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Implementation of YOLO V8 Algorithm in Organic and Anorganic Waste Detection Application for Waste to Energy Management

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Abstract

Waste management in Indonesia is a major challenge, especially in the development of waste to energy (WTE). Accurate classification of organic and inorganic waste is required to optimise energy conversion. This research develops an automated waste detection system in temporary landfill sites (TPS) using the YOLOv8 algorithm, known for its high speed and accuracy. The research involved data collection, development of a YOLOv8-based computational model, and system construction and testing according to field requirements. The results show that YOLOv8 has high performance in detecting organic and inorganic waste, with 99.35% accuracy, 98.6% precision, 98.6% recall and 98.5% F1 score. This system can speed up the waste sorting process and has the potential to be used in domestic and public environments for the automatic detection of waste categories.

Keywords: *Waste Detection; Waste to Energy; You Only Look Once (YOLO) v8*

Abstrak

Pengelolaan sampah di Indonesia menjadi tantangan utama, terutama dalam pengembangan Waste to Energy (WTE). Klasifikasi sampah organik dan anorganik yang akurat diperlukan untuk mengoptimalkan konversi energi. Penelitian ini mengembangkan sistem deteksi sampah otomatis di Tempat Pembuangan Sementara (TPS) menggunakan algoritma YOLOv8, yang dikenal memiliki kecepatan dan akurasi tinggi. Penelitian ini melibatkan pengumpulan dataset, pengembangan model komputasi berbasis YOLOv8, serta pembangunan dan pengujian sistem sesuai kebutuhan lapangan. Hasil menunjukkan bahwa YOLOv8 memiliki performa tinggi dalam mendeteksi sampah organik dan anorganik, dengan akurasi 99,35%, presisi 98,6%, recall 98,6%, dan F1-score 98,5%. Sistem ini dapat mempercepat proses pemilahan sampah dan berpotensi diterapkan di lingkungan rumah maupun area publik untuk deteksi otomatis kategori sampah.

Kata kata Kunci: Deteksi Sampah, Waste to Energy, YOLOv8.

1. Introduction

Waste is material left over from human activities that is a source of concern for many people due to the lack of awareness of the importance of disposing of waste in appropriate locations. Based on data from 111 districts / cities throughout Indonesia in 2023 obtained from the Ministry of Environment and Forestry Directorate General of Waste Management, Waste and Hazardous Waste Management Directorate of Waste Handling, that waste generation in 2023 resulted in 17,931,137.45 tons / year with the composition of Indonesian waste in the form of organic waste (food waste, wood branches, leaves) by 41.3%, plastic waste by 19%, paper waste 11.2%, and others (metal, textile fabrics, leather rubber, glass) 18.3% and the largest contributor of waste from household waste **[1].**

This behavior contributes to various daily problems and environmental pollution that can occur when waste is not managed properly. Currently, waste management and recycling efforts are still constrained by limited technology that can support system improvements. This is crucial considering the significant impacts on human health, safety, and the environment. Effective management strategies for both organic and inorganic waste are needed to avoid future risks.

Failure to manage waste effectively leads to the accumulation of waste that produces unpleasant odors and can be a medium for spreading diseases. The lack of attention and responsibility from the community towards environmental cleanliness makes the waste issue a serious challenge. Furthermore, the limited access of sanitation workers to waste management information technology results in a slowdown in the waste handling process. Having up-to-date information on the capacity of waste bins can help avoid excess accumulation of waste and prevent the spread of diseases. Therefore, an important step to take is recycling waste to prevent accumulation.

The process of recycling waste is done differently according to its type. Organic waste can be recycled into compost or biogas. Non-organic waste can be recycled by re-molding including printing or re-melting without reducing the quality of the dry waste. The process of sorting types of waste consists of two categories, namely organic and non-organic waste. Waste sorting is generally done manually but this method is less effective, because as a result of the lay knowledge of the community, including students about the types of waste and continue to mix waste into one place.

Thus, an application or system is needed that can automatically detect waste from organic and non-organic waste by using a camera on the trash can. The purpose of this research is to develop a system that is able to identify the type of waste and provide notifications when there is garbage that is not placed according to its category. In addition, this research will integrate a visual component that can display a warning if the garbage disposed of does not match the group. This research is expected to be utilized and used by the community in landfills both in the neighborhood and public places to automatically detect the categories of organic and non-organic waste.

