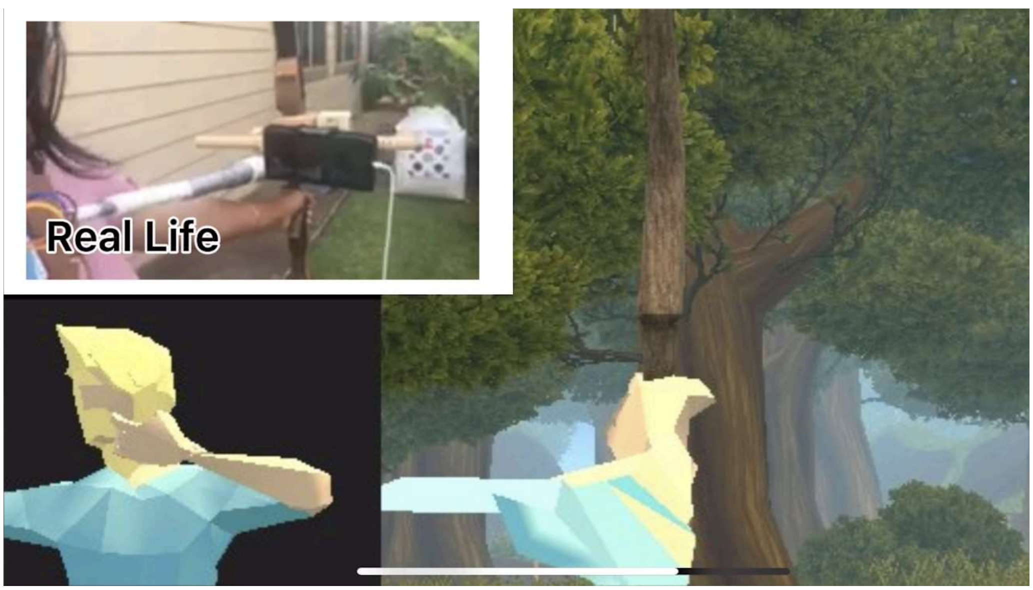
Creating an Archery Simulation with a Virtual Trainer to Prevent Plucking and Collapsing



Sage ʻAulani Tesoro

Kapolei High School

2021-2022

Table of Contents

Letter of Intent

Sage ‘Aulani Tesoro
1180 Kakala St. #602
Kapolei, Hi 96707
October 2, 2021

Mr. Reynon
91-5007 Kapolei Parkway
Kapolei, HI 96707

Dear Mr. Reynon,

My name is Sage ‘Aulani Tesoro and I am currently a junior in Kapolei High School who is planning on completing the STEM Honours. I intend to finish the STEM project that addresses one of the biggest factors in archery: the archer’s back arm and it’s release. This project will be completed with the use of science, technology. engineering, and math.

In archery, there are two places where the bow makes contact with the archer, one of which being the back arm. The motion of the back arm affects both the accuracy and precision of an arrow so it is essential that it moves the same way after every shot. Many archers have a hard time keeping their release consistent due to bad releases. These may include plucking, when the hand moves away from the archer’s face in a sideways motion after the release, and collapsing, when the hand moves away from the face in a forward motion. The main cause for these releases is the lack of back tension. With the correct back tension, the archer’s back arm will follow accordingly which will allow them to shoot with full power in every arrow.

My product will focus on the movement of the back arm of the archer which will help them realize their mistakes, so they can learn to shoot with proper form and will be more precise in archery. I believe my device will allow the archery to build the muscle memory of a clean release which will cause the arrows they shoot to group closer together. I plan on building an attachment to the bow and a phone app that will analyze the motion of the user. This will include sensors and an accelerometer to study where the archer is placing their arm while at full draw and the forces that will affect the flight path of the arrow. Currently I have no mentors; however, I wanted to work with Mr. Kawamura who is our Engineering and Technology Teacher. I also plan on working with two other mentors, one who knows more about the proper technique of shooting a bow and another who is advanced in computer programming, specifically in the language of

C#.

