AI-Drive Plastic Waste Management: An Intelligent Solution For Sustainable Recycling Environment Conservation

Prof. A.P.Kulkarni[1], Omkar Bangar[2], Dnyaneshwari Gore[3], Karan Kawale[4], Sayali Gund[5]
[1]Project Guide, Dept of IT Engineering
[2, 3, 4, 5]Dept of IT Engineering
[1, 2, 3, 4, 5] Sinhgad Institute of Technology, Lonavala, India

Abstract- *Plastic waste is an issue for our environment because it takes a long time to break down. It just keeps piling up in cities, rivers and natural areas causing pollution and hurting animals. The main goal of this system is to find waste in pictures and videos. It uses lots of images of waste to teach a computer model called YOLOv8. After teaching the model can quickly and accurately spot waste in photos, videos and even live camera feeds. When the system finds waste it can help sort. Track it. This makes it easier to deal with waste in a way and make sure it is thrown away in a way that is friendly, to the environment. Overall this system helps find waste easily makes waste management better and keeps our environment clean.*

Keywords: Smart Waste Management, AI Powered Classification.

I. INTRODUCTION

Plastic waste is a global issue for our planet. As population growth in cities and urban areas continues, we are getting rid of more plastic items. This is because we use plastic; as it is affordable, durable and strong and can be used in a multitude of different ways. However, the downside to this is that plastic does not naturally break down or decompose.

This means that every time we put millions of tons of non-decomposed waste into a landfill, ocean, drainage system or in an urban environment, that creates pollution and degrades the natural environment. This affects land, wildlife (animals) and human beings.

Methods previously used for waste disposal, such as manual sorting and recycling of plastic waste, are inefficient. Manual sorting/recycling of plastic waste is tedious to perform, takes a lot of time and effort and cannot accommodate the tremendous amount of waste generated daily. Today, Artificial Intelligence (AI) is gaining popularity among environmentalists as a way to solve many of the world's waste problems, including plastic. AI is a technology that uses data to identify patterns in data, make decisions and perform work, without human assistance. If we are able to integrate AI into waste management, our processes of collecting, sorting, recycling and managing waste would be far improved. Additionally, AI has the capabilities of handling multiple large amounts of waste.

II. METHODOLOGY

1. Problem Identification

We need to figure out the issues with how we deal with waste now like sorting it by hand not being able to recycle it very well and not throwing it away properly. We want to make a system that uses intelligence to find classify and separate plastic waste accurately.

2. Data Collection

We have to get a lot of pictures of waste from different places like: , Public datasets from Kaggle, Roboflow and Open Images , Pictures taken in the real world , Industrial waste collection centers We need to include many kinds of plastic like: , PET bottles , Plastic bags , Containers , Packaging materials

3. Data Annotation

We label the pictures we collected using tools like Label Img and Roboflow. We draw boxes around the things in the pictures and give them the right labels so the system can learn from them.

4. Data Preprocessing

We make all the pictures the same size. We use techniques to make the pictures better: , We reduce the noise , We adjust the brightness , We make the contrast normal We also change the pictures a bit to help the system learn: ,We

rotate them , We flip them , We make them bigger or smaller , We cut them up

5. Model Selection

We choose an algorithm for finding objects, like YOLOv8. We choose it because it is fast, accurate and can work in time which is great for systems that are embedded.

6. Model Training

We split the pictures into groups: , 70% for training , 20% for validation , 10% for testing We use a computer chip to train the model faster. We try to find the settings for the model, like the learning rate, batch size and number of epochs.

7. Model Evaluation

We see how well the model works using numbers like: , Precision , Recall , F1-Score , Mean Average Precision We look at a table to see how accurate the model is.

8. Real-Time Detection Implementation

We connect the trained model to: , Pictures , Videos , Live webcam feed We can. Classify plastic waste in real time.

9. Automated Waste Segregation

We connect the intelligence system to machines: , Conveyor belt , Robotic arm, Sensors The system can separate plastic waste into the right bins automatically.

10. Performance Optimization

We try to make the system work faster. We try to make it work better in lighting. We try to reduce the number of answers.

11. Deployment

We put the model on: devices that can work on their own ,Raspberry Pi , Industrial automation systems ,Cloud platforms

III. LITERATURE REVIEW

Design for an Intelligent Waste Classifying System: A Case Study of Plastic Bottles describes a conveyor belt that can differentiate bottles based on whether they are transparent or opaque using a light-sensitive sensor. The system helps to lessen the need for manual labour, increase safety in the workplace, and provide an inexpensive option for small and medium scale recycling businesses to establish.

Collection of Plastic Packaging of Types:

Sorting Fractions of Plastic Waste Through Automated and Manual Means compares both automated and manual methods for sorting through plastic waste materials using near infrared/visible (NIR/VIS) optical sorting methodology. Results show that optical sorters provide more accurate sorting than manual methods; they are more efficient than manual methods, and they generate substantial economic and ecological benefits when compared to traditional, manual methods.

