Trash-E

Group 26
Critical Design Review

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

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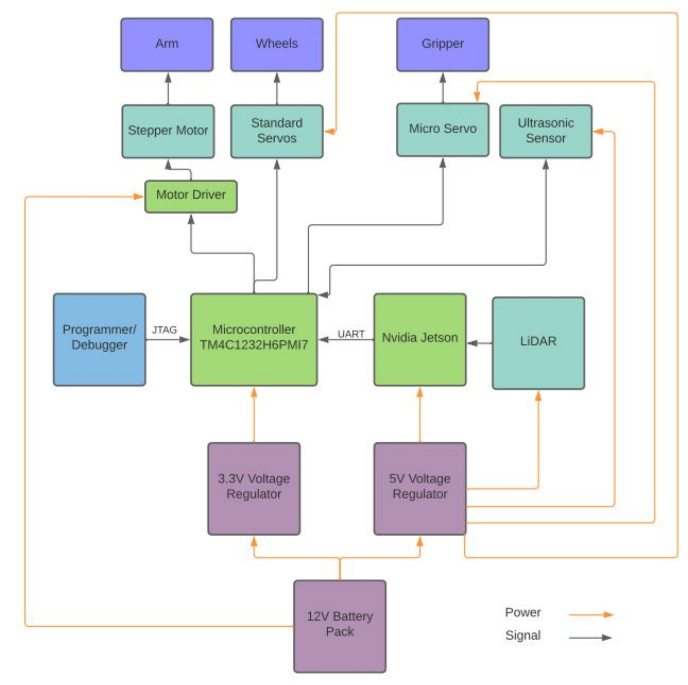
Project Motivation and Goals

- 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	10A
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	SLAM	Computer Vision	Power System
Thomas		P	P	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"

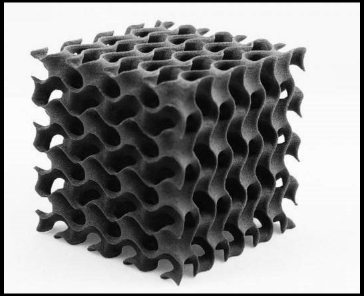
Requirements

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

Gripper

Composition

- PETG
    - 15% gyroid infill allows for lightweight and durable design
- Leak Stopper Rubber Flexx
    - Surface of PETG is smooth and cannot grab hold of objects
- 2x M5 - 16r screws to hold pincers



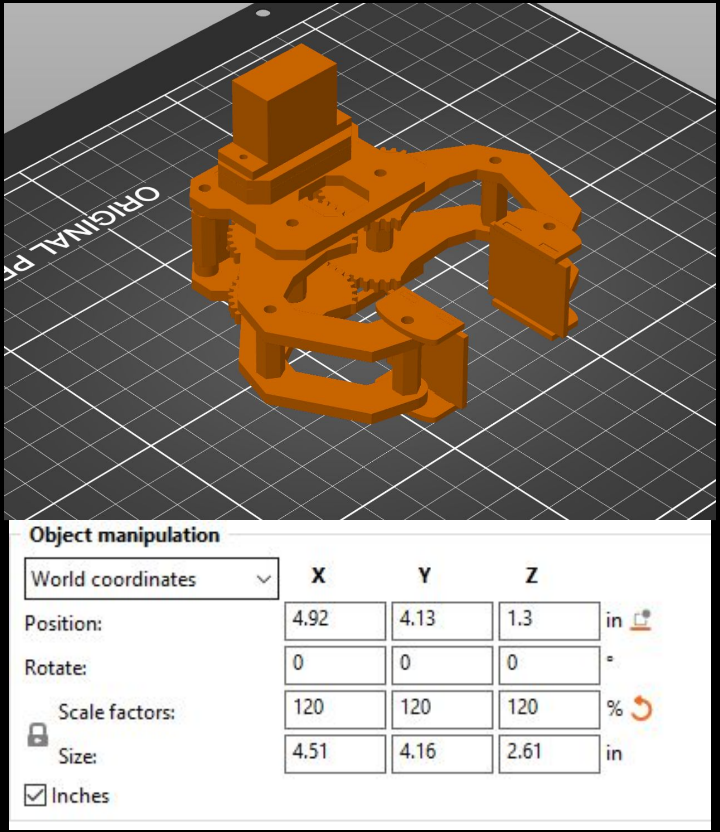
Gripper Alternative

Advantages

- More surface area for gripping object
  - Able to grab object regardless of orientation
- Compact

