

# Smart Waste Management using Deep Learning and IoT

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**Abstract**— The nation's urbanization and population growth pose serious environmental challenges. Ensuring the safety of expanding communities necessitates efficient trash collection and categorization systems. Currently, waste in India is manually separated at various stations, which proves labor-intensive, time-consuming, and hazardous to workers' health due to the volume of garbage. This research proposes a solution by automatically identifying and classifying waste into recyclable, organic, and toxic categories with 95 percent accuracy using deep learning algorithms like VGG16 and MobileNet V2. Repurposing categorized waste can contribute to a more sustainable environment, fostering a promising future with a rich green ecosystem.

**Keywords**—deep learning; VGG 16; MobileNet

## I. INTRODUCTION

The collection of waste is extremely produced daily in India alone [2]. Diseases and pollution thrive in cluttered streets and drains that are overflowing with waste. The government makes every effort to collect waste from housewise, and even automated waste collection systems are available in some of the nation's [9]. However, due to the vast amount of space, in addition to house wise collection, it is now important to have some automation in the area of collecting waste that is lying on the ground and in open areas [4]. Waste collection efficiency is determined by dividing the total volume of solid waste produced over a certain time period by the quantity of solid waste that is collected and carried from streets to disposal facilities [5]. Currently, the effectiveness of waste collection depends on the availability of labour, which is dangerous for people's lives as well. This reliance on human labour can be reduced with the aid of technology, and it will also be more hygienic. Automation is becoming more and more common. Lack of automation and modernization of waste management services means that waste collection remains a labor-intensive activity. The idea of artificial intelligence is the best technique to give a machine intelligence. To be more precise, the discipline of artificial intelligence's machine learning emphasizes on developing new machines carrying the ability to learn without being deliberately programmed. The technology is based on machine learning, and it creates a fully autonomous isolation system in semi-urban and metropolitan areas. In the discipline of machine learning,

it is a concern to figure out how to develop computer programs that eventually become improved with use numerous effective machine-learning applications have recently been created, including data mining tools that can identify fraudulent credit card transactions, data separating frameworks that take into account users' reading preferences, and automated vehicles that can travel on wide interstates. Waste organization can take place physically at the family and be collected through various plans, or it can be segregated as a result of mechanical natural treatment frameworks. The process by which waste is separated into different components is known as waste segregation. Waste separation entails classifying waste as recyclable and organic. In every zone, waste is isolated and collected at the source. In both urban and rural areas of the country, population growth combined with an improved standard of living results in an increase in the age of solid wastes. Like in every other country, India has a clear distinction between the strong waste from rural and urban zones. The demonstration in [12] is organized via CNN innovation using the identified articles acquired from the movement identifier. This work illustrates computer vision and example recognition using descriptors and association with picture recognition by using deep learning. Accumulation of waste in a stream that can't function and flow effectively. The suggested solution is to develop an autonomous system that separates waste. The machine learning algorithm is used by the system to separate the waste. The system recognizes and classifies waste based on the dataset provided to CNN models. The algorithm separates the waste into recyclable and organic groups in this manner.

The research objectives of our paper area are -

- Make a relationship between hardware and software to classify a waste data image.
- Propose a noble model and train the model with two different collected waste image datasets.
- Get a state of art accuracy and classify an unseen image in real time.

- Finally, send the classified data to the hardware system, and according to the data classification the classified garbage is placed into the corresponding bin.

Moreover, rest of the sections are organized as follows. Section II discusses about the related work. Section III provides in details information regarding the architecture and design of the system. Section IV reflects the experimental setup for object detection. Section V describes the hardware design and implementation of the system. Section VI provides the result analysis. Finally, the conclusion part is placed at section VII.

## II. RELATED WORK

Even if computer vision-based trash segregation hasn't been used in our country, there have been many attempts at it worldwide. However, each of these efforts has its setbacks with regard to how well it can execute the task. Most of them use two-stage detectors which are bulky to be deployed/used in IOT and mobile devices. These detectors require more inference time than single-stage detectors. And almost all of them are modeled in which they detect a single waste at a time.

There is currently no automatic waste segregation system at the residential level in Ethiopia, making the creation of a practical, affordable, and eco-friendly classification model for urban households urgent.

The effectiveness of computer processing of images has significantly increased as a result of the significant increase in computer operating speed. CNN (Convolutional Neural Network) based deep learning models have started to take center stage in the area of image recognition and classification.

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So, with the help of computer vision, we can make the process efficient and resilient through image segmentation and classification as waste segregation become a significant concern in our lives. These systems' increasing demand for accurate and effective segmentation and recognition methods ties up with modern computer architectures' increasing processing power and improved image recognition algorithms.

