McMaster University

Software & Mechatronics Capstone

eBin

System Requirements

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Last compiled on February 26, 2020

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1 Revisions

Date	Revision#	Authors	Comments
Oct.14 2019	Revision 0	Anna Wei Alan Yin Ditong Liu Huajie Zhu Junni Pan Zhihao Yang	Initial draft of system requirement
Feb.23 2020	Revision 1	Anna Wei Alan Yin Ditong Liu Huajie Zhu Junni Pan Zhihao Yang	Add context diagram boundaries, specify behavior overview, add a behavior diagram, generalize functional decomposition, delete everything related to the design, rewrite functional requirements that is likely to change to increase traceability

Table 1: eBin Table of Revision

2 Introduction

2.1 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.

2.2 Behaviour overview

The behavior of eBin consists of four major steps: detection, analytics, interaction, and disposal. For the detection phase, the camera periodically takes pictures of the top of the flipping board (where the deposited garbage initially lands) and sends them to the server. The first image sent to the server after garbage has been deposited will be different than its predecessor image, and the server will recognize the change and begin to process the garbage image. For the analytics phase, a well-trained machine learning model will determine the type of garbage based on the information extracted by the server from the garbage image. The AI does this by comparing the garbage to an existing database containing hundreds of other images. The interaction phase consists of the result being displayed on a screen asking the user if the result is correct (this is a optimal function, might not be implemented at the end). Included in the display will be a confidence level indicator of the AI, in percentage form. Finally, the disposal phase is performed by an actuator that drops the garbage into the corresponding sub-bin. There are two possibilities here, if recyclable garbage is detected then will go into the recycling bin, and if non-recyclable garbage is detected then it will go into the non-recyclable garbage bin.

