Year 2 Project

The Application of Transfer Learning in Garbage Classification

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Abstract

There has been a rapid increase in concerns to reduce the negative influences on the environment globally. Among them, the problem of garbage classification such as ambiguity and complexity has been widely concerned around the world. An automatic sorting bin can be the solution for this problem. This report illustrates the individual role of the software and hardware part of the sorting bin and remarks on how the system works together to sort out the trash automatically. In this project, a convolution neural network based on inceptionV3 is used as an image feature extractor to make the program to sort out the trash. For the hardware part, moto servo is used to put the trash into the right zone among four categories: bottle, metal, paper and general waste. As a result, the accuracy of model verification set after transfer learning is higher than 90%, and in 400 random tests, the accuracy rate of the finished product in the actual waste delivery test is almost 83%.

Declaration

I confirm that I have read and understood the University's definitions of plagiarism and collusion from the Code of Practice on Assessment. I confirm that I have neither committed plagiarism in the completion of this work nor have I colluded with any other party in the preparation and production of this work. The work presented here is my own and in my own words except where I have clearly indicated and acknowledged that I have quoted or used figures from published or unpublished sources (including the web). I understand the consequences of engaging in plagiarism and collusion as described in the Code of Practice on Assessment (Appendix L).

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Chapter 1

Introduction

1.1 Introduction and Motivation

According to the research conducted targeting a number of 40 University of Liverpool students, more than half of students 'sometimes' recycle, and 80% of people questioned in the survey preferred to use garbage cans that can be classified automatically (See in Appendix D). Based on this issue faced by user when sorting garbage, this project uses the neural network model based on inceptionV3. This project modifies this model in the last two layers so that the model with a mechanical structure can identify and sort the garbage, including plastic bottles, metal cans, waste paper, and general waste.

1.2 Objectives

The project aim and objectives are divided into two categories. These categories are the overall objectives the team expects to achieve and the set objectives that are expected to lead to the successful implementation of the project.

1.2.1 Overall objectives of the project

The main goal of this project is to use a convolutional neural network inceptionV3 model for transfer learning so that the modified model can effectively identify plastic bottles, metals, waste paper, and general waste. Based on the machine recognition technology, a physical structure is built to classify the above four kinds of objects effectively.

1.2.2 Objectives directed towards the successful implementation

The project objectives are divided into three phases illustrated in the timeline in Figure 1.1.

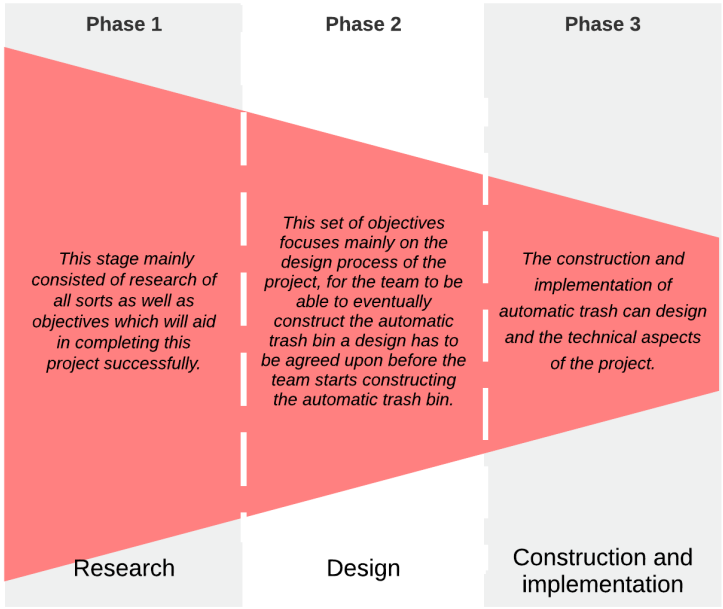

Figure 1.1. Project objectives based on the timeline

Phase 1: Research

- To have a basic understanding of the concept of the project
- To have a deep understanding of the transfer learning of a convolutional neural network in machine learning
- To Make a preliminary selection of necessary project materials and familiar with the essential operation of Raspberry Pi's general-purpose input/output (GPIO)
- Be Familiar with necessary modeling skills of 3D model

Phase 2: Design

- Create a preliminary design of the automatic trash bin on computer-aided design
- Choose the final design according to the design prototype
- Create a prototype of the automatic trash bin
- Design the transfer learning model needed by the project, and design the activity diagram of the project software
- Select materials required for the project
- To design and print 3D components

Phase 3: Construction and implementation

- Develop the software based on the activity diagram which is to be utilized for the operation of the automatic trash bin
- Construction of automatic trash bin according to final design
- Combine the software and hardware together and make final adjustments to the set-up of the automatic trash bin

Chapter 2

Theory

The classifying bins of low artificial intelligence have machine learning technology. According to the team of Jeff Donahue's paper, Google's convolution neural network (CNN) model InceptionV3 [1], a simple parameter training is carried out in the so-called bottleneck layer and the last output layer. In addition, the neural network

layer in the front of the model is used as the feature extractor of the picture [2], [3]. The theoretical explanation of this chapter aims to provide a relatively rigorous theoretical support for this project.

2.1 Basic Theory of Machine Learning

Machine learning technology is a subset of artificial intelligence, which can be traced back to 1763 when Richard Price summarized and published Bayes' algorithm [4]. Nowadays, the main purpose of machine learning is to analyze and get a function relation with mathematical representation through massive data.

2.1.1 Main Categories of Machine Learning

Machine learning can be divided into two categories: supervised learning and unsupervised learning [5]. Supervised learning is to give the correct label in the training set and then use the machine to calculate one or more linear or non-linear functions or super functions, which can be used for data classification or regression analysis. The regression problem is the prediction output of continuous value, while the classification problem is the prediction output of discrete value [5]. In this project, garbage classification which is a classification problem in supervised learning is used.

2.1.2 Objectives of Supervised Learning in Classification

In the design of the classifier at the beginning of the project, only two kinds of garbage images were used as the source of data set, and two features were used to classify each image. For example, as shown in Figure 2.1, feature 0 (X_1) is the grayscale of the main subject of the image, feature 1 (X_2) is the scale of the subject. Among them, the circle represents the characteristics of plastic bottles, while the

diamond represents the characteristics of wastepaper. The goal of supervised learning is to use a linear or non-linear function (or super function in the case of high dimension) to classify images [6].

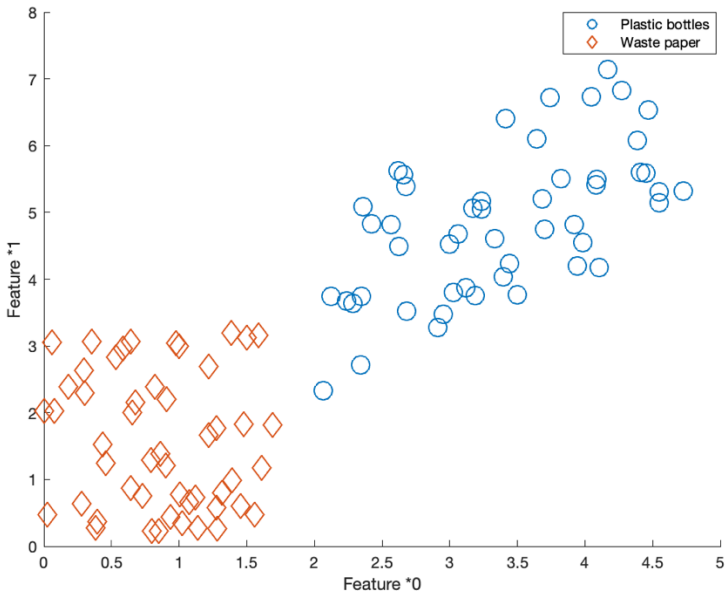

Figure 2.1. Classification problem in simple case

The predicted results could be composed of the following hypothetical function [6], [7]:

$$h_\theta(x) = \theta_0 + \theta_1 X_1 + \theta_2 X_2 + \theta_3 {X_1}^2 + \theta_4 {X_2}^2 + \theta_5 X_1 X_2 + \theta_6 sin(X_1) + \theta_7 sin(X_2) \quad (1)$$

For the $h_\theta(x)$, θ_n is the parameter of the hypothetical function, which is the variable to be found in machine learning [6], [8]. For the hypothetical function, there is a cost function $J(\theta_0, \theta_1, \ldots \theta_{n-1}, \theta_n)$ which makes the function have a local optimal solution [6], [8]. In the optimal local solution, there must be an optimal solution, which makes the parameters obtained from the cost function fit into the hypothetical function. For example, if there are only two parameters, the three-dimensional image of the cost function can be represented like the Figure 2.2. For

the case shown in Figure 2.3, the gradient descent method is generally used to obtain the parameters.

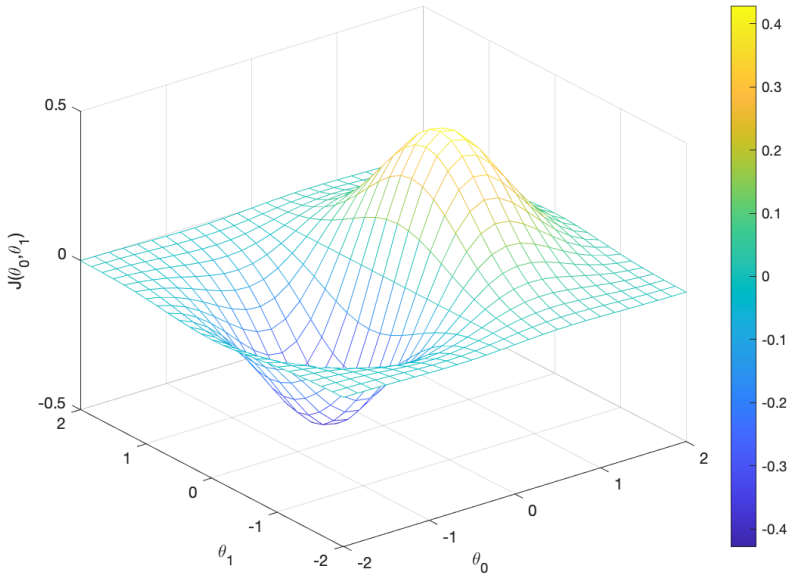

Figure 2.2. Cost function with two parameters

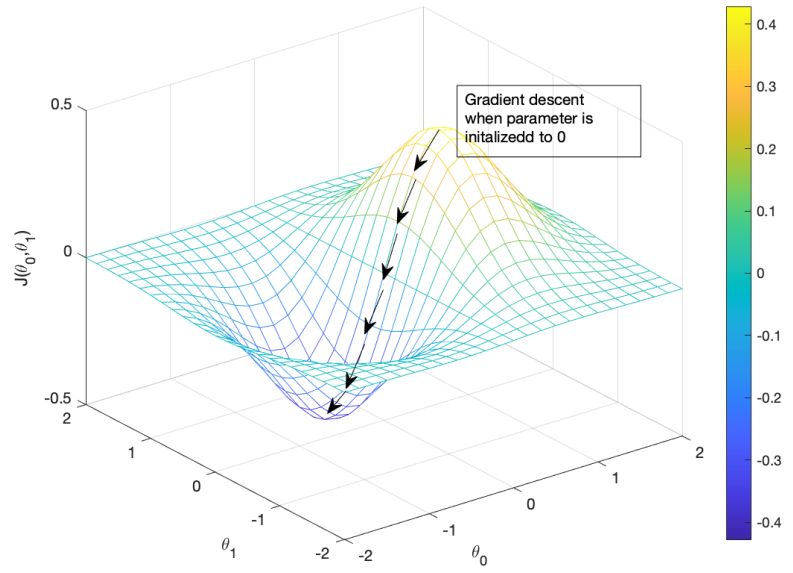

Figure 2.3. Example of gradient descent

For the classification of two variables, the linear function which is calculated by the hypothetical function with cost function $J(\theta_0, \theta_1, \ldots \theta_{n-1}, \theta_n)$ can be used to effectively classify the problems as shown in the Figure 2.4.