An intelligent garbage classifier; that analyzes images from the camera, the robot arm, and the conveyor belt for visual classification is used. It employed watershed to separate an overlapping waste and K-NN for classification, with the shape being the most significant characteristic they took into consideration. Nevertheless, they omitted to mention the classifier's accuracy. Since the same class of garbage might come

in a variety of sizes and shapes, using merely shape alone to identify objects is insufficient.

Mittal, et al, used a Convolution Neural Network (CNN) which is a machine learning algorithm, was utilized as the model in this study and was applied to a dataset of images of trash. This study classifies diverse waste images into the appropriate categories and continues to provide training accuracy and test accuracy at 91 percent and 81 percent respectively [6].

Huiyu, Liu, Owolabi Ganiyat O, and Sung-Ho Kim, claimed a different waste classification model to classify different types of waste using deep learning algorithm, which was mainly applicable to recycle the garbage. Through the proposed scheme of that paper, a deep learning paradigm was reflected to classify the garbage autonomously.[1]

Chu et al, developed a multilayer hybrid deep learning system that efficiently disposes of unwanted objects scattered by the public in open space. CNN and MLP are used for extracting and consolidating the features to classify waste as recyclable or not. The cameras in the open spaces then detect the garbage, identify the type and disposal procedure, and alert the authorities accordingly to maintain a clean environment.[7]

Supasan et al, deployed robots to manage waste efficiently. The authors implemented a smart robot that detects waste and segregates it. An image processing unit allows the robot to detect the garbage lying around. In addition, sensors detect distance, weight, and other physical properties.[8]

K. Gayathri Devi, has proposed an idea that the wastes are been segregated as metallic waste and non-metallic wastes with the help of metal sensor. And in some papers, they simply use magnets to segregate metallic and nonmetallic, but they didn't get accurate results. In some other paper they only detect the wet and dry wastes with the help of moisture sensors and segregate accordingly. And also odour sensor is used to segregate degradable wastes which makes foul smell. The notable dispute in waste architecture is that trash bins by the side of open loopholes becomes avalanched far ahead on time in advance of the beginning of following cleanliness action. It leads to various threats such as foul odour and ugliness to that region which might also be the root reason for spread of a variety of diseases.[3].

BakriNasreldeen, proposed a new idea called recycle bot which uses image processing technique to distinguish waste into recyclable and non-recyclable material. Zig Bee is also used. This system is complex and communication between modules is necessary to work efficiently. A methodology for collection of domestic waste and disposal of it was proposed using an IOT based system. The main aim of municipalities is to keep the localities clean, but does not aim segregation and recycling techniques of waste at domestic level. The automatic waste management system uses artificial

intelligence deep learning technique to classify waste into biodegradable and non-biodegradable.[9].

Liu Y, Fung K-C, Ding W, Guo H, Qu T, Xiao C, developed an automated system based on a deep learning approach and conventional techniques by aims for the accurate separation of waste into recycling categories in order to reduce the damage caused by improper garbage disposal, more specifically residential. Glass, metal, paper, and plastic were among the four garbage categories taken into consideration. They get an accuracy of 80 percent using SVM and 88 percent when using KNN. Results indicate that the computational cost of CNN algorithms is typically higher than that of conventional techniques, necessitating more powerful computing facilities [2].

Bobulski, J, used a novel approach to waste management that utilizes deep learning algorithms. The proposed system is an integrated and effective waste management plan based on the challenges highlighted in the related work section. The system uses sensors to measure the peak of the garbage bin after it has been full. This waste management system keeps employees informed about waste amounts regularly. When the waste bin is about to fill, it also sends a warning to the appropriate waste collection authority. To improve garbage recycling, the suggested system includes a method for sorting waste into different types.[4].

Based on the findings from the existing research, it has been observed that most of the current models do not yield improved classification accuracy. In contrast, in our work, we exploit the advantages of both vision information and artificial intelligence-based technology, whereby our model can distinguish organic and recyclable material and classify them into distinct categories. Further, to measure the working ability of the Vgg16 model, which tends to achieve much higher accuracy than the previous predicted results.

### III. ARCHITECTURE AND DESIGN OF THE SYSTEM

An automatic waste segregation machine is designed and implemented using both sensors and deep learning methods. Initially, a waste collection inlet is used to collect the waste and a conveyor belt is used to convey the waste from one end to another end. Afterwards, the presence of the waste is detected by using an ultrasonic sensor. After detecting the presence of the waste, the conveyor belt creates a delay for 10 seconds to capture the image of the waste using the camera module mounted in the conveyor belt. Then the captured image of the waste is sent to the processing unit (Computer) to process the real-time image of the waste using deep learning method. To classify the waste into organic and recyclable waste, Vgg16 is used. For deep learning, Vgg16 is a pre-trained convolutional neural network. Basically, it is trained over our collected dataset. A serial communication is established between an ATmega 2560 AVR microcontroller and the processing unit of the system to send the detected output to microcontroller from the processing unit. When an object is detected, a

signal is sent to microcontroller via the serial communication from the processing unit to control the servomotors. The depicted block diagram in Fig.1 shows the step-by-step mechanism of the automatic waste segregation machine.

