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SEGRO: Key Towards Modern Waste Management

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***Abstract*—This paper focuses on the fact that with modernization and advancement in technology, we can improve the overall urban waste management system. The current smart bin segregates waste and puts it in the appropriate part, but none has connectivity. Thus, even if smart bins are deployed widely, they won't be viable enough, without proper collection facilities for them. We develop a central server which is connected to each of the smart bin and undertakes all the necessary functions such as tracking all the bins for their garbage level, tracking all the trucks and generating optimised routes for the truck drivers. Also in the current scenario, the recycling industry is very disorganised. Sending the collected waste directly to these industries helps in saving time, fuel and storage space. Thus, a consolidated system which serves as an end to end product for waste management is discussed in this paper.**

***Index Terms*—waste segregation, route optimization, recycling waste, waste classifier, smart bins, deep learning**

I. INTRODUCTION

Considering the current scenario in our country, we see that waste disposal, segregation and collection, collectively is one of the biggest challenges faced by the authorities. With the rise in urbanization, there is an urgent need for solid waste management. The initiative undertaken by the current Prime Minister, Shri Narendra Modi, the Swachh Bharat Mission, has made us proactive in developing a solution to this problem. Therefore, we propose SEGRO - so that we can say grow to our environment. The most important reason for efficient waste collection, disposal is for the protection of the environment and health of the population. We often see that though the technology is advancing, the waste collection sector is still not automated and hence there is still a wide scope present for the advancement of waste collection, disposal and recycling strategies. [1] Here they state the challenges that are faced in the Municipal Solid Waste Management in India. They provide a conclusion stating that installing decentralized solid waste processing units in metro cities is the way to go. They state that development of recycling industry sector is of utmost importance in developing countries like India.

SEGRO is an end to end solution, encompassing waste disposal, segregation, collection and the effective usage of recycled waste. We propose a solution that will not only effectively segregate the waste into different types based on their life-cycle but also will provide an optimal algorithm for the collection of waste.

II. LITERATURE REVIEW

A. *Smart Bin*

In [2] , different types of smart bins are compared based on their utilities. Most of the bins discussed segregate waste into metallic, dry and west waste. Metallic nature is detected by sensing the impedance of the waste and the Dry/Wet nature is determined by sensing the capacitive difference between the waste and the bin. In [3] , A smart bin has been designed with different types of sensors. They have utilised LoRa in their proposed model of a smart bin.

Waste Classifier: The existing garbage classification system in India consists of unsystematic waste collected from homes which are separated manually. Manual separation of waste involves high risk of diseases due to unhygienic practices. Image Classification with Deep Learning has advanced a lot and can be used for automating the old tradition human driven methods for waste classification.

Proposed for a hierarichal deep learning approach for classication of waste in food trays. They adopted for the state of the art algorithm (Faster RCNN) for object detection and classification.

Proposed the idea of RecycleNet where they used the TrashNet dataset and used DenseNet family of networks pre-trained on the ImageNet Dataset. The disadvantage of such a network was it was slow in the prediction time and hence they altered the connection patterns of the skip connections in the dense block. With fine tuning 121 layered DenseNet model they were able to achieve 95% test accuracy for waste classification.

Here they use Caffe as the deep learning framework for creating a waste classifier. They created a layer of features that received the pixel of image as the input. The edges present in the image were recognized using edge detection algorithm. Later the object in the images were extracted using vari-ous image processing algorithms like feature extraction. Deep Learning was used to check if garbage was biodegradable or not.

One of the common approach [7] used for object detection and classification is using Convolutional Neural Networks which are primarily used to solve difficult tasks such as recognizing patterns in the image and then classifying to a suitable type. Fast Region Based Convolutional Neural Networks is another approach which classifies at a faster rate providing an increase in the magnitude of detection and

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classification accuracy. Fast-RCNN speeds up the process of training a VGG-16 network compared to RCNN. [8]

Yolo (You Only Look Once) [9] is a new approach to object detection which involves detection of multiple objects in the frame. It creates bounding boxes across the detected object and classifies them . Yolo makes single pass over the images and assigns class probabilities to them. Yolov3 [10] is an update to the existing Yolo algorithm.

