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Smart Trash Bin to Prevent Animal Disturbance Using Raspberry Pi and Deep Learning

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Abstract: A trash can is an indispensable component of human daily life. It is ubiquitous and extremely useful for keeping the city clean. However, littering is a frequent and widespread problem. Not only do humans litter, but so do animals, particularly monkeys. Animals are constantly searching for food, and when we discard our food waste, they are attracted and leave their natural habitats. Following that, the user may forget to lock the trash can, which may end up in the hands of the animal. With the aid of a deep learning system that detects and identifies human subjects, a smart trash bin with an autonomous locking mechanism will be used in this project to reduce animal disturbance. In this paper, Raspberry-Pi 4 module is being used. Moreover, this article describes a human subject identification method and its real-time displacement using the OpenCV library of programming roles, which is primarily aimed at Raspberry Pi with camera module. The smart trash bin system helps to reduce animal disturbance and minimise littering.

Keywords: Raspberry Pi, smart trash bin, object detection, animal disturbance

1. Introduction

Trash bin is an essential tool for human daily activities [1]. It can be found everywhere and very useful in keeping the city clean. However, littering is a common issue that occurs frequently. Litter is defined as any type of rubbish strewn in little volumes in inappropriate locations [2]. It adds up over time. It also paints a negative picture of a location. Having said that, littering is not only done by humans but also by animals especially monkeys. This is because, a lot of forest area have been developed into urban area.

This effects the animal's ecosystem and they tend to target trash bin as their food resource. Based on that, the smart trash bin project is important because it may help to prevent the disturbance of animals and tend to keep the environment cleaner. Although locking mechanism may sound useful, sometimes it's very inconvenient for the consumer as they need to unlock and lock whenever they use the trash bin. Followed by that, the user might also forget to lock the trash bin which may end up in the animal's hand. An automated trash bin which can lock and unlock by itself with the help of image recognition to differentiate between human and animal would be useful for the consumer. This may prevent the animal disturbance. Furthermore, the aim of this project is to create a system that is advanced, user friendly and also affordable by the consumers. In order to accomplish the project, a lot of previous research studies have been observed and the ideas have been analysed.

A study has been carried out to implement Artificial Intelligent (AI) that automatically catches a falling trash [3]. In this study, Arduino and NVIDIA Jetson Nano were used as the underlying hardware to develop AI smart home. Besides that, another study has been carried out which able to segregate trash and send alert to the user whenever the

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trash bin is full [4]. In this study, Raspberry-Pi and IoT based system have been utilised. However, this system can only send alert if the trash bin is full but it won't be able to send alert if the trash bin has been breached by an animal.

2. Materials and Methods

2.1 Hardware and Software

Hardware and software components make up the core of the design of smart trash bin. Components needed for the program to run are found in the hardware section. The Raspberry- Pi 4 board, Raspberry-Pi camera, Arduino Nano, and servo motor are the components. This equipment enables the smart trash can to function. The circuit schematic for the smart trash bin is shown in Fig. 1. The primary hub for the other parts is the Raspberry-Pi board. Following that, a ribbon cable is used to link the Raspberry-Pi camera and board. Then the servo motor is linked to the Raspberry-Pi board, along with the Arduino Nano.

The Arduino Nano board is linked to the servo motor. The connection is typically made by connecting the servo motor's power to the Raspberry-Pi board's 5V supply. The servo motor's ground is then connected to the Raspberry-Pi board's ground pin. The signal wire from the servo motor is then connected to the Arduino Nano board's digital pin D9. Pulse width modulation, which is created by the Raspberry Pi, is used to rotate the servo motor at lower rates [5]. Then, to establish the signal, digital pin D2 on the Arduino Nano board is connected to GPIO pin 18 on the Raspberry-Pi board. As shown in Fig 1, power and ground are also connected to the Raspberry-Pi board.

