The Embellisher

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Problems

Unclean streets in urban and underdeveloped areas lead to...

- Increased pollution
- Sanitization hazards
- Intensive human labor
- High cleaning costs

City	Population	Area (Sq. Miles, Land)	Street Cleaning Spending (FY 16-17)	Spending per Capita	Street Cleaning FTE Count (FY 16-17)
Baltimore*	611,648	80.9	$24,284,646	$39.70	N/A
Chicago	2,704,958	227.3	$8,548,428	$3.16	71
Long Beach	470,130	50.3	$5,313,421	$11.30	15
Los Angeles*	3,976,322	468.7	$12,400,000	$ 3.12	111
Minneapolis	413,651	54.9	$8,800,000	$21.27	54
Oakland*	412,040	55.9	$15,000,000	$36.40	61
Portland	639,863	133.0	$7,461,034	$11.66	30
Sacramento	501,334	97.9	$936,292	$1.87	7
San Diego	1,406,630	325.2	$3,282,000	$2.33	40
San Jose	1,015,785	177.5	$6,320,000	$6.22	18
Seattle	713,700	83.9	N/A		N/A
Median	**639,863**	**97.9**	**$ 8,004,731**	**$8.76**	**40**
San Francisco	864,816	46.9	$34,988,059	$40.46	302

Figure 1: Spending & Staffing for Street Cleaning - Surveyed FY 2016-17

https://stormwater.pca.state.mn.us/index.php?title=Cost_considerations_for_establishing_and_maintaining_a_street_sweeping_program#:~:text=The%20case%20studies%20showed%20widely,cost%20was%20%24487%2Fcurb%20mile.'
https://sfbos.org/sites/default/files/BLA_Report_Street_Cleaning_Cost_Survey_062518.pdf

Use Case

Problems	Needs
Increased pollution	Identify garbage on sidewalks
Sanitization hazards	Pick up and collect garbage
Intensive human labor	Navigate autonomously
High cleaning costs	Restrictive budget
Public safety (simplified)	Avoiding obstacles

Idea: a **garbage collecting robot**

ECE Areas: Software Systems, Hardware Systems

Use Case Requirements

Requirement	Metric	Rationale
Object Classification ML Model	>= 85% mAP	Always a tradeoff between precision + recall True positives > false positives Can reach trash in > 1 way
	>= 70% recall rate	
Object Avoidance	>= 95% success rate	Reliability + consistency under normal conditions
Efficiency	>= 90% pick up rate	9 out of 10 trash collected
Voltage	<= 14.8V	Vacuum cleaner needs 14.8 V
Weight (carry)	>= 0.5 lb	~ 15 soda cans ~ 12 plastic water bottles
Room Size	>= 4ft x 8ft	Models simplified sidewalk

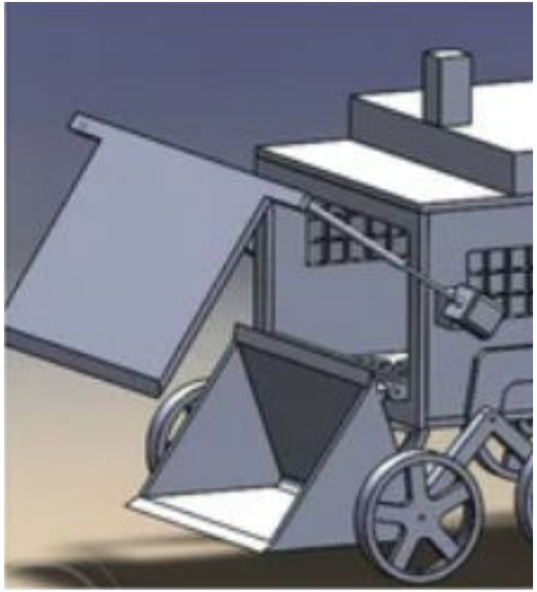
https://policyadvice.net/money/guides/how-many-aluminum-cans-make-1-pound/

