Trash-E

Group 26
Final Presentation

Thomas Greco	Computer Engineer
Christian Mayo	Computer Engineer
Alex Rizk	Computer Engineer
Chrizzell Jay Sanchez	Electrical Engineer

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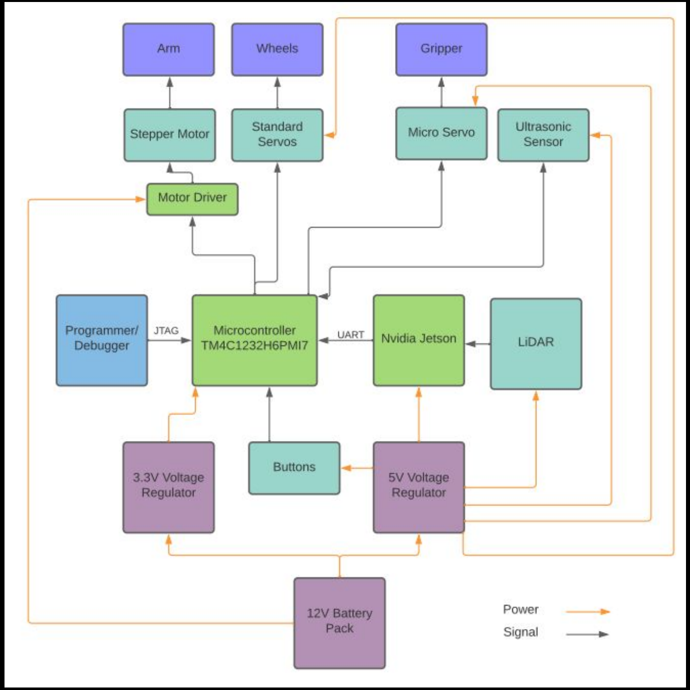
Project Motivation and Goals

- Motivation
  - Current robot cleaners can only pick up small objects, dust.
    - I.e. Roomba
  - Technologies are interesting to group members.
- Goals
  - Autonomous:
    - Movement
    - Cup detection.
    - Locomotion and mapping (SLAM).
  - Mobile power system for all components that fits on chassis.

Specifications

Minimum Run Time	1 hour
Max Robot Dimensions	13x13x20
Max Weight of Robot	10 lbs
Max Size of Storage Bin	8L
Max Current Discharge	12A
Maximum speed of robot	5 mph
The system will be able to detect Red Solo Cups	-
The system will be mobile	-
The system will be able to pick up Red Solo Cups	-

Overall Design



Division of Work

	Chassis	Embedded Software	PCB Design	ROS Navigation	Computer Vision	Power System
Thomas		P	S	P		S
Alex	P	P		S	S	
Christian		S		P	P	
CJ	S		P			P

P = Primary
S = Secondary

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Hardware

Physical Design

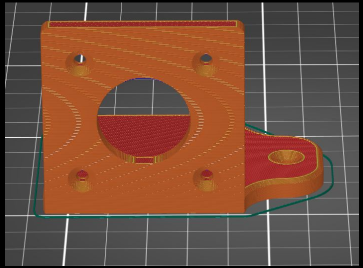
Chassis

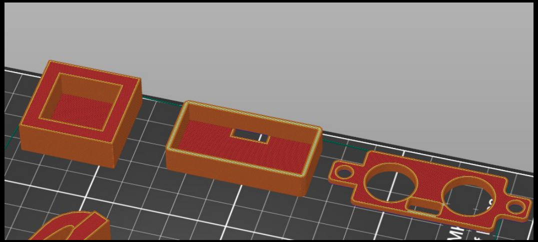
Composition

- Three .35” x1.45” x14” PETG reinforcement bars
- Three acrylic sheets .093” x11” x14”
- Ultrasonic sensor case, NEMA 17 stepper motor bracket, and servo bracket

Requirements

- Should be able to contain several lightweight objects
- Rigid enough to support all electronics
- Lightweight and portable (<= 5lbs)





Chassis Cont.

LiDAR Stand

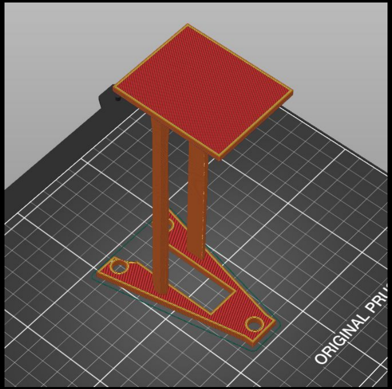
- Gives an elevated area for the LiDAR to operate

