TARGETED RUBBISH ASSORTING SYSTEM HANDLER(TRASH)

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Abstract: *The waste needs to get segregated properly or efficiently for the process of waste management. Our project titled "TRASH – Targeted Assorting System Handler" proposes a system that is capable for the Industry level. The wastes are broadly classified into two levels: recyclable and non-recyclable ones. It aims at recognizing the recyclable objects from the garbage on a large scale. To simplify this process , we came up with a deep learning approach that uses CNN or transfer learning. (Through the transfer learning which uses pre-trained parameters, through this technique we look for achieving higher than 90% accuracy). Thus, it will help in easy segregation of useful recyclable items. We will be implementing a deep learning model which will be done in two phases. The first model will classify the image into garbage and non-garbage ones respectively. After this processing, the output of first model phase will be inputted into the second phase for further classification and detection of recyclable objects. Two models are need to be built because a single object may or may not be considered as a garbage. There are unique forms of algorithms for detection task, however YoloV3 is satisfactory appropriate for item detection. Through this we can classify the recycling item gift withinside the garbage.*

Keywords: Waste segregation, CNN, transfer learning, object detection, object classification, VGG19, YOLO V3.

1.INTRODUCTION

India is witnessing street corners and walkway transforming into garbage dumps. According to [1], India generates the most waste globally, says World Bank. Every year, 2.01 billion tonnes of waste is generated every year which is estimated to increase by 70%to reach 3.4 billion tonnes by the year 2050. These statistical figures forewarn us that if some steps have not implemented then it would be a great threat to the humanity. The accumulation of waste has become a serious problem, and if not handled properly, it may endanger health. It is obvious that there may be no fee from waste, as power or material, if it isn't segregated.

In our country most of the segregation of wastes are rely upon the manual inspection. As per [2], there are estimated two million waste-pickers exist in India today. What is definite that these families are living in an extremely unhygienic areas which will ultimately result into dangerous hazards in the living of them. These issues are needed to be solved to achieve a healthy environment which demands for a technology that can ensure that the waste will not end in landfills, but will processed and reused [3].

For the development of a Smart City, we propose an automatic detection method to help alleviate garbage problems. With this in mind, it motivated us to develop an automated system which is able to sort the waste. With the system in place, the beneficial separated waste can still be recycled and converted to energy and fuel for the growth of the economy. Since 1950s, around 8.3 billion tons of plastic have been produced worldwide and only 9% of it has been recycled. It is seen that the municipal authorities has to invest lot of heavy capital and man power for the recycling purpose. Chandigarh despite of ranked 11th cleanest city in Swachh Survekshan 2017, waste segregation is still is norm for Chandigarh[4]. So, such type of system is the Need Of an Hour that is capable to do these tasks. The system will categorize the useful data with the use of classification algorithms. It aims at recognizing the recyclable objects from the garbage on a large scale.

2. RELATED WORK

There's been a gradual enhancement in the techniques used in object detection and object classification. The machine learning techniques were widely used in detection and classification. In machine learning, Support Vector Machines (SVMs) are supposed to best suitable for the classification of any data. This algorithm gives an accuracy of 63% [5]. But the issue with this algorithm is the high accuracy and also it does not perform well with the data having noise in it. [6] In cases where the number of features for each data point exceeds the number of training data samples, the SVM will underperform.

The similar work done before was a project from TechCrunch Disrupt Hackathon [7] in 2016 in this the group members created "Auto-Trash", an auto-sorting system that can differentiate between compost and recycling using Raspberry Pi active module and camera. This project was built using Google's TensorFlow and it also comprises hardware components. There is something important about Auto-Trash is that it can only categorize whether object is compost or recyclable, which is an uncomplicated process than recognizing firstly whether the image is having garbage or not and then further classifying it as recyclable or non-recyclable. The goal of the team is to reduce human error and eliminate any effort they have made for project classification.

