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Design and Implementation of a Smart Garbage Bin for Solid Waste Management using Computer Vision and Internet of Things

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Abstract

The increasing global population and urbanization have led to a significant rise in solid waste generation, posing serious environmental challenges. Proper waste management and efficient waste segregation are crucial to reducing the environmental impact and promoting sustainable living. The majority of the waste is not recycled correctly due to faulty waste segregation, and this research paper presents the design, development and implementation of a Smart Garbage Bin (SGB) equipped with computer vision and sensors for automatic solid waste segregation. The proposed SGB employs computer vision algorithms to identify and classify different types of solid waste, including organic waste, metal waste, plastic and other waste. The research outlines the methodology used for the development of the SGB, which involved the integration of cameras and sensors to create an automated waste segregation system. Advanced algorithms are utilized to train the computer vision model, enabling accurate waste classification and minimizing false positives. The results demonstrate the effectiveness of the Smart Garbage Bin in segregating solid waste, promoting recycling efforts, and reducing the burden on conventional waste management systems. By employing this technology, communities can significantly improve waste sorting accuracy and lower the environmental impact of mismanaged waste. The Smart Garbage Bin's ability to automatically segregate solid waste marks a significant advancement in waste management practices, fostering sustainability and paving the way for more intelligent and greener cities.

Keywords: Computer vision, Waste Management, Internet of Things, Smart Garbage Bin, Customizability.

1. Introduction

Solid waste management is a crucial and complex process that involves the collection, transportation, disposal, and recycling of various types of solid waste generated by human activities. As societies continue to grow and urbanize, the generation of solid waste has become a significant environmental and public health challenge. Effective solid waste management is essential to minimize environmental pollution, conserve natural resources, and promote sustainable development. Solid waste encompasses a diverse range of materials, including household waste, industrial byproducts, electronic waste, and more. Improper handling and disposal of these wastes can lead to a variety of adverse impacts, such as soil and water contamination, air pollution, habitat destruction, and the spread of diseases. Over the years, the field of solid waste management has evolved, incorporating innovative techniques and technologies to address these challenges. Modern approaches prioritize waste reduction, reuse, and recycling, aiming to reduce the amount of waste that ends up in landfills or incineration facilities. Recycling solid waste consists of a complicated process to sort out various waste materials such as metal, plastic, organic and other wastes. Proper segregation at source is the first step to stop recyclable items from ending up in landfills **(**Ortaliz et. al., 2020**)**. A modified way of sorting solid waste is to use computer vision **(**Ramsurrun et. al., 2021**)**. The waste product is being classified using computer vision and multiple sensors **(**Ortaliz et. al., 2020**)**. A camera connected to a microcomputer along with other sensors will help in detecting the type of waste after which the bin's internal mechanism will make sure the waste reaches its proper trashcan **(**Ortaliz et. al., 2020**)** **(**Suddul et. al., 2018**)**. The main pro of this garbage bin is the flexibility and customizability it offers with the variety of wastes it can detect using computer vision. By separating recyclable materials from other waste streams, this garbage bin can significantly increase recycling rates which helps divert more waste from landfills thus reducing the environmental impact of waste disposal.

2. Materials & Methods

2.1 Sensors and Modules Used in the Mechanism:

1. ***Orange Pi 5*** – The Orange Pi 5 is the brain of this garbage bin. It is chosen over the famous Raspberry Pi because of its capability to run the YOLOv5 Algorithm much smoother with a higher fps as compared to the Raspberry Pi as it has a built-in NPU (Neural Processing Unit) with 6 Tops computing power making it much more suitable for AI Applications **(**Orange Pi 5, 2023**)**.
2. ***Camera Module*** – The Camera Module connected to the Orange Pi 5 is used to enable the Orange Pi to make detections using the YOLOv5 algorithm. The Camera Module will have LEDs attached to it which will turn on when the camera module is making detections as it is difficult to make detections in a dark environment.
3. ***Servo Motors*** – The motors are used to rotate the Gates (Gate 1, Gate 2, Gate 3) accordingly based on the detections made by the camera module and the sensors to get the waste to the proper trashcan.
4. ***Humidity Sensor*** – The Humidity Sensor helps detect any increase in humidity after the trash is introduced in the garbage bin thus helping in the identification of wet wastes. Based on this and the detections made using the camera module it helps in the identification of organic wastes **(**Das et. al., 2021**)**.
5. ***Inductive Proximity Sensor*** – The Inductive Proximity Sensor helps in detecting metal and thus identifies metal wastes such as metal cans.
6. ***Infrared Sensor*** – The Infrared Sensor helps in detecting if a waste is thrown in the bin and thus activates the whole garbage bin. The main purpose of this sensor is to save power thus making the garbage bin power efficient.

