Lab 5 - Final Project Report

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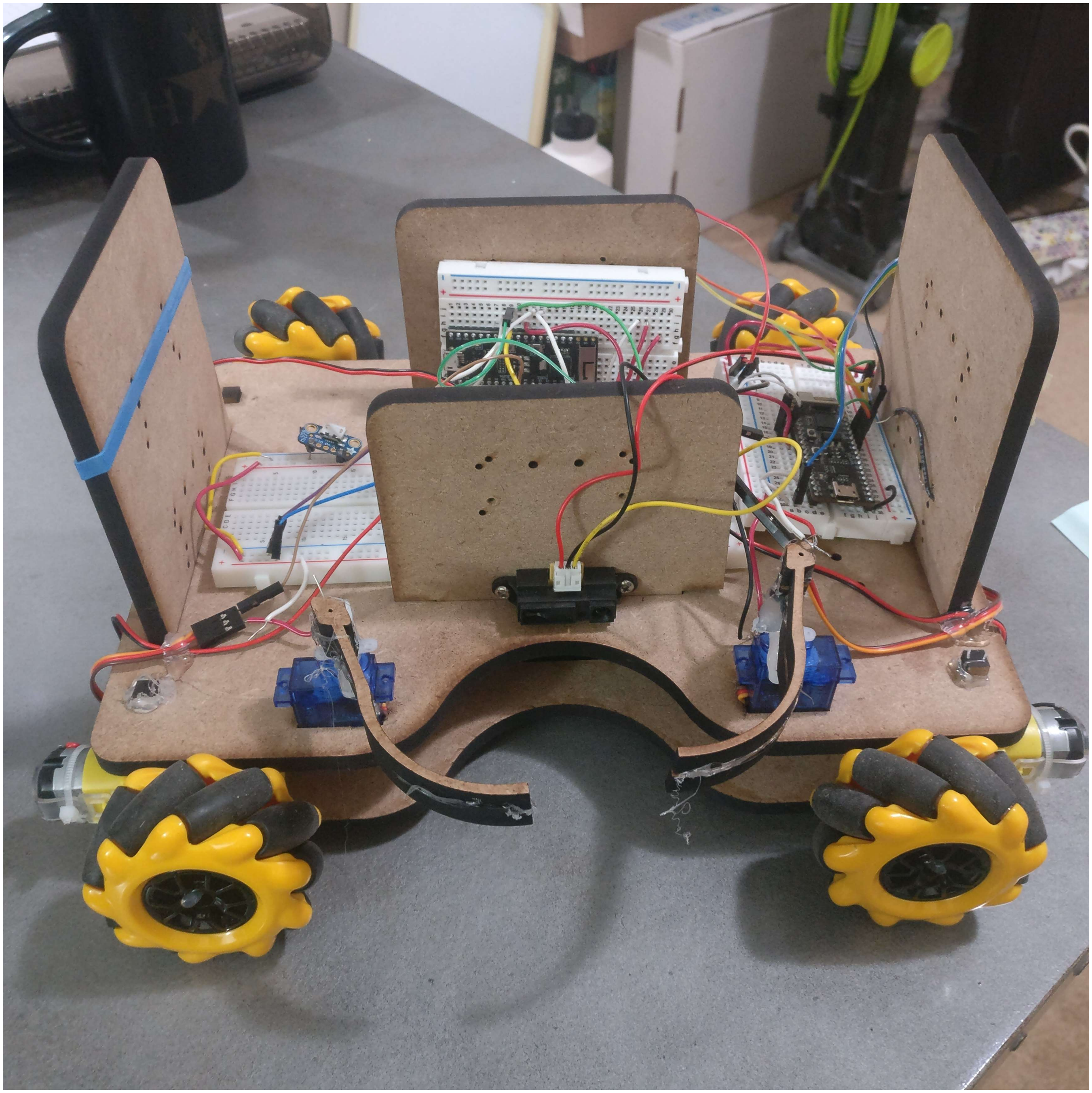