Tom, John and Sam [9] performed waste classification into Compost, Recycling and Trash bins. They implemented their model with the help of VGG19, which is comprised of convolutional blocks. After training their data on 150 epochs, they achieved an accuracy of 88%. They've trained their model consisting 100 epochs with a low learning rate of 0.0001. They proposed of a model built using the same methodology where the data is scarce or either self-produced. So, we aim to build our model with more precision.

3. OUR APPROACH

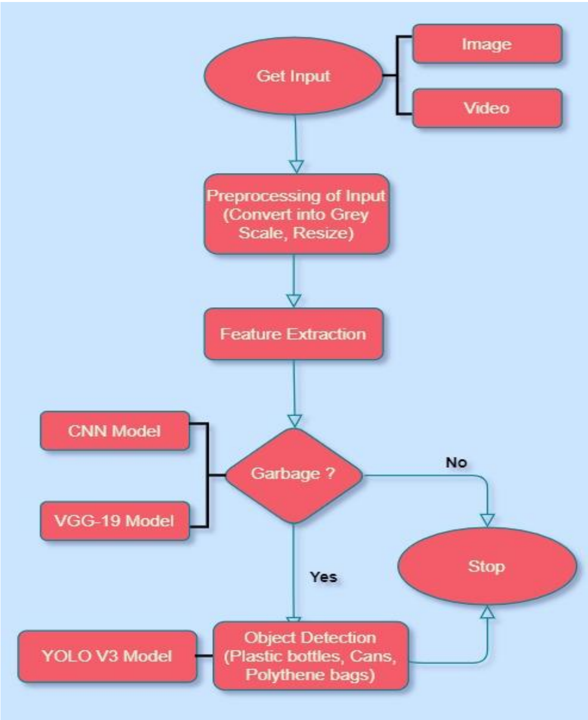

Fig-1: System Flow Chart

3.1 Our Dataset

1) Dataset for Classification.

Data collection is the most important preparation for object detection or classification. Our experiment essentially solves two types of problem, namely whether the area contains garbage or not. Considering the complexity and diversity of urban scenes, we collect non-garbage as well as garbage containing images. In non-garbage images, urban scene classes that contain buildings, neat roads and neat lawn etc. Data augmentation techniques were performed on dataset because the dataset was insufficient on Kaggle, etc. Some images are downloaded manually using different search queries on which augmentation is been performed, and some images are taken from the GINI dataset.

The GINI dataset was no fully considered as gives only 87.69% of accuracy [10]. This resulted in a compilation of 5534 images, out of which 2627 images were of garbage and rest 2907 are non-garbage images. Secondly, if the image contained garbage, then it will detect whether garbage is recyclable or non-recyclable.

Fig 2(a). Garbage Dataset

Fig 2(b). Non-Garbage Dataset

Fig-2: Dataset before Augmentation

Fig 2(a) depicts the garbage dataset that is before the augmentation and Fig2(b) depicts the non-garbage dataset before augmentation

Fig 3(a). Garbage Dataset

Fig 3(b). Non-Garbage Dataset

Fig-3: Dataset after Augmentation

The dataset shown in Fig 3 depicts the garbage in which augmentation is performed in the garbage dataset as well as in non-garbage dataset.

In all the models a single task is being performed i.e., either object detection or classification. We have divided our model into two phases. In phase 1, object detection will be performed which will detect whether the input image contains garbage or not. After the processing of our first model the output of the first model is then processed to the second phase. In second phase, model will do further processing iff garbage is present in the image or input. In our second phase, the model will illustrate the category of garbage present in it, for e.g. the model detects the recyclable items like polythene, cans, etc.

2) Dataset for Detection.
Initially we annotated single object images for detecting of a recyclable object. Around 5600 images were downloaded of different objects such as cans, plastic bottle, polythene, etc and from this 4800 images were sorted for annotation. After training the model, the model was only able to detect single object rather than multiple object in the heap of a garbage.