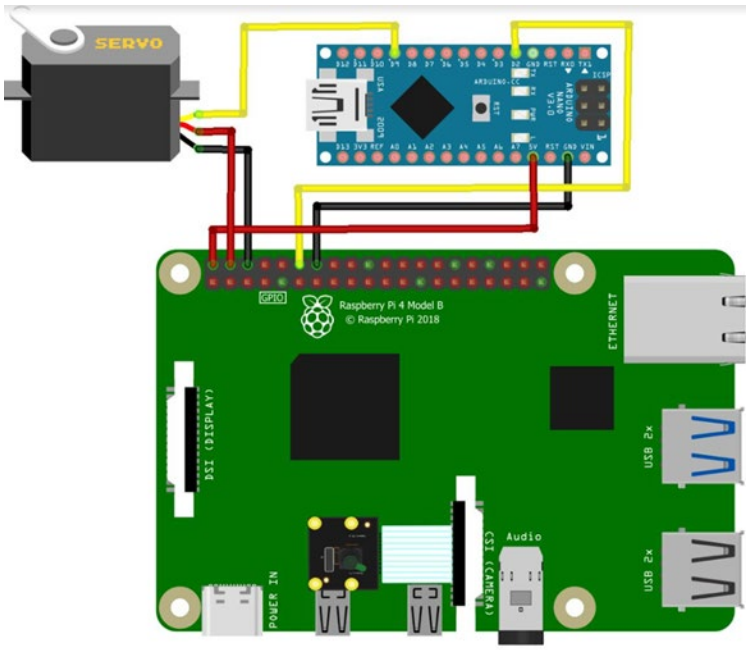


Fig. 1 - The circuit diagram of the Raspberry-Pi board and the other components

3. Functional Flow of the Smart Trash Bin

The proposed Smart Trash Bin offers some advanced features and functionality, including detecting and differentiating between human beings and animals. The flowchart in Fig 2(a) shows the basis workflow of the system. The system starts with camera detection. After the camera detects the user, it will jump into the second process which is to identify whether the user is a human or an animal. If the user has been identified as human, the trash bin locking mechanism will unlock the smart trash bin. However, if the camera detects animals, it will lock the smart trash bin to prevent access.

The datasets are essential for the system's object detection implementation. After that, coco datasets have been used in this project. The coco dataset includes images from a wide range of everyday scenes and covers a diverse set of object categories. It was created to address the limitations of earlier datasets by providing more complex and realistic images with multiple objects in various contexts. First, Fig. 3 shows the zip file that can be downloaded from the coco dataset website is where the pre-trained data is found [6]. In addition, a certain file location must be made on the Raspberry-Pi in order to download the Coco datasets library and the required files to execute the system. The next stage is to configure the code so that the system can recognise a single object, which is a human. The coding to control the camera and lock can be configured using the Thonny Python software.

The process for obtaining the datasets and transferring them to the Raspberry-Pi system is depicted in the flowchart in Fig 2(b). The Raspberry-Pi needs to be set up after the data has been collected. Open CV must be included when configuring the Raspberry-Pi for object detection. In addition, a certain file location must be made on the Raspberry-Pi in order to download the Coco datasets library and the required files to execute the system [7]. The next stage is to configure the code so that the system can recognise a single object, which is a human. The coding to control the camera and lock can be configured using the Thonny Python software.