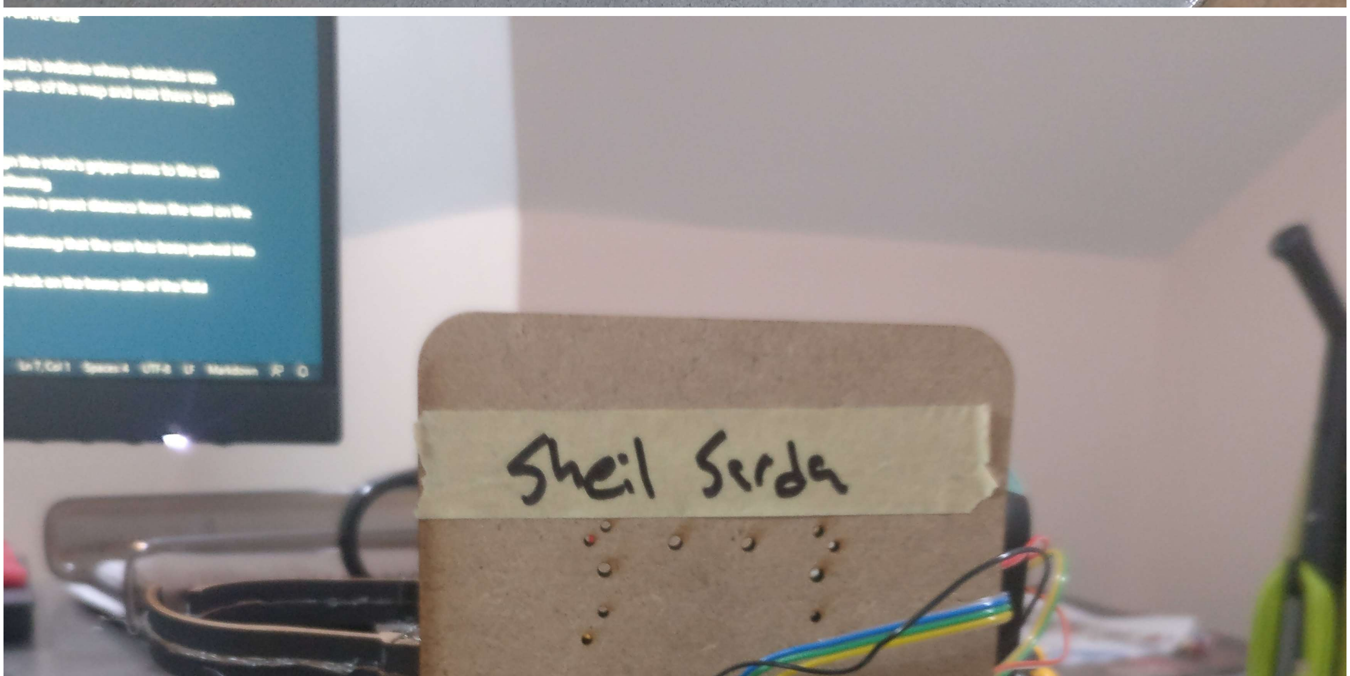
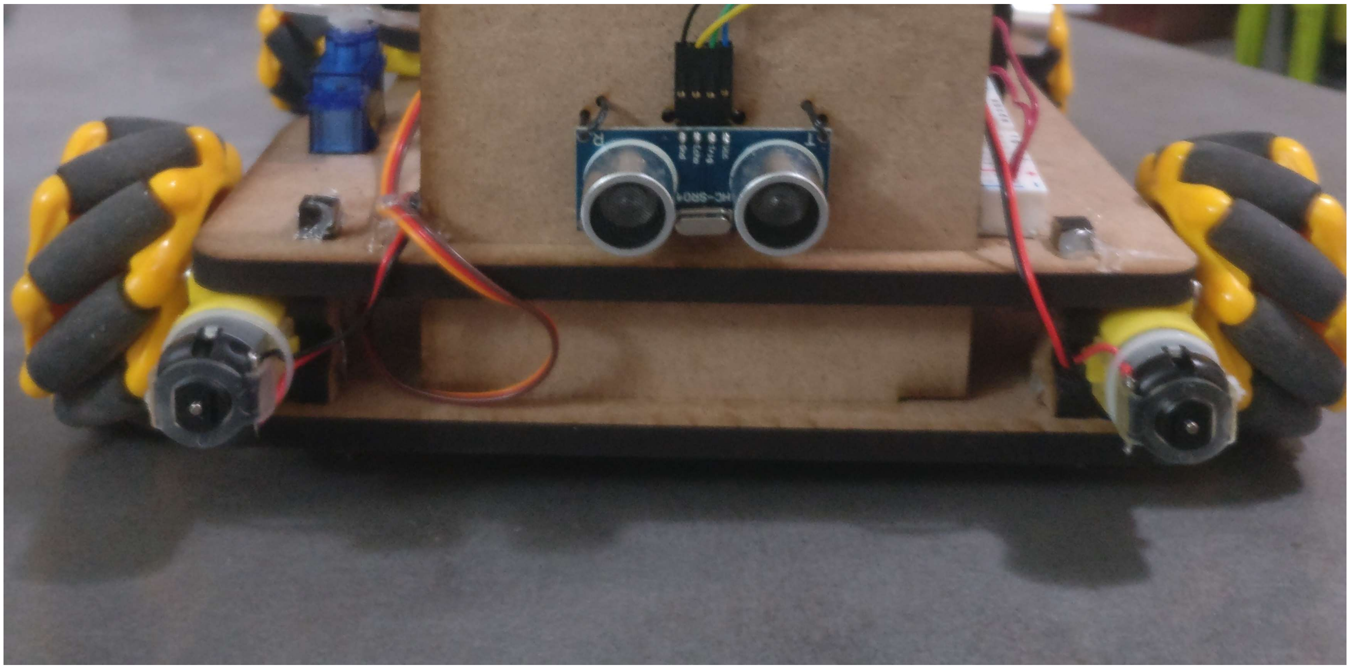
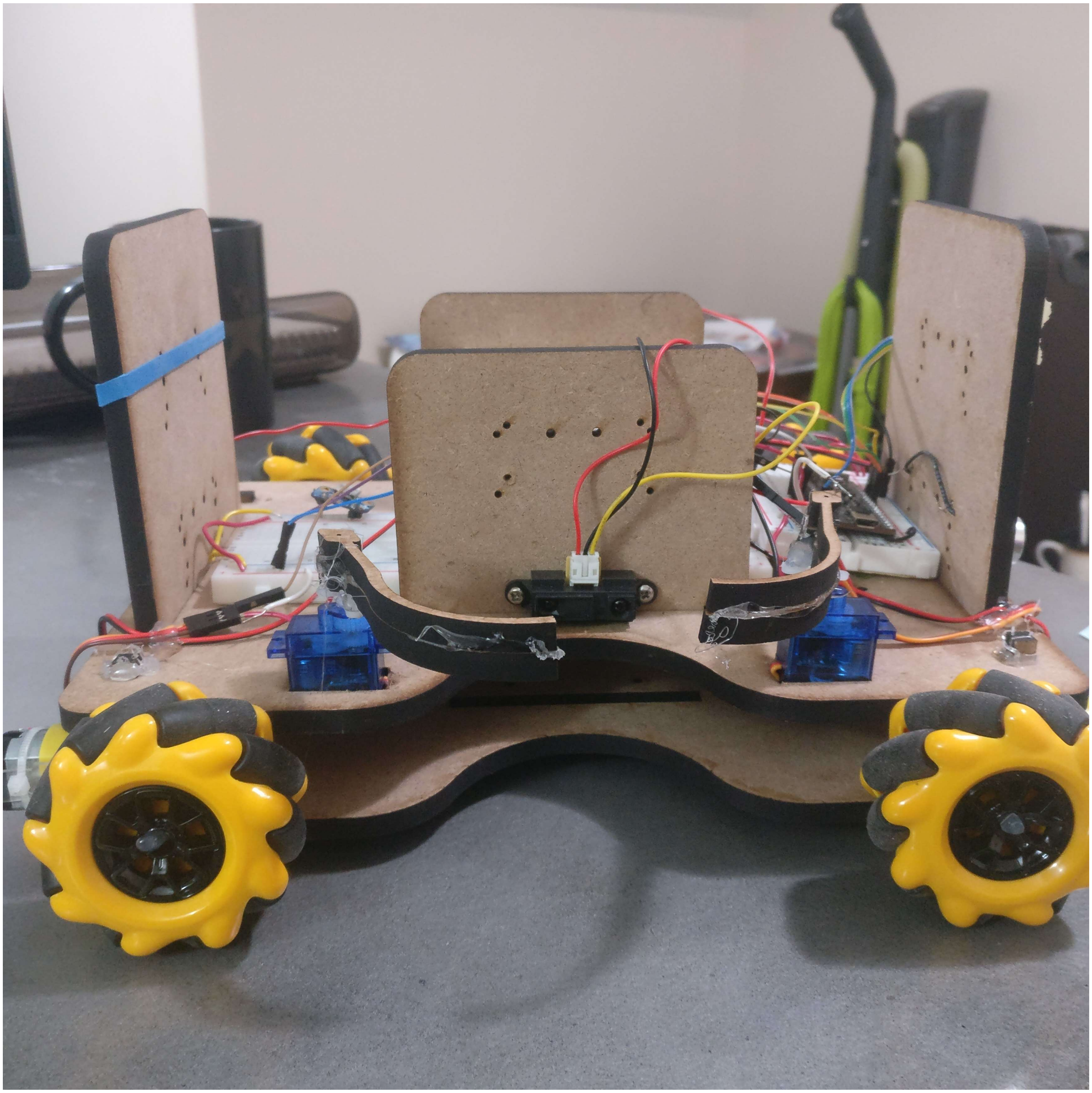
Functionality