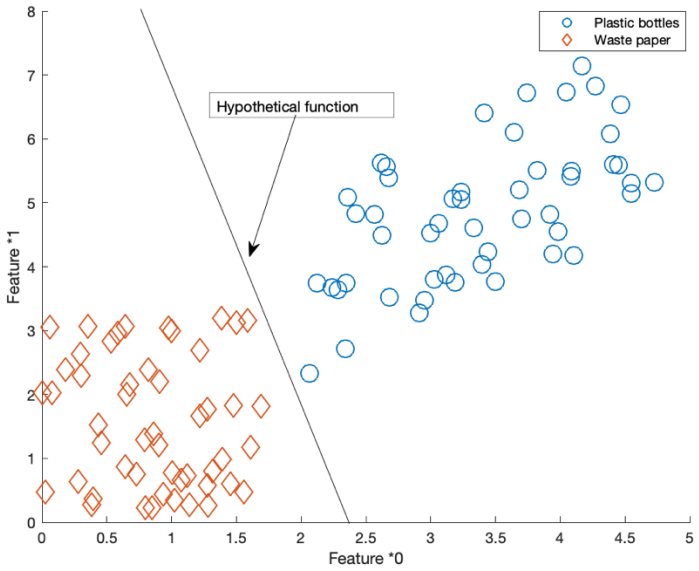

Figure 2.4. Classification problem in simple case with hypothetical function

Using traditional methods will lead to the problem of too many items in a hypothetical function. For example, in the formula (1), only two variables need at least five items to fit. The increase of variables and the combination of different parameters will lead to the increase of the number of terms in square speed, which is difficult for an ordinary computer to carry out practical calculations [8].

2.1.3 Optimization of Complex Problems by Neural Network

For neural network, the problem of too many terms can be resolved. Combined with convolution technology, i.e., filter, backpropagation algorithm, and other algorithms, neural networks can solve these problems [1], [9], [10]. For example, in Figure 2.5, for non-linear and complex classification problems, the neural network can better fit

the hypothesis function than traditional methods. Combined with the project, a convolution neural network is the most effective method to solve the classification problem with a large number of features and parameters.

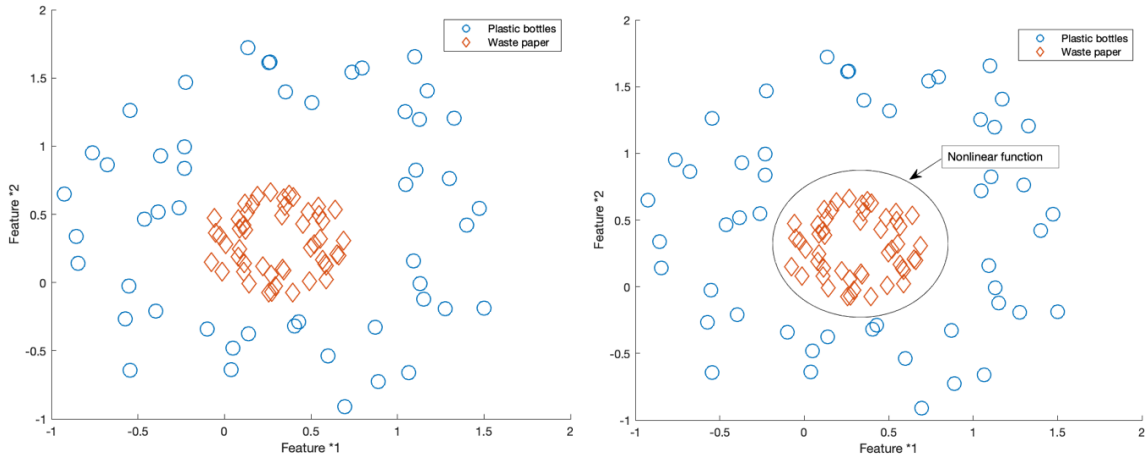

Figure 2.5. Examples of neural networks for complex classification problems

Furthermore, the open-source framework of TensorFlow has a better performance on the non-linear fitting process of a neural network [7]. Figure 2.6 shows the fitting process of non-linear hypothesis function under the condition of complicated classification. Among them, yellow and blue correspond to two categories respectively, among which horizontal and vertical axis correspond to features (no unit), image from left to right, the number of iterations increases in turn (Number of iterations: 0, 80, 142, 242, 324, 892). After the 892nd iteration, the yellow area of the image conforms to the area of the training data, which shows that the neural network can classify complex problems. The structure of the neural network is shown in Figure 2.7, which has eight layers.

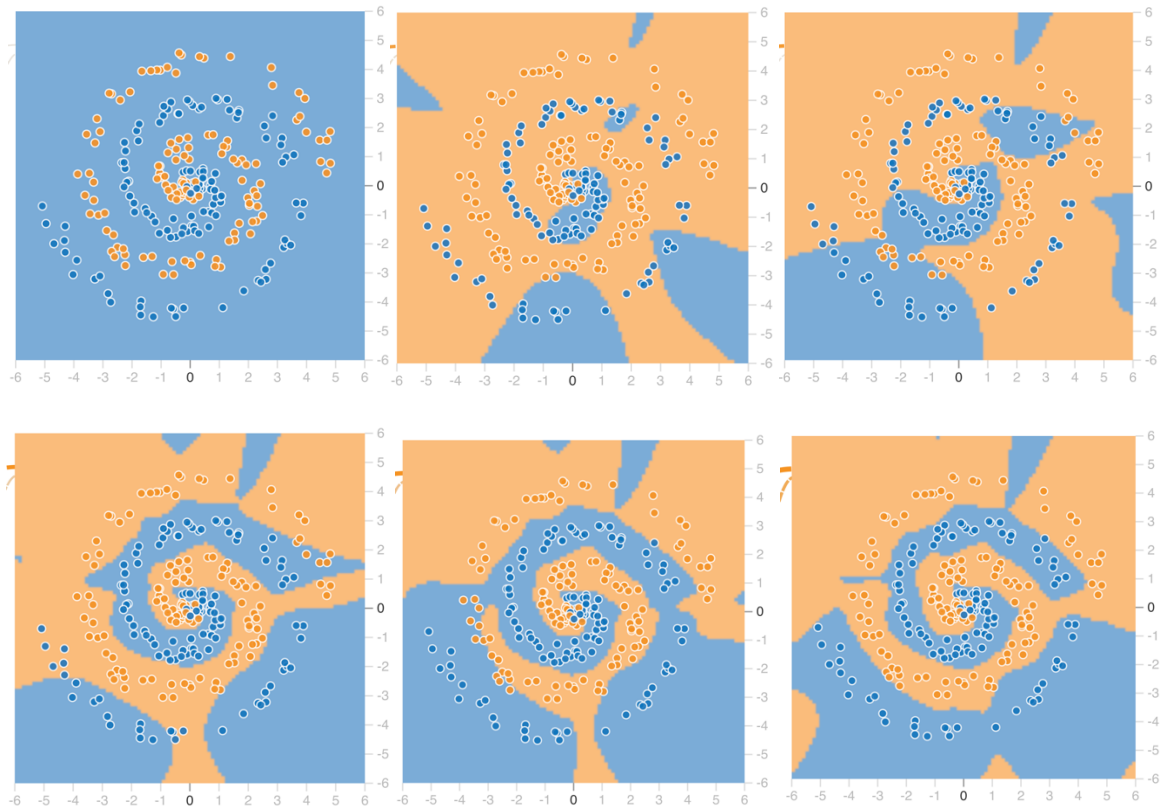

Figure 2.6. Example of 8-layer neural network classification result (From left to right, The horizontal axis and the vertical axis are two different characteristics, taken from [11])

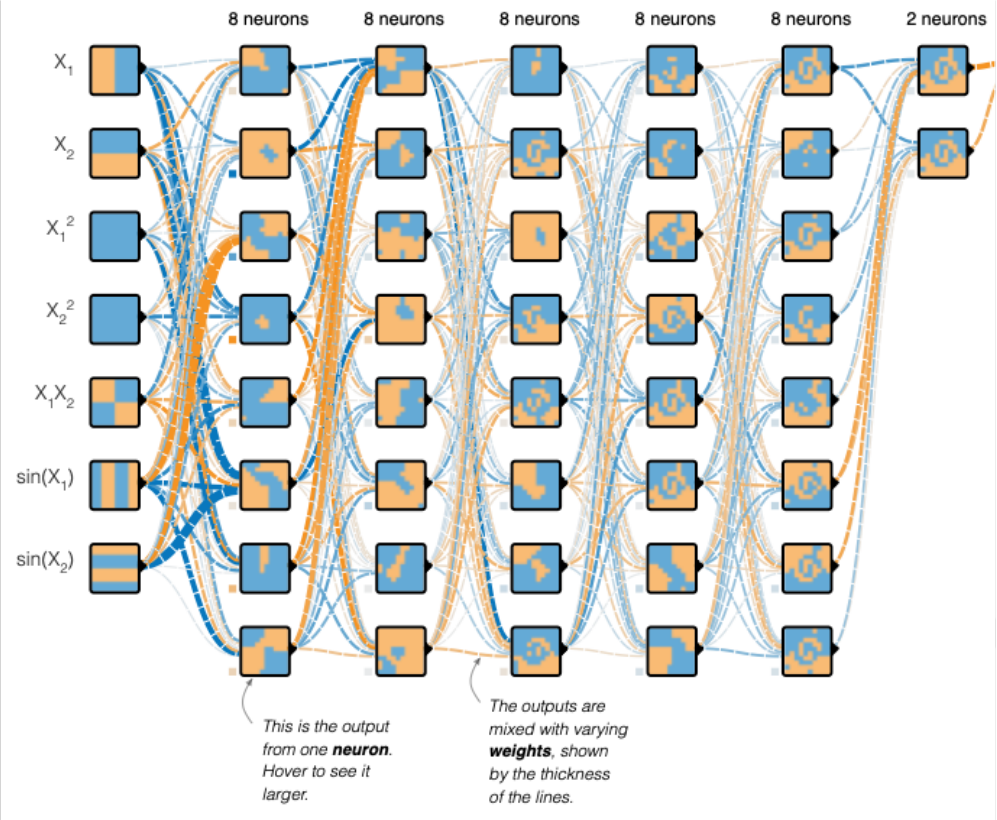

Figure 2.7. Examples of neural network structure (taken from [11])

2.2 Basic Theory of Computer Vision

For this project, the Raspberry Pi needs to take photos and use OpenCV to process the image. This step is necessary for all practical applications of computer vision. However, the difference between the pictures seen by humans and the images processed by computers is vast [12]. For example, for an RGB photo is shown in Figure 2.8. The task of computer vision is to find and summarize the potential rules in an image matrix.