2.2 Design of the Garbage Bin

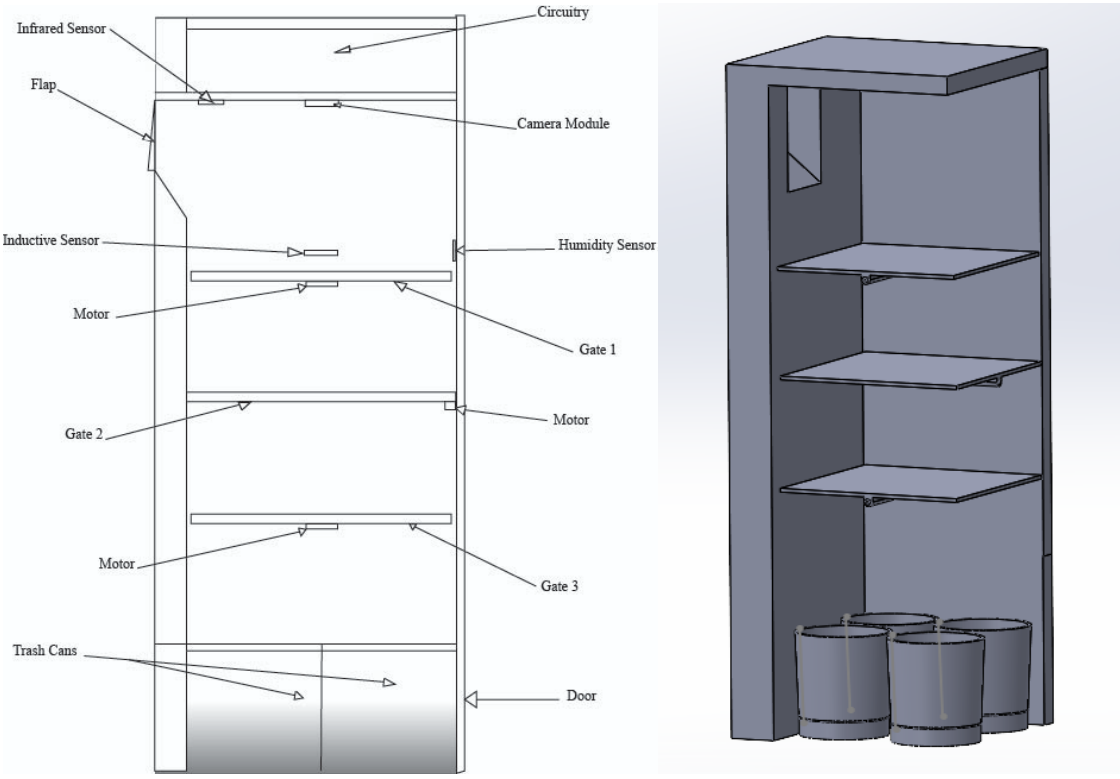
After the waste is thrown in the bin, the infrared sensor senses it and activates the camera and the other sensors. The waste then lands on the first gate (Gate 1) where the detection is made using computer vision and the sensors (humidity sensor and inductive proximity sensor). After the detection is made and the waste is identified as metal, organic, plastic, or other waste, the servo motors rotate the gates accordingly to make sure the waste reaches the proper trashcan **(**Ortaliz et. al., 2020**)**. Figure 1 depicts the diagram of garbage bin of present work.

2.2.1 Design of the Gates

The Gates must be coated with a hydrophobic substance to prevent any wet waste from sticking to them.