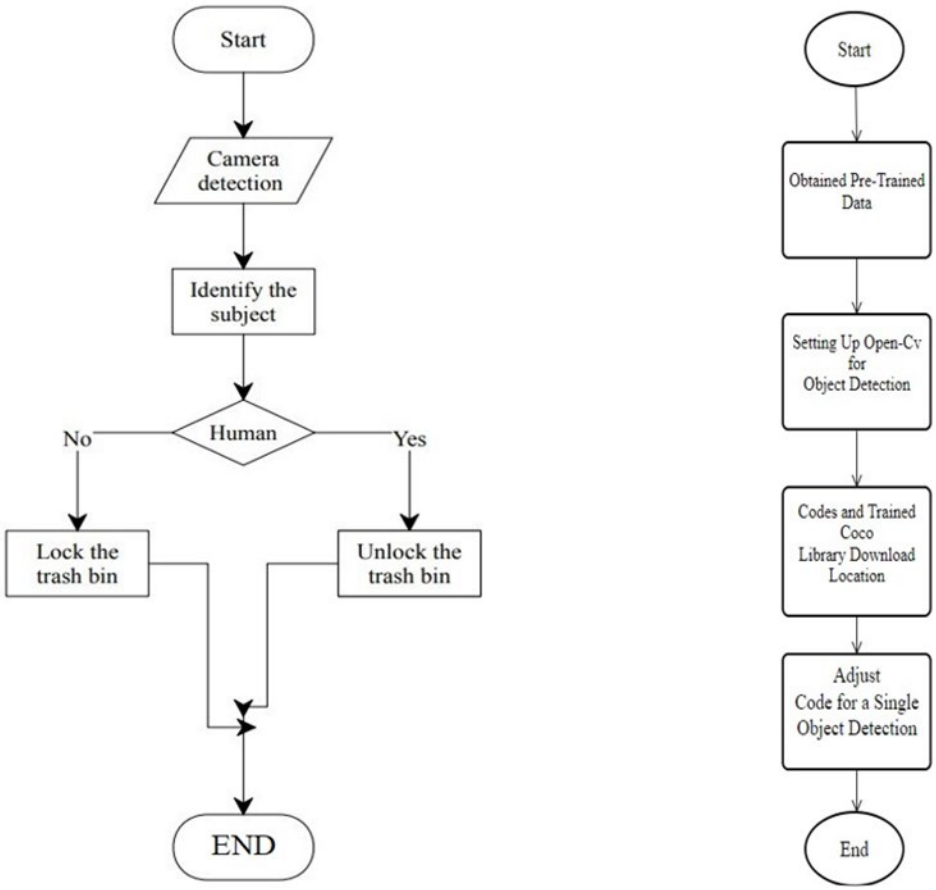


Fig. 2 - (a) Flowchart for functional flow of the smart trash bin (b) Flowchart of the dataset development process

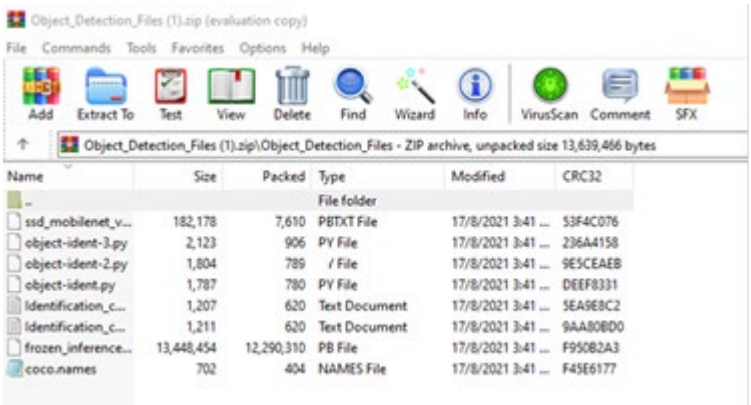


Fig. 3 - The zip file containing all the required coco datasets file [6]

In order for the smart trash bin to operate, the Raspberry-Pi must be programmed to the desired operation. In this project, the program code is built using the Thonny Python programing software. By using this software, the code can

be easily executed on the Raspberry-Pi user interface. The flowchart in Fig 4 shows the flow of the algorithm and hardware of the Smart Trash Bin System.

The flowchart in Fig 4 shows the import flow for the weight paths, which is the frozen inference graph. The process of identifying and saving all necessary items such as graphs, weights, and so on in a single file that can be easily used is known as freezing. Followed by that, the next process in the flowchart includes the threshold for configuring image sizing and the output display configuration.

Furthermore, the code must be configured in order for the Raspberry-Pi to detect only human subjects. The word object should be configured in the code so that the programme detects only one subject, which is the human subject. When a human subject is detected, the Raspberry-Pi sends a signal to the Nano board and prints person on the output display. Furthermore, once the signal is received, the Nano board will send a signal to the servo motor, allowing the servo motor to move its horn arm. The servo motor is able to open the trash bin lid by moving the horn arm. When the GPIO reads low, the servo motor closes the trash lid. When no human subjects are detected, the GPIO will read low.