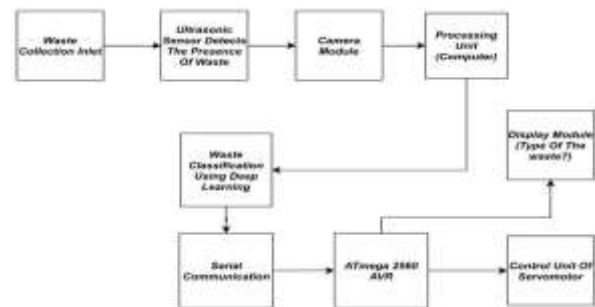


Fig. 1, Step by step block diagram of the automatic waste segregation machine.

#### A. Flowchart of the Segregation Process

The inserted flowchart in Fig. 2 demonstrates the waste sorting maneuver and the mechanism of the servomotor controller unit of the proposed automatic waste segregation machine.

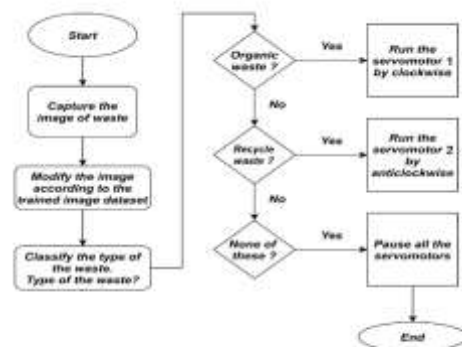


Fig. 2. Flowchart of the segregation Process

Initially, the image is captured by using the camera module mounted in the conveyor belt. After capturing the image, the real-time image of the waste is modified according to Waste and the processing unit of the system displays the type of the processed image precisely. To place the detected waste inside the bins a servomotor-based controller unit is used. Three servomotors are used to place different types of the waste using two directional movement of each servomotor. For instance, when the waste is detected as organic, then the servomotor 1 is run clockwise to place the waste inside the corresponding bin. Similarly, when the waste is classified as recycle, another servomotor is run clockwise to place the waste inside the corresponding bin.

The servomotor-based controller unit of this automatic waste segregation machine is controlled via the serial communication between a microcontroller and the processing unit. The above flowchart indicates that if the

waste is not detected as any of the types, then all the servomotors are stopped. Otherwise, it starts to follow the same segregation process repeatedly. Eventually, it is articulated from the above flowchart that the system follows the same process for each step to classify different type of waste.

**B. Transfer Learning with Waste**

For deep learning, transfer learning is one of the most important techniques whereby a neural network is trained on a specific problem similar to the problem that is being solved. There are several layers in the trained neural network but one or more layers are then used in the new model trained on the problem of interest [21]. There are two straightforward processes for transfer learning and these are given below:

- Using the custom image dataset, training of the model is accomplished.
- The initialization of the training model with weights from a pre-trained model.



**B. Iteration for Achieving Higher Accuracy level and Lower level**

The trained deep convolutional neural network requires several iterations to achieve its best possible output for image classification. The depicted graph in Fig. 6 shows the initial loss level of the network and the final accuracy level of the network after 10 epochs. At the very beginning, the network shows the higher loss level. After doing several iterations, the trained network outperforms its initial level, which is around 90 percent and loss level of the trained network tends to decrease, which is around 10 percent.

**IV. EXPERIMENTAL SETUP FOR OBJECT DETECTION**

**A. Process of Creating Training Dataset**

Initially, for the waste materials, total 27998 images were captured in different lighting condition and orientations. we divided images into two sub categories i.e. organic and recycle. To train up the network, 80 percent of the images were considered as the training dataset and rest of the 20 percent were used as the testing dataset. It is important to split the dataset into two sub-datasets as training and testing for eliminating overfitting and under-fitting of the custom model. In order to verify the precision of the custom dataset, the test dataset was used.

We have collected the dataset from Kaggle dataset site i.e. Waste-Classification-Data.

