EcoBin

A Bin with Fill Level Detection that uses an AI Machine Learning Model to sort Recyclables from Non-Recyclables

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Summary

Despite recycling's many benefits, such as reducing energy and raw material usage, pollution, wastage, and climate change, many individuals do not recycle their trash due to a variety of reasons. Some may simply be lazy, or some may be genuinely unaware of recyclable materials, leading to contaminated waste in the process. This prevents humans from reaping the most benefits from recycling. Adding on a second issue, trash bins tend to overflow when not maintained regularly, increasing pollution, attracting pests, and breeding bacteria amongst the unhygienic trash. My invention, the EcoBin, aimed to alleviate both these issues by providing a trash bin that would automatically sort a person's trash for them along with use indicators to let people know a compartment is reaching near-fill capacity, rendering a 100% success rate overall. *Engineering*

Introduction

Engineering Goal

The engineering goal of this project was to design and create a **portable**, **low-cost**, **autonomous** trash bin that **detects compartment fill levels** to prevent unhygienic overflowing trash bins and additionally **sorts trash into a recyclable compartment of a non-recyclable compartment accurately** in order to increase the rate of recycling and decrease the rate of waste contamination.

Project Origin

When I was learning about recycling as part of a science class, the statistic that "only 32% percent of Americans recycle" shocked me. Only 32%? What if we could harness more from the incredibly beneficial process of recycling, and help our environment prosper to new heights? I then went on to research why people don't recycle, and some reasons include being indolent, or even uneducated about what is recyclable or not – which sometimes leads to them recycling incorrectly and contaminating what could have been useful batches of recyclable material. Additionally, when I walked into Target one day, I saw the trash bin overflowing with waste. Not only was this a displeasing sight, but I soon discovered that it hosted a prosperous breeding ground for bacteria like Listeria to spread. Furthermore, the bin could've even caused more pollution as the trash spills out. And when our school's annual science fair rolled around, I decided to make the EcoBin, who'd sort for the user to make the collection of recyclables more convenient, easy, accurate, and less time-taking. It'd also be able to detect trash levels, introducing a measure to prevent overflowing trash bins. I began working on this project in late December of 2023.

Introduction (cont'd)

Previous Work

None

Work by Others

People have begun making auto-sorting bins such as the TrashBot (by Clean Robotics), and waste-minimizing bins such as the CleanCube (by Ecube Labs). As I began researching my project, I discovered these bins and understood how they too help the environment.

Methods: Procedures and Pictures

Constructing the bin:

1. Cut out a 48 cm x 40 cm rectangle on a large face of a 47 cm x 32 cm x 77 cm cardboard box, leaving at least a 3 cm wide border around the rectangle. Ensure the cutout is closer to the bottom edge of the box face in order to accommodate elements that will eventually be placed at the top of the box face.
2. Wedge a 33 cm x 28 cm cardboard plane in the middle of the box through the cutout. This plane will act as the divider between the recyclables compartment and the non-recyclables compartment.
3. Inside the box, hot glue two "L-shaped" pieces of cardboard to the sides of the box. Ensures they are on opposite sides, not adjacent. The shorter horizontal arm of the "L" should be jutting out.

Attaching Electrical Components:

4. In the back of the box, cut out a hole the size of a mini hobby servo motor and then wedge the servo motor through the hole. It should fit snugly in the incision.
5. Make another incision approximately 17 cm above the hole, and string the servo's wires through the hole.
6. Hot glue a 14 cm x 9 cm cardboard platform to the servo's arm. For more security, wire the arm around the cardboard. This will act as the device's sorting platform.
7. Hot glue the Arduino UNO Rev3 microcontroller to the left of the hole that the servo wires pass through.
8. Hot glue a full-size breadboard to the right of the hole that the servo wires pass through.
9. Hot glue a Ultrasonic distance sensor to a face of the box such that it can detect when an object is placed on the sorting platform.

