

Radio, Robot, Recycle

Karyn Carrión (ECE), Max McCalla (RBE), Alec Norton (RBE), Kylie Solecki (ME), Stephen Wojcik (RBE)
 Advisors: Professor Bashima Islam (ECE), Professor Giovanni Pittiglio (RBE)

Introduction

Recycling requires reliable **identification** and **handling**. Prior systems struggle with classification and manipulation. This project integrates radio, vision, and robotic improvements.

Objectives

- 1 Adapt existing robot arm by increasing movement, control and strength.
- 2 Develop manipulators to pick a variety of objects.
- 3 Develop a system that combines sensor data and implementing sorting procedure.

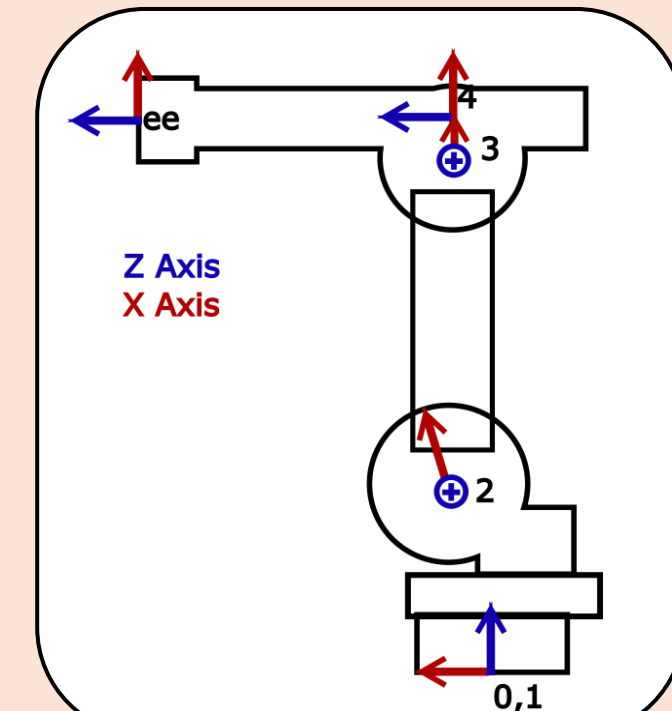
Robot Improvement

Physical Improvements

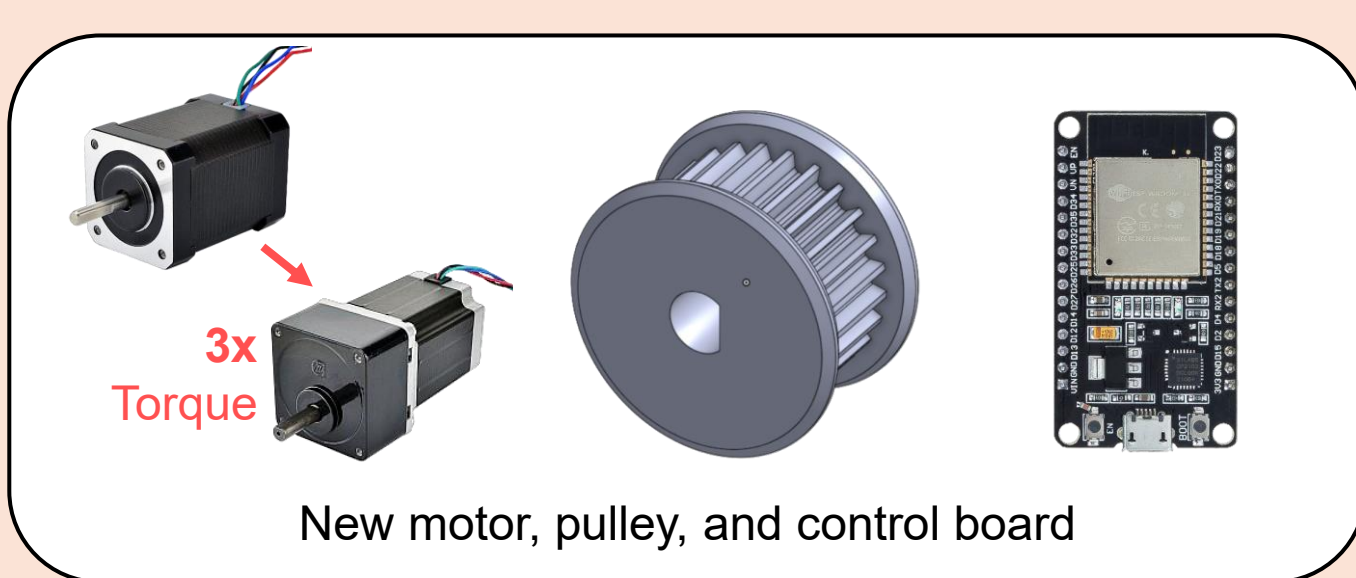
- **New Motors** for higher lifting power
- **Redesigned pulleys** to reduce belt slip