2.2.2 Design of the Flap

The opening of the garbage bin will be small such that if someone has to throw a plastic bottle, they will have to crush it before throwing it, thus preventing any foul play, i.e., reusing the thrown plastic bottle and selling it instead of proper recycling. The flap will be designed to guard the opening of the garbage bin, preventing any unwanted substances from entering the bin that might damage the mechanism. The user will have to push the flap in order to throw the waste.



(a) **(b)**

Figure 1. Diagram of the Garbage Bin (a) 2D view, (b) 3D view (NTS)

2.2.3 Accuracy

The accuracy in identifying the type of waste is significantly increased by employing both computer vision and sensors for detections **(**Ortaliz et. al., 2020**)**.

2.2.4 Scope of Customization in this Garbage Bin

The use of computer vision in detecting waste should theoretically give more customization options based on the environment of the garbage bin. For example: Let's consider a hospital environment. Now, obviously, the type of waste generated in a hospital will be different as compared to the waste generated in a shopping mall. Considering this, the YOLOv5 algorithm can be trained on a distinct dataset containing images of items like syringes, bandages, and so on. This will enable the bin to segregate wastes at a higher level based on the environment it is in.

Another modification could be the use of an UV lamp inside the garbage bin, which would be very useful in a lab environment. This slight modification in the garbage bin would be really helpful in a lab environment, as it would help sterilize the wastes thrown in it to prevent the growth of any unwanted microorganisms.

Another slight modification could be the use of an Ultrasonic sensor, which could be used to monitor if the trashcans are overflowing or not and thus alert the person in charge to empty the trashcans.

2.2.5 YOLOv5 Algorithm

The deep learning model selected for training of the waste object detection is the YOLO (You Only Look Once) v5 model which is found to produce best results in object detection **(**Puthussery et. al., 2023**)**. The YOLOv5 Algorithm was trained on a custom dataset **(**YOLOv5, 2023**)**. A very small dataset was used. All the images in the dataset were collected and manually labelled using "labelImg" **(**Human signal/ labelImg, 2022**)**, an open-source tool. Then it was trained with an epochs value of 200.

3. The Proposed Algorithm for Waste Segregation

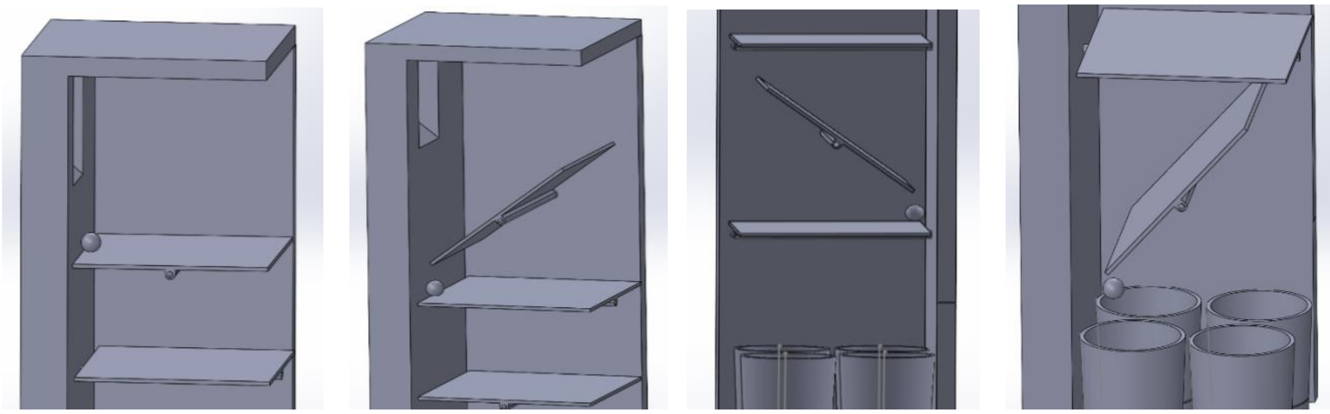
When the user pushes the flap and throws something in the garbage bin the infrared sensor detects it and activates the whole garbage bin.

After the trash is dumped into the garbage bin it lands onto the first gate. Then the camera module using the YOLOv5 algorithm along with the sensors (moisture sensor and inductive proximity sensor) detects the type of waste.