Turning Trash into Treasure:

Creating the Intelligent Bin for Plastic Bottle Recycling discusses an intelligent recycling bin that utilizes a Yolo v5 algorithm for identifying plastic bottles within range of the bin and rewarding users thereafter. This encourages individuals to recycle by providing timely rewards and recognizing users quickly—all the while detecting bottled plastic materials at an exceptionally high level of accuracy.

Detection of Recyclable Solid Waste:

In Solid Waste Image Classification Using Convolutional Neural Networks and PyTorch discusses a model that leverages the power of CNNs to classify solid waste materials accurately. This model is capable of correctly identifying the types of waste being disposed of, including various types of plastic; producing overall high levels of accuracy; and significantly improving the efficiency of winnowing operations upon specific materials being disposed of.

Ocean Waste Detection:

Deep Learning Based Object Detection Techniques for Ocean Based Detection of Plastic Waste outlines the deep-learning object detection methods used by current researchers for detecting and classifying plastic waste present in oceanic environments caused by human activities.

IV. SYSTEM ARCHITECTURE

An architecture description is an official picture and explanation of the construction and operation of a system, written such that you can use reason to describe each part and how the parts work together. The architecture and subsystems of a given system can also contain all the various pieces of a

system; when all those pieces come together they make up a larger, comprehensive, and functioning system, or unit as a result of those pieces fitting together. When completing the overall structure, there will be no gaps or inconsistencies; and both the parts and the whole unit will be constructed without any difficulty or extra work regarding the design of each part or the entire assembly. In addition to this, when properly fitting together each piece will have the ability to contribute to the overall operation of the unit in both type and quantity. This degree

of synergy allows each piece to operate as a part of the integrated unit; and thus both the parts and the unit can operate in harmony. In addition to those described above, many have attempted to formalize the languages used to describe architectures; all of these would collectively make up the architectures used for both system, sub-system and component architecture.

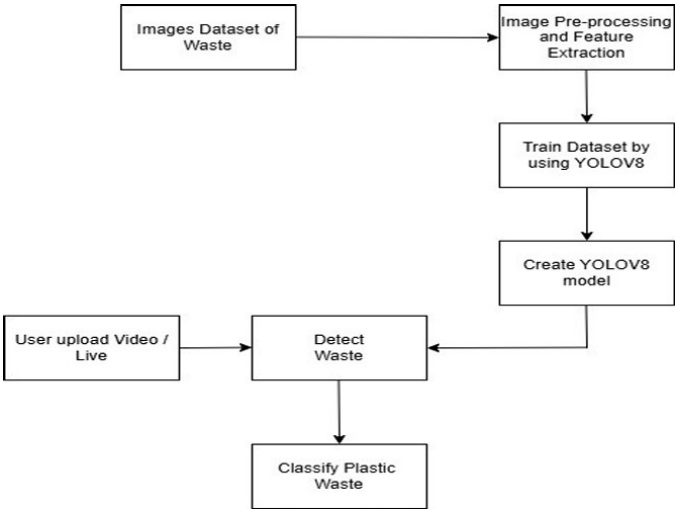


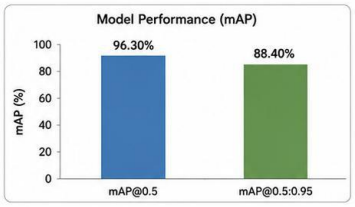
Fig : System Architecture

V. RESULT AND DISCUSSION

1. **Detection Results :** The system successfully detects plastic waste in images, videos and real-time webcam feed.

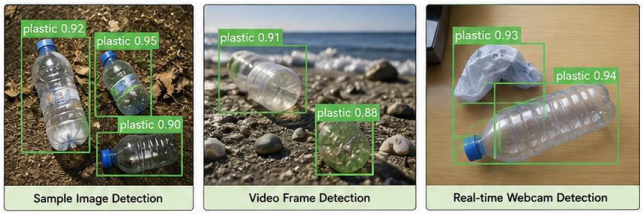
2. **Performance Metrics:** The model is evaluated using standard metrics: Precision, Recall, F1-score and mAP. The YOLOv8 model achieved high accuracy and reliable detection performance

Metric	Videe (%)
Precision	95.30
Recall	94.10
F1-score	94.70
mAP@0.5	96.20
mAP@0.5:0.95	88.40
Accuracy	95.60



3. **Confusion Matrix:** The confusion matrix shows that the model has very low false positives and false negatives, indicating strong classification capability.

4. **Robustness Evaluation:** The model maintains good accuracy in different lighting, backgrounds and object orientations.Works effectively on both single and multiple object detection.