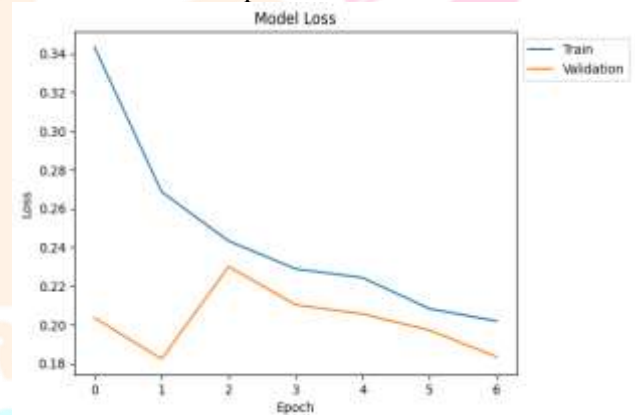


Fig. 3. Comparison of Model Training Loss and Validation Loss

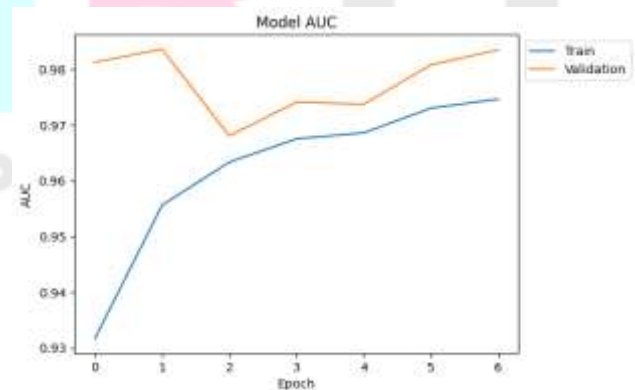


Fig. 4. Comparison of Model Training Accuracy and Validation Accuracy

## V. HARDWARE DESIGN AND IMPLEMENTATION

Before implementing the project, physical design is important to be drafted first. Therefore, AutoCAD design is done before the implementation of the practical design. The total length of the system is taken as 12 feet and the width is 6 feet 5 inches to accommodate all the sensors, servomotors and camera module. The total length of the conveyor belt is taken as 15 feet to convey the waste from one end to another end by using the DC gear motor. The given design in Fig. 7 shows the complete setup of the system.

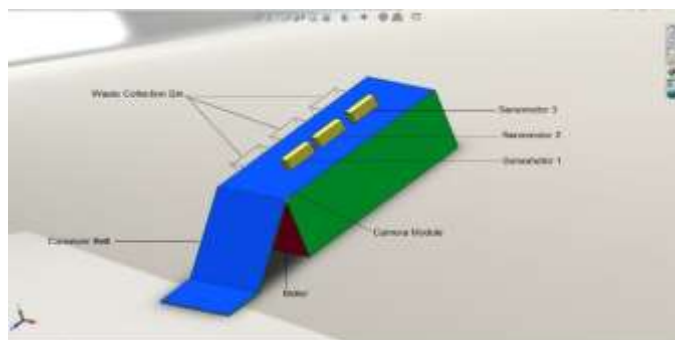


Fig.5. Auto Cad Design of the System

## VI. RESULT ANALYSIS

The system's detection and separation capabilities are commendable, ensuring efficient waste management processes. Upon detection of an object by the sensors, a signal is promptly transmitted from the processing unit, typically a computer, to the servomotor controller. This signal triggers the precise movement of the servomotor to facilitate the separation of the detected waste into the corresponding bin. Once the waste is successfully deposited into the designated bin, the cantilever of the servomotor returns to its initial position, preparing for the next detected waste item. This automated process ensures seamless operation and optimal utilization of resources, as the system swiftly adapts to incoming waste without delay or manual intervention. In essence, the integration of sensors, processing units, and servomotors enables the system to achieve high levels of accuracy and efficiency in detecting and separating waste. By automating these tasks, the system minimizes human error, enhances operational efficiency, and contributes to overall waste management effectiveness. The display module of the system extracts the final output of the network and it shows the type of the waste properly. In addition, it counts the bin number when the waste is placed inside. This process helps the system to trash out the exact bin filled with garbage. The inserted picture in Figure display the final output of the system.

## VII. CONCLUSION

We have compared our proposed 3 CNN method performance with MobileNet V2, EfficientNet B0 and

VGG 16 model to evaluate the impact of the model size has on the efficiency and accuracy metrics. We found that as number of epoch level increased, the accuracy of CNN classifier increased. We have increased the epoch =10. We were able to obtain accuracy of 95 percent with Vgg 16 model and the available Data set from Kaggle which was used. This proves that the model performance enhanced at good rate. As a result, we see that CNN is a strong network using in image classification techniques. As we know, waste segregation is the biggest problem in today's world. We generate huge amounts of waste everyday which has great impacts on the environment, and humanity. So, we have designed a model using the latest trending technology. Our model has provided a good insight of future scope of using CNN and classification of waste materials. High accuracy of nearly 95% is achievable here, as the epoch number increases the efficiency also increases.

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