Waste Classification with Convolution Neural Networks

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ABSTRACT
Waste has always been a problem for humans all around the world. To find a way to reduce it and get rid of it various methods are used, these waste cause a suppressing issue of landfills and an increase in toxicity of the soil. Sometimes, these toxic wastes are consumed by animals. Therefore, waste classification is the initial step in the separation and segregation of organic and recyclable. A CNN model is created from scratch that classifies waste into organic and recyclable categories. A dataset of 25077 images is used and all of them having .jpg extension. The training set had 80% of the dataset and the test set has 20% of the dataset. This paper explores the model and performances of the model which gave an accuracy of 90.66% in classifying waste into organic and recyclable.
Keywords **-** Convolutional neural network, Image classification, Organic, Recyclable, Waste classification.

I. INTRODUCTION

MUMBAI and DELHI are just not the biggest cities in terms of population in India but also the biggest in terms of waste production. According to the estimates of the Central pollution control board (CPCB), Mumbai, and Delhi produce around 11,000 and 7,500 tonnes of solid waste per day [1]. In 2018 for the third consecutive year in a row, Maharashtra had topped the list of municipal solid waste generators in the country, according to data from the Ministry of Housing and Urban Affairs (MoHUA) submitted to the union environment ministry. According to the Brihan-Mumbai Municipal Corporation (BMC), Mumbai produces 7,500 million tonnes of waste per day or 27.37 lakh MT in a year, one-third of the total waste generated in Maharashtra.[2]. There's a widespread of population more than 377 million urban people that live in 7,935 cities and towns and on average generate 62 million tonnes of municipal solid waste annually. And a collection of only 43 million tonnes (MT) of the waste is done, 11.9 MT is treated and 31 MT is dumped in landfill sites. Solid Waste Management is one of the basic indispensable services provided by municipal jurisdictions in the country to keep these built-up/metropolitan centers clean. However, almost every municipal authorities deposit solid waste at a dump yard within or outside the city unsystematically. Experts in India believe that the country is following a fallacious system of waste disposal and management [3].
Waste can be isolated into two categories
(a) Organic waste

(b) Recyclable waste.

Organic wastes left goes in a very slow process of self-degradation. This process of decomposition or degradation is done majorly by microorganisms of various kinds. The process of Composting can be defined as the degradation of organic waste into something which can be reused. Both at household and community level composting of kitchen and yard wastes should be encouraged. Cleanliness starts from the house. Citizens have to make sure that the solid waste generated from one's own house is properly segregated/separated, stored, and disposed of according to the guidelines provided. Different kinds of wastes can be handled and stored in different kinds of containers as provided by the authorities.
For example, Biodegradable/Decomposable waste: Green Container, Recyclable waste: White Container, Others (Hazardous/Inorganic waste): Black Container [4].

Wastes such as biodegradable waste can be decomposed or can be used as a manure for agriculture. We believe that machine learning and Neural Networks can help massively to make waste classification efficient and more effective. This will certainly help in pollution reduction from the waste that our country is currently facing also help the municipal workers by easing their job.

Computer Vision could be a way to empower the workers and employees of BMC who has to handle the waste by helping in their job and making it a less difficult which in turn will help in reducing the pollution in the country. Convolutional neural networks are deep artificial neural networks. CNN can be used to perform object recognition classify images and cluster them. It can be used to identify faces, individual, street signs, tumors. We studied Convolution Neural Networks(CNN) and tried to apply it on classifying the solid waste. The main aim of our experiment is to study and research the performances of the CNN model

that was created.

II. RELATED WORKS

Image recognition has a vast number of people and scholars contributing to it. A lot of important work on convolutional neural networks (CNN) happened for image recognition [5,6,7,8]. Active area of research is object detection [9,10,11]. Convolutional Neural Networks (CNN) has been increasingly helpful in solving many problems such as motion detection, image and video recognition, classification, and semantic segmentation. Now computer vision is being used to solve most of the world's problems to get better efficiency as compared to traditional methods. Reference [12] found that performance significantly increased and improved when CNN models were assigned to classify more than a million images in the ImageNet dataset. Reference [13] compared various pre-trained CNN architectural models and found out the best of them all. Reference [14] compared the waste classification performance of CNN-based frameworks such as Vgg-16 and Resnet with other existing old classifiers such as SVM and KNN and got a result that CNN-based classifiers always have a better performance than the previous old classifiers.

III. METHODOLOGY

A. *Waste classification dataset*

The dataset is taken from the Kaggle website [15]. The dataset contains waste of mainly three kinds of household waste, plastic, and other waste, further, these wastes are segregated into two major classes and that is organic and recyclable. The total images in the dataset are 22500 colored images which are fairly enough to train a neural network effectively. The major sources of data were Google and Imagenet but the sizes of all the images were different so they were normalized for the experiment. The dataset is of 22500 images out of which 80% of the images are used for training which is 22564 images and 2513 images for testing. Further, the validation set uses 20% of the training data for the validation of the neural network.

