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Punching Bag Trainer

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Abstract

In this project, a trainer for a punching bag was designed to help a boxer improve their reaction time and recognize their punching force. These modifications for a punching bag of any size improve how a punching bag can be used. The accelerometers used for this project will be in the wristband of the boxer to keep them from breaking. The display on the punching bag wrap will express to the boxer how they are doing through a graph that displays the average punching force and the boxer's reaction time throughout their training sessions. The purpose of this project is to design modifications for a punching bag that help the user independently train themselves at boxing by measuring the force of their punches and seeing how quickly they can throw a punch.

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1. Introduction

The definition of a personal trainer is someone whose job is to help individuals become stronger and healthier by dictating which exercises should be done and demonstrating them [1]. Personal trainers were an essential part of developing legends such as Muhammad Ali, Rocky Marciano, and Mike Tyson. The amount of one-on-one time it took for trainers to cultivate those boxers' skills, however, is so high that trainers will limit themselves to one boxer when they go professional. The issue that arises in gyms is that there are not enough trainers for the number of boxers. This creates times in-between training sessions where a boxer needs to continue practicing and improving their skills. The motivation for this project came from the need for a remote method of training even when close contact with other people is not an option. As boxing continues to be an elite sport, a growing industry has emerged for punching machines that can measure punching force and improve a boxer's reaction time. This project aims to utilize those two markets and develop a product that can do both.

1.1 Objective and Deliverables

The objective of this project was to:

Design and build a wrap for a punching bag that can be used for independent training.

The deliverables for this project are the following:

- A functioning prototype
- A Finite Element Analysis of the phone mount
- A set of user instructions for the assembly and operation of the apparatus
- A report, presentation, and poster.

This project is intended to be used by those in gyms and those outside of gyms that need to practice punching independently. The team does not intend the device to be fully deployable at the end of the build. It will serve as a proof of concept of a functioning device that can provide results to the boxer. This report includes a set of requirements, a system hierarchy, a mechanical and functional block diagram, a concept of operations, and a budget. Section 2 includes a summary of the background information relevant to the project. In Section 3, what we learned during the project will be discussed.

1.2 Teamwork

The workload for this project was separated into two major areas with one group member leading each area. The electrical systems and wristbands were led by Michael Czoer and the assembly of the wrap and mount was led by Paul Shan. When help was needed in either section the other would come to provide input or assistance. However, the section leads have the choice of making any changes to their section of the project. Although there were no key issues within the team, a process was made if the two team members could not agree on something, a pro/cons list was made and whichever side had more points would be the solution.

2. Background

2.1. Statement of the Problem

During the COVID-19 shutdown, gyms and fitness centers were required to close. This resulted in many boxers being cut off from the equipment and instructors required to practice and train. This restriction caused people's mental health to decline and their physical bodies to lose muscle [2]. A lack of guided instruction can limit one’s ability to train and improve. However, by using attachments to the bag, an individual can improve their reaction time and develop a harder hitting punch. This personal training device will help those who do not have access to trainers and gym resources to develop their skills and practice.

The personal training devices that are on the market already have two focuses: to help show the force of a punch and to show the boxer where to punch. However, very few products are doing both. Name brands that do provide both can cost anywhere up to $4,000. And even with the excessive cost, their designs are so bulky and heavy that transporting them is a huge hassle. This project will focus on developing a system that is affordable and compact for easy transportation/storage.

2.2. Similar Projects

2.2.1 Combat Strike Force Tracker

In Figure 1, the Combat Strike Force Tracker developed by UFC is shown.

Figure 1: UFC Force Tracker [3]

The UFC Force Tracker is a non-wearable wireless design and hands-free device that allows the user to measure the force of their punches, kicks, and overall speed. The way it works is that the tracker is either placed on the bottom of a hanging punching bag or on the top of a standing punching bag. When the user hits the bag whether it is a punch or a kick, the tracker sends the data to the user’s cellphone via Bluetooth and then displays the results to the user by using the app on the cellphone. It is like our project because it involves the use of a phone and Bluetooth to gather data on the punches, but there are some differences as well. In our project, instead of having a data tracker on the punching bag, the data tracking is calculated by the accelerometer that is attached to the wristband of the user.

2.2.2 Stairmaster Boxmaster Tower

In Figure 2, The Stairmaster Boxmaster Tower developed by Stairmaster is shown.

Figure 2: Stairmaster Boxmaster Tower [4]

The Stairmaster Boxmaster is a device that allows the user to punch in various locations. It is like our project because it prompts the user to punch at certain locations, but there are many differences. The Stairmaster Boxmaster Tower weighs 225 pounds and it must be bolted to the ground to keep it stable. That means that this device is not mobile and can only stay in one location. Also, it is priced at $4,099.00, which is expensive for most people. Our project serves the same purposes as the Stairmaster Boxmaster Tower, but it is much easier for transportation because it is lightweight and does not require to be bolted to the ground.

2.2.3 Happy Buy Boxing Speed Trainer

Figure 3: Happy Buy Boxing Speed Trainer [5]

The Happy Buy Boxing Speed Trainer, as seen in Figure 3, is a machine that contains a bar and two small punching bags. When the bar is punched or hit in some way, it continuously rotates 360 degrees until it slows down. It is supposed to help with one's coordination and reaction time. The small punching bag in the middle is used for locating a regular punch whereas the punching bag to the right is used for uppercuts and hooks. This is like our project because its purpose is to help with the user's timing and location of their punches. The difference between this machine and our project is that our project can display the actual measurement of one's punch.

2.3 Applicable Standards

From the literature review, the team found applicable features that could be implemented in their project. These features include light-up punching pads, accelerometer usage, and having an HMI (Human Machine Interface) attached to the punching bag to display the results of the boxer's punches. The accelerometer, as it was used in the UFC tracker, will be implemented for measuring the acceleration of a punch rather than trying to implement a sensor into the padding. From the first and third designs discussed it became apparent that attaching the product to an existing punching bag was preferred as you can take it with you and switch it from bag to bag.

2.3.1 DFEC (Design of Fitness Equipment Criteria)

The ADA (The Americans with Disabilities Act) ensures that there are equal opportunities for those who have disabilities. In 2012, The DOJ (Department of Justice) mandated that accessible fitness equipment must be provided to meet the needs of people with disabilities in public fitness centers [7]. Our project aims to meet this requirement by making sure that even a person with disabilities can utilize it.

2.4 Factors That Impact Design

2.4.1 Public Health, Safety, and Welfare

Safety precautions were highly considered when developing this project. Given that people will be applying force against the design, we had to make sure that the material of the outer layer of the wrap could be able to withstand the force of the punch to reduce the risk of injury during use. Along with this, we have the wiring going through the inner lining of the wrap, that way there are no exposed wires. There is an expected range of force of a punch, but it relies on the weight of the boxer. There was research done by seventy boxers that claimed that an average force of a punch is 776 psi, and the range is from 447 psi to 1066 psi depending on how heavy the boxer is [8].

2.4.2 Global & Economic

We want to make sure that this design can be affordable such that anybody that wants to work on their punching can acquire it. The electronics in this design such as the TRACFONE, transmitter board, and accelerometer must be bought and professionally engineered. However, the wrap and wristbands can be altered or modified to meet the needs of the user. If this product was to be used in another country, the conversion to the metric system may be needed. The material costs may change depending on shipping costs and availability of products.

2.4.3 Ethical & Professional

According to the NSPE (National Society of Professional Engineers) in their Rules of Practice, engineers shall hold paramount the safety, health, and welfare of the public, shall perform services only in the areas of their competence, shall issue public statements only in an objective and truthful manner, shall act for each employer or client as faithful agents or trustees and shall avoid deceptive acts [6]. It is important that this design does not interfere with any of the rules stated. One of the factors that could impact the design is the rule that states that engineers shall perform only services in the areas of their competence. One of the members of the group is a Manufacturing Engineering Technology major and was involved in the design of the mechanical aspects of the design. They had some knowledge of mechanical engineering before the whole design process but learned more about it as the process went on.

