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## **AI and IoT based Garbage classification for the smart city using ESP32 cam**

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**Abstract**--Waste collection and segregation are some of the tasks that require immense human power and knowledge about waste materials to achieve accurate results. But with the growing population and increase in waste materials, it is becoming tougher for workers and organizations that work for waste collection to achieve perfection. To overcome the problem, the study tries to design a smart dustbin that is capable of segregating the waste materials by itself. It separates the waste into biodegradable and non-biodegradable waste. It is done using a combination of components like an ESP32 cam, an AI model, a motor, etc. This Artificial Intelligence (AI) model will be built using the CNN algorithm. The model is trained with many epochs and validated for higher accuracy and lesser loss value. The model will

then be integrated into the dustbin along with other components. This dustbin is also capable of displaying the space availability of the dustbin through IoT. This results in easing the work of the workers in segregating the waste materials and looking for dustbins that are filled.

**Keywords**---garbage, ESP32 cam, algorithm, accuracy, loss.

## **Introduction**

Since the dawn of human civilization, the amount of solid garbage produced by humans has been steadily growing. According to studies, around two billion tonnes of solid garbage are created annually throughout the world. On average, each human produces 0.74 kilograms of garbage every day. This massive volume of garbage needs advanced waste collection and management systems to address the problem of contamination on both land and water. Though most of the waste materials are non-biodegradable, there is also a considerable amount of biodegradable waste. When these waste materials are collected and dumbered together, it becomes difficult to segregate them for proper disposal. Biodegradable waste materials can be directly dumped into soil and they can act as a natural fertilizer for the soil. If some of the non-biodegradable waste is mixed with them, the waste itself becomes a hindrance to the soil nutrition. Unlike biodegradable waste, non-biodegradable waste cannot be dumped carelessly. Certain disposal methods like incineration, recycling, etc. have to be done to ensure that the waste is properly handled. For this to happen perfectly, the waste must be segregated properly. The goal of this study is to create a smart dustbin that can separate waste stuff on its own. It distinguishes between biodegradable and non-biodegradable trash. An ESP32 cam, an AI model, a motor, ultrasonic, and other components are used to do this. As the AI model is like the brain of the dustbin, it will be trained and validated repeatedly to ensure the highest accuracy and the lowest loss value. The construction of the dustbin and the working of every single component is explained individually in the upcoming chapters.

## **Literature Survey**

Researchers from the school of Engineering, Portugal explained in their research that the covid situation has noticeably increased the urban terrain. They stated that the adoption of protective masks and confinement has resulted in an emerging flow of waste growth and pollution in general. Although some garbage is deemed commingled, much of it is recyclable if disposed of appropriately. In a conclusion, recycling is more vital than ever before, not only for pollution management, but as well as for sustainability and resource utilization. They say that the capacity of bins in landfills can be increased by plastic and metal recycling equipment and compactors. Product quantities and filling levels could be sent via an existing network using a World Wide Web information system [1]. There is a pressing need for new ways to dispose of non-biodegradable garbage, such as plastics, according to Indian researchers at the Hindustan Institute. Since synthetic polymers like plastics are being degraded by microbes, it's now possible to develop new biological treatment methods for non-biodegradable

waste. With the help of AI, they created a garbage segregator that can separate plastics from non-biodegradable waste, reducing the environmental impact of both. The recommended WSD paradigm has the following drawbacks considerable initial outlay and oversight [2].

Another group of researchers from the Chalmers University of Technology, Sweden developed a dry waste segregator for household and institutional waste products. They quoted statistics from a research article [3] that every year, over 40 million tonnes of urban municipal trash are created in India alone. India has seen remarkable economic growth since 2011, according to numerous reports. The garbage generation per capita has grown from 400 to 500 grammes per day, with a 13.6 percent increase in decadal waste creation per capita. The equipment they designed is small enough to be put in housing complexes and educational institutions. The prototype sorting system efficiently separates dry garbage into three categories: ferromagnetic metals, paper, and plastic. Metals have the highest total separation efficiency of 90.25 percent in household garbage, while plastic has the lowest at 75.43 percent. Their experiment has shown that their efforts will lead to source separation, resulting in a cleaner and healthier environment [4]. The CNN algorithm is no new in the field of classification. A team of researchers from Firat University, Turkey even developed a multi-level classification using the CNN algorithm. They created thirteen distinct deep CNN model architectures as part of their research. Each deep CNN mesh model's normalized data of lung X-ray picture is examined to identify illness states into the categories of Normal, Viral Pneumonia, and COVID-19. By using the INCA and IRF feature selection methods for the trained CNN, the performance criteria are enhanced, allowing for better analysis, predicting outcomes, and making a faster and more accurate choice. This suggested study suggests that deep CNN models may be used to classify COVID-19 in X-ray pictures [5].