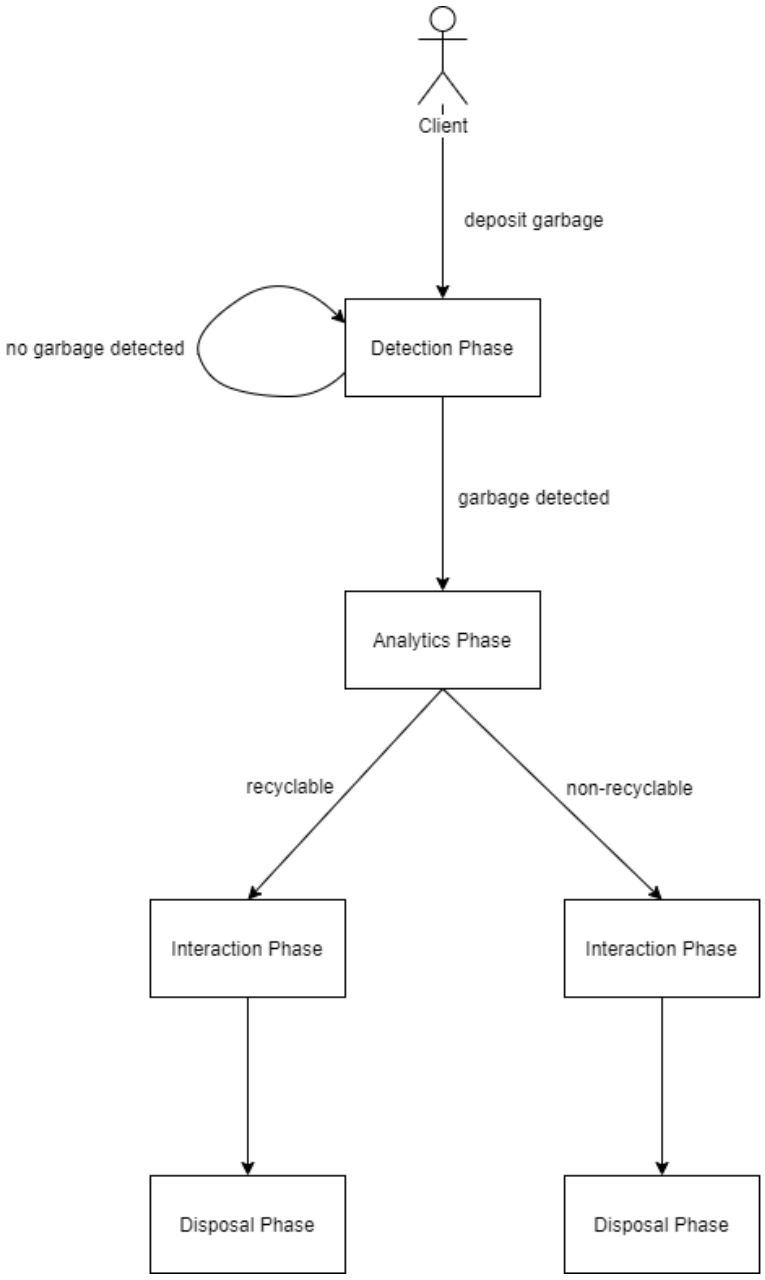

Figure 1: Behaviour Diagram

2.3 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
TBD	To Be Determined
AI	Artificial intelligence

Table 2: Terminologies and corresponding descriptions

3 Project Driver

3.1 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.

3.2 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.

4 Project Scope

4.1 Context diagram

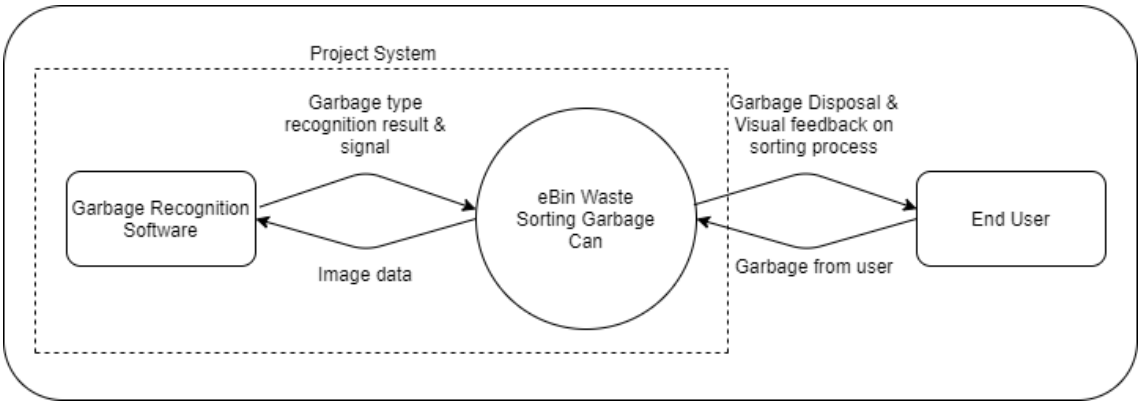

Figure 2: Context Diagram

4.2 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.

4.3 Monitored and controlled variables

4.3.1 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 3: Monitored Variables for eBin

4.3.2 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 4: Monitored Variables for eBin

4.4 Constraints

4.4.1 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.

4.4.2 Operation Constraints

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

4.4.3 Schedule Constraints

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

4.4.4 Budget Constraints

The maximum budget of our project is 750 Canadian dollars.

