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Photogrammetry Booth

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PET PHOTOGRAMMETRY BOOTH

By

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Final Report for 4600:471 Senior Design, [Spring/Fall 2022]

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Abstract

For the Spring and Fall semesters of 2022, our team focused on designing and building a prototype photogrammetry booth to take photographs of people's pets, specifically dogs. The two principal areas of engineering used for this project included mechanical engineering for the structure and electrical engineering for the camera array. Additionally, this project tested team members with market research, learning new concepts and skills related to their designated field, and time management. Research and testing for the photogrammetry booth led to the conclusion that the structure was properly sized, but the camera array was cumbersome and inconsistent. Future iterations of this booth should optimize the structure and redesign the camera system.

Contents

1. Introduction

This senior design project is divided into two portions, mechanical engineering, and electrical engineering. The mechanical portion required the concept of design in designing the booth with SolidWorks for 3D modeling. The electrical portion used an Arduino board to help coordinate image capturing simultaneously. The team incorporated engineering and scientific ideas used in the creation of the booth and set up the Arduino board to capture pets from multiple angles. More angles mean more photos and more photos mean better data for generating 3D models for the 3D printing process

1.1 Premise and Market Research

The premise of this project is to create a photogrammetry booth aimed at taking photos of people's pets, more specifically dogs. Photogrammetry is the use of photo imagery to gather physical information. In this instance, Dr. Choi requests that multiple cameras gather images of dogs so that their physical data can be used to create individualized 3D models. These 3D models would then be 3D printed and colorized by either a person or the 3D printer itself.

The market research for the feasibility was presented to the team by Dr. Choi. Dr. Choi believes there is an extensive market of pet owners that would like to replicate their pets as miniature figures or statues. The market for this service is overpriced or underwhelming in what it delivers. However, by using both a photogrammetry booth and modern 3D printing technology, Dr. Choi believes that customers can obtain great replicas of their pets at much lower costs.

The business strategy put forward would include both offline and online services. The offline services would include the photogrammetry portion where pet owners take their pets to stores like PetSmart or Petco to have their pets scanned. The online portion would include the use of servers and 3D printer farms to handle the captured data and 3D printing process. After the process has been completed, the individualized 3D printed model would be shipped to the customer or to the pet store to be picked up.

According to Dr. Choi's research, the total pet market has an estimated yearly income of $103B. More specifically, his research has narrowed down the target market of dogs to about $269M. Additionally, there is a reported 89.7M dogs in the United States and thousands of local pet shops as well. The potential market is large, and the current research does not consider markets outside the United States.

1.2 Electrical Concepts and Research

The photogrammetry booth project required research into cameras, Arduinos, electrical circuits, and electrical components. Initial market research required learning about photogrammetry booth systems and looking into commercially available units. Most photogrammetry systems on the market use general-purpose parts for stands, lighting, and cameras. However, most of the electrical components were connected to proprietary hardware meant to trigger cameras and augment other electrical systems. Additionally, most of these parts were expensive and did not fit into the allowable budget. Given this research, the electrical system would follow a similar design.

Setting up a custom camera system can be a lot to take up so the right parts for the job must be selected. Given the current course that the design was following, there were two main options that could be brought to fruition. The first and best choice would be for a Raspberry Pi and accompanying camera modules. Raspberry Pi computers are on the cheaper side as well as the camera modules being less than $50. The issue with this approach is availability and camera modulation. Ever since the chip shortage started, Raspberry Pi computers and many other products with computer chips have either become ridiculously expensive or completely unavailable. Raspberry Pi computers fell into the unavailable category. The other main issue was the management of the cameras through the Raspberry Pi. Connecting and managing four or more cameras would require a custom printed circuit board and an understanding of computer inputs and outputs. Those two fields were outside the knowledge of the team. Therefore, the other option detailed below would be how the project started.

The most important part of the booth and what decided the overall size was the camera. The booth itself was to house both a dog and contain enough space that the cameras could take clear photographs. Therefore, it was crucial to acquire and test cameras immediately to set the project in motion. Further details about camera selection are available in Section 2.1.1.

When deciding on how the electrical system would work, learning about components was also a high priority. For that reason, an effort was made to contact instructors at the University of Akron who specialized in electrical engineering. The first instructor contacted was Dr. Igor Tsukerman who teaches electrical engineering to mechanical engineering students. The idea behind the circuit was ran by him and approved, but he admitted that the team should reach out to Dr. Kye-Shin Lee on campus as he specializes in electrical components. An appointment was made with Dr. Lee and that time was used to discuss the general circuit design and which components to use. Dr. Lee said the circuit idea should work and recommended MOSFET transistors specifically for this project. With the general circuit idea and components decided upon, it was time to start testing. Electrical testing and verification information is continued in Section 3.1.

1.3 Mechanical Concepts and Research

The photogrammetry booth weighed heavily on electrical concepts, but the structure upon which the cameras were set and positioned came from the concepts of design. Working with the electrical side in determining a good focal point was important in designing the dimensions of the T-slot bars into a formidable frame. The concept of Pythagoras' theorem was used in determining the accurate focal length that is equal for all bars. SolidWorks was the design tool used to design and pre-assemble all parts before physical assembly. The bars chosen were based on the recommendations given by Dr. Choi and were rated with high strength standards.

2 Design

As mentioned, this project is split into two main sections: the mechanical engineering side and the electrical engineering side. The initial design for each section took place over the Spring 2022 semester and included market research, component research, and team collaboration. Each section also had a certain budget of around $1000.00 which can be more accurately assessed in the Appendix.

