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Image Classifier for Segregation of Waste

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ABSTRACT

With the upcoming new advancements, availability of cheaper goods, and rising demands, the world is also seeing a rise in the generated waste material. Around 62 Million tonnes of waste is generated in India annually, and approximately 68 percent of that goes into collection and only a small 28 percent goes into waste treatment. It is projected that the volume of waste would increase from 64 - 72 million tonnes at present to 125 million tonnes in 2031[1]. Untreated waste is a huge threat to the environment. Solid waste disposed of unhygienically or left untreated, can accumulate and add to environmental degradation. The resources of the world are fast depleting, which further strengthens the case about how essential it is to preach and follow the three R's of Waste management - Reduce, Reuse, Recycle. The segregation, transport, management, and disposal of the trash must be well planned and effectively executed. Still recycling is being done at later stages, that too by manual processes hence inefficient. A majority of consumers also find it difficult to distinguish between different materials and their ability to be recycled.

The objective of this study is to develop a system that can identify the type of item and its category as recyclable. The model would be built using different deep learning and transfer learning techniques. The study is concluded with the development of a web app that predicts the category of waste.

KEYWORDS: *Waste, Recycling, Deep Learning, Image Classification, vgg16, Python Flask*

1. INTRODUCTION

India is a diverse nation, with a rapidly increasing population, and constant developments through industrialization, advancements in technology, and rising demands, there is a rise in the waste being generated now and then. Hence the increase in solid waste generated in cities of India from 48 million tonnes in 1997 and expected to reach 300 million tonnes by 2047[2]. Careless disposal of waste simply does not solve the problem, instead, its ill effects are increasing manifold, by affecting the natural ecosystems, hence causing environmental degradation, health hazards, pollution, and unhygienic surroundings. The municipal corporations in India hold the responsibility for waste collection, and separate bins for biodegradable and inert wastes are provided. But when it comes to mixed wastes, they are dumped and often open burned. Above 90 percent of the waste in India is being dumped unsatisfactorily. [3]

The recycling process as of now is carried out at a very later stage and that too manually. The existing system has a few stakeholders working towards these issues, yet the system requires improvement. Therefore it is very

important to identify the drawbacks of our current waste management system and come up with strategies that can help increase the efficiency of the existing mechanism. It would be necessary to design our waste disposal systems using the boom of digitization and bring these technological advancements to our benefit. One promising area of research and innovation that has begun to address this problem is machine learning and artificial intelligence. Using smart technology to classify waste could be a cost-efficient, safe, and possibly even more accurate method of sorting large amounts of waste in a timely manner, which could thereby help to improve the recycling rate.

By the means of image classification techniques, we can identify and hence help segregate the different waste items into different recycling categories.[4]

2. METHODOLOGY

The project is focused on creating a system using the transfer learning technique and hence creating a web app capable of classifying an image into the correct recyclable category.

Data

The trash image dataset in use was created by SashaankSekar[4] and was downloaded from Kaggle. The dataset consists of 22,500 images and is divided into 2 sub-categories: organic and recyclable objects. The dataset consists of 'Train' Data (85%) and 'Test' Data.

Model Building

Keras and Tensorflow[5] are used to build the Deep Learning Convolution Neural Network. Transfer learning models make use of learnings from previous models and utilize this knowledge to train new models or carry out new tasks.[6] VGG16(Visual Geometry Group) is a model trained on the ImageNet dataset[7]. This dataset comprises more than fourteen million images, belonging to thousands of classes.

We used the VGG-16 model pre-trained on the ImageNet dataset as our base model. The architecture of vgg16 has 16 layers, and that involves the type of layers - convolutional, pooling, and fully connected layers. There are 2 convolutional, followed by pooling, again 2 convolutional and one pooling, followed by blocks of three convolutional followed by pooling, and finally 3 fully connected layers. [8] The activation function used here is softmax.

To this, we added customized dense layers in addition to other layers such as freezing and dropout. Libraries such as MatPlotLib and Seaborn were used to plot results from training and evaluation. Also used for visualizing the base model and dense layers.

The loss function, which is used to compute the quantity that the model should seek to minimize during training, was chosen as Cross Entropy. For regression models, the commonly used loss function is mean squared error function while for classification models predicting the probability, the loss function most commonly used is cross entropy.

We used categorical _crossentropy in this scenario. This is because we had a multiclass classification model (i.e. two or more output labels). The output labels are usually one hot category encoded, i.e. 0 or 1.

Cross Entropy is defined as:

$$L_{\mathrm{CE}} = -\sum_{i=1}^{n} t_i \log(p_i), \quad \text{for n classes,}$$

where t_i is the truth label and p_i is the Softmax probability for the ith class.

The model was set to train for 20 epochs and an early stopping callback was set.

Developing User Interface for the Application

The user interface is developed using HTML, CSS, and JavaScript. The HTML files define the skeleton for the web application, CSS is used to add styling to the HTML elements and javascript is used to make the elements interactive (eg - buttons clickable, form to upload an image, etc).

D. *Application Development using Python and Flask*

Python is a high-level programming language that focuses on code readability for Web Development. These standard libraries in python have pre-coded functions, which can be easily downloaded and modified as per development needs. Flask is a web framework that provides libraries to build lightweight web applications in python. It is developed by Armin Ronacher who leads an international group of Python enthusiasts (POCCO). It is based on the WSGI toolkit and jinja2 template engine. Flask is considered a micro-framework. Flask uses a jinja template engine and Werkzeug WSGI ToolKit. Its file structure includes static files and templates. Static files

consist of CSS files, JavaScript files, and images or other resources, while templates consist of HTML files.[9]

The app uses libraries such as flask, NumPy, Keras, and TensorFlow. The front-end web app allows users to upload images on the form. There are two python scripts to render images from the uploading form and feed it into the model for classification. After training the model over 20 epochs, its weights were saved, and the function prediction utilizes these saved weights to make the predictions. Hence for each uploaded image, the model prediction function is called upon. Finally, the result from the prediction function is sent back to the HTML file (or template) and the classification is displayed - Category - "Organic" or "Recycled", and the Probability score.