Technical Challenges

Requirements	Challenges	Risk Mitigation
Object Classification: 85% mAP, 70% recall	Achieving high enough precision	Test two pre-trained models rather than developing a model from scratch
Efficiency: Pick up 90% of the defined trash components	Working pick up mechanism regardless of orientation	Have a backup pick-up mechanism ready (scoop AND roller)
	Reaching trash	Use simple path finding algorithm
Unobtrusiveness: Avoid obstacles and boundary 95% of the time	Avoid running into them, figuring out how to get around it	Limit obstacles to size taller than robot

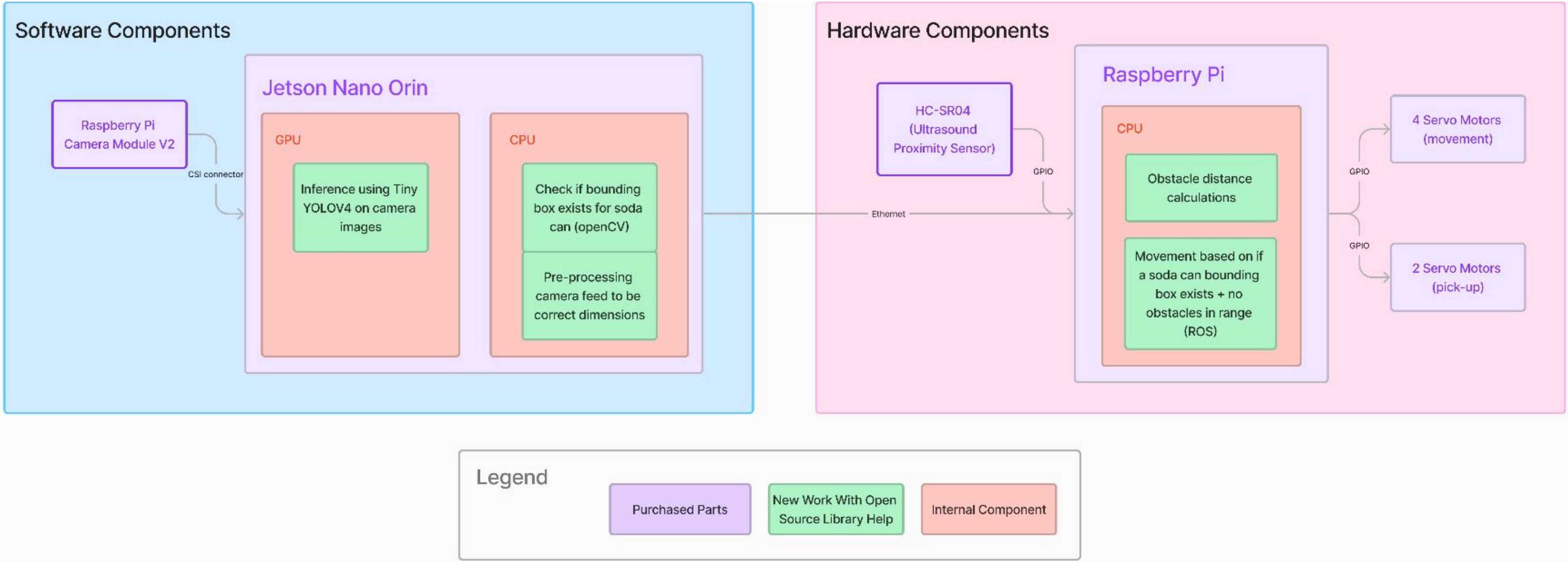
Solution Approach

- Detect Trash
    - Data: Soda Cans, Water Bottles, and Crumpled Paper
    - Tiny YOLO V4 on Jetson Nano Orin (PyTorch, openCV)
    - Camera to detect nearby trash items
- Movement + Trash Pickup
    - Raspberry Pi running ROS
    - Servo motors for wheels and scoop
- Avoiding Obstacles
    - Ultrasonic Proximity Sensor
- Inter-Device Communication
    - Connect Jetson Nano & Raspberry pi over Ethernet
    - Use ROS to communicate over ethernet



https://www.mdpi.com/2079-9292/10/18/2292

Solution Approach (Continued)



Solution Approach (Continued)

Software Systems

- Machine learning
- Computer vision/ image processing algorithms
- Data transmission protocols between Raspberry Pi and Jetson Nano Orin