VI. CONCLUSION

The goal of this project was to create a Plastic Waste Detection System that uses deep learning algorithms. This system is based on a technology called YOLOv8, which's very good at detecting objects. The Plastic Waste Detection System was trained on a lot of pictures to make it better at finding objects. To. Test the Plastic Waste Detection System, a collection of pictures of different types of plastic waste was made. Each picture was labelled with where the plastic waste came from and where it was found. The Plastic Waste Detection System can look at pictures, videos and live camera feeds to find waste in real time. It uses some techniques to make the pictures clearer and to find the parts of the pictures.The Plastic Waste Detection System can find and sort waste automatically so people do not have to do it by hand. This means that the Plastic Waste Detection System saves

people a lot of work and makes it easier to separate and recycle waste. If we add pictures to the collection the Plastic Waste Detection System will be even better, at finding plastic waste. The Plastic Waste Detection System is part of a plan to make waste management smarter and to help the environment by keeping track of plastic waste2.1 Modules

VII. FUT URE WORK

The Plastic Waste Detection System can be improved in a variety of ways. One possible improvement could be to add pictures of plastic waste to the system so that the system can be able to identify the waste. The photographs of plastic waste should be taken under different lighting and environmental conditions. This would improve the accuracy of the Plastic Waste Detection System, and it would allow for the accurate detection of plastic waste in a wide variety of situations. A second way to improve the Plastic Waste Detection System would be to allow it to differentiate between types of waste, such as paper, metal or glass, and food waste. This would allow for improved recycling and waste reduction. Connecting the Plastic Waste Detection System to smart bins that can communicate with the Internet could allow for the automatic sorting of plastic waste. This would also allow for a better understanding of plastic waste. Placing the Plastic Waste Detection System on devices, such as Raspberry Pi or drones, would allow for usage outside of the home. Furthermore, if the Plastic Waste Detection System could operate faster while using less power than it currently does, it could benefit devices with limited power availability. Adding conveyor belts or robotic arms to the Plastic Waste Detection System would create an automated processing station for waste.

REFERENCES

[1] O.Adedeji and Z. Wang, “Intelligent waste classification system using deep learning convolutional neural network,” Procedia Manufacturing, vol. 35, pp. 607-612, 2019.

[2] Z. Yang, Y. Bao, Y. Liu, Q. Zhao, H. Zheng, and Y. Bao, “Research on deep learning garbage classification system based on fusion of image classification and object detection classification,” Mathematical Bioscience and Engineering, vol. 20, no. 3, pp. 4741-4759, 2023.

[3] M. Malik, S. Sharma, M. Uddin, C. L. Chen, C. M. Wu, P. Soni, et al., “Waste Classification for Sustainable Development Using Image Recognition with Deep Learning Neural Network Models,” Sustainability, vol. 14, no. 12, pp. 7222.

[4] G. di Foggia and M. Beccarello, “Drivers of municipal solid waste management cost based on cost models inherent to sorted and unsorted waste,” Waste Management, vol. 114, pp. 202-241, 2020.

[5] H. Bartelings and T. Sterner, “Household waste management in a Swedish municipality: Determinants of waste disposal, recycling, and composting,” Environmental Resource Economics, vol. 13, no. 4, pp. 473 491, 1999.

[6] M. Thumiki and A. Khandelwal, “AI-powered waste classification for industry 4.0,” 2022 IEEE International Students’ Conference on Electrical, Electronics and Computer Science (SCEECS), 2022.

[7] D. Khetarpal, I. Khetarpal, D. Rawat, H. Narang, S, Vats, and V. Sharma, “Smart waste management in industry 4.0,” 2024 OPJU International Technology Conference (OTCON), 2024.

[8] S. Majchrowska, A. Mikolajczyk, M. Ferlin, Z. Klawikowska, M. A. Plantykow, A. Kwasigroch, and K. Majek, “Deep learning-based waste detection in natural and urban environments,” Waste Management, vol. 138, pp. 274-284, 2022

[9] Glouche, Yann, and Paul Couderc. "A smart waste management with self-describing objects." The second international conference on smart systems, devices and technologies (SMART'13). 2013.

[10] Vij, Dimpal. "Urbanization and solid waste management in India:present practices and future challenges." Procedia-Social and Behavioral Sciences 37 (2012): 437-447.

[11] Moh, YiingChiee. "Solid waste management transformation and future challenges of source separation and recycling practice in Malaysia." Resources, Conservation and Recycling 116 (2017): 1-14.

[12] Ghahramani, Mohammadhossein, et al. "IoT-based route recommendation for an intelligent waste management system." IEEE Internet of Things Journal 9.14 (2021): 11883-11892.

[13] Fang, B., Yu, J., Chen, Z. et al. Artificial intelligence for waste management in smart cities: a review. Environ Chem Lett 21, 1959 –1989(2023).

[14] Andeobu, L., Wibowo, S., & Grandhi, S. (2022). Artificial intelligence applications for sustainable solid waste management practices in Australia: A systematic review. The Science of the Total Environment, 834(155389),