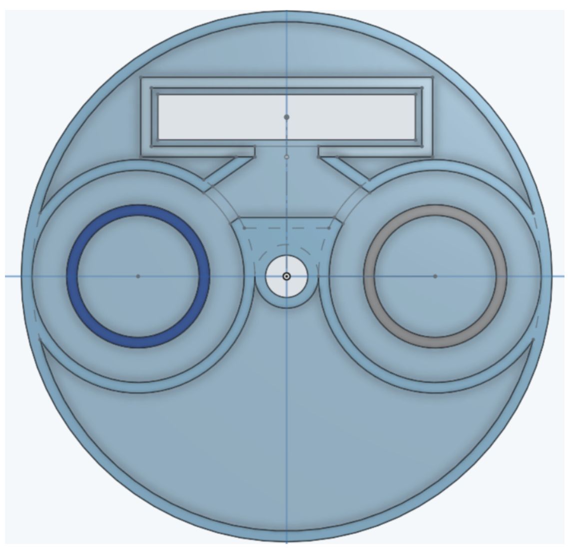

Figure 4.2.1 Main Coil Enclosure

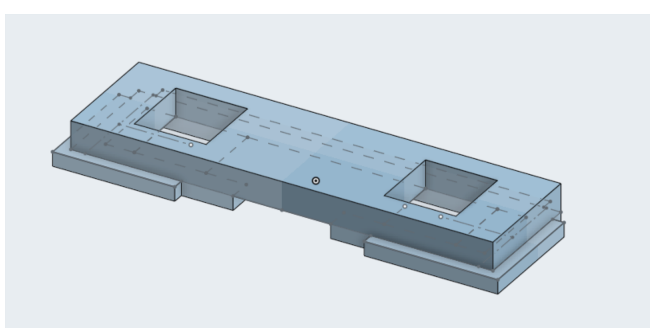

Figure 4.1.2 Button Holder

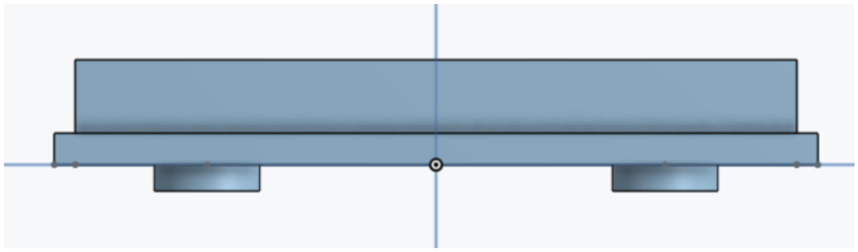

Figure 4.1.3 Button

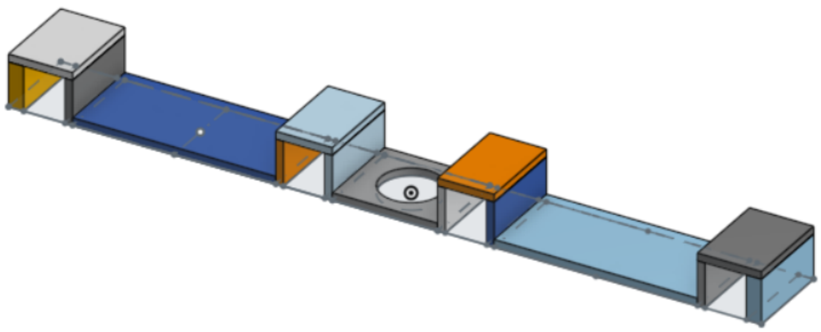

Figure 4.2.4 Coil Holder

4.2 Technical Component

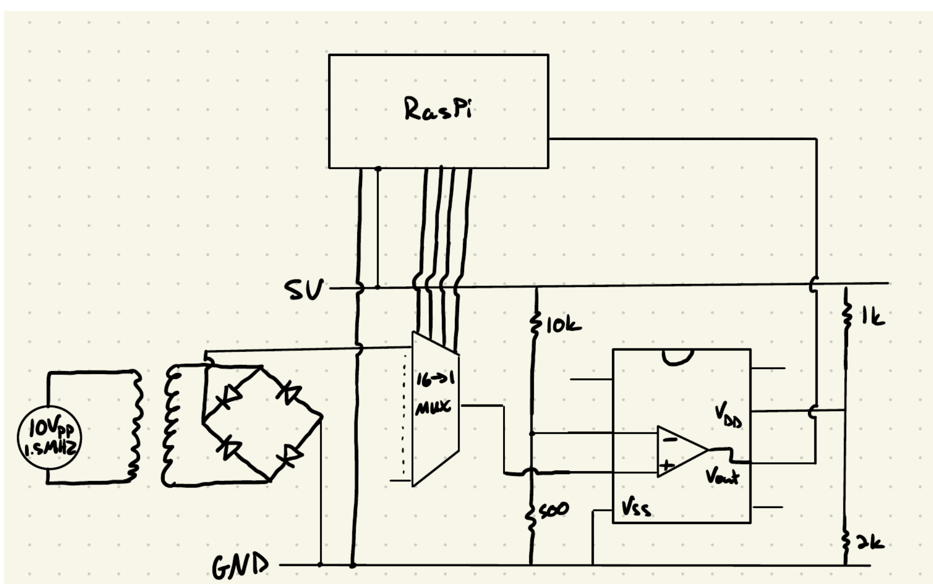

Figure 4.2 Sensor Circuit Diagram

Some circuit elements integrate into the enclosure in the following ways. Two coils and two press buttons are integrated into the front of the coil enclosure in the corresponding indents.

These allow for the signal to be passed through when the button is depressed. Two coils are also mounted on the back of the wall in their designated slots and are then connected to the Raspberry Pi and an AC power source.

The remaining hardware consists of comparators, multiplexers, full bridge rectifiers, an AC power source, a projector, and a raspberry pi. These are connected in the configuration shown in the circuit diagram, such that the AC power source powers the input coil; the AC signal from the output coil (when the frontside button is depressed) is converted to DC with the full bridge rectifier; the multiplexer (controlled by the raspberry pi) selects a signal to read at a given time; the signal is normalized to a constant 3.3V or 0V DC by the comparator; the raspberry pi reads the output of the comparator as a digital signal. At this point these signals are by the software and the resulting game is displayed on the projector.

4.3 Software Component

A major part of the software components of this project are the two games that we developed to be played on the wall. Both of the games were coded in C# on the Unity Game Engine. The first game is a pattern matching game where the computer displays a random pattern over the holds, and the user has to repeat that pattern by activating the holds in the same sequence as the computer. The second game is played by the user holding onto the wall and dodging missiles that slowly fall down overhead. Each time a user is hit, he or she loses a life, and the game ends once a user has survived for 45 seconds or has lost all three lives. The game is calibrated to work with the climbing wall by first taking in a calibration.txt file received from the calibration phase that contains a matrix used to set the location for each of the holds and then takes in a data.txt file that notifies the game which holds are currently being pressed by the user using a matrix filled with 0s and 1s. The game repeatedly checks the data.txt file to see if the activated holds have changed, and if so, the prior holds are deactivated, and the new ones are activated amidst the gameplay.