5 Functional Requirements

5.1 Functional Decomposition

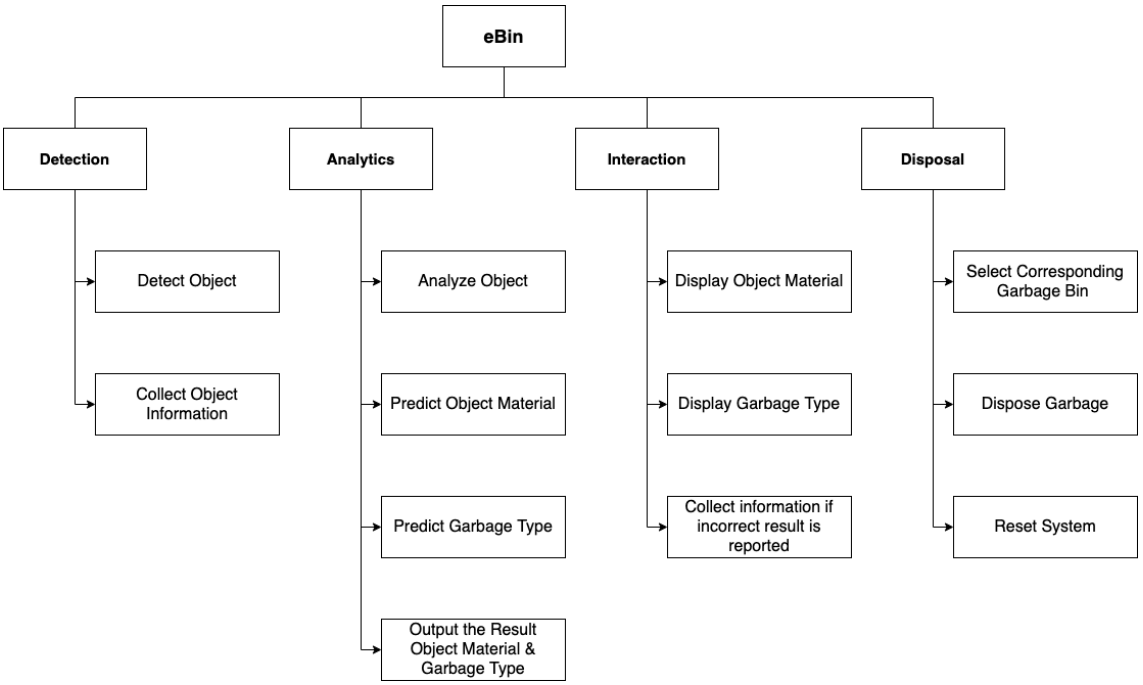

Figure 3: Functional Decomposition Diagram

5.2 Functional Requirements

5.2.1 Detection Functional Requirements

Requirement: DEFR01
Description: The system shall able to hold the garbage for processing
Rationale: The system will not dispose the garbage unintentionally
Fit Criterion: The garbage will not drop unintentionally when it is less than 2 kg
Priority: High
History: Created October 23, 2019

Requirement: DEFR02
Description: The system will be able to detect the object
Rationale: The system will start to work immediately once it detect the object
Fit Criterion: Response time should be less than 1 second
Priority: High
History: Created October 23, 2019

Requirement: DEFR03
Description: The system will be able to catch the information of the garbage properly
Rationale: The system shall catch sufficient information of the object for further analysis
Fit Criterion: Sufficient information is provided to be processed by system
Priority: High
History: Created October 23, 2019

5.2.2 Analytics Functional Requirements

Requirement: AFR01
Description: The system shall be able to analyse the object material properly
Rationale: The system should respond with correct object material according to the object information
Fit Criterion: The result should have at least 80% accuracy
Priority: High **History:** Created October 23, 2019

Requirement: AFR02
Description: The system shall be able to analyse the garbage type properly
Rationale: The model should respond with correct garbage type according to the object information, either recyclable or other
Fit Criterion: The result should have at least 90% accuracy
Priority: High **History:** Created October 23, 2019

5.2.3 Interaction Functional Requirements

Requirement: IFR01
Description: The system should display the result to the user
Rationale: There system should be able to tell the user the object material and garbage type
Fit Criterion: The result should be displayed once the analysis is completed, the display time should be 2 seconds
Priority: Medium
History: Created October 23, 2019

Requirement: IFR02
Description: The system shall able to collect data if result is incorrect
Rationale: The user can report the case if the result is incorrect
Fit Criterion: The information will be saved for further modification if an incorrect case is reported by the user
Priority: Medium
History: Created February 23, 2020

5.2.4 Disposal Functional Requirements

Requirement: DIFR01
Description: The garbage should be disposed to the corresponding bin
Rationale: The garbage should be disposed to either recyclable or other bin based on the result
Fit Criterion: The system should dispose the garbage as expected
Priority: High
History: Created October 23, 2019

Requirement: DIFR02
Description: The system should be able to dispose the garbage in any shape
Rationale: The system should be able to handle any garbage in different shapes without fault
Fit Criterion: All the garbage under size limit can be handled properly
Priority: High
History: Created February 23, 2019