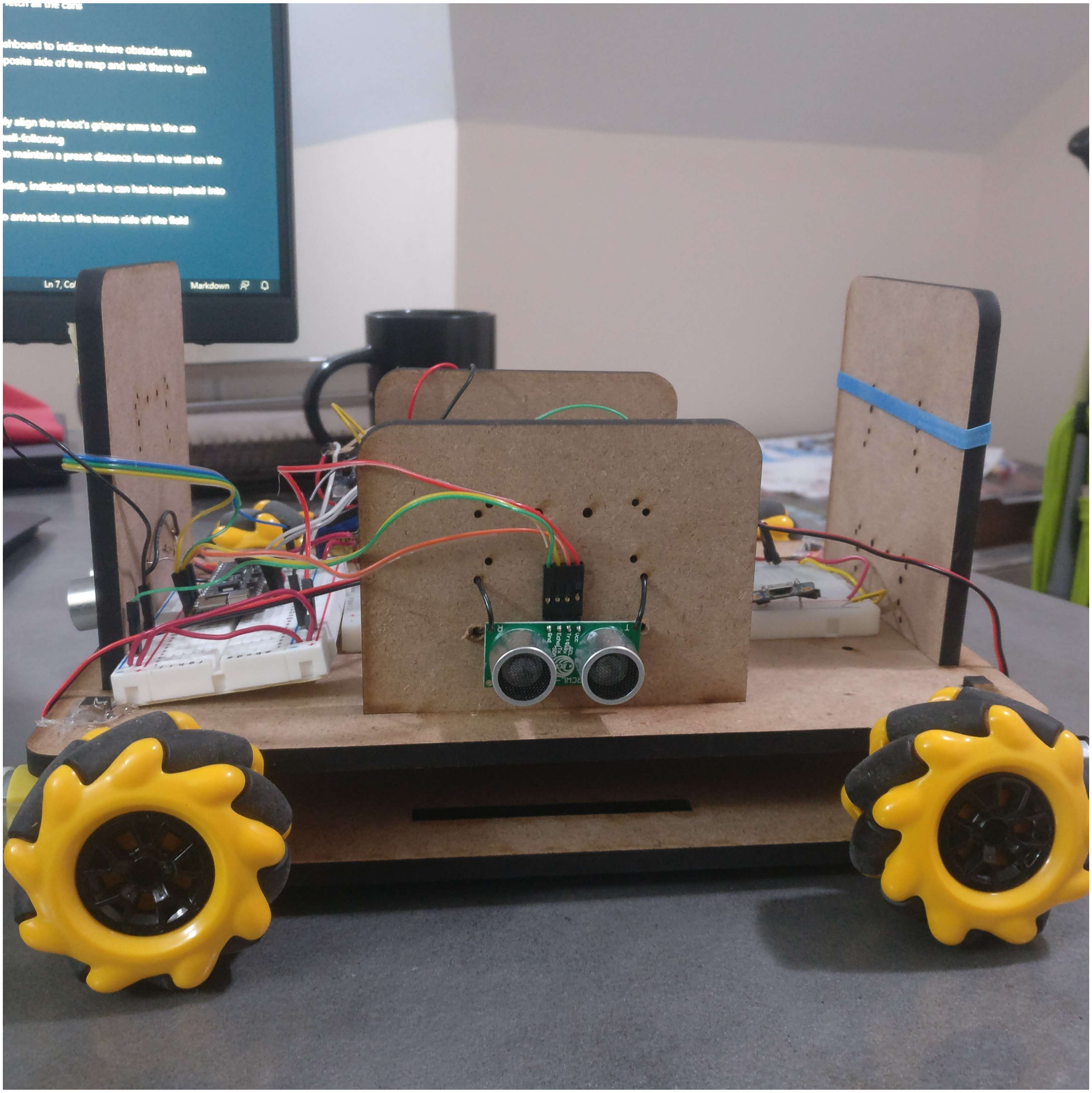
Pictures of Robot




Sheil Serda


HC-SR04





Strategy for the Game (Minimal Functionality)

Can Grabbing

My approach to can grabbing evolved over the course of the competition from using gripper arms to pushing cans and beacons.

Approach 1: **Gripper Arms**:

- Design approved prior for manufacturing used 2 servo motors with arms to lock in the can
- Main challenge with this design was that servo arms did not have enough torque to keep the can locked during movement
- Also the servo horn did not stay locked on to the servo even with the aid of hot glue

Approach 2: **Can Pushing**:

- With holonomic drive the robot can easily navigate around the beacon and push it into the doubling zone
- Only drawback with this approach is the robot cannot pull in cans or beacons that are located near the edge of the map because it doesn't have the space to nudge itself between the wall and can

- Lost a few matches because robot pushed the beacon into the wall and was unable to move it closer to the center
- Partnership with Rafael for the playoff games allowed me to focus on just pushing the beacon into the doubling zone and then venture out in the opposing side to get time points, so did not have to worry about getting cans from the periphery of the map since his nimble robot was able to fetch all the cans

Autonomous Modes

- Left, Right and Front sensor ranging data was available on my dashboard to indicate where obstacles were
- Could leverage wall-following behavior to drive myself to the opposite side of the map and wait there to gain points

