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Plastic Waste Identification Using Deep Learning for Adequate Waste Management

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Abstract

Plastic waste management has emerged as a critical global challenge, prompting concerted efforts from conservation authorities and international organizations like the United Nations to enhance detection and classification strategies. This research distinguishes itself by harnessing advanced deep learning techniques to identify plastic materials at the micron level, surpassing traditional macro-level methods. The primary goal is to classify plastics into four major distinctions, addressing a key challenge in plastic segregation by accurately measuring thickness. Leveraging the YOLOv8 architecture, this approach enables precise classification of plastics into Polyethylene terephthalate (PETE), High Density Polyethylene (HDPE), low density polyethylene (LDPE0, and Polyvinyl Chloride (PVC) categories based on thickness. To achieve this, incorporation of hardware components such as ultrasonic sensors and NodeMCU for detecting thickness variations is used. By facilitating effective segregation according to environmental impact, this innovation revolutionizes waste reduction efforts, offering real-time identification and enhancing overall sustainability in plastic waste management.

Keywords: Deep Learning, Real-Time Identification, Micron Level, YOLOv8

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1. Introduction

The increasing use of plastic and the low recycling rates pose a significant environmental challenge. With only 9 percentage of plastic being recycled, a vast amount ends up in our oceans, causing harm to marine life and ecosystems. To address this issue, a research is proposed that focuses on the identification and sorting of plastic materials at the micron level using advanced technologies such as image processing, artificial intelligence (AI), and deep learning. Traditional methods of plastic categorization are time-consuming and expensive. Automating the sorting process through advanced technologies can significantly enhance recycling efforts and waste management. By implementing AI and deep learning techniques, the research aims to create a system capable of accurately identifying different types of plastics based on microscopic features. This would streamline the recycling process and improve the overall efficiency of plastic waste management. The root cause of excessive waste production often lies in irrational material management. Some plastics, such as single-use plastics, contribute significantly to environmental pollution and can be avoided. However, certain plastics are integral to our daily lives, and complete elimination may be challenging. In such cases, the focus shifts towards finding innovative ways to reuse plastic materials.

When limiting plastic consumption is not entirely feasible, exploring methods for reusing plastics becomes crucial. This can involve initiatives such as creating products from recycled plastics, encouraging the use of eco-friendly alternatives, and promoting a circular economy where plastics are reused and recycled rather than discarded after a single use. Reusing plastic 1 materials not only reduces the demand for new plastic production but also minimizes environmental impact and contributes to a more sustainable approach to plastic usage. In summary, the proposed research aims to address the plastic waste crisis by leveraging advanced technologies for automated plastic sorting. Additionally, the broader perspective emphasizes the importance of responsible plastic consumption and explores ways to minimize environmental impact through the innovative reuse of plastic materials.

2. Related Work

So much of systems have been developed for the identification and classification of plastics. But the existing systems are not capable of identifying different types of plastics with their micron level. The study [1] introduces methods for identifying plastic waste using resin identification codes to improve recycling efficiency, achieving 99.74% accuracy with one-shot learning techniques like Siamese and Triplet loss networks for known categories. Even though supervised and unsupervised dimensionality reduction techniques achieve 95% accuracy, it has limited generalization and less classification accuracy for multiple objects within a single class. Developing automated methods [2] using deep learning, especially convolutional neural networks, to efficiently sort plastic waste from other garbage on conveyor belts is crucial for managing plastic pollution. These methods enable the identification and sorting of different types of plastic, facilitating recycling efforts and addressing environmental concerns in cities. Improving plastic identification and classification using the RGB method [3], expanding beyond previous research focusing on PET and HDPE, include three plastic types for higher accuracy. RGB values are extracted, creating a comprehensive database for precise plastic identification and classification. This methodology combines advanced imaging technology with meticulous data processing for improved waste management and environmental conservation efforts. The research [4] introduces Aqua Trash, utilizing Aqua Vision, a deep learning object detection model, achieving a mean Average Precision (mAP) of 0.8148, effectively detecting and classifying pollutants in oceans and on seashores. This method not only identifies but also localizes waste objects, aiding in cleaning water bodies and conserving the aquatic ecosystem[5,6]. The research aims to track plastic products from garbage dumps to manufacturers using an Android app. Citizens report plastic waste through the app, which captures images and uses YOLOv3 for automatic analysis, storing data in a MySQL database for monitoring and managing plastic waste efficiently. The method [7] presents a plastic detection scheme using deep learning for waste plastics sorting systems, emphasizing the importance of preliminary sorting for resource optimization. The scheme enhances YOLOX and DeepSORT algorithms, integrating data augmentations and optimization techniques for effective detection and tracking. Experimental results show efficient realtime plastic detection, though challenges remain with sorting uneven or smooth materials. Conventional methods for detecting and quantifying ocean plastics have limitations, necessitating exploration of alternative methods. The method [8] explores YOLOv4 and YOLOv5 deep learning algorithms for identifying marine plastics, using augmented datasets sourced from the internet. Evaluation of Mean Average Precision (MAP) shows promising performance, providing insights into algorithmic intricacies and results analysis [9-14].