2.1 Electrical Design and Components

For the electrical portion of this project, it’s important to set up the basic components at play. The goal for the electrical side was to create a functioning camera array that could remotely trigger multiple cameras to take pictures simultaneously. It was imperative to have multiple cameras, a remote triggering device, and means of connecting it all together.

2.1.1 Cameras

With market research for cameras and camera arrays, the following conclusion was made that most cameras are expensive. Looking at commercially available photobooth systems, most systems use extremely high-quality name brand cameras that cost thousands of dollars. For that, those types of cameras were out of the scope of this project. That meant that this booth would need to use cheaper cameras to achieve comparable results.

An initial camera was chosen for testing both the remote triggering system and for the camera quality itself. The internals of the cameras were simpler than expected so playing around with PCB pins to identify what needed to be jumped was straightforward. The initial camera and the other cameras tested have a separate PCB on the top for the various buttons which meant the connections between those boards could be jumped. These connections were important because wires could be soldered onto them and run to the remote triggering system.

After concluding that jumping the camera shutter button pins could be done, the camera itself would then be tested. The initial camera was chosen both because it was on the cheaper side as well as producing 1080P full HD images. Testing with that camera made it clear that it was insufficient and created noisy pictures. Due to that reason, it was decided that a new camera would be chosen to replace it.

The second camera chosen for testing would be the Kodak FZ43. This camera was chosen because the price-point was similar, available on Amazon, and had plenty of reviews with pictures displaying its abilities. Testing this camera revealed that it was much high quality and produced better images. At the beginning of the Fall 2022 semester, a third camera choice was required because the previously used camera was discontinued. Luckily, Kodak succeeded the second camera with a newer version that was only slightly more expensive and slightly more compact, the Kodak FZ55.

Figure 1 Cameras tested and used for camera system.

2.1.2 Remote Triggering System

Originally, it was planned that the photogrammetry booth would use a wireless remote triggering system such as a smartphone or tablet, but for the sake of simplicity, a handheld remote was chosen instead. The handheld remote is reminiscent of old cameras where the camera operator would hide under a cloth and activate the shutter. This remote is 3D printed and wired to an Arduino UNO Rev3. The Arduino is the brain of the simple electrical system and has multiple open pins that can be used for various functions. In its current state, only four of the pins are used with three being digital pins and one being a grounding pin.

The previous completed triggering system that was completed was not sufficient to meet the desired requirement of the project. As a result of this research was carried out in achieving this goal of triggering multiple cameras at the same time. The Esper Trigger box was the solution to this problem, which is shown in figure 3

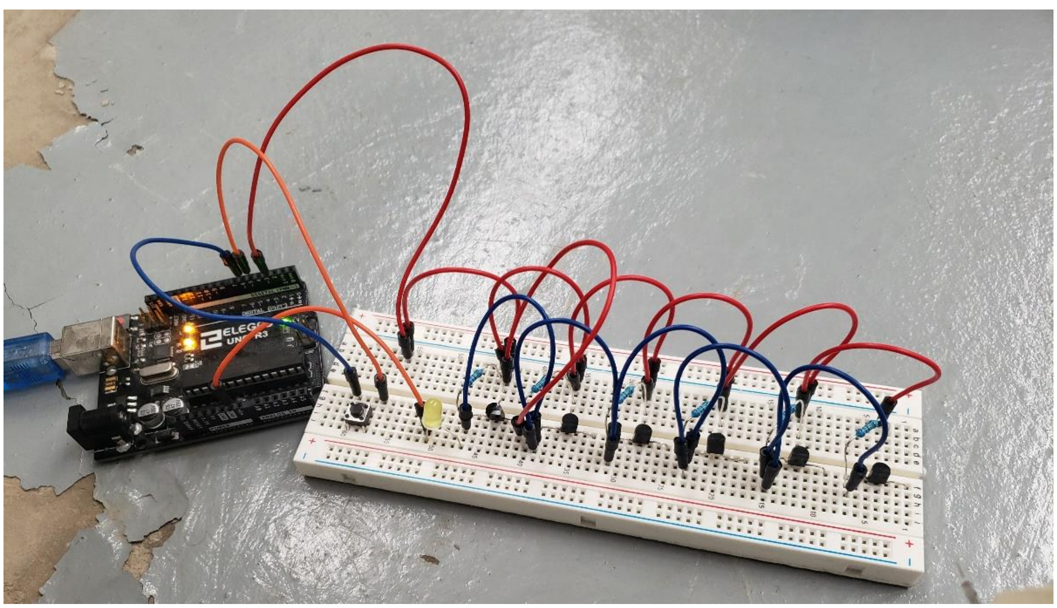

Figure 2 Arduino and breadboard used for camera system.

The pins of the Arduino are connected to a breadboard where the physical circuit of the system comes into play. The breadboard is made up of multiple strips of metal used for connecting and testing circuits. The circuit on the breadboard is constructed using wires, transistors, resistors, an LED. The general operation of the circuit is as follows. The Arduino reads that the hand remote is pressed, then the Arduino sends a pulse to the six transistors. When these transistors receive a certain voltage, they close the internal gate allowing the camera shutter button to be bypassed and set off the cameras.

