Garbage Detection Based on Convolutional Neural Network

Marianne Rario
College of Computer Studies
José Rizal University
Manila, Philippines
marianne.rario@my.jru.edu

Jennifer Marquez
College of Computer Studies
José Rizal University
Makati, Philippines
jennifer.marquez@my.jru.edu

Rikki Mae Martinez
College of Computer Studies
José Rizal University
Rizal, Philippines
rikkimae.martinez@my.jru.edu

***Abstract*— Garbage recycling is an essential aspect of preserving a healthy and ecologically friendly environment. However, proper segregation of waste is a challenging task that requires significant manual labor, exposing workers to hazardous materials and illnesses. Philippine National Statistics Office (NSO) stated that Filipinos generates 7000 tons of waste each day. As a result, people want to utilize a more safer waste management by segregating recyclables and biodegradables at source. In this study, convolutional neural networks (CNNs) were utilized for the implementation of automated waste processes. The waste sorting system classifies different types of garbage, including cardboard, glass, metal, paper, plastic, and trash. The model yields a high overall accuracy of 92%. The model was able to classify garbage accurately even when the images contain clutter or are taken from different angles. The results suggest that the system can be effectively applied in real-world settings to improve the efficiency and accuracy of waste sorting processes.**

Keywords—Recycling, Garbage Classification, Convolutional Neural Network, Deep Learning, Image Classification

I. INTRODUCTION

A. *Background of the Study*

Garbage recycling is a vital phenomenon in maintaining a healthy and environmentally friendly environment. The recycling industry is thriving as people around the globe are becoming more aware of the benefits of utilizing reclaimed products [1]. This will reduce natural resource consumption, garbage disposal, and overall pollution**.** People are eager to use more recycled items while also doing their part to help the environment by properly disposing of their garbage. As a result, it is necessary for additional garbage to be diverted to recycling companies which can only be done after proper segregation.

This is a severe challenge in recycling sectors, particularly in the Philippines, where individuals operating in this industry still need physical labor to segregate garbage. Because garbage segregation is a laborious task for those working in this business, this practice is rarely properly enforced [2]. This is because it exposes workers to a variety of infectious illnesses caused by harmful materials found in waste. To address these persisting issues, the proponents will develop an image classifier that recognizes and detects recyclable waste materials and categorizes them based on the kind of waste components [3].

Deep neural networks are a common machine learning technique for image classification. In addition, deep neural networks are intended to learn complicated patterns from enormous amounts of data without requiring user-supplied knowledge, and convolutional neural networks are a type of machine learning technique that is commonly utilized for image classification [4]. Because it delivers the most accurate results in a variety of image classification tasks.

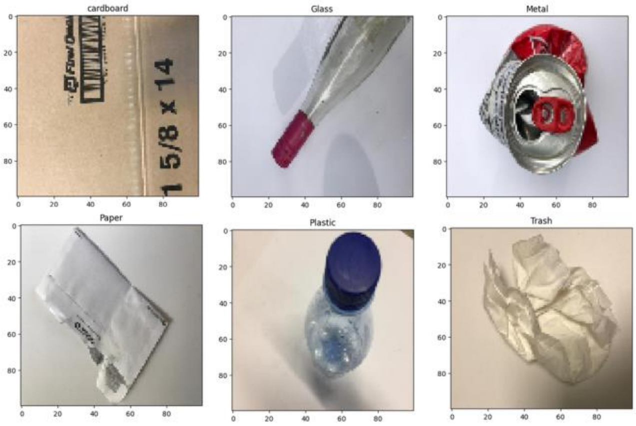

Fig. 1. Sample images from the garbage classification dataset.

The objective of this study is to train the model to be able to predict the input images and classify it into one of the garbage recycling categories, which includes cardboard, glass, metal, paper, plastic, and trash.