3. Proposed Work

The proposed system integrates deep learning technology with an ultrasonic sensor and NodeMCU to address plastic pollution and optimize waste management. It begins with the collection and annotation of a diverse dataset of plastic images, detailing micron values, plastic types, and recyclability status. Through deep learning techniques like Convolutional Neural Networks, the system trains a model to accurately classify plastics based on visual characteristics and micron size thresholds, distinguishing between recyclable and non-recyclable plastics. Integrated into waste management processes, the system utilizes an ultrasonic sensor with NodeMCU for real-time micron value detection, enabling precise plastic categorization. Cameras or scanning devices equipped with this technology capture images of incoming plastic items, feeding data into the model for instant identification and sorting. Continuous refinement through feedback loops ensures improved accuracy over time. Educational outreach accompanies system implementation to raise awareness about plastic identification and recycling practices. This comprehensive approach aims to enhance waste management effectiveness, reduce environmental harm, and advance sustainability goals.

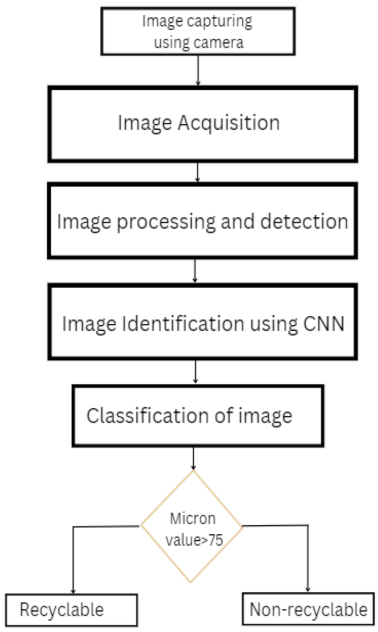

Figure 1. Flow Diagram

The plastic identification system outlined in Figure 1. represents a holistic and adaptive approach to enhance the efficiency of waste management through the amalgamation of deep learning image recognition and thickness detection sensors. The architecture commences with a robust data acquisition phase, where a camera captures high resolution images of incoming waste objects, while thickness sensors measure the plastic's thickness at different points. Materials with a thickness surpassing 75 microns are categorized as recyclable, while those with a thickness below this threshold are designated as non-recyclable.

The subsequent data preprocessing stage integrates image processing techniques, enhancing visual features, and synchronizes thickness measurements with corresponding images. This pre-processed data feeds into a convolutional neural network (CNN) as part of the deep learning model. Trained on a diverse dataset encompassing various plastic types, colors, shapes, and sizes, the CNN extracts features from images and combines them with thickness data for accurate plastic type prediction.

Continuous system monitoring and feedback loops ensure ongoing accuracy by comparing predictions against manually verified samples. Periodic model retraining on new data or improvements to the CNN architecture further enhances adaptability to changes in the waste stream. Real-time processing capabilities enable the system to make swift predictions, crucial for maintaining efficient waste sorting operations.

a. Frontend

HTML provides the structure, CSS styles the elements, and JavaScript adds interactivity. Bootstrap, a CSS framework, offers pre-designed components for responsive and visually appealing web design. Together, these technologies form the core of frontend development for this system.

b. Backend

Python with Django and SQLite is a streamlined stack for backend web development. Django simplifies web app creation with tools for URL routing, database interaction, and more, while SQLite offers a lightweight, serverless database solution.

c. Dataset

The deep learning model is trained using extensive datasets comprising 500 images for PETE, 400 for HDPE, 600 for LDPE, and 400 for PVC. This rigorous training process ensures high accuracy in classifying plastic materials. By exposing the model to diverse samples of each plastic type, it becomes adept at discerning subtle differences in composition and thickness, enabling precise identification in real-world scenarios. This comprehensive training approach enhances the model's ability to accurately classify plastics at the micron level, contributing to more effective waste management strategies and environmental conservation efforts.