2.1.3 Wiring

The wiring for all the electronics uses simple 28AWG wire. Wire gauge is measured in a way that the higher the gauge, the thinner the wire. 28AWG is on the thinner side and is cheap, but it's also effective at keeping voltages intact. The longest wire length for the booth is 17.5ft, but there is a wire to carry current from the camera to the transistor and a wire to carry current from the transistor to the camera meaning the wire set has an effective length of 35ft. For reference, the shortest wire length is 1.5ft with the connection effectively 3ft. Attached at the end of each wire is either a male or female Glarks connector. Glarks connectors are cheap ways to have detachable connections between mediums so they may make the overall experience less cumbersome when having to remove cameras. More importantly, it means that wires could be separately attached to the booth structure.

2.1.4 Arduino and Programming

As previously mentioned, the Arduino serves as the hub for the remote triggering system. Given the simplicity of the system, the code developed for the booth is extremely simple. In its current state, the Arduino is not needed. However, given the low price, use as a power source, and expandability, the Arduino is a welcome addition that serves as futureproofing. The Arduino programming language is based on C/C++ language making it minimal, but it has expanded features specifically meant for hardware tinkering. An Arduino program is developed in a freely available integrated development environment and an Arduino program is referred to as a sketch. The one used for this project is pictured below. A comment accompanies each line of code to indicate what it does.

```
// initialize integer val as 0.
int val = 0;

// the setup function runs once when you press reset or power the board.
void setup() {
  // initialize digital pin 5 as an output (writes voltage).
  pinMode(5, OUTPUT);
  // initialize digital pin 6 as an INput (reads voltage).
  pinMode(6, INPUT);
  // initialize digital pin 3 as an output (writes voltage).
  pinMode(3, OUTPUT);
  //initialize serial port monitor to read pin voltages.
  Serial.begin(9600);

  digitalWrite(5, HIGH);
}

// the loop function runs over and over again forever.
void loop() {
  // set read voltage value at pin 6 as val.
  val = digitalRead(6);
  // write value of val to serial port monitor.
  Serial.println(val);

  //if statement to send voltage pulse to transistors.
  if(val > 0){
    // write voltage value HIGH (value of 1) to digital pin 3.
    digitalWrite(3, HIGH);
    // delay process by 500 milliseconds (0.5 seconds).
    delay(500);
    // write voltage value LOW (value of 0) to digital pin 3.
    digitalWrite(3, LOW);
    // delay process by 5000 milliseconds (5 seconds).
    delay(5000);
  }
}
```

Figure 3 Snippet of Arduino code.

2.2 Mechanical Design and Components

2.2.1 Structural Design

The initial and final structural design of the booth takes a simplistic approach. The booth is constructed of aluminum rails with slots that allow for components to be slotted. Four vertical bars and eight horizontal bars complete the cube structure. Four of the horizontal bars sat at the top specifically for rigidity while the other horizontal bars would originally be used as moveable camera mounting points. With the initial design, these lower bars could be slid vertically up and down to allow for multiple points for photos. However, at the start of fall semester, Dr. Choi mentioned that six cameras would be used rather than four.

With two extra cameras, the booth was redesigned to where three of the moveable bars would be fixed near the bottom. These new bars would serve as structural pieces, but the fourth bar would be moved to the top of the booth. This top-center bar could be used as a mounting point for a hand scanner at the request of Dr. Choi. Additionally, this left one side of the booth open as a designated opening.

2.2.2 Mechanical Components

There are six main components sourced for the booth included: closed gusset brackets, T-slotted framing monitor mounts and positioning arms, T-slotted framing slides, T-slotted framings, T-slotted framing end cap, and rail-to-rail glide panel slide. These components were all sourced and ordered from McMaster-Carr.

2.2.2.a Closed Gusset Bracket

The closed gusset bracket is a part of the that is responsible for the holding of all the bars at different joining points. There are 12 closed gusset rackets used in the assembly of the booth. Three closed gusset brackets are used at each four-meeting points which can be viewed in figure 14**.** Figure 5 shows the engineering drawing.

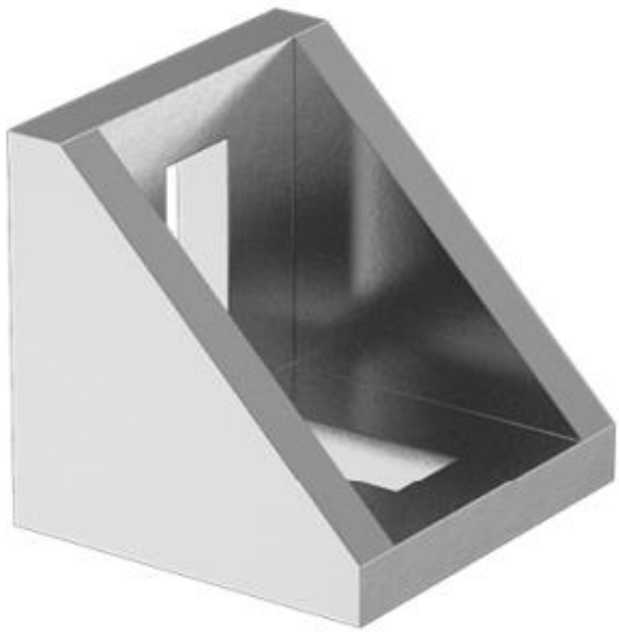

Figure 4 Sample of closed gusset bracket.