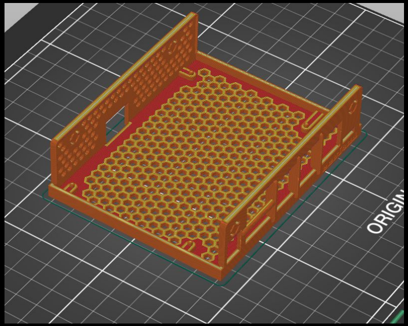
Nvidia Jetson Holder

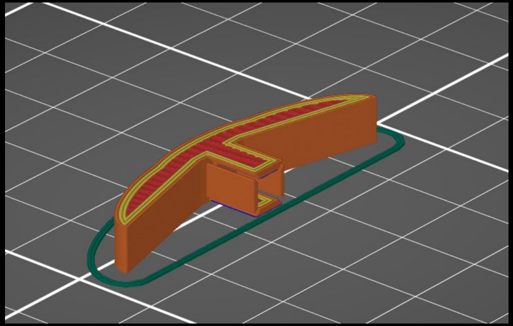
- Keeps Jetson Nano in place during Trash-E's operation

Button Bumpers

- Bumpers placed on corner buttons to increase surface area to correct for collisions



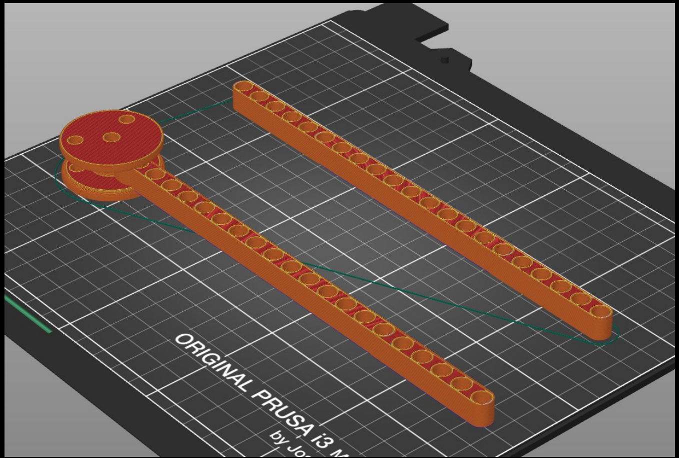




Arm

Construction

- Through hole design allows for easy adjustment and subsequent trimming of arm
- Mounted on front center of chassis in order to grab and move objects into bin



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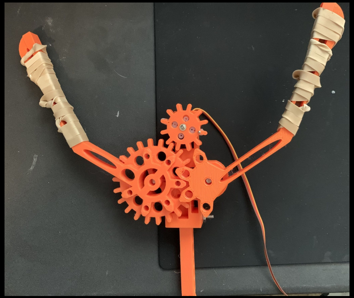
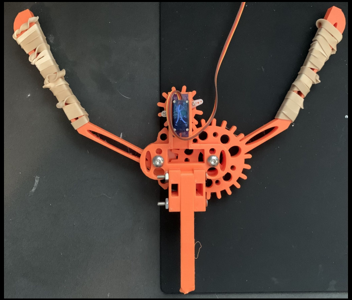
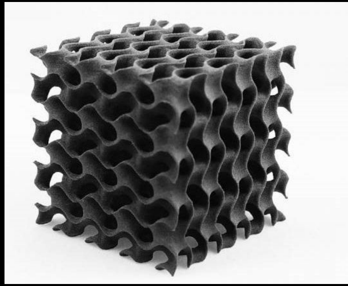
Gripper

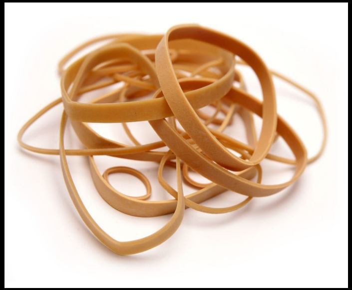
Composition

- PETG
  - 5% gyroid infill allows for lightweight and durable design
  - Mostly empty space
- Rubber Bands
  - Surface of PETG is smooth and cannot grab hold of objects
- 2x M5 - 16r screws to hold pincers









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Wheels

Pololu Wheel for Standard Servo

- Lightweight, but sturdy
- Rubber cover for traction on flat surfaces

Generic Castor wheel

- Slides/Swivels easily and gives three points of contact for Trash-E to move

Hardware

Electrical Design

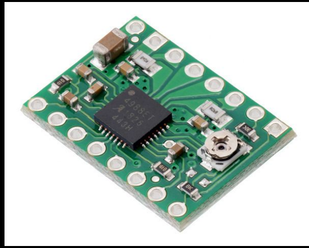
Stepper Motor and Driver Carrier

Twotrees Nema Bipolar 42 Stepper Motor

- Used to drive robot arm
- 1.8° Step Angle
- 42N.cm (60oz.in) Holding Torque

A4988 Stepper Motor Driver

- Operating Voltage: 8 - 35 V
- Maximum Current: 2 A
- Microstep Resolutions:
  - Full, 1/2, 1/4, 1/8, and 1/16



Jetson Nano

- Jetson gets better performance across all models compared to Raspberry Pi 3 with Intel Compute Stick for roughly same price.
- Used to run object detection and process LiDAR information.
- Sends cup position information to MCU via UART.

