Smart Waste Management System

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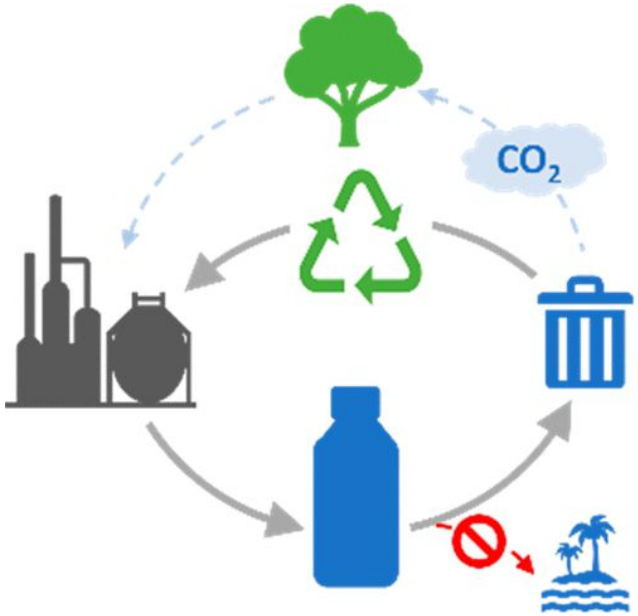
Project Motivation

- Global Waste Issue:
  - Limited landfill space and rising costs
  - Increasing waste production
  - Environmental and health concerns
- Lack of Public Awareness:
  - Limited knowledge about waste classification
  - People unsure about which bin to use
- Objectives:
  - Develop an embedded system with deep learning assistance for real-time waste classification (compost, landfill, and recycle)

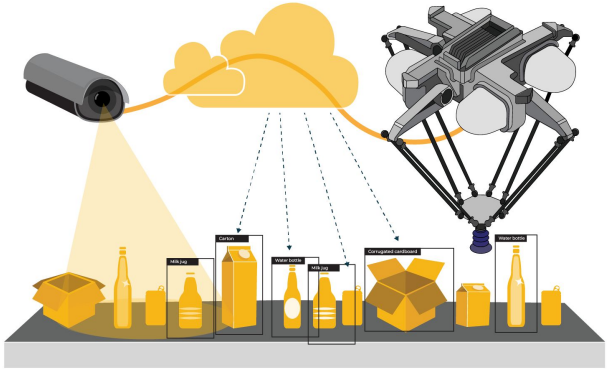
Goals

- Implementation:
  - Deployed above public waste bins and in facilities
  - Assists and educates users on proper waste disposal
- Impact:
  - Ensures correct sorting for efficient recycling
  - Aids in resource management
- Overall Goal:
  - Reduces environmental pollution
  - Addresses waste management challenges
  - Contributes to environmental sustainability



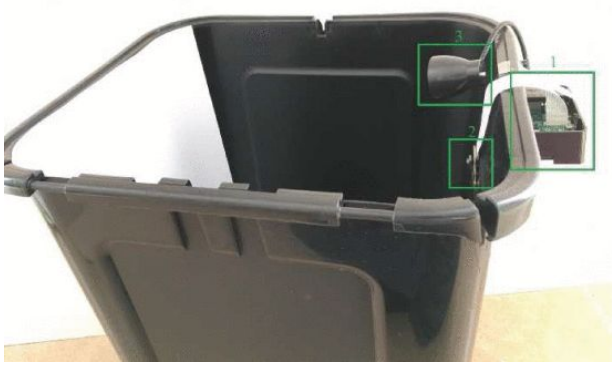
Prior/Related Work

- Current Methods:
  - Manual sorting and categorization
  - Relies on visual inspection and basic waste knowledge
- Limitations:
  - Time-consuming and expensive
  - Prone to human error
- Recent Developments:
  - AMP Robotics utilizes AI and robotics for enhanced accuracy
  - Focus on improving recycling rates
- Challenges:
  - Designed for use in recycling facilities, not household/public settings
  - Higher production costs