Part of the requirements for a STEM project is that the project must integrate aspects and concepts from science, technology, engineering, and math. My project will satisfy this requirement by:

- Science: Using physics to understand the forces needed to shoot an arrow and how small changes in an the archer's form can affect how the arrow flies;Using Myology to understand how muscles work together in the process of shooting a bow
- Technology: Using Unity and Visual Studio Code to program the phone to analyze the movement of the
archer; Using onshape to 3d design a collapsible arrow
- Engineering: Creating a device that will train an archer to shoot their bow with a clean release
- Math: Using geometry to calculate the angle the archer’s arm needs to be for a clean release; Using statistical tests to see if there is a difference between the abilities of the subjects before and after use of my product;

This STEM project will cause me to solve difficult problems in intuitive and creative ways. The expectations of this project will be more intense than any of my other classes including my Engineering and Technology and Computer Science classes.This is also a good opportunity to test other common skills like time management, perseverance, communication, etc. I promise to maintain academic integrity throughout this project. All research will solely be my own or will be properly cited following APA guidelines. All data in my project will be true and accurate. I understand that any plagiarism or falsification of date will disqualify my project from receiving STEM Honors and may result in a zero.

Sincerely,

Sage ‘Aulani Tesoro

STEM Stretch Commitment

I verify that the project below demonstrates stretch learning in the following ways: I engaged in a rigorous and relevant STEM curriculum through a project of my own design, going beyond classroom and graduation requirements.

For this project, I created a simulation that helps archers with their form and allows them to practice safely in any environment. To do this, I tested five participants to observe how close they were able to group arrows before and after the use of the simulation. I challenged myself during this project by using OnShape to 3D design my device, learn how to program using C++ and C#, and create a game using the software Unity. I used OnShape to 3D design possible designs for this product and to create a collapsible arrow. I used the knowledge I learned from OnShape videos to incorporate certain tricks into my design. I also learned how to wire gyroscopes to microcontrollers so that they consistently receive data and use it for other programs. I learned how to use the embedded gyroscope inside a phone to orientate a camera object in Unity.

My biggest stretch was figuring out how to use the program unity and how it connected to Arduino IDE. I've attempted a couple projects on Unity in the past, but it ended in me scrapping the project and using a different software. Being forced to stick with Unity allowed me to learn the mechanics of the game's objects, embedded lines of code, and connecting different programs into other lines of code. I was also able to learn the difference between Euler angles and Quaternions and how they affected the rotation of an object.

From this project, I was mentally and physically challenged to design a product that could solve a problem of an archer's form.

Mentor Agreement Form

STEM Honors Project
Mentor Agreement Form

Thank you for agreeing to serve as a STEM Mentor! Your mentor student should have already received your approval to mentor him/her, have fully completed this form (except for your signature) and will go over this form with you to ensure you understand your important role in his/her project.

1. The role of a mentor is to assist a student in designing and carrying out his/her project in a safe and timely manner.
2. By agreeing to mentor a student(s) you are acknowledging that you possess a working understanding in a given field, though the project may lie somewhat outside of your specific expertise. Your signature also indicates that you have spoken directly with the student(s) and agreed upon a specific purpose for their experiment.
3. By signing this contract, you are also agreeing to help lead the student to resources that will enable them to do background research for their chosen topic.
4. It is the student's responsibilities to gather their equipment, set their experiment, and carry it out. It is also the student's responsibility to meet all deadlines for their class.
5. Students are required to go over the calendar of due dates with you before you sign the mentor agreement.
6. A student may receive help from any number of adults to complete a project, but they may only have one official mentor. Only the official mentor may sign official paperwork

Agreement:

I agree to mentor the above project. I understand my role is to act as a source of information, guidance and inspiration, but, in the end, it is the student's responsibility to complete the project.

Mentor's signature: X ______________________

Date: 10/5/21

Documentation of Hours

Date	Task	Time	Evidence	Initial
7-13-21	Brainstorming	5hr	Screenshot (12) - Copy.png	
7-21-21	Project Presentation	1 hr		
10-1-21	OnShape Fundamentals: CAD	125 hr	2021-09-30 (1).png	
10-2-21	Letter of Intent	30 min	Page 3	
10-7-21	OnShape Practice Project	1 hr	Screenshot 2022-04-28 10.01.39 AM.png	
10-8-21	Mentor Agreement Form	5 min	Page 6	
12-1-21	Orthographic Drawing	1 hr	Screenshot 2022-04-28 9.30.31 AM.png	
12-13-21	Prototype Testing	10 min	IMG-1782.JPG https://drive.google.com/file/d/1f1MRhN7quu4c7pEe8N_AlYfasvjiEUra/view?usp=sharing	

