

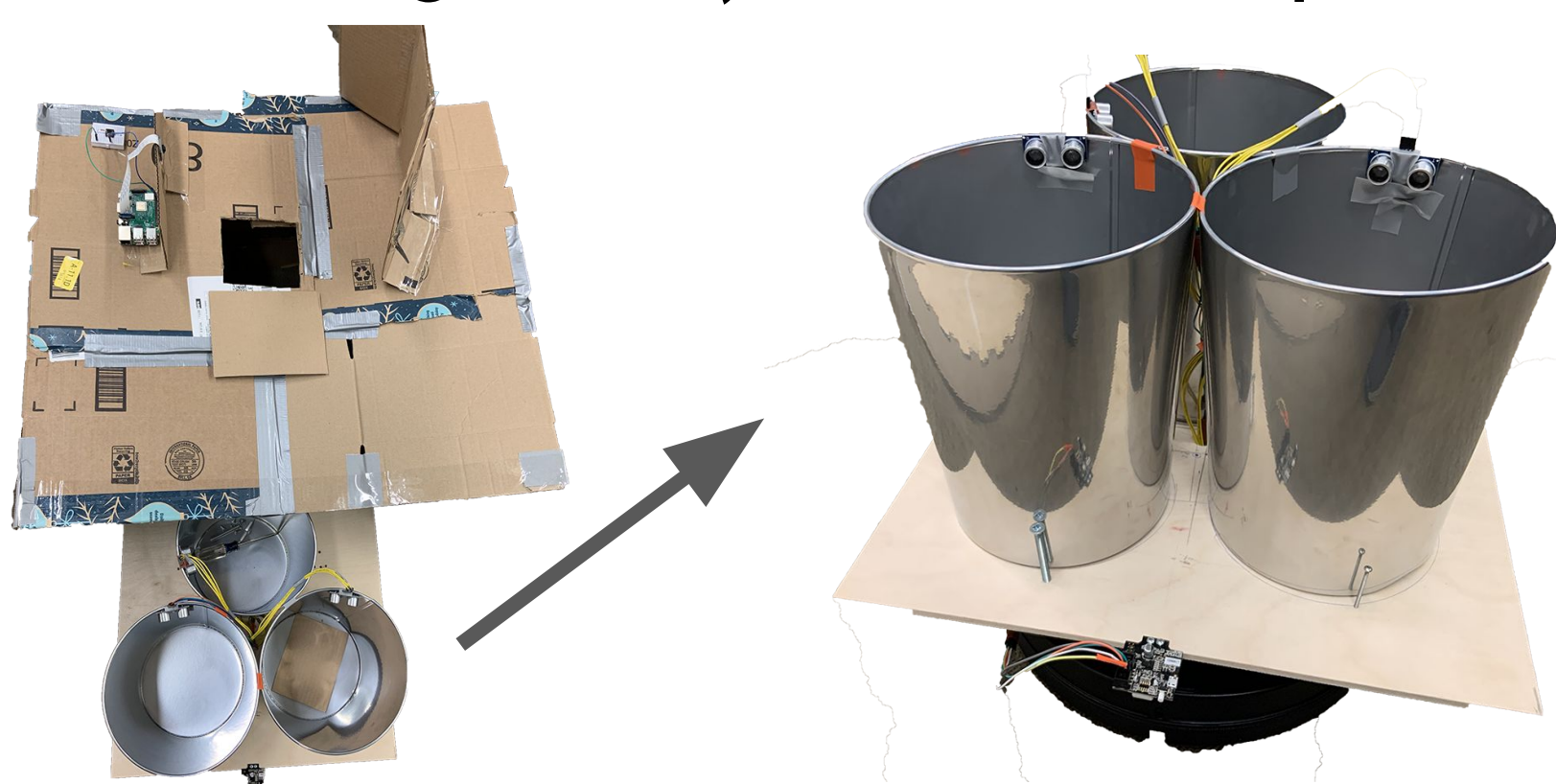
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Project Goal

Recycle | **Compost** | **Landfill**

Streamline the waste removal process by:

- Automatic waste collection through classifying and actuating correct bins to users using computer vision classification
- Autonomous waste disposal by following paths (tapes on the ground) to trash disposal location