Disadvantages

- Possibly heavier due to needing more screws
- Cannot reach as far



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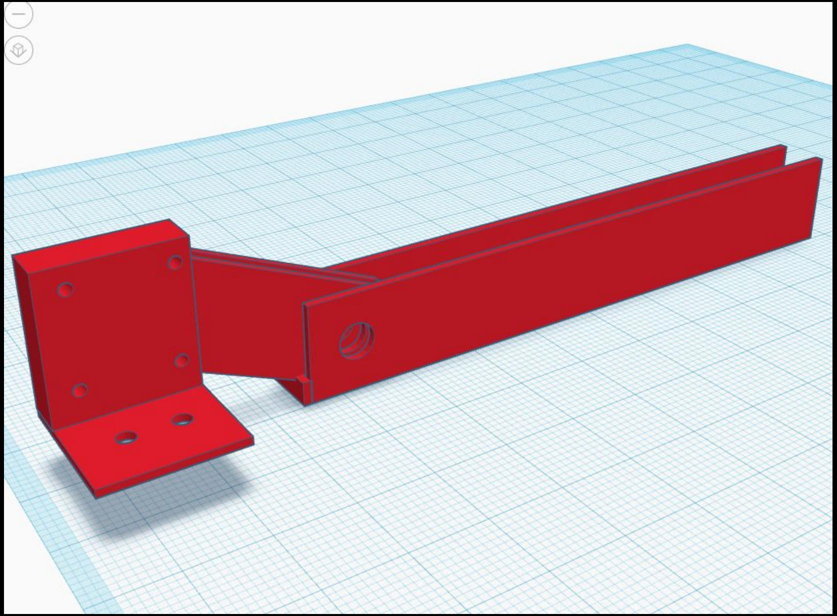
Arm

Construction

- Can either be shaped out of acrylic sheets or 3D printed
- Mounted on front center of chassis in order to grab and move objects into bin



Wheels

Pololu Wheel for Standard Servo

- Lightweight, but sturdy
- Made specifically for our size servos
- Ease of use, just put them onto the servo
- Rubber cover for traction on flat surfaces

Hardware

Electrical Design

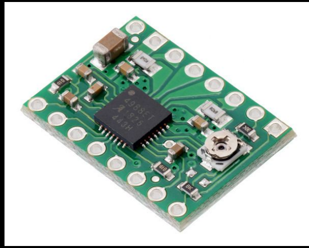
Stepper Motor and Driver Carrier

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



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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