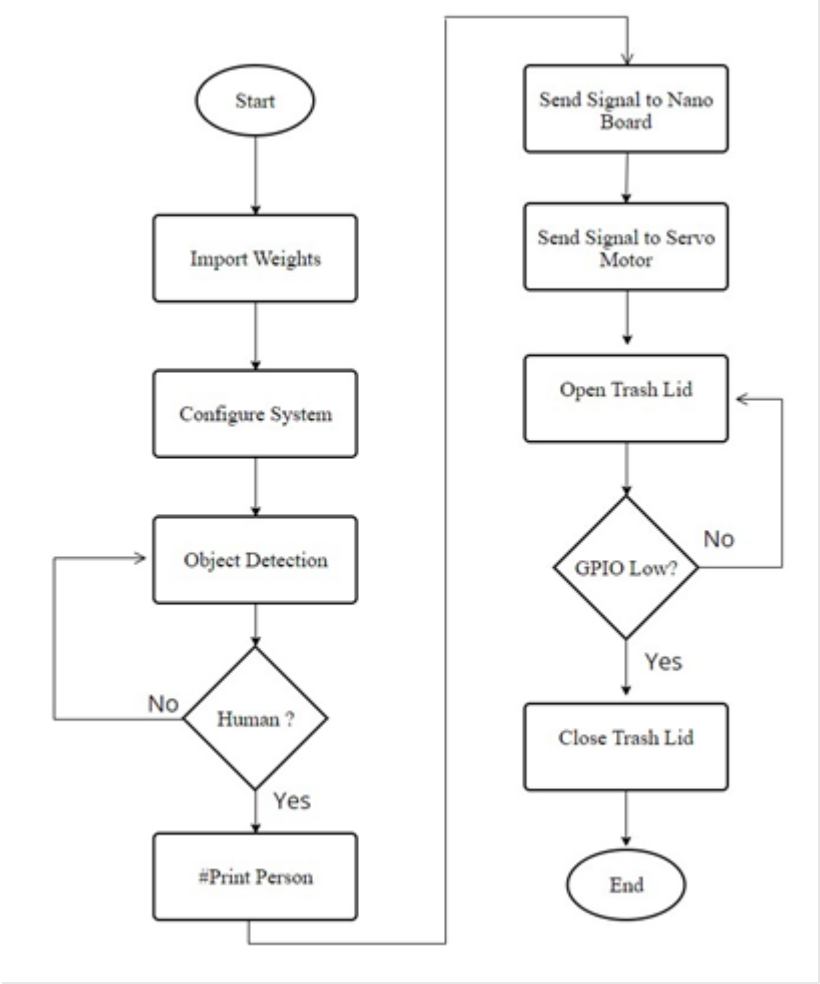


Fig. 4 - The flowchart of the algorithm and hardware process

4. Results and Discussion

The prototype of smart trash bin design is basically made up by using polystyrene material and a trash bin. The polystyrene is in square shape and it's being glued together to form a base to place the smart trash bin model. A hole has been cut onto the polystyrene in order to place the raspberry pi board along with the other components. The Styrofoam was then pierced to allow easy access to the wires for the power supply and LAN cable. Fig 5 shows the final design of the smart trash bin prototype. The prototype design primarily illustrates the trash bin model as well as the Raspberry-Pi camera mounted in front of the design model.