Extra Components / Functionality

- Using a short-range Time-of-Flight (ToF) sensor to autonomously align the robot's gripper arms to the can
- ToF range was < 10cm so it would not be sufficient to also do wall-following
- Use the Sharp IR sensor also located on that side of the robot to maintain a preset distance from the wall on the robot's left and detect cans in an interrupt-driven manner
- Once can is detected, minimize the distance that the ToF is reading, indicating that the can has been pushed into reach of the grippers
- Close the grippers, turn 180 degrees, and use wall following to arrive back on the home side of the field

BOM in Appendix

Mechanical Design

Lessons for improvement

- Sensor mounts were too high for the walls of the field, so had to drill new mounting holes in the front, right and left plates to mount the ultrasonic and Sharp IR sensors lower
- Cutout for picking up the can was too small, so it was hard to precisely align the robot to pick up the can just through visual feedback over the internet
- Making motor mounts out of 0.25" MDF meant that I was not able to find long enough screws to go through both sides and secure them with a nut (25mm is the largest size available in the GM lab)

Actual vs Intended performance

Besides the evolving can grabbing approach described in the previsous ection, another difference between simulated vs actual performance was that over time, motors started to wiggle left and right making it harder to strafe with the holonomic drive since the geometry of the wheels was changing

CAD drawings in Appendix

Electrical Design

Actual vs Intended performance

- Actual vs Intended performance was as expected for all the motor driving parts since I was reusing most of the same components from the racecar lab
- Reliably reading sensor data was a new expereince for me, and all went to plan since I was able to use the I2C setup code to relay values from the secondary ESP32 to the primary one

Lessons for Improvement

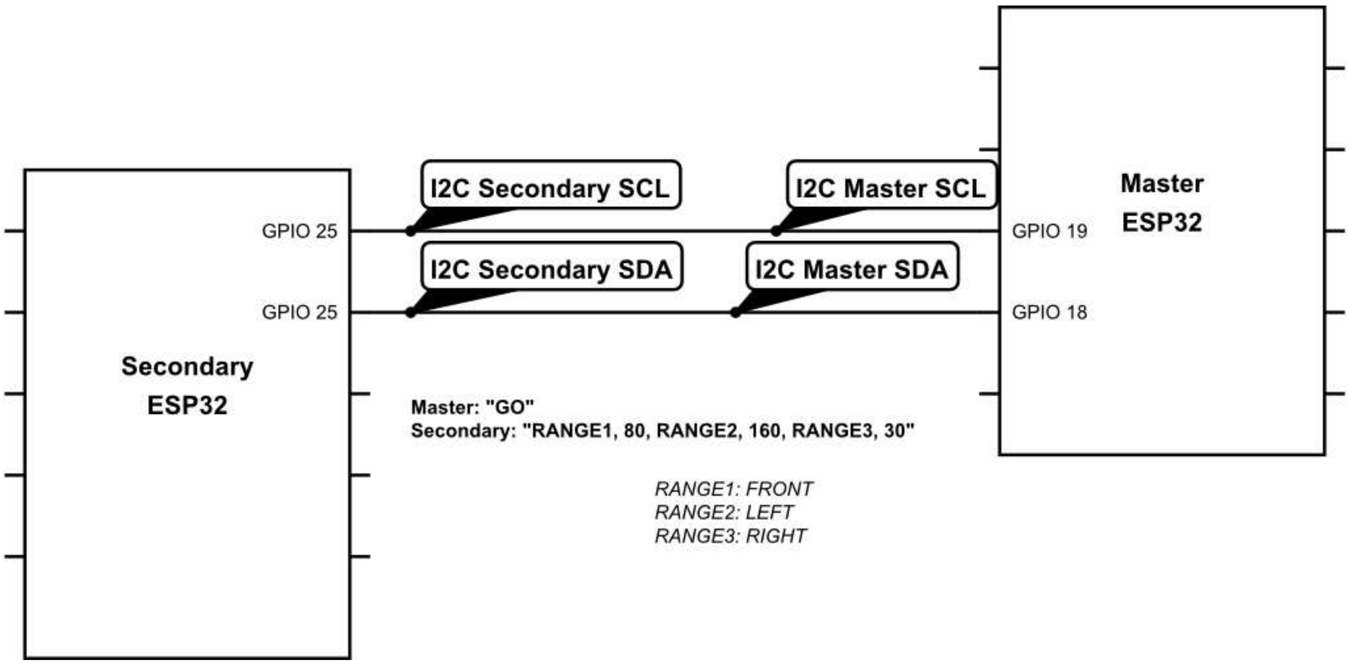
- Plan out the pin-out diagram for wiring all the sensors before purchasing them, since this would have highlighted the fact that I would not be able to use my I2C-based ToF sensor before it was too late
  - I2C pins on my secondary ESP32 were occupied with its connection to the primary ESP32

- As an alternative, could have used a Teensy as a 3rd microcontroller in my circuit, utilizing its master I2C pins, and also connected it to the I2C bus from the secondary to the the primary ESP32

Schematics in Appendix

Processor architecture and code architecture

Block diagram of MCU



Software approach

Used I2C distributed computing approach

- **Master ESP32** was responsible for:
  - Web Server Hosting
  - Motor Control for drivetrain
  - Requesting Sensor data from Secondary ESP32 and doing wall-following + displaying it on webserver via Ranging view
  - Controlling grippers for grabbing cans
- **Secondary ESP32** was responsible for:
  - Using Analog reads to read in data from Front and Left ultrasonic sensors
  - Using I2C to read in data from the Sharp IR sensor
  - Communicating range information to the primary ESP32 via I2C
- **Web Interface** for control:
  - Started with joystick control and customized it for holonomic drivetrain
  - Integrated ranging code on the joystick view
  - Added Gripper open / close buttons
  - Added discrete movement buttons for N / S / E / W movements which propel the robot in precise distances, previously impossible with just the joystick

Lessons for Improvement

Do not underestimate the value of adding more buttons for automating movement patterns that are commonly used in races

- Follow Left / Right wall
- Rotate around the control tower in the center of the map to sweep away cans located there

- Use control law to wall-follow a specific distance away from the wall using text box on web interface

Retrospective

Most important thing learned

- Importance of good design choices
- How to make a strong yet nimble robot
- How to design a good UI for controlling robots

What was the best parts of the class

How willing to help all the TAs were in troubleshooting my robot and helping debug potential issues over Zoom once I had dropped off the robot for the final competition

What you had the most trouble with

Using the final competition guidelines to design a purpose-built robot which would be great at doing the main objectives well. E.g. how Rafael's nimble robot was able to quickly pick up cans and beacons