2.5 Requirements

1. The wrap must weigh no more than 30 pounds
2. The software must register the acceleration of a punch up to 8g
3. The system in storage must fit into a space of 4.5-foot x 1 foot x 1 foot
4. The system must be able to run for 15 continuous minutes

3. Concept Selection

3.1 Design Concept 1: Light and Sensor Implemented Inside a Punching Bag

How it works

The first design consists of force sensors, lights, and wiring being implemented inside the punching bag. This design can be seen below in Figure 4. The concept starts with taking the punching bag apart and then carefully implementing the components inside. Then, after implementing all the components, we would have to connect wiring to all the components that will then be connected to a display outside of the punching bag sitting on a tripod.

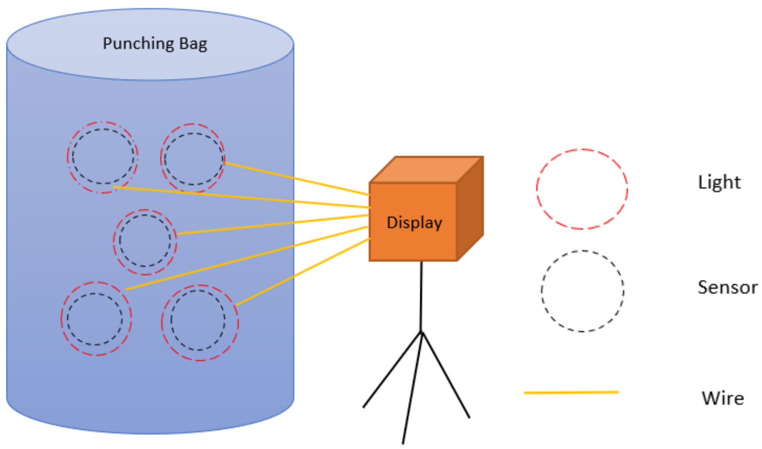

Figure 4: Concept #1 Design

Pros and Cons

In Table 1, the pros and cons of this concept are shown. The advantage of this design is that it would keep all the components safe from being damaged since they are protected by the outer shell of the punching bag. However, there are multiple disadvantages to this design. To make this design happen, we would have to completely take the punching bag apart which would cause more problems for us. The problem is that it will not be aesthetically pleasing when it is finished, it could take more time, and given that there will be some circuitry inside the punching bag, the bag is at risk of catching fire, but it is a small risk.

Table 1: Pros and Cons of Design Concept 1

Pros	Cons
Compact Design as all the components fit in the wrap	Punching bags would have to be torn into to get components inside.
Could be stored in small spaces	Repairing components inside punching bag would be difficult

3.2 Design Concept 2: Lights/Sensors Placed Around a Punching Bag and using Python

How it works

In this design, all the components are placed on the exterior of a punching bag, as opposed to the inside of the bag, and connected to a display. This design can be seen below in Figure 5. The lights and sensors would also be connected to a Python library that would perform all the calculations of the forces acting on the sensors. The display would be sitting on a tripod just like it is in design concept 1.

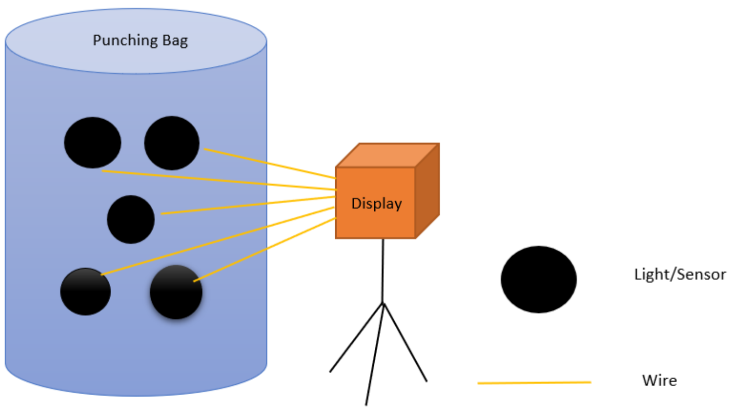

Figure 5: Concept #2 Design

Pros/Cons

In Table 2, the pros and cons of this concept are shown. The advantage of this design is that the sensors could receive a more accurate measurement of the forces acting on them because there is material covering the sensors like they are in concept 1. However, there are many things that could go wrong with this design. The lights and sensors could be easily damaged because they are dealing with the direct force of the punch. Leaving these components to be required to withstand the force of the punches. Also, it would not be easy for the user to remove the apparatus from because they would have to disconnect each component individually before moving the apparatus.

Table 2: Pros and Cons of Design Concept 2

Pros	Cons
Compact Design since all the components are attached to the wrap	Could record random swaying of the bag as a punch
Can easily repair sensor/LEDs if damaged	Requires a damping force of the punching bag to be found

3.3 Design Concept 3: Fabric Wrapped Around Punching Bag Containing All Components.

How it works

In this design, all the components will be implemented on a big piece of fabric that will then be attached to the punching bag using cinch straps and Velcro. connected to a display. This design can be seen below in Figure 5. The user wears a wristband with an accelerometer, battery, and Bluetooth transmitter. The accelerometer measures the force of the punch, the Bluetooth transmitter sends data from the accelerometer to the display, and the battery supplies power to both the accelerometer and Bluetooth transmitter. The lights will be covered with vinyl material for protection and provide a soft surface for the user to punch without harming themselves.

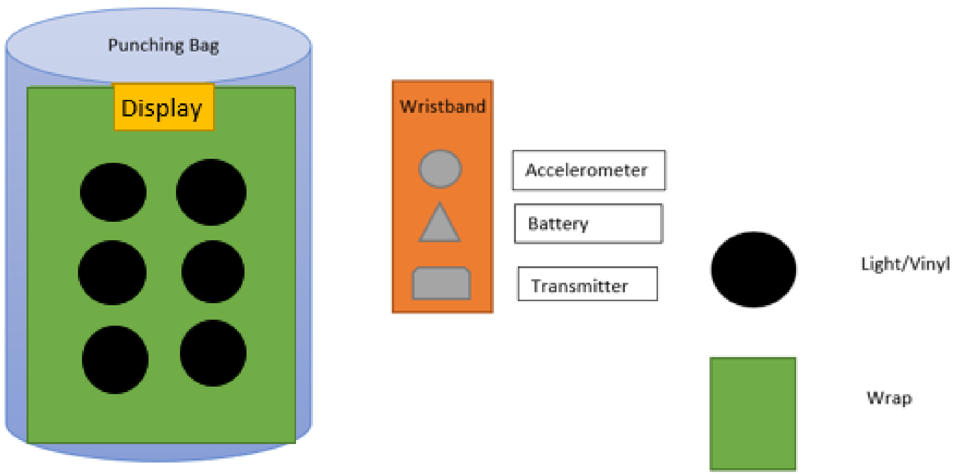

Figure 6: Concept #3 Design

Pros/Cons

In Table 3, the pros and cons of this concept are shown. The advantage of this design is that it can be easily applicable to the punching bag, it gives the components some protection, and the display is a location where the user can easily see the results of the punches. The only disadvantage is that it heavily relies on Bluetooth to connect the separate devices. If the team is unable to figure this step out in time, the whole project would fail.

Table 3: Pros and Cons of Design Concept 3

Pros	Cons
Wireless Sensors	Bluetooth can be difficult to program
Slimmer wrap	More microcontrollers required
Sensors and LEDs can be easily replaced	

3.4 Design Chosen & Justification

Using the Analytic Hierarchy Process, in Figure 7, the team broke down the key points that we wanted our project to focus on. Those points being simple application, a compact design, and easy transportation. With these points, we realized that Design Concepts #1 and #2 only met one point each, whereas Design Concept #3 met all three.

