Mini Project 2: 3d scanner

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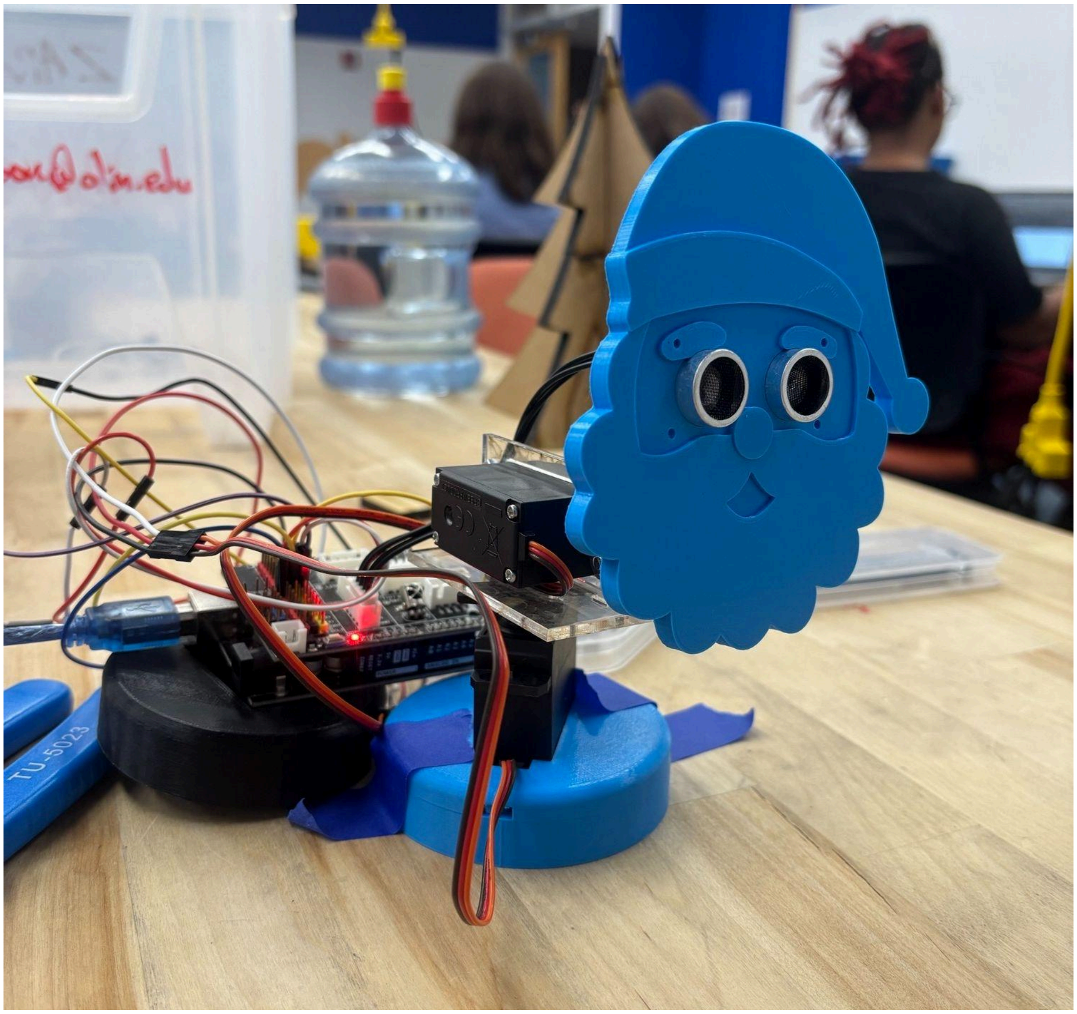
9/26/25



