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Zero-Smart Recycle Bin : IoT-Object Detection Based Smart Trash Bin System

Mochamad Azkal Azkiya Aziz*

School of Computing and Informatics, Albukhary International, University Jln Tun Razak, Alor Setar, 05200, MALAYSIA

*Corresponding Author Designation

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Abstract : Inadequate global recycling rates led the world to face a worsening waste management crisis. Humans keep producing numerous tons of waste every year while the landfills of the waste remain piled up and poison the world's health sustainability. Zero-Smart Recycle Bin is designed to promote recycling movement to achieve zero net carbon emission goals. The target of the system is notably for the environmentally conscious or recycling activist, as well as for other groups in society. This paper focuses on designing the system and discussing the proposed system. The system is designed to identify and segregate the waste into different categories such as paper, metal can, and plastic bottles. The device is designed to be operated automatically using Raspberry Pi3 due to The efficiency of the processor and the compatibility with the network . The Raspberry Pi3 is integrated with object visual detection by using YOLOv5 and inductive-capacitive sensors to identify the material of the waste. The system also involves an integrated web application as the user platform. The research has achieved in proposing the design of the system, however the realization of the system design into a real product yet is still beyond of this research. Further study is aviseably required to verify and test the proposed framework and algorithm to get more desired result in the future.

Keywords: Zero Carbon, Recycling, YOLOv5, Raspberry Pi3

1. Introduction

Today's world waste management crisis drives significant problems such as causing global warming from its emission and many threats to the global ecosystem. A study found that the waste landfills generate 20 percent of methane emission [1]. Besides its impact on the environment, it is confirmed that the landfill potentially spread infectious disease and can bring harm to health [2] Due to inadequate recycling systems to reduce the amount of waste, humans have mostly failed to manage the waste and leave it undecomposed. The existing waste still remains settled, landfills are piling up while the number of new produced waste keeps increasing and worsens the world's health sustainability. A global report found that there are 400 million tonnes of plastic waste produced yearly while around 7 million tonnes of aluminum remain not recycled every year [3]. Moreover, a report shows that the

* *Corresponding author: azkal.aziz@student.aiu.edu.my*

world's population will be doubled in the coming 2050, meaning that the projected of the waste production will also increase drastically. The same study also expect that the waste will grow to 3.40 billion tonnes by 2050[4]. The fact the landfills not only polluting the lands through soild form waste, the carbon emissions also worsens environmental health. Thus, the urge to come up with a solution in this sector is necessary.

As part of the zero net carbon emission campaign in reducing the undecomposed waste, this system is designed to promote and to facilitate the recycling movement. The target of the system is notably for the environmentally conscious or recycling activist, as well as for other groups in society. This system is called a "Zero-Smart Recycle Bin" which consists of two primary tasks: detecting and segregating the waste according to its type. The word "Smart" refers to the capability of the device to automatically recognize and differentiate the type of the waste. The output of the device is to categorize the waste into metal cans, plastic bottles, and paper. Extensively, this system is integrated into web applications as users' platform. The main purpose of the web application is to get more engagement with the users where the registered users will earn points for every submitted waste. It is meant to facilitate and motivate them in participating in recycling campaigns. The point earning depends on the amount of the submitted waste by the users in which every single waste that is detected by the system will be counted with point. More often the users submit the waste, the more points the users will earn.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

2.1 System Flow Design

This paper focuses on designing the appropriate system for the proposed system using literature review techniques. In this paper, the proposed system is explained by using an activity diagram as shown in **Figure 1**. The use of the activity diagram in this case is advantageous for this research in achieving the picture the system flow with its progression actions sequentially and any alternatives scenarios. Furthermore, it is easily understandable.

Figure 1 illustrates the proposed system's flow where the user can be using the Zero-Smart Recycle Bin with or without member activation. On idle time, the waste detection devices will be activated after the IR sensor detects waste is inserted. The inserted waste triggers the waste detection devices to initiate the detection. The following step involves waste detection devices such as camera, proximity sensor, and weight sensor to detect and identify the waste. There are three parameters that are used to determine the classification of the waste which are visual, material, and weight.

The visual of the object is determined by using a camera and a convolutional neural network based object detection; YOLOv5. The Proximity sensor is used to determine the material of the object. Meanwhile the weight sensor is used to validate the type of the corresponding waste with its relevant weight. After the waste is identified, the next step is segmentation of the waste according to its type where the unidentified waste will be categorized as invalid input. The registered user that used member activation will earn points according to the submitted waste. At the end of phase, the system will deactivate the trash detection system and will be on idle. The system will be operated by using Raspberry Pi 3.