Hardware & Software Architecture

Electronics

Raspberry Pi

- Wireless networking
- Google Cloud API Client
- Trash classifier
- BLE master

Pi Camera
CSI

Button
GPIO



NRF52832+Buckler

- BLE Slave
- Gyroscope
- Trash actuator

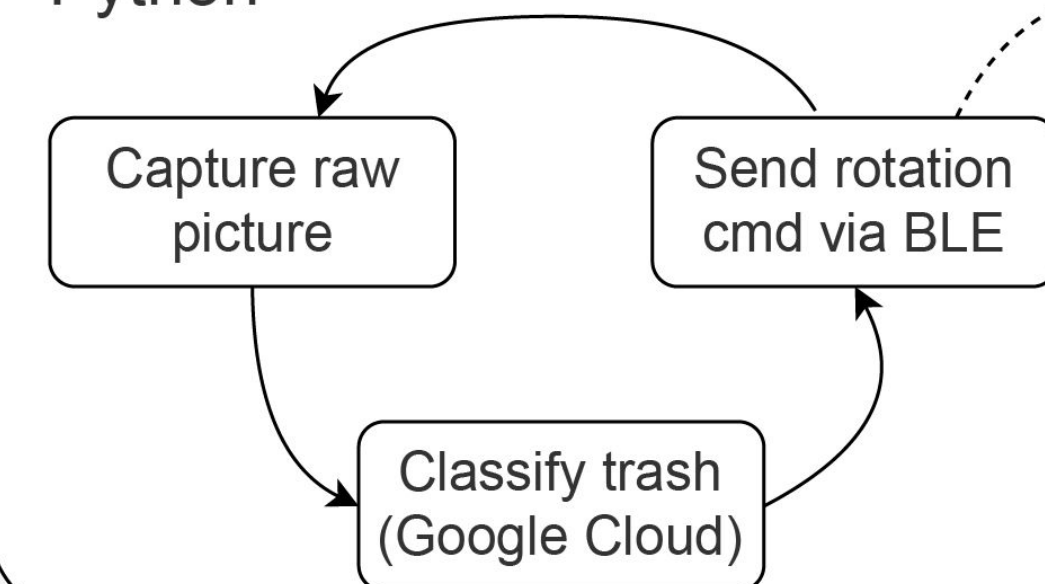
Kobuki Robot
UART

CMUPixyCam
SPI

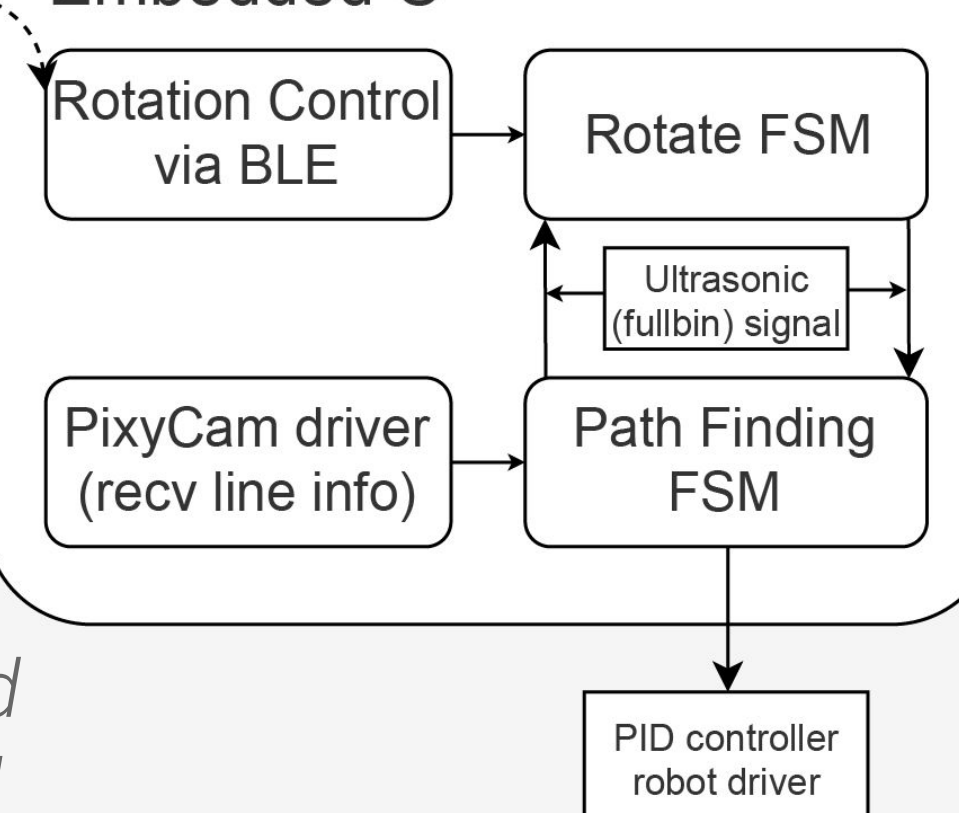
Ultrasonic Proximity
GPIO

Software