To solve this issue, we opt our second approach in which we annotated the objects in the heap of garbage only. For this around 2600 garbage images were sorted and from this only 1115 images can only be used for the training of the model because the Indian garbage is so congested as it not possible for the model to detect the objects.

Fig 4(a).

Fig 4(b).

Fig-4: Dataset to be used for annotations

The images in Fig 4 shows the sample images from our dataset which will be used for the training of the YOLO model. The objects on which we have trained our model initially are plastic bottles, cans and polythene bags.

3.2 Garbage detection using CNN

There is different type of algorithm for classification task, but CNN is best suitable for image classification. Deep learning algorithm (CNN) takes input image, extract the features and learned the weight and biases.

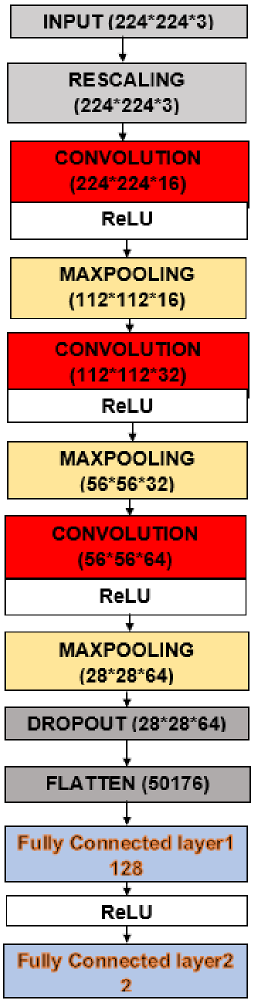

Fig-5: Basic Block of the Classification Model

The implementation is been performed on the CNN model architecture, in this architecture the network has an input RGB image size is 224x224, Image pixel are rescaled into [0,1] . We have used kernels of 3x3 size. After that pooling was performed over a 2 * 2 pixel windows with stride 2. we have implemented two dense layer with ReLU activation function. A dropout layer has also been used which may help the model to reduce the chances of overfitting.

The ReLU (Rectified linear unit) activation function ensures less cost in computation and also it does not have a vanishing gradient problem. This activation function may be defined as

y=MAX(0,x)

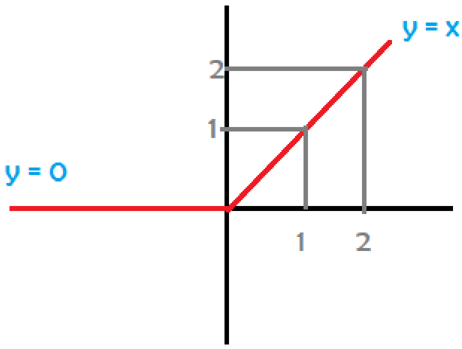

Fig. 6 ReLU Function

In this model training we have used ADAM optimizer and for measuring the loss we have used Categorical Cross Entropy. ADAM optimizer is computationally efficient and less computational expensive.

$$CE = -\sum_{i=1}^{C'=2} t_i log(s_i) = -t_1 log(s_1) - (1 - t_1) log(1 - s_1)$$

We have trained the model on 10 epochs and achieves 84% accuracy.

```
Epoch 15/15
136/136 [==============================] - 203s 1s/step - loss: 0.3494 - accuracy: 0.8453 - val_loss: 0.4609 - val_accuracy: 0.8040
```

Further we have increased the number of epochs due to this we find that training accuracy is increased but the validation loss is also increased proportionally .So the model is Overfit , to remove we have also add Dropout layer but it didn't get affect the validation loss.

```
Epoch 25/25
136/136 [==============================] - 195s 1s/step - loss: 0.2613 - accuracy: 0.8908 - val_loss: 0.5323 - val_accuracy: 0.8086
```

3.2 Garbage detection using VGG-19 model

To overcome this issue of overfitting, we decided to build our model on the concept called Transfer Learning because it allows us to build accurate models in a timesaving way[8]. The transfer learning model was built by using VGG19 model. This technique is used as when we train our own data on the top of pretrained parameters, the accuracy eventually becomes more refine as in CNN there's a lot of time needed in training of the dataset. The basic architecture of VGG19 model is shown in the figure below[11].