Even in waste management and segregation, the CNN algorithm is used. T. J. Sheng et al stated that the effectiveness of the current waste management techniques is not enough to recycle the amount of waste produced in this recent generation. They used the technologies of AI and the Internet of Things (IoT). An intelligent management solution was detailed in their article, which includes sensors to keep tabs on the state of the bins, the LoRa protocol for transferring minimum-power, maximum-range data, and object recognition built on TensorFlow for sorting garbage. They concluded that the current waste management system can be improved, leading to a greener and healthier society [6]. Another group of researchers from the UKM of Malaysia performed research on the development of a smart waste management system. They stated that due to the fast development of cities' populations, waste management systems are encountering issues, resulting in massive amounts of garbage produced. Traditional trash management systems were also criticized for their inefficiency. Using TensorFlow Lite and the LoRa-GPS Shield mostly in an IoT environment, they came up with a smart trash management platform. The following are the findings of their investigation. Biodegradable waste and non-biodegradable can all be found in the bin. It is possible to transmit the garbage fill rate and the computer's GPS location to the LoRa receiver across a radius of 5 kilometers by use of the LoRa module. This allows the waste management system administrator

to keep an eye on the bin's state from afar and determine when to collect rubbish from it [7].

## Materials and Methods

A dataset consisting of 22500 images of biodegradable and non-biodegradable waste is obtained from Kaggle. The collected dataset then undergoes the processes shown in figure 1 for the development of a smart garbage classification system.

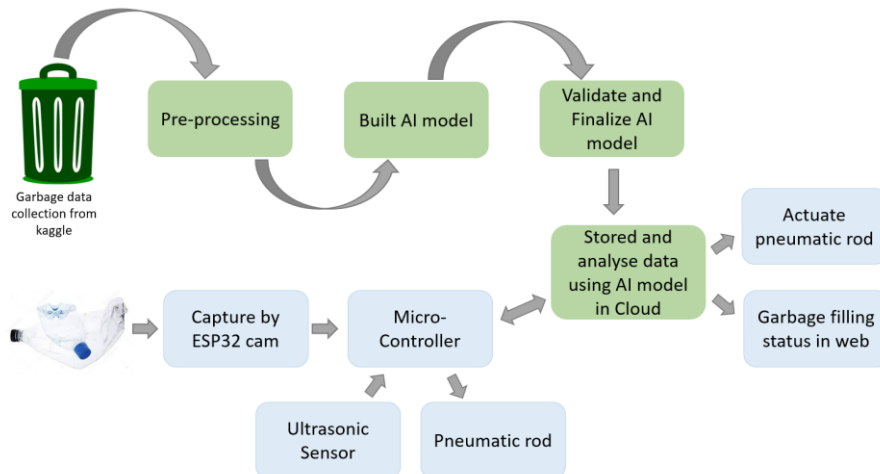


Figure 1. Workflow of the smart dustbin

## Software components

As shown in figure 1, from Kaggle, a dataset of 22500 photos was gathered. This dataset contains a variety of waste items, including both biodegradable and non-biodegradable garbage. The obtained data is then processed and used to build the AI model. This AI model is designed using the Convolutional Neural Network (CNN) algorithm. The model is then trained again and again to reach higher accuracy and lower loss value. The model is then validated and finalized. The finalized model is then integrated into the dustbin.

## Hardware components

The main hardware component of this research is the dustbin itself. The model of the dustbin is shown in figure 2. The dustbin is equipped with an ESP 32 camera. This cam is an effective tool that is capable of fine time measurements [8] and even in the development of smart houses [9]. The image of the waste being thrown into the dustbin is captured by this cam. The captured image is then sent to the cloud and is then sent to the AI model. The model then predicts the type of waste material and activates the microcontroller.