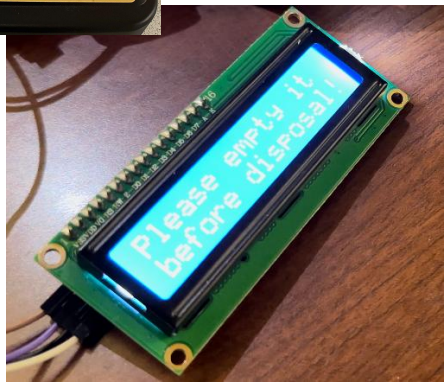
Related Work

- [1] Foukia, N. (2022). CleverTrash: An ML-based IoT system for waste sorting with continuous learning cycle. The Institute of Electrical and Electronics Engineers, Inc. (IEEE) Conference Proceedings. https://doi.org/10.1109/ICECET55527.2022.9872943
- [2] Li, X., & Grammenos, R. (2022). A smart recycling bin using waste image classification at the edge. arXiv.org. https://arxiv.org/abs/2210.00448

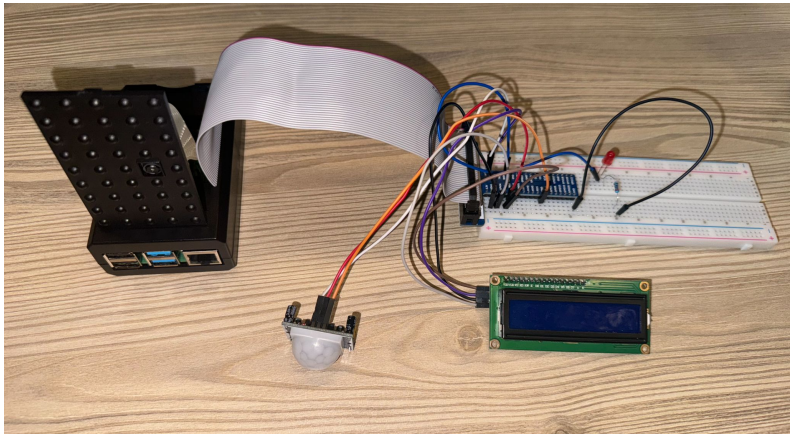


Novelty

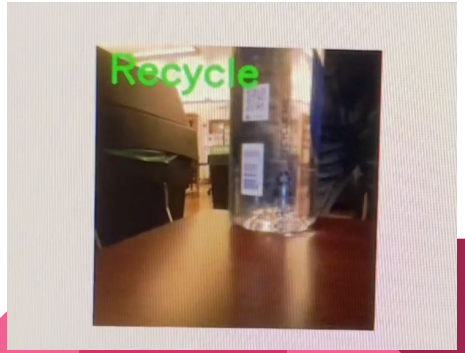
- Features:
  - Designed for personal or public use
  - Low power consumption and cost-effective
- User-Friendly Functionality:
  - Effortless waste classification for users
- Customized Feedback System:
  - Provides tips for proper waste disposal
  - Example:
    - Suggests emptying the bottle before disposal
    - Suggests disposing of any food leftovers in the compost bin



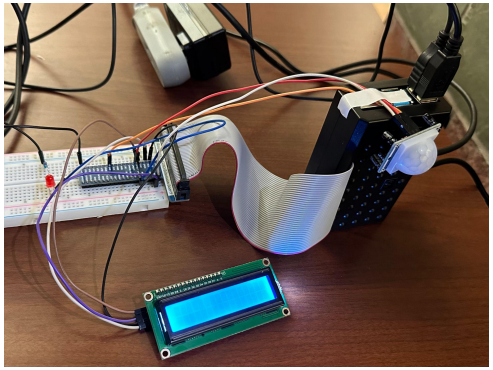
Technical Methods



- Main Hardware components
  - Raspberry Pi 4
  - Pi Camera v2
  - I2C LCD1602 Display Screen
  - Infrared Motion Sensor
- Real-time image/video processing
  - Use OpenCV library to capture and process images with the camera
- Waste Classification Model
  - Pretrained Quantized Mobilenet V3 Large
  - Use Pytorch for Transferring learning of waste items
  - Trained on the mixed kaggle datasets (about 14000 images)