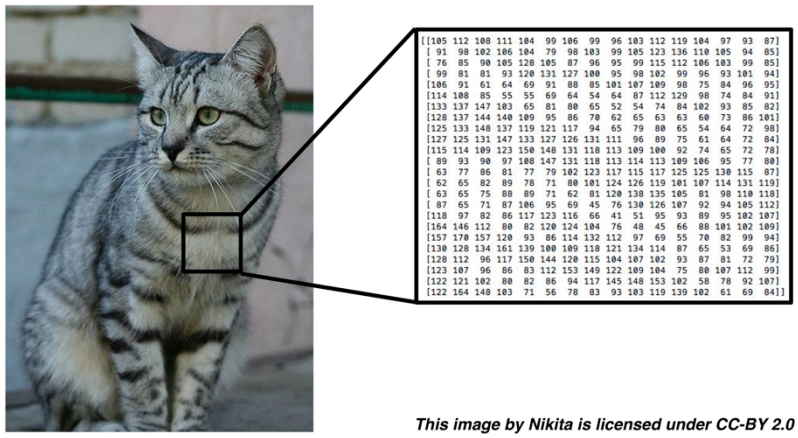

Figure 2.8. Examples of RGB image in code (taken from [12])

2.2.1 Challenges of Computer Vision

Computer vision faces the following challenges which are summarized by Justin Johnson from Stanford [12]:

- Background Clutter
- Illumination
- Intraclass Variation

In this project, as the camera has a particular elevation, background will be changed partially. Therefore, changing light for instance, under different light conditions, the recognition accuracy will fluctuate the output. Addition, there are many different shapes and colors of plastic bottles in this category. These challenges will directly affect the output results of the hypothesis function, which may lead to continuous errors under some extreme conditions.

2.2.2 Application of Convolutional Neural Network in Computer Vision

InceptionV3 model belongs to convolution neural network, and its structure chart is shown as follows [1]:

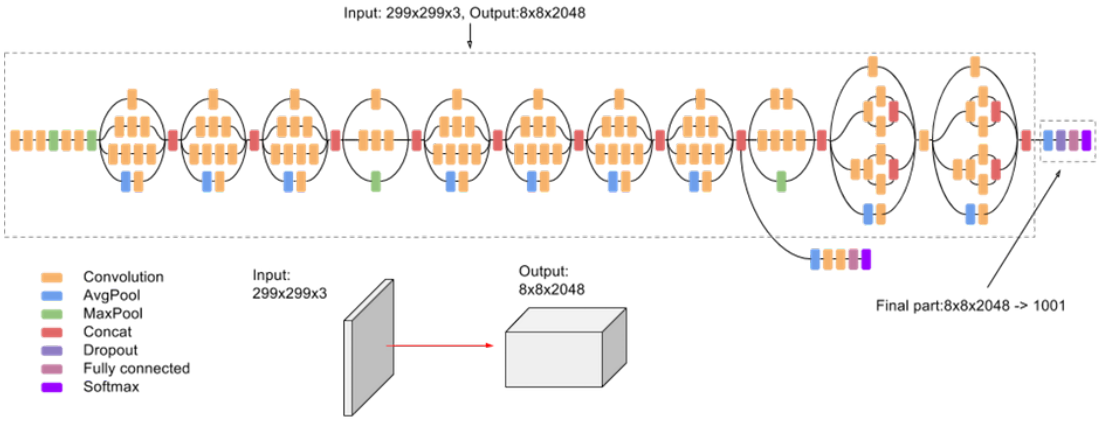

Figure 2.9. InceptionV3 model (taken from [13])

In this garbage classification project, the InceptionV3 model is used as the basic model, and most parameters of the hidden layer are unchanged, so the time cost of GPU calculation is relatively smaller than that of the self-built model. This method of using pre-trained models is called transfer learning [2]. Based on this project, the InceptionV3 model is used as the feature extractor of the image.

Chapter 3

Design and Implementation

In this design and implementation chapter, the development and design steps of software and hardware will be introduced in detail below each subtitle. The overall design flow chart of the project is shown in Figure 3.1.

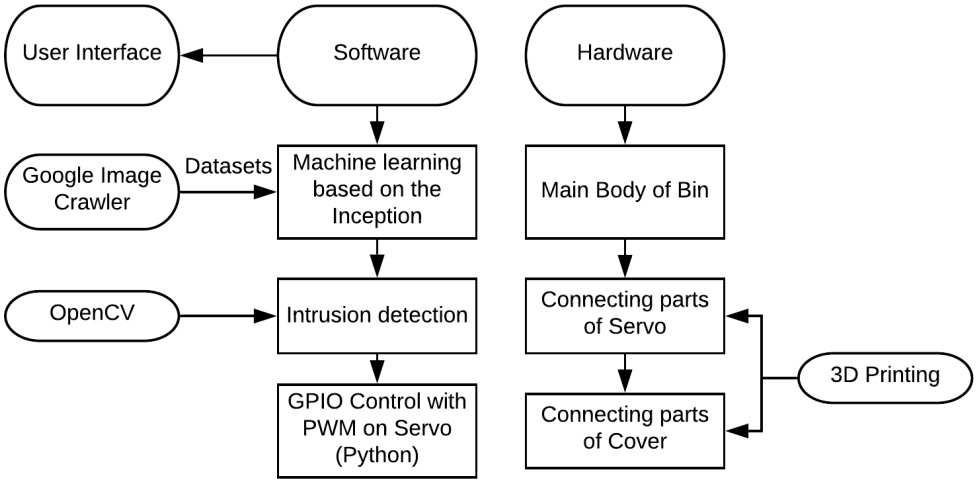

Figure 3.1. Flow chart of the project

3.1 Materials Table

Table 1. Software and Package List

Software/Package Name	Version
Keras	2.0.1
imageio	2.6.1
imgaug	0.3.0
numpy	1.17.4
opencv-python	4.1.2.30
opencv-python-headless	4.1.2.30
tensorflow	1.15.0
PyQt5	5.14.0
Google-images-download	#0d2bf8f
Bottleneck	1.3.1

Table 2. Hardware List

Hardware Name	Type No.
Raspberry Pi 4 Model B, BCM2711 SoC, 4GB DDR4 RAM, USB 3.0	RPI4-MODBP-4GB
Raspberry Pi Accessory, Raspberry Pi 4 Model B Official PSU, USB-C, 5.1V, 3A	SC0216
Raspberry Pi 7" Touch Screen	RASPBERRYPI-DISPLAY
Raspberry Pi Camera V2 Camera Module, CSI-2, 3280 x 2464 Resolution	Raspberry Pi Camera V2
Micro Servo	Tower Pro SG92R - 169
Ultrasonic Distance Sensor	HC-SR04

3.2 Software Design and Implementation

Even if the pre-trained model is used, the number of input data sets cannot be too small. For neural networks, the more data sets mean the opportunity for neural networks to find out the details, and also means the higher the probability that the hypothesis function can finally be coupled. Besides, this project follows the method of reducing the use of regularization, which improves the transfer accuracy [14]. Figure 3.2 shows the reduce the use of regularization (Dropout) to improve the accuracy of transfer learning.

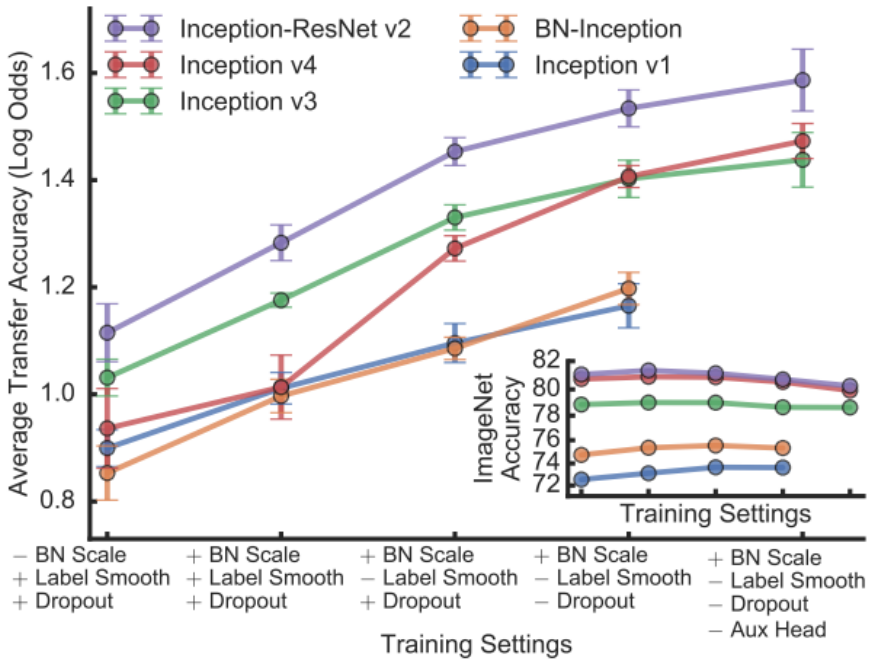

Figure 3.2. ImageNet training settings have a large effect upon performance of logistic regression classifiers trained on penultimate layer features (taken from [14])

3.2.1 Dataset Preparation

This project uses a large number of data sets from Google images and collects about 50000 pictures by using Python-based crawlers, which is an open-source plug-in unit called Google-images-download [15]. However, not all the photos can be used as a suitable training set, most of the photos have too much interference, which will affect the accuracy of machine learning. After sorting out, only the 2451 images can be used as a training set. These photos are divided into 80 % training sets, 10 % validation sets and 10 % testing sets.

3.2.2 Dataset Enhancement and Vectorization

Due to the small number of data sets, data enhancement methods need to be used to expand the data set, thereby enhancing machine learning for image feature

extraction. This project uses imgaug with OpenCV2 to enhance the image [16], [17]. For example, for the same picture, imgaug can produce rotation, noise, blur and other operations on the picture, and then the same picture can produce many types of new pictures. After that, the same picture can produce many types of new pictures, which is helpful to expand the data set. Figure 3.3 shows an example of imgaug style. Also, the picture needs to be vectorized before using machine learning. The bottleneck library is used here to make the picture to vectorize.

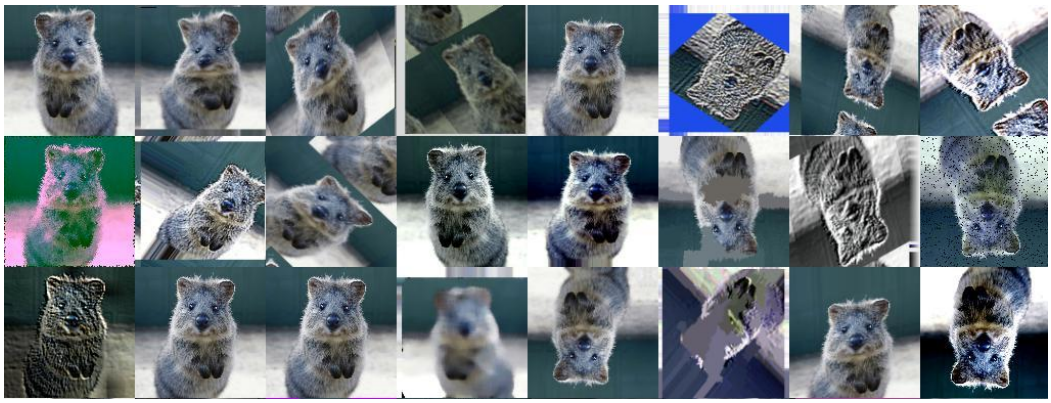

Figure 3.3. Example augmentations of one input image (taken from[16])

3.2.3 Training Process

The activity diagram of the training process is shown in Figure 3.4. Firstly, the vectorized data set is loaded into the main function. Secondly, the InceptionV3 model is read. Thirdly, the parameters of the penultimate layer are read. Fourthly, the last layer full connection layer and loss function are defined. Then, the training begins. After the training, the new model will be tested. If the accuracy of the model meets 90%, it will stop. Otherwise, the parameters need to be modified or adjusted for the data set.