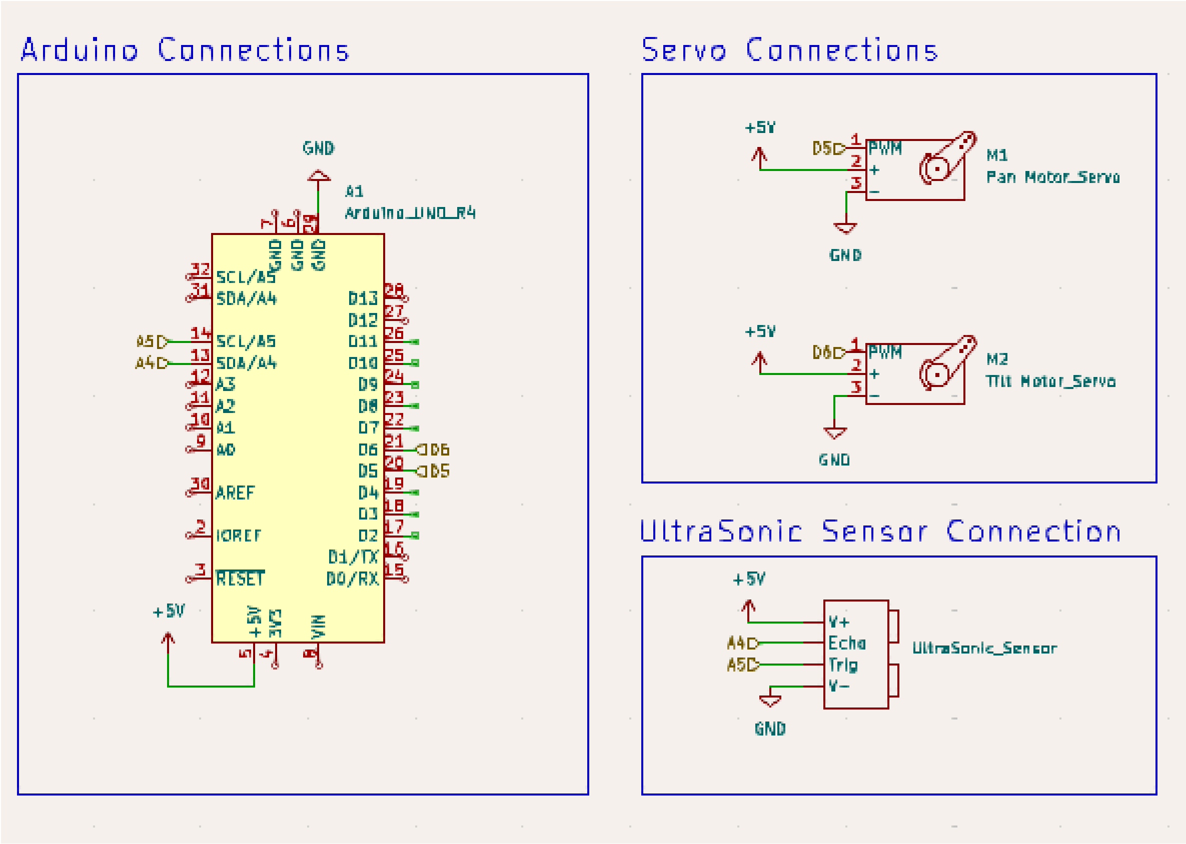
Project Introduction:

We created a pan/tilt mechanism using the 2 servos and 1 distance sensor provided for us that is controlled by an Arduino. Since the servos and sensors must be returned after the mini project, we mechanically designed our project so that we could disassemble our design. We transmitted servo angle and distance information from our sensor to our laptop for storage and, ultimately, visualization. Using a software package of our choice (Python) we created a 3D visual representation of an object of known, well-defined geometry, for our example we used a christmas tree. We themed our project around Christmas.

Electrical Circuit

The electrical circuit of our project was very straightforward. We had our 2 servo motors each connected to the +5V and GND pins, then each servo motor's signal was connected to Digital Pinouts. For our distance sensor we decided to use an HC-SR04 Ultrasonic sensor because it was more accurate than the infrared sensors provided to us in class. The HRC-SR04 Ultrasonic sensor was connected to +5V, GND, a trigger pin and an echo pin. The trigger tells the sensor to send a sound wave and the echo pin receives the reflected wave. We also attached our Arduino to an Arduino Shield so that wiring would be easier, but it does not change the circuit schematic or affect the circuit at all. Our complete circuit schematic can be seen in Figure 1. We also attached an image of our Ultrasonic sensor which can be seen in Figure 2.