To build a real-time detection system, an object detection system is needed with the help of a camera. Object detection is a process used to determine the presence of certain objects in a digital image **[2].** Basically YOLO is an object detection approach that uses convolutional neural networks for object detection **[3], [4]**. As in research **[5]** for Mask Product Defect Detection using YOLOv5 obtained weight with a MAP (Mean Average Precision) value of 0.92 and all mask objects can be detected properly with an accuracy level of 97.1%, then research **[6]** explains how the implementation of YOLOv3 to identify and classify office waste in the form of paper, plastic bottles and cans by producing object detection accuracy of 94%. Previously, research has also been carried out related to the manufacture of organic and non-organic waste sorting prototypes that still use microcontrollers **[7]**. The novelty of this research is the detection of inorganic waste in a pile of more detailed organic waste based on the category of inorganic waste which is made into training data on a neural network which will produce the final result, namely waste that does not pass the sorting process to be processed into new renewable energy.

In this research, the object detection system uses the YOLOv8 (You Only Look Once version 8) method which is the latest version of YOLO, which brings several improvements over the previous version YOLOv5 **[8]** so that YOLOv8 was chosen in this research. It is hoped that with this research the author can provide solutions to the problems raised. Then it can find out the performance of YOLOv8 in detecting inorganic waste and being able to speed up the waste sorting process. In addition, this research is expected to be a reference for further research.

2. Method

2.1. YOLOv8 (You Only Look Once version 8) Method

YOLOv8 (You Only Look Once version 8) is the latest iteration of the well-known YOLO algorithm for real-time object detection. Developed by Ultralytics, YOLOv8 features several enhancements over its predecessor [9], including a more advanced and efficient architecture. The YOLOv8 architecture combines Feature Pyramid Networks (FPN) and Path Aggregation Networks (PAN), which enables the model to detect objects at various scales more accurately. In addition, YOLOv8 uses an anchorless approach, which simplifies the training process and reduces the complexity of anchor box selection. Here for the architecture of YOLOv8 Available in **Figure 1.**

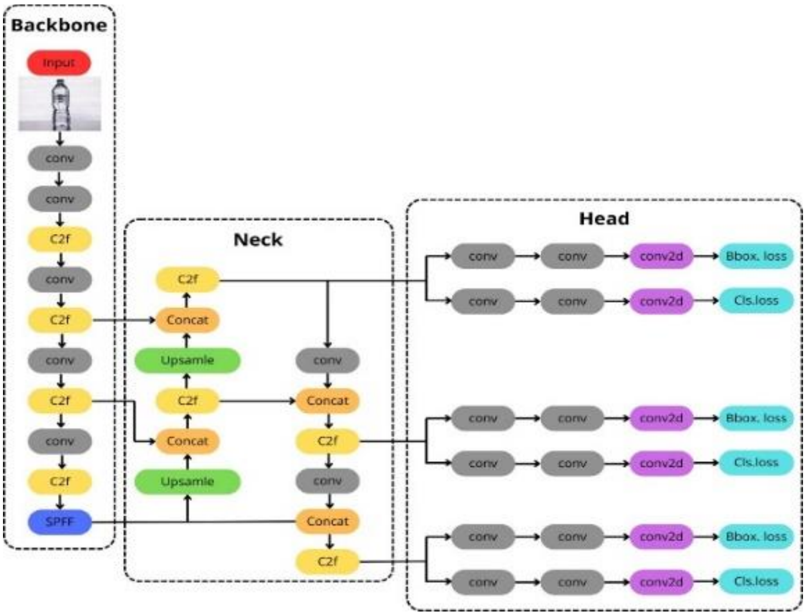

Figure 1. YOLOv8 Architecture

Enhancements in YOLOv8 also include optimizations in training techniques and the use of the latest convolutional neural network (CNN) technology. YOLOv8 implements a number of techniques such as more advanced data augmentation and customized loss functions, all of which aim to improve object detection performance under various conditions. The result is a faster and more accurate model, with the ability to perform inference in real-time even on hardware with limited computing power.