B. *Research Problem*

The aim of this study is to develop a garbage identification model based on CNN. It specifically seeks to provide answers to the following questions:

- Can a garbage identification system using CNNs be used to identify whether the garbage is cardboard, glass, metal, paper, plastic, or trash?
- How effectively is CNN detecting different kinds of garbage, such as cardboard, glass, metal, plastic, or trash?
- To determine which categories of garbage the system detects most accurately.

C. *Significance of the Research*

The study results will be beneficial to the following sectors:

- Businesses: Almost every business waste and needs to ensure that it is disposed properly. It anticipates that the findings of this study will be helpful for effectively disposing of business waste and segregating it.

- Government: Despite the existing waste management system and the level of compliance, the Philippines cannot cope with its vast garbage alone. To achieve waste management and sustainable recycling, it is necessary to implement good governance by creating a solid awareness and replicating innovative and appropriate technologies such as this study.
- Communities: By putting waste management systems into place, communities may improve communication, encourage local involvement, and create beneficial local relationships. Communities can benefit from this study by learning how to dispose of waste properly to prevent diseases and river flooding. This may also be the first step in encouraging people to sort their trash and clean up any items that can be recycled or used again.
- Future Researchers: The researchers aim that the results of this study will be helpful for further research on using deep learning to identify garbage types using convolutional neural networks. Future researchers interested in working on CNN-based image classification models will also be able to use the custom dataset generated in this study.

D. *Review of Literature*

Waste Sorting Using Deep Learning - the study developed a CNN-based system for detecting and sorting different types of garbage in a waste sorting facility. The model accurately classified different kinds of garbage, achieving an overall accuracy of over 95%. Additionally, the study evaluated the performance of the CNN in real-world conditions, showing that it could accurately classify and sort garbage even when the images contained clutter or were taken from different angles. Overall, this study provides evidence of the effectiveness of using CNNs for garbage detection in real-world settings. The ability of CNNs to accurately classify different types of garbage, even in challenging conditions, makes them well-suited for this task [5].

Automatic Waste Segregation System Using Image Processing - Develop a system for automatically segregating waste based on image processing techniques. The system uses a camera to capture images of garbage and then applies image processing algorithms to identify and classify different types of waste based on their visual characteristics. The study evaluated the system's performance using a dataset of images of garbage and found that it could accurately classify different types of waste with an overall accuracy of 98%. This study demonstrates the potential of using image processing techniques for automated waste segregation, which could improve the efficiency and accuracy of waste management systems [6].

Automatic Waste Sorting System Based on Image Recognition Technology - The study presents a system for automatic waste sorting using image recognition technology. The system uses a convolutional neural network (CNN) to identify and classify different types of waste, including paper, plastic, metal, and glass. The main contribution of this paper is developing and evaluating a CNN-based system for automatic waste sorting. The system can accurately classify waste types, improving waste sorting efficiency and accuracy; this is an essential step toward developing more sustainable waste management systems [7].

II. Data and Methodology

This section discusses the research methodology. It comprises the dataset context, followed by the data preparation process, and the model architecture.

A. *Data Context*

The dataset used in this research came from the Kaggle site and is composed of random images of garbage. Those images were classified into 6 categories.

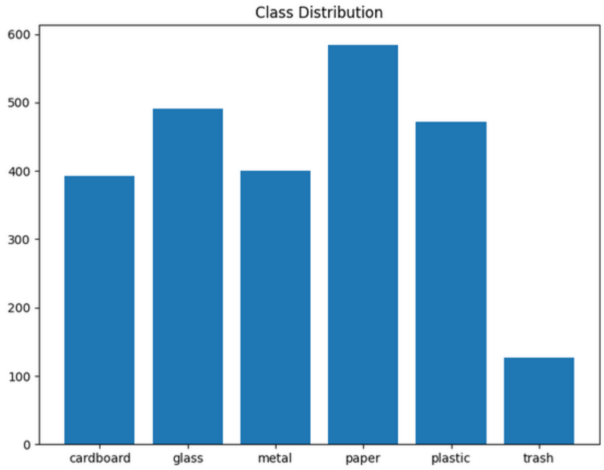

Fig. 2. Class distribution for the garbage classification dataset.