What you wish was improved

Helping students visualize what the final match was going to look like, either by staging a TA robot fight or simulating it virtually

Anything else about class

One of the best courses I have taken in my 4 years at Penn. Huge thank you to all the TAs and Prof. Mark Yim for making the experience so engaging and entertaining

Appendix

BOM (Bill of Materials)

x General	Quantity	
Laser Cut Parts	1	
Protoboards	4	
o **Parts from kit**		
ESP32 Pico + Cable	1	
SG-90 Servo	4	
TT Motors	4	
5V microUSB breakout	2	
Beston Battery	1	
o **Electronics**		
H-Bridge (SN754410)	4	
NAND gate (74HC00)	4	
DIP IC Socket (Deep sockets)	16	
2 feet of 22 AWG wire (different colors)	2	
x **Standoffs**		
4-40, MF, 1/2"	12	Secure 2nd layer to 1st layer (< 1inch)
4-40, MF, 1"	8	Secure 3rd layer to 2nd layer (1.5inches)
4-40, MF, 1/4"	16	Protoboards to 2nd and 3rd layer
x **Fasteners - Pan Screws**		
4-40 Washer	24	
4-40 Nut	30	
4-40, 1/4"	30	
4-40, 1/2"	8	
x **Fasteners - Flat Screws**		
M3 25mm	16	TT Motors
M3 Nut	16	

x General	Quantity
Protoboards	6
Bump Switches	8
MF Header Row	4
FF Header Row	4
LTR-4206E 940nm IR Phototransistor	4
LTE-4206 3mm 940nm IR Emitter	4
LTR-301 940nm IR Phototransistor	4
LTE-4208 5mm 940nm IR Emitter	4
Beston Battery	1
o **Parts from kit**	
ESP32 Pico + Cable	3
Breadboard	2
Box of Jumpers (as included in kit)	1
o **Electronics**	
8 feet of 22 AWG wire (4 different colors)	
x **Standoffs**	
4-40, FF, 1"	16
4-40, MF, 1"	16
x **Fasteners - Pan Screws**	
4-40, 3/4"	30
4-40, 1"	8
x **Fasteners - Flat Screws**	
M3 25mm	16

Penn Engineering Financial Services (PEFS)

PURCHASE ORDER REQUEST FORM

Requestor information

Name	Sheil Sarda
Phone number	610-203-3275
Email address	sheils@seas.upenn.edu

Date	4/15/2021
Delivery address	PH: (610) 203-3275 28 East Levering Mill Road Bala Cynwyd, PA 19004
Account to charge	XXX-XXXX-X-XXXXXX-XXXX-XXXX-XXXX

Vendor information

Vendor name	Amazon
Vendor website	https://www.amazon.com/

Shipping

Shipping notes	Please select Amazon prime (or fastest) shipping method for which additional costs will not be incurred

Product information

Quant.	Cat. or model no.	Vendor description and product selection notes	Link to product webpage	Alternative if unavailable	Unit cost	Total cost
1	GP2Y0A21YK0F	Low Voltage Labs - IR Distance Sensor 10-80 cm with 8 inch Cable GP2Y0A21YK0F GP2Y0A21	https://www.amazon.com/dp/B08FZP1F8Q/	Supplier: Amazon Link: https://www.amazon.com/GP2Y0A21YK0F-GP2Y0A21-Infrared-Proximity-Distance/dp/B075FPR2VX/ Quant: 1 Cost: $9.98 Shipping: Prime	$8.99	$8.99
1	B08KCR7QR6	Omni-Directional Wheel, Drive Controller Board, TT Motors	https://www.amazon.com/Robotic-Omni-Directional-Controller-Raspberry-Microbit/dp/B08KCR7QR6/	Supplier: Adafruit Link: https://www.adafruit.com/product/4678 Quant: 2 Cost: $4.95 * 2 Supplier: Adafruit Link: https://www.adafruit.com/product/4679 Quant: 2 Cost: $4.95 * 2	$21.99	$21.99
					Total cost	$30.98

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Delivery address	PH: (610) 203-3275 28 East Levering Mill Road Bala Cynwyd, PA 19004
Account to charge	XXX-XXXX-X-XXXXXX-XXXX-XXXX-XXXX

Vendor information

Vendor name	Adafruit
Vendor website	https://www.adafruit.com/

Shipping

Shipping notes	Select fastest shipping method for which additional shipping costs are not incurred

Product information

Quant.	Cat. or model no.	Vendor description and product selection notes	Link to product webpage	Alternative if unavailable	Unit cost	Total cost
1	4007	Ultrasonic Distance Sensor - 3V or 5V - RCWL-1601	https://www.adafruit.com/product/40	Supplier: Adafruit Link: https://www.adafruit.com/product/3942 Model no: 3942 Description: HC-SR04 Quant: 1 Cost: $3.95 Shipping: Fastest shipping method for which additional shipping costs are not incurred	$3.95	$3.95
1	3942	HC-SR04 Ultrasonic Sonar Distance Sensor + 2 x 10K resistors	https://www.adafruit.com/product/3942	Supplier: Adafruit Link: https://www.adafruit.com/product/4007 Model no: 4007 Description: RCWL-1601 Quant: 1 Cost: $3.95 Shipping: Fastest shipping method for which additional shipping costs are not incurred	$3.95	$3.95
2	4679	Left Mecanum Wheel - 48mm Diameter - TT Motor or Cross Axle	https://www.adafruit.com/product/4679			
					Total cost	$7.90

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Name	Sheil Sarda
Phone number	610-203-3275
Email address	sheils@seas.upenn.edu
Date	4/15/2021
Delivery address	PH: (610) 203-3275 28 East Levering Mill Road Bala Cynwyd, PA 19004
Account to charge	XXX-XXXX-X-XXXXXX-XXXX-XXXX-XXXX