Python



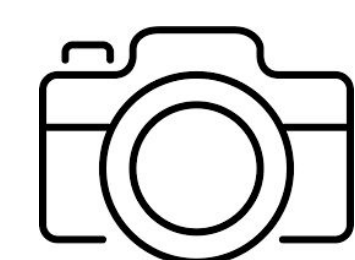
Embedded C



Other Open source codes: Buckler and NRF52832 libraries; Google Cloud API

Computer Vision & Classification

Image captured by camera

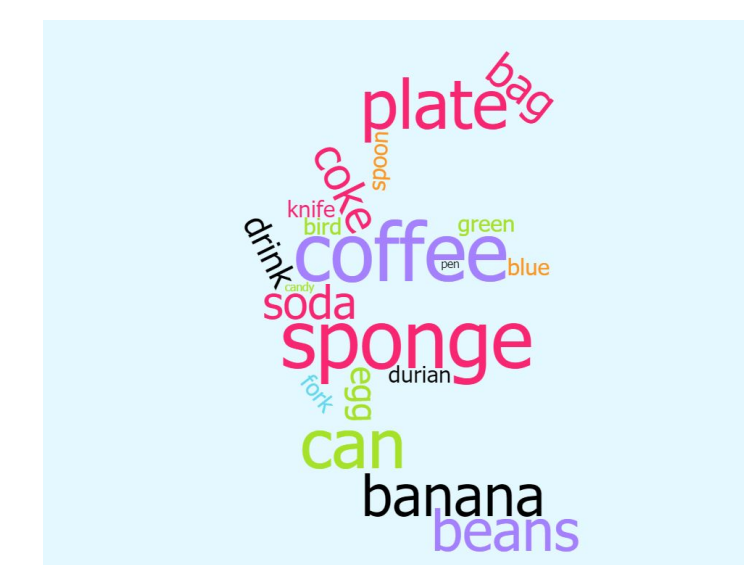


Sent to Google Cloud for Classification



Labels are returned, and matched with hard coded labels for *recycle*, *compost*, and *landfill*.