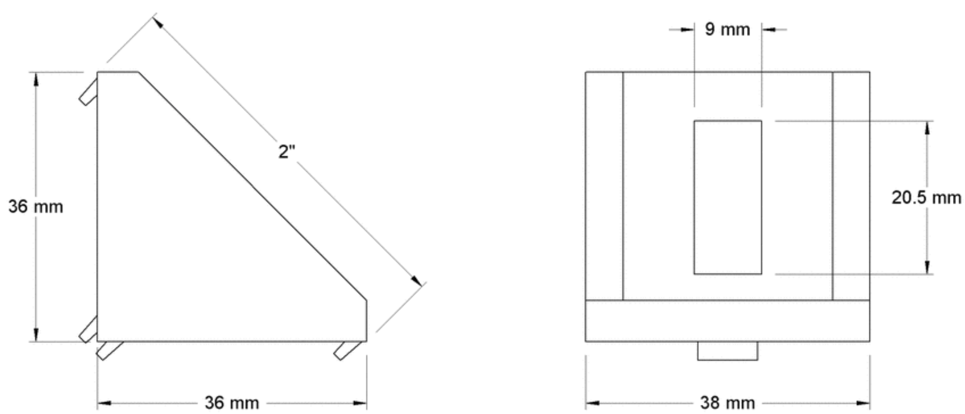

Figure 5 Engineering drawing of closed gusset bracket.

2.2.2.b Ball-Grip Positioning Arm for Hand-Held Devices

The ball-grip positioning arm for hand-held devices is an important part of the booth that is responsible for the gripping of the camera. This part consists of two balls-like heads, one at the top and bottom. This gives the model the chance to rotate at desired degrees to get a clear picture of the object with a camera. The two figures in a and b show the object and drawing.

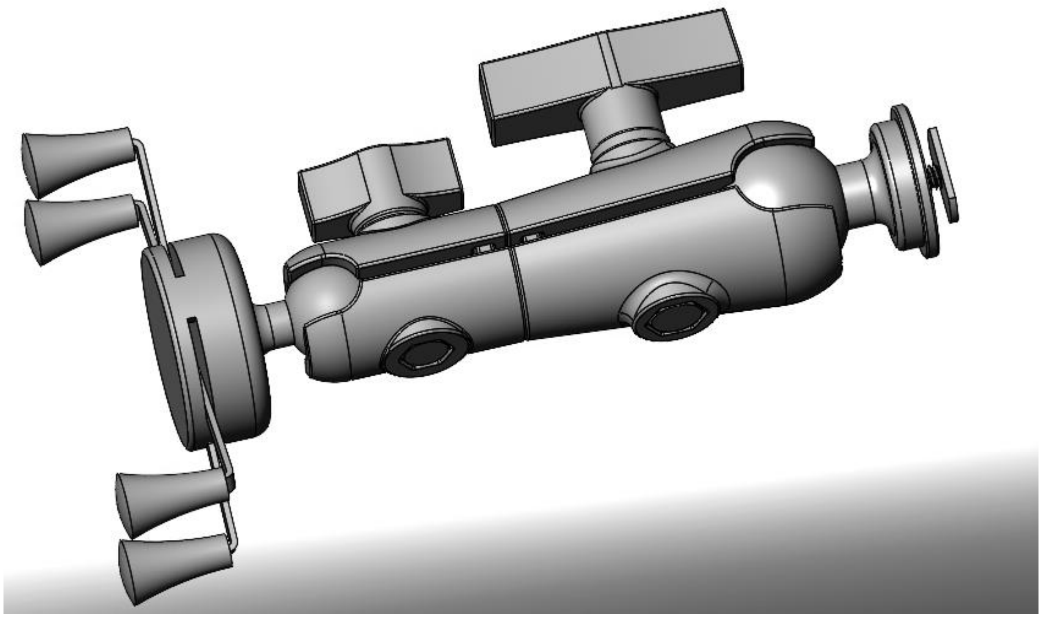

Figure 6 Sample of ball-grip positioning arm for hand-held devices.

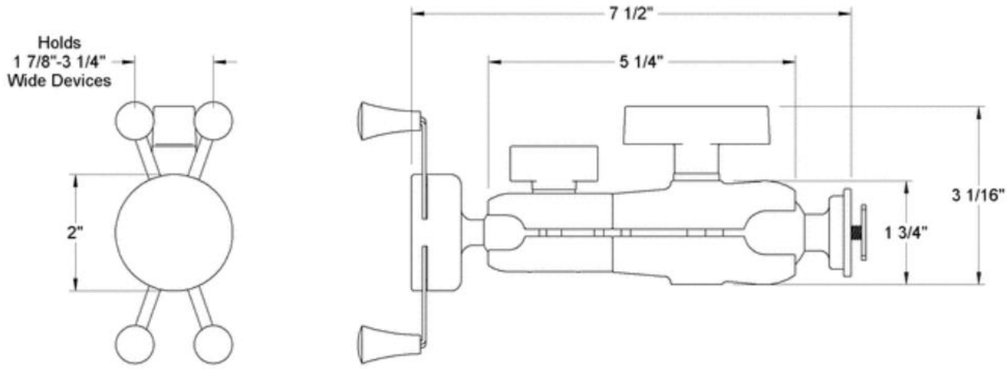

Figure 7 Engineering drawing of ball-grip positioning arm.

2.2.2.c T-Slotted Framing

The T-slotted frame is the backbone of the booth. Every other part of the booth is connected to the T-slotted frame. It was important to choose a material that was strong and could easily span around 6ft with a load placed on it. Additionally, the slotted nature of the rails was important for mounting.