1-22-22	Final Design	4 hr	Screenshot 2022-04-28 3.23.42 AM.png Screenshot 2022-04-28 3.17.17 AM.png Screenshot 2022-04-28 3.16.49 AM.png Screenshot 2022-04-28 3.16.31 AM.png	
1-23-22	Working of Final Product (Cutting plywood)	30 min	IMG-2532.JPG	
2- 17-22	Gyroscope Coding (Character Point of View)	2 hr	2022-04-27 (7).png https://drive.google.com/file/d/16o3zocHZolMyM1ZuA_JFoKePQDvR66qE/view?usp=sharing	
2-19-22	Gyroscope Coding (Movement of a game object/cube)	3 hr	2022-04-27 (14).png https://drive.google.com/file/d/1AsWxPFmVN3uHtcOCYHIQ5cRvivYgTCgR/view?usp=sharing	
4-1-22	Gyroscope Coding	30 hr	https://drive.google.com/file/d	

	(Movement of character's arm)		/1kq-VbxBVtF9T1vLknZN9v2CnVZswxQeE/view?usp=sharing 2022-04-27 (12).png 2022-04-27 (13).png	
4-15-22	Testing Final Product (Attachment)	15 min	IMG-4189 (1).JPG https://drive.google.com/file/d/1IOJmGgZNwfDw0C7jTx8tDCxW_SJ08Kpb/view?usp=sharing	
4-15-22 4-16-22	Mini Details on Program (fix arm movement; movement of string)	10 hr	2022-04-27.png 2022-04-27 (10).png 2022-04-27 (8).png IMG-4193.PNG	
4-17-22	Testing	5 hr	IMG-3964.JPG https://drive.google.com/file/d/1XWW0SZDx_GnG2vKGifR9tl7Kt8JFS1Gn/view?usp=sharing https://drive.google.com/file/d/16Zhhsvdp1grRnXNw2qoBqa54HwBcwECA/view?usp=sh	

			aring https://drive.google.com/file/d/1eXDKcHjKBkR0EmFnGu4OWpUMn6PyZ30-/view?usp=sharing	

Research Paper

Creating An Archery Simulation With A Virtual Trainer To Prevent Plucking and Collapsing

Sage ‘Aulani Tesoro

Kapolei High School

Table of Contents

Abstract

An archer must be precise in their every move in order for their arrows to land in the same spot after each shot. The key research question pertaining to this problem is “What can improve the precision and muscle memory of an archer so that the distance between their shots will be closer together?” It is easy to adjust the bow if the arrows aren’t accurate; however, correcting precision goes more in depth, which is why it’s emphasized that one should work on their precision before accuracy. Once the archer gets the arrows to group in their desired way, they “simply move their sight toward the group to make the arrows hit the target’s center” (Archery 360). This can only be corrected if the archer can perform the same motions for every shot. This includes the muscles, position of arms, the amount of power put into the bow, and more. All these factors can be corrected with a device that places an archer in a virtual reality that would allow them to use their own bow so they could practice the motions done with a real bow without having to go to an archery range. It would also show them their form in real-time so they could see and fix their mistakes without a coach. Researching this problem will allow many archers, both beginners and advanced, to improve on their form and technique with the sport.

Introduction

What can improve the precision and muscle memory of an archer so that the distance between their shots will be closer together? The shot of the arrow can be affected by multiple things like wind, materials of the bow/arrow (Bowhunters United), the point of contact with the archer, and the use of different muscles. Although most of these things are beyond the ability to change, it doesn't mean the archer can't learn to adapt to these situations. The way the archer uses their muscles can be changed along with how much they use them. This could be taught by a virtual trainer and can be improved with muscle memory.

The device that was created is similar to the product made by Accubow in which it improves the steadiness of an archer's front arm and serves some muscle memory from the back arm (Accubow); however, their product caters more towards compound bow users. This is because the company did not consider the bending of an arrow when it is shot. This is due to two main reasons: the archer's paradox and the initial movement of arrow flight. When thinking about how to shoot an arrow, it's believed that the arrow's tip will be placed on the target and it is aligned with the target; however, when it is knocked onto the string, the arrow goes around the riser (NUSensei). This idea is called the archer's paradox which results in the arrow being placed in a way that is angled away from the target, causing the arrow to bend back and forth while it's shot. In addition, when shooting a recurve bow, the string must slip around the archer's fingers which causes the force of the string to push the arrow away from the center, making it bend even more. This factor is called "initial movement." Compound archer's do not have to worry about the initial movement of their arrow due to their mechanical trigger. This topic would require more research in order to consider how the form of the archer amplifies the archer's paradox and the initial movement of the arrow.