10. Hot glue 2 Ultrasonic sensors, one facing downwards on each L-shaped piece attached previously.
11. On a mini breadboard, attach one red LED and one blue LED.
12. Adhere the mini breadboard above the cutout on the box.
13. Using the DuPont wires, attach the 5V and 1 ground pin on the Arduino to the positive and negative rails of the full size breadboard respectively.
14. Attach all the power wires of the electrical components to the positive rail of the full size breadboard, and attach all the ground wires of the components of the negative rail of the full size breadboard. Connect the rest of the wires to the digital pins on the Arduino. Use electrical tape to keep wires grouped together.
15. Hot glue a USB webcam in such a manner that it can clearly take a picture of a piece of trash on the sorting platform
16. Train a machine learning model that accurately differentiates an aluminum can, glass cup, and plastic water bottle into a "recyclable" class, and an apple, orange, and a chip bag into a "non-recyclable" class (this project used Teachable Machine).
17. Write and upload code to perform the following tasks:
    a. Trigger a compartment's respective LED when the ultrasonic sensor situated on the L-shaped piece detects that trash is 10 cm or less away from it.
    b. Take a picture of the trash when it is detected by an ultrasonic sensor
    c. Process the image through the machine learning model
    d. Differentiate into either the recyclable class or the non-recyclable class
    e. Move the servo motor one way or the other depending on the findings

Testing:

*Ensure the Arduino and the USB camera are connected to the computer via USB. The Arduino must receive 5V from the USB port.

FOR TRASH SORTING:

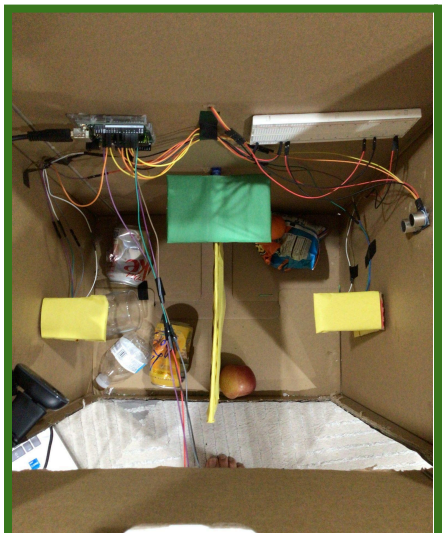
18. Input one aluminum can into the bin, and observe whether or not it correctly sorts it into the recyclable bin.
19. If it does, record the trial as a “Success”. If not, record it as a “Failure”.
20. Repeat steps 18-19 four more times to conduct five test trials in total.
21. Repeat steps 18-20, but using a plastic water bottle, glass cup, orange, apple, and a chip bag (The plastic water bottle and glass cup should go into the recyclable compartment, whilst the orange, apple, and chip bag should go into the non-recyclable compartment).
22. In the end, calculate all of the trials’ average success rates

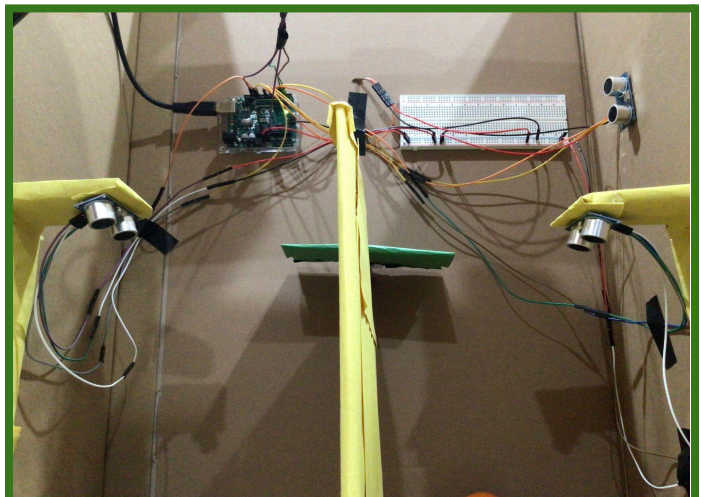
FOR LEVEL DETECTION:

23. Fill up the recyclables compartments with trash until it reaches less than 10 cm away from the ultrasonic sensor. Ensure the corresponding LED lights up. The LED should continue to stay lit up as long as the distance is 10 cm or less. Decrease the trash levels, and make sure the LED turns off. If these conditions are met, mark the trial as a Success. If not, mark it as a Failure.
24. Repeat step 23 four more times to conduct five test trials in total.
25. Repeat steps 23-24 but with the non-recyclables bin and its corresponding LED.
26. In the end, calculate all of the trials’ average success rates.

