Firat Univ Jour. of Exp. and Comp. Eng., 1(3), 122-128, 2022

Firat University Journal of Experimental and Computational Engineering

Fırat Üniversitesi Deneysel ve Hesaplamalı Mühendislik Dergisi

Classification of recyclable waste using deep learning architectures

Derin öğrenme mimarileri kullanılarak geri dönüştürülebilir atıkların sınıflandırılması

Arzu SEVİNÇ[1]*, Fatih ÖZYURT [2]

[1,2] Department of Software Engineering, Faculty of Engineering, Firat University, Elazig, Turkey.
[1]arzusevinc99@gmail.com, [2]fatihozyurt@firat.edu.tr

Received: 14.09.2022
Accepted: 07.10.2022

Revision: 21.09. 2022

doi: 10.5505/fujece.2022.83997
Research Article

Abstract
Managing waste in big cities is a big problem. Wastes are dangerous in terms of causing environmental pollution and affecting human health. In particular, solid wastes such as glass and plastic do not dissolve in the soil for a long time and pollute the environment. By recycling such solid wastes, the surrounding waste can be reduced. Therefore, it is important to classify waste and to recycle the separated waste. In this study, a data set consisting of 22500 waste images was used. The data set contains color image data with a size of 227 x 227 pixels. The data used in the study are divided into two as organic and recyclable waste. This study proposes a deep learning-based system for classifying waste. With such a system, wastes can be classified and recycled. The data was trained with the ResNet 50 architecture and the CNN architecture created to classify waste, and accuracy rates were compared. The CNN architecture created to classify waste is more successful for this data set with an accuracy rate of 91.84%.

Keywords: Waste classification, Deep learning, Convolutional neural network, ResNet-50 architecture.

Özet
Büyük şehirlerde atıkların yönetilmesi büyük bir problemdir. Atıklar çevre kirliliğine sebep olması ve insan sağlığını etkilemesi açısından tehlikelidir. Özellikle cam, plastic gibi katı atıklar toprakta uzun süre çözünmeyerek çevreyi kirletmektedir. Bu tarz katı atıklar geri dönüştürülerek çevredeki atıklar azaltılabilir. Bu yüzden atıkları sınıflandırmak ve ayrıştırılan atıkların geri dönüştürülmesi önemlidir. Bu araştırmada 22500 atık görüntüden oluşan bir veri seti kullanılmıştır. Veri seti, 227 x 227 piksel boyutundaki renkli görüntü verilerini içermektedir. Çalışmada kullanılan veriler, organik ve geri dönüştürülebilir atık olarak ikiye ayrılmaktadır. Bu çalışma atıkları sınıflandırmak için derin öğrenme tabanlı bir sistem önermektedir. Bu tarz bir sistemle atıklar sınıflandırılarak geri dönüştürülebilir. Veriler ResNet 50 mimarisi ve atık sınıflandırmak için oluşturulan CNN mimarisi ile eğitilerek doğruluk oranları karşılaştırıldı. Atık sınıflandırmak için oluşturulan CNN mimarisi %91,84 doğruluk oranı ile bu veri seti için daha başarılı olduğu görülmektedir.

Anahtar Kelimeler: Atıkların sınıflandırılması, Derin öğrenme, Evrişimsel sinir ağı, ResNet-50 mimarisi.

1. Introduction

There is an increasing waste management problem around the world. Tons of waste are discarded every year, and this number increases every year. With the development of industry in major cities, waste management has become even more difficult. the waste count is estimated to be 2.2 billion tons by 2025 [1]. As waste increases, it is more difficult to create free space for waste with the effect of urbanization. In this case, it is often seen that the waste is burned. However, the burning of waste causes air pollution, which triggers cancer. So waste is a danger to the environment and human health.

Recycling waste is an environmentally and economically useful method. In this way, raw resources can be recovered, energy can be preserved, air and water pollution can be reduced, and parts allocated for the refuse area can be reduced. Countries have started implementing some systems to recycle waste. Important steps are taken for the waste problem, especially in a crowded country like China. There has been a recent study of artificial intelligence integrated in order to classify waste.