Model	Application	Framework	NVIDIA Jetson Nano	Raspberry Pi 3	Raspberry Pi 3 + Intel Neural Compute Stick 2
ResNet-50 (224×224)	Classification	TensorFlow	36 FPS	1.4 FPS	16 FPS
MobileNet-v2 (300×300)	Classification	TensorFlow	64 FPS	2.5 FPS	30 FPS
SSD ResNet-18 (960×544)	Object Detection	TensorFlow	5 FPS	DNR	DNR
SSD ResNet-18 (480×272)	Object Detection	TensorFlow	16 FPS	DNR	DNR
SSD ResNet-18 (300×300)	Object Detection	TensorFlow	18 FPS	DNR	DNR
SSD Mobilenet-V2 (960×544)	Object Detection	TensorFlow	8 FPS	DNR	1.8 FPS
SSD Mobilenet-V2 (480×272)	Object Detection	TensorFlow	27 FPS	DNR	7 FPS
SSD Mobilenet-V2 (300×300)	Object Detection	TensorFlow	39 FPS	1 FPS	11 FPS

Camera

SainSmart IMX219

- Compatible with Jetson Nano
- 160° FOV
- Capable of 1080p, 720p, and 480p

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Microcontroller Selection

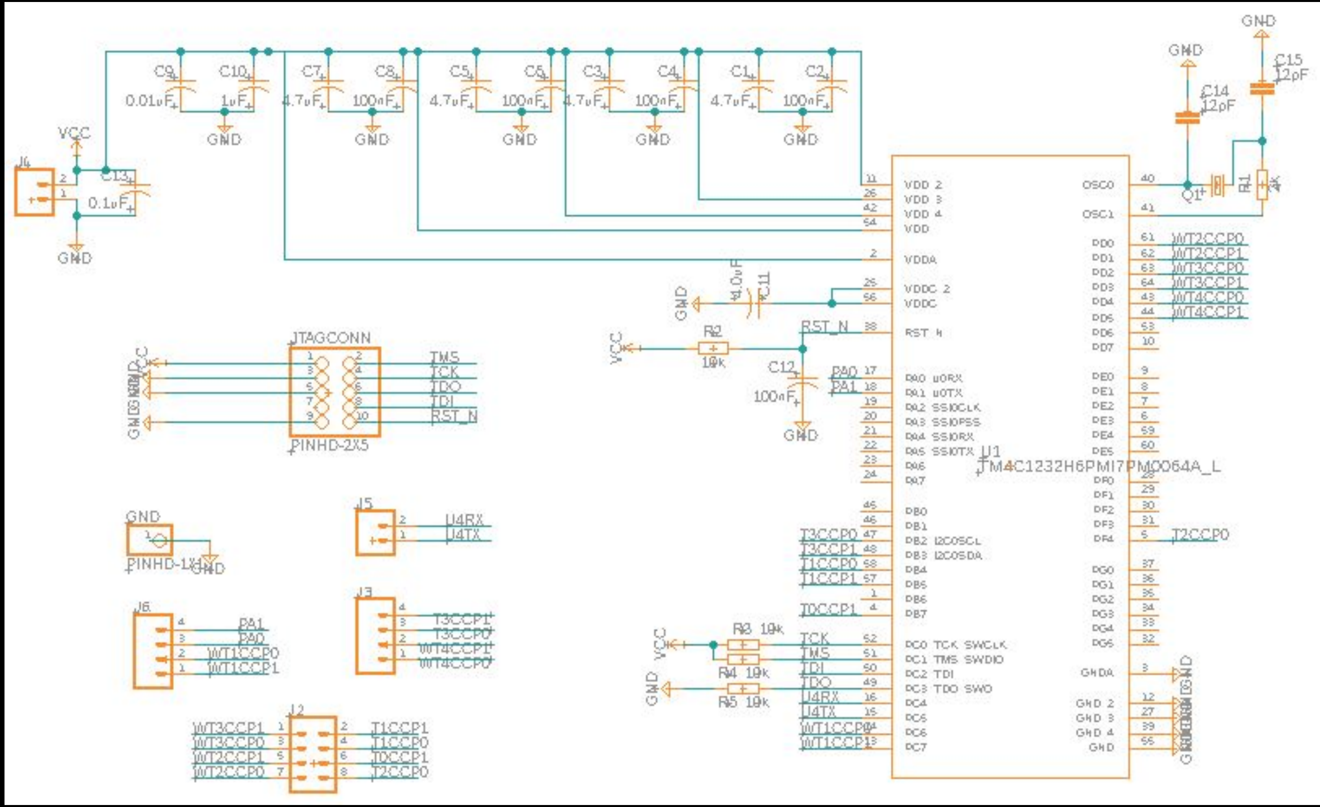
Used to control and drive signals for the following:

- Stepper motor/driver
- Standard and micro servos
- Ultrasonic sensor

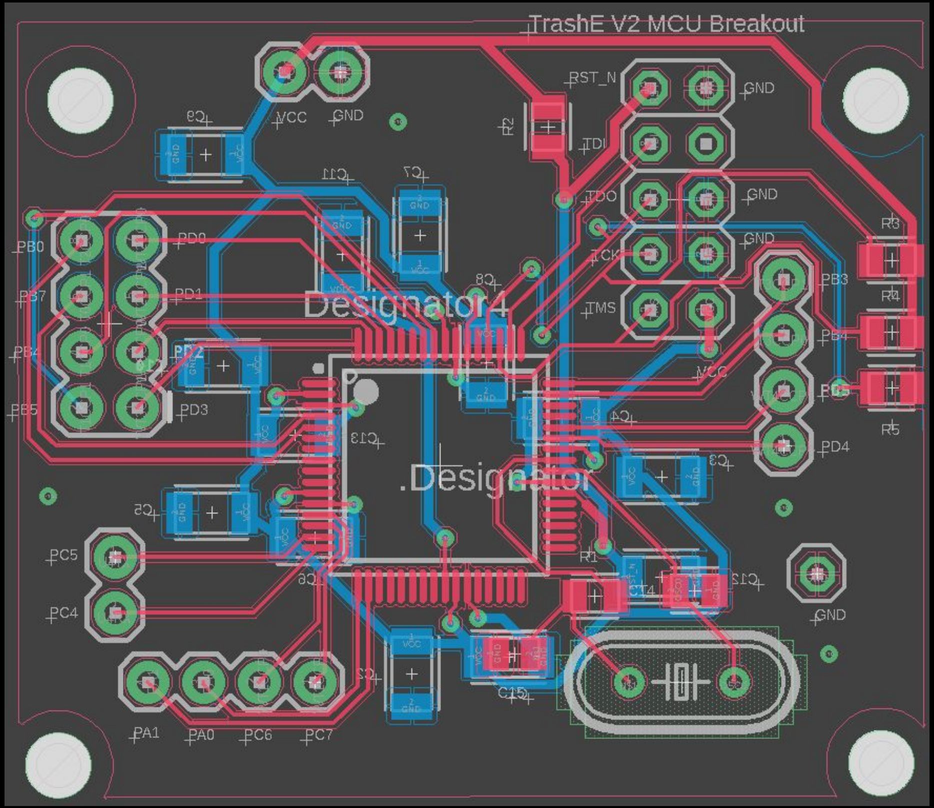
Will communicate with Jetson for coordinates of cup through UART.

	TM4C1232H 6PMI7	STM32G0B1 KCT6
Price	$7.14	$5.62
Core Speed (MHz)	80	64
I/O Pins	49	30
Flash Size (kB)	256	256
Operating Voltage (V)	1.08 - 3.63	1.7 - 3.6
Package	LQFP	LQFP

MCU PCB Schematic



MCU PCB



TrashE V2 MCU Breakout
VCC
GND
RST_N
GND
TDI
TDO
GND
GND
TCK
TMS
PB3
PB4
PD4
GND
PB0
PD0
PD1
PD3
PC5
PC4
PA1
PA0
PC6
PC7
R3
R4
R5
R1
R2
C15
.Designator
Designator4

Servos

Adafruit 169 Micro Servo

- Used for gripper opening/closing
- Type: Positional
- Torque: 22.22 oz-in

Adafruit 154 Standard servo

- Used for wheel movement
- Type: Continuous
- Torque: 44.52 oz-in

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Ultrasonic Sensor

HC-SR04

- Detect distance between arm and cup.
- More resistant to outside factors compared to infrared.
- Less accurate with edges of objects.
    - Only need to detect when cup is very close.

$$Distance = \frac{\left((High\ Level\ Duration) * 340\frac{m}{s}\right)}{2}$$

LiDAR

EAI YDLIDAR X2L

- Used for navigation of environment.
- 360 2D Laser.
- 7Hz scan rate.
- 8m scan distance.

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Hardware Challenges

Challenge	Solution
Cup slips out of gripper when picked up.	Utilize rubber bands.
Trash-E would get stuck on obstacles.	Add two buttons on either side for object avoidance.
Linear voltage regulators overheating due to drop in voltage.	Make two smaller voltage step downs between two regulators instead of one larger one.

Power Design

Power

Unit	Voltage Requirement	Maximum Current
Stepper Motor Driver	12 V	2 A
Stepper Motor	12 V	2 A
Continuous Servo (2x)	5 V	1.5 A (2x)
Jetson Nano	5 V	3 A
LiDAR	5 V	1 A
Ultrasonic Sensor and micro servo	5V	<200mA
MCU	3.3 V	<.1 A