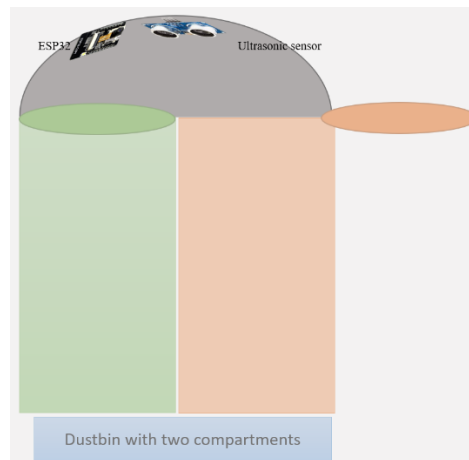


Figure 2. Dustbin mode

The microcontroller used here is the NodeMCU module. This module is more suitable for home-based applications [10]. This module activates the motor which is connected to the top part of the dustbin. It is used to open the respective compartment based on its type. An ultrasonic sensor is also attached to the lid of the dustbin. It is used to measure the distance between the lid and the waste material inside the bin. If the distance is so small that the bin can't accommodate another waste, it simulates the ThingSpeak software to send an alert message stating the bin is full.

### Data acquisition and pre-processing

A dataset comprised of 22500 images is downloaded from Kaggle. This dataset is a collection of various waste materials consisting of both biodegradable and non-biodegradable waste. These images include wastes like a banana peel, water bottles, a corn cob, etc. A sample image from the dataset is shown in figure 3.

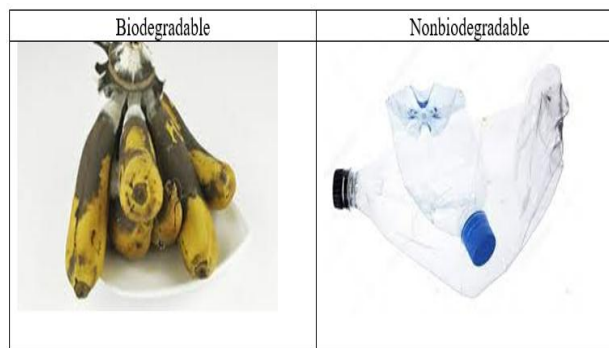


Figure 3. Sample data

The images are then pre-processed using the below process to ensure uniformity and higher efficiency of the model.

**Image resizing**

Image resizing is the process of altering the dimensions of all the photographs in a dataset so that they are all the same size. The total number of pixels in an image can be increased or decreased when scaling it. When an image is zoomed or extended, picture resizing guarantees that image quality is preserved. Another significant benefit of picture scaling is the ability to eliminate undesirable regions of the image.

**Image rescaling**

To make a new version of a picture with a different size, the rescaling or resampling method is utilized. As it turns out, these techniques aren't entirely faultless. Rescaling is also used by certain academics to evaluate channel interdependencies [11]. This method is difficult because it necessitates a careful balance of sharpness, efficiency, speed, and smoothness. The ability to delete undesirable image sections is another significant benefit of photo scaling.

**CNN Model**

An AI model is a computer-generated classification system for photos, texts, and even noises. A variety of AI algorithms can be used to generate this AI model. Among the algorithms are CNN, radial basis function, recurrent, and pre-trained. CNN was used to build the AI model in this study. CNN surpasses various other AI algorithms based on accuracy, which is why this is the case. Deep Learning (DL) is what the CNN method is all about. In comparison to certain other image classification methods, CNN requires very little pre-processing. This implies that, in contrast to previous methodologies, the network learns to improve the filters (or kernels) through automated learning [12]. The CNN approach has several benefits over other DL-based classification algorithms, including the fact that it does not require considerable preprocessing. The CNN methodology is performed on the basis cortex's layout, which would be analogous to the biological brain's connecting concept of neurons. Many convolutional layers could be applied to classify images using the CNN approach. The increased count of layers results in lessening the number of AI models required. The CNN algorithm is one of the best methods for extracting high-level properties from a picture, such as edges. The architecture of the CNN algorithm used in this research is shown in figure 4.