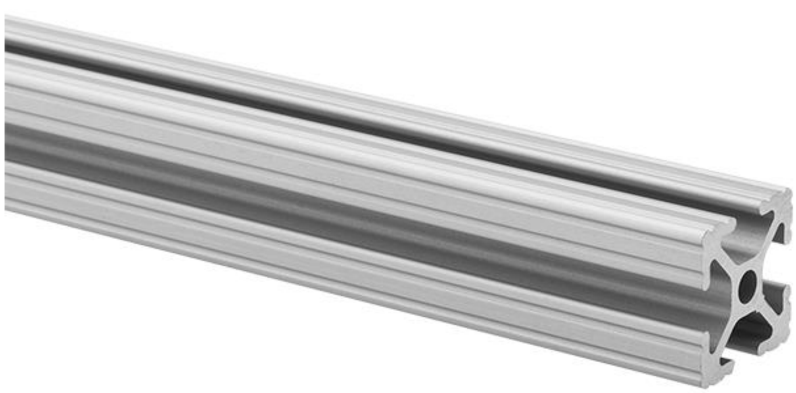

Figure 8 Sample of single four-slot aluminum rail.

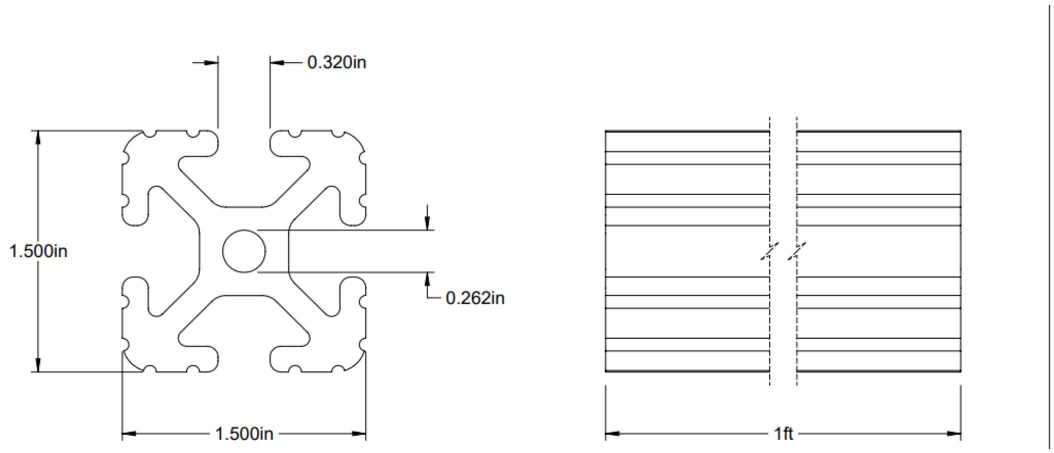

Figure 9 Engineering drawing of single four-slot aluminum rail.

2.2.2.d Rail-to-Rail Glide Panel Slide

The rail-to-rail glide panel slide is the connector of the T-slotted frame that was to carry the cameras. It gave the bar the opportunity to slide up and down with the operator's help. However, these guides did not lock in place and could slip out of the rail given the sizing. This meant that a different system would have been developed in place to hold the bars. After the redesign, these rail slides were deemed unnecessary.

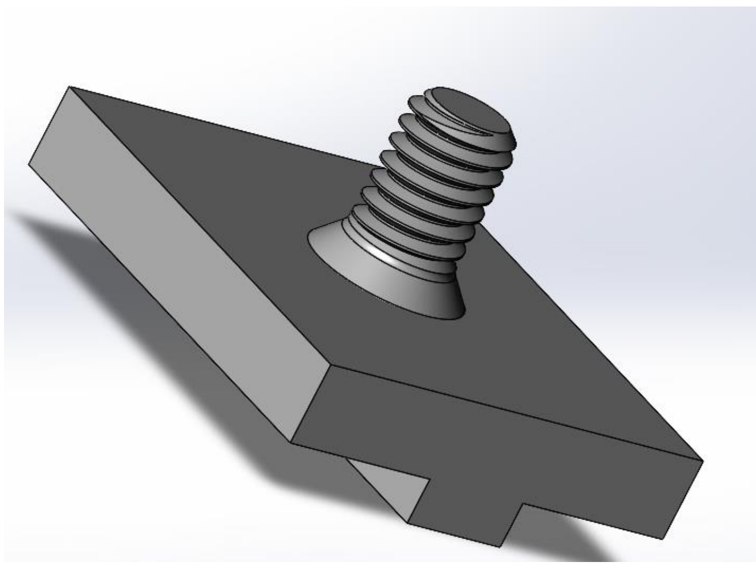

Figure 10 Sample of rail-to-rail guide.

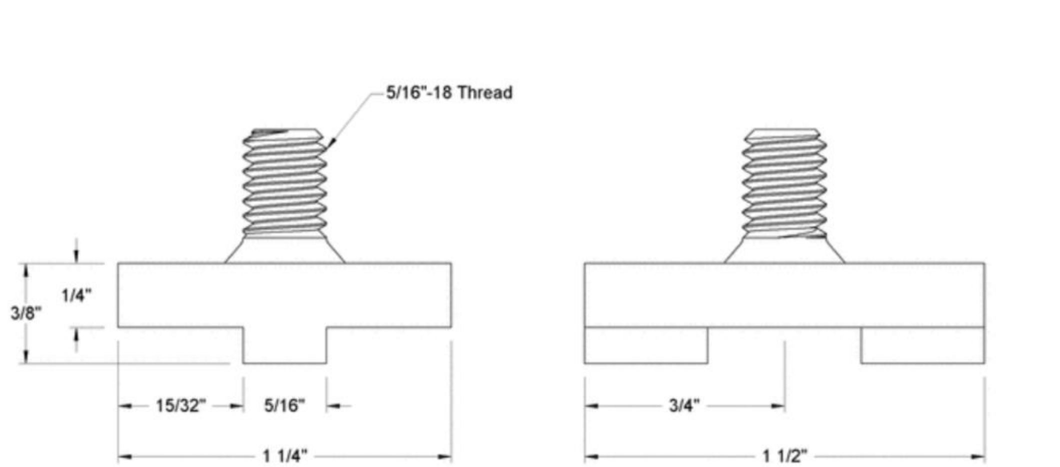

Figure 11 Engineering drawing of rail-to-rail guide.