*Corresponding author

Many countries have done research in this area to recycle waste. Scientists have shown that waste can be classified with an autonomous system using image classification techniques. A study in this area uses thermal imaging techniques to classify recyclable materials. This technique has achieved success from 85% to 96% [2].

The classification and recycling of waste is essential for a healthy life. However, different types of waste make this classification difficult. Through deep learning methods, images are reviewed for the classification of waste, so recyclable waste can be classified. The excess of waste types and the difficulty of their solution are the main reason scientists are concentrating on deep learning methods for waste management. In an investigation, the image is classified with AlexNet, DenseNet169, VGG16, GoogleNet models, and then DenseNet169 image classification models based on transfer learning are used. Compared to these methods, the DenseNet169 models based on transfer learning were found to have an 82.8% accuracy and a higher success than other models [3]. In another study in this area, the TrashNet dataset was trained using the DenseNet121 architecture. DenseNet121 architecture achieved a high accuracy rate of 99.6% with this data set [4]. Another study conducted a system using the R-CNN model to determine the size when using CNN to classify. This system has been successful with accuracy rates from 90% to 96.7% [5]. In this research, paper, glass, plastic and organic wastes were classified using DCNN architectures. The highest success has been achieved in the classification of organic wastes. In organic waste, the 5-layer DCNN architecture achieved a 76.7% accuracy rate and the 4-layer DCNN architecture achieved an 83% accuracy rate [6]. A study using the TrashNet dataset uses a ResNet18-based image classification model to classify waste. This successful model has an accuracy of 95.87% [7]. In a system created using deep learning-based classifier and cloud computing technique, waste is divided into 6 categories. In this study, the classifier created using Mobilenetv3 architecture achieved a good result with a accuracy rate of 94.24% [8]. The deep learning method has shown successful results in the classification of waste.

Table 1. Comparison of publications in the literature

Method	Accuracy
Thermal Imaging Techniques [2]	%85 - %96
DenseNet169 [3]	%82,8
DenseNet121 [4]	%99,6
R-CNN [5]	%90 - %96,7
Four layer DCNN and five layer DCNN [6]	%83 and %76,7
ResNet-18 [7]	%95,87
MobileNetV3 [8]	%94,12

This study is a study to recycle waste. In the study, it was aimed to classify the wastes by using a data set consisting of two categories. The wastes in the data set are divided into organic and recyclable. The data is trained using two different architectures. First, the data set was trained using the CNN architecture created for the classification of waste. The dataset was then trained using the Resnet50 architecture. Finally, the success rates obtained from the training of the two architects were compared and it was determined which architecture would be more successful for this study.

2. Method and Material

2.1. Dataset

The dataset used in this study was accessed via Kaggle [9]. The images in the dataset are divided into organic and recyclable. Contains 22500 data consisting of color images. This image data has 227 x 227 pixels. Figure 1 shows the organic waste images in the dataset and Figure 2 shows the recyclable waste images. Organic waste is usually made up of foods such as vegetables and fruits that can be thawed out in nature. The recyclable waste consists of waste such as glass, plastic, nylon, wood, metal.

The problem of classification of wastes is important for the environment and human health all over the world. This data set was used to solve the problem of waste classification. The data set used is divided into two categories as recyclable and organic waste. Organic wastes that can be dissolved in the soil are wastes that are not harmful to the environment. Wastes such as glass, plastic which does not dissolve in the soil for years, are recyclable wastes. Classification of wastes and determination of recyclable wastes will solve our problem. In this respect, the data set used in the study is sufficient for the solution of the problem of classification of wastes.