- At least 11 A needed at maximum load

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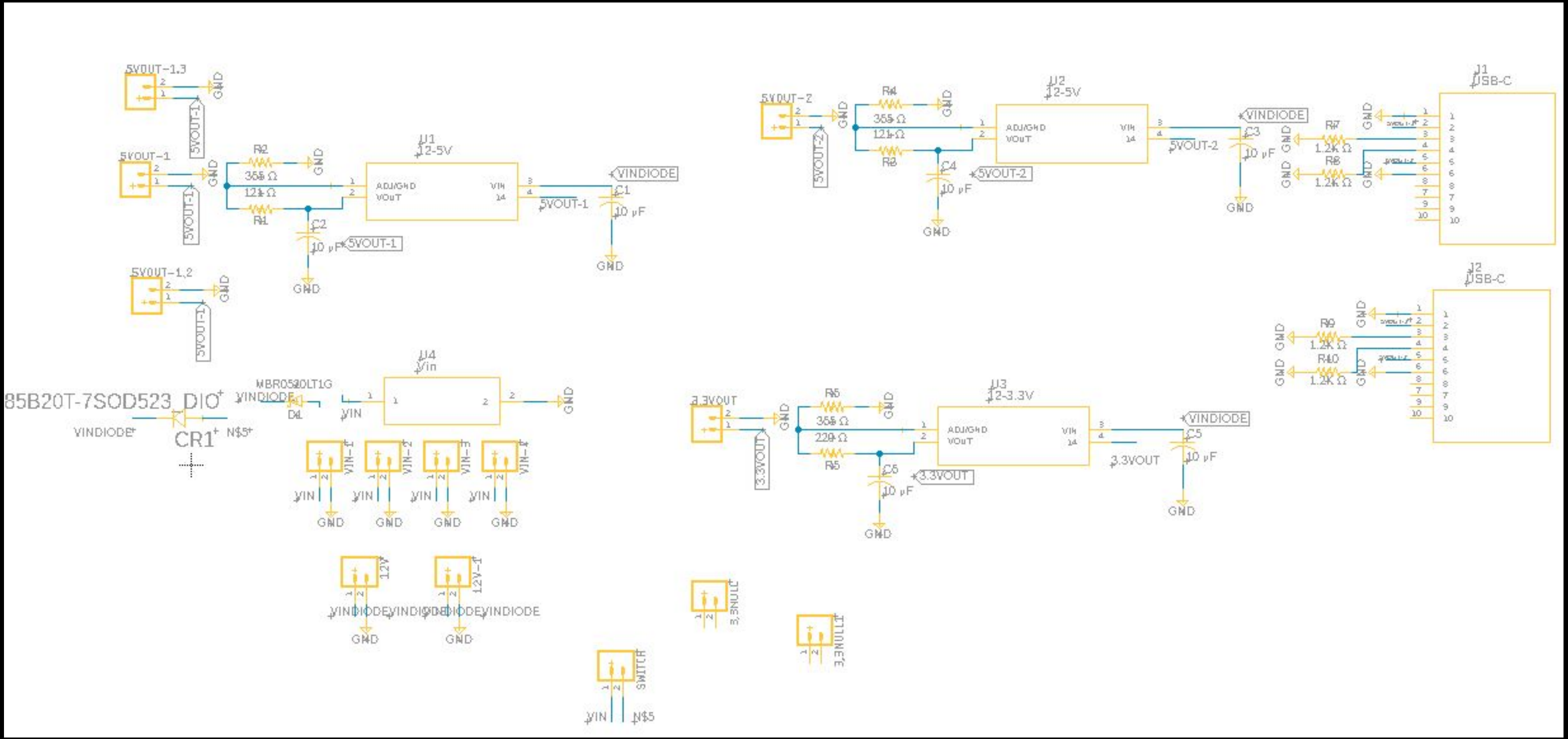
Regulator Selection

- Original Design
  - A0Z2254TQI-11
  - Unable to output desired values
  - Few 10 A regulators in stock at the time

- New Design
  - LM1084IS-ADJ
  - Splits load between 3 regulators
  - Stack two PCBs on top of each other

Specification	LM1084IS-ADJ	AOZ2254TQI-11
Input Voltage	6.5 V - 29V	6.5 V - 28 V
Output Voltage	1.25 V - 27.5 V	0.8 V - 23.8 V
Max Current	5 A	10 A