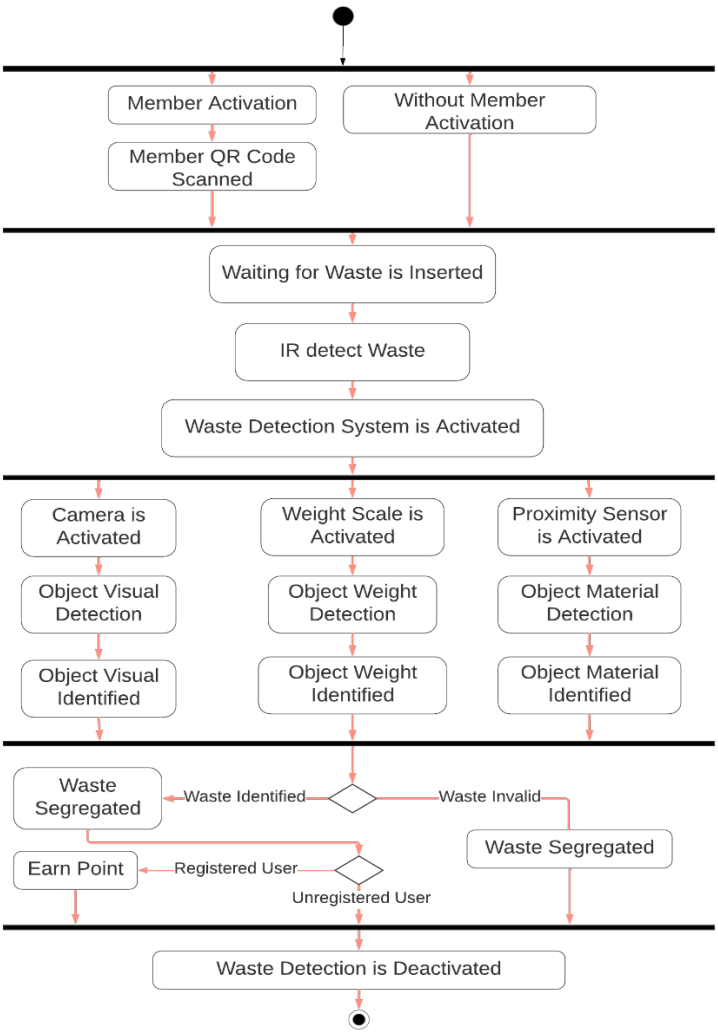

Figure 1: Activity Diagram of the Zero-Smart Recycle Bin

2.2 Waste Detection

Essentially, waste detection is the important part of the system. The ability and the accuracy of the system to sorting the waste will determine the success of the system to recycle the waste. As it has been discussed previously, the waste detection will be based on multilayer parameters which are visual, material and weight. The presence of the visual of the waste will be the first parameter that will be detected by the system. The idea behind the visual detection is similarly when human conventionally sorts the waste based on the form. Then the following parameters are used to confirm the detected waste by the object detection. The use of the material helps the system to check the validity of waste type from its visual by checking the material. Furthermore, the remaining parameters help the system to recognize the waste in some occasions in which the shape of the waste is hardly recognized. Hence, the existence of the material and weight parameters act to double-check the input thus increase the accuracy of the system.

YOLOv5 is used to detect the waste based on its visual. YOLOv5 is a deep convolutional neural network that is based on the YOLO (You Only Look Once) algorithm to identify specific objects in real time by using a single neural network forward propagation [5]. The YOLOv5 proposed with PyTorch and CSPDarknet53 as the backbone that make it different from the previous version [6]. It provides better performance of the algorithm to solve the repetitive gradient information, reduce the layer, increase accuracy and propagation. This system proposed inductive and capacitive proximity sensors to detect the material of the waste. Inductive sensor is used to detect the metal material waste by utilizing

a low frequency electromagnetic field whilst capacitive is used to detect the nonmetal material waste which in this case to detect paper and plastic by utilizing electrostatic field [7]. Both visual and material of the object will be compared with the relevant weight of each type.

2.3 Web Application

To extend the purpose of the system, the system requires web application as a platform for the users. The proposed web application for the system is explained by using a use case diagram in the following **Figure 2**.