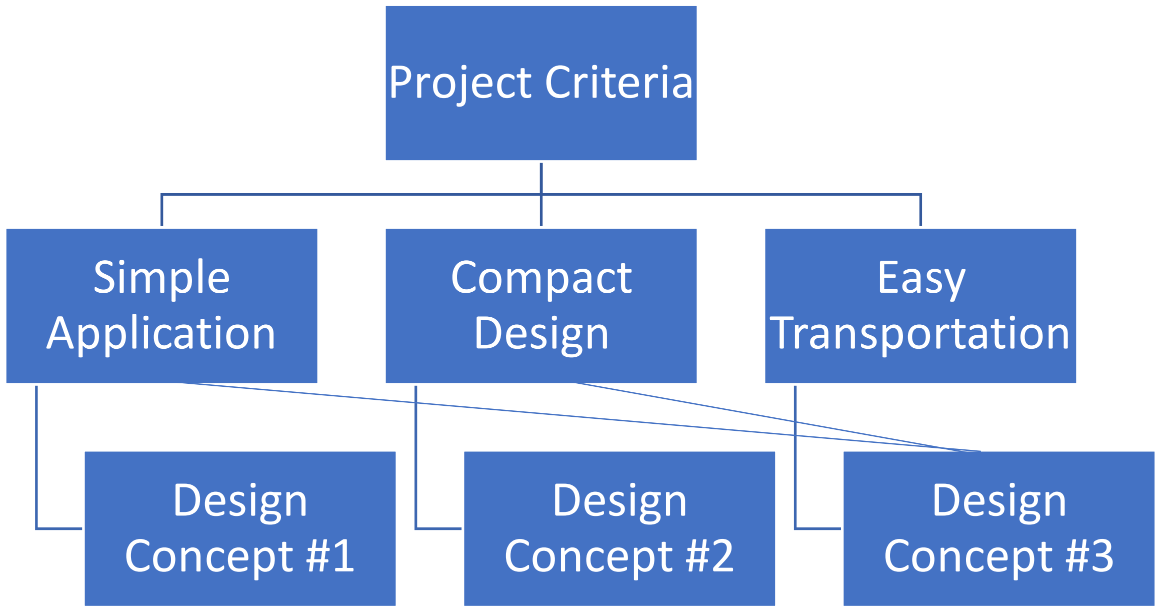

Figure 7: Analytic Hierarchy Process

The team chose to perform further engineering analysis on Design Concept 3. This was chosen because of the simple application of the components; compact design of the wrap/wristbands and its small size makes it ideal for easy transportation. Also, out of all the design concepts, the group felt like it could be easily developed before April 28th, which is the due date.

4. Final Design and Analysis

4.1 Overview of Operations

Assembly Instructions

Step 1) Position the wrap around a punching bag, with the strike points facing the user.

Step 2) Use the Velcro straps on the back of the wrap to secure it to the punching bag.

Step 3) Attach the display mount to the top of the wrap and slide the phone into the mount.

Step 4) Secure the wristbands on to the boxers' wrists and put on standard boxing gloves.

Step 5) Follow the Concept of Operations to see how to start the system.

Concept of Operations

Step 1) Turn on the wristbands, cell phone and the wrap

Step 2) Connect the cellphone to the three microcontrollers

Step 3) Initiate program on the cell phone

Step 4) Begin punching the strike points as they light up

Step 5) Observe results of punch of cell phone

4.2 Description of Final Design

This design consists of two main sections: a wrap that attaches to the punching bag and a pair of wristbands. This wrap will have six strike points that will act at punching positions for the boxer. It will also have a phone mount on the top of the wrap, in black, as seen below in Figure 8.

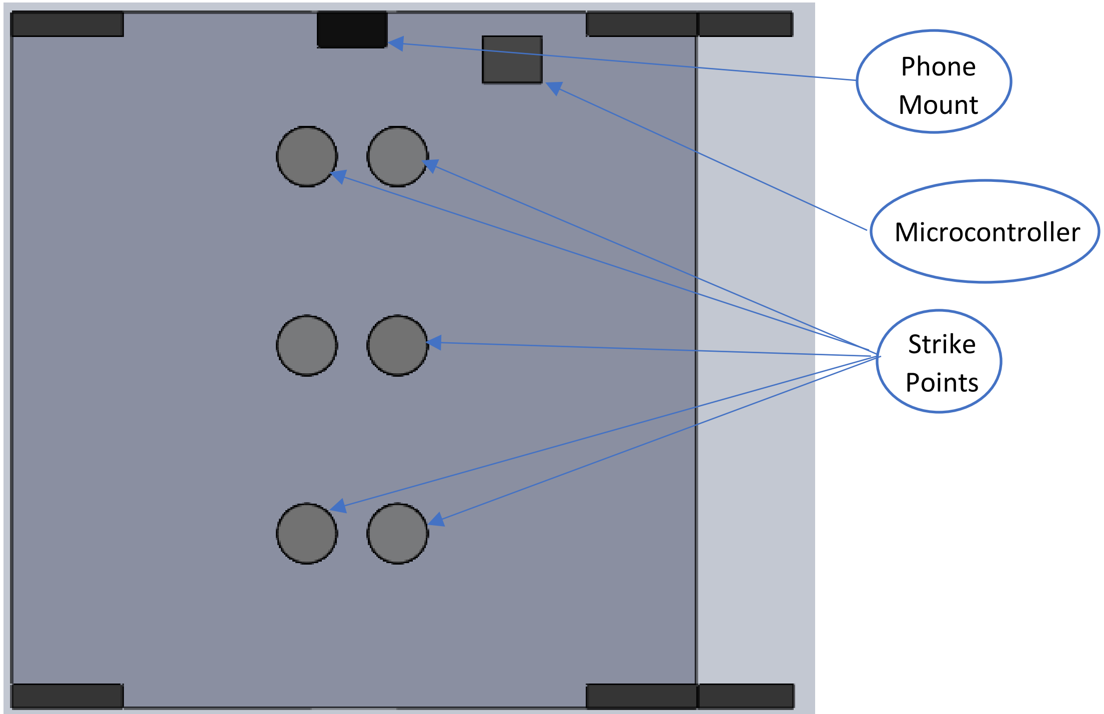

Figure 8: Wrap Diagram

The two wristbands will be worn by the boxer during training, as seen in Figure 9. These wristbands will have accelerometers on them along with a microcontroller to send the data to the display (cell phone). With the accelerometers being in the wristbands of the user, the vectoral acceleration of each punch can be measured directly from the boxer's hands. The data from both the left and right wristbands would then be sent to the cell phone using Bluetooth from a transmitter that is within the microcontroller.

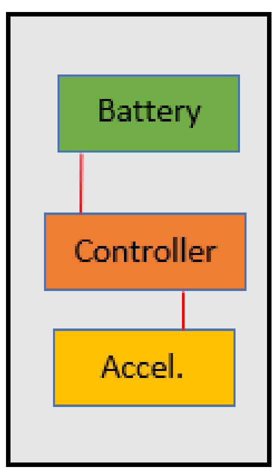

Figure 9: Wristband Diagram

With the major difficulty of design concept 3 being Bluetooth programming, the team believes that this design would be the easiest to build upon and implement. With this design in mind, an equation was needed to be able to calculate the force exerted on the punching bag. This equation and the development calculations are available in the appendix of this report under "Calculations". There will continue to be six lights positioned as stated previously. The positioning of the strike points was selected based on the normal striking angles of a boxer, when delivering punches such as a straight or jab. These lights are an important part of the project as they will help to improve the boxer's reaction time and perfect the accuracy of primary punching locations. The order of the lights turning on will be randomized to recreate the randomness of a trainer or opponent in a match.

The mount for the cell phone will be made using filament and a 3-D printer. This mount will sit on the lip of the wrap and will allow the phone to slide in and out as needed. The Android-based cell phone that will be in the mount will be communicating wirelessly, using Bluetooth, with the wristbands and the strike point controllers. It will be able to gather data and present said data on the screen of the phone. Each wristband will be powered using a 3.7 V battery that was recommended with the purchase of the nRF52840 boards. This battery will be able to supply the required voltage to both the LIS3DH accelerometer and the nRF52840 transmitter boards. Having the accelerometer and nRF52840 boards on the wristbands, we are expecting the boxer to be able to position these wristbands under their hand wraps. This expectation on the user's end is intended to limit any effect that the wristbands might have on the boxer's mobility.

4.3 System Overview

4.3.1 System Hierarchy

In Figure 10, the system hierarchy for this project can be seen. In this hierarchy, the project was split into two main sections. The first section is the wrap and all the physical components required to assemble it. The second section is all the electrical components used in the project. This includes components required for the wristbands and the wrap.