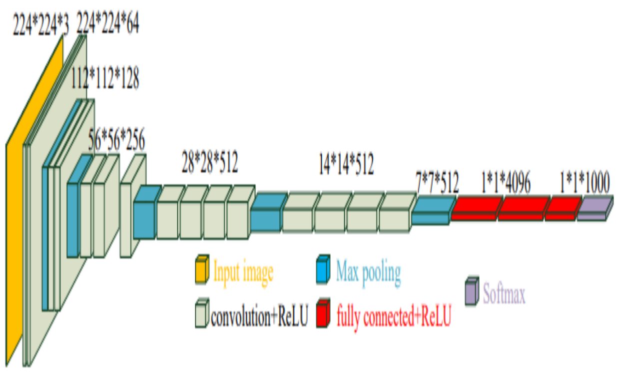

Fig. 7 VGG-19 network model

The VGG-19 is been improved in the network depth. As compared to a single convolution, it uses an alternating structure of multiple convolution layers and non-linear activation layers[11]. VGG19 network contain RGB image size of 224*224, in this kernel size is 3x3. For improving the anti-distortion ability of the network to the image, Maxpooling is performed with their default value parameter, which is further modified by using the ReLU activation function which us then, selects the largest value in the image area as the pooled value of the area. The SoftMax function is used at the output layer for getting the probability for two classes, i.e., garbage class and the non-garbage class.

We have frozen all the layers and trained the model with our own Garbage dataset and trained our own classifier. By using this VGG-19 network model we train the first phase of our model, i.e., the garbage detection model, which results in 98% of train accuracy and 90.8% of validation accuracy. These results are achieved in 10 epochs as shown in figure below.

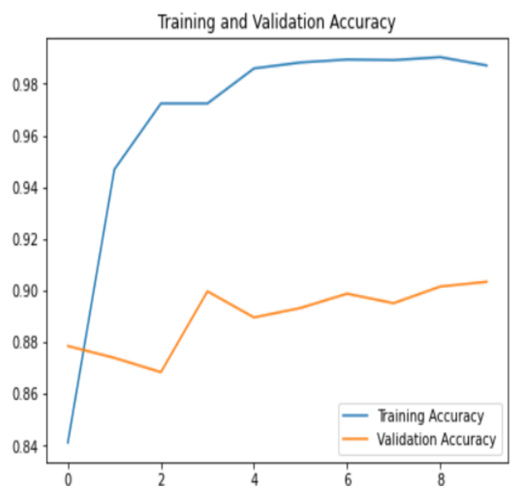

Fig.8 Accuracy of Detection Model

3.4 Object Detection using YOLO

The second phase classifies the recycling object present in the garbage. The model will be capable of detecting objects like polythene, cans, bottles, etc. For object classification and detection, we are using Yolo V3, an improved version of Yolo algorithm which uses DARKNET-53 framework as it's feature extractor[12].

Fig 9. Network Model of Yolo

Darknet-53 will be used which is a 53 convolution network layer. It acts as a framework for the YOLOv3 object detection approach. Input Layer size is (1,416,416,3) and the output layer size is (1,1067,8). Output layer is a list of bounding box, classes & scores. Theses denoted by following an array of list

[P,box_x,box_y,box_w,box_h,C1,C2,C3].

where P is the probability of the class, C is the class i.e. C1-palstic bottle,C2 - Can and C3 - polythene bags.

The bounding box will be predicted using linear regression. The loss function can be calculated in this model as given below:

Class category loss = Sum(Binary Cross Entropy(y, y') * object mask).

During an epoch, the loss function is calculated for all data elements and is guaranteed to provide the quantitative loss measure in the given epoch. The iteration vs loss curve of the Yolo v3 model is shown below in figure 10, and from the image we can say that the loss is minimal which is a good indicator.