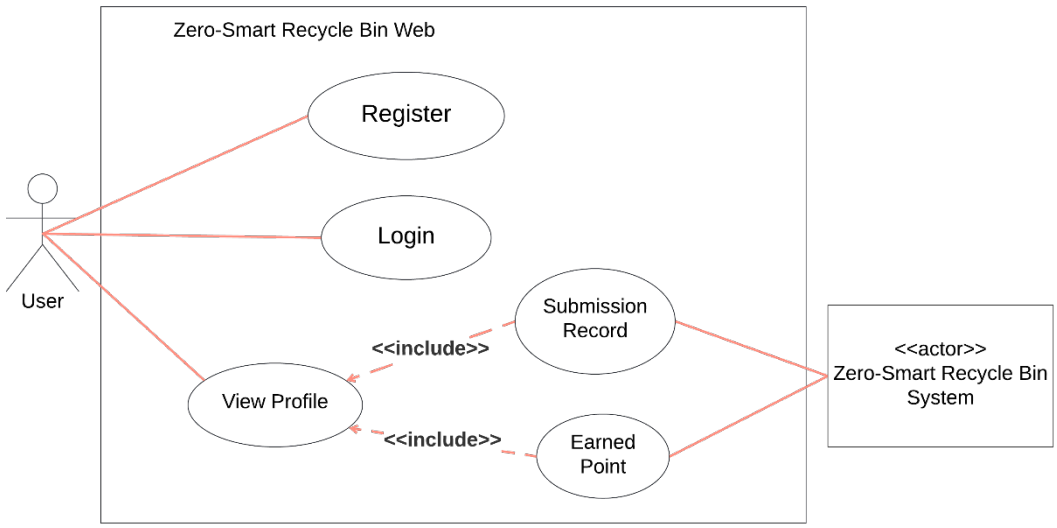

Figure 2 : Use Case Diagram of the Zero-Smart Recycle Bin User Web Application

The purpose of this web application is as the platform for the users to earn points for every submitted waste. The users will be provided with a user profile after they register. The users can see the accumulated points and see the submission record of the types of the waste, the time and the location of the bin. The proposed web application is using Hypertext Preprocessor (PHP) based framework that consist of PHP, HyperText Markup Languager (HTML), Cascading Style Sheets (CSS), The phpMyAdmin, and the My Structured Query Language (MySQL). The HTML and CSS are used for the front-end side of the website. The HTML and CSS corresponding on the contents and its display. The PHP is proposed as the server-side together with phpMyAdmin and MySQL as the database management system. The PHP framework is proposed due to the efficiency and the flexibility in handling this case [8].

3. Results and Discussion

3.1 Raspberry Pi

Raspberry Pi3 is a 64-bit quad-core ARM Cortex-A53 small computer with 1.2GHz clock speed that is equipped with 1GB LDDR3 900MHz SDRAM that makes its performance significantly higher than its predecessor with wide connectivity with many peripherals [9]. It is equipped with on-board Ethernet, WiFi, and Bluetooth that makes it more convenient for internet of things purposes[10]. One of the disadvantages is that this single board computer consumes more energy compared to its predecessor [11].

3.2 YOLOv5

YOLOv5 is known as the latest version of the YOLO algorithm that succeeded the YOLOv3. However, unlike YOLOv4, it adapts to the Pytorch framework instead of following its predecessor by using Darknet as its framework. A test over YOLOv5, YOLOv4, and YOLOv5 on 15 different objects

shows that YOLOv5 outperformed YOLOv4 and YOLOv3 with nearly 70 percent of average precision. [6][11][12]. However, the performance of can be influenced by its model. A study found that YOLOv5 has significant improvements on its recall rate to improve the accuracy with the R-FCN (Region-based Fully Convolutional Network) model method [5].

3.3 Proximity Sensors

Both inductive and capacitive sensors are commonly used in contactless industrial applications. A study found that an inductive sensor is accurate in detecting tin and can waste material at 98 percent accuracy [13]. Meanwhile a study proved that capacitive is effective in detecting non-metal waste material such as plastic and paper by comparing the amount of its dielectric constant [14].

3.4 Recommendations

Although the proposed system consists of proven research and tested methods, the implementation of the proposed system still should be validated and examined. The scope of the system's accomplishment covers the effectiveness and the efficiency of the system in executing the tasks. One of the limitations of the proposed system is that it is only capable of processing one waste object at one cycle. In this case, further research can be done by optimizing the algortihms thus can recognize multiple object simultaneously. Also, the environment of the system should be measured to maintain the accuracy of the waste detection devices. The fact that the system will be automatically operated, meaning that the system should fit with the surrounding environment such as the hardware the peripherals and the necessities mechanism. Furthermore, the user's experience aspect should also be considered to provide convenience. Henceforth, it is highly necessary to examine the implementation in real-world settings.

4. Conclusion

This paper focuses on presenting the design of the Zero-Smart Recycle Bin system as part of the zero net carbon emission campaign and to promote the recycling movement. The main output of the proposed system is to facilitate recycling in which the device is capable of identifying and segregating metal cans, plastic bottles, and paper waste. The waste detection system involves the visual, material, and weight detection in waste segregation. However, at this extent, the implementation of the proposed design in a real-world setting is still unaccomplished.

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