Figure 1



Full schematic of Electrical Circuit & Arduino

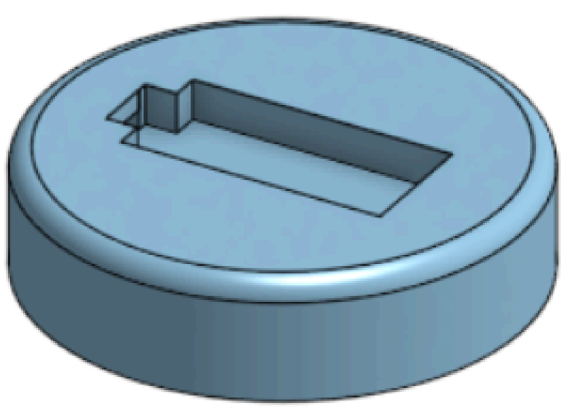
Figure 2

UltraSonic Sensor

<u>Mechanical Design:</u>

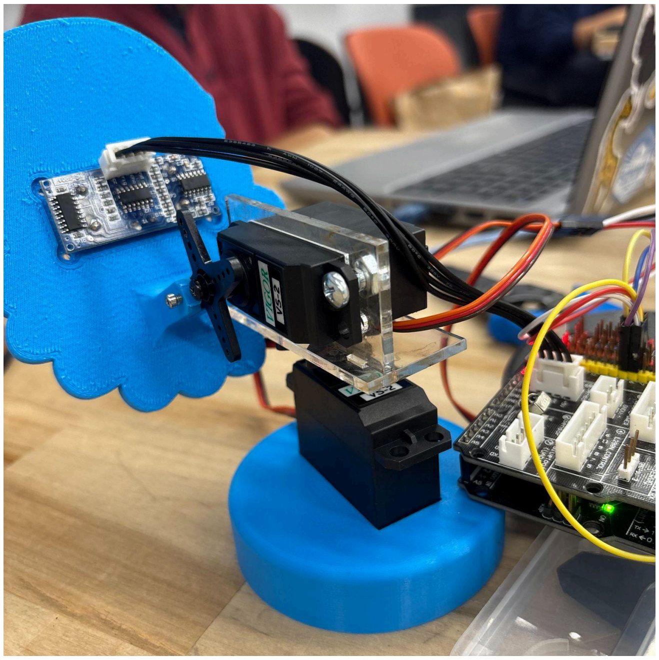
The mechanical design of our project was done using OnShape and 3d printed on Prusa i3 Mk3 3d printers. We created a circular base to hold the project steady which can be seen in Figure 3. To create our pan & tilt mechanism we created an L bracket out of acrylic using Helix laser cutters in the shop. The L bracket was designed so that the bottom servo rotates the top servo along the x-axis (AKA it lets the pan & tilt move horizontally), and the top servo rotates the ultrasonic sensor along the y-axis (AKA lets the pan & tilt move vertically). The pan & tilt mechanism can be seen in Figure 4. We also created a mount to mount the ultrasonic sensor to the servo motor and designed it to look like a Santa Head with the transmitter and receiver of the ultrasonic sensor as the eyes of Santa. The ultrasonic sensor mount can be seen in Figure 5. Then we created our object to scan modeled as a Christmas tree made out of MDF using the Helix laser cutter. Then we decided to make a 2d cardboard version of our Christmas tree. Our Christmas tree objects can be seen in Figure 6.

Figure 3



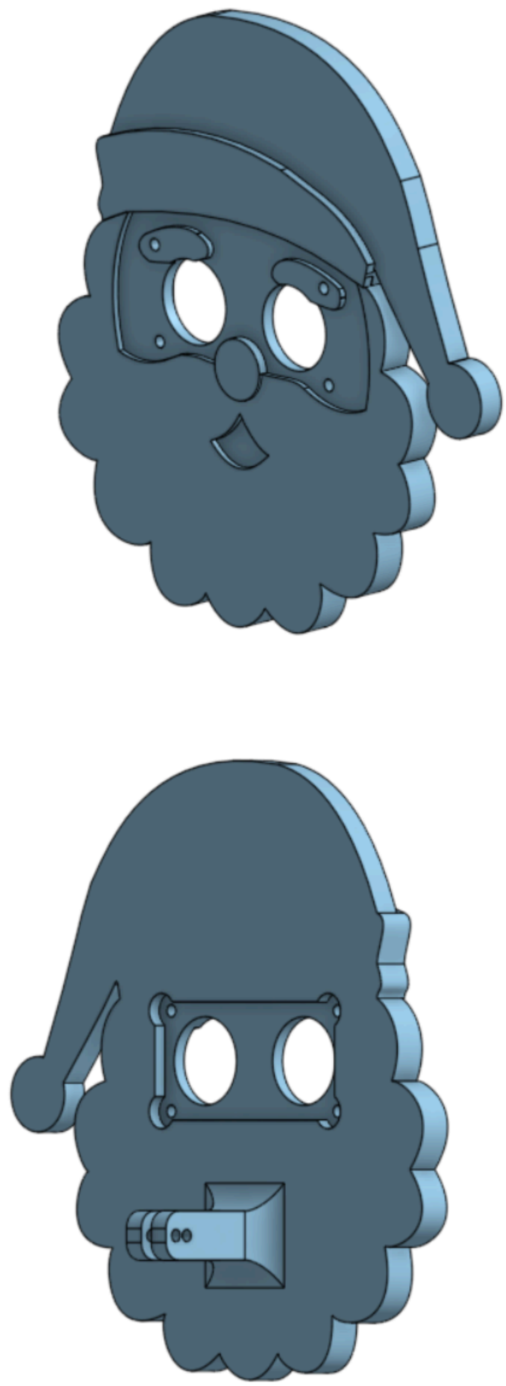
3d printed project base designed in Onshape

