

Bin There Dump That

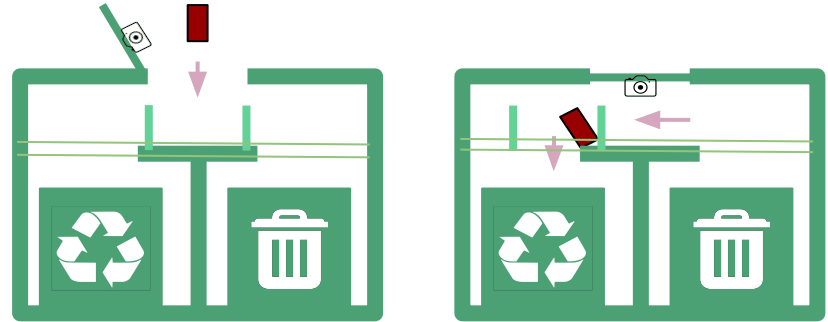
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Application Area

Automatic trash can for sorting recyclables vs. non-recyclables one item at a time

- Target Audience: CMU campus
- Goal: Increase recycling rate
- Assumptions
 - No liquids, single-material items
- Recyclables
 - Paper/Cardboard
 - Metals
 - Glass
 - HDPE/PET plastic



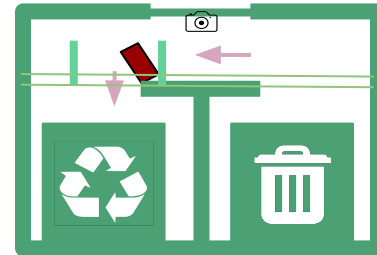
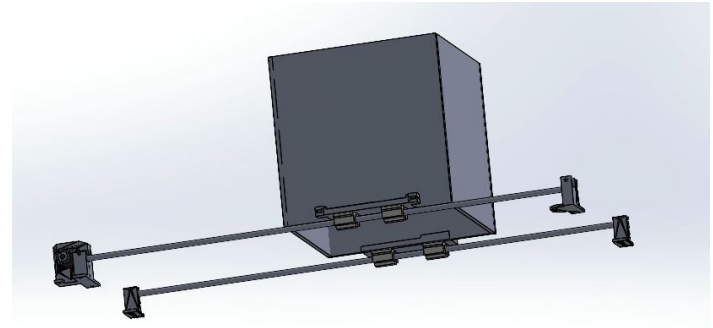
Solution Approach - Classifier

- Image Classifier
 - Retrained Resnet-101 Network to classify:
 - Metals
 - Paper
 - Cardboard
 - Glass
 - Plastic Bottles
 - Trash (non-recyclables)
- Sensor Classifier
 - Binary classifiers to classify:
 - Metals vs nonmetals (inductive sensor)
 - Glass vs non-glass (capacitive sensor)
 - HDPE Plastic vs non-HDPE plastic (capacitive sensor)
- Overall Classifier: recyclable vs. non-recyclable