Along with that, compound bows apply more pressure on the archer's front arm muscles rather than back because the force used to pull the string back is decreased due to let off, making the weight of the bow heavier than a recurve. Since the mechanics of a recurve bow is different from a compound, this project will focus more on the consistency of the archer's posterior deltoid, infraspinatus, brachialis, latissimus dorsi, trapezius, and rhomboids (Accubow). However, this does not mean every muscle that's drawing the bow should be used. The hand and fingers must be relaxed so "the string can push right through them" (Archery 360) as the arm moves straight back. If there isn't enough back tension, the archer's arm will move away from their face in a motion called plucking, and "can induce a lateral motion in the string" (NUSensei) called string oscillation. The archer may also collapse their front arm forward because they either are not properly aligned with the target or they stopped pulling the string during the process of the release.

Taking these factors into consideration, the archery trainer must focus on the movement of the back and drawing arm's muscles. This could be done with a gyroscope on the hand that draws the bow to check the amount of back tension and the placement of the hand after the release is finished. Before the release, the angle at which the sensors are elevated is around 35 degrees. After the release, the elevation gap should get shorter around 25 degrees and the lateral position should stay the same. If the lateral position changed, it means that the archer either plucked the string or collapsed. There will also be an attachment to the bow to allow the user to see a virtual range with a fake arrow so the archer can practice safely anywhere without any repercussions of dry firing.

Research and Design Procedures

If someone were to use the virtual simulation, then their shots will be more precise. In other words, after working on the proper form to shoot a bow with the device, the measurement between their arrows will be smaller.

Design Process

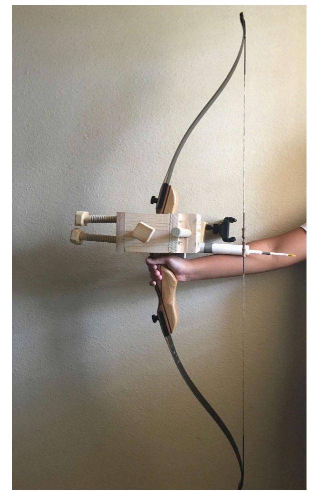


Figure 1: Prototype

For this project, a few devices were created and manipulated in order to improve the archer's precision. These things include, creating a stand to connect a phone and a retractable arrow to the archer's bow, creating a virtual world on a phone app that will simulate an archery range, and installing a gyroscope sensor into a finger tab.

The prototype was used to test dimensions of the stand and the strength of the retractable arrow. The stand was made out of wooden slabs, wooden dowels, and screws (Figure 1). The arrow was 3d printed at a thickness of 0.125 cm. The prototype put a lot of stress on the front arm due to its weight and the arrow snapped during the first test.

In the final design, the stand was made out of plywood instead of wooden slabs and was attached with wood glue instead of screws. The arrow was reprinted at a thickness of 0.25 cm, foam was added to absorb shock from the arrow, and the phone holder was replaced to fit varying phone sizes (Figure 2). A sensor that provides a gyroscope was connected to an arduino motherboard and was attached onto the back of a glove finger tab. An Arduino IDE

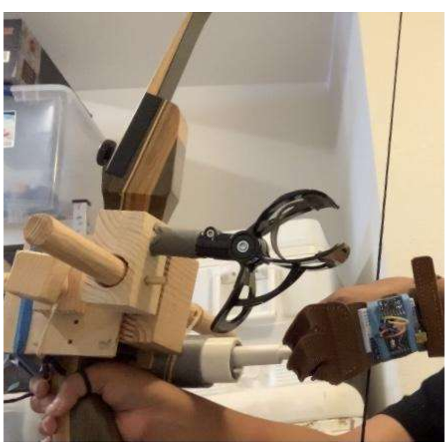


Figure 2: Final Product

was programmed so it read and used the measurements from the sensors in quaternions. This measurement is a four element vector that expresses the orientation of an object using the variables “x, y, z, w.” The measurements were then read by the game-making software Unity® to create the virtual reality for the phone. This app uses the measurements to move and orientate the arm of a human figure within the virtual world (Figure 3). The app also gathers the gyroscope measurements from the phone to orientate that direction the archer is facing. This person is a free game object that was created by the company *Distant Lands Productions* and was downloaded from the Unity Asset Store. The props and environment seen within the simulation were also downloaded from the Unity Asset Store. The environment was created by *Triforge* and the props were created by *OsMan 3D Artist*.