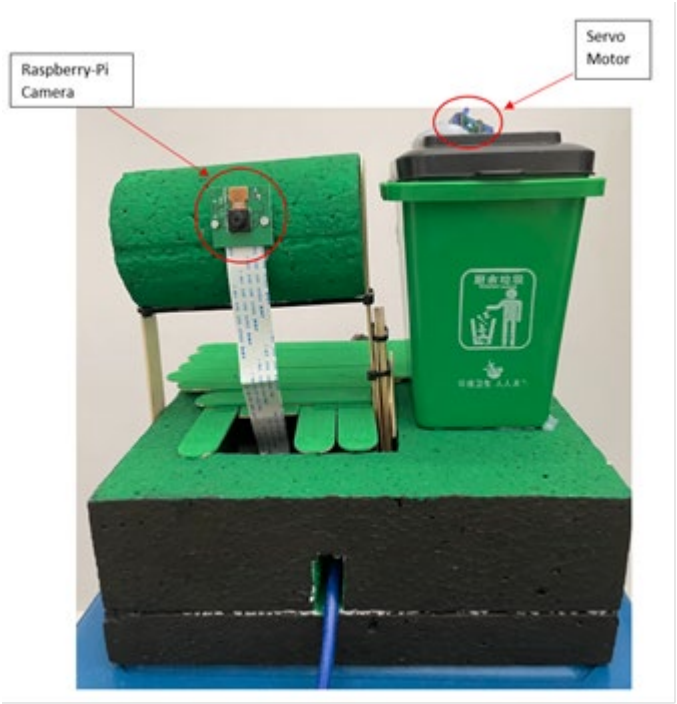


Fig. 5 - The prototype design of the smart trash bin

The smart trash bin lid opens upwards thanks to the servo motor horn arm. The servo motor moves when it receives a signal from the Raspberry-Pi and Nano board. The steel rod connects the servo motor horn arm. The steel rod was then hot glued to the top of the smart trash bin lid. The location of the servo motor on the smart trash bin model is shown in Fig 6. When the Raspberry-Pi camera detects a person, it sends a signal to the servo motor, which causes the trash bin lid to open [8]. To open the trash bin lid, the servo motor moves upwards.

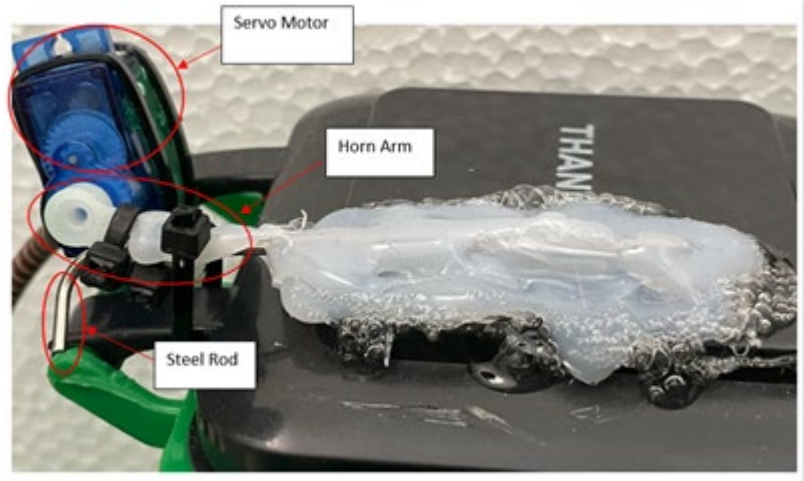
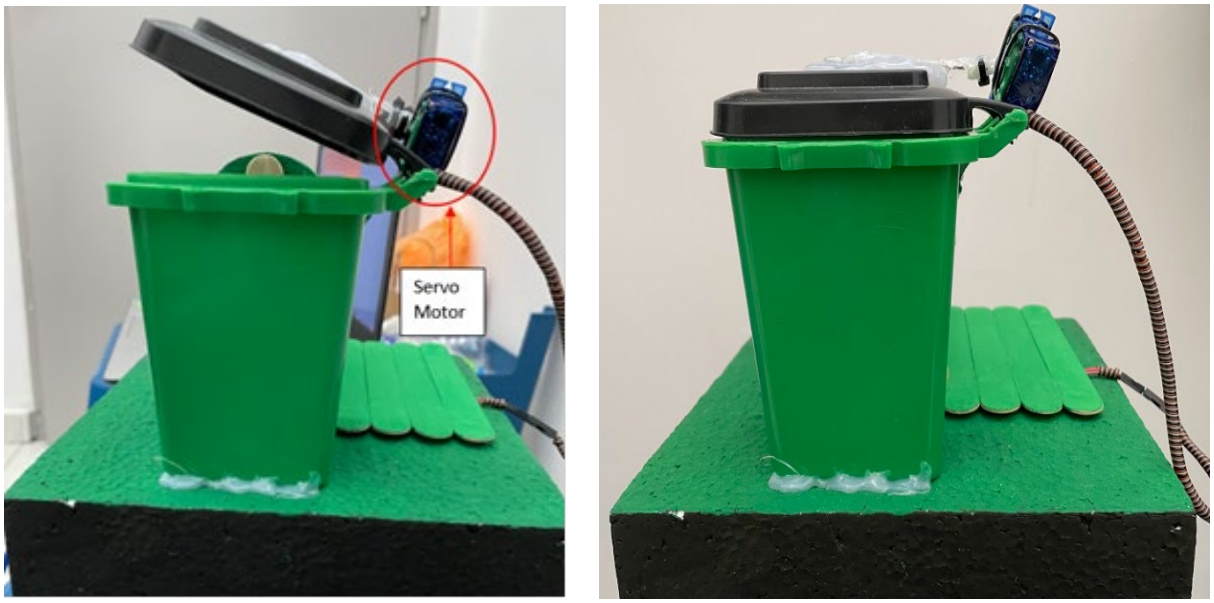