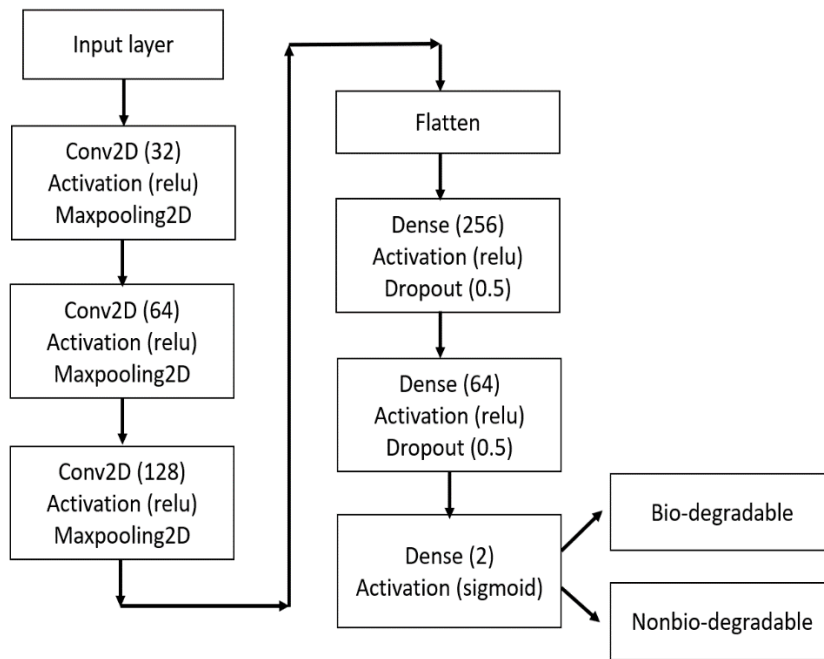


Figure 4. The architecture of the CNN model

From figure 4, it can be seen that there are 7 layers in the CNN architecture excluding the input layer. The input layer acts as the first layer. The input values are then sent into the second layer aka the Conv2D (32) layer. The output of the second layer is then sent to the third layer or the Conv2D (64). The process then follows the same pattern and the values reach the seventh layer. The last layer is the dense (2) layer or the activation (sigmoid) layer. This layer is the one that classifies the content in the image as biodegradable and non-biodegradable.

## IoT

Software is built using the ThingSpeak platform. This is an IoT platform that is used to combine, view, and analyze images that are stored in the cloud and it also produces an output in an easily understandable form [13]. The quantity of biodegradable trash currently presented inside the dustbin is displayed in the windows created using ThingSpeak. It also holds information about the last time a biodegradable waste was discarded in the trash. A separate pane shows the same information for non-biodegradable garbage. Two alert windows are used to display the availability of space inside the dustbin.

## Result and Discussion

A dataset composed of 22500 images was downloaded from Kaggle. The obtained dataset is then preprocessed. The preprocessing techniques include image resizing and image rescaling. An AI model is developed using the CNN algorithm. The processed images are utilized to train and test the model. The accuracy of the model is pictorially explained in the form of a graph in figure 5.

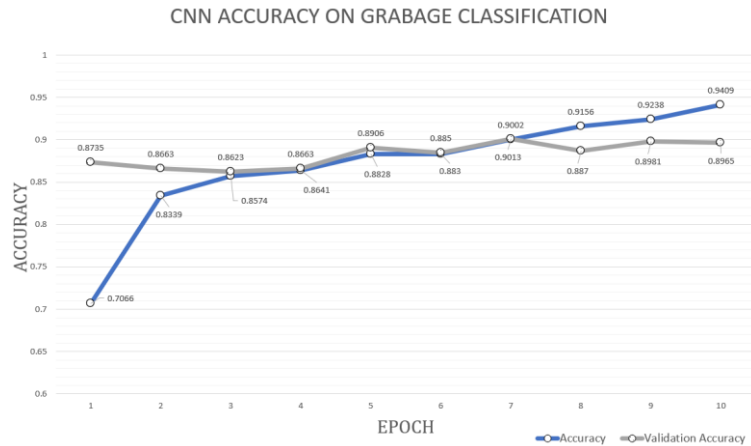


Figure 5. Accuracy graph of CNN

This can be seen in the initial epoch when real accuracy and validation accuracy are very far apart, but as the number of epochs grows, the accuracy gap reduces. To make sure the model is working fine it is also necessary to compare the loss value. The actual loss values and the loss values of the model during validation are shown in a graph in figure 6.

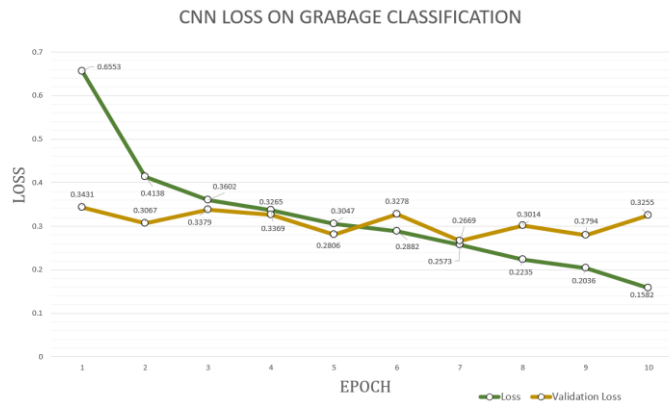


Figure 6. Loss value of CNN

Just like the accuracy value, the difference between the actual loss and the validation loss is quite high in the initial epoch and it gradually decreases. By the end of the final epoch, the validation loss reaches its minimum value of 0.1. This loss is so small that it is negligible. This increases the efficiency of the model in the prediction of the type of waste. The model is then tested using real-time images to ensure perfect performance. When waste is thrown into the dustbin, it falls into the top part of the dustbin where it will be captured as an image by the ESP 32 cam. The image is then saved to the cloud and is then sent to the model for testing. The results of the test are tabulated and shown in figure 7.