Figure 4



Fully assembled pan & tilt mechanism

Figure 5



Ultrasonic sensor mount designed in Onshape (Front & Back)

Figure 6

(Christmas tree objects (MDF & Cardboard)

<u>Software Design:</u>

All of the source code can be found on our GitHub at https://github.com/Zaraius/3d-scanner.

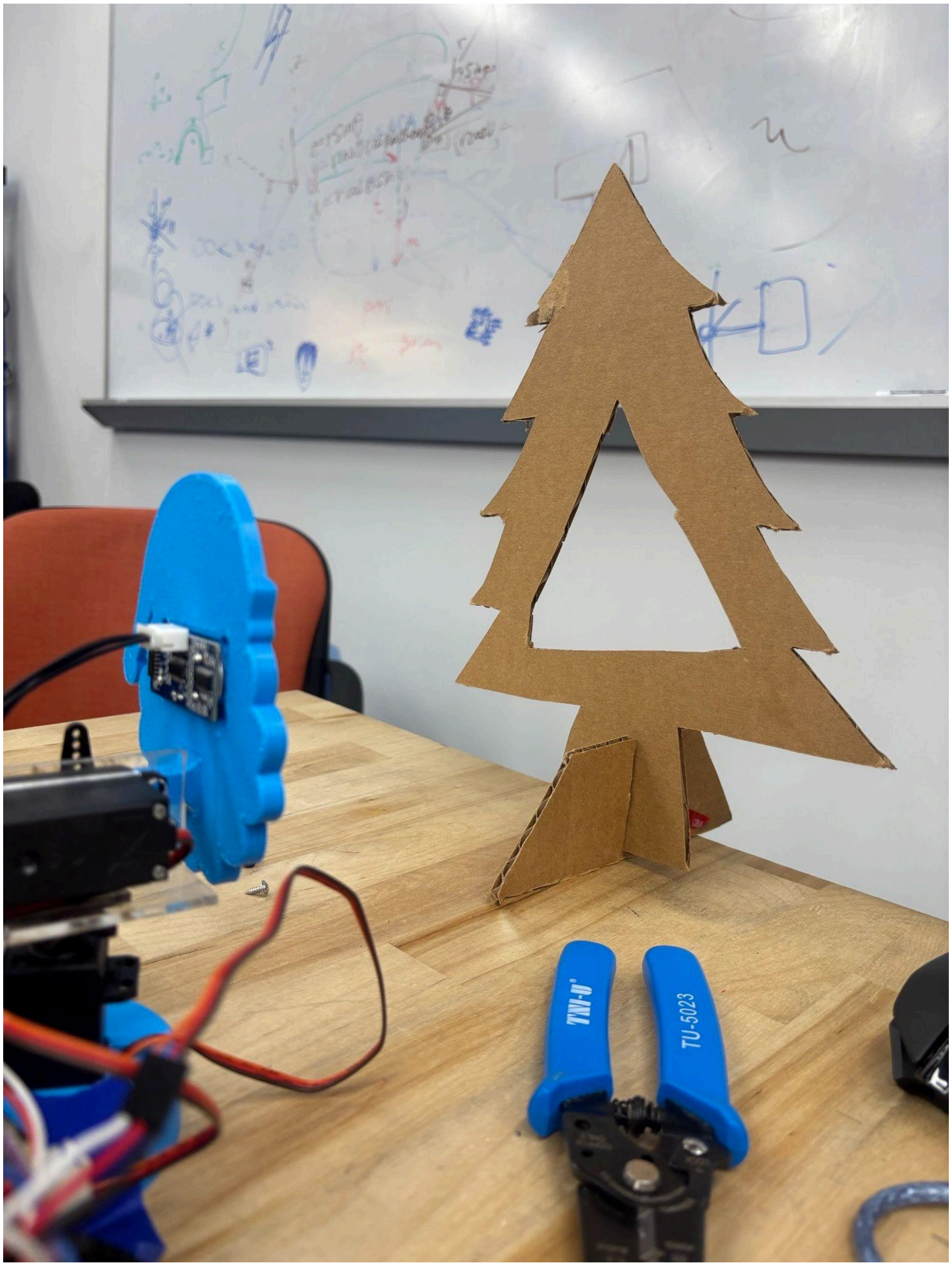
Our Arduino code is arduino_scanner.ino, which moves the servos in a sweeping motion and finds the distance using the ultrasonic sensor. It prints the servo_angle, tilt_angle and duration between the trig and echo signal to the Serial.