Electrical Improvements

- Rebuilt control system around **ESP32**
- Improved communication and motor control



Kinematics Frames

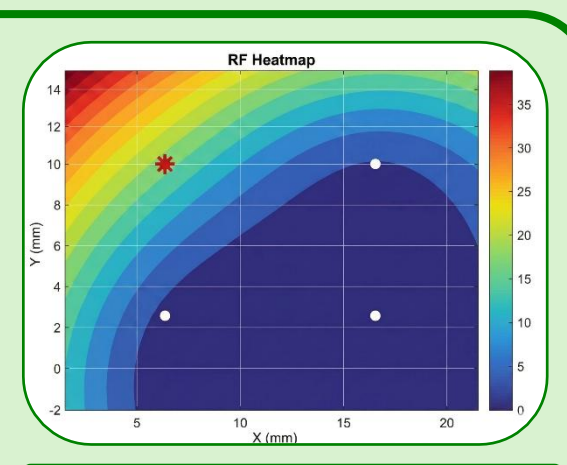
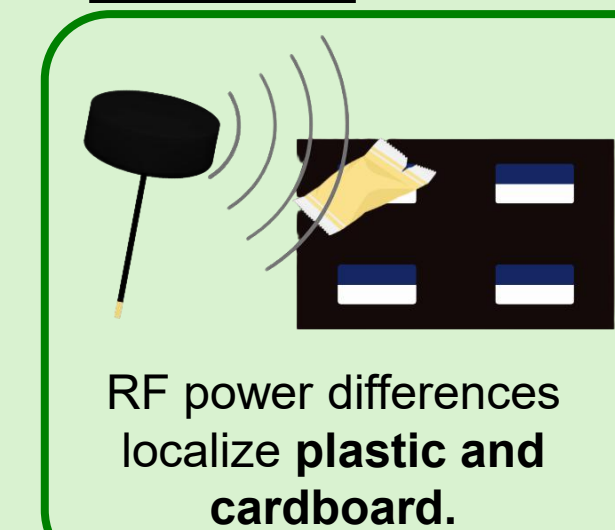


New motor, pulley, and control board

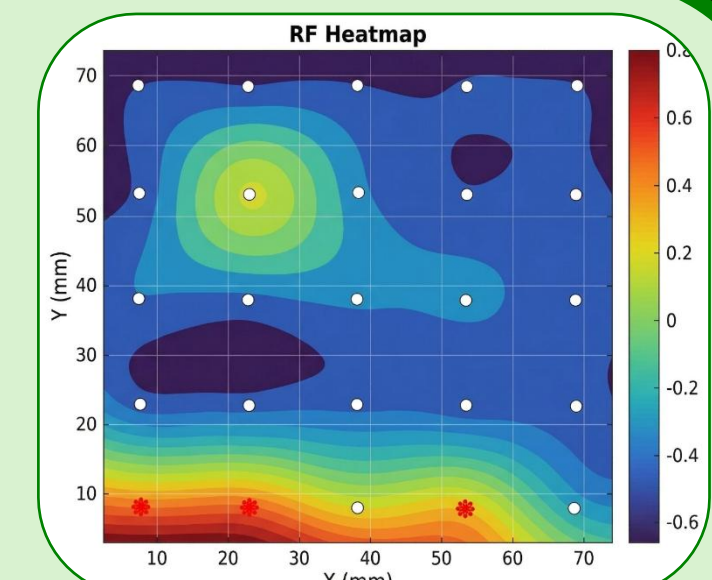
Programming Improvements

- **New kinematics** code using DH and Iterative IK
- **Onboard motor control** with offboard kinematics

Radio



4-Tag Occlusion Heatmap



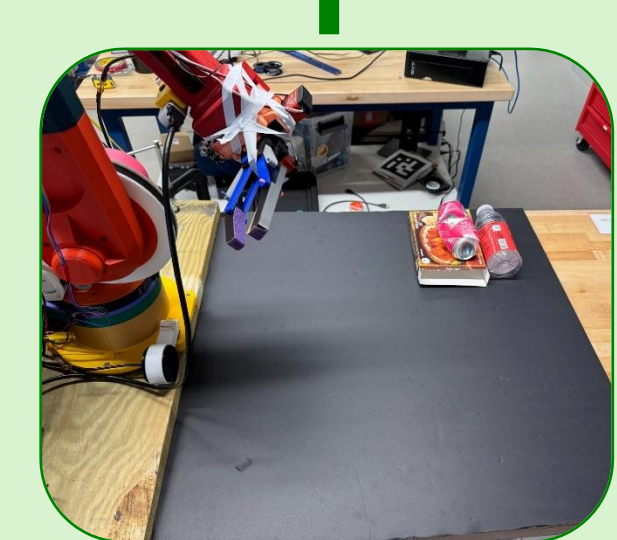
25-Tag Occlusion Heatmap

Calibration
 Maps empty-table coordinates and **baseline frequencies**.