Compared to YOLOv5, YOLOv8 offers advantages in terms of flexibility and efficiency [10]. With the anchor-free approach, users no longer need to manually set anchor boxes, which simplifies the training process and adapts the model to various data sets. In addition, optimizations to the architecture and training techniques make YOLOv8 more adaptive to modern object detection challenges, making it an ideal choice for applications such as automated driving, surveillance systems, and robotics. There are several studies that apply

YOLOv8 such as Research [10], [11] to detect objects with 7 object class samples namely: bottles, chairs, humans, pots, gallons, garbage cans, and buckets, the evaluation results show that the YOLOv8 model provides excellent performance then high-speed drone objects [11], [12], license plate recognition systems [13] and smart fire detection systems for urban areas [14] Overall, YOLOv8 represents a significant evolution in object detection algorithms, maintaining the speed and accuracy advantages that characterize YOLO [15], [16] while adding new innovations that improve its performance in various application scenarios. With these improvements, YOLOv8 continues to strengthen its position as one of the leading algorithms in the field of computer vision.

2.2 Research Stages

The development of a system for the detection of organic and inorganic waste in the waste sorting process using the YOLOv8 (You Only Look Once version 8) method requires several stages. The following is a flowchart of the research stages shown in Figure 2.

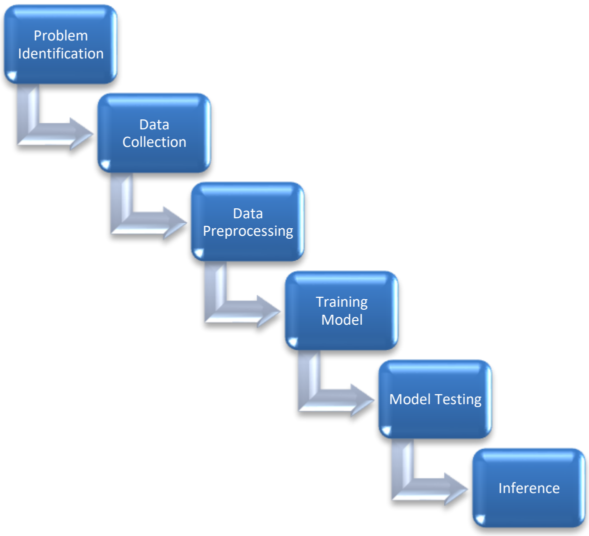

Figure 2. Research flow

2.2.1. Data Collection Technique

When building an object recognition system using the YOLOv8 method, a dataset is required. A dataset is a collection of data that is used as reference data during the model training process. In this study, the dataset used is 1000 images consisting of five classes of inorganic waste, namely plastic bottles, plastic, glass, cans and sterofoam, and two classes of organic waste, namely leaves and vegetables. The dataset is collected by directly photographing the object to be detected and by taking images from the internet platform, so that a variety of object models can be obtained.

2.2.2. Data Processing Technique

After the dataset is obtained, the data needs to be processed first or called the Preprocessing process. The preprocessing stage is a stage to label or mark each data that will be trained. This marking aims to determine the location of objects and object classes in an image to be detected so that the model can learn the object criteria to be detected during model training.

From the results of the dataset annotation, the data split stage is then carried out for training and validation data. The most common split comparison is 80%: 20% so 80% training data and 20% validation data. Then the new data can be carried out the training process.

2.2.3. System Performance Evaluation

To determine the performance of the YOLOv8 model, an evaluation is carried out using a number of metrics. These parameters include accuracy, precision, recall, and f1-score. To evaluate the ability of the model, equations (1), (2), (3), and (4) are used.

$$Akurasi = \frac{(\mathrm{TP+TN})}{(\mathrm{TP+FP+FN+TN})} \quad (1)$$

$$Presisi = \frac{(TP)}{(TP + FP)} \quad (2)$$

$$Recall = \frac{TP}{(TP + FN)} \quad (3)$$

$$F - 1\,Score = \frac{(2 * Recall * Precision)}{(Recall + Precision)} \quad (4)$$

True Positive (TP) is an interpretation that is predicted to be positive and is correct. True Negative (TN) is an interpretation to predict negative and it is correct. False Positive (FP) is a type 1 error that interprets the prediction result as positive and it is wrong. Finally, False Negative (FN) is a Type 2 error, a very dangerous Type 2 error that interprets a negative prediction result and it is wrong.