Figure 1. Organic waste images in dataset

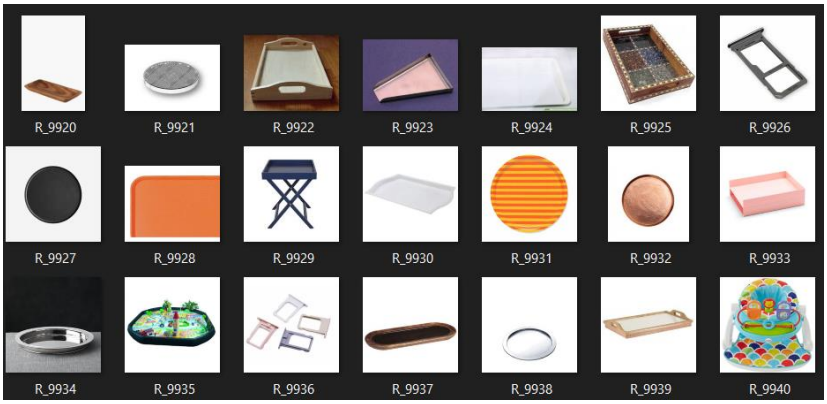

Figure 2. Recyclable waste images in dataset

2.2. Waste classification model based on CNN Architecture

CNN is an algorithm that can extract properties of objects in an image and distinguish objects from each other. The convolutional neural network is a mathematical structure composed of multiple layers and uses the process of convolution. Convolution is a mathematical process that produces a new function that shows how a shape is changed by another shape. CNN consists of a layer of input, an output layer, and different layers between these two layers. The middle layers are the layers that perform mathematical operations (convolution).

The convolution layer is the layer that extracts the properties of the image. A filter matrix is created in the convolution layer and circulated over the image. The pooling layer is used to reduce data size and processing time. Important information is preserved while reducing size. There are different types of pooling. The first is the maximum pooling, which uses the maximum value of the neuron clusters. The average pooling extracts an average value from these clusters and uses that value. The collection of all neuron values is total pooling. The fully connected layer has been named because the neurons on the layers are completely connected to each other. The matrices pass through fully connected layers to sort the image.

A CNN model has been created for this study. This CNN model is shown in Figure 3. The model consists of 5 convolution layers, 5 pool layers, and 3 fully connected layers. The activation function uses the sigmoid function. The curve of this nonlinear function is similar to the S shape. The values obtained from the Sigmoid function are between 0 and 1. When calculating the probability of anything, the sigmoid function is usually preferred.

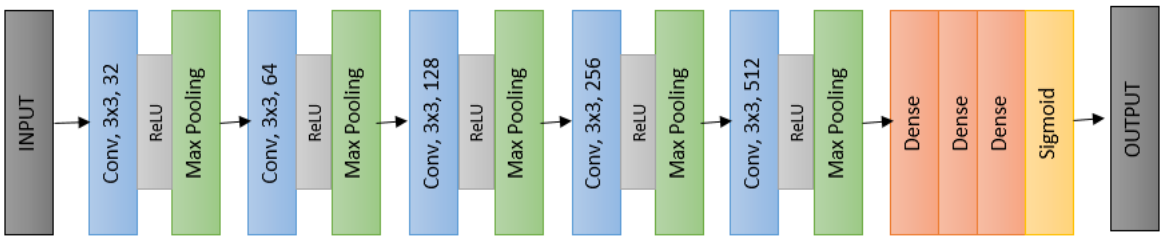

Figure 3. The basic structure of CNN architecture for the classification of waste

CNN architecture includes 5 convolution layers, 5 pooling layers and 3 full link layers. There is a ReLU activation function between the convolution layer and the pooling layer. After the full link layer, there is a Sigmoid activation function. The block diagram for this architecture is shown in Figure 4.