The waste is classified as the class with the most label matches



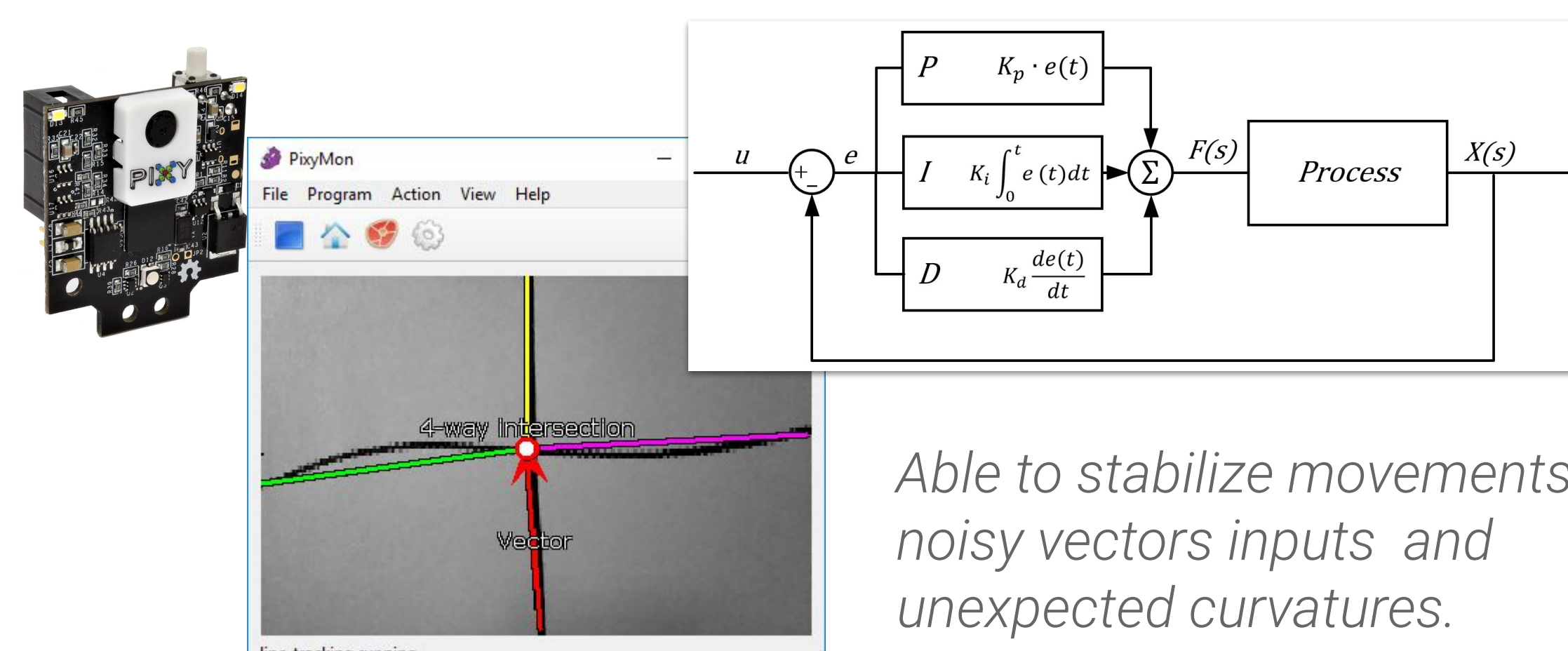
Buckler Raspberry Pi BLE Communication

Once the Raspberry Pi receives a waste classification, it sends a **BLE** message to the Buckler to **rotate** the correct waste bin so a user can input waste.



Path Finding by a PID Controller

When bins are full, Kobuki carries bins to waste disposal. PixyCam takes ground pictures and returns colored tape vectors, which are used for path finding using Yakindu StateCharts and PID controller.



Able to stabilize movements with noisy vectors inputs and unexpected curvatures.

Evaluation & Tradeoffs

Trash classification accuracy:

- ❑ We can classify **distinct** objects such as apples, potato chip bags, and soda cans.

	No Object	Recycle	Compost	Landfill	Overall
Accuracy	71.43%	100%	100%	57.14%	71.43%
F1 Score	0.80	1.00	1.00	0.67	0.79

Sensor accuracy:

- ❑ Gyroscope: MPU9250 on Buckler gives bad accuracy ($\pm 10^\circ$ each rotation), and bins are no longer aligned. We **augmented rotation measurement with vector information** from PixyCam.
- ❑ Ultrasonic sensor can produce false bin fullness signals due to random reflections in a small bin. To eliminate error, we require 5 positives in a row.
- ❑ Colored tape vector info from PixyCam has 10% errors. This motivated us to use **PID feedback** controller which is immune to the error.

Connections to Course Topics

Sensors and Actuators:

- ❑ Raspberry Pi Cam: Camera taking trash pictures.
- ❑ CMUPixyCam: Visual sensor reading colored tapes on the ground.
- ❑ Ultrasonic Proximity Sensor: detecting bin fullness.
- ❑ Buckler MPU9250 Gyroscope: tracking rotation.
- ❑ Kobuki: Actuator driving and carrying all bins.

Networking:

- ❑ Bluetooth Low Energy used for communicate between Raspberry Pi and Buckler..

Continuous dynamics:

- ❑ Kobuki drives itself using a PID feedback controller with colored tape vectors as inputs.

Finite-state machines:

- ❑ Kobuki carries three bins and uses a Hierarchical State Machine to model its states and actions.