CNN BASED SMART WASTE SEGREGATION AND COLLECTION SYSTEM

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Abstract— Waste management is an increasing concern in urban areas worldwide, because of population growth and environmental sustainability goals. To address this challenge, this paper presents a Convolutional Neural Network (CNN)-based waste segregation and collection system that uses the power of computer vision and machine learning. The proposed system is used to automate the process of waste segregation, optimizing the sorting of waste into bio-degradable, reusable ,recyclable waste and trash in real time .Utilizing a camera for capturing the images of incoming waste materials and moving the waste at their respective collection points. The images are processed using a deep learning YOLOv8 model, which identifies and classifies the waste items into bio-degradable, recyclable and non-recyclable categories with high accuracy. This innovative waste management solution holds the potential to change the waste collection and recycling processes, making them more cost-effective, environmentally friendly, and aligned with the ability for sustainable waste management practices.

Keywords: Waste Management, Convolutional Neural Network, Biodegradable, Recyclable, Reusable, Waste segregation, YOLOv8.

I. INTRODUCTION

In the present increasingly urbanized world, the management of waste has become a important concern. The fast growth of populations has led to an increase in waste generation, so there is a need for more efficient and sustainable waste management practices. As the core of this challenge lies in the need for effective waste segregation, a process traditionally dependent on manual labor and may lead to inaccuracies. In response to this challenge, emerging technologies, particularly Convolutional Neural Networks (CNNs), are transforming waste management by automating the waste segregation and collection process. This paper introduces a ground breaking CNN-based YOLOv8 model for waste segregation and collection system, an important innovation aimed at revolutionizing the way we manage and process waste in urban environments. This system automates waste product recognition and sorting, increasing the efficacy and sustainability of waste management practices. It does this through the use of artificial intelligence and computer vision. The rapid increase in urbanization and increasing concerns about environmental sustainability have created a need for more efficient waste segregation and collection techniques. Traditional methods, reliant on human labor, are not only labor intensive but also prone to errors and inconsistencies. Moreover, as waste continues to diversify, segregating bio-degradable, reusable, recyclable and trash has become a complex challenge. The CNN-based waste segregation and collection system presented in this paper uses YOLOv8 deep learning algorithm to address these challenges. It processes images of waste in real-time, accurately classifying the waste. This system not only streamlines the waste segregation process but also significantly reduces the need for manual labor, minimizing health and safety risks associated with handling waste materials. Additionally, it promotes recycling by ensuring that recyclable materials are properly sorted and directed to recycling facilities, thus reducing landfill waste and supporting environmentally sustainable goals .

II. LITERATURE SURVEY

[1] A.P Puspaningrum et al., discusses a "Waste Classification Using Support Vector Machine with SIFT-PCA Feature Extraction," the OpenCV library is used to prepare photos acquired from waste. It uses SVM and SIFT-PCA feature extraction which had achieved a great accuracy.

[2] Shanshan Meng and Wei-Ta. Chu; "A Study of Garbage Classification with Convolutional Neural Networks," used SVM with hog feature and CNN to classify the waste. The waste is classified into six groups. It was discovered that suggested model had a 97% accuracy.

[3] Dimitris Ziouzios, Dimitris Tsiktsiris, Nikolas Baras, Minas Dasygenis, "A Distributed Architecture for Smart Recycling Using Machine Learning". It has an precision of 81.43% and separates garbage into different categories: recyclables, non-recyclables, and organic waste. Mobile-Net has a fantastic accuracy score of 90.65% when compared to all the other transfer learning models.

[4] Minhyu Gao, Dawei Qi, Hongbo Mu, Jianfeng Chen ,"A Transfer Residual Neural Network Based on ResNet-34 for Detection of Wood Knot Defects", offers classifying garbage using a CNN and an SVM algorithm. The ResNet-50 model is employed in this paper.

[5] Suchisrit Gangopadhyay and Anthony Zhai, " CGBNet: A Deep Learning Framework for Compost Classification," it segregates brown and green compost using computer vision, it used CGBNet to achieve an accuracy of above 95%.

[6] Karen Simonyan and Andrew Zisserman, "Very Deep Convolutional Networks for Large-Scale Image Recognition," the authors used several models and discovered that basic CNN networks operate effectively however residual blocks are present or not.

[7] Kashif Ahmad, Khalil Khan and Ala Al-Fuqaha, "Intelligent Fusion of Deep Features for Improved Waste Classification," introduces double fusion approach for image based waste material classification. It uses multiple deep learning models using a variety of fusion methods and significantly outperforms other models by 3.58%.

