Waste Classification Through Image Processing

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Abstract

For a green and eco-friendly environment for future generations, there is a need to sustain the ecosystem. It is crucial to prevent waste and manage it in a manner that is categorized into recyclable and non-recyclable categories. Our waste classification technique used a powerful object detection model YOLOv7, which allows for optimal waste classification compared to its previous older version, YOLOv5. The dataset included around 16000 annotated images, which was categorised into six different classes; biodegradable, cardboard, glass, metal, paper, and plastic. The research highlights the importance of using YOLOv7 as a favourable option for waste classification from images. We have compared the results of YOLOv7 and YOLOv5 through the help of precision and recall graphs.

Index Terms

Waste Detection, Waste Management, YOLOv5, YOLOv7, Deep Learning.

I. Introduction

In the era of urbanization, productive and effective waste management is now needed more than ever for a sustainable environment. According to the World Bank, global annual waste production is going to increase up to 3.4 billion tonnes over the next 30 years [1]. For this matter to be resolved, this paper aims to provide an improved method of sustainable waste management system with the help of powerful methodologies like Digital Image Processing and Deep Learning [2].

There is a need for technological advancement in waste management systems because using the conventional method for detecting waste is time-consuming, labor-intensive, and prone to human errors. Image Processing uses algorithms to manipulate, process, or restore images. This branch of computer vision has revolutionized the course of action of processing images. Researchers have used Digital Image Processing along with Deep Learning Algorithms to efficiently sort waste images into different sub-classes, making the process significantly easier. The efficient sorting of waste into recyclable and non-recyclable categories not only holds sustainability significance but also reduces the exposure of human to harmful waste.

To understand how Image Processing makes waste classification possible, we need to understand the working principles of algorithms that can perform image recognition. Initially, we will be discussing the previously done work and research on waste image classification techniques in section 2. Then, we move on to our method of performing waste image classification with the help of the YOLOv7 (You Only Look Once) model. Not only that, we will also compare the results from the YOLOv7 with its previous version YOLOv5 in sections 3,4 and 5. To summarize our venture of waste management, we will conclude our findings in section 6.

II. Literature Review

An immense amount of research has been going around to build an efficient waste management system. Several machine learning models are being used for the classification of waste. To begin with the history of these models, we will start our discussion with already published research in Waste classification and detection.

Computer Vision is a field of artificial intelligence that deals with training computers to understand the visual world. Object detection and image classification are two popular applications of this field [3]. Object detection involves identifying objects in images and image classification is predicting the class of an object in the image. With computer vision and popularity of deep learning combined in previous decades, several models of object detection were produced. A research on YOLO (You Only Look Once) model was performed in 2020, that implemented an YOLOv3 model for waste detection in real-time video, contributing to efficient waste management [4]. Another research focused on Deep Learning Algorithms for Underwater Trash Detection explored YOLOv2, Tiny-YOLO, Faster RCNN, and SSD for underwater trash detection, achieving varying mean Average Precision (mAP) scores [5]. Automatic Trash Detection System with Narrowband IoT proposed a system using an improved YOLOv2 for automatic trash detection and identification, employing the narrowband Internet of Things [6]. A Trash Classification study experimented with Fast RCNN for classifying different waste types, achieving a mean Average Precision (mAP) of 0.683 [7]. Another research focused on Object Classification with the help of Trashnet dataset with SVM and CNN models for classifying trash objects, demonstrating the efficacy of SVM in certain scenarios [8]. A new model RecycleNet for Recycling Object Classes was developed which used a deep convolutional neural network, for classifying recyclable object classes using the Trashnet dataset [9]. Another honorable work was Multilayer Hybrid System for Strong Image Features which outperformed CNN when waste items lacked distinguishing image features [10].

In this research, we decided to use the popular object detection model YOLOv7 (You Only Look Once). The reason to use YOLOv7 is that it was released in 2022, therefore most of the waste detection research has been done on previous versions of YOLO. We aim to highlight this powerful object detection tool, which can enhance and improve waste management systems.