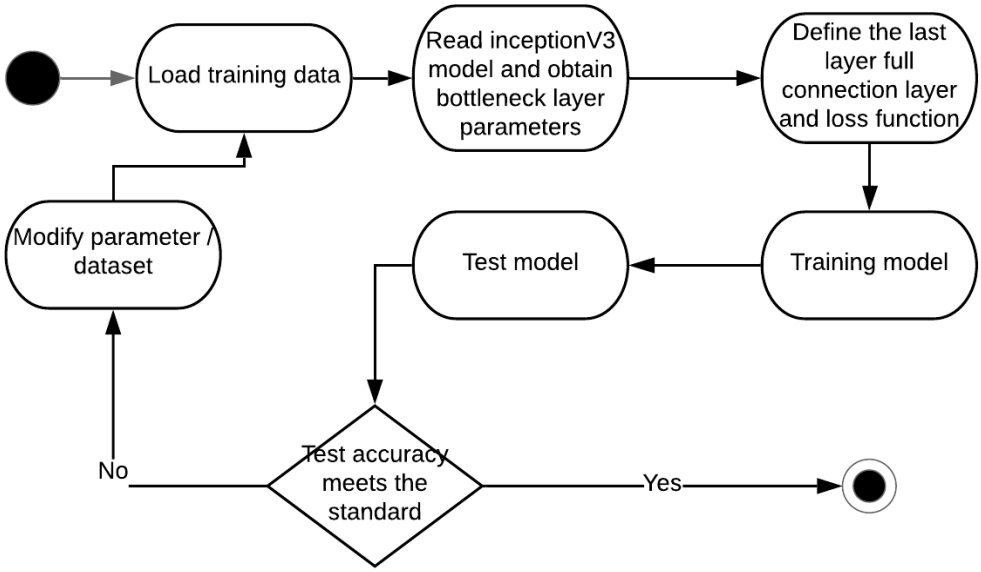

Figure 3.4. Training process activity diagram

3.2.4 Servo Control

The control of the servo means precise control of the rotation angle of the servo, because if the angle is not accurate, the two rotation planes of this project may be stuck. The use of the servo in the project is shown in Figure 3.5.

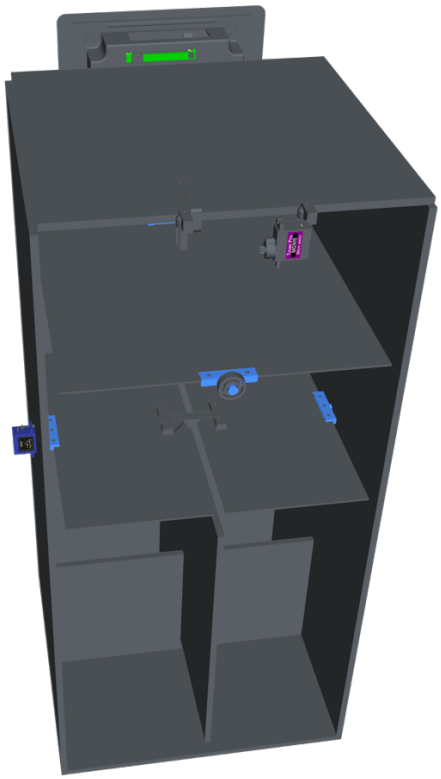

Figure 3.5. Demonstration of using the servo in the project

Firstly, there is a 40-pin general-purpose input/output (GPIO) connector in the Raspberry Pi, and each of the servo needs to be connected to one GPIO [18], [19]. After connection, there is a keyword 'Servo pin' in the compiled program of Raspberry Pi. Tests show that the keyword needs to be set whenever operating a servo, which means if another servo needs to rotate, the servo pin should be cleared and reset to another PIN.

In order to make the servo turn accurately, it uses a technology called Pulse Width Modulation (PWM) [19]. In servo control, the direction of the axis is determined by the duration of the pulse [19], [20]. Figure 3.6 shows the working principle of PWM

in the servo. Moreover, Table 3 shows the relationship between duty cycle and rotation degree. For example, in some types of the servo, when the duty cycle is 50 %, the rotation degree of the servo will be kept at 90 degrees. The parameters of PWM depend on the model of the servo.

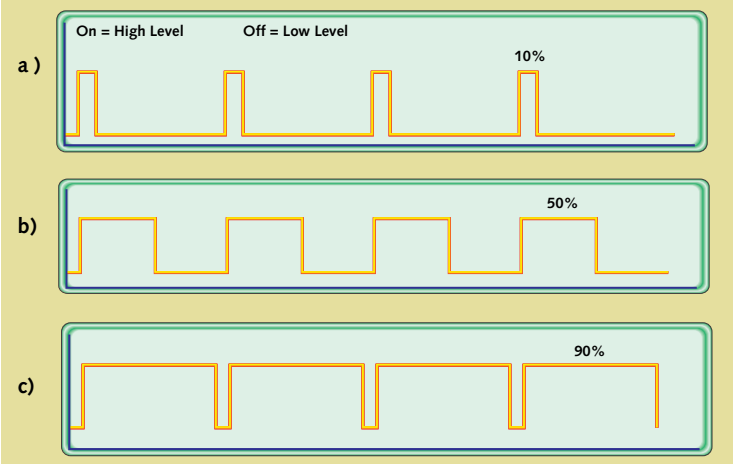

Figure 3.6. PWM example (taken from [20])

Table 3. Relationship between duty cycle and rotation degree in SG90 [19]

t	Duty Cycle	Direction
1 ms	5%	0 degrees
1.5 ms	7.5%	90 degrees
2 ms	10%	180 degrees

Figure 3.7 shows that angle and time are linear (The maximum rotate degree of the servo is 180). In the model of SG90, the function relation between angle and time is [19]:

$$duty = 5 / 180 * degree + 5 \quad (2)$$

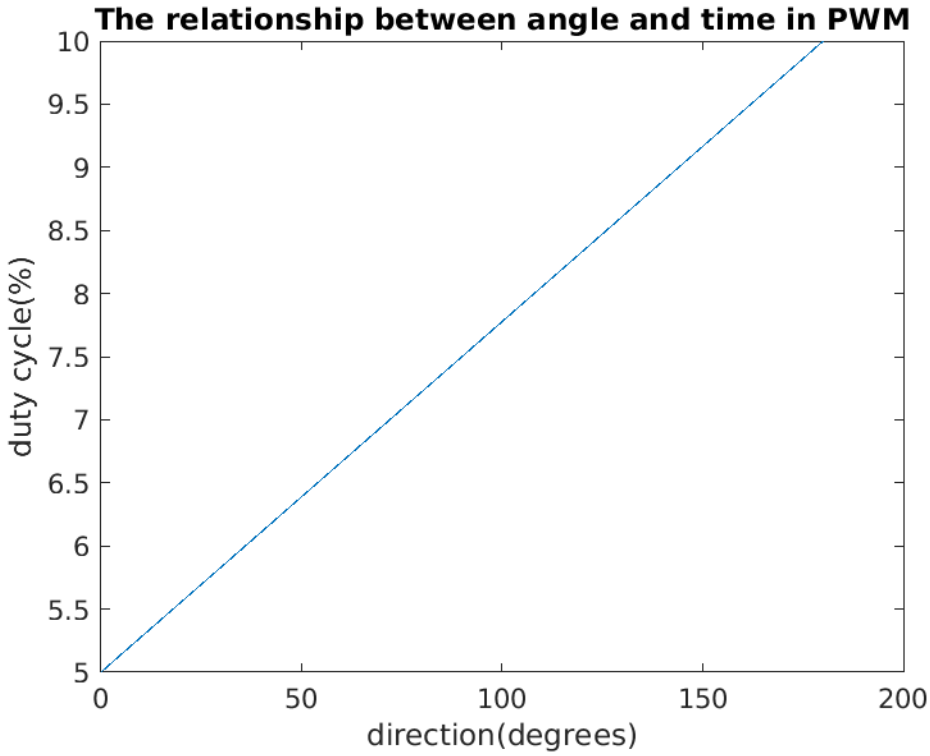

Figure 3.7. The relationship between angle and time in PWM of SG90 [19]

In addition, each time after a servo rotating, there is a vibration in the servo. The reason is that there will be an impulse for each period. To make the duty cycle equal to 0 after rotation can solve this problem.

3.2.5 User Interface

The design of the user interface contains the structure of UI and explanation of UI with user interaction. The PyQT is a UI design framework based on C++, which is used for this project [21]. The main interface is shown in Figure 3.8.

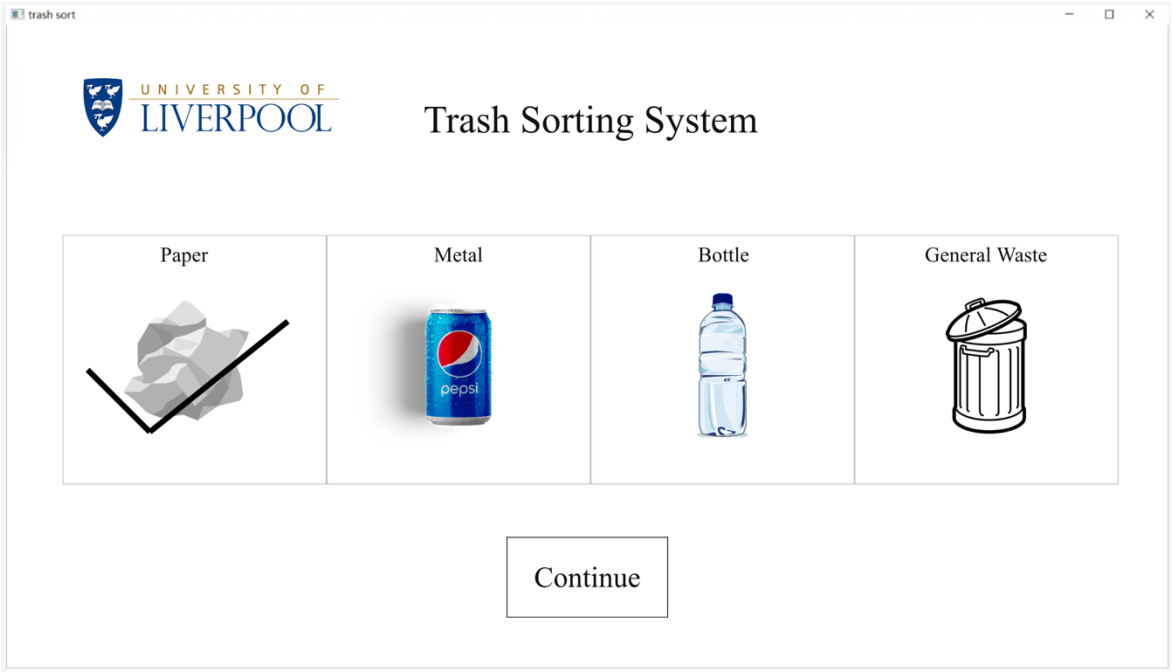

Figure 3.8. The main user interface based on the PyQT

From Figure 3.8, there are four types of waste, which are paper, metal, bottle and general waste. In addition, there is a checkbox near each of the pictures. At the bottom of the interface, there is a button labelled 'Continue'. When the program is initiated, all the checkboxes are not ticked. When the user touches the button 'continue'. It will go on the following program and return the result, which is the waste belong to.

3.3 Hardware Design and Implementation

As shown in Figure 3.9, the hardware of this project is mainly divided into three main parts: microcomputer part with aided hardware (camera, screen and speaker), servo with motion sensor and physical structure.