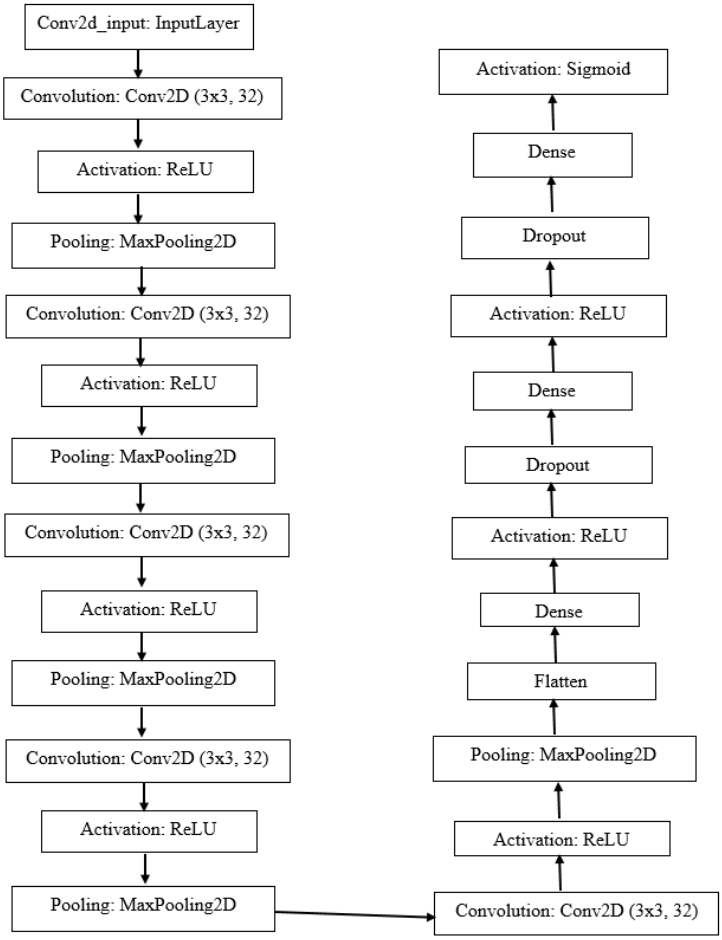

Figure 4. Block diagram of CNN architecture

2.3. ResNet 50 Architecture

ResNet [10], has won the ILSVRC-2015 competition. It consists of up to 152 layers of convolution. The ResNet 50 architecture has a 50-layer depth. The ResNet architecture uses short paths. These short paths contribute to reduced deterioration and increased operating speed. Figure 4 contains an image of the ResNet 50 architecture.

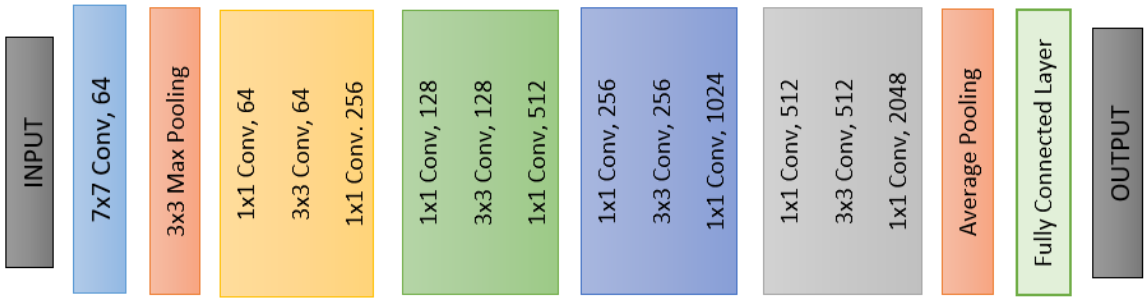

Figure 5. The basic structure of Resnet 50 architecture, a pre-trained CNN architecture

3. Result and Discussion

Convolutional neural network models are used to classify waste. Data is trained using the Resnet 50 architecture, and the CNN architecture created for this study. The accuracy rates obtained as a result of the training are compared.

The graphic of data trained with CNN architecture is shown in Figure 5. The figure has accuracy and loss graphics. This architecture has an accuracy of 91.84%. The CNN architecture created uses 5 convolution layers, 5 pool layers, and 3 fully connected layers. It also uses sigmoid as an activation function.

The dataset used contains 22500 waste images. 85% of data is used for training and 15% for testing.