2.2.2.e T-Slotted Framing End Cap

Finally, the T-slotted framing end cap makes the end of the T- slotted frame look neat. The end cap helps cover the sharp edges of the frame from injuring anyone who mistakenly contacts them. Also, they allow the rails to contact the flooring in a softer fashion.

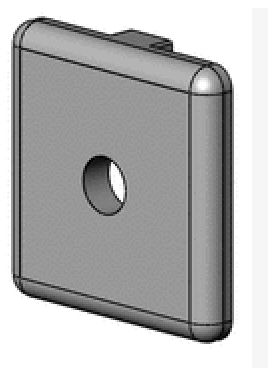

Figure 12 Sample of T-slotted end cap.

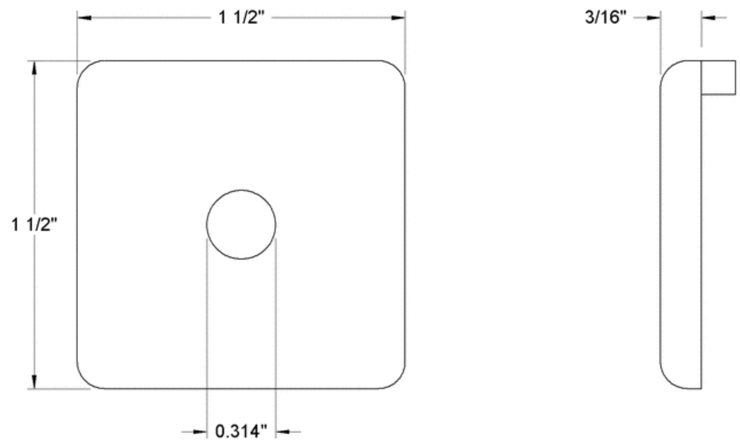

Figure 13 Engineering drawing of T-slotted end cap.

2.2.2.f Assembly

All the components above were assembled to create the final booth structure. The rails of the booth were connected through the gusset brackets and accompanying hex bolts. Rail-to-rail guides were not used in the final structure due to the redesign. The positioning arms were slid into place on the four vertical rails to hold the cameras. Finally, the endcaps were placed on the bottom of the four vertical rails as feet caps.

Figure 14 Assembled booth based on initial design.

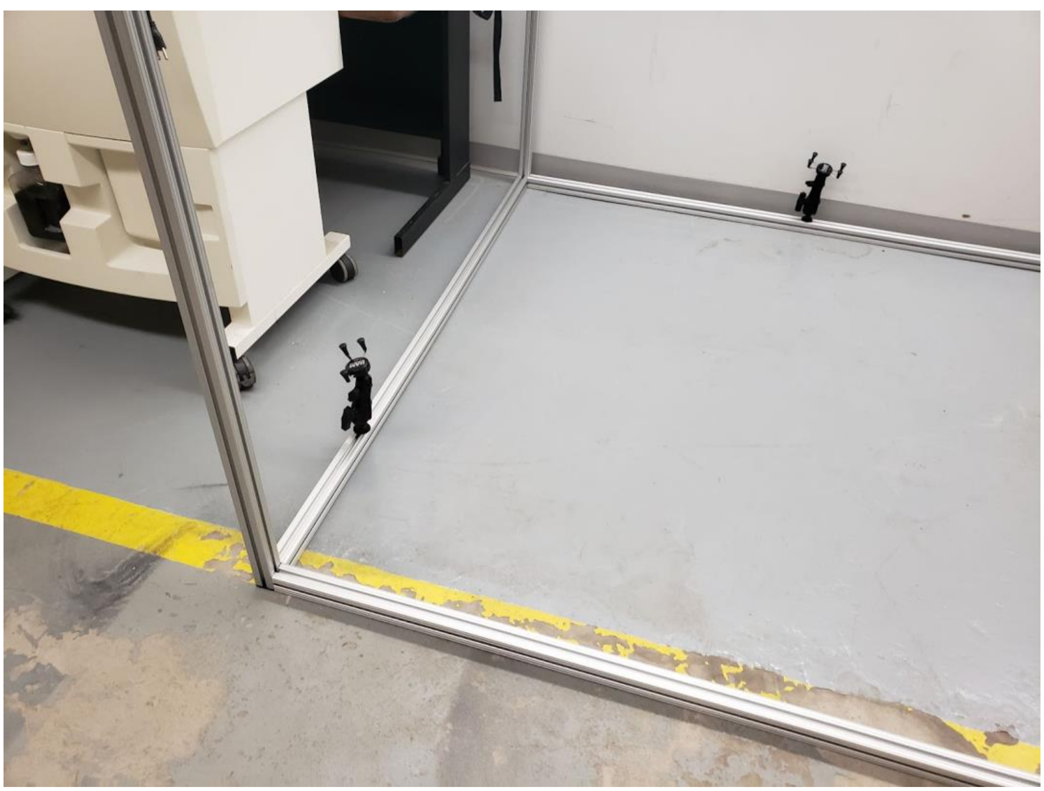

Figure 15 Another view of the initial design assembled.