3. RESULTS AND DISCUSSIONS

Evaluating Deep Learning Model

Upon making predictions on the test data, the following accuracy and loss vs the number of epochs plots are obtained. The highest accuracy obtained was .94 (or 94%). Overall the accuracy of 93.9% was obtained when 20 epochs were taken into consideration. The overall loss was 0.365 (or 36.5%).

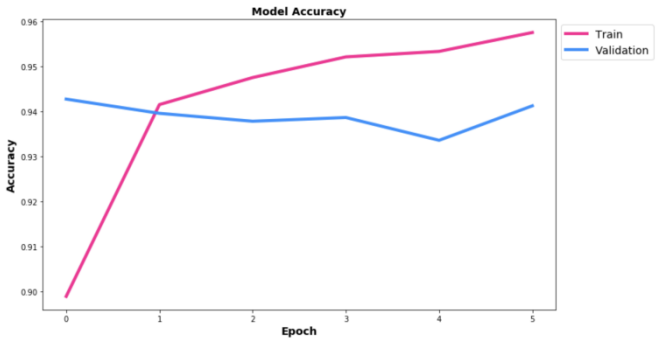

fig1: vgg16 evaluation - accuracy v/s number of epochs

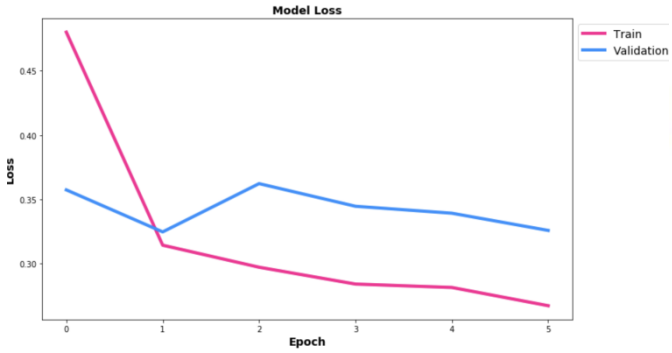

fig2: vgg16 evaluation - loss v/s number of epochs

Confusion Matrix

A Confusion matrix is an N x N matrix used for evaluating the performance of a classification model, where N is the number of target classes. The matrix compares the actual target values with those predicted by the machine learning model. This gives us a holistic view of how well our classification model is performing and what kinds of errors it is making.

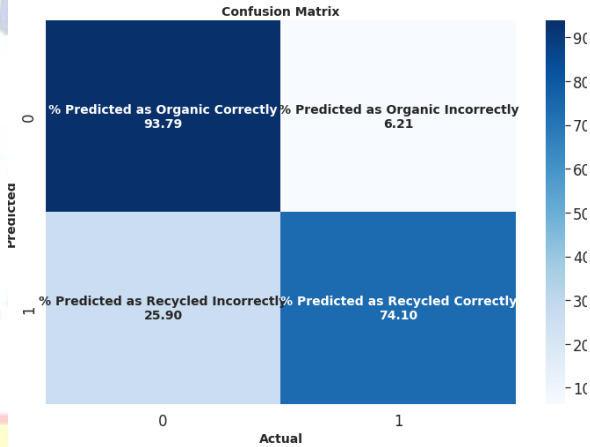

fig3: confusion matrix for TEST data Evaluation

Evaluation of Web Application developed

The web application consists of a home page with a form to upload the image to be classified. On clicking submit, the result is generated and displayed on the same page. The result comprises the respective category - "Organic" or "Recyclable", along with a probability. Screenshots of the resulting web application are attached below.

fig4: Home Page of Web App

fig5: Uploading Image

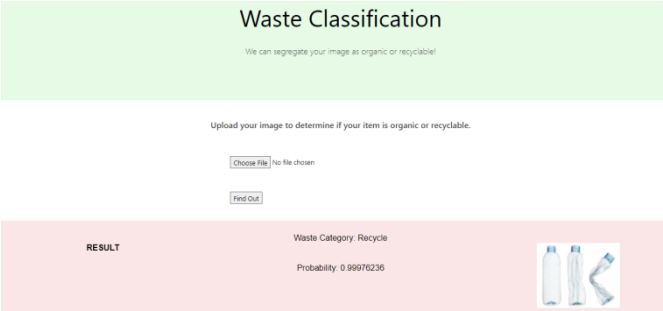

fig6 : Result

4. CONCLUSION AND FUTURE SCOPE

The objective of this study was to develop a model that can classify an image into one of the six categories - 'glass', 'paper', 'cardboard', 'metal', 'plastic', 'trash'. We are able to come up with a transfer learning model that gives realistic classification of the waste images into different classes of recyclable items. We observed that due to the usage of pre-trained deep learning models, we were able to achieve better accuracy in classifying unseen data. This study has been performed meticulously and hence provides accurate results which can be further taken forward from here. This study can be taken forward by adding more classes of data. Also, more advanced models could be taken up for further improving the accuracy. This model can find use in developing optical sorting systems which can be used on both household levels and large scale waste management areas, to make the recycling process efficient.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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