McMaster University

Software & Mechatronics Capstone

eBin

System Requirements

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1 Introduction

1.1 Project Overview

Waste segregation is legally required in most countries. Sorting or arranging how people throw away their garbage is an integral part of the whole recycling process since waste management companies need to sort everything out first before loading it into recycling machinery to start the recycling process. Effective segregation of wastes means fewer recyclable materials goes to landfills or be incinerated which helps the environment to achieve sustainable development. Most places in campus have different kinds of garbage bins. Students and stuffs throw away tons of garbage every day, but it is doubtful whether the garbage is disposed in the correct bin. Imaging when a class is over, students crowd out to catch the next class and they walk pass the garbage bins trying to throw away their garbage. The students should have enough time to find the corresponding bin and dispose it correctly. For the types of garbage bins on campus, there are mainly four types: organics, paper, bottles and cans and the other. Since organics only appear in certain dining area (cafeteria, kitchen, etc.) and it is especially hard to handle and clean, we do not consider sorting it. And Papers and bottles and cans can be combined as mixed recyclable. There leaves only two type of garbage, mixed recyclable and the other. These two are also the most commonly seen garbage sorting bins in most places. To provide a more convenient way for users to sort and dispose their garbage, we introduce our eBin. When user throw garbage into eBin, it will determine the type of garbage using image recognition and ideally, displace it on a screen so that the user will know which type the garbage belongs to. Once the type is recognized, it will dispose it into the corresponding sub-bins.

1.2 Behaviour overview

The behavior of eBin consists of four major steps: detecting, sorting, displaying result and dropping garbage. For the first step, after the image is collected, it is sent to the server with other information of the garbage. Then a well-trained machine learning model will determine the type of garbage based on the information, and the result will be displayed on a screen asking the user if the result is correct (this is a optimal function, might not be implemented at the end). The dropping action is finally performed by an

actuator, dropping the garbage into the corresponding sub-bin.

1.3 Naming Conventions and Terminology

Term	Description
eBin	eBin is our garbage sorting machine
sub-bin	sub-bins are the two small bins embedded in the large bin
SOC	SOC stand for system on chip

Table 1: Terminologies and corresponding descriptions

2 Project Driver

2.1 The Purpose of The Project

The main purpose of eBin is to provide schools and universities with a better alternative to existing garbage bins. Current problems with garbage bins (and garbage sorting in general) on campus include cost of maintenance, inconvenience to the user, and, most importantly, an inaccuracy in the garbage sorting itself with leads to an increased amount of time and resources required from waste management facilities to further sort the garbage. eBin aims to eliminate all the above problems through the use of its image recognition technology to automatically sort garbage. Firstly, the automated garbage-sorting technique incorporated into the device will allow for the eBin to be more clean than traditional garbage bins. This means that eBin does not need to be cleaned as frequently as existing garbage bins, thus cutting back on maintenance cost. eBin also allows a much more convenient approach for garbage disposal to users – instead of having to figure out which bin to throw their garbage into, users now need only to place their piece of garbage on top of the eBin's sorting platform and image recognition will do the rest. This also leads to the final point – with the elimination of human error in the garbage sorting process, only a minimal amount of time and resources will be required from waste management facilities to sort garbage. There is even the possibility that through the use of eBin, garbage collected from

these bins can completely bypass sorting altogether and proceed directly to waste treatment.

2.2 The Client, the Customer, and Other Stakeholders

There are three main stakeholders for the eBin: the client being the school or university using this product, the consumer being students, staff and visitors to the school or university, and lastly, waste management facilities that perform waste management services for these schools and universities. Universities can use eBin anywhere on campus in place of their current garbage bins, and special configurations (such as custom logos and changing the size of the bin) can be made to cater to the individual needs and requirements of each separate university. Having the eBin abide to current laws and regulations of the university as well as regulations of the city and province the institution is in will be imperative to the success of the product. The consumer can be anyone in the university that is able to use the eBin for garbage disposal, mainly students, professors, and other staff of the institution. Lastly, the performance of the eBin will also affect waste management facilities who are in charge of waste management for these universities. As stated earlier, the eBin aims to lessen the time and resources that these waste management facilities have to use for garbage sorting, and being able to achieve this is crucial to the success of the eBin product.