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Camera

SainSmart IMX219

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

Microcontroller Selection

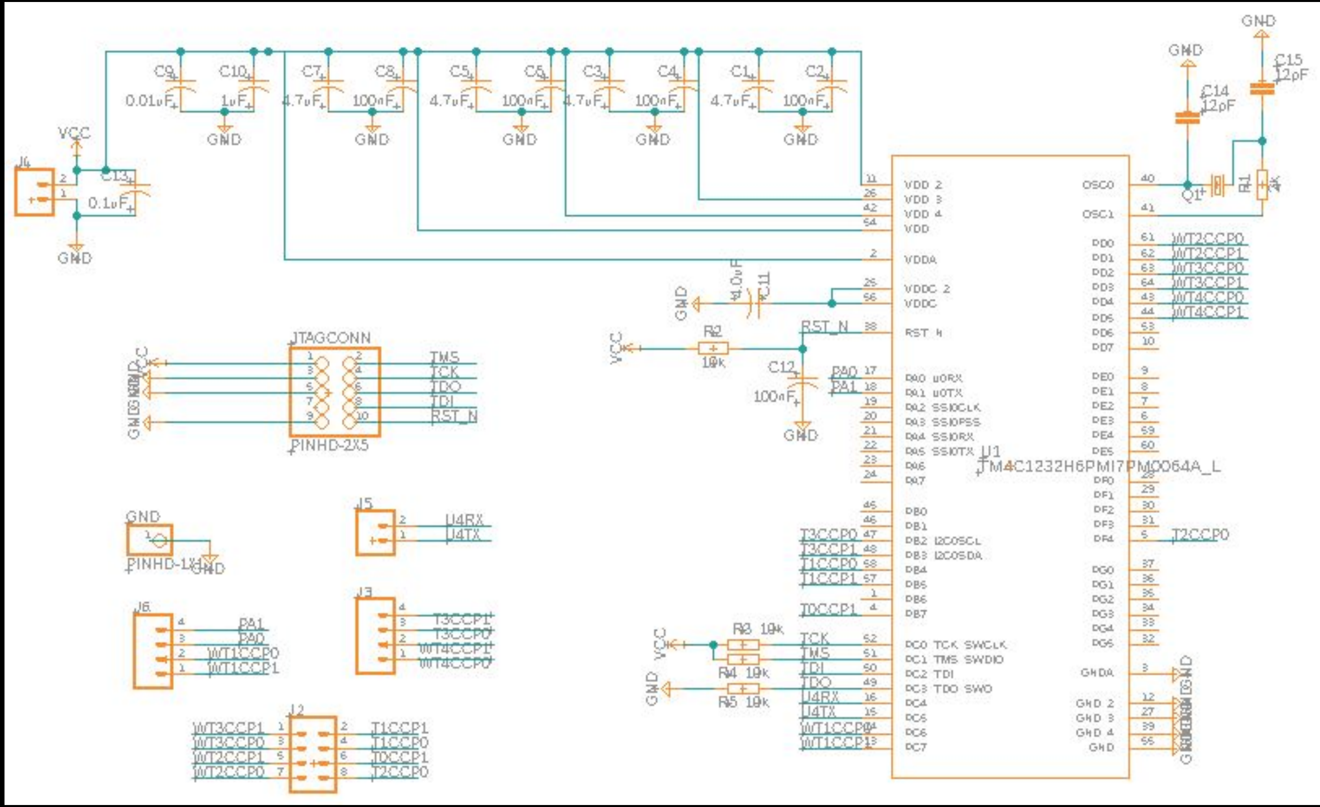
Used to control and drive signals for the following:

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

Will communicate with Jetson for coordinates of cup through UART.

	TM4C1232H6PMI7	STM32G0B1KCT6
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