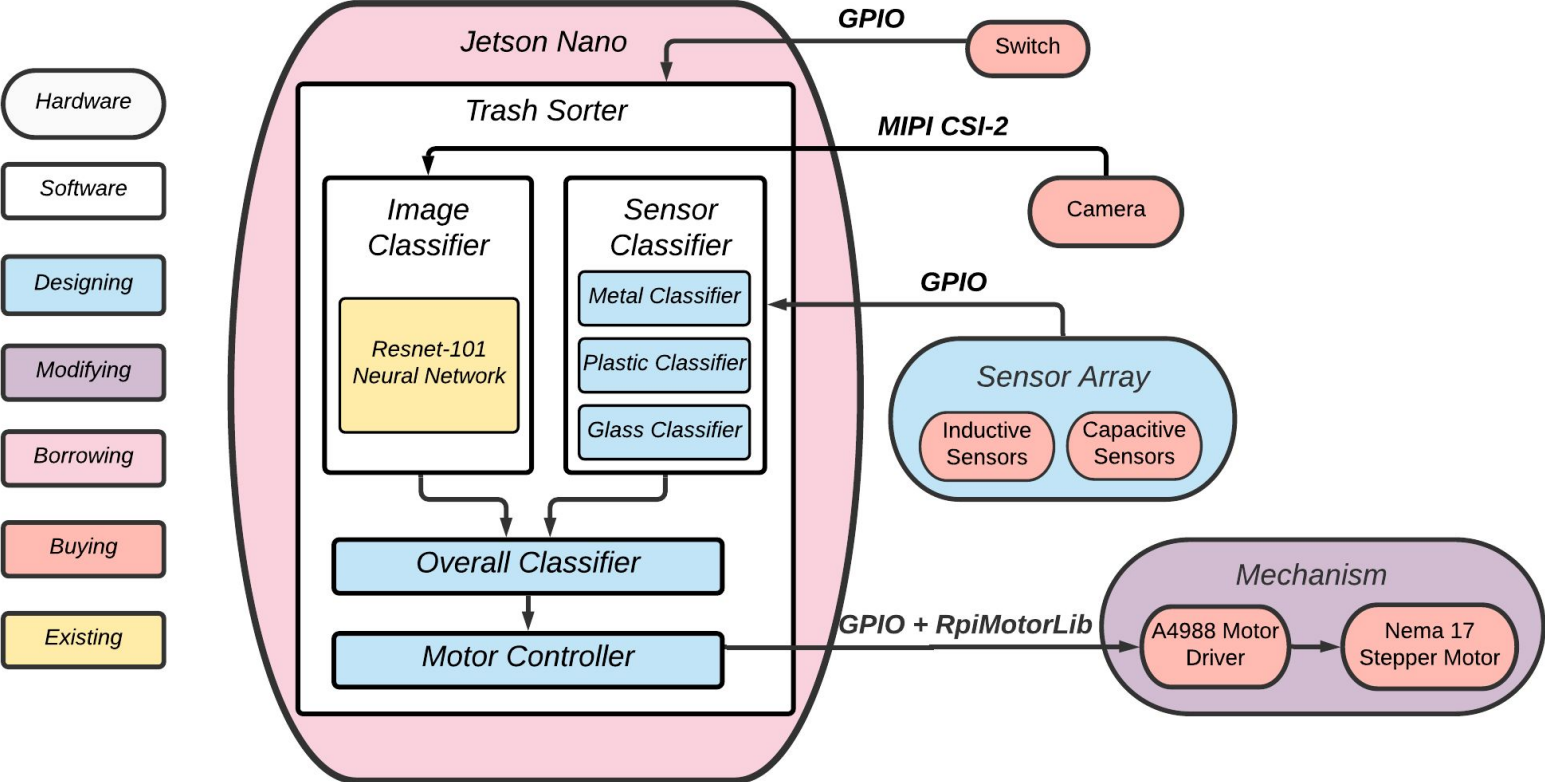


Solution Approach - Hardware

- Trash dropped into sensor box
 - Sensor array embedded into bottom platform
 - Camera mounted below lid
- Walls of box push trash into correct bin
 - Belt driven linear motor actuator
- Components
 - Jetson Nano
 - Nema 17 Stepper Motor + A4988 Motor Driver
 - Raspberry Pi Camera v2
 - Sensors (Inductive, Capacitance)
 - LED strip