Material Library
 Stores RF signatures for cardboard, plastic, glass, and aluminum using **cosine similarity**.

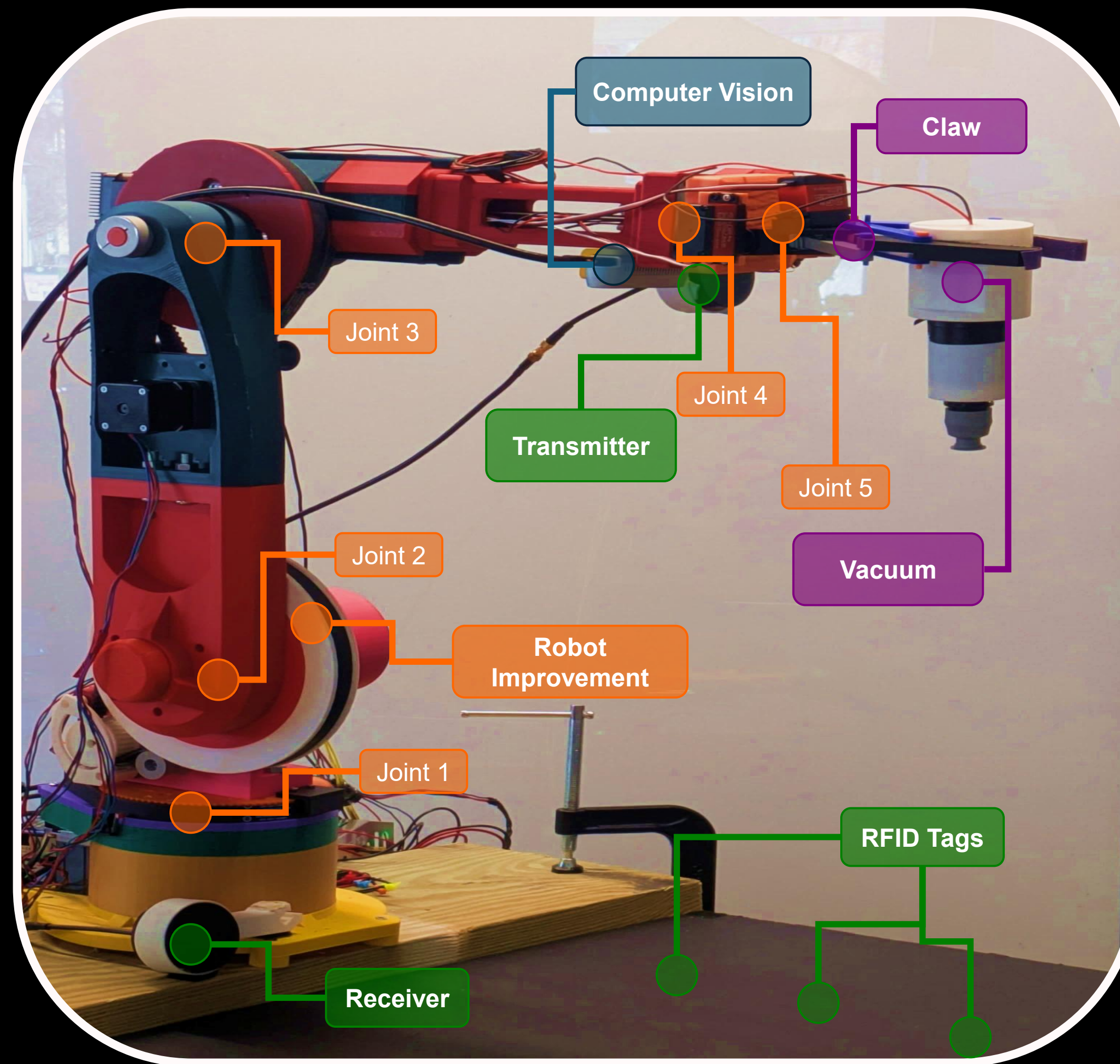
Live Scan
 Uses **anomaly detection** (inverted sorting) to compare live scan against library.