Power Supply PCB Schematic



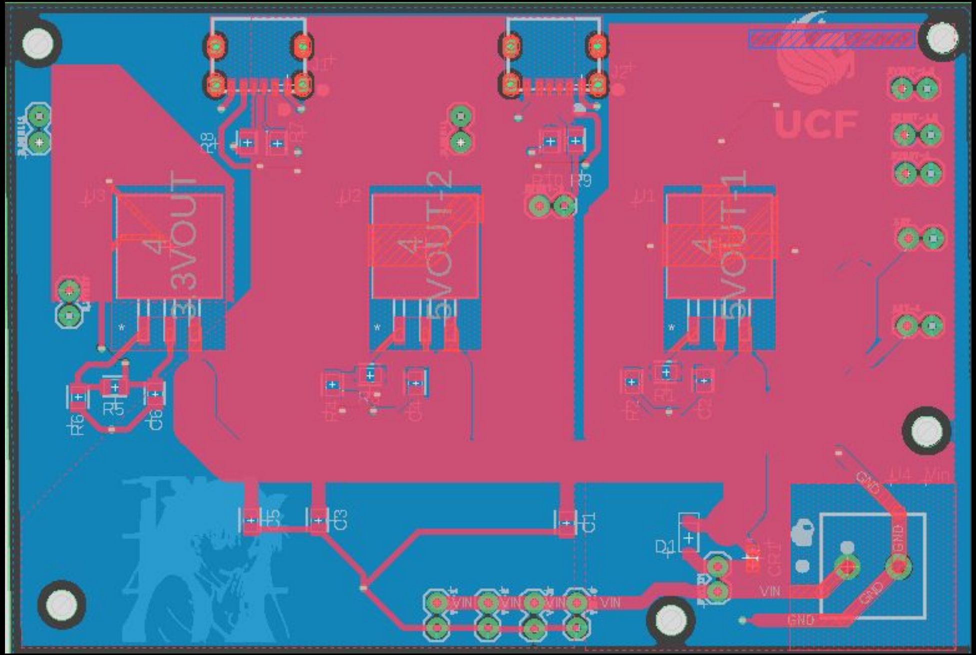
Power Supply PCB (old)

Two 12 to 5V Buck Converters

- One branch for the Servos
- One branch for the Jetson and LiDAR
    - Has 6 pin USB-C
- Splits the current draw of the power hungry components

One 12 to 3.3V Buck Converter

- Powers the MCU



Power Supply PCB (new)

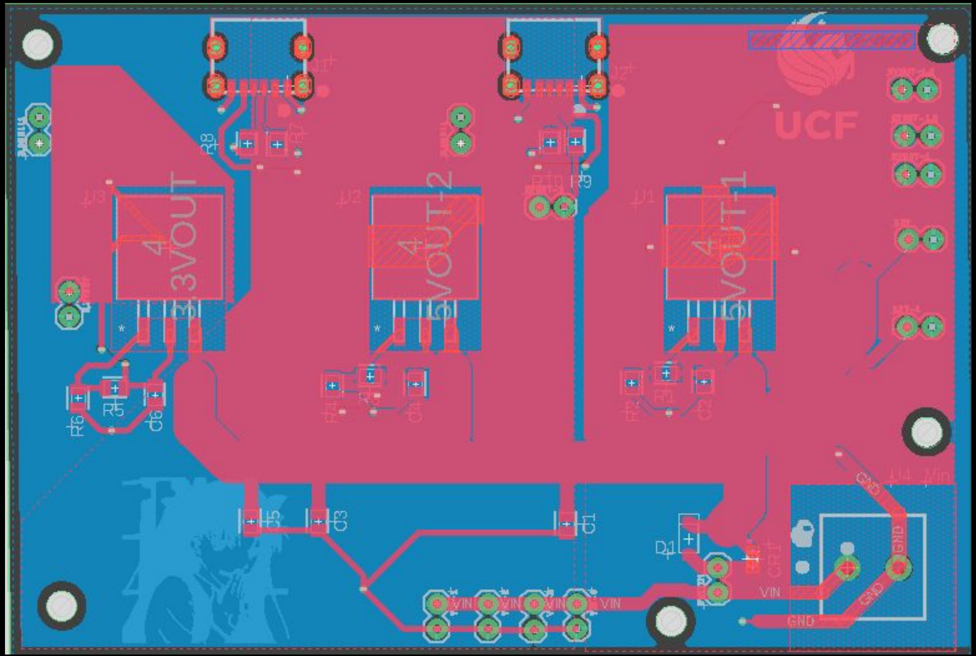
12 to 8V Buck Converters

One 12 to 3.3V Buck Converter

- Powers the MCU

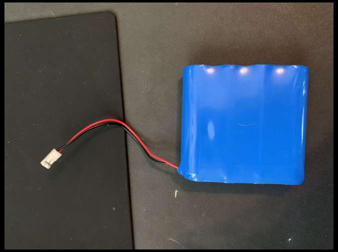
Second PCB stacked on top

8 to 5V Converter



Battery

- 18650 12V Battery Pack 2600mAh
  - 3 packs in parallel
  - 7800 mAh total capacity
  - Donated by Smart Charging Technologies



- External Battery Pack
  - USB-C port requires USB-C controller
  - USB-C controllers are not available for our requirements
  - Powers the Jetson Nano and LiDAR only

Software Design

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Software Design: Overview

Object Detection

- Use object detection on the Jetson Nano to detect cups.
- Send information about a cup’s location to the MCU.
- Written in Python.

SLAM

- Use SLAM software to autonomously maneuver the area when there are no cups in sight.
- Written using ROS Melodic and Python.

Microcontroller

- Receive data about a cup’s location.
- Control Trash-E’s motors, arm, and sensors.
- Written in C.

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Software Design: Object Detection

PyTorch

- Open-source machine learning library by Meta.
- Used to train our object detection model.
- The model architecture used is SSD MobileNet V1.

Dataset

- Single class: Red plastic cup
- ~ 500 images
- Training, validation, and testing sets are split 60/20/20 respectively.
- Images were captured and labeled by ourselves.