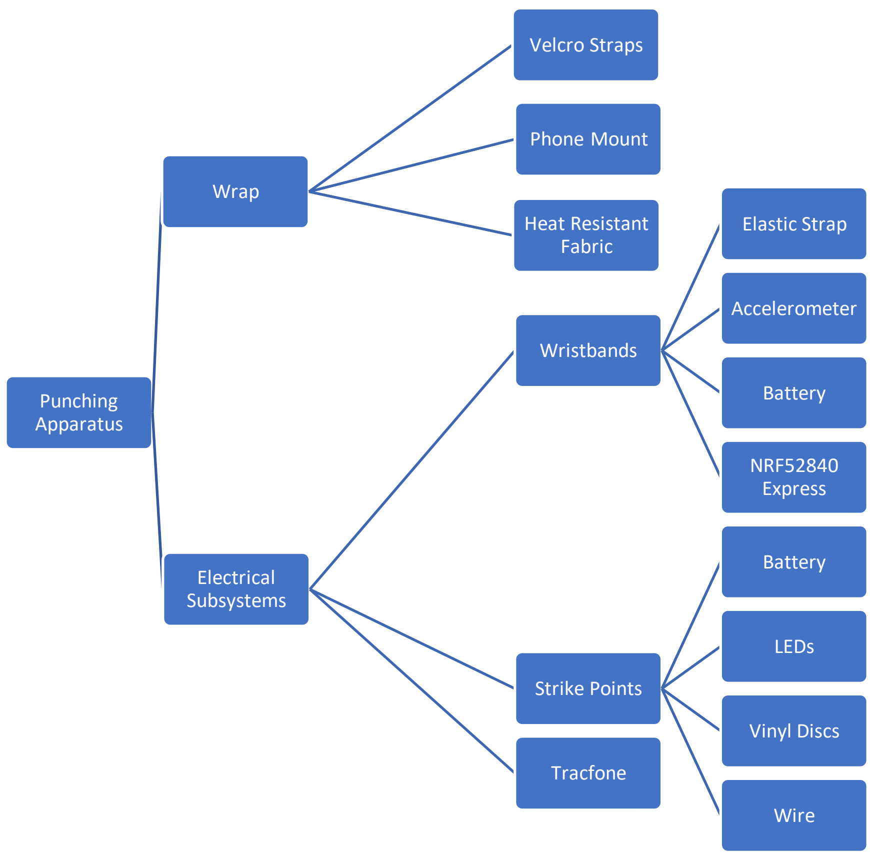

Figure 10: System Hierarchy

The sequence chart in Figure 11 shows how the components in the system work together. It begins when the user starts the program with the TRACFONE and once it is turned on, one of the six LEDs will light up along with the activation of the reaction timer. As the user is punching toward the strike point, the accelerometer will detect the acceleration and that value will be used to calculate the force by the controller. After that, all the data is sent to the TRACFONE where it will display the measurements of the force of the punch in Newtons and reaction time in seconds. Then, the program will continue looping until the user ends the program by turning off the TRACFONE.

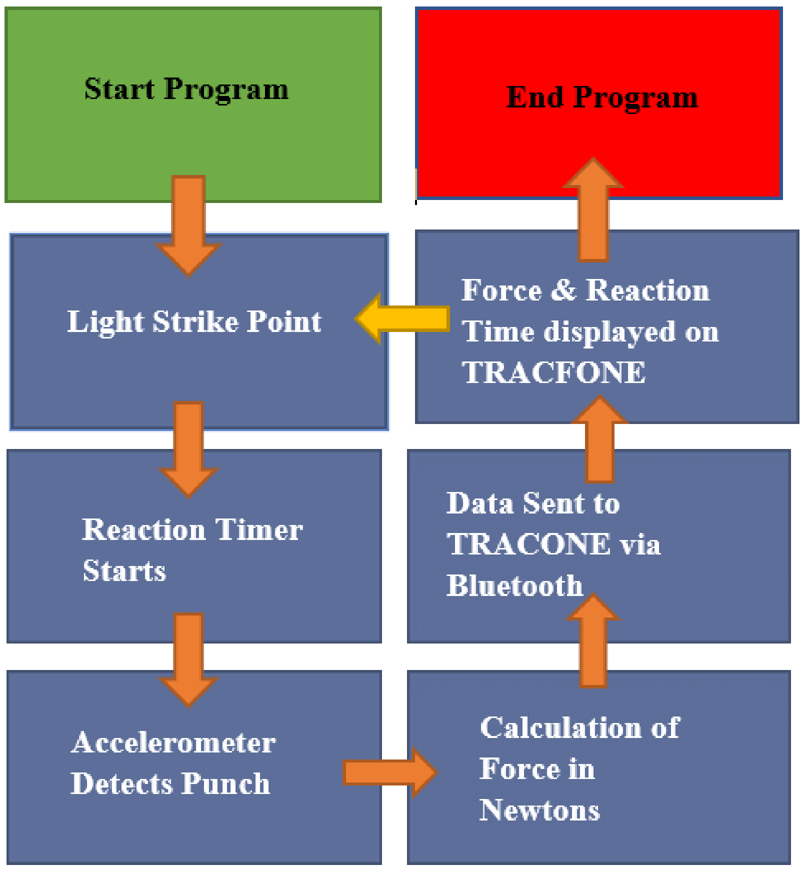

Figure 11: Sequence Chart

4.4 Mount for TRACFONE

To attach the TRACFONE to the wrap, a 3D printed mount was designed. The gap near the back of the mount is where the wrap will be placed. A finite element analysis was done with the use of SolidWorks Simulation to see where the stress, displacement, and strain were taking place. All 3 tests are shown in the Appendix. Figure 12 shows the initial design of the mount, but changes were made after the FEA of the initial design. To reduce stress and strain, the edge on the top of the mount and near the back was filleted because stress tends to occur at the edges. Before making this change to the mount, the maximum amount of stress on the mount was 77,264 Pascals and the maximum amount of stress was 0.836 Joules per meters cubed. After the fillet was applied to the mount, the maximum amount of stress reduced to 32,366 Pascals and the strain was reduced to 0.101 Joules per meters cubed. Then, to minimize the displacement, the length of the gap where the wrap will be inserted was shortened. Figure 13 shows the final design of the mount.

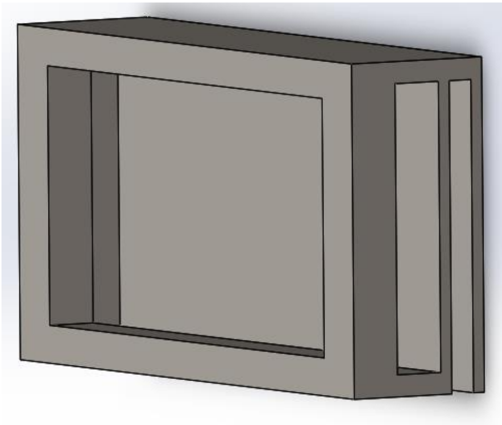

Figure 12: Initial Design of the Mount

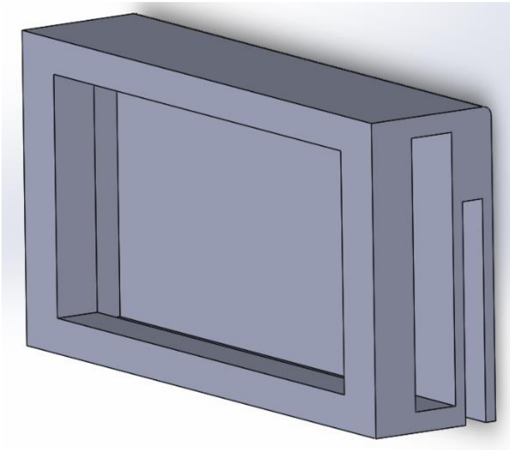

Figure 13: Final Design of the Mount

After conducting FEA's on both designs, a stress-strain graph was made to show the difference in stiffness between the two designs. The stress-strain graph can be seen in Figure 14. The blue line represents the initial design, and the orange line represents the final design. Each line has its linear equation next to it. The slope in the linear equation represents Young's Modulus which is its stiffness. You can see that the slope of the final design's line is much larger than the initial's which means that after making the changes to the initial design, it became stiffer and more structurally sound.