The six-classification included in garbage classification dataset includes cardboard (393), glass (491), metal (400), paper (584), plastic (472), trash (127) and this dataset are shown in Fig. 1.

B. *Data Preprocessing*

The steps that were applied for the data preprocessing for all the images in the dataset in each step is described below and in Fig. 3:

- Step 1: Resized all the images in the dataset to 32 x 32 pixels to match the input layer of the model.
- Step 2: Converted all the images to grayscale to simplify the model's algorithm and computational requirements.
- Step 3: Normalized image dataset by dividing each pixel value to 255. The pixel value ranges from 0 to 255 for each the channels (RGB). Dividing it by 255 is necessary to normalize it to 0 to 1 range.
- Step 4: Flatten all the images into a vector matrix.
- Step 5: Shuffled the train dataset for equal distribution of the data for splitting.
- Step 6: Split the data into three sets – train, test, and validation. This is undergone to avoid data overfitting and to increase the model accuracy score.

C. *Convolutional Neural Network Architecture*

For the Garbage classification, we build a CNN architecture model which has a better performance for classifying images [8].

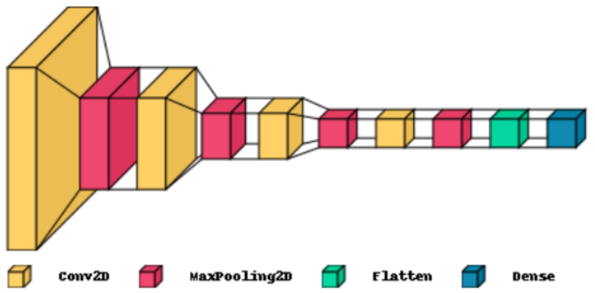

Fig. 3. CNN graph architecture based on the compiled model.

This architecture utilizes 2D convolutional layers to capture features of images. It also uses a number of filters to allow applications of nonlinear activation functions and reduce the number of parameters needed. The researchers also added max pooling layers to decrease the dimensions of the input layer and the total number of parameters to be learned by the model. These layers serve an important function that preserve essential features of the images after each of the convolutional layers were applied while preventing data overfitting errors and reducing the co-adaptions between neurons. After the convolutional blocks, we applied a flatten layer that flatten the feature matrix into a column vector. Then we added a dropout layer which regularizes and adds noise to the hidden units of the model. This dynamic enables the model to use fully connected layers at the end to do the dataset classification.

The residual block also uses two activation functions: the Rectified Linear Unit function (ReLU) and the Softmax function. ReLU is applied in the hidden layer to avoid vanishing gradient problems and produce a better computation performance. And in the last dense layer, we use softmax function for activation which fits the categorical crossentropy loss function.

D. *Experimental Settings*

Hyperparameter tuning was done in the model implementation. It is a model optimization technique for determining the set of hyperparameter values that generates highest accuracy results for better performance. In this research, adjusting hyperparameters was done to achieve the highest performance possible for the mode. It is a technique in determining the best hyperparameter values using experimentation.

Table I shows the 4 experimentations that were tested throughout the hyper parameter tuning process. The first experimentation has the accuracy of 32%, then followed by the other experimentations of 35%, 42%, and 21% accuracy.

TABLE. I. FINE TUNING (E1 – E4)

Parameter	Experimentations			
	E1	*E2*	*E3*	*E4*
epoch	10	20	25	30
batch size	10	15	20	25
learning rate	0.01	0.001	0.001	0.01
optimizer	Adadelta	Adadelta	Adam	Adam
hidden layers	2	3	4	10
accuracy	32%	35%	42%	21%

Table II shows another 4 experimentations that were tested throughout the hyper parameter tuning process. The fifth experimentation has the accuracy of 64%, then followed by the other experimentations of 72%, 79%, and 92% accuracy. As can be seen, experiment 8 got the highest accuracy score of 92%. In addition, it has 85% test accuracy for experiment 8.