Vendor information

Vendor name	Pololu
Vendor website	https://www.pololu.com/

Shipping

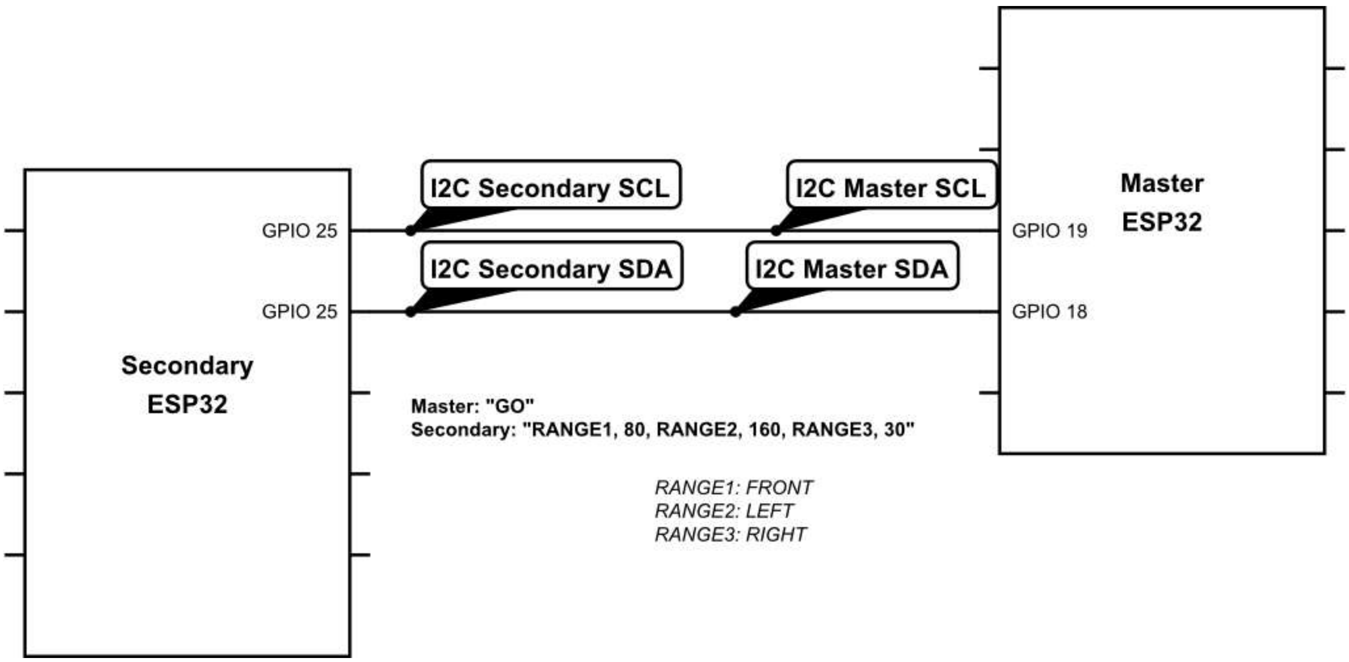
Shipping notes	Select fastest shipping method for which additional shipping costs are not incurred

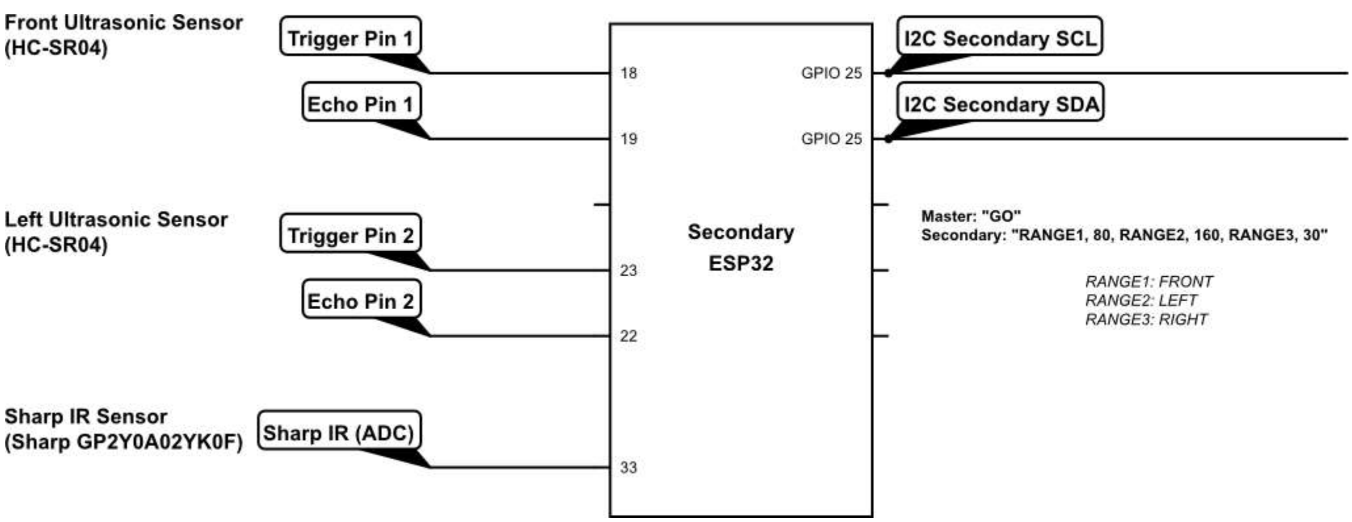
Product information

Quant.	Cat. or model no.	Vendor description and product selection notes	Link to product webpage	Alternative if unavailable	Unit cost	Total cost

1	2489	VL6180X Time-of-Flight Distance Sensor Carrier with Voltage Regulator, 60cm max	https://www.pololu.com/product/248	Supplier: Adafruit Link: https://www.adafruit.com/product/3316 Model no: 3316 Description: VL6180X Quant: 1 Cost: $13.95 Shipping: Fastest shipping method for which additional shipping costs are not incurred	$8.49	$8.49
					Total cost	**$8.49**