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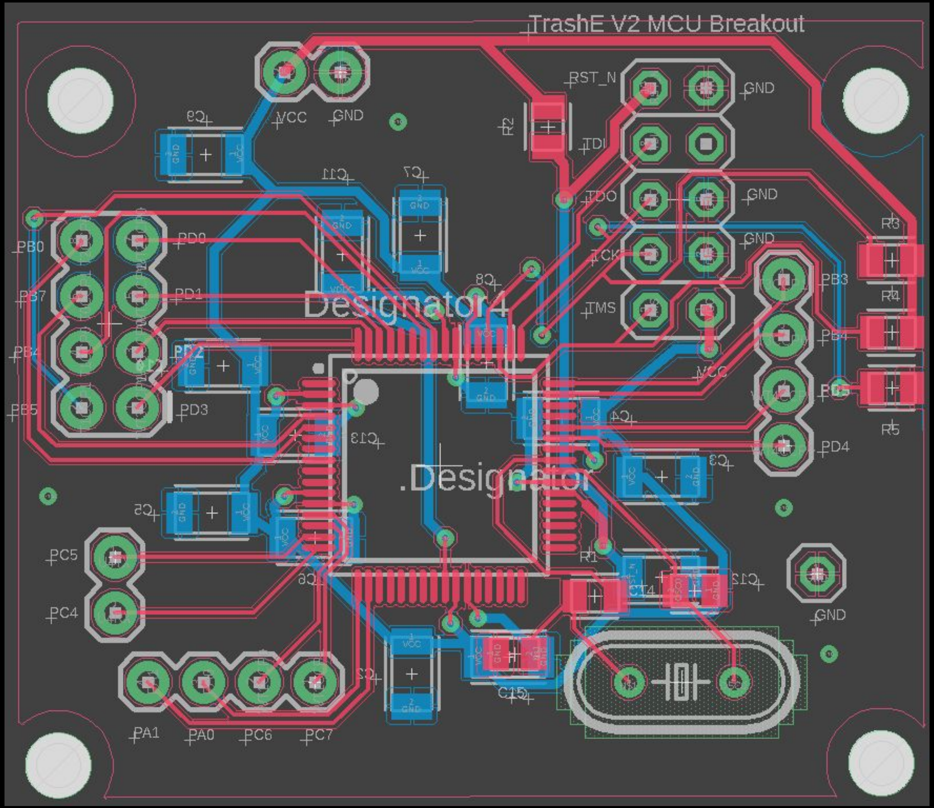
MCU PCB



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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.

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

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LiDAR

EAI YDLIDAR X2L

- Used for Simultaneous Locomotion and Mapping (SLAM).
- 360 2D Laser.
- 7Hz scan rate.
- 8m scan distance.

Hardware Challenges

Challenge	Solution
Cup slips out of gripper when picked up.	Utilize rubber spray.
Weight distribution of components on the chassis.	Place batteries in the back to counterbalance the weight of the stepper motor and arm.
Traces in PCB weren't wide enough. Lots of heat being generated.	Calculate appropriate trace widths and reprint boards.

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
- 4 A will not be going through regulator

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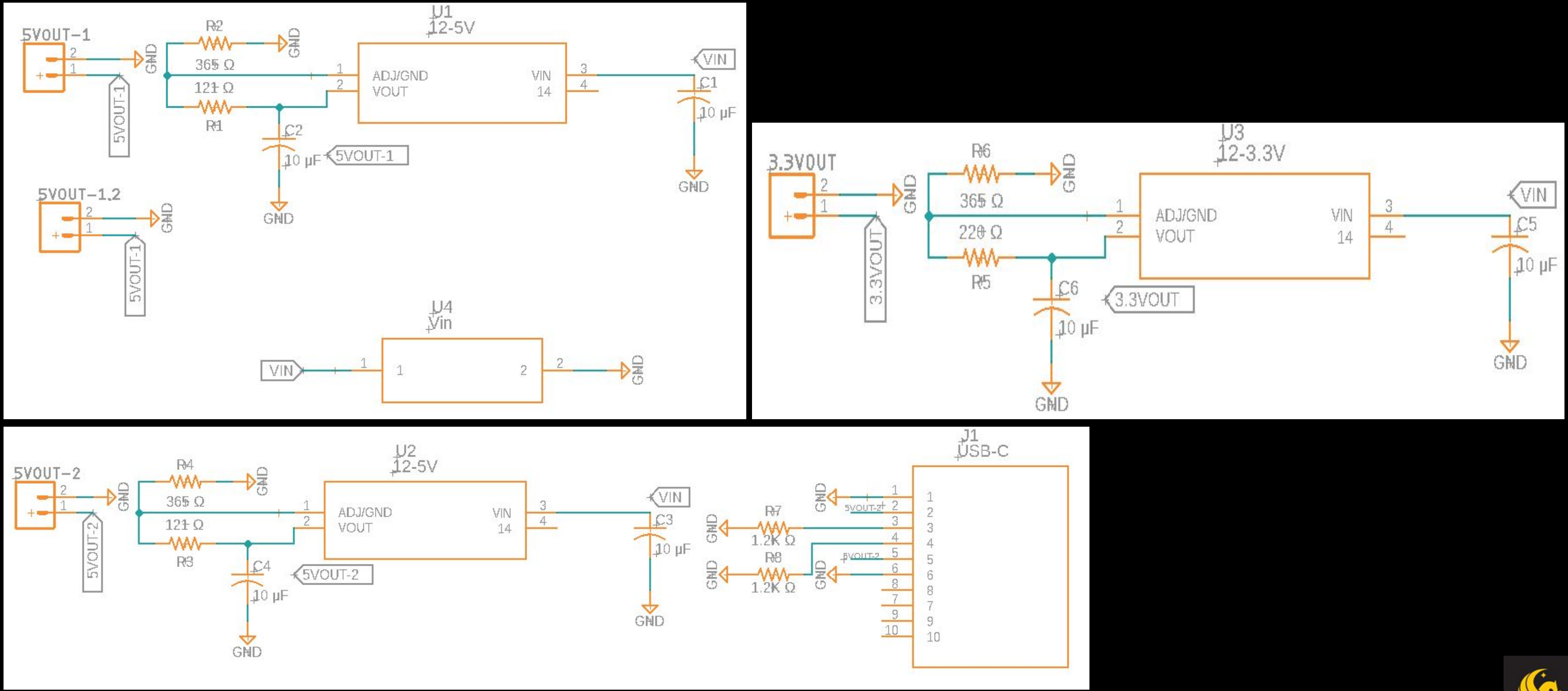
Regulator Selection