2.2.3 3D Printed Components

For the project, various parts were fabricated using 3D printing. These 3D parts mainly took the form of clips or mounts and printed using personal material extrusion 3D printers. A mix of PLA and ABS was used to create the parts. The first part created was a simple wire clip that could hold the wires in place neatly that travel around the booth. Mounts were made for the Arduino, breadboard, and the two upper cameras. The last parts 3D printed were the housing for the hand trigger.

Figure 16 3D printed camera mount on right with two earlier iterations on left.

3. Design Verification

Testing for the photogrammetry booth mostly took place in the second half of the Fall 2022 semester. Testing for the booth included getting functional results and optimizing certain parameters. More specific details are below.

3.1 Electrical Verification

While most testing was done during the second semester, some testing was done on components during the first semester, namely the camera. The size of the booth was highly dependent on the camera selection given that they needed enough distance to capture good images. The first camera was chosen due to the cheaper price and reported image quality. However, after testing, it was revealed that the first camera gave the team poor image data. From that, a new Kodak camera was selected that created much better photos for only about $50 more.

Testing was also required for the Arduino, circuits, and selected electrical components. As mentioned, the transistors chosen were recommended by Dr. Ky-Shin Lee and they worked as expected once the circuit was complete. The circuit had two main iterations, one where all the cameras were wired through a single transistor and the final iteration where all the cameras had their own transistor. Having the cameras run through one transistor would leave extra transistors for additional features and allow for tighter activation time. However, using one transistor caused electrical issues such as when a camera was shut off, it would cause the other cameras to take pictures. For that reason, all the cameras were given their own transistor.

3.2 Mechanical Verification

Since most of these parts are physically held it is much easier to put them together for the verification process. All the parts highlighted above were assembled to achieve the desired model. The verification process was focused on the movement of the bars with the cameras and the stability of the bars. The closed gusset bracket is another part that is essential in holding the T-slot bars together. Putting together the bars were slid to the desired position and the goal was achieved. In summary, all bars are functional and can be moved as seen in the picture below.

Figure 17 Assembled booth based on final design.

3.3 General Verification

With verification done separately on the electrical and mechanical side, it was time to bring the booth together. There were attempts made to get the booth to fully function correctly. The first attempt was unsuccessful as the Arduino and breadboard were having voltage issues. For that reason, all the cameras on hand were fired manually to achieve results. Photos were taken of stuffed animals as subjects. Each of the stuffed animals was different in size to simulate different sized dogs. The four lower cameras were put in place inside the mounts and angled to the correct orientation. The results of the first attempt revealed issues with the booth, but the size and placement of the cameras was deemed satisfactory.

The second attempt at getting the booth to work was half successful. Changes to the wiring and code for Arduino seemed to fix the original voltage issues, but further issues arose as seen in the third verification attempt. Wire clips were 3D printed for the second attempt and this allowed the wiring to be left in place as opposed to being scotch taped to the frame. The first and second attempts also only

used the four lower cameras as mounts for the two upper cameras were not available yet. The electrical side worked sporadically, and images were able to be captured.

The third and last attempt was also half successful. Mounts for the two upper cameras were now designed and printed which allowed for full testing. However, electrical issues cropped up again which meant that booth did not work reliably. At this point, one of the cameras was not working correctly, so only five images were captured with the system while one was fired manually. From this testing, it is believed that the issues stem from use of the breadboard and the booth's location. The original voltage issue was fixed but given the open nature of the breadboard and the location of the booth by operating machines, the most likely culprit of the remaining electrical issues is due to interference. Higher electrical currents in the air around the booth cause issues with open contacts on the Arduino and breadboard. If given a proper enclosure, it is possible that the system would work more reliably. Also, some kinks in the circuit may have an issue with current flow resulting in the lower reliability.

After three rounds of half successful testing, the team tried to use the gathered photo data to create a 3D model. The first attempt was with Autodesk ReCap, a software meant for creating 3D models with photos. After installation, it was found out that ReCap is mainly for mapping out physical spaces and required at least 20 photos. The next attempt was with 3DF Zephyr, but the program would not function correctly. The third attempt was with RealityCapture, but the software was not usable without a license and that was not available to the team. The final attempt was with Meshroom, a free and open-source software meant for creating models with photo data. This software would also fail to create a model with the given data. The six images used for testing can be seen below.