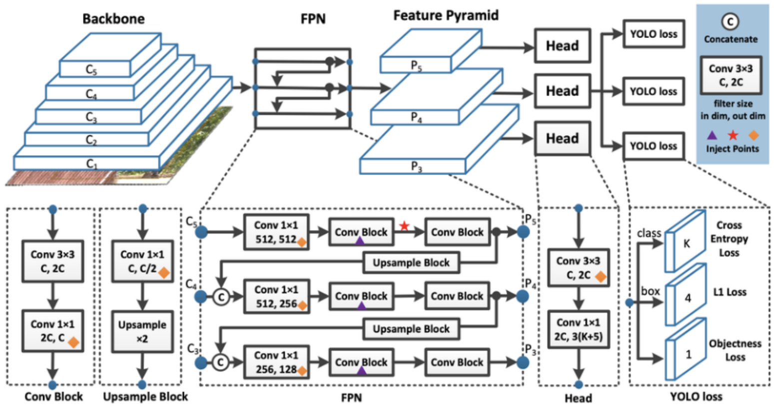

Fig. 1: YOLO network architecture

III. Methodology

This study involves the use of the newly launched YOLOv7 training model, which has not been repeatedly tested with garbage datasets. Figure 1 shows the network architecture used by the family of YOLO models. The architectural innovations in YOLOv7 are what makes it stand out in front of its previous versions. The YOLOv7 model introduces Extended Efficient Layer Aggregation Networks (E-ELAN) to enhance its computational blocks while preserving the integrity of the transition layer architecture. Through the use of group convolution, E-ELAN expands both channel and cardinality within computational blocks, a departure from conventional methods, resulting in a more diversified learning of features while retaining the original ELAN design [11].

Another improvement in YOLOv7 is its model-scaling strategies, it adopts a novel approach to model scaling specifically designed for concentration-based models. In contrast to traditional scaling methods that encounter challenges in concatenation-based models due to intricate dependencies between depth and width, YOLOv7 employs a compound scaling method. This method adeptly adjusts both factors concurrently, ensuring a harmonious modification that maintains the intrinsic properties of the model [11].

Our research employs a self-prepared dataset comprising approximately 16,000 images of multiclass garbage instances captured in a real-world environment, characterized by cluttered backgrounds. The performance evaluation of the recently released YOLOv7 model is conducted using our unique dataset of real waste images. Our dataset had annotated images of six different classes, biodegradable, cardboard, glass, metal, paper, and plastic.

IV. Implementation Details

In the implementation phase of our waste detection and classification project, we used Kaggle Notebooks as our primary platform for training YOLOv7 and YOLOv5 models. Kaggle Notebooks provided us with powerful GPUs and collaborative environment, enabling us to efficiently execute and share code, datasets, and results. For our specialized task of detecting waste images and classifying them into six differnet categories—biodegradable, glass, metal, plastic, cardboard, and paper—we used the YOLO (You Only Look Once) architecture, renowned for its real-time object detection capabilities. YOLOv7, the latest version, and YOLOv5, a widely adopted and older version, were chosen for their effectiveness and robust performance. The Kaggle platform facilitated streamlined access to powerful GPU P100, crucial for the computationally intensive training process. Additionally, Roboflow Universe was used to access diverse datasets, allowing us to create a varied and representative dataset for training. There were almost 16000 images present in our dataset. We implemented our waste detection and classification models, trained them on Kaggle, achieving accurate categorization of waste images across the specified six categories in best.pt file. Then we were able to use this resulting file with detect.py file (provided in appendix A) to detect waste in any given image.

We used Tkinter library of Python to create a GUI for our YOLOv7 model. The GUI is given in Figure 2, where input and output images are shown side by side. The output images had the objects detected in the shape of a square, and the number of objects detected was shown at the bottom of the image.

V. Experimental Results

This analysis is focused on comparing the performance of YOLOv7 and YOLOv5 based on precision and recall metrics. Precision emphasizes the accuracy of positive predictions, while recall highlights the model's ability to capture all positive instances.

Fig. 2: An image tested on our GUI developed on YOLOv7 model

A. Precision Analysis

1) Precision at High Confidence Levels: Precision is a pivotal metric in scenarios where false positives can have significant consequences. YOLOv7 showcases an impressive precision of 1.00 at a confidence threshold of 0.930 as seen in figure 3, outperforming YOLOv5, which achieves the same precision but at a higher confidence threshold of 1.000 which can be seen in figure 4. YOLOv7's ability to maintain perfect precision at lower confidence levels suggests its superiority in applications where a balance between precision and recall is crucial.

2) Precision Across Different Classes: Both models exhibit expected behavior, with precision generally increasing as confidence levels rise for individual classes. This consistency is essential for applications with diverse object classes, ensuring reliable predictions across the board.

3) Average Precision Across All Classes: The average precision across all classes reaching 1.00 in both models signifies their capability to achieve high accuracy. However, the distinction lies in the confidence levels at which this precision is attained, indicating YOLOv7's potential for superior accuracy at lower thresholds.