- 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

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



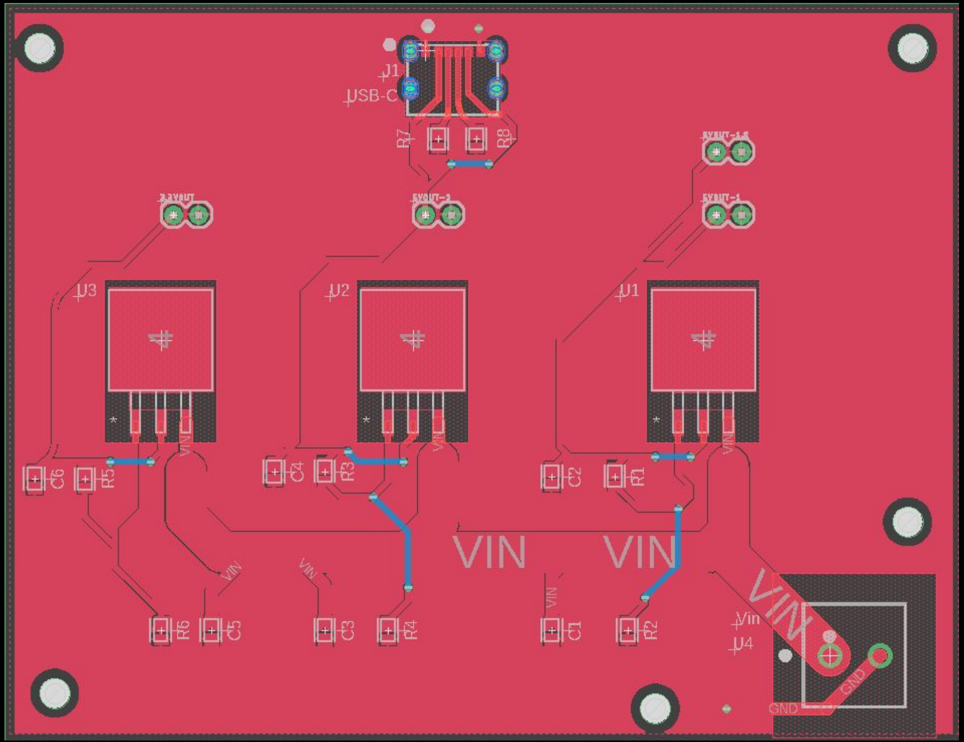
Power Supply PCB

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



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Battery

- 18650 11.1 V Battery Pack 15 Ah
  - 15.0 A Max Discharge Current
  - 750 grams
  - If USB-C Port implementation works