Fig. 6 - The placement of the servo motor on the smart trash bin model

The open state of the smart trash bin happens when the person is detected is shown in Fig 7(a). If something other than a human approach the smart trash bin, it will not trigger a response, and the bin will remain closed. This is because the system is only programmed to detect human subjects, preventing the trash bin from opening when an unwanted disturbance approaches the smart trash bin. Fig 7(b) also illustrates the smart trash bin in a closed state.



(a) (b)

Fig. 7 - (a) The smart trash bin in open state and (b) The smart trash bin in close state

The Raspberry-Pi camera can pick up a human subject image and recognise it as a person with an accuracy of 74.9 percent. When the coding in the Thonny Python programme is run, the live feed of the Raspberry-Pi camera can be seen on a small window by using the mobaxterm software. Fig 8 shows a system that can recognise a human subject as a person.

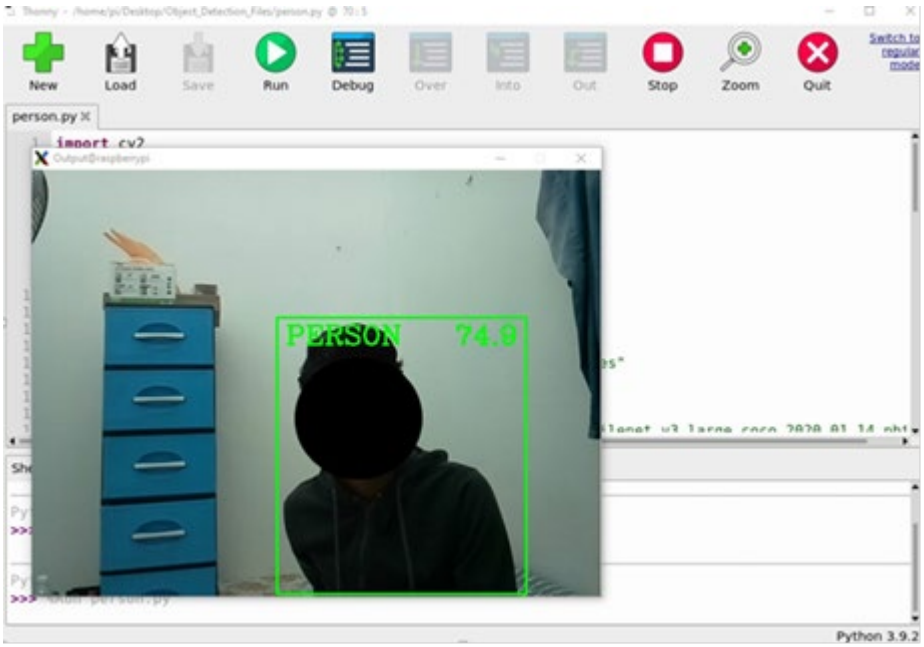


Fig. 8 - The output of the Raspberry-Pi camera detection

4.1 System Analysis

Ten test runs were carried out to assess the response time of the smart trash bin system. The test results are shown in Table 1. The table shows how long it takes the trash bin to open and close after a subject is detected. Seconds are used to measure time. The table shows the detection accuracy of the Raspberry Pi. The system detects a random object and a human subject and repeats the test five times. The trash lid data is measured in seconds, as shown in Table 1. For this measurement, stopwatches were used. When the camera detects a subject, the stopwatch begins to count down. The stopwatch is set to record the time it takes for the trash lid to open. When the subject moves away from the camera, the

stopwatch resets and begins counting again to determine how long it takes the trash bin to close again. The camera detection data is also gathered by timing how long it takes the Raspberry-Pi camera to display the camera feed when a subject appears in front of it.