3. Results and Discussion

The entire data set that has been formed is 1000 data divided into 800 training data and 200 validation data, after the training process that produces a YOLOv8s model. The model training process was carried out for 2 hours 56 minutes with epoch 100, and batch 8. The training model cannot be used directly on the system, it is necessary to evaluate the model first using a confusion matrix. The use of confusion matrix is used to evaluate the model using accuracy, precision, recall, and f1-score parameters. The following is the confusion matrix of the YOLOv8 model training results in this study, available in **Figure 3**

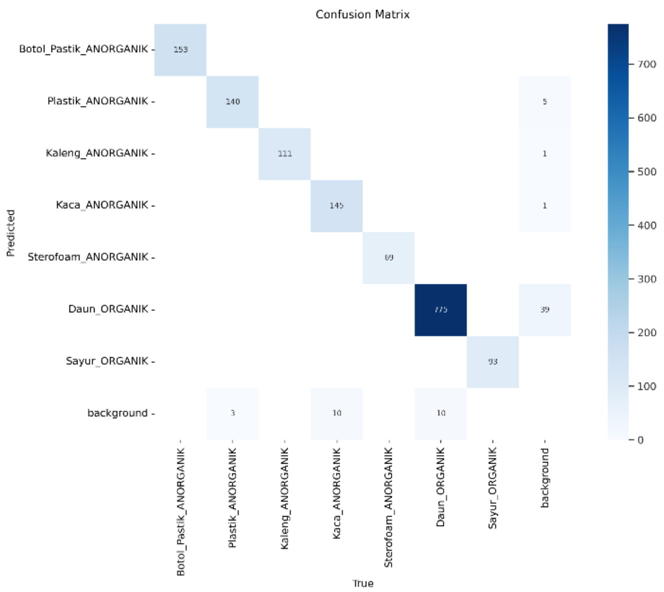

Figure 3. Confusion Matrix Results Validation

Based on the results of the confusion matrix in Figure 3, there are two sides, namely predicted and true. Predicted is the result of model prediction on validation data, while true is the truth label, on each side there are 7 classes. The background class is a class that arises due to object detection errors, such as there are other objects detected even though the object is not a member of the object that should be detected. Background classes usually represent FP (False Positive) and FN (False Negative) conditions. From these results, the accuracy, precision, recall and f-1 score can be calculated. The following is the calculation of accuracy, precision, recall and f-1 score in the Leaf class.

TP	=	775
TN	=	711
FP	=	39
FN	=	10

To determine the accuracy of the model in predicting leaves, the calculation is carried out with the equation below.

$$Accuracy = (TP + TN) \,/\, (TP + TN + FN + FP)$$
$$Accuracy = (775 + 711) \,/\, (775 + 1417 + 39 + 30)$$
$$= 96.81\ \%$$

From the calculation of the accuracy in the previous equation, the accuracy value obtained is 96.81%, then the calculation of the precision value is done with the following equation

$$Precision = (TP) / (TP + FP)$$
$$Precision = (775) / (775 + 39)$$
$$= 95.21\%$$

Furthermore, to find out the recall value of the model in predicting is calculated by the equation below.

$$Recall = TP / (TP + FN)$$
$$Recall = 775 / (775 + 10)$$
$$= 98.73\ \%$$

After obtaining the accuracy, precision, and recall values to determine the f1 score value of the model in predicting is calculated by the equation

$$F - 1\ Score = \frac{(2 * Recall * Precision)}{(Recall + Precision)}$$
$$= 96.94\%$$

According to the calculations that have been carried out, the plastic bottle class has an accuracy value of 100%, precision of 100%, recall of 100% and f-1 score of 100%. Then for testing on other classes is also done with the same calculation, the following detailed results of the YOLOV8 model evaluation calculation are available in **Table 1.**

Table 1. YOLOv8 Model Evaluation Results

Class	**Accuracy**	**Precision**	***Recall***	**F1-Score**
Plastic Bottle	100%	100%	100%	100%
Plastic	99,46%	96,55%	97,90 %	97,22%
Cans	99,93%	99,11%	100%	99,55%
Glass	99,27%	99,32%	93,55%	96,35%
Sterofoam	100%	100%	100%	100%
Leaf	96,81%	95,21%	98,73%	96,94%

Class	Accuracy	Precision	*Recall*	F1-Score
vegetable	100%	100%	100%	100%
Average	99,35%	98,6%	98,6%	98,58%

According to the calculation results, the YOLOv8 model has a good performance level with performance values above 90% for all evaluation parameters. The model is best at detecting sterofoam and vegetable objects with 100% accuracy, 100% precision, 100% recal and 100% f1 score. Thus, the model can be said to be feasible for use in inorganic waste detection systems. The next step is to implement the model in the system. For the implementation, the researchers used a personal computer with Intel Core i9 CPU specifications. To facilitate the operation of the researchers propose an interface. Interface or interface has a very important function as a means for the system to access object data to be detected, whether in the form of images, videos, or directly. The following is the appearance of the inorganic waste detection system interface shown in Figure 4

Figure 4. System Run Page Display

In accordance with Figure 4 the display of the run page section in this section there are 4 buttons with 3 buttons used to select the detection mode that will be used whether detecting photos, videos, or directly and 1 button to stop the running programme.