Figure 7. Test results

From figure 7, it can be seen that the actual output and predicted output are the same in almost all cases. For instance, in the first case, the given image is a moldy bread which is biodegradable waste. The model correctly predicts its type. Once the type of waste is identified by the model, a motor that is connected inside the dustbin is activated. This motor pushes the waste into its compartment. If the model predicts the waste as a non-biodegradable waste, then the rod pushes it into the non-biodegradable part of the dustbin. Hardware is also designed and connected using the IoT in the ThingSpeak software. This is used to send an alert message to the user when almost 95% of the dustbin is filled. It also displays the number of biodegradable waste and non-biodegradable waste in separate windows for better understanding. A sample view of this model is shown in figure 8.

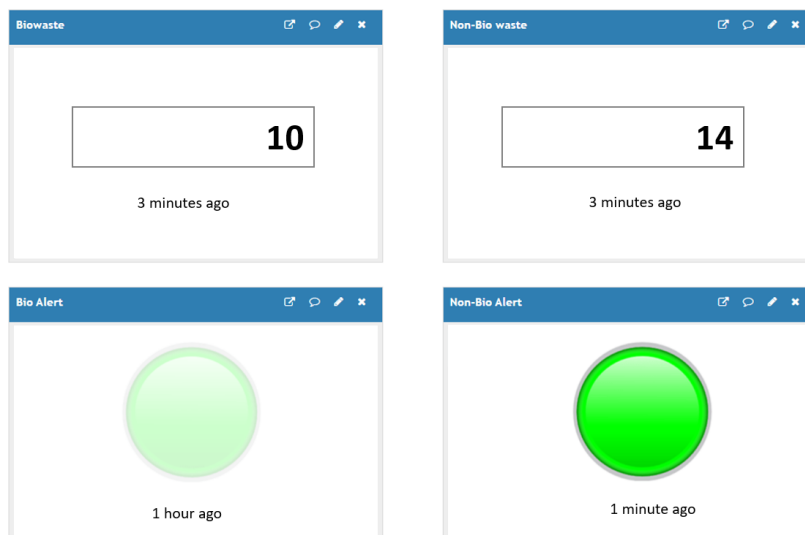


Figure 8. The ThingSpeak Dashboard

The first window displays the number of biodegradable wastes that are currently present inside the dustbin. Along with that, it also contains information about the last time a biodegradable waste is thrown into the dustbin. The second window

displays the same above-mentioned details but for the non-biodegradable waste. The third and the fourth window are alert windows. It contains a bulb-like component that glows when 95% of the dustbin is filled along with the time details about the last waste that was thrown. This is done using the ultrasonic sensor which was connected to the lid of the dustbin. It measures the distance between the lid and the waste materials and if the distance is smaller and is not enough to contain another waste, it sends an alert to the user. The biodegradable waste part of the dustbin still has some space resulting in the bulb staying in off mode. But for the fourth window, the bulb glows as 95% of the non-biodegradable part is filled.

### **Conclusion**

From Kaggle, a dataset of 22500 photos was gathered. After then, the data is preprocessed. Image resizing and rescaling are two preprocessing approaches. The CNN algorithm is employed to build an AI model. The model is trained and tested using processed photos. The model is then trained and validated for higher accuracy and lesser loss. When the model reaches its best performance, it is integrated into the dustbin. This dustbin is connected with an ESP32 cam which clicks an image of the waste which was dropped into the dustbin. The image was then sent into the model and the model accurately predicted the type of waste thrown. A motor is also connected and is used to push the waste material into its respective portion. A hardware model is also designed for user interaction purposes. It displays the number of wastes thrown into the dustbin along with the time when the last waste was thrown individually for both types. The IoT platform shows an alert when 95% of the dustbin is filled. In the end, this smart dustbin is a game-changer in places like malls and beaches as it reduces the time and effort of the cleaning workers. It is because it can separate the waste by itself and also alerts the user about the space availability of the dustbin. When used in large numbers, it can be helpful in the reduction of pollution along with making the segregation process simpler.

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