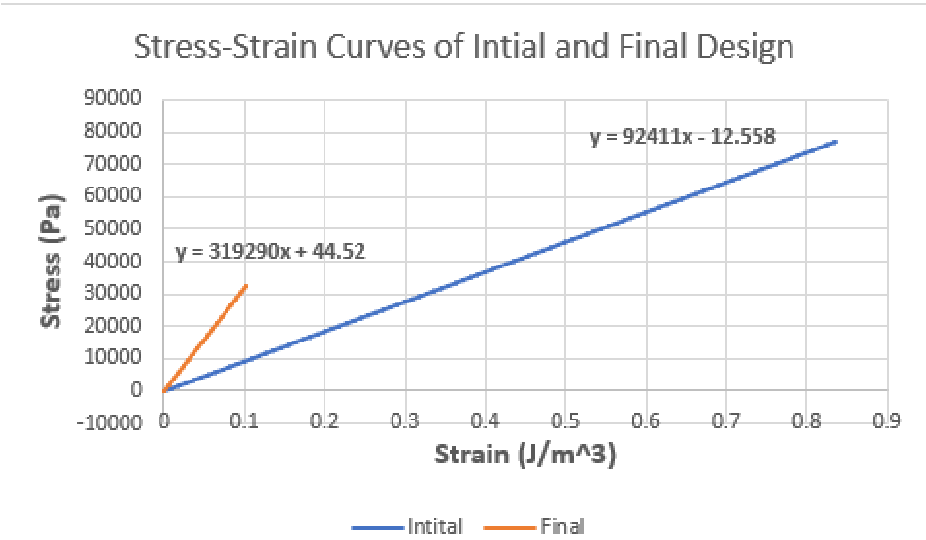

Figure 14: Stress-Strain Curves of Initial and Final Design

4.5 Assembly of the Wrap

The first step of assembling the wrap was to fold the fabric to meet the dimensional specs of a standard 100-pound punching bag. After sewing the folded edges of the wrap to itself, the cinch straps were then attached to the wrap at the four corners. This would allow the wrap to be fastened to the punching bag or even to a larger punching bag if needed. When the cinch straps are secured, the next step is to connect the circular discs of clear vinyl. For this prototype we used 6-inch diameter discs cut from the vinyl that was purchased. We chose to use super glue to attach the vinyl to the wrap, making sure that they were evenly spaced in two columns and three rows. Using the same adhesive, the Styrofoam could be attached around the edge of the vinyl. The step for the wrap at this point is to poke holes about an inch above each disc large enough for an LED diode to fit through, so that later in development the electrical system can be wired up.

4.6 Assembly of the Wristbands

The first step for assembling the wristbands was to create the bands themselves. Using the elastic material, a band was created that was able to fit the team members wrists. These two bands were then sewn to create the loop for the user's wrists. The next step was to determine the type of connection that was needed for the accelerometer and the microcontroller to communicate. For this prototype, the team chose to use I2C communication. This type of communication is also referred to as two-wire communication. When using I2C communication only four wire connections are needed between the accelerometer and the microcontroller: Power (Vin), Ground (GND), Serial Clock (SCL), and Serial Data (SDA). After these two boards are soldered together, they are then connected to the elastic wristbands by sewing the boards using the four holes on each board. For this prototype, the batteries were not connected to the wristbands. This was to allow for easier access to the system for testing and safer storage.

4.7 Development of the Source Code

When the source code was being developed for this project, many stages occurred. Initially, the code was being developed on a program called "CrossWorks Studio". It was believed that this program would be able to code the nrf52840 microcontroller, however, that was wrong. This program was unable to communicate with the board, so some research was required. The next program I tried was one called "IAR for ARM". This program at first worked fine until the accelerometer code was being worked on. This program was not set up for I2C communication with another device. So, the team then began using a program called "Arduino". This program allowed the team to continue using the C++ programming language and provided us with multiple libraries to reference. With this program, the strike-point code was easily developed. This code randomly generates a number between one and six. The associated strike-point LED would turn on for one second and turn off.

The next source code was for the wristbands which turned out to be the hardest. This required multiple libraries to be downloaded to allow for the LIS3DH functions to be used along with the Serial Print functions to work. After a lot of tinkering, the code was able to read in x, y, z accelerations from the accelerometer. That data was then able to be compiled into a vectoral acceleration using the Pythagorean Theorem. With this value, a threshold was set up that would allow the code to only save data points above 20 m/s^2. This threshold value was selected after doing an initial run of the code with no threshold and reading the graph. This value was selected as it was above the acceleration of an idle boxer, but not too high to where soft blows were missed. With this threshold the data above that point could be examined to determine the peak data points. Those peaks were then used to calculate the force of the punch. The software for both systems is available in the Appendix in Figures 24 through 26.

4.8 User Instructions

One of the deliverables for this design was a set of user instructions. The first step is to attach the wrap to the punching bag by using the Velcro straps that are on the sides located at the top and bottom of the wrap. The second step is to place the mount on the wrap by inserting the clip of the mount between the punching bag and the wrap. After that, you can place the TRACFONE inside the mount and make sure the battery charger port of the TRACFONE is facing the open end of the mount slit where you insert it. Also, make sure the TRACFONE has its Bluetooth on for the controller to connect with it. Step three is to connect the ion battery to the controller that is located near the top of the wrap. For step four put on the wristbands and turn the program on through the TRACFONE. After completing these steps, the system would be properly operating for the user.

5. Final Prototype Testing Results

There were a few tests done on the design. The tests include the sample run of the strike-points, finite element analysis of the mount (stress, strain, and displacement), and the running of the wristbands. After creating the code on Arduino, the controller containing the software was attached to all the LEDs. The lithium-ion battery was then connected to the controller to see if the controller would function properly. This was confirmed by the LEDs turning on in random order for a second timeframe. After testing this, we concluded that the LED system worked properly.

Even though a finite element analysis was done on the mount using SolidWorks Simulation, we went ahead and tested the strength of the mount by placing the TRACFONE inside the mount to see if the mount could withstand the weight of the TRACFONE. The analyses of stress, strain, and displacement ended up being accurate after the testing. The finite element analyses are in the Appendix.

The wristbands were composed of elastic fabric, controllers, batteries, and accelerometers. After both were assembled, we tested them by putting the wristbands on and punching a pillow. The use of a pillow was required as the accelerometer needed to be plugged in to the computer so we could see the data coming through the controller. We did this test because it is important that the accelerometer can calculate the acceleration of the punches accurately. We had also planned to develop a wireless transmission between the wristbands/wrap and the TRACFONE. Unfortunately, we were unable to utilize the phone which means we could not test the controller's ability to transmit the data, but we were able to see if the accelerometer could measure the acceleration of the punches and it ended up working correctly.

6. Disposal Plan

When this project is done, the prototype of the wrap and wristbands will be given to the client, Dr. Tennant. With this in mind, another senior design group could pick up the project from where we left off.

7. Budget

The budget for the components purchased for this project is attached in the Appendix. Some minor materials were left out of the Budget table, as the actual cost of these components was negligible. Those materials consisted of the cylindrical Styrofoam used on the strike-points and the adhesive used to attach the strike-points to the wrap. Although these costs were not explicitly mentioned, the total cost was raised slightly to account for these materials.

8. Lessons Learned

The lessons we learned throughout the process are to order your components as soon as possible, do not procrastinate, and make sure you are always communicating with your partners. We also learned how to program with Bluetooth, and how to implement programming methods to make code simpler to understand while also being more efficient.

9. Future Work

If this project were to progress further, a few changes to the design and component selection would be made. First, the fabric used for the wrap would be changed to a material that has less elasticity. The fabric we used provided a lot of 'give' when the Velcro was tightened, resulting in a loose connection between the wrap and the punching bag. For the wristbands, we would recommend utilizing technology that is already available on the market, such as MetaWear sensors. This type of device can gather and transmit data in a more compact form than we were able to do. The last suggestion for future use would be to change the design of the mount. The mount that was 3-D printed was merely a vessel to hold the phone, its shape and sizing is not efficient or ergonomic.

10. Conclusion

The objective of this project is to design and build a wrap for a punching bag that can be used for independent punching practice. After the assembly of the design, all the components were tested to ensure that the design worked properly. We made sure the electrical components were working properly together, made sure that the mount containing the TRACFONE was structurally sound, and made sure that the strike point code accurately calculated the force of the punches. With this design, people can now get more use out of a punching bag because of the measurement of the punches and the measurement of their reaction time. There are other designs out there that are like this, but they are expensive and are difficult to transport to other places. The deliverables for this project are the following: a functioning prototype, a set of user instructions for the assembly and operation of the apparatus, a report, presentation, and poster. The next step is to use newfound knowledge to utilize programs such as Python to achieve the requirements.