[8] P Ganesh and K Haridas, "Deep Learning Approach In Separation Of Biodegradable and Non-biodegradable and waste using Faster R-CNN, "This paper presented at the manual waste separation is risky and time-consuming.so an automated system is proposed in this paper.

[9] Haruna Abdu and Mohd Halim Mohd Noor, "A Survey on Waste Detection and Classification Using Deep Learning," Waste management systems are made up of a bunch of connected systems that do all sorts of complex tasks. Recently, deep learning has become popular as an alternative way of computing to tackle different waste or waste management issues.

[10] Youpeng Yu and Ryan Grammenos."Towards artificially intelligent recycling Improving image processing for waste classification.", presents WasteNet model which uses AI for waste classification. Using transfer learning and data augmentation, it had achieved a 95.40% accuracy.

III. Problem Statement

The growing issues of waste management throughout the world necessitate a creative solution. The project's objective is to develop a garbage segregation and collecting technology. The garbage is separated using the Convolutional Neural Network-based YOLOv8 model in such a manner that it may be recycled or re-used in the majority of cases. The primary goal of this article is to automate the process of garbage categorization and collection by using CNN to recognize distinct categories of waste. Because garbage is identified as reusable or recyclable, it is both environmentally and economically beneficial because the usage of physical labor is eliminated.

IV. Conceptual Model

YOLOv8:

You Only Look Once (YOLO) is a model of CNN. It is based on a deep neural network architecture, which is essentially a CNN used for recognizing, image segmentation, and classifying objects.

YOLO is made up of numerous layers of CNN and fully connected neural network layers that are being used for the extraction of information from photos and predict item bounding boxes and class labels. YOLO is a real-time object detection system capable of detecting and locating many items in a single picture or video frame.

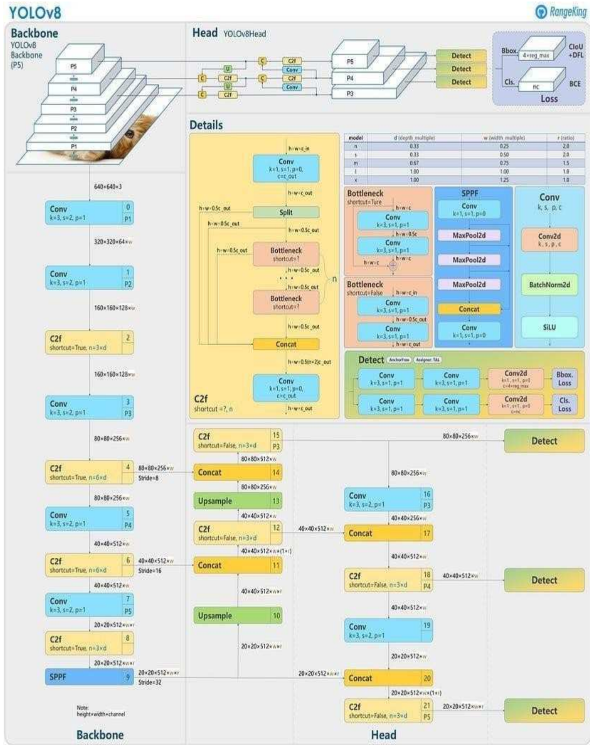


Fig.2.YOLOv8 Architecture

System architectural model :

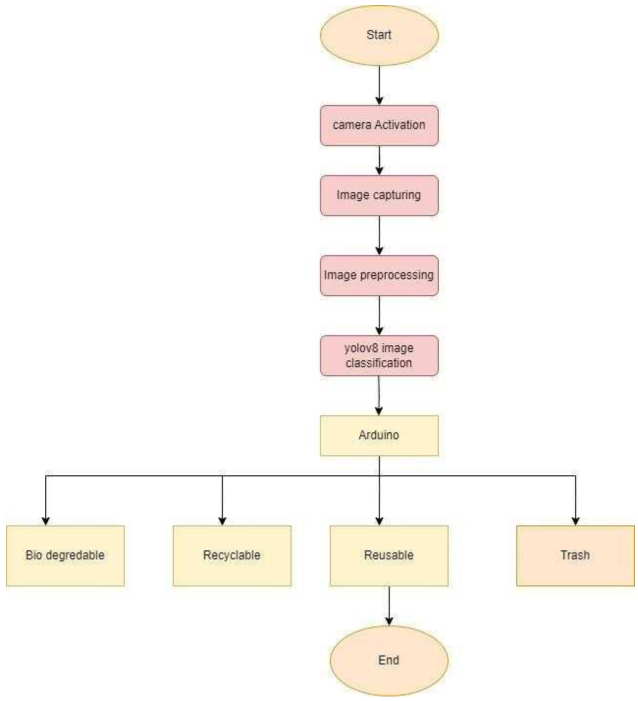


Fig.3.System Architecture

V. IMPLEMENTATION DETAILS

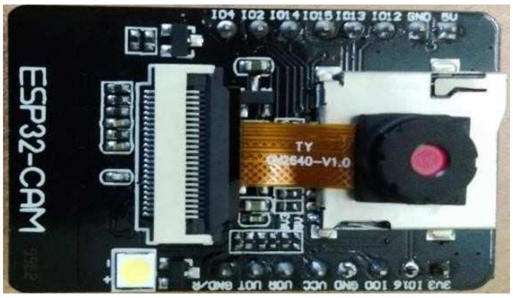
A. Hardware Components

These are the hardware components used in our project:

1. Servo motor: It is used to move the object on the conveyor belt into their respective bins.

2. Microcontrollers (Arduino UNO): The microcontroller used in our project to direct the servo motor to move in response to orders from the central control unit is called an Arduino UNO.

3. Camera module (ESP32 CAM): This microcontroller is used to capture the images and sends the images for processing it.



B. Software and Iot configuration

I. Software Platform:

Our system relies on the Arduino IDE as the foundation for seamless IoT integration. This platform provides the versatility required for effective communication with IoT devices. The Software used for processing the images is PyCharm and the software used for training the model is Jupyter Notebook.

II. IoT Device Configuration:

Each IoT device undergoes meticulous configuration to ensure it can communicate efficiently with the central control system. This includes network settings and firmware updates.

III. Communication Protocol:

Our system employs the UART for relaying commands and data between the central control system and IoT devices. This protocol enables real-time responsiveness.

IV. Data Handling and Processing:

The central control system processes and stores data from IoT devices. To extract the characteristics from the photos and determine the kind of garbage, pre-processing techniques are used.

V. Separation Module:

The central control unit commands the stepper motor to move the waste to it's corresponding bins.

These key configurations form the core of our CNN based smart waste segregation and collection systems.

C. Software Implementation

The suggested system's primary goal is:

1) Sort the garbage into its several categories, including trash, recyclables, reusables, and biodegradables.
2) To use CNN to make the segregation simpler, quicker, and more effective.
3) To use the YOLOv8 model for accurate prediction of waste in real time.

Methodology:

Data Preparation:

Collection and annotation of the dataset for our project. Annotation is done for each image with bounding boxes specifying the object's location and label. Create training, validation, and test sets from the dataset that has been produced.

Data augmentation generates new data from existing data by employing different transformation techniques such as flipping, altering the brightness, rotating, and changing the contrast. For the dataset's robustness, it is collected from diverse sources by recording videos and images with mobile phones and cameras in varied lighting situations, angles, and backdrops.

Training:

On the newly constructed dataset, the YOLOv8 model is trained. Based on the validation set, the loss and other performance parameters are tracked. The other model's training required a large amount of time and computer power. While YOLO has achieved high accuracy in object detection in real-time with high speed.

The Yolo process the images in a single step whereas other object detection algorithms use more than one number of steps during the data processing.

Performance:

The predictions done by the YOLOv8 model are evaluated for its performance on the validation and test datasets using several measures such as accuracy, precision, recall, and F1 score, necessary adjustments are taken to improve the model's performance. The model is fine tuned for increasing its prediction accuracy and for the faster real-timedetection and the classification of the data. Various deep learning models are analyzed and the YOLOv8 model is used for our project since it requires a swift real-time prediction of waste.

Visualization:

We use the above generated model to predict the waste images and had drawn bounding boxes on the input image to visualize the detected objects and their labels.

Formulas :

Accuracy of the system is calculated as:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \times 100\%$$

In order to reduce any problem that can result from imbalanced data, the performance measures were used to find the best model during the testing phase in addition to accuracy.

The performance measures are :

$$\text{Precision} = \frac{TP}{TP+FP} \times 100\%$$

$$\text{Recall} = \frac{TP}{TP + FN} \times 100\%$$

$$F1 \text{ score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \times 100\%$$

Accuracy is found by taking the arithmetic mean precision (mAP) of the average precision (AP) values of the classes

$$AP = \left(\frac{1}{n}\right) \Sigma_{Recall}\, Precision(Recall) = 1$$

$$mAp = \frac{1}{\mid \text{classes} \mid} \sum_{c\in \text{classes}} \frac{\#TP(c)}{\#TP(c) + \#FP(c)}$$

VI. RESULT AND DISCUSSION

The data we used to perform separation is divided into four classes (Bio-degradable, Reusable, Recyclable, and Trash). These classes are designed in such a way that we can separate the items into the appropriate category and encourage them to use it in an environmentally friendly manner rather than dumping all of the waste together.