Fig. 1-Sample images with labels

B. *Pre-processing*

The images in the dataset are of different sizes some are of 150x120 pixels and some are of 120x120 pixels because the images are taken from different sources and to have some computing done on them we needed to normalize the images to 100x100 pixels so that the order remains the same for all of the images after the normalization is done an array of these images are created and the array had 3 parameters which were the height of image, width, and channel. The channel is kept 3 because of RGB in a colored image. This array is converted into float32 and divided by 255 to bring the value of each image between 0 and 1 so that computing done on the image is much faster and efficient. Imagedatagenerator is used to augment the dataset and also expand the dataset and the parameters which were used were image zoom by 0.1, height, and width shift by 0.2. The height_shift and width_shift move the image randomly by a fraction.

C. *The Architecture of CNN Model*

The CNN model is sequential because the sequential model allows stacking up the layer, unlike the functional model, there in total 5 major layers in this model in the first four-layer 2 convolutions are performed on the image, one batch normalization and one max-pooling within them refer Fig 2. The activation function is kept the same and that is Relu(Rectified linear unit) in all of the 5 major layers. The first layer does not act as a convolutional layer instead it acts as a tensor therefore input shape of the image is declared in this layer. In the first layer, we have created 32 feature maps with a filter/kernel of size 3X3 pixels which automatically indicates that the stride was of 1. The size of image is reduced after every convolution that can be computed by the formula [(n-f)+1] where n is the size of image and f is the size of filter applied, over here n is 100 and f is 3 therefore after 1st convolution the size of the image would be 98x98 pixel refer Fig 2. Again 2nd convolution is applied and the size reduces to 96x96 this reduction of size help in finding out the features of the image. The batch normalization layer is also applied so that the network doesn't get the problem of internal covariate shift during backpropagation and also to fasten up the training process .1st Max pooling is done of pool size 2x2 so that we can retain all the features and also reduce the size of the image for further computation. The size of the image is now reduced by half as seen in fig 2. The last part in this layer is the dropout layer so that the model doesn't overfit and 20% out of all neurons is dropped. All of this is part of the 1st major layer and just like the 1st layer, there are more 3 layers added with an increase in the number of feature maps to 64,128, 256 in 2nd,3rd, 4th layer and rest is kept the same refer to figure 2. The size of images keeps on reducing so that the feature of the image is identified in detail. In the last layer flatten method is applied to provide input in a single array to the dense or fully connected layer. These fully connected layers are hidden layers that do the work of classifying into the categories of Organic and Recyclable. We have created 3 dense layers of sizes 512, 256, and 128. These layers connected with the output layer of size 2 gives the result whether the image is Organic or Recyclable, the process is shown in fig 2. The optimizer selected was 'adam' as it has an adaptive learning rate and the metrics are chosen as accuracy for compiling the model. here are in total 1,862,498 trainable parameters and 960 non-trainable to avoid overfitting.

Layer (type)	Output Shape	Param #
conv0 (Conv2D)	(None, 98, 98, 32)	896
conv1 (Conv2D)	(None, 96, 96, 32)	9248
bn0 (BatchNormalization)	(None, 96, 96, 32)	128
maxpool0 (MaxPooling2D)	(None, 48, 48, 32)	0
dropout0 (Dropout)	(None, 48, 48, 32)	0
conv2 (Conv2D)	(None, 46, 46, 64)	18496
conv3 (Conv2D)	(None, 44, 44, 64)	36928
bn1 (BatchNormalization)	(None, 44, 44, 64)	256
maxpool1 (MaxPooling2D)	(None, 22, 22, 64)	0
dropout1 (Dropout)	(None, 22, 22, 64)	0
conv4 (Conv2D)	(None, 20, 20, 128)	73856
conv5 (Conv2D)	(None, 18, 18, 128)	147584
bn2 (BatchNormalization)	(None, 18, 18, 128)	512
maxpool2 (MaxPooling2D)	(None, 9, 9, 128)	0
dropout2 (Dropout)	(None, 9, 9, 128)	0
conv6 (Conv2D)	(None, 7, 7, 256)	295168
conv7 (Conv2D)	(None, 5, 5, 256)	590080
bn3 (BatchNormalization)	(None, 5, 5, 256)	1024
maxpool3 (MaxPooling2D)	(None, 2, 2, 256)	0
dropout3 (Dropout)	(None, 2, 2, 256)	0
fc (Flatten)	(None, 1024)	0
Dense0 (Dense)	(None, 512)	524800
Dense1 (Dense)	(None, 256)	131328
Dense2 (Dense)	(None, 128)	32896
dropout4 (Dropout)	(None, 128)	0
Dense3 (Dense)	(None, 2)	258

Total params: 1,863,458
Trainable params: 1,862,498
Non-trainable params: 960

Fig. 2 -CNN architecture

IV. PERFORMANCES AND OUTPUT

A. *Performance*

The model stopped right after the 38th epoch because there was no improvement in validation loss since the last fifteen epoch so the model stopped training and considered the epoch which had the highest accuracy for weights.