Figure 3: Picture of Simulation

Testing Procedures

The results were gathered from five participants in total, three with no archery experience beforehand, one with little experience, and another with seven years of practice. Three of them were right eye dominant and the other two were left. They each shot from a distance of three yards and were told to shoot the same spot for every arrow, not the middle of the target. They shot five arrows to practice before shooting the five more that were recorded as quantitative data. Each distance between the arrows were measured in centimeters

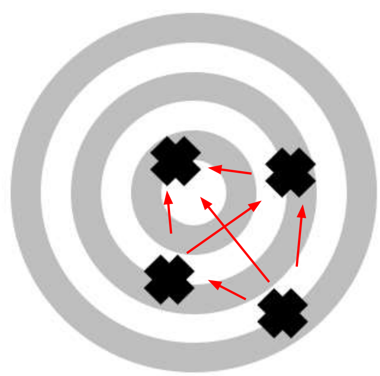


Figure 4: How the arrow distances were measured

similarly to the arrows in Figure 4; however, if any arrow missed the target completely, the measurement was recorded as 50 cm. They then used the trainer to shoot the built-in arrow and the trainer showed the user their form so they could improve it. This portion of the test went on for two 15-minute sessions with a five minute break in between. After another 10 minute break, the same procedures from the previous test were conducted. If the average measurement of the distance between arrows were closer together in this group than the first group of arrows, it showed that the archer improved with the virtual trainer.

Results/Data

Table 1: Measurements between Arrows Before and After the Use of the Device (cm)

Participant 1	Before	After
Measurement 1	6	5.5
Measurement 2	22	10.3
Measurement 3	22	12
Measurement 4	25	13.7
Measurement 5	24.5	12.5
Measurement 6	16.5	13.5
Measurement 7	16	7
Measurement 8	18.5	8.5
Measurement 9	33.7	9.9
Measurement 10	15.3	1.8

Table 2: Measurements between Arrows Before and After the Use of the Device (cm)

***Note: Measurements for arrows that missed the bail were marked as 50cm**

Participant 2	Before	After
Measurement 1	50	50
Measurement 2	50	50
Measurement 3	50	50
Measurement 4	50	50
Measurement 5	6.5	9
Measurement 6	30.5	13.3
Measurement 7	38.5	16.8
Measurement 8	24.5	11.8
Measurement 9	33	15
Measurement 10	32.5	3.9

Table 3: Measurements between Arrows Before and After the Use of the Device (cm)

Participant 3	Before	After
Measurement 1	3.8	1.5
Measurement 2	6.5	5.5
Measurement 3	7.1	3.9
Measurement 4	10.5	4
Measurement 5	3	5
Measurement 6	5.5	3
Measurement 7	4.8	3.5
Measurement 8	3.1	6
Measurement 9	3.5	2.6
Measurement 10	5.4	3

Table 4: Measurements between Arrows Before and After the Use of the Device (cm)

Participant 4	Before	After
Measurement 1	34.3	28.5
Measurement 2	41	27.5
Measurement 3	47	32.5
Measurement 4	53	33.5
Measurement 5	13	11
Measurement 6	15	8.5
Measurement 7	20.3	8.5
Measurement 8	17	7
Measurement 9	22	8
Measurement 10	5.9	0.5

Table 5: Measurements between Arrows

Before and After the Use of the Device (cm)

Participant 5	Before	After
Measurement 1	3	4.5
Measurement 2	4.6	1.5
Measurement 3	7.5	10.5
Measurement 4	17	4
Measurement 5	7	4.5
Measurement 6	2.1	7.3
Measurement 7	15.2	15
Measurement 8	8.5	10
Measurement 9	15	3
Measurement 10	13	7.2

Table 6: Average Measurements from each Participants Before and After the use of the Device

	Before	After
Participant 1	19.95	9.47
Participant 2	36.55	26.98
Participant 3	5.32	3.8
Participant 4	26.85	16.55
Participant 5	8.02	6.75
Average	19.338	12.71