The dataset we utilized for this study has 10,325 photos divided into four groups, with each class containing a different number of photographs, as seen in the bar graph below.

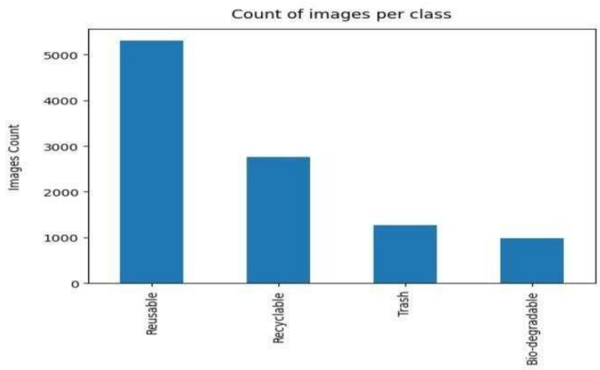


Fig.4.Image per class

The Example images of our dataset:

Fig.5. Dataset Images

The Model used to train is YOLOv8, which has given a high accuracy for classifying the classes in an efficient and effective way .

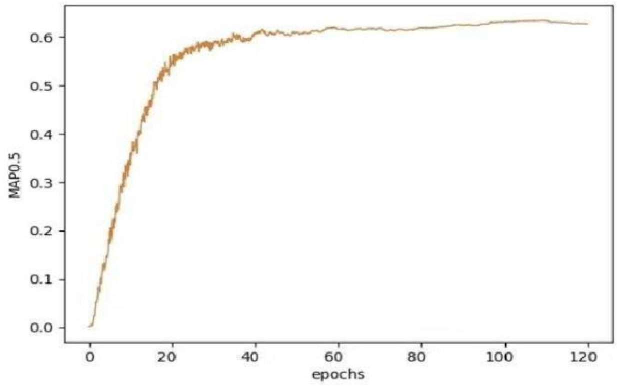


Fig.6. YOLOv8 mAP

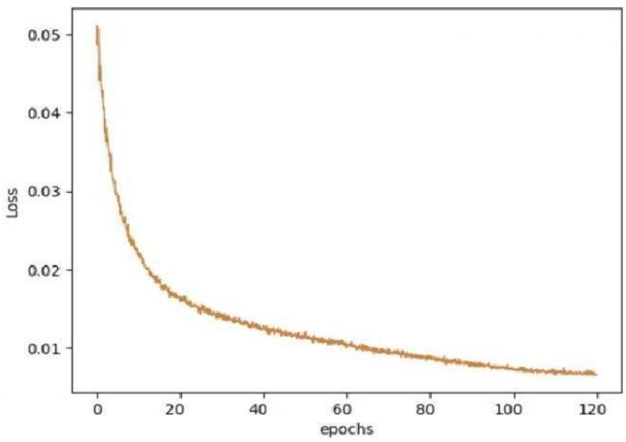


Fig.7. YOLOv8 Loss

The different models and their data are presented in the table below:

Model	Parameter	Model Size	mAP	FPS
YOLOv4-Tiny	9.57M	40 MB	53%	72
YOLOv4	24.49M	53.2 MB	62%	84
YOLOv8	38.25M	73.8 MB	70%	92

Fig.8. Models and parameters

This YOLO model for classifying the 4 classes has achieved a greater accuracy, which is show below.

	precision	Recall	Fi-Score	Support
Reusable	0.96	0.83	0.87	324
Recyclable	0.93	0.81	0.90	119
Trash	0.90	0.92	0.88	78
Bio-degredable	0.84	0.79	0.80	52
Accuracy			0.97	573
Macro avg	0.90	0.84	0.87	573
Weighted avg	0.85	0.85	0.85	573

Fig.9. Accuracy of classes

This table represents the comparison of different YOLO models and their data:

Model	Accuracy	Verification accuracy	Loss	Verification Loss
YOLOv4-Tiny	0.9265	0.9269	0.7982	0.7565
YOLOv4	0.932	0.9301	0.7798	0.7382
YOLOv8	0.961	0.9534	0.7425	0.7083

Fig.10. Comparision of Models

These are the images of the prediction of waste done using the custom trained YOLOv8 model:

Fig.11. Predicted Images

VII. CONCLUSION

The project represents a significant rise in the field of waste management, which increases the demand for a better solution for handling these massive amounts of garbage. This project provides a comprehensive solution for trash management that is both ecologically and economically beneficial. This project combines the capabilities of computer vision with a convolutional neural network to improve garbage segregation and collection into their appropriate collection sites. It lowers the dangers of the manual employees who are utilized to efficiently handle garbage.

VIII. ACKNOWLEDGEMENT

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