Software Design: Object Detection

Jetson Inference

- Inference and real-time vision library for the NVIDIA Jetson platform.
- APIs allow features such as displaying detection boxes, running model inference, and returning detection data.
- Simple integration with PyTorch and TensorRT libraries.

TensorRT

- Used to optimize trained models so that they run faster and more efficiently on an Nvidia Jetson GPU.

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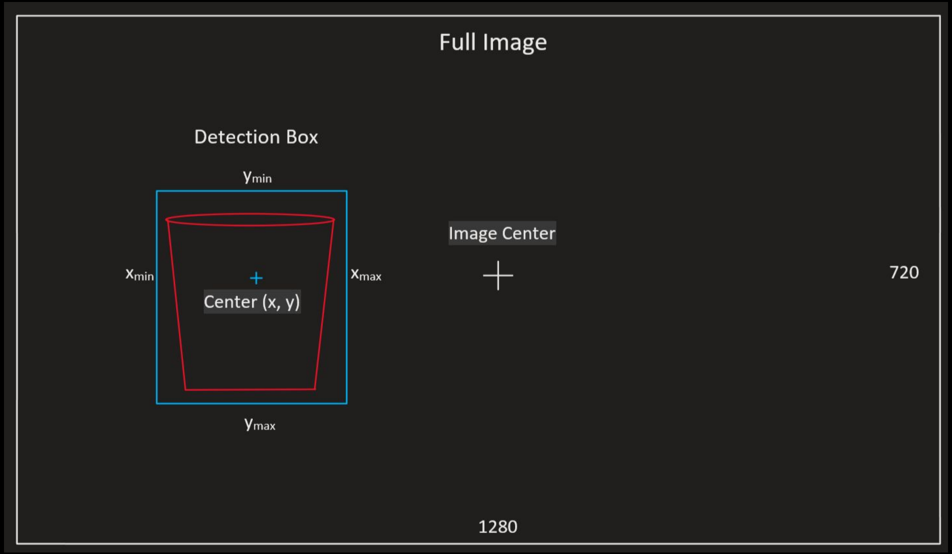
Software Design: Communication with MCU

PySerial is used to send UART communication from the Jetson Nano to the microcontroller.

The object detection software determines if the cup is centered on the image and adjusts the servo motors accordingly using a PWM signal.



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Software Design: Robot Operating System (ROS)

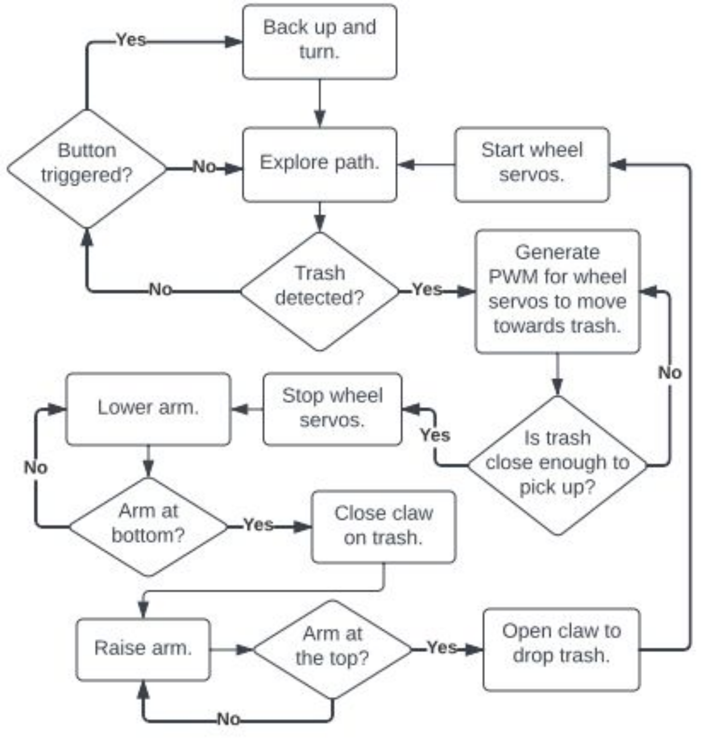
Offers open source libraries for general robotics in Python

- Seamlessly integrates with object detection code

Used for:

- Simultaneous Locomotion and Mapping (SLAM)
  - Hector SLAM
  - Generate a map of an unknown area using laser scans.
- Augmented Monte Carlo Localization (AMCL)
  - Determine robot's estimated position with laser scans.
- Move Base
  - Creates a path to a goal on the map and controls Trashe-E movement.

Software Design Flowchart



Software Challenges

Challenge	Solution
TensorFlow 2 Object Detection API would not install properly on the Jetson Nano.	Use the Nvidia Jetson Inference library instead.
Original TensorFlow 2 model could not be converted to TensorRT engine and inference performance was poor.	Switch to PyTorch model instead for simple integration with Jetson Inference and TensorRT.
No physical odometry info from wheel encoders.	Use lidar scan matching node in ROS.
Little documentation of programming this MCU due to popularity of the development board.	Utilize programmer on development board with breakout pins to flash code onto PCB MCU.