4. Results and Discussion

This research focus on the classification of plastics based on the data collection done. The figures show the classification of plastics based on the 4 types. The type of plastics includes PVC, HDPE, LDPE and PETE. The input data is fed into the model, which uses CNN to compare it with the trained dataset. The model then categorizes the plastics into various types accordingly. Figure 2 shows the home page of the system which consists of three main classification methods. The first method classifies the uploaded image by comparing it with the trained dataset. It is shown in Figure 3. The live method produces output based on the plastic waste detected by the camera which is shown in Figure 4. An invalid output message is displayed as shown in Figure 5 for non-plastics. The result from the hardware unit is depicted in Figure 6 and Figure 7 which classifies the plastic waste as recyclable or non- recyclable based on micron value.

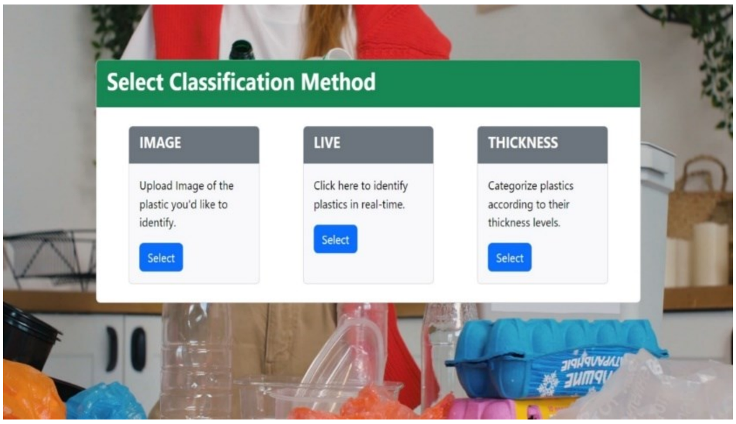

Figure 2. Home Page

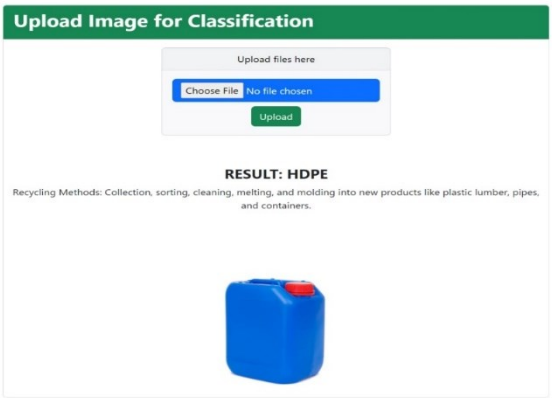

Figure 3. Uploaded Image Classification

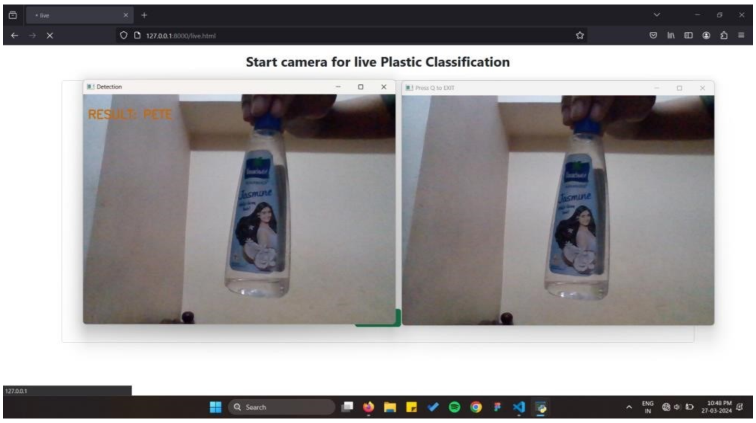

Figure 4. Plastic Waste Classification using Live Method

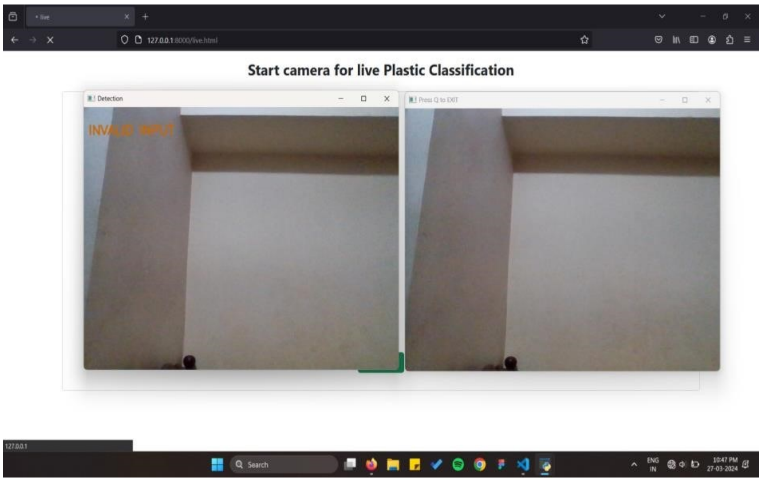

Figure 5. Invalid Input

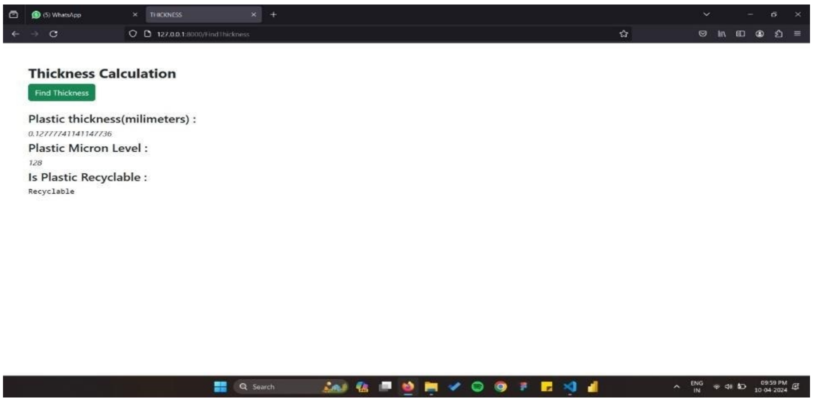

Figure 6. Sensor Output (Recyclable)

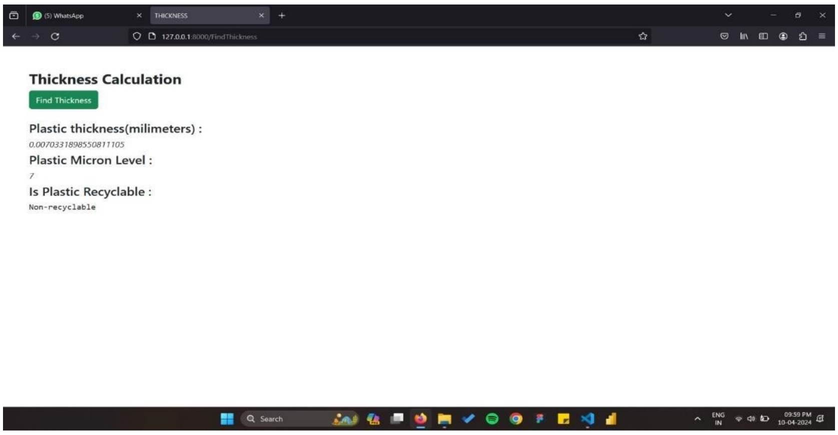

Figure 7. Sensor Output (Non-Recyclable)

5. Conclusion

Utilizing deep learning for plastic waste identification holds significant promise for enhancing waste management practices. Through the development and deployment of accurate models, it becomes possible to automate the sorting and recycling process, reducing the environmental impact of plastic pollution. Employing micron-level plastic waste identification methods offers a more efficient means of determining recyclability. This approach streamlines the sorting process, facilitating more effective waste management practices. Furthermore, it empowers consumers and recycling facilities to make informed decisions, ultimately reducing contamination in recycling streams and promoting a circular economy. Implementing plastic identification technology can greatly benefit municipal authorities and waste collectors by reducing the risk of disease transmission. By accurately identifying recyclable plastics, waste collectors can handle materials more safely, minimizing direct contact with potentially hazardous substances. This not only protects the health and well-being of waste collectors but also contributes to overall public health by reducing the spread of diseases. Furthermore, improved waste sorting through identification technology enhances the efficiency of recycling processes, ultimately leading to cleaner and healthier communities.

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