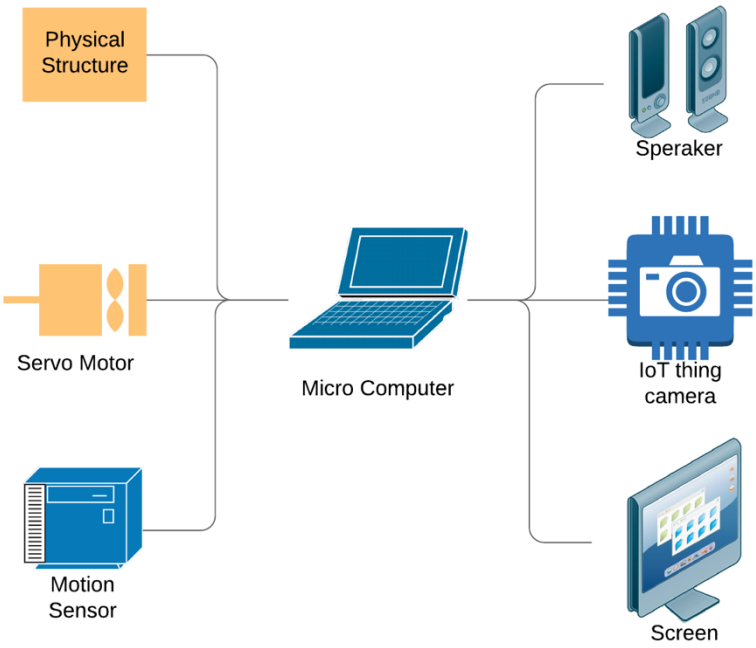

Figure 3.9. The hardware of this project

This image illustrates that the garbage can classification structure is mainly composed of two planes. One plane is driven by the servo to rotate. The other plane uses bearing to assist rotation. The plane of the upper half is 30 cm * 30 cm square while the other one has the same size as the edge. However, there is a gap of about 4cm in the middle. Therefore, the lower plane can still be classified after the upper plane rotates. It is the primary mode of the project to classify four different kinds of garbage mechanical structures. The demonstration in classification mode is shown in Figure 3.11. Some parts of this project belong to custom parts. Therefore, the 3D printing connection components are used in the project.

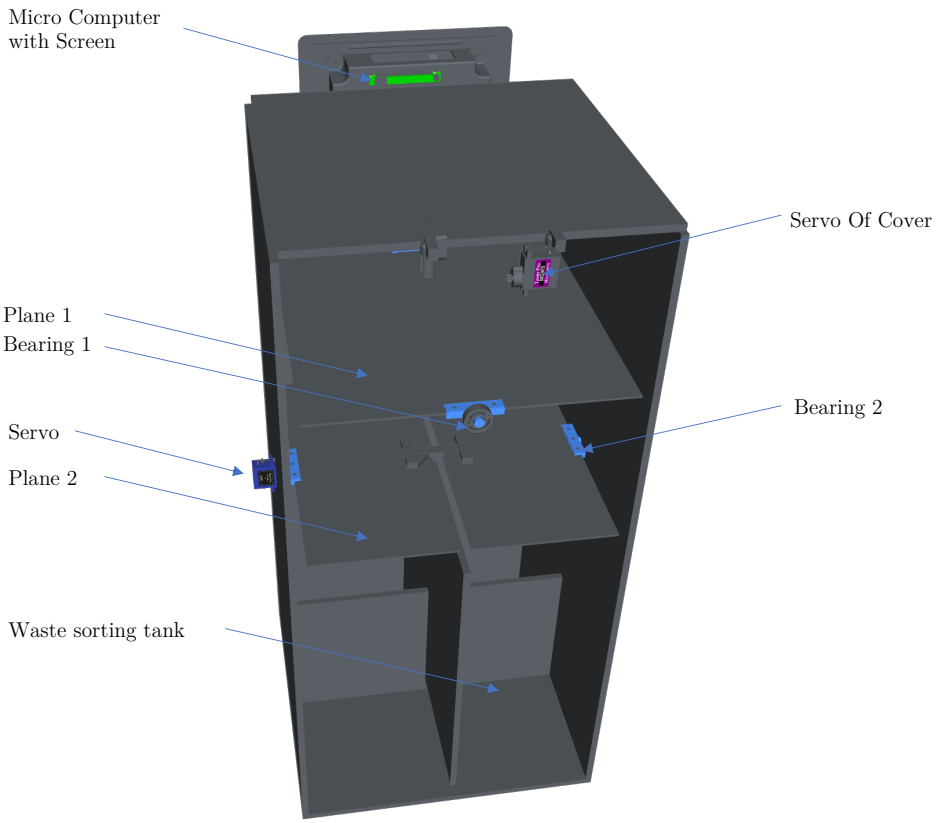

Figure 3.10. The actual structure of the automatic garbage bin

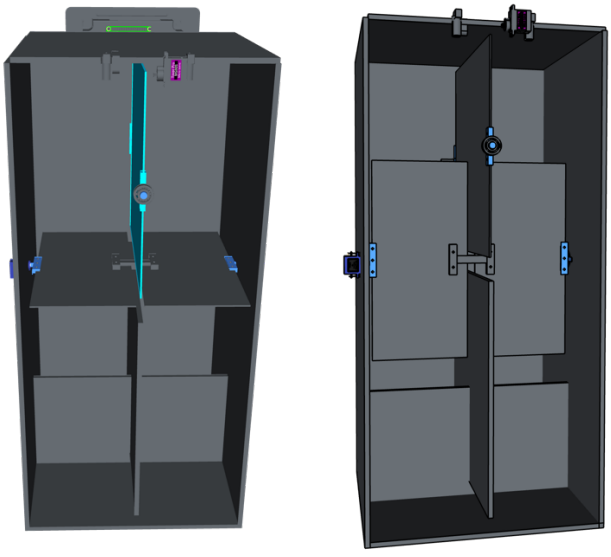

Figure 3.11. Plane rotation demo

Chapter 4

Results and Analysis

4.1 Transfer Learning Results and Analysis

The training and validation accuracy and the variation of cross-entropy are shown in Figure 4.1 and Figure 4.2. After 10,000 times of learning, the accuracy of the training set has reached 100%. The accuracy of the verification set has reached 93%. Lastly, the cross-entropy is almost 0.02, indicating that machine learning has achieved relatively high accuracy. However, this result is only a test of the existing data set. Therefore, there will still be high instability in the actual recognition process of this project. For example, the light and background interference mentioned in the previous chapter will reduce the confidence level of image classification. In extreme conditions, the confidence level may be lower than 60%.

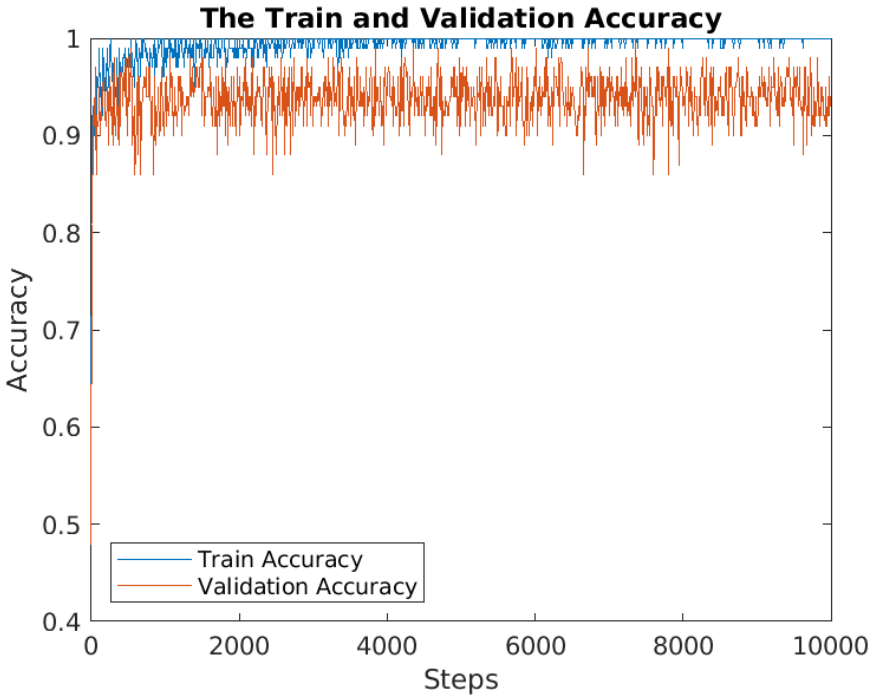

Figure 4.1. The training and validation accuracy

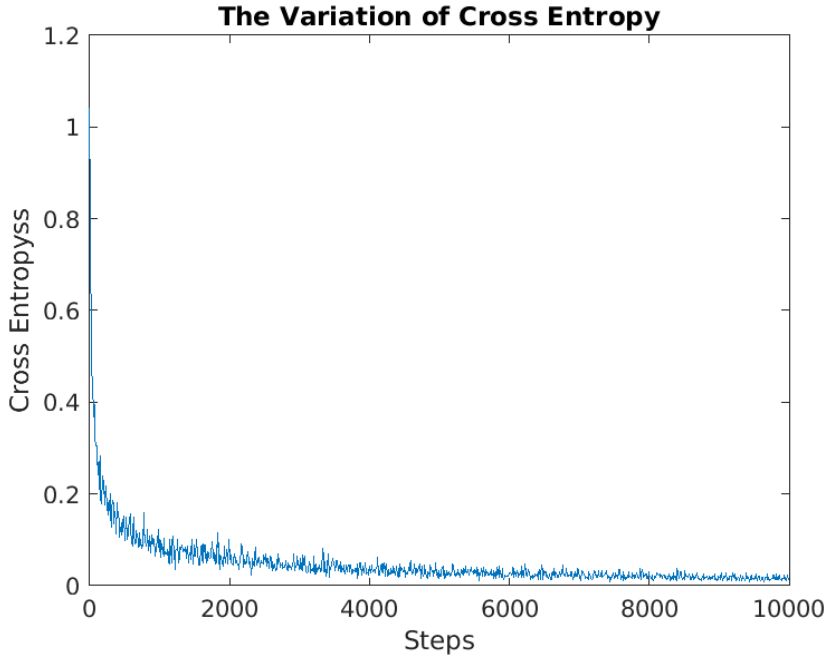

Figure 4.2. The variation of cross entropy

4.2 Stability of Mechanical Mechanism

The mechanical classification structure of the project has been tested randomly. The test items include wastepaper of different texture and sizes, cans of different weight, plastic bottles of different height and weight. The number of tests is 300, and the test results are as follows in Table 4:

Table 4. Mechanical structure stability test

Items	Num. of times	Result	Reason
Paper	73	Success	/
Paper	27	Fail	Paper too large, stuck plane
Cans	89	Success	/
Cans	3	Fail	Can stuck in gap
Cans	8	Fail	Too high quality, Servo stalled
Plastic bottles	93	Success	/
Plastic bottles	5	Fail	Too high quality, Servo stalled
Plastic bottles	2	Fail	The plastic bottle does not fall off at the balance point of gravity

Based on the test results, it is shown that the mechanical structure has a high stability for items other than paper, reaching more than 90%. However, due to the different sizes of paper, wastepaper is relatively easy to stick to the servo.

4.3 Achievement of Project Objectives

Finally, the mechanical structure which can be used for classification is combined with the computer vision program. Four groups of tests are carried out for the whole system. The test results are as follows in Table 5.