3 Project Scope

3.1 Context diagram

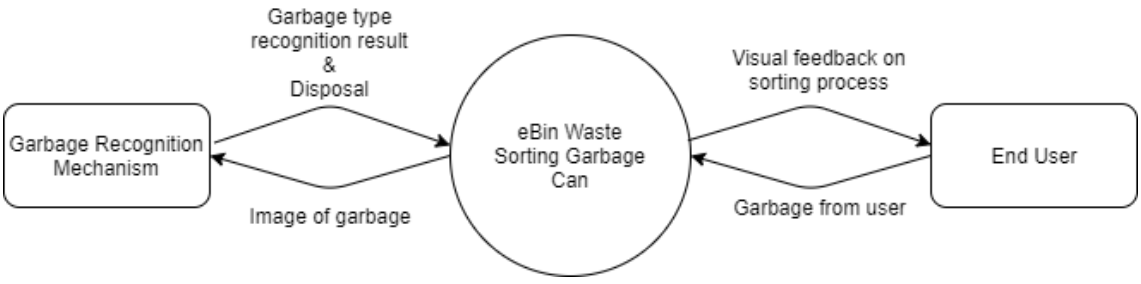

Figure 1: Context Diagram

3.2 Constants

- GARBAGE_PROCESS_TIME= 5000ms
  - How long it takes to identify garbage, display garbage type and dispose garbage into bin.
- GARBAGE_RECOGINTION_TIME= 3000ms
  - How long it takes to identify garbage.
- OBJECT_TYPE_DISPLAY_TIME= 2000ms
  - How long it displays the object type.
- GARBAGE_TYPE_DISPLAY_TIME= 2000ms
  - How long it displays the garbage type.
- GARBAGE_DISPOSE_TIME= 2000ms
  - How long it takes to dispose garbage into bin.
- RESET_TIME= 2000ms
  - How long it takes to reset the system.
- GARBAGE_CLASSIFICATION_NUMBER= 2
  - How many types of identified garbage can dispose into bin.
- MAX_CONCURRENT_USERS= 1 user
  - How many concurrent users our ebin will support.
- TOTAL_BIN_CAPACITY= 40L
  - How much garbage can dispose into bin.
- SUB_BIN_CAPACITY= 20L
  - There are two sub bins in the whole bin. This is the capacity of every one sub bin.
- GARBAGE_PLATE_HOLDING_CAPACITY= 2KG

– How much the garbage identification plate can hold when the garbages are put on it.

3.3 Monitored and controlled variables

3.3.1 Monitored Variables

Name	Type	Range	Units	Physical Interpretation
object_detected	Boolean	[0, 1]	N/A	If object to recognize is detected
object_type	String	Various	N/A	Type of object with highest possibility based on the results of analysis
garbage_type	String	Recyclable or Others	N/A	Type of garbage based on object classification
output_percentage	Percent	[0, 100]	%	Estimated accuracy of result represented in percentage
processing_status	String	Various	N/A	The status of current processing stage

Table 2: Monitored Variables for eBin

3.3.2 Controlled Variables

Name	Type	Range	Units	Physical Interpretation
input_info	Image	N/A	N/A	The input image taken from built-in camera
hinge_default_degree	Degree	[0, 360]	Degree	The initial degree of hinge
hinge_rotation_direction	Boolean	[0, 1]	N/A	Desired hinge rotation direction
hinge_rotation_degree	Degree	[0, 180]	Degree	Desired hinge rotation degree

Table 3: Monitored Variables for eBin

3.4 Constraints

3.4.1 Development Constraints

The project is developed in two parts. One is software. The other is hardware. In the software, we use python to develop the garbage recognition. In the hardware, we use stepper motor to control the plate.

3.4.2 Operation Constraints

Both garbage recognition and the control of plate are operated by raspberry pi, which is a tiny desktop computer.

3.4.3 Schedule Constraints

The project must be finished before April on 2020, the development of process will follow the schedule of deliverable.

3.4.4 Budget Constraints

The maximum budget of our project is 750 Canadian dollars.