Waste Segregator: There are many smart bins in the market , readily available for use. A GREENBIN [10] is a very good example of a smart bin which segregates the waste into different categories automatically. It uses different types of sensors, which though accurate , may not be able to correctly predict the actual type to which the material belongs. We overcome this drawback by using a camera module in our proposed methodology.

Bins not being collected once they are full is the only reason why bins overflow. [11] proposes a solution where once the bin is full, it informs the master board receiver that it is ready to be collected. The major drawback of this is that between the time the bin sends this message and the waste is collected, the bin can overflow. Thus a change in this part is also proposed

B. Waste Collection

Route optimization is an important aspect of this paper, we will be having a look at TSP for the same. TSP being practical problem, it tries to find minimum distance between given set of points by traversing each point only once except the initial point. Many techniques exist such as Ant Colony optimization [12], Genetic algorithms, neural networks etc. Generic methods of TSP are pretty good, but [13] proposes the usage of data pertubation, to enhance the solution. A case study involving the use of shortest route optimization is done in [14].

III. WASTE CLASSIFIER

A. Convolutional Neural Network using ResNet Architecture

1) Data Preparation: For training of the model,we used the TrashNet dataset which consisted of six different types of waste cardboard, paper, plastic, metal, trash and glass.The dataset consists of around 2500 images in total.

2) Training the Model: The model was created using the ResNet34 architecture. Residual neural networks are convolutional neural networks which has a lot of layers. The advantage of using ResNet was that it was pretrained on the ImageNet database thus having the idea of classification of ob-jects. The 34 in ResNet34 specifies the number of layer in the model. Networks with a larger number of layers (deep neural network) are beneficial over shallow neural networks. This was implemented using Fastai based on PyTorch.We used Google Colab for training the model. Training the model on GPU speeded up the process.The model was run for 20 epochs. We used transfer learning here by using the pretrained weights on the ImageNet Database.

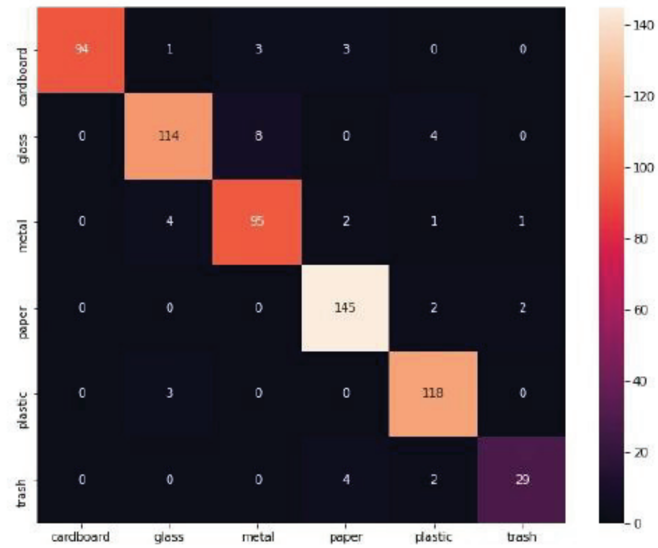

Fig. 1. Results : The heat map helps in getting to know the test accuracy using ResNet architecture.We can infer that majority of the types were classified accurately. The test accuracy of the model achieved was 93.7%.

B. YOLOv3 (You Only Look Once)

1) Data Preparation: The same TrashNet dataset was used for training YOLOv3 as well. Before feeding the images to our neural network here,we need to annotate the images stating the class of waste to which they belong. For the purpose of annotation we use the Visual Object Tagging Tool(VoTT). Once the images are annotated, a csv file is generated consisting of the region of interest coordinates of the image and is then fed to YOLOv3.