Standards & Constraints

Constraints:

- Economic:
  - Use parts and resources currently owned if possible.
  - Utilizing senior design and TI Innovation lab.
- Time:
  - Utilize more expensive manufacturing house due to production times.
- Safety:
  - Ensure speed of robot is low to minimize risk of damage to anything in its path.

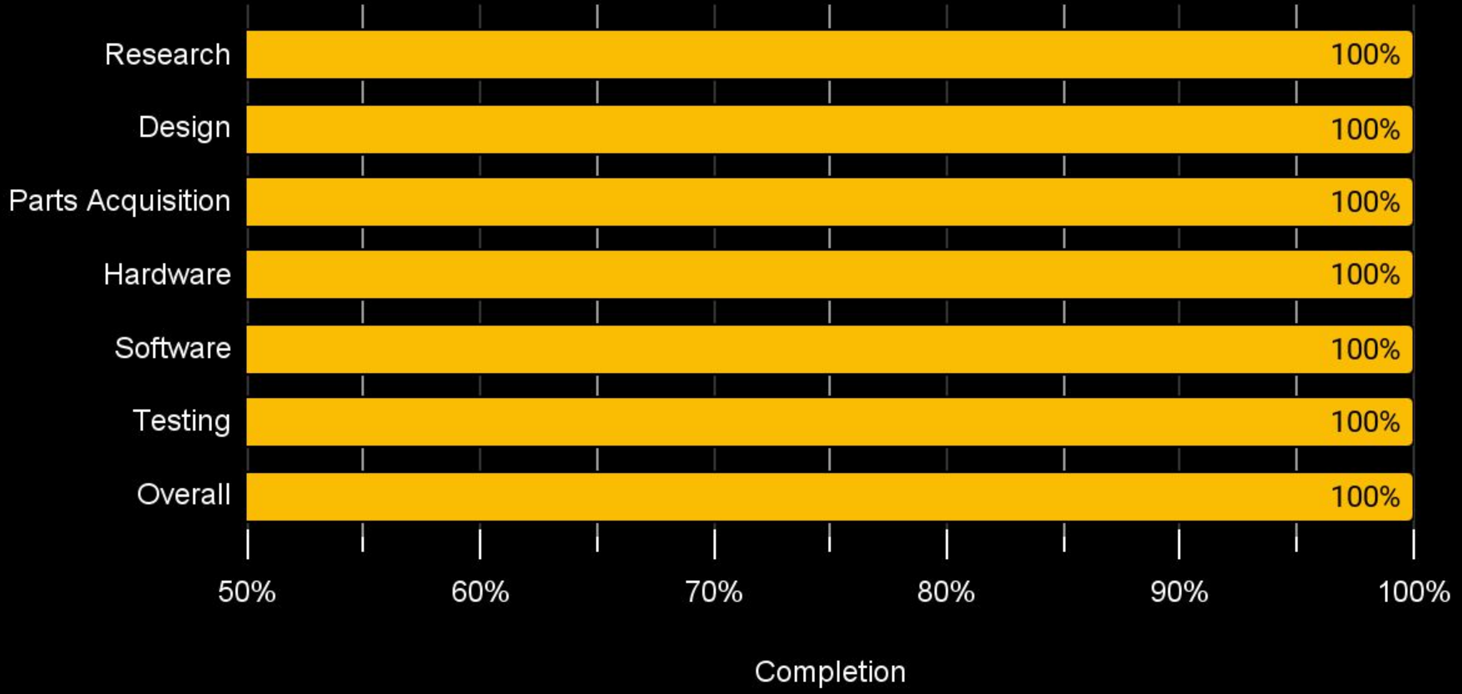
Standards:

- UART
- C Standard
- Laser Safety Classification
- USB-C Standard

Administrative Content

Current Progress

Group 26 Trash-E



Budget

Type	QTY	Unit Cost	Total Cost
Wheels	2.00	$4.75	$9.50
Motor Driver	1.00	$5.47	$5.47
Stepper Motor	1.00	$9.99	$9.99
Servos	2.00	$11.95	$23.90
Micro Servo	1.00	$3.62	$3.62
Ultrasonic Sensor	1.00	$4.45	$4.45
MCU	1.00	$7.14	$7.14
PCB	1	$22.00	22.00

Type	QTY	Unit Cost	Total Cost
Jetson Nano	1.00	$59.00	$59.00
Camera	1.00	$22.00	$22.00
Lidar Rangefinder	1.00	$69.99	69.99
Chassis/ Bucket	3.00	$7.50	$22.50
Arm	1.00	3D Printed	3D Printed
Gripper	1.00	3D Printed	3D Printed
Battery Pack	1.00	$15.99	$15.99
Lithium ion batteries	6.00	$7.00	$42.00

Total: $317
Budget: $450