TABLE. II. FINE TUNING (E5 – E8)

Parameter	Experimentations			
	E5	*E6*	*E7*	*E8*
epoch	35	40	45	60
batch size	28	30	32	45
learning rate	0.0002	0.001	0.001	0.01
optimizer	Adadelta	Adadelta	Adam	Adam
hidden layers	2	3	4	7
accuracy	64%	72%	88%	92%

Table III shows the classification performance based on compile CNN architecture. Two optimizers were utilized and compared. As can be see, Adam optimizer yields a better training and test accuracies.

TABLE. III. FINE TUNING (OPTIMIZER)

OPTIMIZERS	TRAINING ACCURACY	TEST ACCURACY
Adadelta	88%	84%
Adam	92%	85%

E. *System's Ideal Functionality*

A CNN-based system for garbage identification is capable to automatically classify and sort a wide range of garbage types in real-time accurately for appropriate disposal and recycling purposes. Additionally, it is scalable and adaptive allowing for the accommodation of new garbage types for further waste management procedures.

III. RESULTS AND DISCUSSION

In this research, the outcomes were achieved by applying CNN classification algorithm to display the maximized accuracy in garbage class prediction. CNN generated an accuracy score of 92.96% which proved that this model has a potential to be used as a tool for predicting garbage classes. Moreover, this could be used as a complimentary feature for various existing waste management procedures.

Table IV shows the summary accuracy of each class which includes cardboard, glass, metal, paper, plastic, and trash. The accuracy was achieved with highest fine-tuning combinations of 60 epoch, 45 batch size, 0.01 learning rate, and an Adam optimizer.

TABLE. IV. ACCURACY OF EACH GARBAGE CLASS

CLASS	ACCURACY
cardboard	75%
glass	67%
metal	71%
paper	66%
plastic	67%
trash	91%

Fig. 4 shows the evaluation of the model. It shows the accuracy and losses for training as the number of epoch increases. This model achieved the high overall 92% accuracy with the Adam optimizer and has 60 number of epochs.

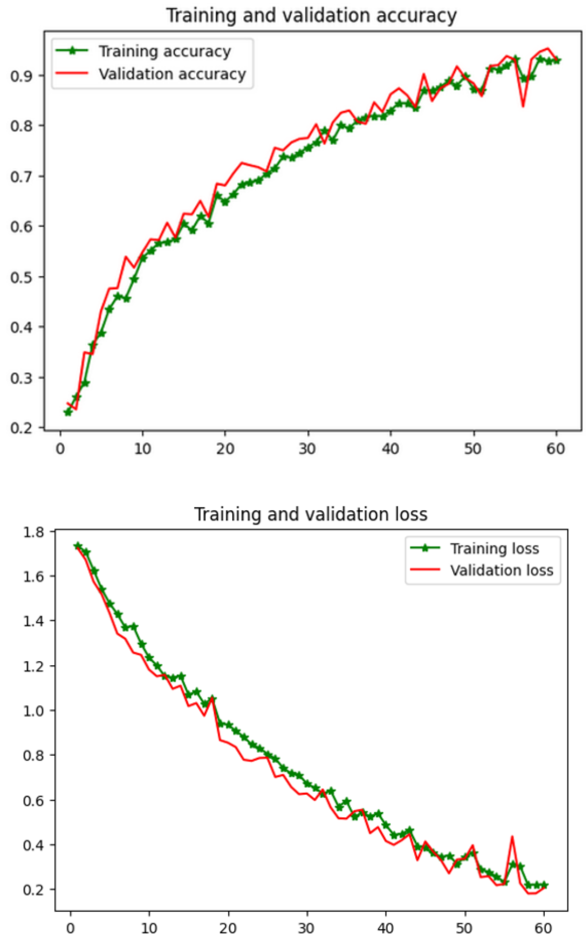

Fig. 4. Evaluations of accuracy and loss based on CNN architecture.