4) Robustness and Reliability: The width of the precision curve is indicative of a model's robustness. YOLOv7's wider curve suggests it maintains high precision over a broader range of confidence levels, enhancing its reliability in real-world scenarios.

5) Model Comparison: Based on precision metrics alone, YOLOv7 emerges as the preferred choice, offering higher precision at lower confidence thresholds compared to YOLOv5. This characteristic is crucial in applications where minimizing false positives is paramount.

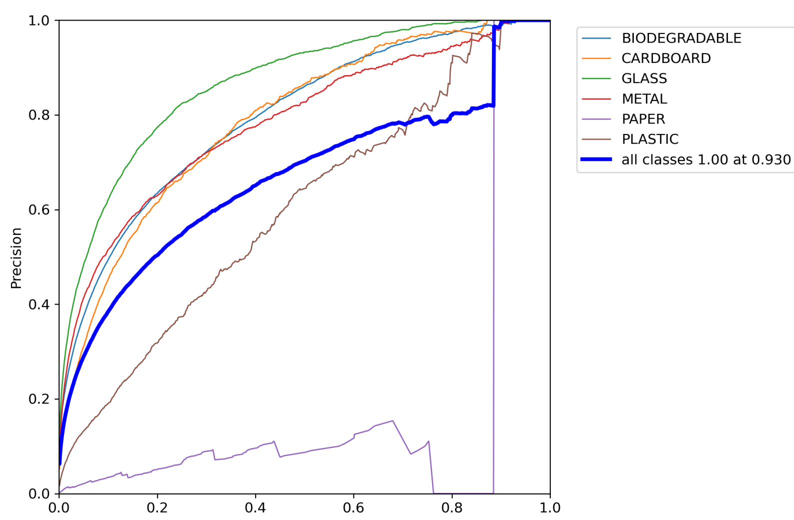

Fig. 3: Precision-Confidence graph of YOLOv7

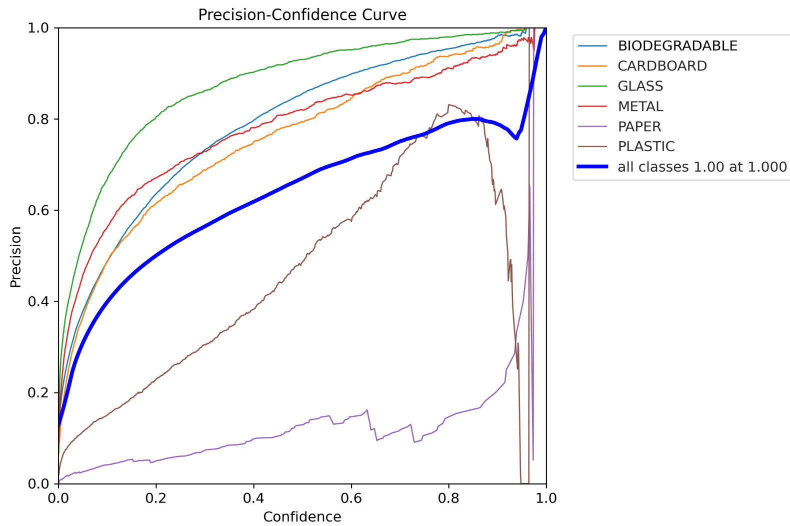

Fig. 4: Precision-Confidence graph of YOLOv5

B. Recall Analysis

1) Overall Recall Across All Classes: YOLOv7 starts with a higher overall recall of 0.81 as highlighted in figure 5, indicating its ability to detect more positive cases at the lowest confidence threshold. YOLOv5 starts at a slightly lower starting recall value of 0.77 as seen in figure 6. As confidence increases, both models experience a decline in recall, emphasizing the trade-off between inclusivity and precision.

2) Model Comparison: While YOLOv7 initially exhibits a superior overall recall, the differences diminish as confidence levels rise. The individual class performance remains comparable, with YOLOv7 having a slight edge at certain confidence levels.

C. Overall Comparison

1) Precision vs. Recall: The comparison between precision and recall further solidifies YOLOv7's superiority. Its early achievement of high precision, coupled with a higher initial recall, positions it as a versatile choice catering to applications where both precision and recall are crucial.