Our Python visualizer is 3d_visualizer.py, which connects to the Arduino over serial and takes in the servo_angle, tilt_angle, and duration. It uses our calibration curve, which we calculated earlier and turns the duration between sound waves into a distance measurement. We convert these measurements into x, y and z positions and then display them.

<u>1D scan & 2D scan:</u>

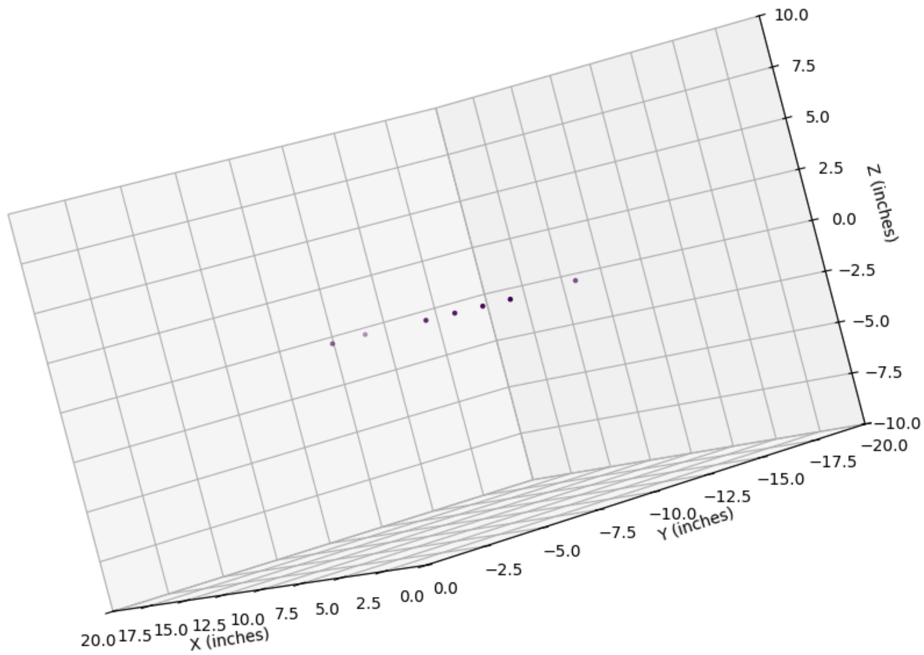
Our 1-dimensional scan is the exact same setup as our 2-dimensional scan except we only move our pan servo. We used the cut-out Christmas tree for this scan which has two edges and then a hole in the middle. The 1D scan setup can be seen in Figure 7, and the plot of our 1D scan can be seen in Figure 8. The final 2d scan can be seen in Figure 9. A side view of the final 2d scan can be seen in Figure 10.