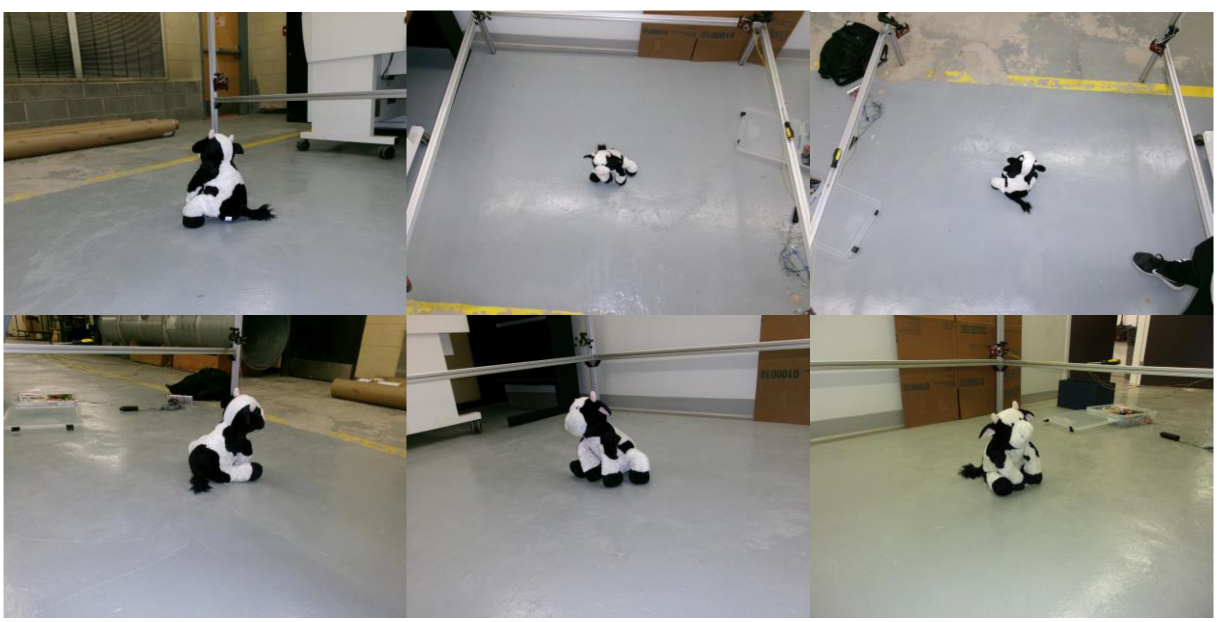

Figure 18 Test photo data of stuffed animal.

Figure 19 Test photos with larger subject.

Figure 20 Test photos with smaller subject.

4. Costs

Listed below are the final Bills of Materials for the electrical portion and mechanical portion, respectively. The parts for this project were purchased primarily by Dr. Choi and his University of Akron Research Account. Table cells colored gray indicate that the part was purchased by team members. Labor for this project was exclusively done by the team except for machine shop services by Aaron Trexler, the instructor. This project had an estimated cost of $2277.57 over the Spring and Fall 2022 semesters.

4.1 Electrical Bill of Materials

Table 1 Electrical Parts Costs

Part	Manufacturer	Retail Cost	Quantity	Total Unit Cost
Digital Camera (1)	IEBRT	$51.99	1	$51.99
Digital Camera (2)	Kodak	$99.99	1	$99.99
Digital Camera (3)	Kodak	$99.99	5	$499.95
Wires (per ft.)	McMaster-Carr	$0.32	100	$32.00
Wires	Fermerry	$16.99	1	$16.99
SD Card	SanDISK	$9.99	5	$49.95
Transistor	Digi-Key	$0.42	10	$4.20
Arduino UNO Rev3	Elegoo	$39.49	1	$39.49
Glarks Connectors	Glarks	$14.91	1	$14.91
Total (Purchased)				**$730.08**
Total				**$809.47**

4.2 Mechanical Bill of Materials

Table 2 Mechanical Parts Costs

Part	Manufacturer	Retail Cost	Quantity	Total Unit Cost
T-Slot Frame (8ft.)	McMaster-Carr	$83.22	4	$332.88
T-Slot Frame (6ft.)	McMaster-Carr	$58.87	8	$470.96
T-Slot Endcap	McMaster-Carr	$2.30	4	$9.20
T-Slot Rail Guide	McMaster-Carr	$5.17	8	$41.36
T-Slot Position Arm	McMaster-Carr	$81.22	4	$324.88
T-Slot Bracket	McMaster-Carr	$9.82	24	$235.68
Total				**$1468.10**

5. Conclusion

5.1 Accomplishments

From the start, the team set out to build a functioning prototype of a pet photogrammetry booth. The result is a prototype that works unreliably. However, testing allowed the size and possibility of the booth to be proved.

5.2 Uncertainties

The current system can function, but it is unreliable. The current system in place has some more leg room, but looking at it now, the team believes a different approach ma provide better results as detailed below. The current size of the booth also may not be suitable for extremely large dogs.

5.3 Ethical considerations

Given the nature of the prototype booth, there were no ethical considerations at play. However, if commercial photogrammetry were to come into play in the future, ethical considerations would have to be made for the pets inside. Safety for the pet would have to be considered. Lighting, which would have to be custom, would also have to be considered so as not to irritate or harm animals inside. Electrical components would have to be covered so as not to shock or harm users or animals as well.

5.4 Future work

There are two main paths that this project can go down, but regardless of which, the current team believes this project should be handed off to electrical or computer engineers. Given that most of this project relied on the electrical side, having students that better understand electrical concepts and components would greatly benefit the project.

From that, there are two main paths that this project could continue down. The first path is to continue with the currently available electronics and design. The Arduino allows for a more extensible system, but it is limited. Given that, the team believes the best course of action is to pursue a Raspberry Pi system with custom camera modules. Raspberry Pi computers are much more extensible, but they also take a lot more knowledge to up and running. Additionally, handling 4+ camera modules with a Raspberry Pi would facilitate a custom PCB which is much closer to electrical engineering. Given the size and price of camera modules, it is possible to fit plenty more inside the booth to gather more photo data as well.

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Appendix A Requirement and Verification Table

Table 3 System Requirements and Verifications

Requirement	Verification	Verification status (Y or N)
1. Stable Structure	1. Does it stand?	Y
2. Proper Size	2. Works with multiple sized pets?	Y
3. Camera Triggering	3. Is it simultaneous?	Y
4. Reliable Triggering	4. Can it be done with confidence?	N