Table 5. Mechanical structure with the computer vision program test

Items	Num. of times	Result	Reason
Paper	76	Success	/
Paper	19	Fail	Mechanical failure
Paper	5	Fail	Wrong recognition to the general waste
Cans	91	Success	/
Cans	8	Fail	Mechanical failure
Cans	1	Fail	Wrong recognition to the general waste
Plastic bottles	81	Success	/
Plastic bottles	2	Fail	Servo rotates too fast
Plastic bottles	17	Fail	Mechanical failure
General waste	83	Success	/
General waste	11	Fail	Mechanical failure
General waste	6	Fail	Wrong recognition

The total number of attempts is 400 and bottles, cans, and paper account for a quarter. The correct rate was almost 83%, which means it failed to fall into the

right position sometimes. There are several reasons which contributed to the slight malfunction or failure of the system. The first reason for the failure was that the mold of the servo did not connect the servo tightly, which leads to the incomplete rotation. Another reason for it was that the bottom part was hit by the bottle fallen last time and moved a little. The last reason for failure was that the speed of rotation was too fast. The object fell to another room after being flipped by the board due to inertia instead of sliding against the board. These factors may be adjusted in the future. For example, the speed of rotation can be slower. Moreover, the gap between two parts of the board can be more extensive. In conclusion, the success rate of the whole project is high. Even thought there were some issues, they were expected and may be altered.

Chapter 5

Discussion and Conclusions

5.1 Discussion

In general, in the actual test of garbage classification, the average accuracy rate is 83%. The relatively high success rate of garbage classification is mainly due to the test accuracy of more than 90% of hypothesis functions and relatively stable mechanical structure. In detail, in the bench inspection, it succeeds to sort out all the trash to the right zone. However, under this accuracy rate, it is still possible to cause inconvenience to end-users. Any convolutional neural network model cannot achieve complete accuracy but improving the accuracy has been a significant goal for computer vision scientists.

The main limitation of this project is that it cannot get a large number of useful data sets. However, the accuracy may be increased if more training dataset of images are added. However, a good quality dataset needs much time to gather, and it cannot be achieved without the support of big data. Another limitation is from a commercial perspective. It still needs to be improved for practical use as the material cost for this bin is about 200 pounds. The most significant factors on the increase in cost are Raspberry Pi and the screen. In this case, product cost can be reduced by mass production. If the cost problem is solved, it would be highly competitive as the government's policy toward environmental issues is strongly addressed currently.

Considering the fact that the undergraduates which handled this project are the only year two students with minor experience and background in such a complex system, for instance, an AI system or types of materials to construct the product, there are a few objectives that have not been met by the team. However, many other objectives have been achieved by the group members, which led to the success of the automatic sorting trash bin. A very critical objective set by the team has been achieved which was to be able to work together as a team and avoid any complications between the members. If a team does not work together appropriately this would have a negative effect on the work that they would present. In addition, another objective was to divide the four members into two groups hardware and software with two people per group to be able to complete more work during one laboratory session. It has been successfully implemented by the group and has proven that this step aided in the rapid progression of the project. Furthermore, all progress of the project has been recorded in a logbook and a blog. As for the product itself, most objectives were accomplished, such as creating a system that would be able to identify and distinguish between four categories, the final product which has an 83% recognition rate, the machine which was able to identify plastic bottles, metal cans, as well as paper, the fourth category was labeled as general waste. Hence any object the system does not recognize by the angles of the object is classified as general waste.

5.2 Future Work

In the future, in order to reduce the project cost and improve the recognition speed, the supercomputer in the cloud can be used for calculation. In contrast, the microprocessor in the local area can reduce further hardware costs. For example, as

shown in Figure 5.1, when the local photos are taken and uploaded to the supercomputer in the cloud through the microprocessor, the supercomputer returns the recognition result to the microprocessor after the operation, and then the microprocessor orders the servo to classify.

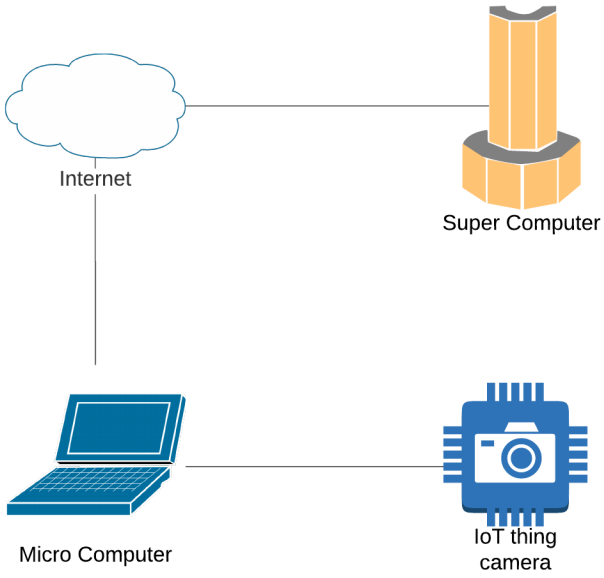

Figure 5.1. Garbage classification combined with cloud in IoT

5.3 Conclusions

In this project, an automatic trash bin system was designed. Machine learning is the core technology of it, and the time costs of the project were significantly reduced through transfer learning methodology. Combined with the classification mechanism designed by the team, it can automatically classify garbage into the four types with an almost 83% success rate in 400 attempts. However, it still has some parts needed to be improved in the future. Recognition rate and mechanical structure stability need to be further improved. As this project affects many other industries, it can be applied to refuse disposal station or other industry which can use this technology of classification.

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Appendices

Appendix A

A.1 Role allocation/responsibility matrix

	Member Name	**Title(s)**
1	A-Ro Han	Developer
2	Haoran Cheng	Designer
3	Mobarak Shekhah A D Kh	Technical writer
4	Xuhui Gong	Project manager

A.2 Contribution to project deliverables

	Member Name	Deliverables	Comments
1	A-Ro Han	Poster, hardware, report (description. Introduction)	
2	Haoran Cheng	User interface, circuit, code, structure, report (section 3), software	
3	Mobarak Shekhah A D Kh	Poster, blog, soldering, hardware, report (section 1), structure, logbook	
4	Xuhui Gong	Code, report (section 2), automatic trash bin 3D design, purchase MDF sheets	

A.3 Attendance record

	Member Name	Attended the weekly meeting? (Yes/No)					Comments
		Week1	Week2	Week3	Week4	Week5	
1	A-Ro Han	N	N	Y	Y	Y	Sick leave approved in W1 and W2
2	Haoran Cheng	Y	Y	Y	Y	Y	
3	Mobarak Shekhah A D Kh	Y	Y	Y	Y	Y	
4	Xuhui Gong	Y	Y	Y	Y	Y	

A.4 Supervisor weekly meeting log

Year 2 Project (ELEC222/273) – *Supervisor meeting* – Week 1

Date: 29/1/20 Supervisor: James Bradley

Project Title: Automatic trash bin

Student Names /Attendees:	1. Xudun Gong	2. Haoran Cheng
3. Shekhar Mobarak	4.	5.

Summary of week's activities:

One meeting taken place to plan activity & distribution of work activity between group members. All parts are order & ready on Friday (Lab).

Problem, issues and concerns:

need to build to build a more stable structure than discussed in the preliminary report.

Tasks for next week/Actions for next meeting:

start to build the structure & combined software & hardware together.

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☒ Satisfactory ☐ Good

Comments/Recommendations:

Rapid progress required on challenging project

Supervisor Signature: James Bradley.

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 2*

Date: 05 February 22 **Supervisor:** Dr James Brusey

Project Title: Automatic Trash Bin

Student Names /Attendees:	1. Haoran Cheng	2. Xuhui Gong
3. Shekinah Mybacrak	4.	5.

Summary of week's activities:

finished a Prototype (design) to test before the final Design is constructed. We tested our code and almost finished our software part of the project

Problem, issues and concerns:

A problem faced were 1 is what material is going to be used for the final design (it was later decided that MDF sheets are to be used) Another issue to focus now to connect all the parts together, motor and design a solution has been found and the team will try to implement this week (A 3D printer is to be used to solve this issue)

Tasks for next week/Actions for next meeting:

Main objective for this weeks lab session is to find a suitable material which is highly durable and will be able to handle the weight of each material.

A meeting will be held on the 6th of February

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☐ Satisfactory ☑ Good

Comments/Recommendations:

Good progress / on schedule.

Supervisor Signature: James Brusey

Year 2 Project (ELEC222/273) – *Supervisor meeting* – *Week 3*

Date: 12/02/20 **Supervisor:** James Bradley

Project Title: Automatic Trash Bin

Student Names /Attendees:	**1.** Xuhui Gong	**2.** Haoran Cheng
3. Shelnan mobarak	**4.** A-Ro Han	**5.**

Summary of week's activities:

The bin was built by using wood the construction of the bin was successful. The software system was [illegible] (constructed) into the bin The servo system was tested.

Problem, issues and concerns:

There were a couple of problems faced the components which connected the servo to the board are not strong enough (3D printer is easier to print parts) however a suitable model has not been created yet The printing components are therefore easily damaged by the force. The other issue is that the servo speed is too fast [illegible] the component cannot be used several times so the code has to be altered To solve this problem a component is to be designed to fit the servo's perfectly which is also stronger the code is to be edited to let the servo motors speed decrease.

Tasks for next week/Actions for next meeting:

- For this week a cover is to be manufactured by the team for the trash bin and it is to be tested for its efficiency
- A button for the bin is to be built.
- The whole project has to be complete by the next laboratory session.
- Service life of steering gear connection
- code to let servo speed decrease
- User interface display
- lines and RPI problem, need to ensure good connection of line
- [illegible] of machine learning
- Another type of trash (category)

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☐ Satisfactory ☑ Good

Comments/Recommendations:

Excellent progress – working proto type already.

Supervisor Signature:

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 4*

Date: 19/02/2020 **Supervisor:** Dr James Bradley

Project Title: Automatic Trash Bin

Student Names /Attendees:	**1.** Haoran Cheng	**2.** Xuhui Gong
3. Shekhar Mobarak	**4.** A-Ro Han	**5.**

Summary of week's activities:

- many photos were taken in different angles in order to increase the accuracy of the algorithm
- The dividers were created for the bottom part, the height was adjusted in a way where no other objects from another category falls in the wrong division. The size of the motor was adjusted.

Problem, issues and concerns:

The components printed were not strong enough however it's durability is better than the ones printed before but it still need to be adjusted. The lower part of the design needs to be longer. The interface was tested but we have not tried it with the system. The line is too heavy we need to think of something that might make it lighter.

Tasks for next week/Actions for next meeting:

A cover is to be printed. Need to improve the line, it is heavy we need to make it lighter.

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☐ Satisfactory ☑ Good

Comments/Recommendations:

Some nice work done – v good progress

Supervisor Signature:

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 5*

Date: 24102120 Supervisor: James Bradley

Project Title: Automatic Trash Bin

Student Names /Attendees:	1. Xuhui Gong	2. Haoran Cheng
3. Shekhan mobarak	4. A-Ro Han	5.

Summary of week's activities: The circuit on breadboard was soldered successfully, a cover was created for the bin. The height of the dividers was altered to a higher height to avoid object into falling to other categories.

Problem, issues and concerns:
The cover has to be changed to (cardboard) material instead of wood. A speaker has to be implemented. User interface if it is successfull we will use it if not we will not include it in the final product.

Tasks for next week/Actions for next meeting:
A suitable cover has to be created. must work on user interface and implement a speaker onto the final model. The main aim is to complete the whole project altogether if something does not operate such as UI it would be neglected in addition the categories have been altered so the program has to identify them, bottle, can, paper, general.

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☐ Satisfactory ☑ Good

Comments/Recommendations:
Very good progress, basically the demo ready.