Choosing between YOLOv7 and YOLOv5 depends on the specific needs of the application. YOLOv7 excels in scenarios where high recall is essential, making it suitable for applications prioritizing the detection of positive cases. Simultaneously, its superior precision at lower confidence levels makes it a strong contender in precision-sensitive applications. YOLOv5, with

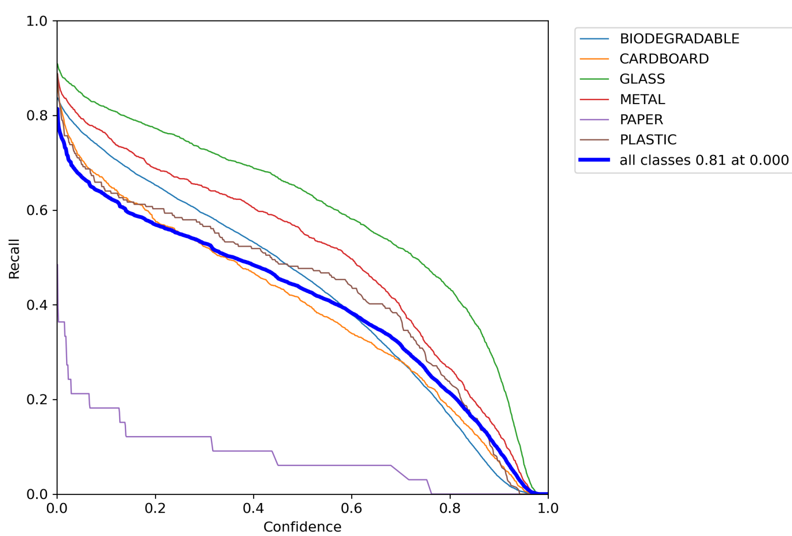

Fig. 5: Recall-Confidence graph of YOLOv7

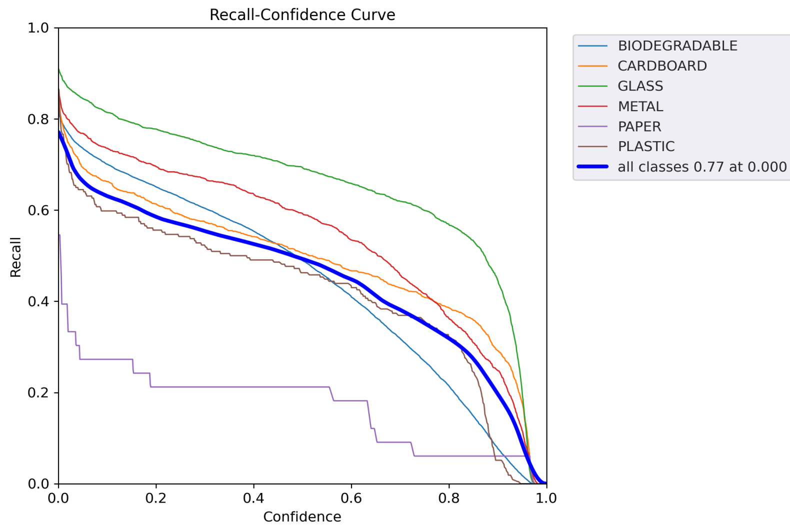

Fig. 6: Recall-Confidence graph of YOLOv5

its perfect precision at high confidence, may be preferred in situations requiring utmost certainty in predictions, albeit with a more conservative approach. Ultimately, the decision hinges on the nuanced requirements of the application, balancing the importance of precision and recall in achieving optimal model performance.

VI. Conclusion

Efficient sorting of waste is crucial for an eco-friendly environment. In this research, we were able to face the challenge of identifying objects in waste images and classifying them into six different classes using YOLOv7. We also compared the performance of YOLOv7 with its previous version YOLOv5. The comprehensive and rigorous comparison of both models gave us the final deduction that YOLOv7 was superior in both precision and recall when compared with YOLOv5. In the era, when there is a continuous rise in research of powerful waste classification systems, YOLOv7 holds as a favourable option. Our future directions will include to work with larger datasets with new classes added in it, so that our detection model can make stronger predictions.

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https://universe.roboflow.com/material-identification/garbage-classification-3/model/2

Special thanks to WongKinYiu for providing us with open-source YOLOv7 model.
https://github.com/WongKinYiu/yolov7

Special thanks to ultralytics for providing us with open-source YOLOv5 model.
https://github.com/ultralytics/yolov5

Appendix A

The code that we have used to train our models of YOLOv7 and YOLOv5 can be found in this repository, which can be used to understand our project and future directions.
https://github.com/ZainabbHaider/ADIP-Project-final

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