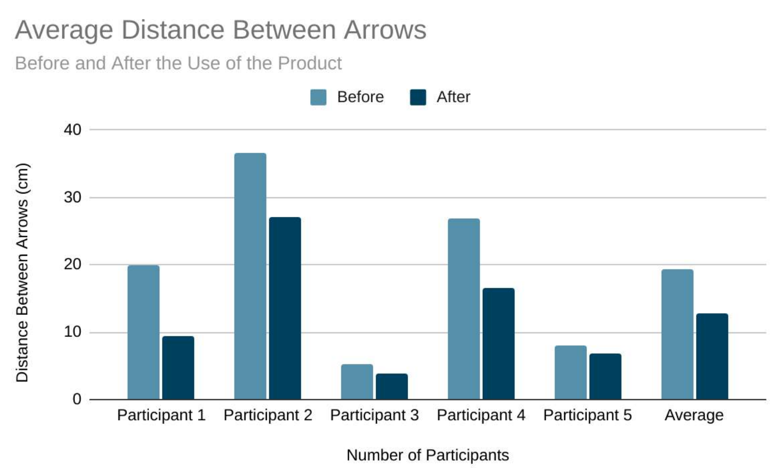


Figure 5: Average Measurements from each Participants Before and After the use of the Device

The results of this experiment produced multiple means: the mean for the distance between arrows for each participant and the mean for the distance overall seen in Figure 5. For each individual participant, the measurements in the first test did not correspond to the second test because the distances weren't measured by specific arrows. This means that when finding the statistical significance, it required a two sample t-test. However, the averages of the distances for each participant in the first test did correspond to the measurements in the second test because the data measures the before and after effects of the device. This means a paired t-test is also needed to test the significance of the results. The difference between these tests is that the two sample t-test measures if there's a difference between two sets of data, whereas the paired t-test measures if there's a difference in a group between two points in time (DataTab). The paired t-test is done by first finding the differences between the corresponding data (shown in figure 7). When plugging these results into the formula for the paired t-test, the t distribution, -3.09408, was less than the t distribution of the level of significance, -2.132. This allows for the alternate hypothesis to be accepted, the mean of the distance between arrows after the use of the device is less than before the use of the device. When plugging in the data from the individual tests into the two sample t-tests, their p-values were less than the level of significance, 0.05. This also allows for the other alternative hypothesis to be accepted for each participant, the two data sets were statistically different.