Figure 7



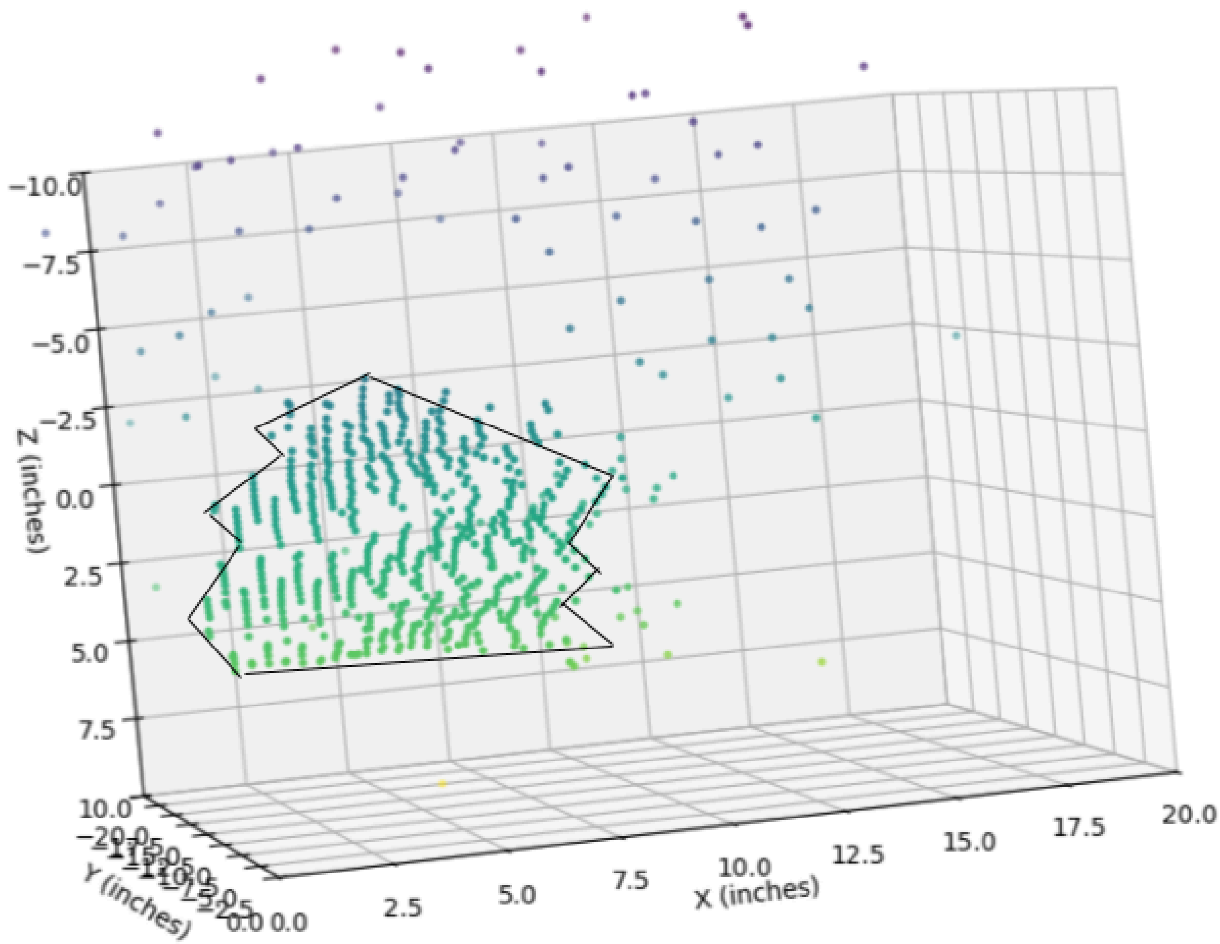
Setup for 1D Scan

Figure 8



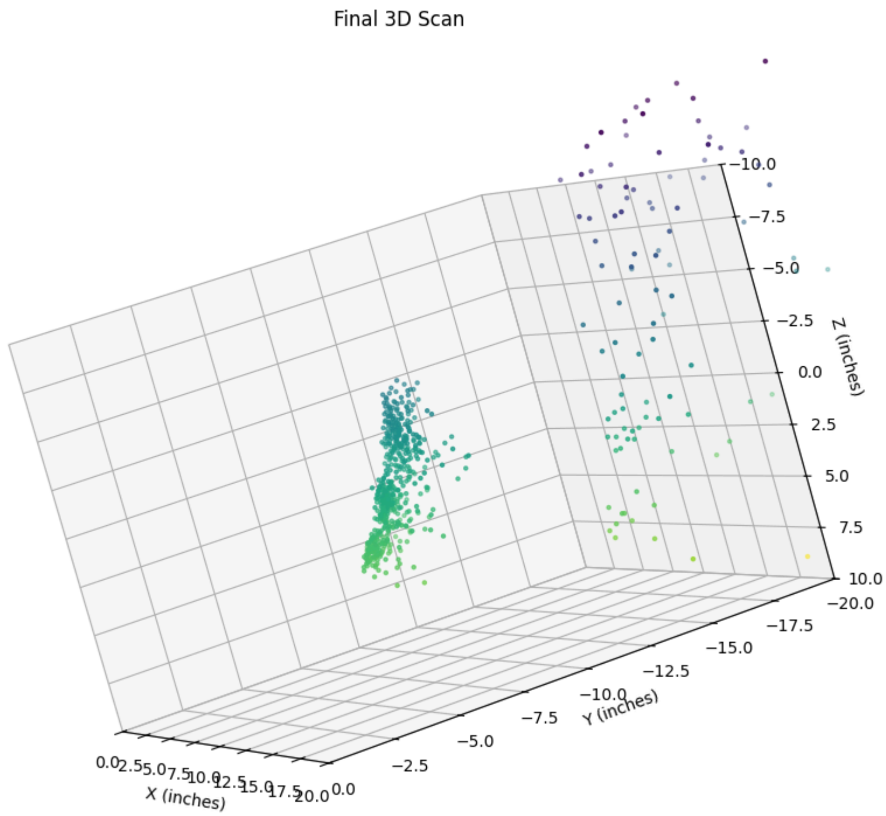
Plot for 1D Scan

Figure 9



2D scan - Front view of Christmas tree(Added an outline around Christmas tree to help visualize)

Figure 10



Side view of Christmas tree and background

<u>Testing & Calibration:</u>

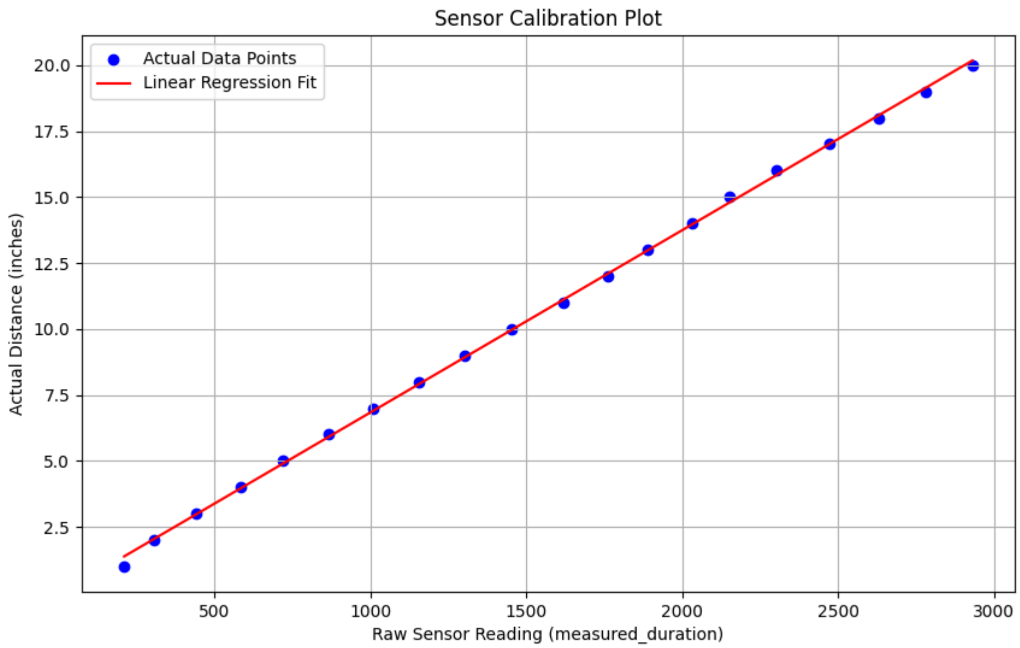
Here we describe the process we used to test our sensor.

To test our HC-SR04 Ultrasonic sensor we put a ruler on the table and held our sensor in place. We took a piece of cardboard and moved it from 1 inch to 20 inches with 1-inch increments and wrote down the duration the sensor took to send and receive the signal. The duration directly relates to the distance because we are measuring how long it takes for the sound wave to travel.

To help us do calibration and testing we created a calibration plot depicting analog voltage readings vs actual distance in Figure 11 below. We also created an error plot showing the predicted distance and actual distance for distances not included in our calibration routine which can be seen in Figure 12.