The Fig. 5 below shows that the CNN successfully classifies majority of all different household garbage. However, there is a great probability to some classes that the model may mistake garbage with glass and metal, or paper and glass.

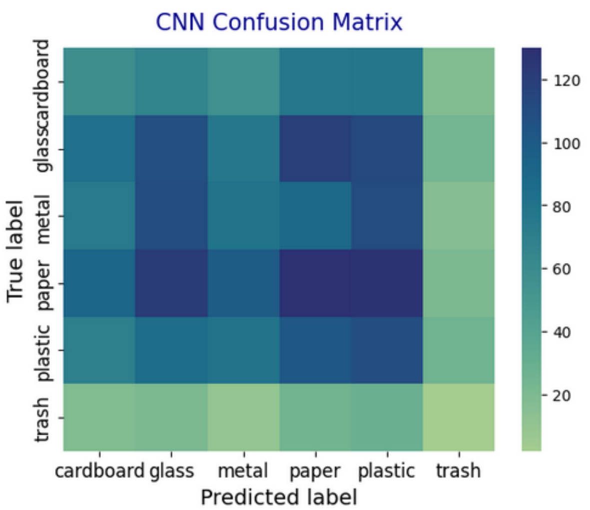

Fig. 5. Confusion matrix of the compiled CNN architecture.

Fig. 6 shows the results by comparing predictions with the original garbage labels. As can be seen, all images were correctly predicted. The image classified as cardboard has the probability of 99%, glass 87%, metal 99%, paper 96%, plastic 83%, and trash with 98%.

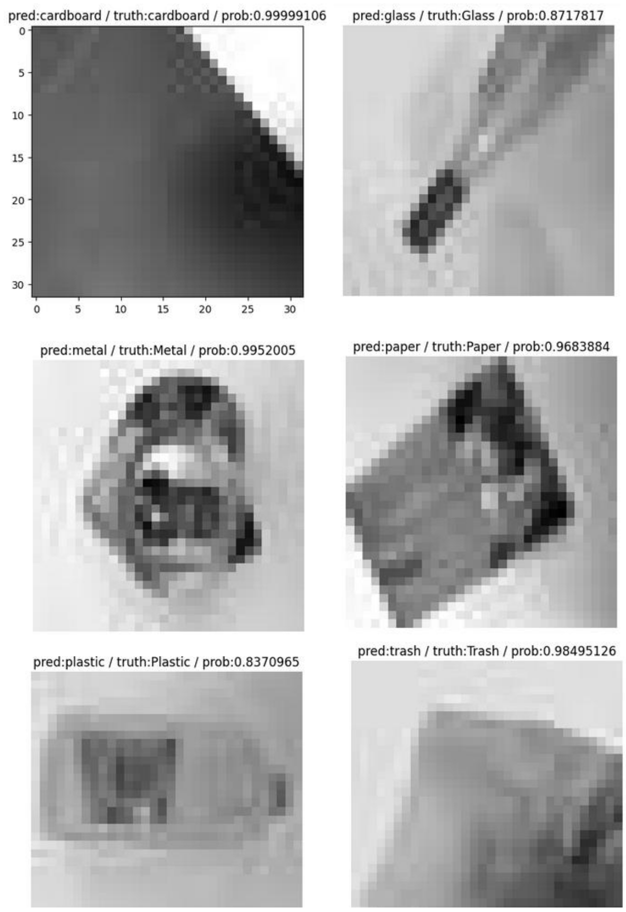

Fig. 6. Comparing predictions with the original garbage labels.

IV. Conclusion

The garbage detection based on convolutional neural network (CNNs) is a promising approach for addressing the growing problem of waste management. This architecture is a type of deep learning algorithm and have been shown to be effective in object recognition tasks, making it well-suited for detecting type of inputs data, as well the capability to process large amounts of data in real-time. It is a powerful tool for improving the efficiency and accuracy of waste management systems. However, the success of this approach depends on the availability of large amounts of high-quality training data, as well as careful fine-tuning of the CNN to ensure its performance in real-world situations.

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