Supervisor Signature: James Bradley

Appendix B

Contribution degree

	Member Name	Contribution (%)
1	A-Ro Han	22.00
2	Haoran Cheng	27.50
3	Mobarak Shekhah A D Kh	23.00
4	Xuhui Gong	27.50

	Hardware 30%	Software 30%	Poster 5%	Blog 5%	Report 25%	Sustainability 5%
A-Ro Han	25	0	80	0	30	60
Haoran Cheng	22.5	50	2	0	22	5
Mobarak Shekhah A D Kh	30	0	15	100	26	30
Xuhui Gong	22.5	50	3	0	22	5

Appendix C

Partial Source Code

The tf part based on the TensorFlow official website and [3]
https://www.tensorflow.org/hub/tutorials/image_retraining

```
import keras
import shutil
import tensorflow as tf
import sys
import os
import argparse
import datetime
import time
import cv2
import numpy as np
from PyQt5.QtWidgets import *
from PyQt5.QtGui import *
from PyQt5.QtCore import *

def sort():
    Cans = 0
    Paper = 0
    Plastic_Bottle = 0
    # lists all files to be tested in test_input folder
    list_images = os.listdir(image_path)

    with tf.compat.v1.Session() as sess:
        for igs in list_images:
            # load the image data

            image_data = tf.compat.v1.gfile.FastGFile(image_path + igs,
'rb').read()

            # Feed the image_data as input to the graph and get first prediction
            softmax_tensor = sess.graph.get_tensor_by_name('final_result:0')

            predictions = sess.run(softmax_tensor, {'DecodeJpeg/contents:0':
image_data})

            # Sort to show labels of first prediction in order of confidence
            top_k = predictions[0].argsort()[-len(predictions[0]):][::-1]
            # print('\n' + igs + ' :')
            human_string = label_lines[0]
            score = predictions[0][0]
```

```
            # print('%s (score = %.5f)' % (human_string, score))

            if human_string == "cans" and score >= 0.65:
                Cans += 1
            elif human_string == "paper" and score >= 0.97:
                Paper += 1
            elif human_string == "plastic bottle" and score >= 0.65:
                Plastic_Bottle += 1
    print(Cans)
    print(Paper)
    print(Plastic_Bottle)

    print("Eneter number")
    a = input("input")
    aa = str(a)
    if aa == '1':
        show(1)
    elif aa =='2':
        show(2)
    elif aa =='3':
        show(3)
    else:
        show(4)

    # if Cans > Paper and Cans > Plastic_Bottle:
    #     print("can")
    #     show(1)
    # elif Paper > Cans and Paper > Plastic_Bottle:
    #     print("paper")
    #     show(2)
    # elif Plastic_Bottle > Cans and Plastic_Bottle > Paper:
    #     print("plastic_bottle")
    #     show(3)
    # else:
    #     print("qwer")
    #     show(4)


def detect():# The detect() function is based on the open-source from the
Github/Univmalik/OpenCCTV



def clear():
    shutil.rmtree("/Users/xg/Desktop/images")
    os.mkdir("/Users/xg/Desktop/images")
```

```
def loop():
    while True:
        detect()
        sort()
        clear()

def show(num):
    app = QApplication(sys.argv)
    example1 = CellImageSize(num)
    example1.show()
    app.exec()

class CellImageSize(QWidget):

    def __init__(self,num):
        super(CellImageSize,self).__init__()
        self.initUI(num)

    def initUI(self,num):
        self.setWindowTitle("trash sort")
        self.resize(1700, 500);
        layout = QVBoxLayout()
        hlayout =QHBoxLayout()

        tablewidget = QTableWidget()
        tablewidget.setIconSize(QSize(400,200))
        tablewidget.setColumnCount(4)
        tablewidget.setRowCount(1)

        #tablewidget.setSpan(1,0,1,4)
        tablewidget.setHorizontalHeaderLabels(['paper','metal','bottle','glass'])

        self.button1 = QPushButton('continue')
        self.button1.setText('continue')
        self.button1.setFixedHeight(100)
        self.button1.setFixedWidth(300)

        self.button1.setCheckable(True)
        self.button1.toggle()
        self.button1.clicked.connect(lambda: self.close())

        hSpacer=QSpacerItem(1,1)



        for i in range(4):
            tablewidget.setColumnWidth(i,400)
```

```
for i in range(4):
    tablewidget.setRowHeight(i,400)

for k in range(4):
    i = 0
    j = k
    z = k+1
    item = QTableWidgetItem()
    item.setIcon(QIcon('./images/%d.jfif'%z ))
    tablewidget.setItem(i,j,item)

ct1 = QCheckBox('', self)
ct2 = QCheckBox('', self)
ct3 = QCheckBox('', self)
ct4 = QCheckBox('', self)

if(num==0):
    print('0')
    ct1.setChecked(0)
    ct2.setChecked(0)
    ct3.setChecked(0)
    ct4.setChecked(0)
if (num == 1):
    print('1')
    ct1.setChecked(1)
    ct2.setChecked(0)
    ct3.setChecked(0)
    ct4.setChecked(0)
if (num == 2):
    print('2')
    ct1.setChecked(0)
    ct2.setChecked(1)
    ct3.setChecked(0)
    ct4.setChecked(0)
if (num == 3):
    print('3')
    ct1.setChecked(0)
    ct2.setChecked(0)
    ct3.setChecked(1)
    ct4.setChecked(0)
if (num == 4):
    print('4')
    ct1.setChecked(0)
    ct2.setChecked(0)
    ct3.setChecked(0)
    ct4.setChecked(1)

tablewidget.setCellWidget(0, 0, ct1)
tablewidget.setCellWidget(0, 1, ct2)
```

```
        tablewidget.setCellWidget(0, 2, ct3)
        tablewidget.setCellWidget(0, 3, ct4)

        layout.addWidget(tablewidget)
        hlayout.addSpacerItem(hSpacer)
        hlayout.addWidget(self.button1)
        layout.addLayout(hlayout)
        self.setLayout(layout)



if __name__ == '__main__':


    os.environ['TF_CPP_MIN_LOG_LEVEL'] = '2'

    image_path = '/Users/xg/Desktop/images/'

    # Loads label file, strips off carriage return
    label_lines = [line.rstrip() for line
                   in
tf.compat.v1.io.gfile.GFile("tf_files/retrained_labels.txt")]

    # Unpersists graph from file
    with tf.compat.v1.gfile.FastGFile("tf_files/retrained_graph.pb", 'rb') as f:
        graph_def = tf.compat.v1.GraphDef()
        graph_def.ParseFromString(f.read())
        _ = tf.import_graph_def(graph_def, name='')


    try:
        show(0)
        loop()
    except KeyboardInterrupt:
        sys.exit()
```

Appendix D

Survey Result

A survey was created to enable the group members to understand the publics requirements, specifically the university of Liverpool students. After the results were obtained the team attempted to apply the suggestion to the automatic trash bin.

Questions

The questions of the survey are written below;

1. Do you think that recycling helps preserve the environment?

- Yes
- No
- If you chose no, please explain why?

2. Do you tend to recycle often?

- Yes
- Sometimes
- No
- If you chose no, please explain why?

3. In your opinion what do you think happens if recycling is not promoted?

4. Do you think the recycling system nowadays (color codes) is straightforward and comprehensible?

- Yes
- No

- If you chose no, please explain why?

5. Do you think an automatic sorting bin may ease the operation of recycling?

- Yes
- No
- If you chose no, please explain why?

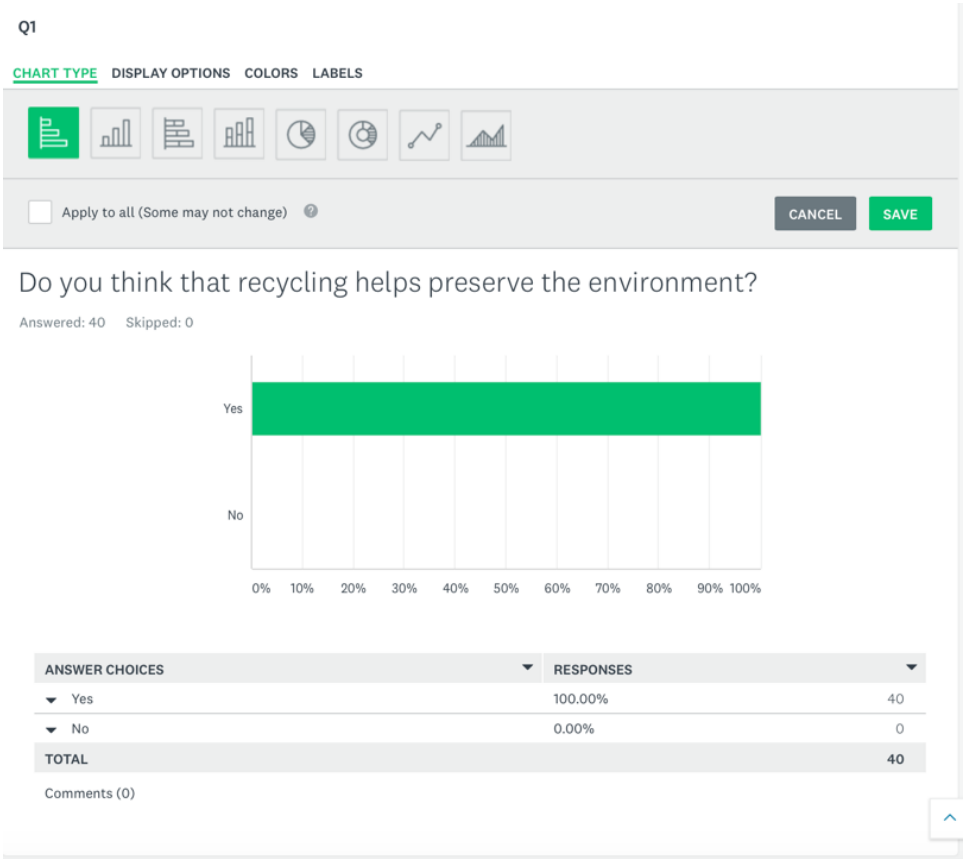
6. Would you buy an automatic sorting bin?

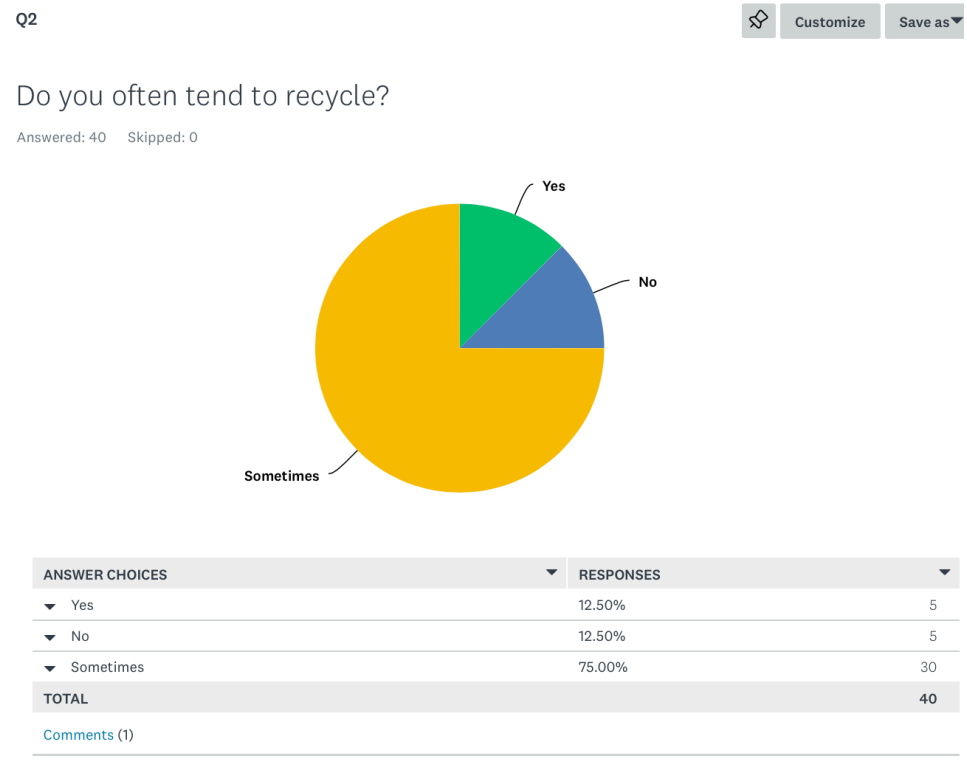
- Yes
- No
- If you chose no, please explain why?