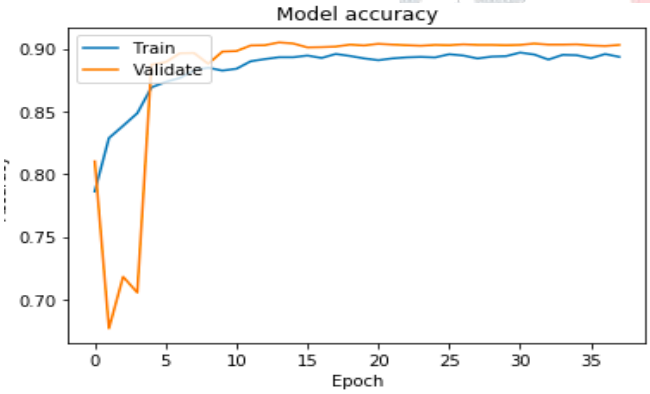

Fig. 3-Model Accuracy

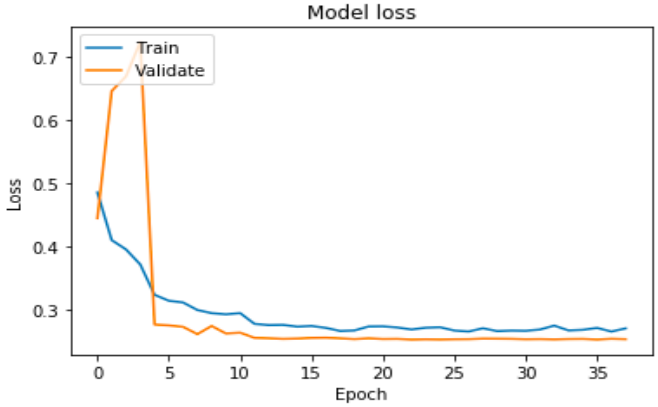

Fig. 4-Model Loss

In figure 3 there is a steep drop in the accuracy of the validate set as the model came across many different types of images which had different features but belong to the same category right up until the 5th epoch after that there is a huge increase in the accuracy as almost most of the features are identified and model was able to predict correctly. The model loss in Fig 4 there is a steep increase in the validation loss as it kept guessing the wrong classification for a first epoch as the model was not familiar with all the image that belong to the same class as there are a lot of images from different types of waste some are of household waste and some are industrial but after the 3rd epoch, there is a steep drop in the loss from almost 0.75 to 0.2 later it remained almost the same as the model became accurate.

B. *Output*

The model accuracy on the testing dataset was found out to be a staggering 90.66%. The error rate is 9.44% and the test loss is 0.24441

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Test Loss : 0.24411449805228205
Test Accuracy : 0.9068841934204102
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Fig. 5-Accuracy

The result of the experiment can be understood with the help of a confusion matrix where the rows represent the true label in which the first row is for Recyclable images and the second row is for Organic images and the columns represent predicted label, the first column indicates predicted Recyclable images and the second olumn indicates predicted organic images. 1350 images of recyclable waste are correctly identified but 51 recyclable images were wrongly identified as organic. In the second row, 127 organic images were wrongly identified as Recyclable images and 985 images were correctly identified as organic images.

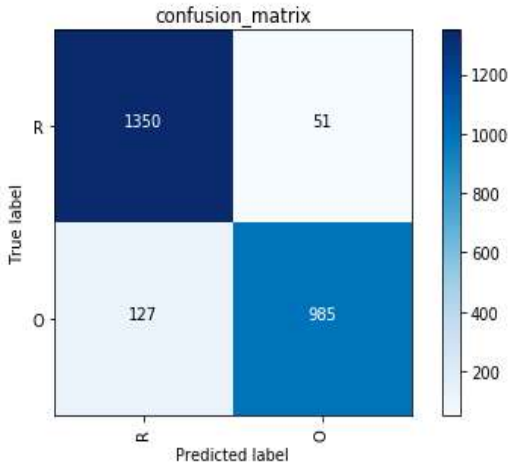

Fig. 6-Confusion Matrix

V. CONCLUSION

Here we demonstrate a model that can recognize and classify the image into Organic and Recyclable waste later the waste can be more specific like plastic, lead, industrial, and more. The amount of toxic material or plastic inside a waste can also be identified by object detection. It is assumed that the result can be more accurate by approximately 3-4% using the VGG-16 or Resnet model. These models have trained on a huge dataset approximately more than 10000 images. Image recognition is an amazing way to understand the neural network and develop techniques of deep learning to solve some problems. In the future, we hope to develop an app that can click pictures of the waste and give the classification result of the same.

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