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Appendix:

Budget

Table 4: Budget

	Item	Source	Unit Cost	Units	Total Cost
1	Green LED diodes	Digikey.com	$0.41	10	$4.10
2	Vinyl Discs	Amazon.com	$8.99	1	$8.99
3	Red and Black Wire	Amazon.com	$6.07	3	$18.21
4	LIS3DH Accelerometer	Adafruit.com	$4.95	2	$9.90
5	Black Knit Heavy Stretch Elastic 1.5 in.	Amazon.com	$9.99	1	$9.99
6	TRACFONE	Bestbuy.com	$39.99	1	$39.99
7	Lithium-Ion Battery	Adafruit.com	$7.95	3	$23.85
8	Display Mount	3-D Printed In-House	$~	1	$~
9	Cinch Straps	Amazon.com	$12.89	1	$12.89
10	Thermal Resist Silver Heat Resistant Fabric	Amazon.com	$17.49	1	$17.49
11	Feather nRF52840 Express	Adafruit.com	$24.95	3	$74.85
				Total:	$225.26

Weight Table

Table 5: Weight Table

	Item	Unit Weight (oz)	Units Used	Total Weights (oz)
1	LED diodes	Negligible	6	Negligible
2	Vinyl	11.5	0.7	8
3	Red and Black Wire	1.06	~3	3
4	Accelerometer	0.5	2	1
5	Black Knit Heavy Stretch Elastic 1.5 in.	8.4	~0.4	~3.4
6	Battery	0.37	3	1.11
7	Tracfone	6.03	1	6.03
8	Velcro Straps	10.56	~0.5	5.3
9	Thermal Resist Silver Heat Resistant Fabric	6	~1	6
10	Tracfone Mount	~	1	~
			Total:	**33.84**

Two Failure Modes and Effects Analyses

Table 6: FMEA for Design/Build

Item	Failure Mode	Cause of Failure	Possible Effects	Level	Action to reduce failure rate or effects
Shipping	Broken Parts	Improper transportation procedure	Invest in new parts	High	Purchase back-up materials
Defective Materials	Components not working as expected	Manufacturing fault	System failure	High	Replace components with back-up materials
No Bluetooth Signal	Improper programming	Insufficient knowledge	Product rendered unusable	Medium	Research Bluetooth connection between raspberry pi's

Table 7: FMEA for End User

Item	Failure Mode	Cause of Failure	Possible Effects	Level	Action to reduce failure rate or effects
Broken Components	Stress	Fatigue	System Failure	High	Carry back-up material
Broken Wiring	Poor soldering	Punch	Product rendered unusable	Medium	Do not punch non-punching pad areas
Transportation/ Storage	Broken parts	Bad transportation technique	Invest in new parts	High	Transport/store product in bag
No Data on Display	User error	Wristbands inactive	Product rendered unusable	Low	Follow operating procedure

Mechanical Block Diagram

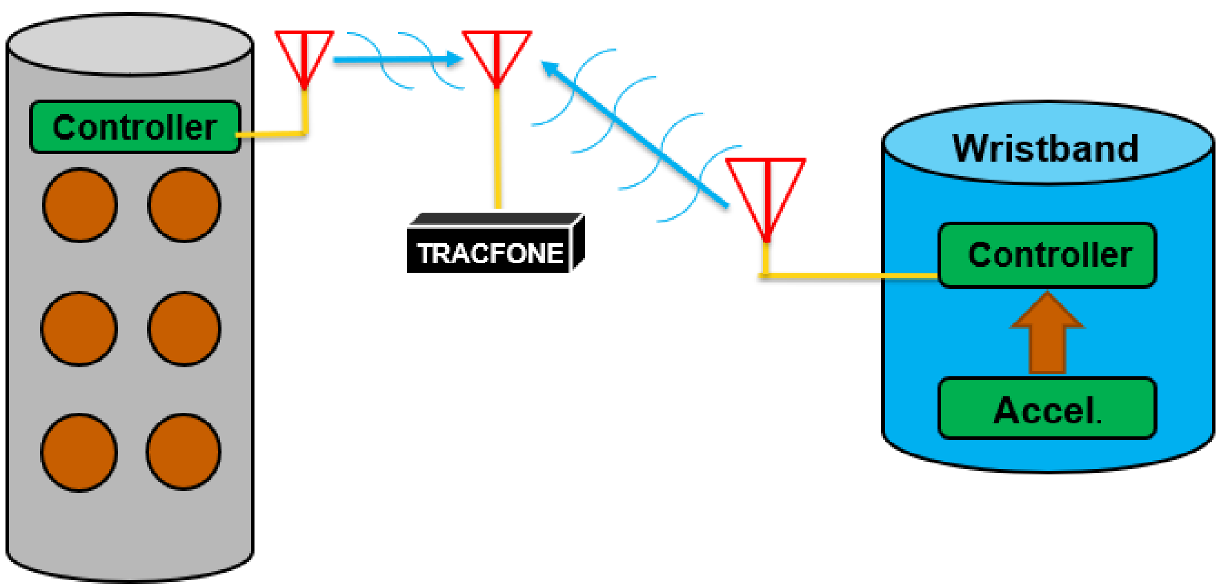

Figure 15: Mechanical Block Diagram

Calculations

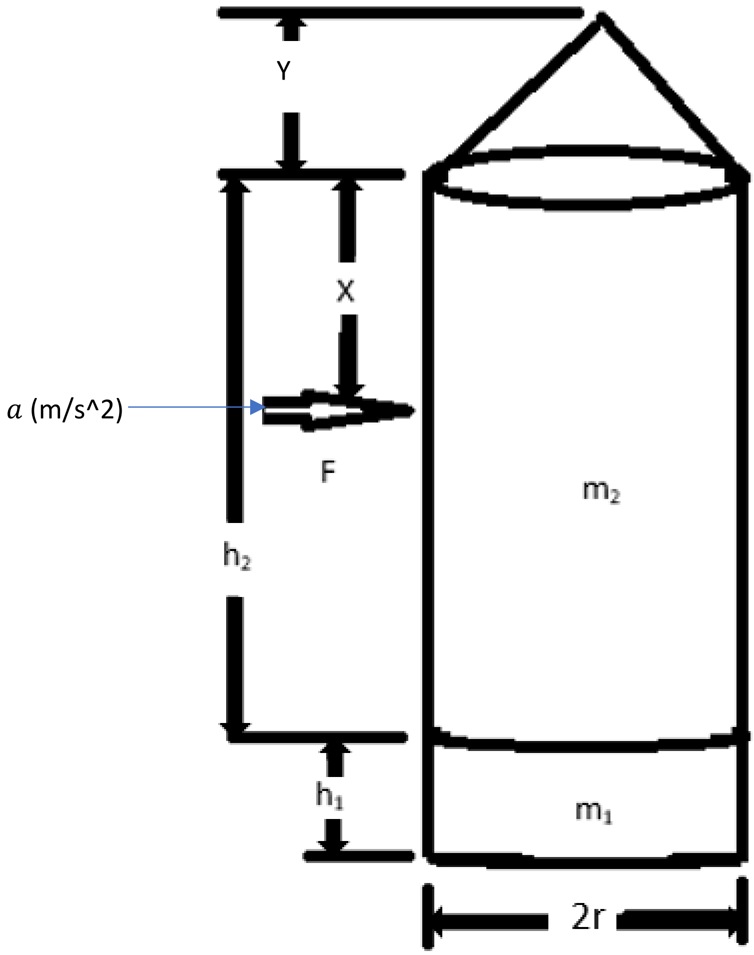

Figure 16: Diagram Used for Calculations

$$I_{tot} = I_{m_1} + I_{m_2} = \left[\left(\frac{m_1}{12}\right)(3r^2 + {h_1}^2) + m_1\left(y + h_2 + \frac{h_1}{2}\right)\right] + \left[\left(\frac{m_2}{12}\right)(3r^2 + {h_2}^2) + m_2\left(y + \frac{h_2}{2}\right)\right]$$