After the detection is made the first gate along with the other gates rotate accordingly to put the waste in the correct trashcan.

3.1 Rotation of the Gates

Rotation of gates after throwing garbage in the bin is discussed below and Figure 2 depicts the steps of movement of garbage inside the bin through the gates.



(a) (b) (c) (d)

Figure 2. Steps of movement of Garbage inside the Bin

Step 1	Trash lands on the first gate and gets detected and identified through the camera (above) and the sensors (on the sides). (Figure 2a)
Step 2	After trash gets detected and identified the first gate rotates accordingly (allowing the object to quickly get to the second gate) and quickly rotates back to its initial position. (Figure 2b)
Step 3	As the waste has been identified, the motors rotate the gates accordingly to get the trash to its labelled trashcan. (Figure 2c)
Step 4	The trash thus gets collected in the proper trashcan. (Figure 2d)

4. Results and Discussion

The YOLOv5 Algorithm was able to detect the type of wastes although for better results, a much larger dataset with a lot of variations in the data must be used to prevent issues like overfitting.

In the loss function graph, it can be observed that as each training epoch progresses, the loss is diminishing and converging towards a lower value, signifying that the model is undergoing learning. Thus, from the graph it can be observed that the model is learning. Figure 4 is showing the loss function graph.

The results look promising and this algorithm can be trained on a custom dataset to detect a wide variety of wastes generated in various settings thus giving it a lot of customizability.