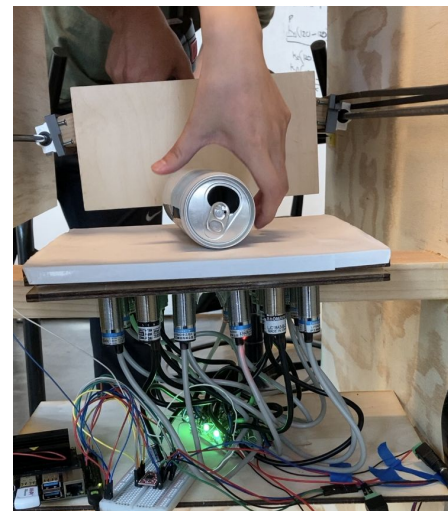
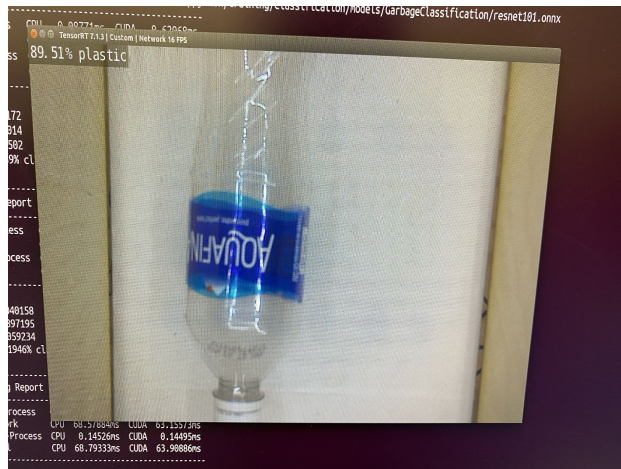


Block Diagram



Complete Solution

- All subsystems are integrated
- For final demo, show end-to-end classification
 - User places trash into bin and trash can automatically push it to correct bin



Design Trade-Offs

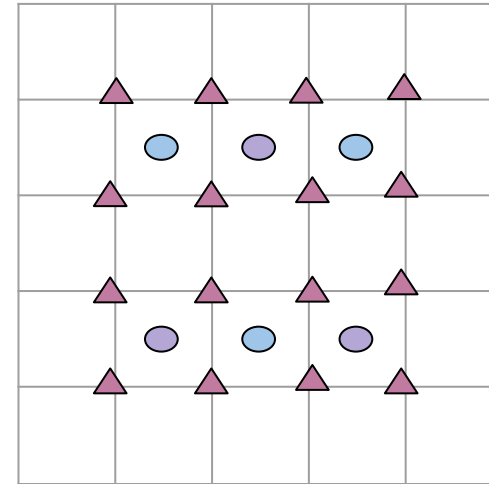
Sensor Classifier

- Type of sensors (Capacitive, Inductive, IR, LDR, etc)
 - Accuracy vs cost
- Placement/number of sensors
 - Accuracy vs cost vs space on platform

Mechanism

- Step delay
 - Accuracy vs latency
- Gear size
 - Cost/complexity vs latency
- Motor
 - Weight vs latency

Sensor Platform Design

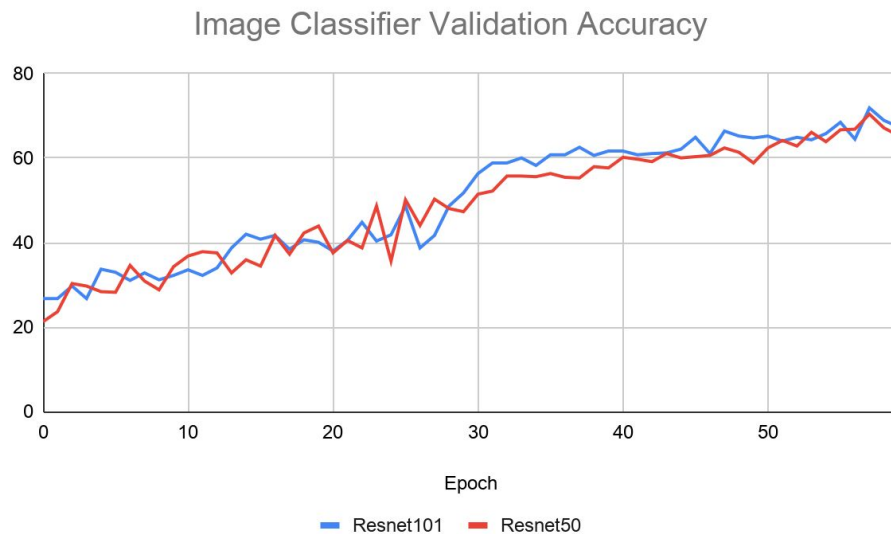


- ▲ 1 Inductive Sensor
- 2 Capacitive Sensors for Plastic
- 2 Capacitive Sensors for Glass