Hardware Systems

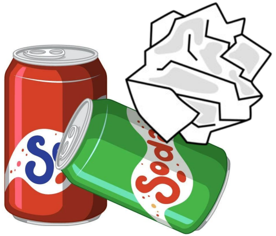
- Sensor integration
- Motors for controlling robot movement and pick-up mechanism
- Communication protocol between compute devices

Testing, Verification, and Metrics

3x5ft

3-5 soda cans
To test object-classification & pick-up mechanism

4x6ft



5-8 soda cans & crumpled paper
Continuing testing object -classification

4x8ft

5-8 soda cans, crumpled paper & empty water bottles
Cardboard boxes to imitate large objects

Testing, Verification, and Metrics

For each test, we record:

1. Count of trash-defined objects that were collected
2. Count of collisions with non-trash objects in the defined space

Metrics:

1. Percentage of defined trash components that were picked up in the given space → verify efficiency
2. Collision with non-trash objects → verify unobtrusiveness
3. The accuracy and recall metrics of the object classification model → validate performance

Tasks and Division of Labor

- Object Classification (Ritu)
  - Connect & set up camera
  - Code for overall ML pipeline on Jetson Nano Orin
- Motor Control (Hirani)
  - Set up Raspberry Pi (installing Linux, ROS)
  - Define & test robot motion
  - Enforce the motion requirements for the pick up mechanism
- Building (Ella)
  - Build robot base
  - Define space requirements for electrical + mechanical components
- Integration (Group Effort)
  - Fit parts onto robot base
  - Define & integrate communication between Raspberry Pi & Jetson Nano Orin

Schedule

Task Title	Task Owner	Start Date	Due Date	Status	Week 1 (2/5)	Week 2 (2/12)	Week 3 (2/19)	Week 4 (2/26)	Week 5 (3/4)	Week 6 (3/11)	Week 7 (3/18)	Week 8 (3/25)	Week 9 (4/1)	Week 10 (4/8)	Week 11 (4/15)
Object Classification															
Decide an object classficiation ML model	Ritu	2/5	2/12	Not Started											
Train & test ML model on exisiting dataset	Ritu	2/12	2/19	Not Started											
Write codes for overall ML pipeline on Jetson Nano Orin	Ritu	2/19	2/26	Not Started											
Connect and set up the camera	Ritu/Ella	2/12	2/19	Not Started											
Test the model using new pictures from the Raspberry Pi camera	All	2/26	3/11	Not Started											
Motor Control															
Research ROS	Hirani	2/5	2/12	Not Started											
Set up Raspberry Pi (installing Linux, ROS)	Hirani	2/12	2/19	Not Started											
Define software requirements for motion and obstacle avoidance	Hirani/Ella	2/5	2/12	Not Started											
Write code and iteratively test the requiremnts	Hirani	2/12	2/19	Not Started											
Set up actuators for the pick up mechanism	Ella	2/19	2/26	Not Started											
Write code for pick up mechanism	Hirani	2/19	2/26	Not Started											
Test motion, obstacle avoidance, and pick up mechanism using simple test cases	Hirani/Ella	2/26	3/11	Not Started											
Integration/Testing									Spring Break						
Finalize on design sketch and dimensions of the robot structure	All	2/5	2/12	Not Started											
Build/ cut out wood for base structure	Ella	2/12	2/19	Not Started											
Assemble/wire wheels, Raspberry Pi, and actuators for pick up mechanism	Ella	2/19	2/26	Not Started											
Test the integrated parts	Ella	3/11	3/18	Not Started											
Define communications between Raspberry Pi and Jetson Nano Orin	All	2/19	2/26	Not Started											
Make connections between Raspberry Pi, motor control, and Jetson Nano Orin	Hirani	2/26	3/11	Not Started											
Test motion control works well with the object classficiation using simple test cases	All	3/11	3/18	Not Started											
Final Testing															
Test the system with one soda can	All	3/11	3/18	Not Started											
Test object classification and pick up mechanism using 3-5 soda cans	All	3/18	3/25	Not Started											
More soda cans (5-8) and variations (adding crumpled white paper)	All	3/18	3/25	Not Started											
Use 5-8 soda cans, crumpled paper, empty water bottles, cardboard boxes	All	3/25	4/1	Not Started											
Slack															