4 Functional Requirements

4.1 Functional Decomposition

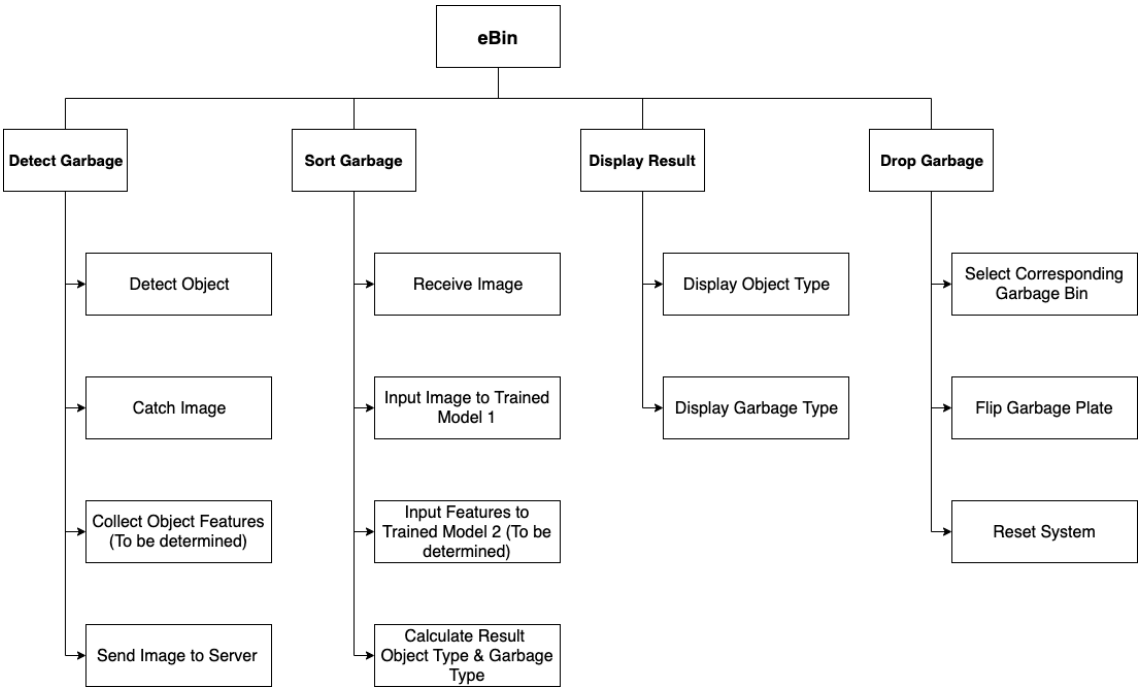

Figure 2: Functional Decomposition Diagram

4.2 Functional Requirements

Requirement: FR01
Description: The garbage plate shall hold the garbage for processing
Rationale: The plate will not flip unintentionally when it holds the garbage
Fit Criterion: The plate must stay stable and do not flip when the garbage is less than 2 kg
Priority: High
History: Created October 23, 2019

Requirement: FR02
Description: The system will be able to detect the object when it is placed on the plate
Rationale: The system will star to work immediately once the user put garbage on the plate
Fit Criterion: Response time should be less than 1 second
Priority: High
History: Created October 23, 2019

Requirement: FR03
Description: The system will be able to catch the image of garbage properly
Rationale: The camera shall catch a clear image of the object
Fit Criterion: Image is clear and must be able to be processed by the recognition model
Priority: High **History:** Created October 23, 2019

Requirement: FR04
Description: The system shall be able to analyse the object type properly
Rationale: The model should respond with correct object type according to the image
Fit Criterion: The result should have at least 80% accuracy
Priority: High **History:** Created October 23, 2019

Requirement: FR05
Description: The system shall be able to analyse the garbage type properly
Rationale: The model should respond with correct garbage type according to the image, either recyclable or other
Fit Criterion: The result should have at least 90% accuracy
Priority: High **History:** Created October 23, 2019

Requirement: FR06
Description: The system should display the result to the user
Rationale: There should be a screen to show the object type and the garbage type
Fit Criterion: The result should perform when the analysis is complete, the display time should be 2 seconds
Priority: Medium
History: Created October 23, 2019

Requirement: FR07
Description: The garbage should be disposed to the corresponding bin
Rationale: The plate should dispose the garbage to either recyclable or other bin based on the result
Fit Criterion: The plate should be able to flip 90 degrees steadily
Priority: High
History: Created October 23, 2019

Requirement: FR08
Description: System shall reset to initial state after perform each actions
Rationale: The plate should be reset to horizontal and the screen should be reset to instruction interface
Fit Criterion: The reset process should be completed in 2 seconds
Priority: High
History: Created October 23, 2019

5 Nonfunctional Requirements

5.1 Look and Feel Requirements

Requirement: LFR01
Description: eBin has the traditional shape of a square garbage bin, with a square opening at front for disposal.
Rationale: The design follows the common knowledge of a garbage bin, which reduces the learning difficulty for users.
Fit Criterion: eBin fits in the conceptual model of a traditional garbage bin.
Priority: Medium
History: Created October 23, 2019

5.2 Usability and Humanity Requirements

Requirement: UHR01
Description: The interface of eBin uses colors, icons and plain English.
Rationale: English is the most internationally used language. Icons and colors follow the common design pattern of garbage bins.
Fit Criterion: Interface of eBin only contains icons and plain English.
Priority: Medium
History: Created October 23, 2019