- 18650 11.1 V Battery Pack 7500 mAh
  - 15.0 A Max Discharge Current
  - 410 grams
  - Backup Power Supply

Backup Power Supply

- USB-C port may require USB-C controller
- USB-C controllers are not available for our requirements
- Backup battery pack to power the Jetson Nano and LiDAR only

Software Design

Software Design: Overview

Computer Vision

- Use object detection on the Jetson Nano to detect cups
- Send data 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 in ROS and Python

Microcontroller

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

Software Design: Object Detection

TensorFlow

- Open-source machine learning library by Google.
- Includes an object detection API with many functions to create, train, and evaluate our computer vision model.
- TensorFlow was chosen because it has more support.

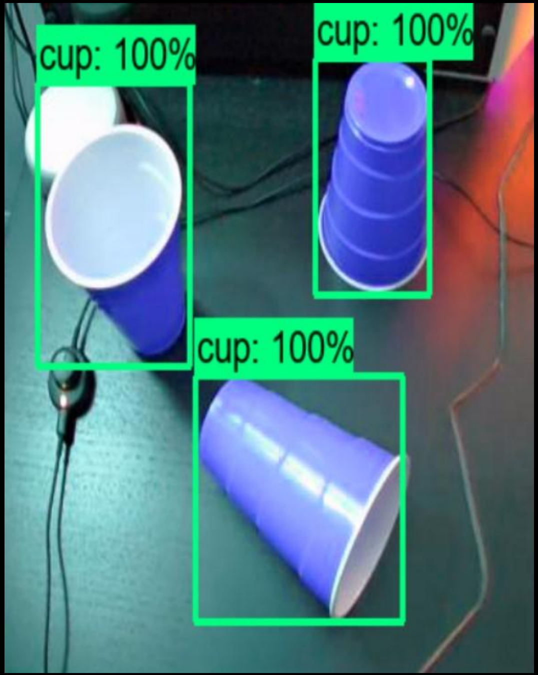
TensorFlow Detection Model Zoo

- Includes state of the art pre-trained detection models which can be used to train custom datasets on.
- We chose to use the SSD MobileNet V2 320x320 model since it would perform the best on a Jetson with its lower resolution.

Software Design: Object Detection

OpenCV

- An open source computer vision library.
- Used for image preprocessing and obtaining a camera feed for our object detection model.
- Allows us to display detection boxes on the camera feed.



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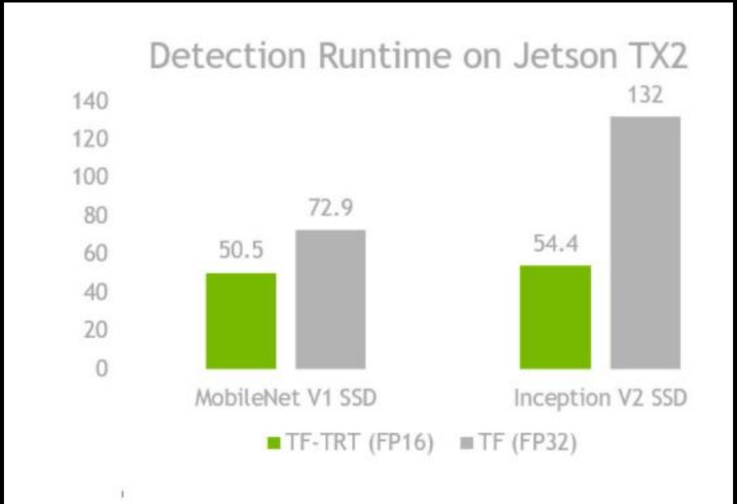
Software Design: Object Detection on Jetson Nano

The Jetson Nano will be running an inference of the model we trained on the desktop.

TensorRT

- Used to optimize trained models from TensorFlow so that it runs faster and more efficiently on an Nvidia Jetson Nano.