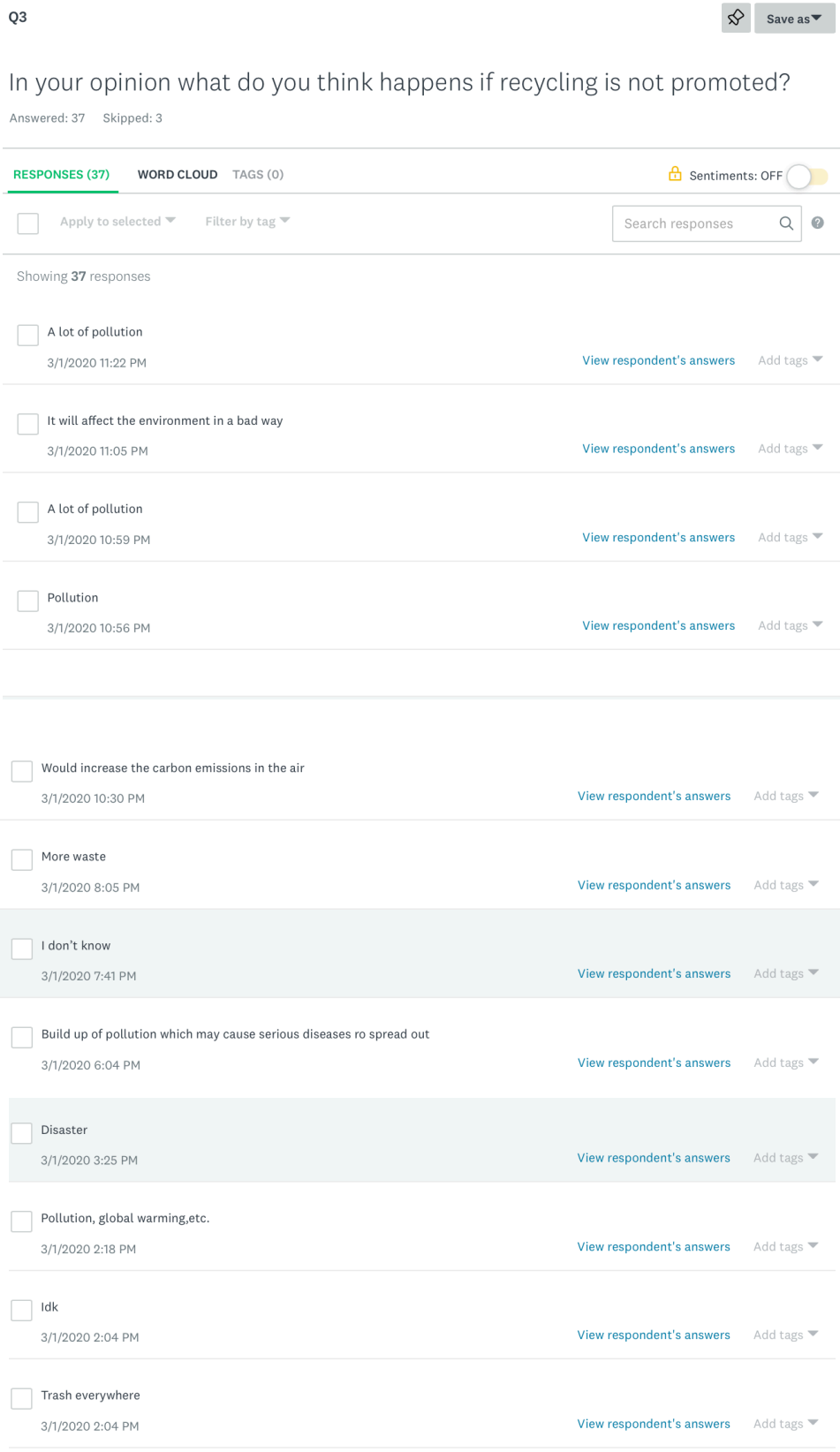
7. If you were to design this product what would you include?

- Motion detector for cover
- AI voice to y3ln what object has been thrown into the bin
- Brail instructions of the sides of the bin for the visually impaired
- Screen to show identification of object
- Easy dispensing of the rubbish
- Other

Results


Q1
CHART TYPE
DISPLAY OPTIONS
COLORS
LABELS
Apply to all (Some may not change)
CANCEL
SAVE
Do you think that recycling helps preserve the environment?
Answered: 40 Skipped: 0
Yes
No
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
ANSWER CHOICES
RESPONSES
Yes 100.00% 40
No 0.00% 0
TOTAL 40
Comments (0)


Q2
Customize
Save as
Do you often tend to recycle?
Answered: 40 Skipped: 0
Yes
No
Sometimes
ANSWER CHOICES
RESPONSES
Yes 12.50% 5
No 12.50% 5
Sometimes 75.00% 30
TOTAL 40
Comments (1)


Q3
Save as
In your opinion what do you think happens if recycling is not promoted?
Answered: 37 Skipped: 3
RESPONSES (37)
WORD CLOUD
TAGS (0)
Sentiments: OFF
Apply to selected
Filter by tag
Search responses
Showing 37 responses
A lot of pollution
3/1/2020 11:22 PM
View respondent's answers
Add tags
It will affect the environment in a bad way
3/1/2020 11:05 PM
View respondent's answers
Add tags
A lot of pollution
3/1/2020 10:59 PM
View respondent's answers
Add tags
Pollution
3/1/2020 10:56 PM
View respondent's answers
Add tags
Would increase the carbon emissions in the air
3/1/2020 10:30 PM
View respondent's answers
Add tags
More waste
3/1/2020 8:05 PM
View respondent's answers
Add tags
I don't know
3/1/2020 7:41 PM
View respondent's answers
Add tags
Build up of pollution which may cause serious diseases ro spread out
3/1/2020 6:04 PM
View respondent's answers
Add tags
Disaster
3/1/2020 3:25 PM
View respondent's answers
Add tags
Pollution, global warming,etc.
3/1/2020 2:18 PM
View respondent's answers
Add tags
Idk
3/1/2020 2:04 PM
View respondent's answers
Add tags
Trash everywhere
3/1/2020 2:04 PM
View respondent's answers
Add tags

Increase in global warming, sea species dying
3/1/2020 1:59 PM View respondent's answers Add tags

Environmental crisis
3/1/2020 1:29 PM View respondent's answers Add tags

I believe that the environment would be highly damaged
2/29/2020 5:16 PM View respondent's answers Add tags

you would need more products to make extra plastic because no one is recycling
2/29/2020 3:54 PM View respondent's answers Add tags

you would need more products to make extra plastic because no one is recycling
2/29/2020 3:54 PM View respondent's answers Add tags

global warming, animals going extinct, trash all over the planet
2/29/2020 3:49 PM View respondent's answers Add tags

.
2/29/2020 3:48 PM View respondent's answers Add tags

Bad
2/29/2020 3:47 PM View respondent's answers Add tags

People wouldn't be motivated to recycle

Increase in pollution, overflow of landfills & destruction of natural habitats.
2/29/2020 2:06 PM View respondent's answers Add tags

The earth will polluted, and the plastics will not decompose
2/29/2020 1:47 PM View respondent's answers Add tags

It won't affect countries that are developed and are well aware of the benefits of recycling
2/29/2020 1:43 PM View respondent's answers Add tags

More waste in our environment
2/29/2020 1:41 PM View respondent's answers Add tags

Global warming

2/29/2020 1:40 PM View respondent's answers Add tags

Global warming will happen

2/29/2020 1:37 PM View respondent's answers Add tags

Waste and pollution

2/29/2020 12:57 PM View respondent's answers Add tags

more and more dirty trash

2/29/2020 3:51 AM View respondent's answers Add tags

Some materials may not get maximize utilization

2/28/2020 5:59 PM View respondent's answers Add tags

Trash will accumulate which will finally threat the environment

2/28/2020 5:45 PM View respondent's answers Add tags

A lot of waste

2/28/2020 4:02 PM View respondent's answers Add tags

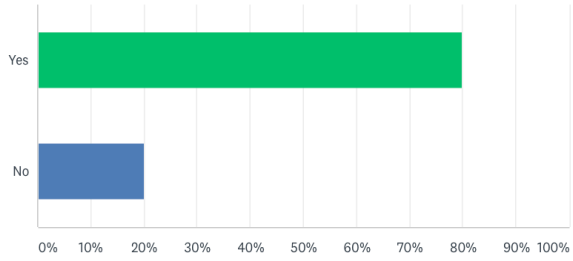
Bad environment

2/28/2020 3:42 PM View respondent's answers Add tags

Q4 Customize Save as

Do you think the recycling system nowadays (i.e color codes) is straightforward?

Answered: 40 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	80.00%	32
No	20.00%	8
TOTAL		40

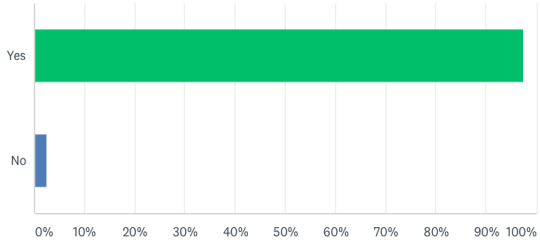
Comments (5)

Q5

Customize Save as

Do you think an automatic sorting bin may ease the operation of recycling?

Answered: 40 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	97.50%	39
No	2.50%	1
TOTAL		40

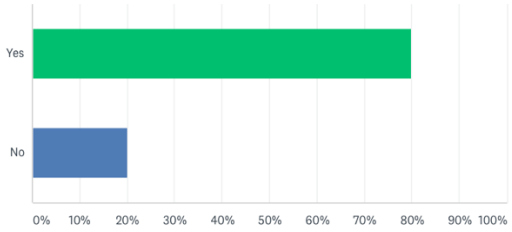
Comments (0)

Q6

Customize Save as

Would you invest in an automatic sorting bin?

Answered: 40 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	80.00%	32
No	20.00%	8
TOTAL		40

Comments (2)

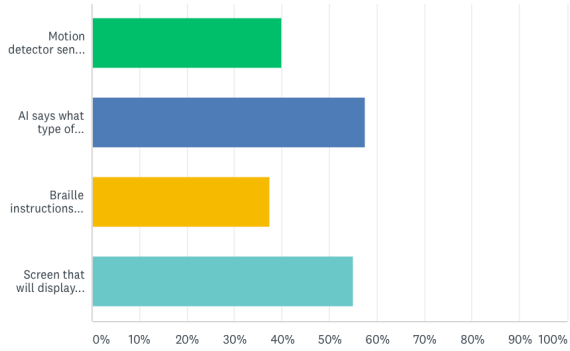
RESPONSES (2) WORD CLOUD TAGS (0) Sentiments: OFF

Q7

Customize Save as

If you were to design this product what would you include?

Answered: 40 Skipped: 0



ANSWER CHOICES	RESPONSES	
Motion detector sensor for cover	40.00%	16
AI says what type of material is identified	57.50%	23
Braille instructions on the sides for the visually impaired	37.50%	15
Screen that will display the description of object	55.00%	22
Total Respondents: 40		

Comments (0)

It would be expensive

2/28/2020 6:01 PM View respondent's answers Add tags

People can sort the trash themselves.There is no need for a trash bin to sort

2/28/2020 5:45 PM View respondent's answers Add tags