Schematics of all electronic circuits





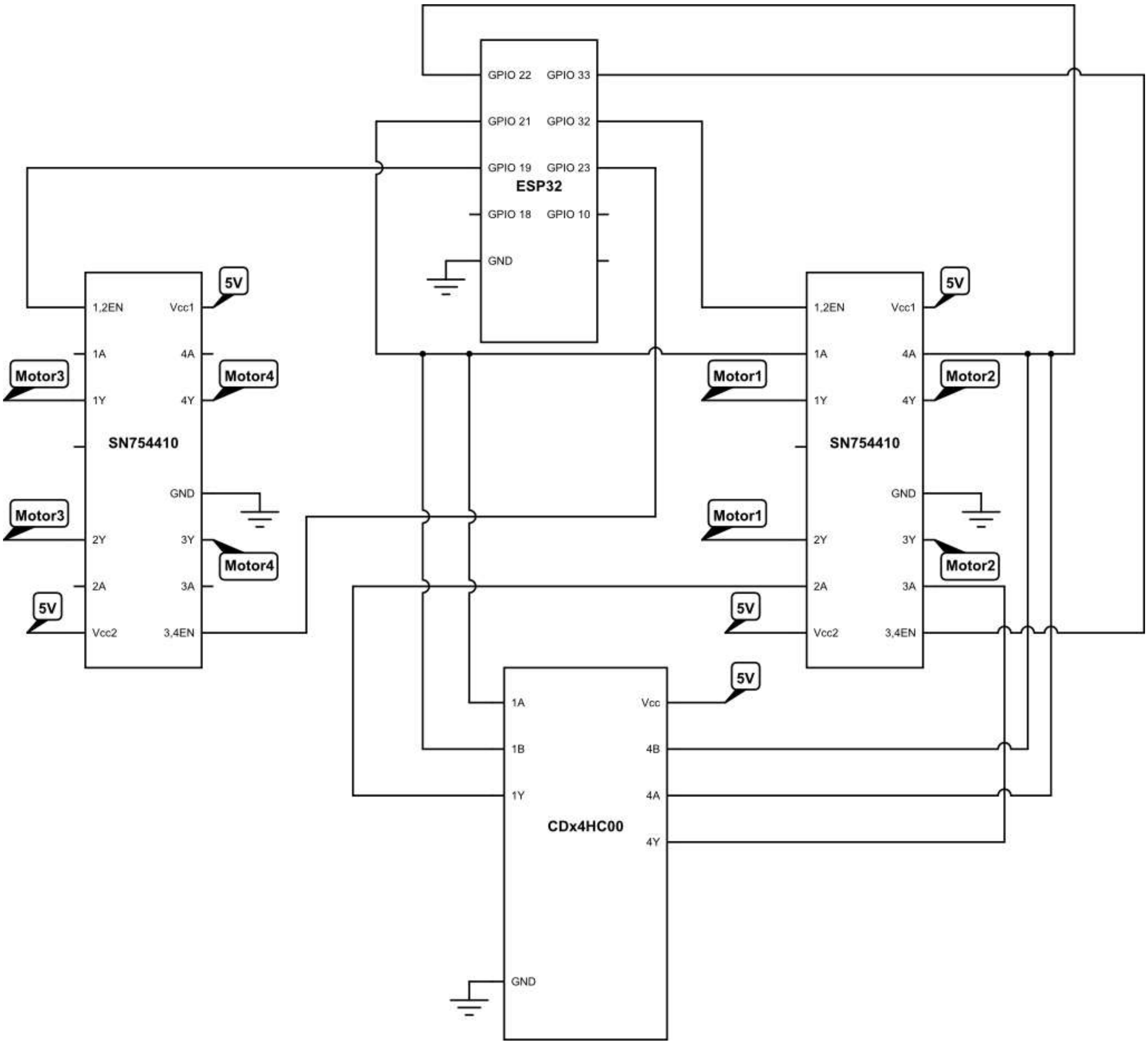
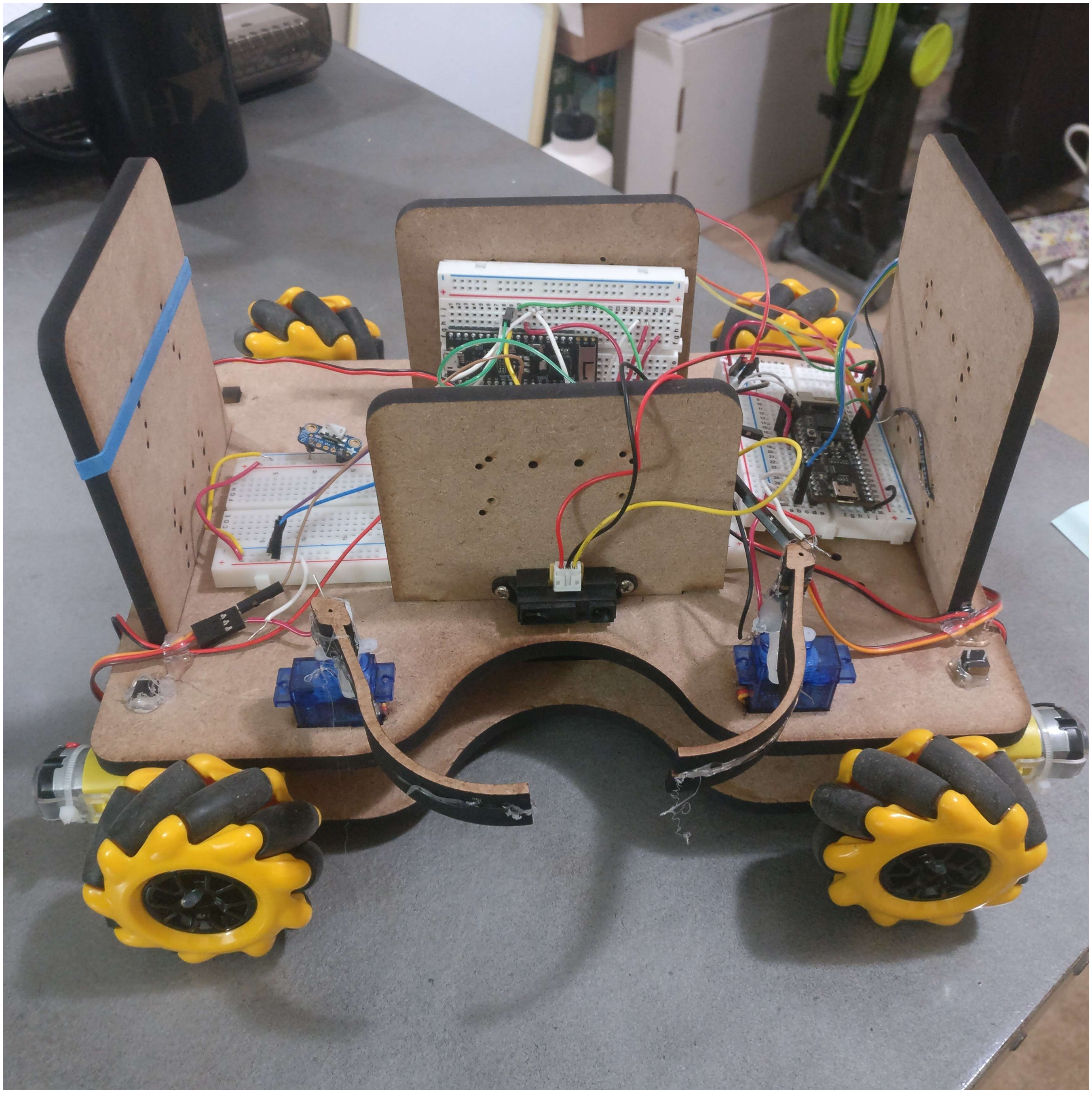
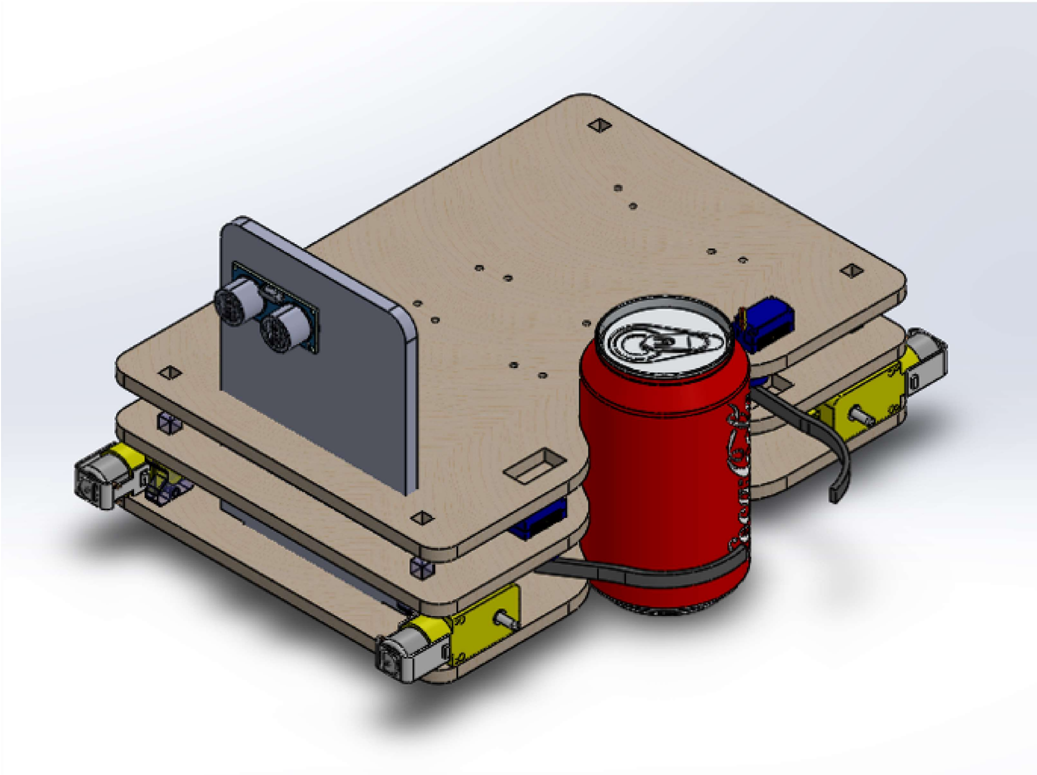
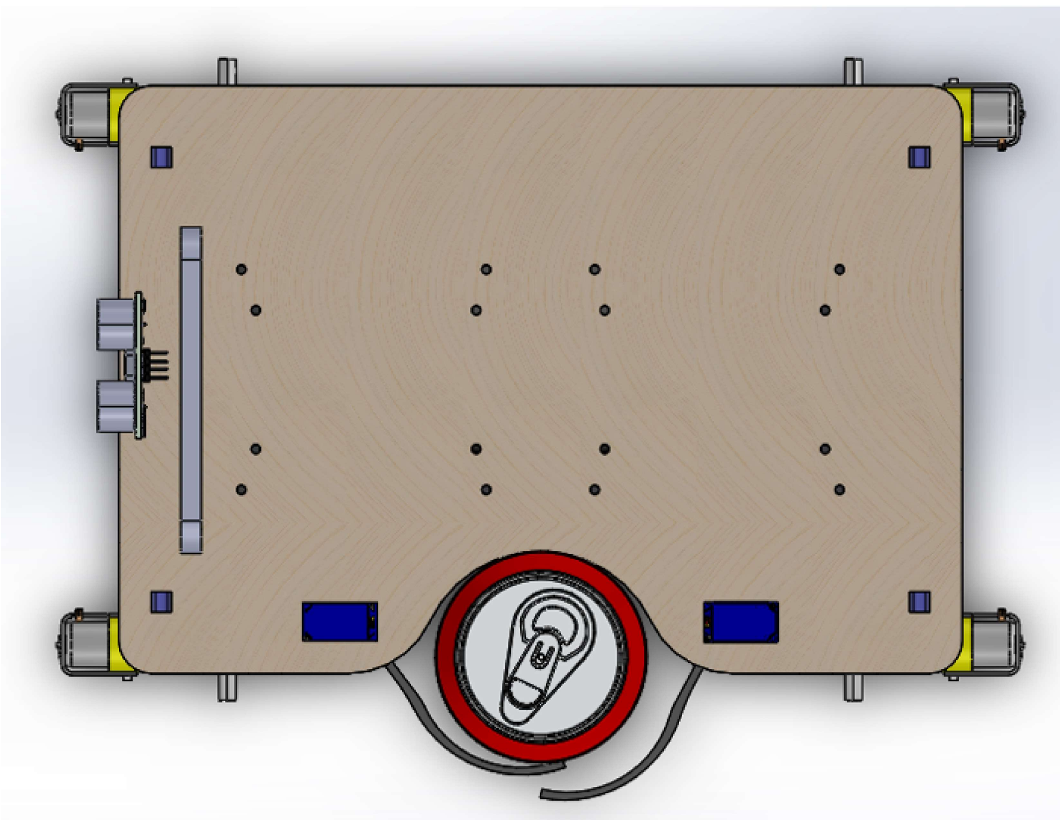


Photo / Rendering of full robot



CAD drawings





All data sheets for all components that are not parts supplied by the ministore (either links or copies of data sheets)

1. VL6180X: https://www.st.com/resource/en/datasheet/vl6180x.pdf
2. Sharp GP2Y0A02YK0F: https://www.sparkfun.com/datasheets/Sensors/Infrared/gp2y0a02yk_e.pdf
3. HC - SR04: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf

Videos of functionality

Final Project Day 3 (Finals): https://youtu.be/rbyzACLpvsc?t=13435

Upload all code to canvas (separately)