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
 - o Glass
 - HDPE/PET plastic





Solution Approach - Classifier

- Image Classifier
 - Retrained Resnet-101 Network to classify:
 - Metals
 - Paper
 - Cardboard
- ► Recyclables

- 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 0
- Placement/number of sensors
 - Accuracy vs cost vs space on platform Ο

Mechanism

- Step delay
 - Accuracy vs latency 0
- Gear size
 - Cost/complexity vs latency 0
- Motor
 - Weight vs latency 0

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

Image Classifier Validation Accuracy



Metrics, Testing, & Verification

Component	Testing Strategy	Metric	Results		
Mechanism	- Mechanism accuracy (pushing object to correct bin)	99% Accuracy	100% Accuracy		
Classifier	 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	 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

Materials by Waste Generation, 2018

EPA



Plastics by Waste Generation, 2018



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

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





Gantt Chart

Challenges

- Sensor Calibration
- Xavier → Nano
- Rebuilding trash exterior

	TASKS	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Finals
		2/22	3/1	3/8	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/3	5/10
	Milestones	Proposal Presentation		Design Presentation	Design Repor	t			Interim Demo	erim Demo		Final Presentation	Final Report/Demo
1	Mechanism	Mechanism											
	Finalize Mechanism Design	JT	JT										
	Order Mechanism Parts		т	т									
	Build Mechanism				JT	JT	т	т					
	Connect motors to Jetson Nano						J						
_	Build sorting box			4 Ball (1999) (1999) (1999) (1999) (1999)	-	т	т	A.A.C					
	Build infrastructure					т	т						
	Integrate mechanism + infrastructure							т	т				
	Test Mechanism							JT	JT				
2	Sensor Classifier												
	Order Parts	т			L							I	
	Collect sensor data & test sensors			All	All							1	
	Build sensor array			-	All	L	d	0					
	Integrate sensor array with Jetson						J						
	Calibrate sensors						L	L					
	Build model for sensor classifiers						J	J					
	Test sensor classifiers							L	L	т			
	Improve sensor classifiers										L		
3	Image Classifier												
	Find datasets		J										
	Research Models		IJ	LJ									
	Build Model				J								
	Train model on existing dataset					J							
	Collect Images of real objects								т				
	Train model on dataset + added images							J	J	IJ	LJ		
	Manually test classifer (images of real objects)								J	IJ	All	All	
4	Integration												
	Integrate camera with box						т		[
	Integrate sensor with image classifier					1	J	J					
	Test overall classifier (images + sensors)								LJ		LT		
	Test overall (classifier + mechanism)									All			
	Improve overall classifier										LJ	All	
5	Milestones												
	Design Presentation		All										
	Design Report			All	All								
	Final presentation											All	
	Final report / demo												All

March

April

May