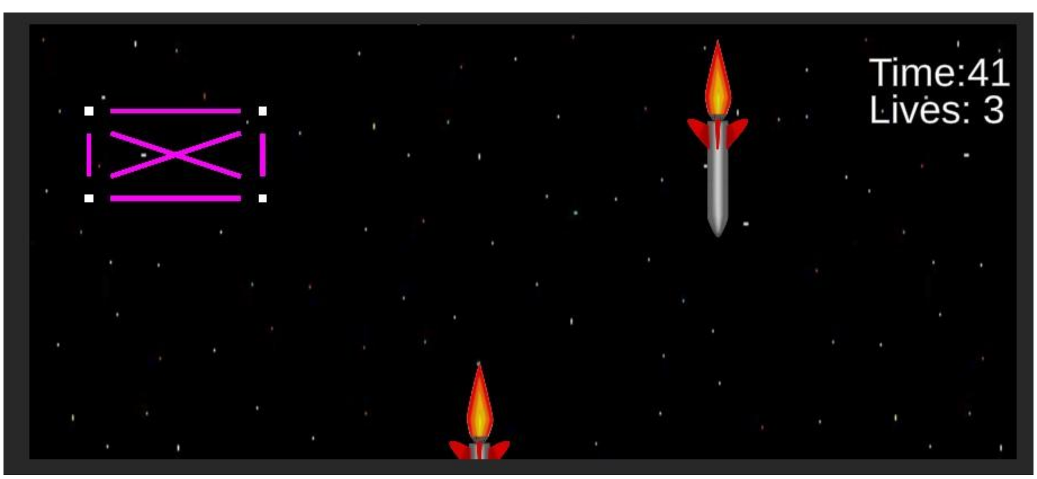

Figure 4.3.1. Missile Launch AR Wall Game

Cost Breakdown

5.1 Team Budget

The current cost breakdown for the Augmented Reality Climbing Wall will primarily consist of components from the hardware and software side of the project. For our budget, we were lucky enough to find some of the parts already available to us such as the Raspberry pi and some of the circuitry, but the other parts of the hardware will have to be purchased. In this breakdown, we will discuss the budget that we have spent for this project along with how much the project will cost for the customer.

Items	**Description**	**Cost**
1	Rides to and from Level99	$60.43
2	Lithium Ion Batteries	$47.82
3	Battery Charger / Connection Cables	$39.27
4	8 Multiplexers	$70.09
5	LC650 Projector 4K	$67.50

Table 5.1 Project Budget

Here is the breakdown of the amount we have spent so far for our project. We are expecting that in these final weeks we will make some additional hardware purchases as it was recommended to us that we should have extras of some of the components such as Raspberry Pis and things of that nature.

5.2 Customer Price

Since our primary customer will be pre-established climbing gyms, the cost of the system reflects that we will not be supplying a wall and climbing holds. However, what we will be giving to the client as our final deliverables if a climbing gym is interested in purchasing our project would be the following:

1. 100 climbing hold sensors
2. Raspberry Pi
3. Multiplexers and Circuitry
4. Projector

We assume that each climbing hold which includes the coils, enclosure with buttons, and other circuitry will cost approximately $2. A customer buying 100 sensors is if they want the full scale wall, but there are other packages depending on how many sensors the client wants. We also assume that each multiplexer will be around $8.75. The number of multiplexers needed will also depend on the number of sensors bought as each multiplexer serves 25 holds, so a full scale wall will need four multiplexers.

Item	Quantity	Cost
Climbing Sensors	100	$200
Raspberry Pi	1	$100
Multiplexers and Circuitry	4	$35
Projector	1	$80

Table 5.2 Cost Sheet

Using this cost sheet, if a client wanted 100 climbing sensors for the AR wall, it would cost them $415. We would also possibly charge $50 for the installation fee as we would need time to install the sensors and perform the initial calibration phase, which we would also teach the client how to perform, so they could change the wall as they saw fit without need to contact us.

Engineering Standings

Throughout our project, we have tried to adhere to the standards set by the IEEE (Institute of Electrical and Electronics Engineers) organization. The IEEE has created 21,000 standards and projects that span 175 countries and include 34,000 global participants. Many of the standards that we tried to follow throughout the duration of our project dealt with many topics including Computer Technology, Consumer Electronics, Batteries, Software and Systems, and the National Electric Safety Code to name a few.

Here are some of the ways we ensured that we were following the standards set out by the IEEE organization:

- Ensured power needed to send signal from sensor to microcontroller did not exceed standards set out by the National Electric Safety Code.
- When we were planning on using Lithium Batteries, we made sure that they were not volatile and could safely be inserted into the sensors.
- Checked to ensure any leaked voltage would not exceed the standards set for consumer electronics.
- All software libraries imported for the climbing wall games were from trusted and safe sources.
- Ensured that the multiplexers were used in accordance with the standards set by the manufacturer.
- Assembled circuits and voltage comparators in compliance with the specifications for this type of circuit along the safety code established.
- The game engine used to create the games played on the wall is a trusted source that has been endorsed by many respected game developers.
- The games being played contained content that was suitable for people of all ages and backgrounds to play.
- Properly checked that the enclosures to the climbing hold sensors was not dangerous and contained no pieces that could cause harm by themselves.
- Ensured that the magnetic fields produced by the coils were within the standards set by the National Electric Safety Code

Appendix

Appendix A - Specifications

Requirement	Value/Range
Hold enclosure dimensions	4in x 4in x 0.3in
Hold sensor power source	Wall powered AC function generator
Hold enclosure thickness (9V prototype)	0.75in
Hold enclosure thickness (lithium ion prototype)	0.45in
Hold enclosure thickness (AC power final product)	0.3in
Hold sensor current draw	100mA - 200mA
System use time before battery recharge	Indefinite