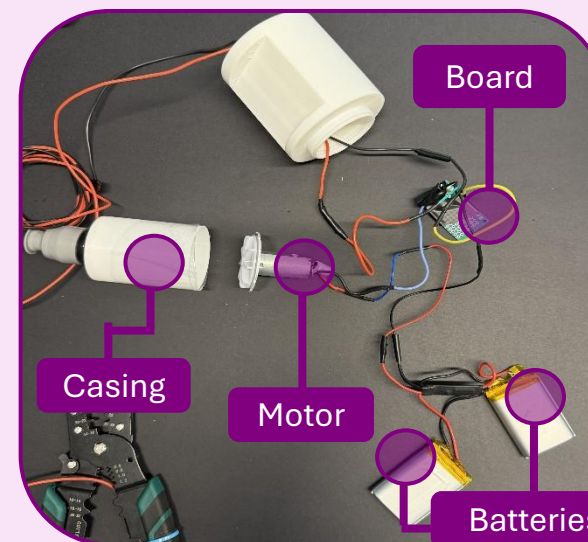
Bistatic 915 MHz Radar Setup

Takeaways

- 1 Integrated recycling robot using RFID and computer vision.
- 2 Improved manipulation.
- 3 Sensor fusion to improve object classification, localization and handling.



Vacuum



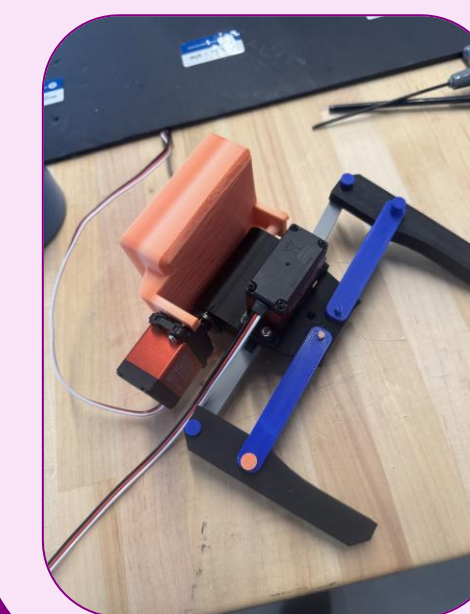
Vacuum Overview

The vacuum extension allows the robot to pick up **lightweight** objects, such as plastic, that are **difficult** for the gripper to handle.

Object Overview

Objects ranging in size, weight, material, and rigidity were successfully picked up due to the multiple end effector set-up. These items ranged from 0.5 to 300 grams.

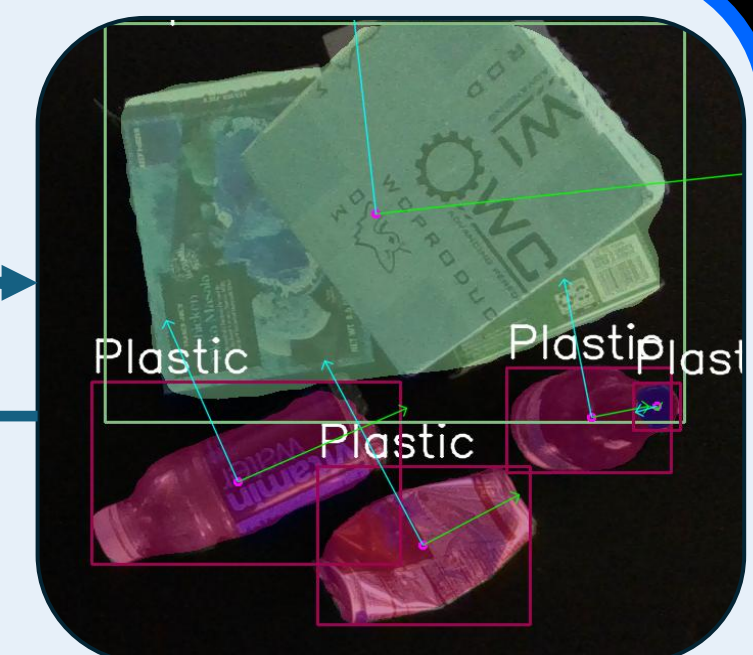
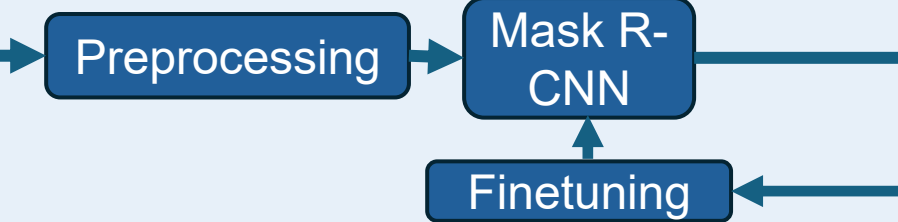
Gripper



Gripper Overview

The claw gripper allows the robot to grasp and manipulate rigid objects weighing from 10 grams to 300 grams.