$$Fx = I_{tot}\frac{a}{x} \rightarrow \boxed{F = \frac{I_{tot}}{x^2} * a}$$

Figure 17: Equations Used for Calculations

FEA (Finite Element Analysis) of Mount

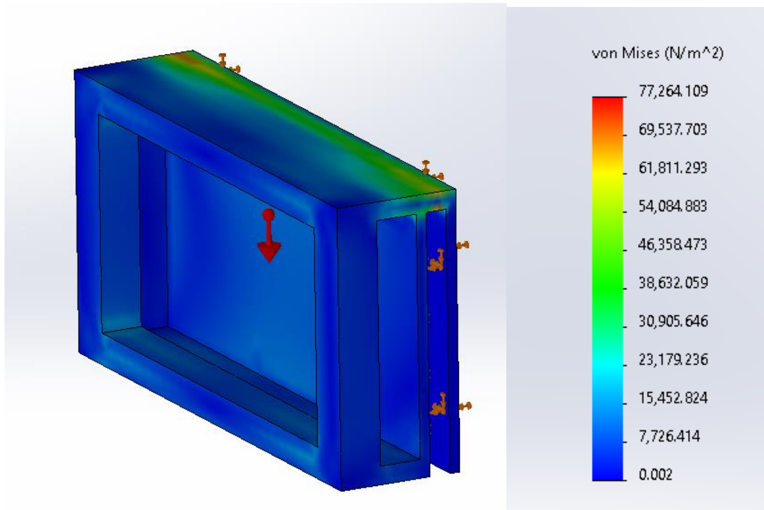

Figure 18: Stress Analysis of the Initial Design

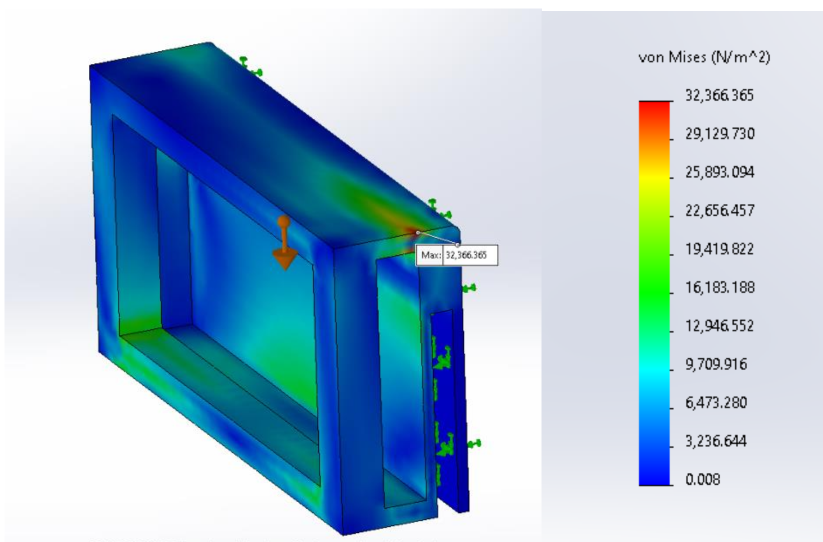

Figure 19: Stress Analysis of the Final Design

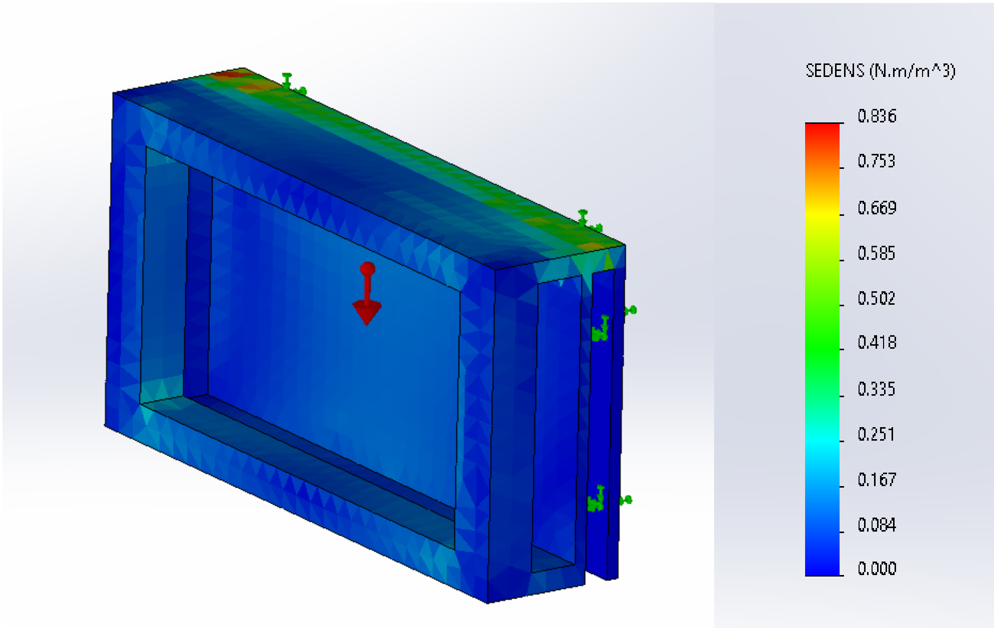

Figure 20: Strain Analysis of the Initial Design

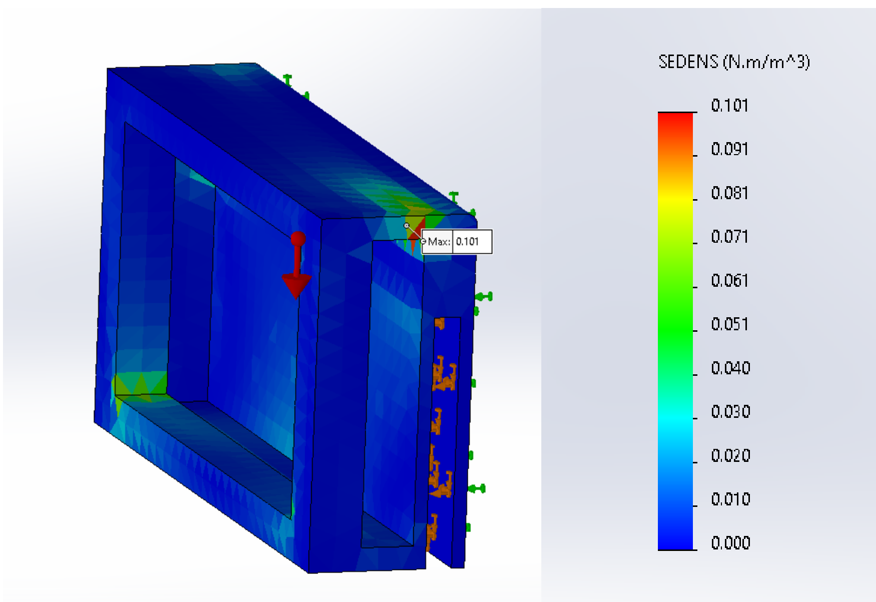

Figure 21: Strain Analysis of the Final Design

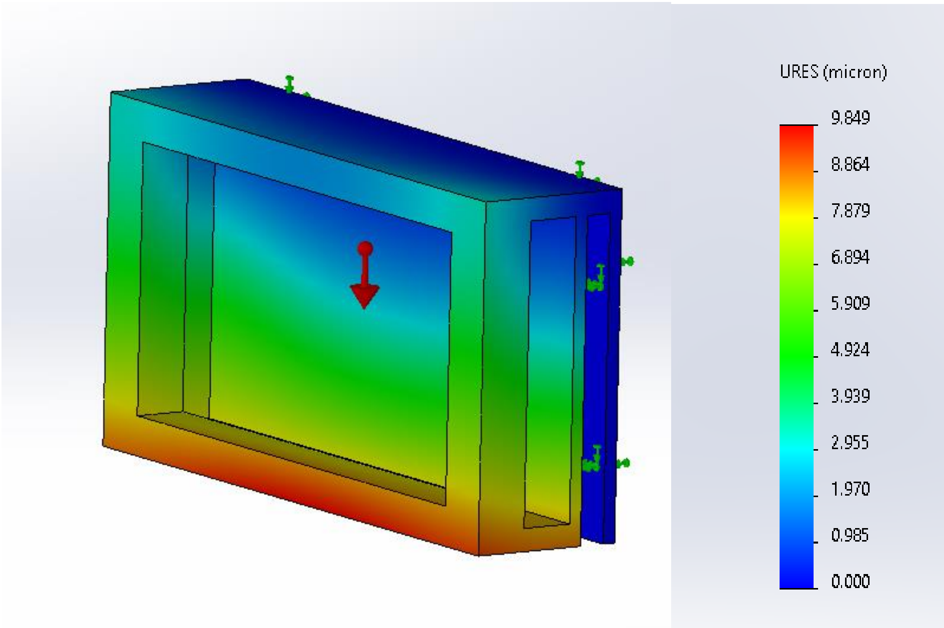

Figure 22: Displacement Analysis of the Initial Design

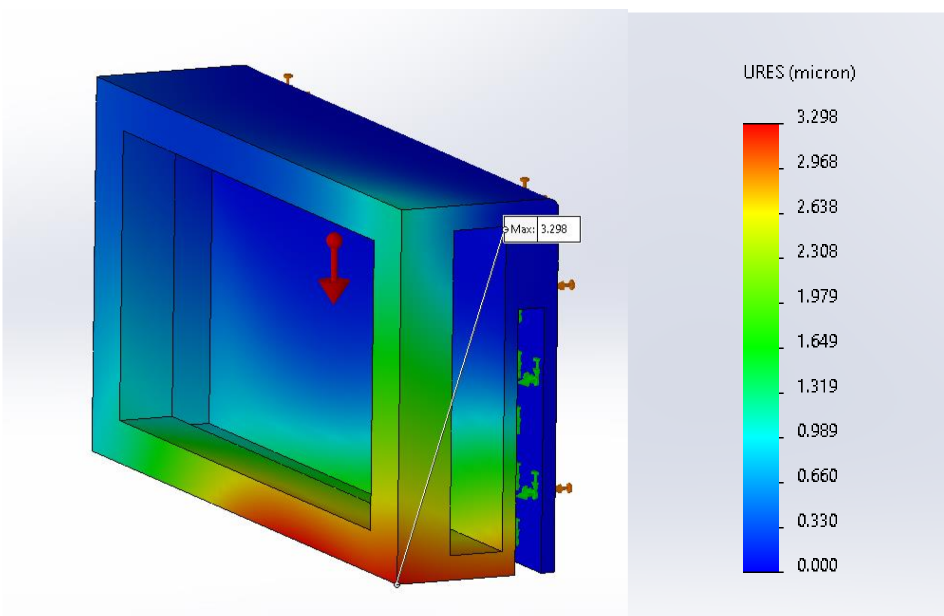

Figure 23: Displacement Analysis of the Final Design

Software

```
#if defined(USE_TINYUSB)
#include <Adafruit_TinyUSB.h>
#endif

#define LED_1 A0
#define LED_2 A1
#define LED_3 A2
#define LED_4 A3
#define LED_5 A4
#define LED_6 A5
byte PickedLED;
byte LASTPicked = 10;
byte LED;

void setup()
{
pinMode(LED_1,OUTPUT);
pinMode(LED_2,OUTPUT);
pinMode(LED_3,OUTPUT);
pinMode(LED_4,OUTPUT);
pinMode(LED_5,OUTPUT);
pinMode(LED_6,OUTPUT);
}

void loop()
{
  digitalWrite(LED_1, LOW);
  digitalWrite(LED_2, LOW);
  digitalWrite(LED_3, LOW);
  digitalWrite(LED_4, LOW);
  digitalWrite(LED_5, LOW);
  digitalWrite(LED_6, LOW);
  PickedLED=random(1,7);
  while(PickedLED==LASTPicked)
  {
    PickedLED=random(1,7);
  }
  if(PickedLED==1)
  {
    LED=LED_1;
  }
  else if(PickedLED==2)
  {
    LED=LED_2;
  }
  else if(PickedLED==3)
  {
    LED=LED_3;
  }
  else if(PickedLED==4)
  {
    LED=LED_4;
  }
  else if(PickedLED==5)
  {
    LED=LED_5;
  }
  else if(PickedLED==6)
  {
    LED=LED_6;
  }
  else
  {}
  digitalWrite(LED, HIGH);
  delay(750);
  digitalWrite(LED, LOW);
  LASTPicked=LED;
}
```

Figure 24: Strike Point Source Code

```
#include <Wire.h>
#if defined(USE_TINYUSB)
#include <Adafruit_TinyUSB.h>
#endif
#include <Adafruit_LIS3DH.h>
#include <Adafruit_Sensor.h>

#define CLICKTHRESHHOLD 10  //10-20 is the range for 8G
Adafruit_LIS3DH lis = Adafruit_LIS3DH(); //I2C
uint32_t X,Y,Z,x_r,y_r,z_r,Accel,Force;
int maxVal =0;
int Array[20];
int i=0, h1=0.0762, h2=1.27, r=0.168, m1=40.8, m2=4.536, x=0.8, y=0.38;
/*                Main Code                  */
void setup(void)
{
  Serial.begin(9600);
  //Serial.println("X:,Y:,Z:"); // Legend
  lis.setRange(LIS3DH_RANGE_8_G);   // 2, 4, 8 or 16 G!
  int lsb_value = 16;
  Serial.print("Range = "); Serial.print(2 << lis.getRange()); Serial.println("G");
  lis.setDataRate(LIS3DH_DATARATE_50_HZ);