Precautions:

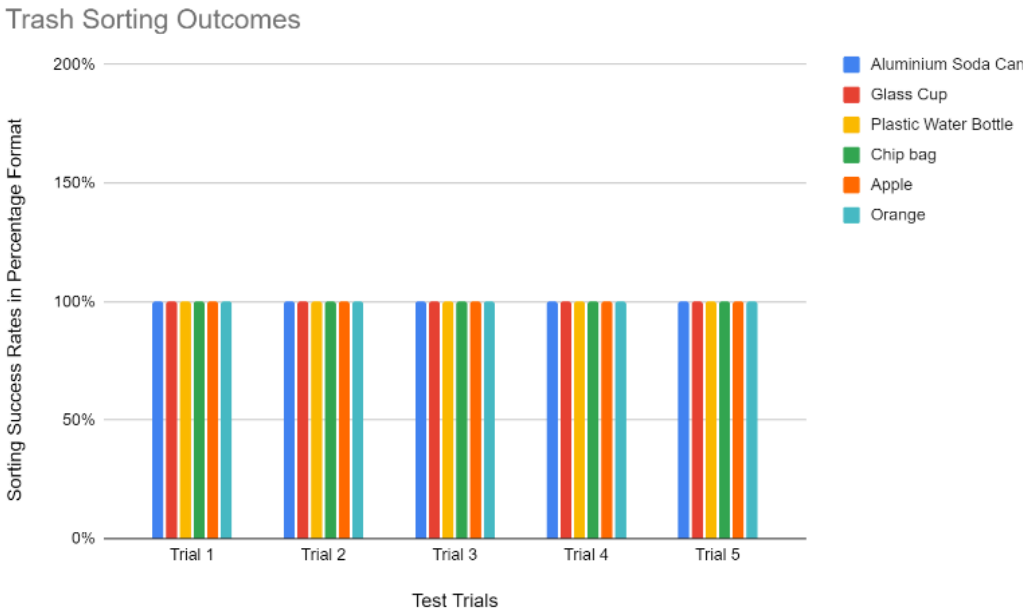
- Ensure no water touches the circuitry
- Ensure the microcontroller or any other parts are not short circuited



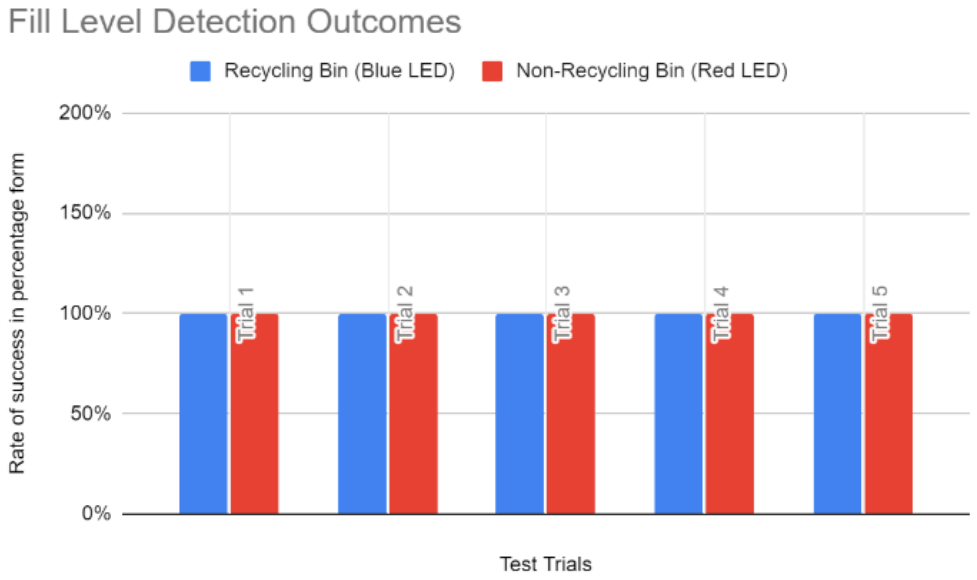


Results: Testing Data Tables and Figures

	Trash Sorting Outcomes					
	Recyclables			Non-Recyclables		
	Aluminium Soda Can	Glass Cup	Plastic Water Bottle	Chip bag	Apple	Orange
Trial 1	Success	Success	Success	Success	Success	Success
Trial 2	Success	Success	Success	Success	Success	Success
Trial 3	Success	Success	Success	Success	Success	Success
Trial 4	Success	Success	Success	Success	Success	Success
Trial 5	Success	Success	Success	Success	Success	Success
Success Rate in percent form	100%	100%	100%	100%	100%	100%



	Fill Level Detection Outcomes	
	Recycling Bin (Blue LED)	Non-Recycling Bin (Red LED)
Trial 1	Success	Success
Trial 2	Success	Success
Trial 3	Success	Success
Trial 4	Success	Success
Trial 5	Success	Success
Success Rate in percent form	100%	100%



Results (cont'd)

Did the EcoBin Fulfill its Engineering Goal?