5.2.5 Core Functional Requirements

Requirement: CFR01
Description: System shall reset to initial state after perform each operation cycle
Rationale: eBin will be reset to initial state
Fit Criterion: The reset process should be completed in 2 seconds
Priority: High
History: Created October 23, 2019

Requirement: CFR02
Description: System shall be stable when the application is running
Rationale: The system should perform proper step after each required action
Fit Criterion: The system should not perform unexpected action when the program is running
Priority: High
History: Created February 23, 2020

6 Functional requirements likelihood of change

Requirement	Likelihood of change	Rationale	Ways to change
DEFR01	very unlikely	key implementation aspect	N/A
DEFR02	very unlikely	key implementation aspect	N/A
DEFR03	very unlikely	key implementation aspect	N/A
AFR01	unlikely	subject to scope definition and time constraints	Material of the garbage may not need to be analyzed, only the type of garbage must be identified
AFR02	very unlikely	key implementation aspect	N/A
IFR01	likely	subject to scope definition and time constraints, this requirement has a lower priority compared to other requirements	The way how the system interacts with users varies.
IFR02	likely	subject to scope definition and time constraints	The way how the system interacts with users varies.
DIFR01	very unlikely	key implementation aspect	N/A
DIFR02	very unlikely	key implementation aspect	N/A
CFR01	likely	this is the most easy way to develop a stable machine	may change to a system that is always running without resetting between each operation

CFR02	very unlikely	Ensures that the garbage sorting machine works stably	N/A

7 Nonfunctional Requirements

7.1 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

7.2 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

7.3 Performance Requirements

Requirement: PR01
Description: The accuracy of sorting and disposing two types of garbage should be greater than 80%.
Rationale: To be competitive, eBin should have an accuracy greater than sorted by human.
Fit Criterion: Overall accuracy of the system is greater than 80%.
Priority: High
History: Created Feb.23, 2020

Requirement: PR02
Description: Each garbage classification process should be completed in under 6 seconds.
Rationale: eBin should operate efficiently enough to accommodate moderate user load.
Fit Criterion: Each garbage processing is done within 6 seconds.
Priority: High
History: Created Oct.23, 2019

Requirement: PR03
Description: The noise caused by the system operting should be lower than 80dB.
Rationale: eBin should be quiet enough to not distract people around.
Fit Criterion: Noise level of eBin when processing does not exceed 80dB.
Priority: Medium
History: Created Feb.24, 2020

7.4 Operational and Environmental Requirements

Requirement: OER01
Description: eBin should have suitable condition for garbage detection
Rationale: Suitable conditions like sufficient lighting and space are required for garbage detection
Fit Criterion: Detection process can be completed properly
Priority: Medium
History: Created Feb.24, 2002

7.5 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

7.6 Security Requirements

Requirement: SR01
Description: eBin will not cause harm to users and the environment
Rationale: Any dangerous behaviors to users and the environment are prohibited
Fit Criterion: No dangerous behaviors to users and the environment
Priority: Medium
History: Created October 23, 2019

7.7 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

7.8 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

8 Nonfunctional requirements likelihood of change

Requirement	Likelihood of change	Rationale	Ways to change
LFR1	unlikely	Should look like a traditional garbage bin so that people do not need to spend time getting used to it	Our design can be creative but that is not the scope of this project
UHR01	very unlikely	subject to scope definition and time constraints	N/A
PR01	very unlikely	subject to scope definition and time constraints	N/A
PR02	very unlikely	subject to scope definition and time constraints	N/A
PR03	unlikely	subject to scope definition and time constraints	N/A
OER01	very unlikely	key implementation aspect	N/A
MSR01	unlikely	subject to scope definition and time constraints	N/A
SR01	very unlikely	Ensures product safety standards are met	N/A
CPR01	very unlikely	Ensures that the product does not violate any cultural and political regulation	N/A
LER01	very unlikely	Legal requirements	N/A

9 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.

10 Project Issues

10.1 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)

10.2 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.

10.3 New Problems

Currently, there is no further problems.

10.4 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.

11 References

N/A