  lis.setClick(1, CLICKTHRESHHOLD,20,20,255);
  //(uint8_t c, uint8_t clickthresh, uint8_t timelimit = 10, uint8_t timelatency = 20, uint8_t timewindow = 255)
  delay(50);
}

void loop()
{
  if (! lis.begin(0x18))
  {
    Serial.println("Couldnt start");
    while (1) yield();
  }
  else
  {
      lis.read(); // Get x,y,z raw data
      x_r=lis.x; //raw
      y_r=lis.y; //raw
```

Figure 25: Accelerometer Source Code Part One

```
        z_r=lis.z; //raw
        lis.begin(0x18,0x33);
        lis.read();
//        Serial.print("\t\tx_g: "); Serial.print(lis.x_g);
//        Serial.print(" \ty_g: "); Serial.print(lis.y_g);
//        Serial.print(" \tz_g: "); Serial.print(lis.z_g);
        /* Display the results (acceleration is measured in m/s^2) */
        sensors_event_t event;
        lis.getEvent(&event);
//        Serial.print("\t\tX: "); Serial.print(event.acceleration.x); Serial.print(",");
//        Serial.print(" \tY: "); Serial.print(event.acceleration.y); Serial.print(",");
//        Serial.print(" \tZ: "); Serial.print(event.acceleration.z);
//        Serial.println(" m/s^2 ");
        X=event.acceleration.x;
        Y=event.acceleration.y;
        Z=event.acceleration.z;

        // Convert to a vectoral magnitude
        double CurrPoint = sqrt(X*X + Y*Y + Z*Z);
        Serial.print("\t\tVector: "); Serial.println(CurrPoint);
        Array[i]=CurrPoint;
        i++;
        if (i>=19)
        {
          // find the max
           for (int i = 0; i < (sizeof(Array) / sizeof(Array[0])); i++)
           {
              if (Array[i] > maxVal)
              {
               maxVal = Array[i];
              }
            }
            if (maxVal > 20)
            {
              Serial.print("\tThe Punch was travelling: "); Serial.print(maxVal); Serial.println("m/s^2");
              Accel=maxVal;
              /* Convert max values to Force*/
              Force=((74.4276-70)/(0.64))*Accel;
              //Force=((((m1/12)*(3*r*r+h1*h1)+m1*(y+h2+(h1/2)))+((m2/12)*(3*r*r+h2*h2)+(y+(h2/2)))-70)/(x*x))*Accel;
              Serial.print("\tThe Force of the Punch is:"); Serial.print(Force); Serial.println("N");
            }
            i=0;
        }
        /* Send forces to the phone*/
        //Wire.beginTransmission(Address) // The address is the I2C address of the phone
        // After storing the peaks in value.pot, move it to the write command
        //Wire.write(Force)
        //Wire.endTransmission(Address)
      }
    //}
    return;
}
```

Figure 26: Accelerometer Source Code Part Two