After the model can run on the system, the last step to determine the reliability of the system is testing the detection directly on organic and non-organic waste objects. This aims to determine the actual performance of the YOLOv8 model that has been applied to the inorganic waste detection system. The following is an example of object detection results on the organic waste detection system presented in **Figure 5.**

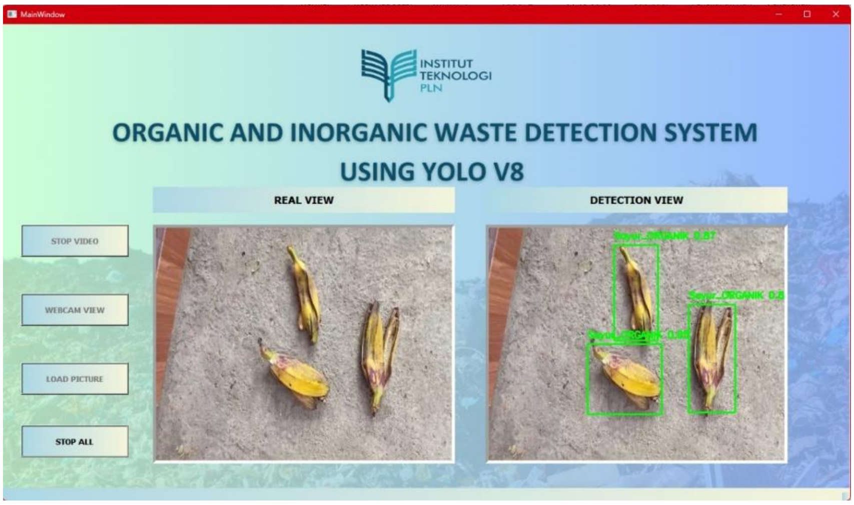

Figure 5. Results of Direct Organic Waste Detection

From Figure 5, it can be seen that the system can detect organic waste objects marked by the formation of a bounding box that covers the waste object. For more details, the direct test results are presented in **Table 2.**

Table 2. Live Detection Test Results

Testing Number	Object Count	Detection Result		Accuracy
		True	False	
1	1	1	0	100%
2	1	1	0	100%
3	1	1	0	100%
4	1	1	0	100%
5	1	1	0	100%
6	5	5	0	100%
7	4	4	0	100%
8	1	1	0	100%
9	2	2	0	100%
10	2	2	0	100%
11	10	10	1	90.91%
12	10	10	0	100%
13	10	10	0	100%
14	10	10	1	90.91%
15	10	9	1	90.00%
16	10	10	0	100%
17	10	8	2	80.00%
18	3	3	0	100%
19	3	3	0	100%
20	3	3	0	100%

Testing Number	Object Count	Detection Result		Accuracy
		True	False	
Accuracy average				98%

The test results presented in **Table 2** show that the model can detect objects with an accuracy of 98%. However, there are still errors that occur, errors that occur during testing there are two errors, namely the object failed to be detected which occurred in the 15th and 17th tests and the error condition caused by the background detected as an object as happened in the 11th and 14th tests.

From all the test results, the YOLOv8 model can detect inorganic waste well with an accuracy of 98%. Thus the YOLOv8 method is very effective in detecting inorganic waste objects as many as 7 classifications, namely plastic bottles, plastic, cans, glass, and sterofoam, leaves and vegetables.

4. Conclusion

After carrying out all stages of testing, it can be concluded that the YOLOv8 method can run well on the inorganic waste detection system. YOLOv8 has excellent performance as shown by the results of model evaluation using confusion matrix with an average accuracy of 99.35%, precision 98.6%, recall 98.6%, and f1-score 98.5%. Furthermore, from the results of direct testing, the YOLOv8 model has an average accuracy of 98%. With this hail it can be concluded that by using the YOLOv8 method inorganic waste can be detected properly and has high accuracy. So that it can simplify and speed up the process of sorting waste as a renewable energy fuel.

In this research, the author realises that each model has its own advantages and disadvantages, perhaps development and improvement can be made, including increasing the number of image data sets and using devices that have higher specifications in order to get maximum results.

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