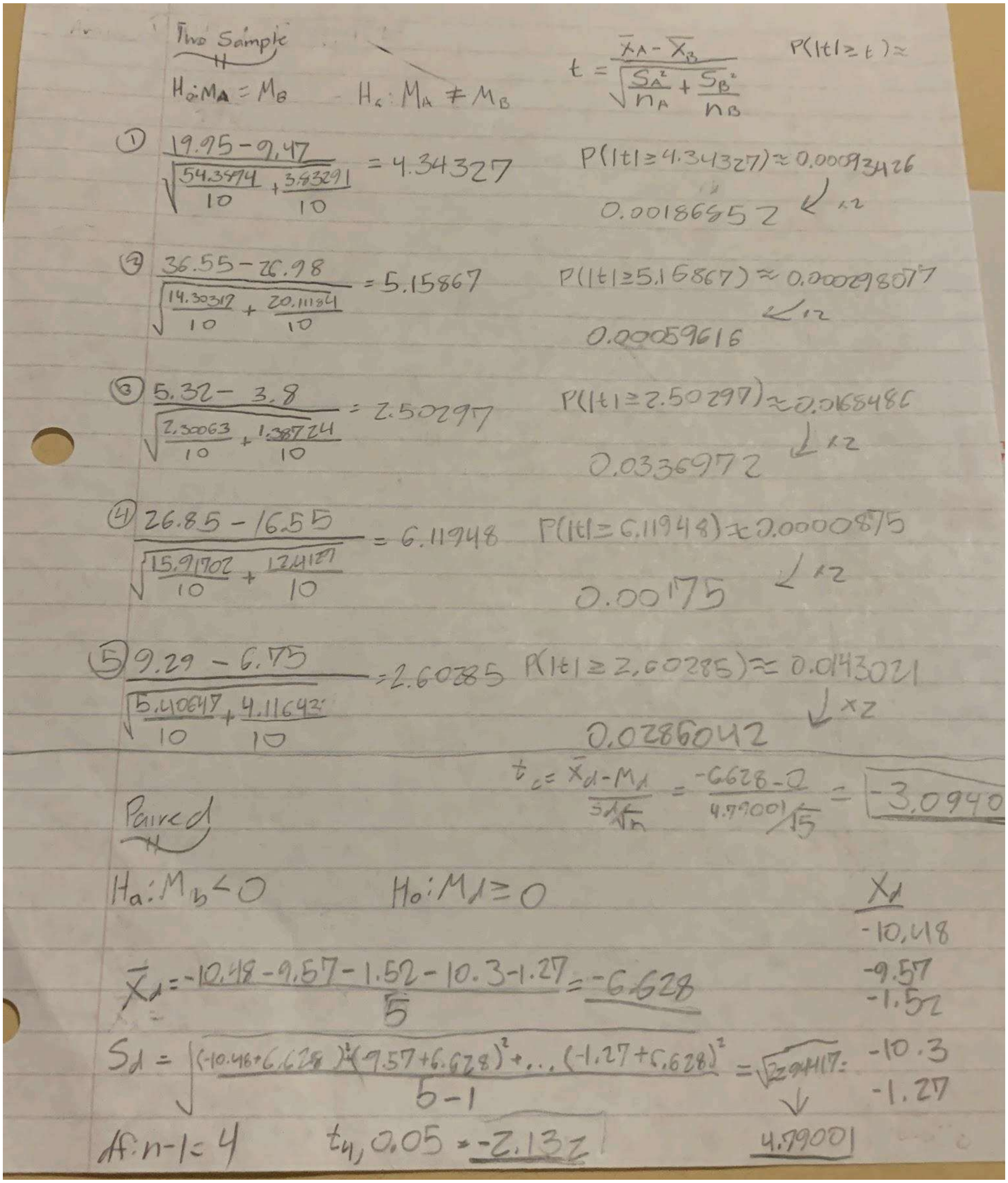


Figure 6: Calculations

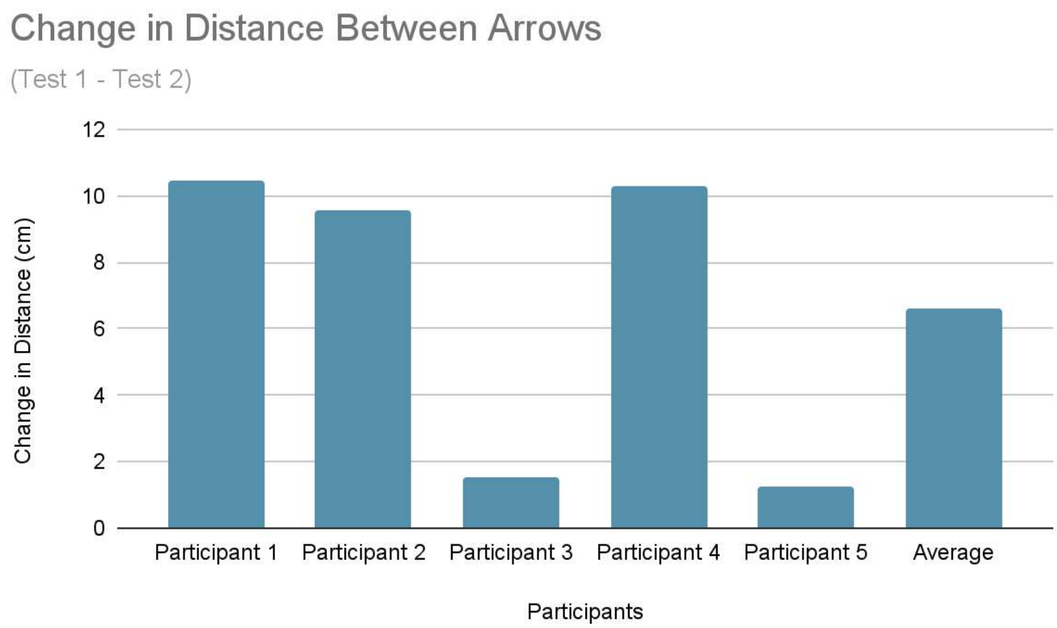


Figure 7: Change in Distance Between Arrows

Conclusion

Overall, the device did improve the precision of the archer and their form and my hypothesis was accepted. This is because all of the participant's average distance between arrows decreased after the use of the device and the data was statistically different enough to show it was significant. This is because the difference between the means divided by the variance of the data were less than the alpha value. However, many errors could have affected the test including the lack of participants and arrows, recording arrows that missed the bail as 50 cm, and more. In addition to this, the lack of info gathered from the prototype caused little improvement in the final product. This project gave an insight on how technology and simulations are programmed to help people improve in their day-to-day life using multiple softwares and programming languages. This information can and will be useful to whoever investigates how the form of an archer may affect the placement of the arrows and how to correct it using muscle memory. Further improvements could be made to this device including the incorporation of wind into the app, making the attachment more compact and stable, finding ways to absorb the shock of the arrow, making the simulation wireless, etc.

