Image Classification of Organic and Inorganic Waste Using Convolutional Neural Networks

Fahmi Wafi Mubarokh[1*]

[1]*STIKI Malang, Jalan Raya Tidar No.100 Karangbesuki, Kec. Sukun, Kota Malang, Jawa Timur , Indonesia*

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Correspondence Email:
191111035@mhs.stiki.ac.id

Abstract

Indonesia will become the third largest contributor of plastic waste in the world in 2024. This is due to the suboptimal management and recycling of waste. One way to reduce the accumulation of waste in the environment is through waste separation as the first step in recycling. In the field of informatics engineering, this process can be implemented using Convolutional Neural Network (CNN), a deep learning method designed to recognize and classify objects in digital images. This study aims to develop a high-accuracy CNN model for waste type classification using the TensorFlow framework. The analysis was carried out to determine the most appropriate CNN architecture in separating waste optimally. By implementing this algorithm, an automatic waste separation system can be built to support the efficiency of the recycling process. This research is expected to accelerate and simplify the waste separation process, while encouraging more effective waste management.

1. Introduction

The leftover products of production activities, both from industries and households, that are no longer used are known as waste. In Indonesia, waste is generally divided into two types, organic and inorganic waste. Organic waste comes from living things and is easily decomposed in less than six months. On the contrary, inorganic waste comes from non-renewable materials and has the characteristic of being difficult to decompose, so it takes decades to decompose in the soil(Fantara, Syauqy, & Setyawan, 2018). According to a World Bank report, nearly 4 billion tonnes of waste is generated annually worldwide, with urban areas contributing significantly to this amount. It is estimated that the amount of global waste will increase by 70 per cent by 2025(Kohsasih, Agung Rizky, Fahriyani, Wijaya, & Rosnelly, 2022). Current waste management is still limited to the conventional method, where waste is only transported from its source to temporary disposal sites without any processing. In fact, the ideal waste management procedure includes collection, recycling, transport to temporary disposal sites, and finally disposal in landfills(Wong, 2022).

1.1 Literature Review

To face the aforementioned challenges, people need to have a deeper understanding and awareness of how to classify waste types. Therefore, various studies have been conducted in the field of waste classification, including:

The first research, conducted by Octavia Devi Safitri Sunanto and Putranto Hadi Utomo, implemented deep learning with Convolutional Neural Network for the classification of organic and inorganic waste images, the research used data division into 80% for training data and 20% for test data, and applied Convolutional Neural Network with dense layers of 128 layers and 50 epochs, successfully achieving perfect accuracy in training data and test data. Thus, the Convolutional Neural Network model proved effective for classifying inorganic and organic waste images(Sunanto & Utomo, 2022).

Another study by Kelvin Leonardi Kohsasih, Muhammad Dipo Agung, Rizky, Tasya Fahriyani, Veronica Wijaya and Rika Rosnelly, compared Convolutional Neural Network (CNN) and Multi-Layer Perceptron (MLP) algorithms for image-based waste classification. As a result, CNN showed superior performance with accuracy, precision, recall, and f1-score reaching 98%, while MLP only achieved 43% accuracy. Although the training time of CNN is longer, its superiority in litter classification makes it a more effective choice, making a significant contribution in the application of machine learning for waste management(Kohsasih et al., 2022).

Furthermore, research conducted by William Hutamaputra, Rifky Yunus Krisnabayu, Marrieska Mawarni, Fitra Abdurrachman Bachtiar and Novanto Yudistira, compared the performance of Convolutional Neural Network VGG16 and ResNet34 on bottle waste classification system. As a result, Convolutional Neural Network testing showed that the VGG16 and ResNet34 architectures achieved an accuracy of 96.39% and 91.57% respectively in recognising plastic and non-plastic bottles. These results indicate that VGG16 is superior to ResNet34, both in terms of accuracy and training time efficiency(Hutamaputra, Krisnabayu, Mawarni, Yudistira, & Bachtiar, 2022).

Based on the explanation of the problems that have been described, this research aims to classify the types of organic and non-organic waste by utilising image processing using the Convolutional Neural Network (CNN) algorithm. The main goal is to achieve a high level of accuracy and produce the right prediction.

2. Research Methods

A. Data collection

This research will perform a process ofimage classification process. The main focus in image classification is to distinguish between organic and inorganic waste. The total dataset used is 25,112. The dataset for training data is 22,599 with a division of 12,600 for organic waste and 9999 for inorganic waste. The test data used totalled 2513 with a division of 1401 for organic waste and 1112 for inorganic waste.

B. Convolutional Neural Network

Convolutional Neural Network (CNN) is a type of neural network algorithm with a complex structure designed to process various types of data, such as images and audio. CNN architecture is inspired by the way neurons work in the human or animal brain. They are very popular and widely used, especially in image classification tasks. CNNs are able to accept input in the form of images and automatically perform feature extraction from the data(Hutamaputra et al., 2022).

C. TensorFlow

TensorFlow is an open-source library for machine learning developed by Google and supports multiple programming languages. In transfer learning, TensorFlow is used to process models such as Inception-v3, which can be retrained using new data to produce classifiers with efficient computation and high accuracy. TensorFlow integrates computational algebra and compilation optimisation techniques, making it easy to compute various mathematical expressions despite the challenge of considerable processing time(Sunanto & Utomo, 2022).

3. Result and Discussion

Waste classification using the Convolutional Neural Network (CNN) algorithm is performed through the following steps:

1. Importing TensorFlow and Dataset

The dataset used totalled 25,112 data, consisting of 14,001 organic waste data and 11,111 inorganic waste data. The data is divided into two parts, 80% for training data and 20% for testing data.

2. Building the Model

The model was developed by composing 128 dense layers, adding Rectified Linear Unit (ReLU) activation function, and Max Pooling with pool size (1,0). The training process was conducted for 50 epochs, where one epoch represents one full cycle of the algorithm learning the entire training dataset.

3. Optimisation Algorithm Usage

Adam's algorithm was used for optimisation because it is easy to implement, computationally efficient, requires small memory, is not affected by gradient scaling, and is suitable for large data or parameters.

The final result shows an almost perfect accuracy rate of 95%. Thus, the CNN algorithm proved to be effective in performing litter classification and provided excellent predictions.

4. Conclusions

To improve the efficiency of the recycling process, waste can be classified into organic and inorganic. This classification process uses the Convolutional Neural Network (CNN) model. In the study, the data was divided into 80% for training and 20% for testing. The CNN model used has 128 dense layers and was trained for 50 epochs. The results show perfect accuracy in both training and testing data. Thus, the CNN model can be relied upon to effectively classify organic and inorganic waste images.

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