Requirement: UHR02
Description: Garbage disposal process should operate under 40db.
Rationale: eBin should operate with the noise level under public library ambient sound.
Fit Criterion: Noise level of eBin when processing does not exceed 40db.
Priority: Medium
History: Created October 23, 2019

5.3 Performance Requirements

Requirement: PR01
Description: Each garbage classification process should be completed in under 5 seconds.
Rationale: eBin should operate efficiently enough to accommodate moderate user load.
Fit Criterion: Each garbage processing is done within 5 seconds.
Priority: High
History: Created October 23, 2019

5.4 Operational and Environmental Requirements

Requirement: OER01
Description: eBin should have built-in light source in case of low light condition.
Rationale: Sufficient background lighting is required for image recognition to function accurately.
Fit Criterion: Sufficient lighting is provided for eBin.
Priority: Medium
History: Created October 23, 2019

5.5 Maintainability and Support Requirements

Requirement: MSR01
Description: Garbage bins should be easily removable.
Rationale: Removable garbage bins provides easy access for maintenance.
Fit Criterion: 2 garbage bins are removable for maintenance.
Priority: Medium
History: Created October 23, 2019

5.6 Security Requirements

Requirement: SR01
Description: eBin must have wires and functional equipment hidden.
Rationale: To avoid potential safety issue, users should not have easy access to mechanical or electrical parts.
Fit Criterion: No exposed functional equipment and wires.
Priority: Medium
History: Created October 23, 2019

5.7 Cultural and Political Requirements

Requirement: CPR01
Description: Icons and messages on eBin must not contain any cultural and political violations.
Rationale: Proper images and languages are needed to ensure eBin does not violate any cultural and political regulation.
Fit Criterion: Icons and languages used in eBin follow cultural and political rules.
Priority: Medium
History: Created October 23, 2019

5.8 Legal Requirements

LER01
Description: All the external resources used in design process must be licensed and cited.
Rationale: The correct use of licensing and citation can avoid potential legal issues.
Fit Criterion: All external resource are licensed and cited.
Priority: High
History: Created October 23, 2019

6 Undesired Event Handling

1. In the case of power shortage, the system should have the ability to restore itself to the initial stage.
2. If the garbage recognition mechanism returns an ambiguous result, the system should treat the object as "Others".
3. To prevent the over weighted object, instructions should be provided on the interface.
4. The opening of eBin garbage can is limited to prevent oversized object.

7 Project Issues

7.1 Open Issues

1. Accurately distinguish between different types of garbage
2. Quiet, depending on where we want to use the garbage bin (library, lecture hall, etc.)
3. Efficient (ability to handle multiple garbage within a short period of time)
4. Easy to clean and maintain
5. Educational purpose

6. Robustness (plate which holds the garbage/motor, etc.)
7. SoC selection (Raspberry Pi or other products)
8. Cost
9. Size (capacity)
10. Exterior (colour, shape, etc.)
11. Power issue(built-in battery or external power supply)

7.2 Off-the-Shelf Solutions

We cannot train the machine to perfectly distinguish any garbage; however, we can perform a research on what are the most common garbage that people thrown away in a specific location, and then we can achieve a relatively high accuracy at this specific location. Or, we make a user interface, allow users to tell if the garbage bin is sorting correctly, this way we can build a self-improving model.

7.3 New Problems

Currently, there is no further problems.

7.4 Tasks

Tasks	Estimated Time of Completion
Build of garbage sorting machine learning model	TBD

Table 4: Tasks

7.5 Risks

There is a chance that it sorts the garbage into a wrong bin, which is against the scope of this project and is not good for educational purpose. However, we will try to make it as accurate as we can.

8 Requirements That Are Likely To Change

1. Number of bins used may be changed depending on how many types of garbage we want to sort, for now it is two – one for recyclable, one for the others.

2. Accuracy of image recognition may be improved once we have created the machine learning model, we will teach it to accurately distinguish most common garbage.

3. SoC may be changed based on this STRS, as some of the microcomputer is not capable of handling all the required process fast enough. For now, we are considering Raspberry Pi as our microcomputer, it may also be degraded to some other product for saving the coverall cost.

4. The power of hinge motor and the material of flipping plate may be changed based on the maximum weight of garbage we want to handle. Research is required to find out the heaviest garbage that is likely to be thrown.

5. Size/shape/colour etc. to achieve a good-looking exterior.

6. Location of the bin might also be changed base on future research, library, lecture hall are the designated location for now.

9 Requirements That Are Not Likely To Change

1. The approach of garbage sorting is not likely to change – we intent to create a machine learning model by TensorFlow, train it well enough to sort different types of garbage.

10 References

N/A