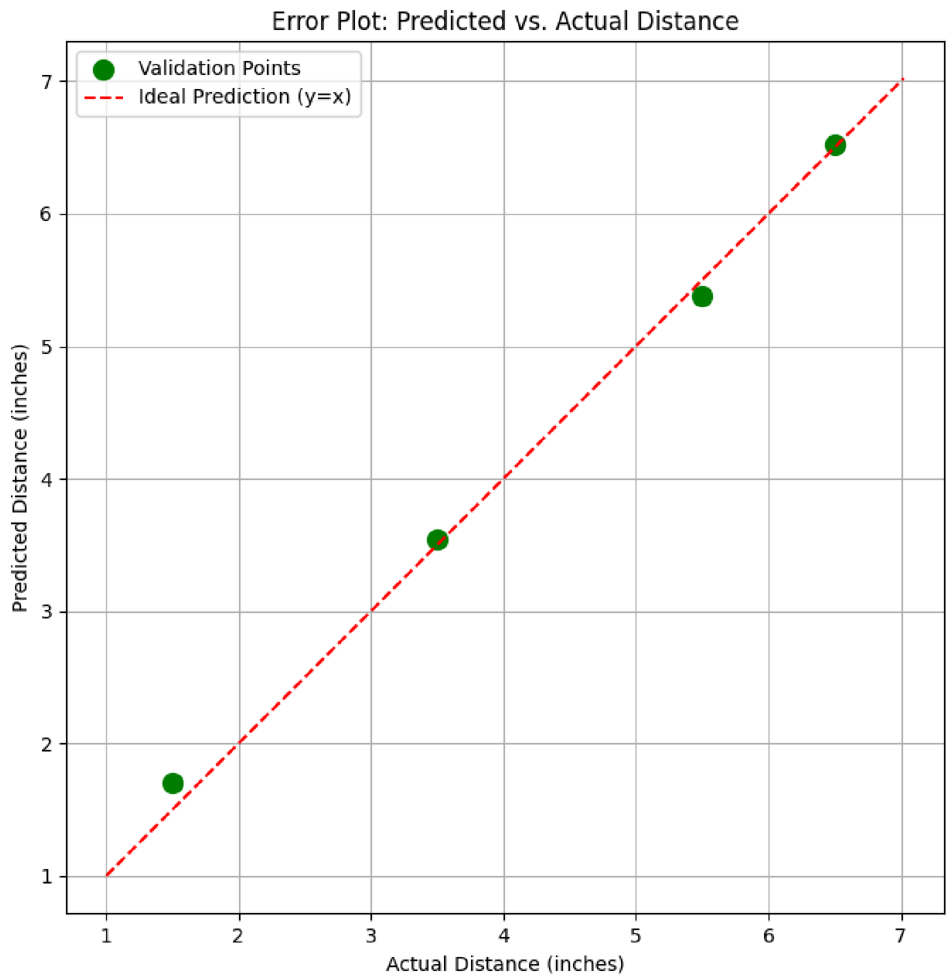
Since this was an Ultrasonic sensor, we already knew what the conversion should have been, which is (time * the speed of sound)/2. As an additional check, we compared our calibration results to this.

Figure 11



Calibration plot depicting analog voltage reading vs. actual distance

Figure 12



Error plot showing the predicted distance and actual distance for distances not included in the calibration routine

Reflection on design and Demo Video:

Demo Video: https://youtu.be/oV6U0yKGgyw

We are very happy with our electrical design. It was a very clean and straightforward circuit consisting of just an Arduino, 2 servos, and an ultrasonic sensor and we experienced no electrical troubles. The only thing we think we could have improved upon was wire management.

We are happy with our mechanical design as it achieves the goal of the 3d scanner and also has the Christmas theme which we wanted. If we had more time we would've added a housing for our Arduino and routed the wires better. The Arduino could have been out of a reindeer sled with the wires being the ganglion that Santa holds onto the reindeer with. While we did try to account for the ultrasonic position in xyz space changing based on the servo angle, our measurements would have been more accurate if the ultrasonic sensor were closer to the center of rotation. We could have also fixed the ultrasonic sensor mount to the tilt servo more securely and prevented the minimal amount of shaking that we had.

Our Arduino code achieves a scan of a slice of a 3d image but cannot get any information from behind the object which is linked with the mechanical design. Another improvement we could have made is to first find the edges of objects and set that as our parameters which would save time from scanning the background. Our Python code which translates the servo angles and duration of the signal into an x, y, z position has the most room for improvement. We converted using angle positions and basic trigonometry but we aren't fully happy with these results and think the error lies somewhere in this process. We might have incorrectly measured the length from the rotation of the servo to our sensor.