As is clearly visualized by the data, the EcoBin was successfully able to meet all of its criteria.

Explanation and Data Analysis

The EcoBin was able to sort recyclables from non recyclables 100% of the time with the trained dataset, and the fill level detection was also rendered successful 100% of the time. Every single test and trial was successful, showing that the invention was able to **integrate the machine learning model, code, and all electrical parts properly** in order to achieve the intended goals set. There were no outliers, and the bin ultimately met its constraints of being low cost (under $150), autonomous, portable, trash-sorting, and level-detecting.

Discussion

Interpretation

Overall, the EcoBin's test results display the fact that it was successful in meeting its engineering goal. The outcome that occurred aligned with my expected results, and it illustrated that the machine learning model, level detection, and sorting worked together with the electronic circuit successfully to make the bin fully functional with the trained dataset. **The webcam took a picture of the trash when it was detected on the sorting platform, then the image was processed through the model to allow the computer to decipher its recyclability, and finally it was physically sorted by a motor controlled by the Arduino into the correct compartment**. As for the level detection, **the ultrasonic sensors detected the presence of an object when it was ten centimeters away, triggering on the respective LED for the compartment to indicate that trash levels were approaching maximum capacity**.

Discussion (cont'd)

Challenge Faced and Solution

A challenge faced was making the sorting platform sturdy enough to support the weight of the trash and securely stay attached to the servo shaft attachment. This issue was overcomed using a wire to intertwine each of the attachment's holes with the cardboard plane by wrapping it through and around the two items. Moreover, hot glue was used to firmly secure the apparatus. Finally, the platform was positioned in such a way that it could rest on the compartment divider below it

What makes the EcoBin different?

There exists a TrashBot, that sorts materials automatically, along with auto-compacting bins such as the CleanCube that deplete trash levels. However, the Ecobin sorts recyclables from non recyclables **and** provides level detection, but it does so at a fraction of the cost. In fact, the TrashBot costs about between $1,500 and $5,000, whilst this invention costs less than $150. It also combines both ideas to be the "all in one trash can" that solves multiple real world problems. Furthermore, it uses an easy-to-train machine learning technology that makes adding trash types easy and quick.

Conclusions

Conclusions Reached

Programmed to sort trash based on an image recognition model, the EcoBin successfully sorted all trained pieces of trash with an overall 100% success rate per trial (every trial was a success!). The machine learning implementation within the bin, which included the webcam, model, and computer, proved to be a useful and innovative way to integrate the functionality of accurate sorting, and even possessed the capabilities to sort trash that wasn't photographed as part of the model. (For example, a soda can with a different design, or glass of different shape). Moreover, its level detection capabilities were also functional, with every single trial testing whether the level detection worked with the LED indicators rendering a 100% success rate per trial (every trial was a success, again!). The ultrasonic sensors, when worked with an Arduino microcontroller, proved to be very efficient at detecting levels of trash. Overall, every trial and test conducted as part of EcoBin's testing was a success, meaning the ultimate goal was achieved with efficient technology such as machine learning and ultrasonic sensors. The project turned out as expected!

Real-World Applications and Further Research

Some ideas for further research include teaching the machine to sort materials such as cardboard or paper, adding different compartments for each material (metal, plastic, etc.), and sending an SMS message when bins are deemed to be almost full. A chute can also be added so it can further emulate a conventional trash bin, and a larger sorting platform can be created so that waste of bigger sizes can be sorted. It can also be trained to sort multiple pieces of trash, or other sensors, like inductive sensors, can be added to add a second layer of accuracy. The bin can be used in standard homes and parks around the world to encourage recycling and make it less fool-proof in its first stage of collection. Going forward, I'd love to improve the structure of the bin and market it to companies and the government to help Earth in the long run.

Scope of Work

Personal Contributions and New Work

In order to bring this project to life, my major contributions include:

- Researching, formulating the design of the bin, fully fleshing out the plan, finding the parts and materials needed, and creating the approach to the engineering goal
- Creating the electrical circuit, creating a fully self-taken dataset of pictures for an image classification model
- Integrating the model into the bin, coding the level detection and object prediction communication using Python and Arduino IDE
    - In order to learn advanced coding techniques to work with AI Machine Learning, I referred to the Teachable Machine (a platform which I used to create a model) to understand how utilize models in the most efficient way
- Constructing, attaching parts, and testing the bin
- Collecting data, creating visuals

Acknowledgements

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All the resources used in this project were completely **free of cost.**

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