STEM Components

Science

The use of physics allows for the understanding of the different forces that may affect the bow, including gravity, the string, and the effect of the archer's paradox. In addition to that, myology explains why every muscle is used for certain purposes and how each one of them is used in conjunction with others to shoot a bow.

Technology

The use of programming softwares such as Unity®, Arduino IDE, and Visual Code Studios to create the app the virtual trainer for the archer. Also, the use of OnShape to 3d design a collapsible arrow for the archer to shoot.

Engineering

The identification of a problem and developing a solution. Creating prototypes, identifying improvements, and remodeling to create a design for a final product.

Math

The use of geometry to calculate the angle of the archer's arm. The use of basic arithmetics to help perform the necessary math formulas in order for the app to work. The use of statistical tests to perform a Paired T-Test and Two Sample T-Test to analyze if there is a difference between the abilities of the subjects before and after use of the device.

References

A. (2019, October 15). How to Diagnose and Improve your Recurve Release [Video]. YouTube. https://www.youtube.com/watch?v=dzJ7HxYlD28&feature=youtu.be

Accuracy vs. precision. Archery 360. (2019, August 20). Retrieved November 22, 2021, from https://archery360.com/2019/08/20/accuracy-vs-precision/.

Archery annoyances | the Archer's paradox ... - youtube.com. (n.d.). Retrieved November 22, 2021, from https://www.youtube.com/watch?v=jOiCxFbFIEM%3Fhd%3D1.

Einsmann, S. (2019, October 16). Fingers Release Tip. Archery 360. Retrieved October 22, 2021, from https://archery360.com/2019/10/16/fingers-release-tip/

Fayad, T. (2019, October 23). Muscle Memory 101 - The Startup. Medium. Retrieved November 4, 2021, from https://medium.com/swlh/muscle-memory-101-a409ff7f7e90

Holbrook, J. (2021, March 11). Don't Blow It: How Wind Affects Bowhunting. Bowhunters United. Retrieved October 20, 2021, from https://bowhuntersunited.com/2017/12/01/dont-blow-it-how-wind-affects-bowhunting/

Meet your muscles: What you use in archery. (n.d.). Retrieved November 22, 2021, from https://accubow.com/Meet-Your-Muscles-What-You-Use-In-Archery_b_9.html.

N. (2019, December 31). Archery | Clean Releases (and How to Avoid Plucking the String) [Video]. YouTube. https://www.youtube.com/watch?v=UZMr2Rd_yk0&feature=youtu.be

"Test, Chi-Square, ANOVA, Regression, Correlation..." *t*, https://datatab.net/tutorial/paired-t-test.

Reflection

STEM Capstone is a very fun yet rigorous course that encourages students to go beyond what they think they can do and accomplish the impossible. It allows the freedom to explore whatever the student desires, whether it's to help the elderly or to create a simulation. As someone who wants to explore the computer science field and specifically game development, this project taught me how much perseverance it takes when your program always fails. Looking at a program for hours straight can be mentally exhausting and extremely discourage someone. However, that doesn't mean one should give up and trash all their hard work. All programmers understand this feeling which is why it's always good to ask for help. I often do programming by myself because someone doesn't have the same thought process as me, but when I got extremely frustrated with a program, I called my cousin and he'd find the smallest error in my code, like putting a different port number.

In addition to that, I learned how to use game-making softwares like unity that will make it easier to create game-oriented programs. Combined with Arduino IDE and Visual Code Studios, I learned how to program in C++ and C#. I also learned that when finding the orientation of something, programs use quaternions, a four element vector, instead of the standard "x,y,z" coordinates. This is because it avoids gimbal lock which "removes" an axis of rotation.

This project made me realize the potential I have despite me not knowing much about programming. There is so much to learn about the world; however, as long as I don't give up and approach it as little parts at a time, I will be able to expand my knowledge more than I could imagine.