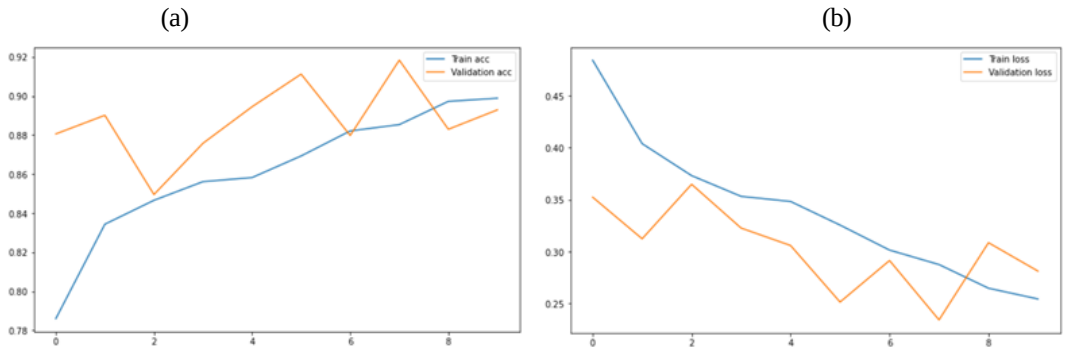

Figure 6. Graphics for CNN architecture. (a) Accuracy plot, (b) Loss plot

The accuracy plot as a result of training the Resnet 50 architecture with this data is shown in figure 1. The highest accuracy obtained was 81.34%. The Resnet architecture is an architecture with a depth of 50 layers. As the activation function, it uses the softmax function. The Softmax function is the activation function that interprets the numbers according to the possibilities [11].

85% of the data used here is used for training and 15% for testing. Waste data is color and 227x227 pixel size data.

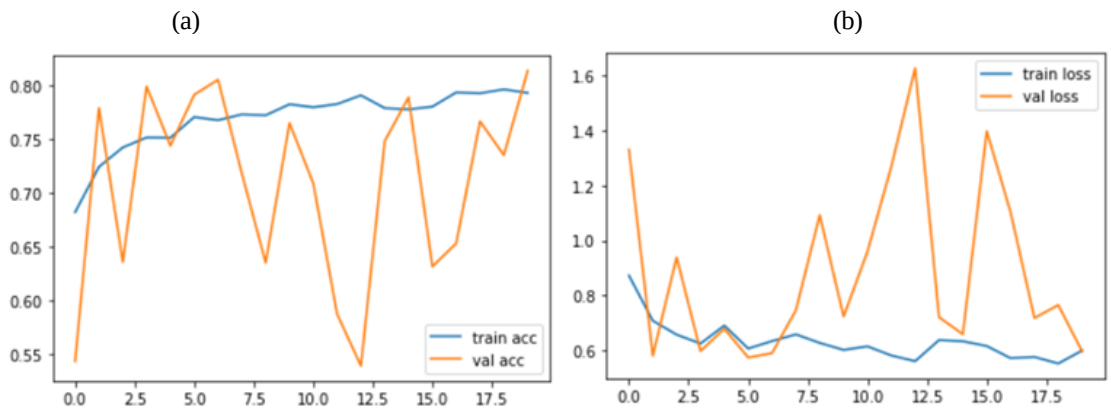

Figure 7. Graphics for Resnet-50 architecture. (a) Accuracy plot, (b) Loss plot

Results graphics from the training of both architects were given above. When the results are analyzed, it is seen that the CNN architecture were created to classify waste is better. CNN architecture has a 91.84% accuracy ratio, while ResNet50 architecture has an 81.34% accuracy ratio. There is a 10.54% difference between them. For deep learning, this difference is a high difference.

4. Conclusions

The purpose of this study is to ensure that highly produced waste is classified so that it can be recycled. The data used in this study is divided into organic and recyclable. The dataset contains a total of 22500 waste image data. This data has been trained using Resnet50 and Cnn architecture. By studying the accuracy rates obtained as a result of the inclination, it was determined which architecture was more successful. The training of CNN architecture resulted in a 91.84% accuracy ratio. The ResNet50 architecture achieved an 81.34% accuracy ratio. CNN architecture is seen to be more successful in the classification of waste for this dataset.

5. Author Contribution Statement

In this study, Author 1 contributed making the design, literature review, contributed to forming the idea, the analysis of the results; Author 2 contributed to checking the spelling and checking in terms of content.

6. Ethics Committee Approval and Statement of Conflict of Interest

“There is no need for an ethics committee approval in the prepared article”
“There is no conflict of interest with any person/institution in the prepared article”

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