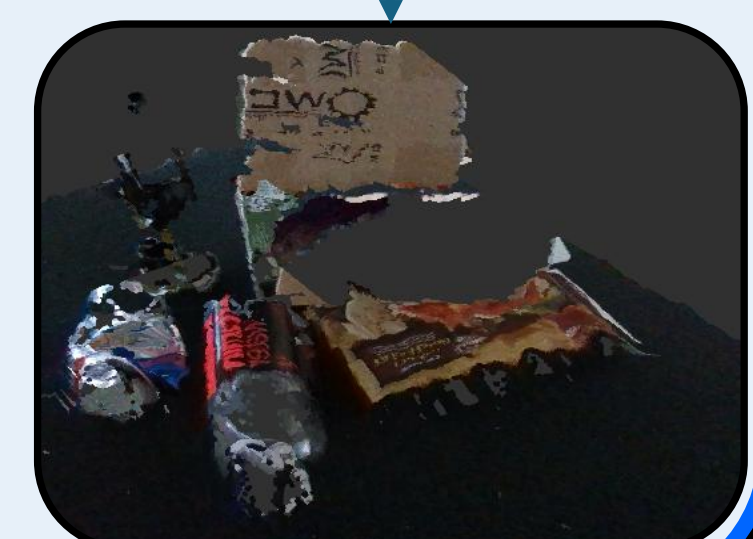
Computer Vision



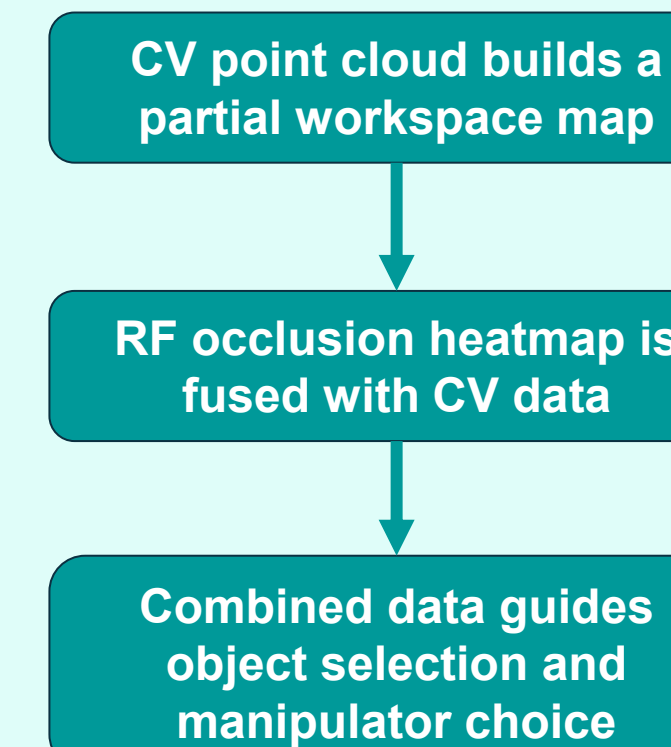
- Developed instance segmentation model comparable to prior work (~53%)
- Detects **glass, plastic, metal, paper, trash, and other**.

Pipeline:

- 1 Use Trash Annotations In Context (**TACO**) dataset.
- 2 Preprocess and augment image
- 3 Label images and finetune model with environment.
- 4 Generate object masks and pose estimates with point cloud.



Sensor Fusion



Key Results

- Radio:**
 - Localized waste objects in 4-tag system.
 - Resolved multipath fading and mixed-pile occlusion in 25-tag system.
- Gripper:**
 - Increased gripping strength from 30 grams to 900 grams.
- Computer Vision:**
 - Classified and localized waste objects.
- Vacuum:**
 - The extension was able to pick up 80% of materials tested.
- Robot Improvement:**
 - Tripled torque output.
 - Eliminated electronics errors.

Future Works

- Radio:** Implement monostatic radar setup, hardware shielding, and expand material library.
- Vacuum:** Improve battery system and upgrade to wireless connection.
- CV:** Use point cloud to classify objects, test different datasets for performance, upgrade camera hardware.
- Robot & Gripper:** Upgrade gears to increase strength. Increase degrees of freedom for angled pickup.