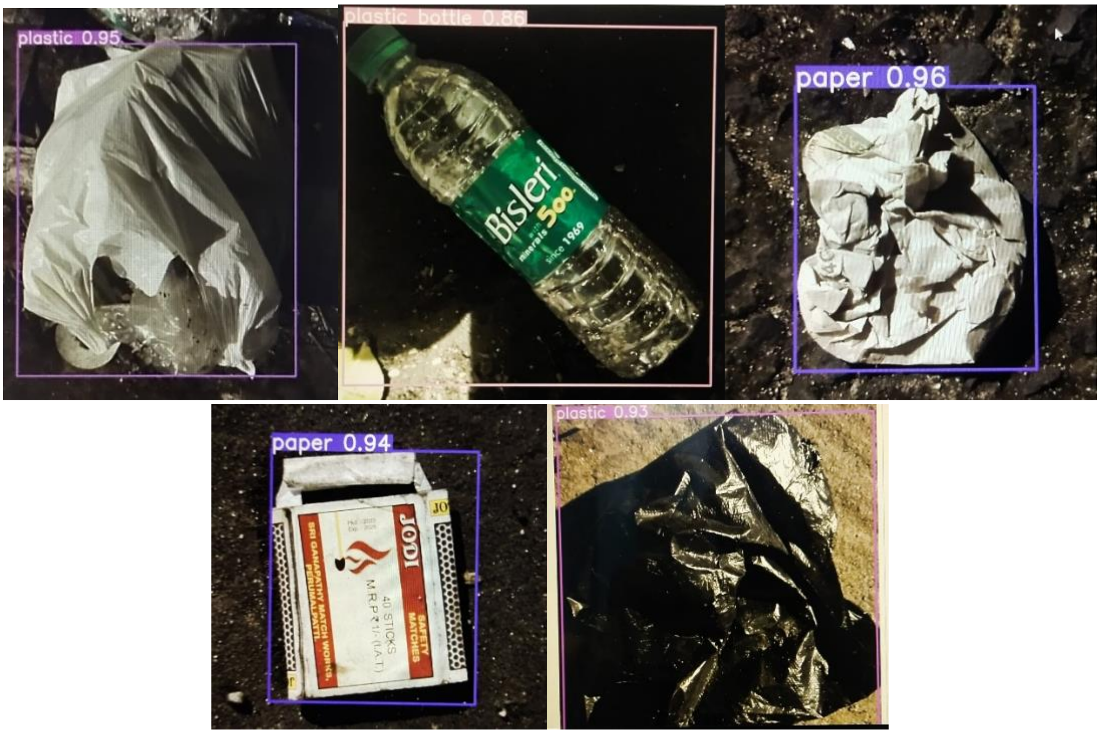


Figure 3. Detection of Garbage using the YOLOv5 Algorithm

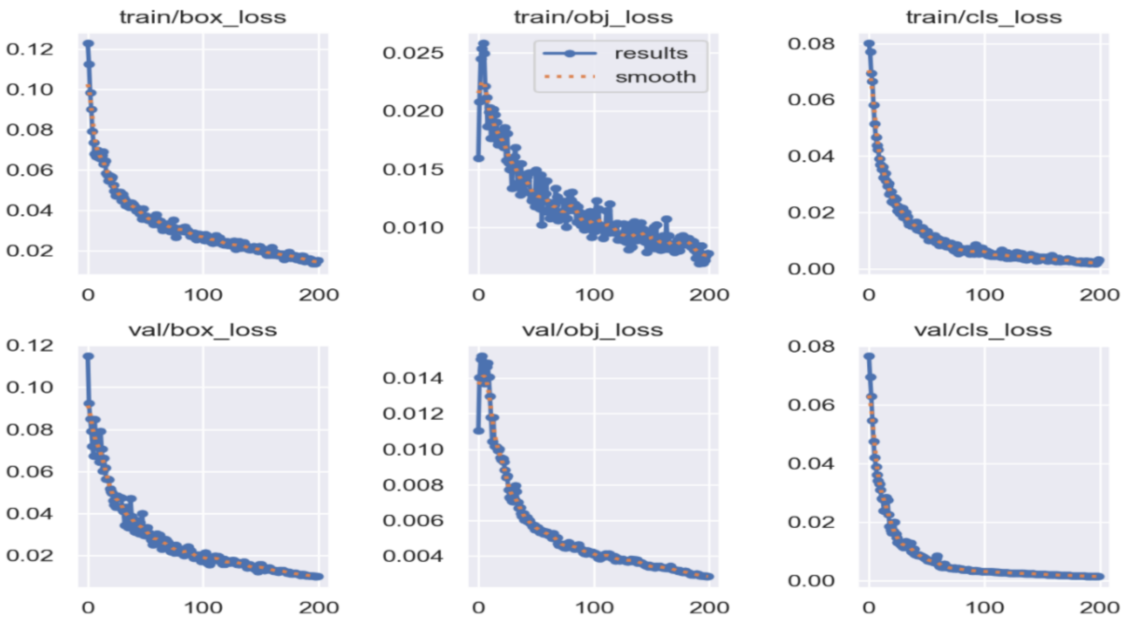


Figure 4. Loss function graph

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References

Das, A., Shukla, A., Manjunatha, R., & Lodhi, E. A. (2021). IoT based solid waste segregation using relative humidity values. In 2021 third international conference on intelligent communication technologies and virtual mobile networks (ICICV). IEEE. 312-319

Human signal/ labelImg (2022). https://github.com/HumanSignal/labelImg

Orange Pi 5 (2023). http://www.orangepi.org/html/hardWare/computerAndMicrocontrollers/details/Orange-Pi-5.html

Ortaliz, N. L. Z., Ama, A. E. D., Fuentes, Albert, A. O., Jurado, J. A. G., Tan, Engr. M. J. T. (2020). Automated Waste Segregation System Using Trained Optical and Material Sensors with User Communication Capabilities. 814th International Conference on Science, Technology, Engineering and Management at: Kuala Lumpur, Malaysia

Puthussery, P., Cherian, N. M., Kiran, T. K., Sreeja, M. U., & Philip, A. O. (2023, May). Green dream: A deep learning based real-time model for automatic waste segregation from video streams. In AIP Conference Proceedings (Vol. 2773, No. 1). AIP Publishing.

Ramsurrun, N., Suddul, G., Armoogum, S., & Foogooa, R. (2021, May). Recyclable waste classification using computer vision and deep learning. In 2021 zooming innovation in consumer technologies conference (ZINC). IEEE. 11-15

Suddul, G., & Nedoomaren, N. (2018). An Energy Efficient and Low Cost Smart Recycling Bin. International Journal of Computer Applications, 180(29), 18-22.

YOLOv5 (2023). https://github.com/ultralytics/yolov5/wiki/Train-Custom-Data