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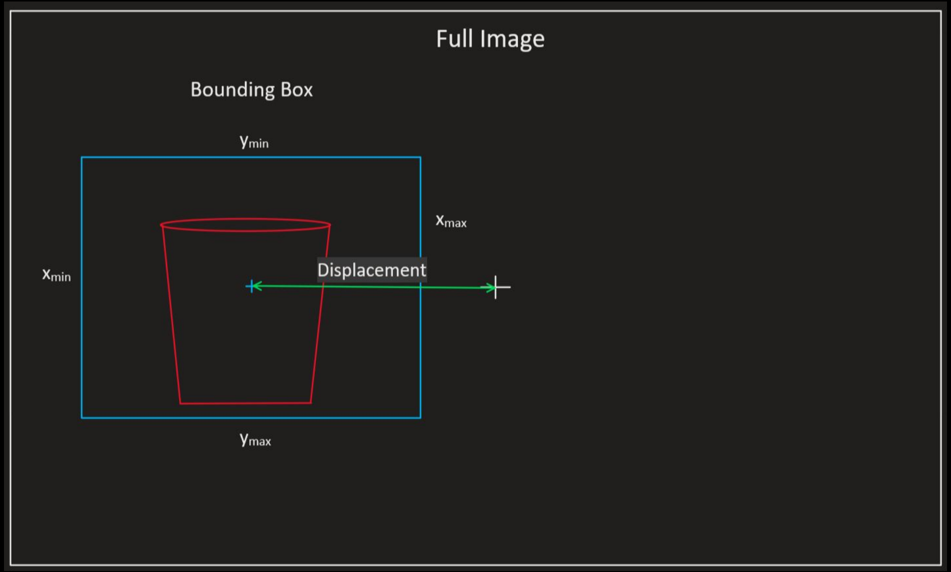
Software Design: Communication with MCU

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

The software will determine if the object is centered on the image and adjust the servo motors accordingly using a PWM signal.



Software Design: Simultaneous Localization and Mapping (SLAM)

- ROS Navigation Stack
  - slam_gmapping wrapper to create map.
  - amcl for the 2D localization system.
  - move_base to send goals in the real world.

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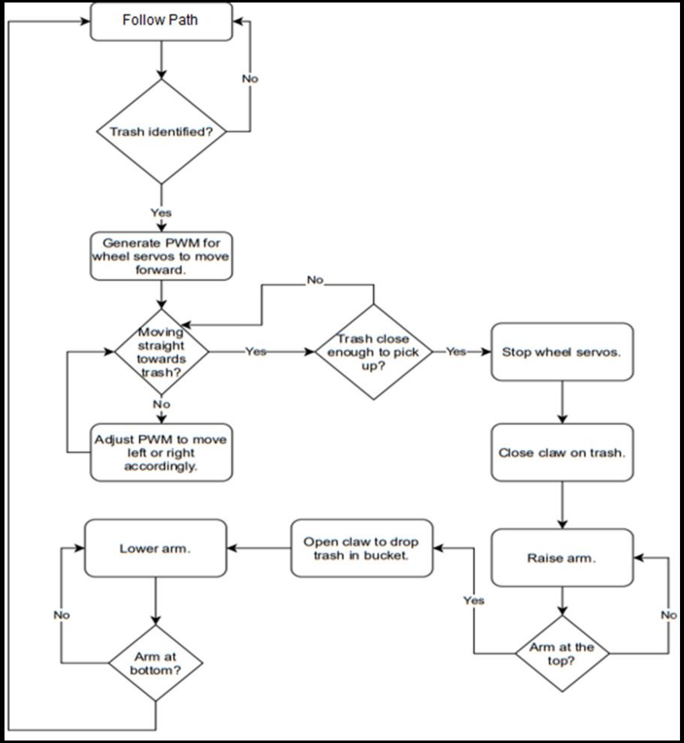
Software Design Flowchart



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Software Challenges

Challenge	Solution
Low object detection model accuracy regardless of the amount of images in the dataset and training steps.	Removed hi-res photos from the dataset and included only photos that matched the resolution of the 1080p camera.
Object detection model reported high accuracy in the evaluation metrics but performed poorly in real-time performance.	The images going into the model were in BGR format. Converting the image to RGB resulted in the correct performance.
Little documentation of programming this MCU due to popularity of the development board.	Utilize programmer on dev board with breakout pins while learning to program MCU with OpenOCD.