- Feedback Mechanism
  - Use 16x2 LCD display to show:
    - Main categories: compost, recycle, landfill
    - Score: the probability of the waste belonging to the category
    - Proper suggestions: based on the 12 subcategories



- Power Saving
  - Only activate the camera and deep learning model (high power consumption) when Infrared Motion Sensor senses human motion (within 3 meters)
  - Red LED to indicate initiation
  - Otherwise the system is in sleep mode
  - After activation, goes back to sleep after 10-15 seconds

Experimental Evaluation

- Transfer Learning Metrics
  - 91.30% validation accuracy after 10 epochs
  - 0.2831 validation loss after 10 epochs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Epoch 6/10
Train Loss: 0.2214, Train Accuracy: 93.26%
Validation Loss: 0.2898, Validation Accuracy: 90.79%

Epoch 7/10
Train Loss: 0.2115, Train Accuracy: 93.71%
Validation Loss: 0.2804, Validation Accuracy: 91.01%

Epoch 8/10
Train Loss: 0.2012, Train Accuracy: 93.80%
Validation Loss: 0.2819, Validation Accuracy: 91.45%

Epoch 9/10
Train Loss: 0.1875, Train Accuracy: 94.37%
Validation Loss: 0.2850, Validation Accuracy: 91.19%

Epoch 10/10
Train Loss: 0.1815, Train Accuracy: 94.50%
Validation Loss: 0.2831, Validation Accuracy: 91.30%
```

- Real-time Results
  - Accurate classifications for majority of times
  - There are some errors, could be caused by
    - Lighting conditions
    - Distance from camera
    - Background noise
    - Camera quality
    - Dataset imbalance
  - LCD screen and Infrared motion sensor are working correctly
  - User-friendly interface and experience
- Power Consumption Estimate
  - Close to 0% CPU usage during sleep mode and ~70% CPU usage during activation

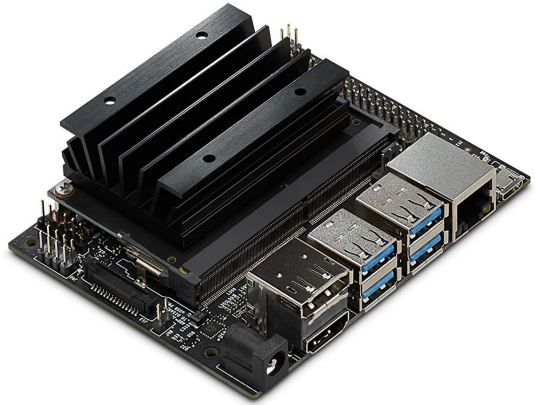
Demo

Conclusions

- Innovative Solution
  - Targeting both personal and public use, with an emphasis on low power consumption and cost-effectiveness.
- User-Friendly Design
  - Provide practical tips for proper waste disposal
  - Making it accessible to a wide range of users
- Effective Power Management
  - Activates the high-power-consumption components only upon human motion detection and then returns to sleep mode

Future Directions

- Enhancing Accuracy
  - Further improvements can be made to the waste classification model to address errors
- Broader Dataset Training
  - Expanding the dataset for training the classification model could improve accuracy and versatility in different environmental settings
- Advanced Sensory Capabilities
  - Incorporating additional sensors or improving existing ones to enhance the system's responsiveness and accuracy



Contributions

Waste Classification Model: (Minkai)

Real-time Classification: (Minkai)

Power Saving: (Minkai and Yuhan)

Feedback Mechanism: (Yuhan)

Hardware Integration: (Yuhan)

Thank You!