Design Trade-Offs

Image Classifier

- Number of epochs
 - Training time vs accuracy
- Resnet-50 vs Resnet-101 Model
 - Training time vs accuracy
 - Resnet-50: ~11 hours
 - Resnet-101: ~24 hours



Metrics, Testing, & Verification

Component	Testing Strategy	Metric	Results
Mechanism	<ul style="list-style-type: none">- Mechanism accuracy (pushing object to correct bin)	99% Accuracy	100% Accuracy
Classifier	<ul style="list-style-type: none">- Image classifier: classification accuracy of images of objects (from existing dataset + our images)- Sensor Classifier: classification accuracy of real objects- Overall Classifier: classification accuracy of real objects	90% Accuracy	90.61% Accuracy False Positive: 11% False Negative: 6.6%
All	<ul style="list-style-type: none">- Classifier Latency: time taken to classify 1 image/object- Mechanism Latency: time taken to move 1 object	Overall latency < 1s	Overall: < 2.78 s Classifiers: 0.117s Mechanism: 2.66s

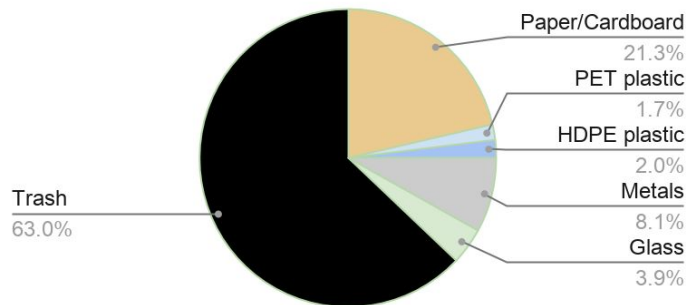
Classifier Accuracy Results

Material	Sensor Accuracy	Image Accuracy	Overall Accuracy
Plastic	79.64	42.72	89.82
Metal	96	82	98
Glass	76	90	96
Paper/Cardboard	52.2	84.8	91.56
Trash	92	96	89
Overall	67.08	80.62	90.61

50 trials/material for sensor, image classifiers
100 trials/material for overall classifier

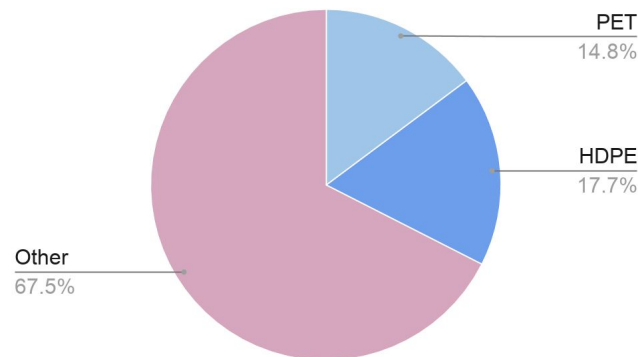
Materials by Waste Generation, 2018

EPA



Plastics by Waste Generation, 2018

EPA



Summarized Results

- Classifier Accuracy: 90.61%
 - Recyclables: 93.36%
 - National recycling accuracy: 31%
 - Trash: 89%
 - Our contamination Rate: 11%
 - National contamination rate: 25%
- Mechanism Accuracy: 100%
- Overall Latency: 2.78 s
 - Classifiers: 0.117 s
 - Mechanism: 2.66 s