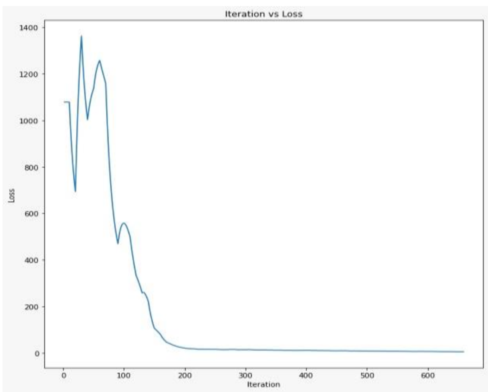

Fig 10. Iteration vs Loss Curve of Yolo V3

The model is trained on Google Colab and it provides online Tesla K80 GPU for faster training. The training time taken by the model is 3.5 hours. Yolo algorithm takes an input image and see only ones for prediction Unlike sliding window approach. On image it will produce a grid and in each grid it will detect the object and produce the probability. It is a method to select single anchor box from different overlapping anchor boxes. It discarded the overlapping bounding boxes using IOU threshold. IOU. Threshold is a number from 0 to 1 that specifies the amount of overlap between the predicted and ground truth bounding box.

The model is trained on 1000 iterations and the learning rate is 0.01. The accuracy of our model is calculated through mAP (Mean Average Precision). mAP compares the bounding box of the basic truth with the found box and returns a score; the higher the score, the more accurate the model's detection. The mAP of our model is 70.21% at IOU threshold of 0.5.

4. EXPERIMENT AND RESULTS

First, the image or video was passed into the first model and the classification model checks whether the input have the garbage or not. If yes, then the output of classification was pass to the second model, i.e., Detection model (Yolo model) as an input and Yolo will detect the objects like plastic bottle, can, cardboard, polythene bag etc.

Table 1 and Table 2 shows the results we have obtained in classification and detection models respectively in different epochs and iterations.

Table 1: Results obtained in Object Classification

Model	Epochs	Training Accuracy	Validation Accuracy
CNN	15	94%	75%
	25	89%	80%
VGG-19	10	98%	90.8%
	50	99%	88%

Table 2: Results obtained in Object Detection Model

Model	Iterations	IOU threshold	mAP
YOLO	1000	0.5	70.21%

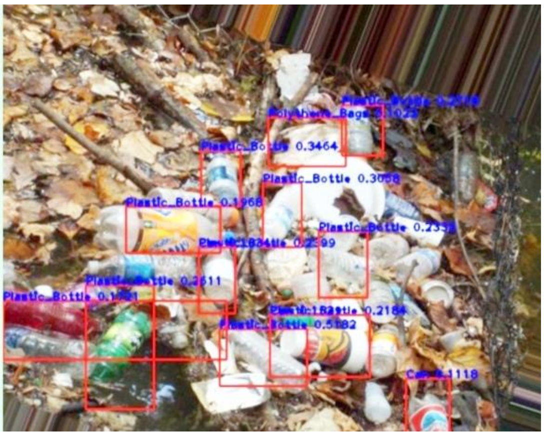

Fig 11(a)

Fig 11(b)

Fig 11. Sample Output Images of our Proposed Model

5. CONCLUSIONS / FUTURE SCOPE

In this project, we have successfully implemented Transfer Learning by using VGG-19 network model for garbage and non-garbage classification and in yolo v3, we detected and classified recyclable objects. Although, we are capable of detecting the multiple objects present in the dataset. Also, we have successfully implemented the working of our model on video.

Our future criteria is that we would like to extend TRASH (Targeted Rubbish Assorting System Handler) to recognize and categorize more number of objects from an image or video. This will help us to enhance recycling facilities by processing multiple recycling objects rather than single object Further important addition could be done is that detecting and classifying more than one object. This would improve large scale classification of recycling materials..

Finally, we will like to continue expanding our dataset by adding more images to it the garbage dataset section, and if possible into other sections also, and then releasing it with more accuracy.

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