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

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Administrative Content

Current Progress

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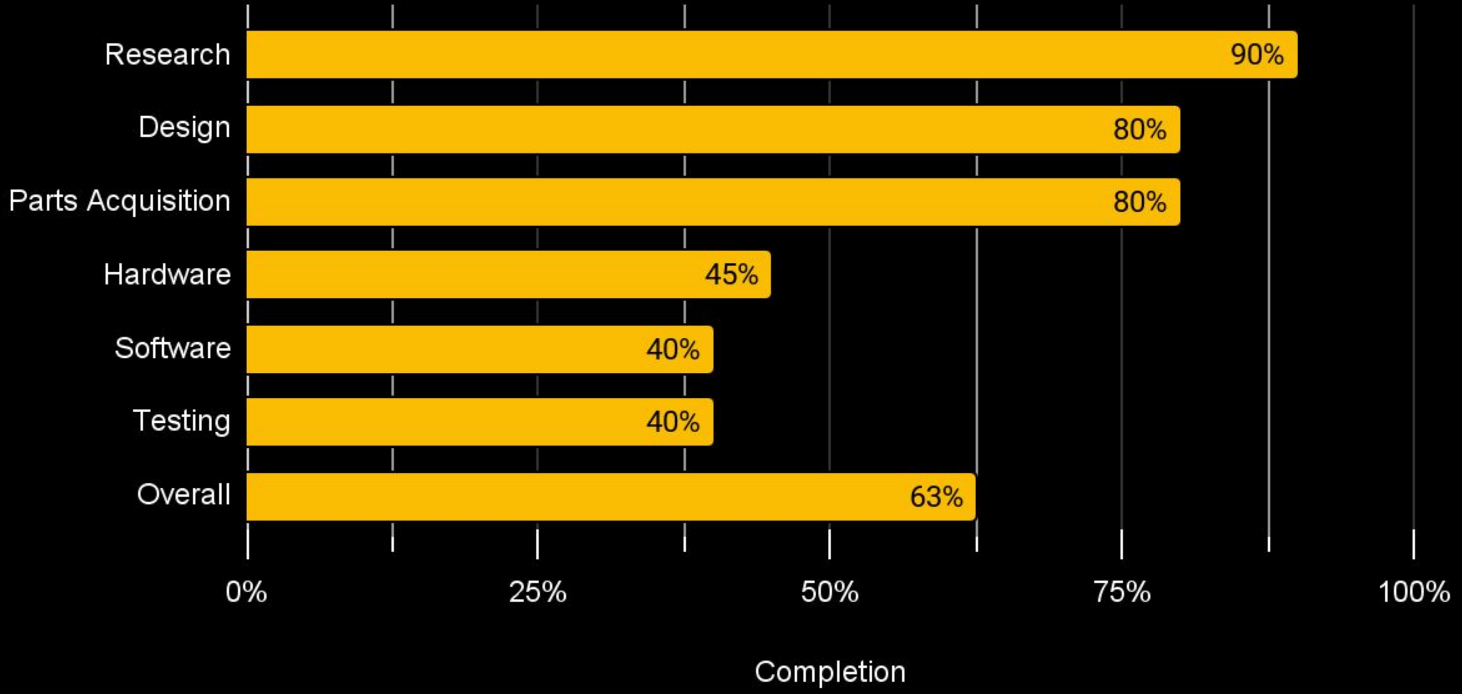

Budget

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

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Immediate Plans

- Finish housing of robot
- Test the object detection model on the Jetson Nano
- Microcontroller programming
- Begin SLAM and LiDAR programming
- Solder PCBs on arrival
- Determine which batteries to use