Table 1 - Comparison of execution time of the smart trash bin operation and detection

Subject	Average access Time of Each Detection (second)		
	Trash Lid Open	Trash Lid Close	Camera detection
Human	03.43	10.12	03.26
Human	02.45	08.92	02.28
Human	03.67	09.23	03.50
Human	02.98	09.89	02.81
Human	03.20	08.79	03.03
Non-Human	0	0	02.21
Non-Human	0	0	03.06
Non-Human	0	0	03.56
Non-Human	0	0	02.87

The performance of the smart trash bin has also been analysed. The success and failure rates were calculated, and data from ten test runs was compiled and shown in Table 2. The distance when the camera detects a subject is shown in Table 2, followed by the detection rate and camera accuracy.

Table 2 - Comparison of camera detection distance and their success rate

Distance of subject from the camera view (meter)	Camera Detection Success/failure rate	Detection Accuracy (percentage)
0.05	FAIL	0
0.08	FAIL	0
0.15	SUCCESS	71.23%
0.20	SUCCESS	73.45%
0.25	SUCCESS	75.39%
0.30	SUCCESS	71.45%
0.35	SUCCESS	73.98%
0.40	SUCCESS	72.56%
0.45	SUCCESS	71.68%
0.50	SUCCESS	74.22%

A data graph has been plotted from Table 1 to show the performance of the smart trash bin when it detects a subject and operates the trash lid to open and close. The data graph in Fig 9 shows the changes in success rate that occur as the subject's distance from the camera increases. It can be concluded that the smart trash can detect objects at a greater distance than at a closer range. The orange line from the graph represents when the trash bin lid is closed while the blue line represents when the trash bin is open. The grey line represents as the camera detection.

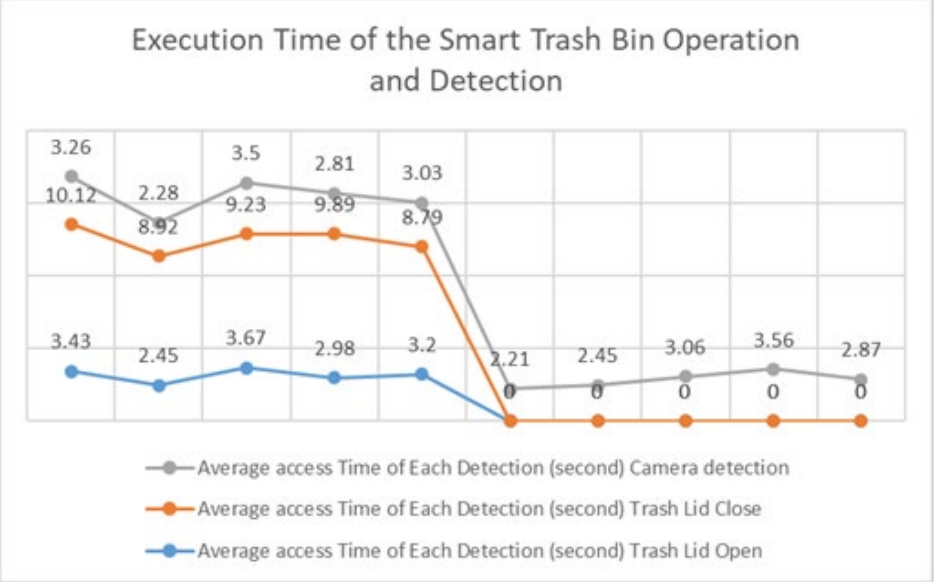


Fig. 9 - The output graph of execution time for the smart trash bin operation and detection

5. Conclusion

There are three objectives have been outlined to achieve the aim of this study, which is to create a smart trash bin which able to detect human and prevent animals accessing it with the help of a locking mechanism. The first objective of this study is to design a hardware for the trash bin which has a locking mechanism. By implementing the locking mechanism, it prevents animals such as monkey accessing it. Furthermore, the locking mechanism acts as a safety measure to secure the trash bin from unwanted access. The second objective is to implement deep learning technique to differentiate between human and animal for easier autonomous locking and unlocking process. Eventually, the deep learning technique is successfully implemented with the aid coco datasets and Python programming software. Besides that, the final objective of this study is to analyse the results and performance of the developed deep learning system. By analysing the performance, further improvements can be implemented into the smart trash bin so that the system becomes more reliable and convenient for the consumer to utilize it.

Acknowledgement

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