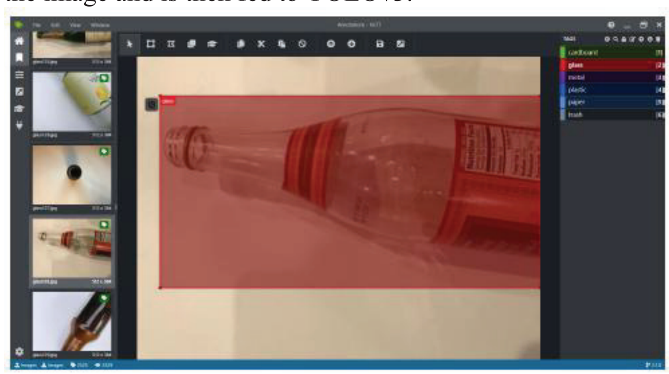

Fig. 2. The images are annotated using VoTT for training purposes of YOLOv3.

2) Training the Model: YOLOv3 provides as with 106 fully convolutional layers which are the main reason behing why YOLOv3 takes a lot of training time. In order to cope with this we make use of GPU which is enabled using CUDA. OpenCV is used to generate the bounding boxes. The model is trained for several epochs until a desirable loss is achieved or the value gets stabilized. Yolo itself rotates the images by certain angles in order to increase the accuracy. Once the model is trained, the weights are being saved. The overall

Mean Average Precision mAP was found to be 84.44%.Mean Average Precision is an important parameter in evaluating object classification.As mAP approaches to 1,accuracy increases.

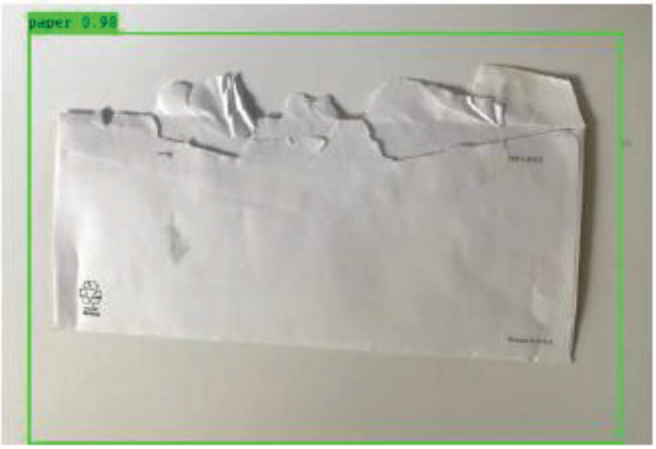

Fig. 3. YOLOv3 identifies paper with an accuracy of 90%

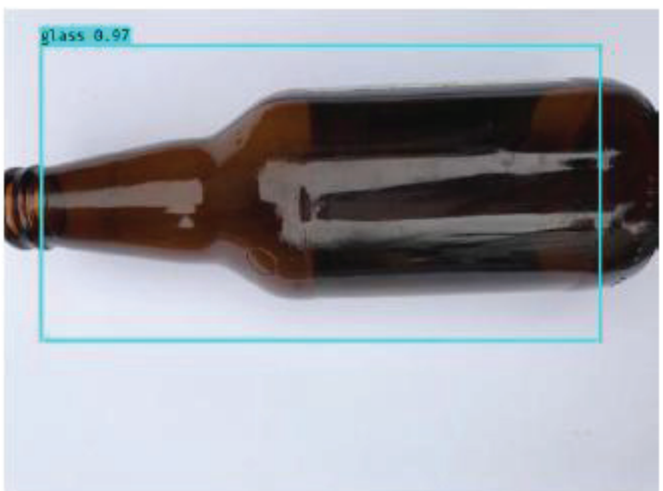

Fig. 4. YOLOv3 identifies glass with an accuracy of 97%

IV. SMART BIN

Each smart bin will have 6 compartments built inside it, covered with flaps. It will consist of a camera module ,to capture the image of the waste when it is being thrown , and a Raspberry Pi Module , which will be used for the classification of the waste. The smart bins will also have level sensors and communication modules, so that it can interact easily with the server.

In our proposed methodology for waste classification ,we consider dividing the waste into 6 categories, on the basis on the rate at which they decay and also the way in which they are recycled. The six categories majorly consist of dry waste and are cardboard, paper, glass, plastic, metal and trash, trash being all the other types of waste not belonging to the first five types.

When the user throws any garbage in the bin, one at a time, the image is captured by the camera module and the classifier mentioned above, in the Raspberry Pi module, classifies the waste . It then, based on the type of waste, opens the flap of the compartment for that waste type.

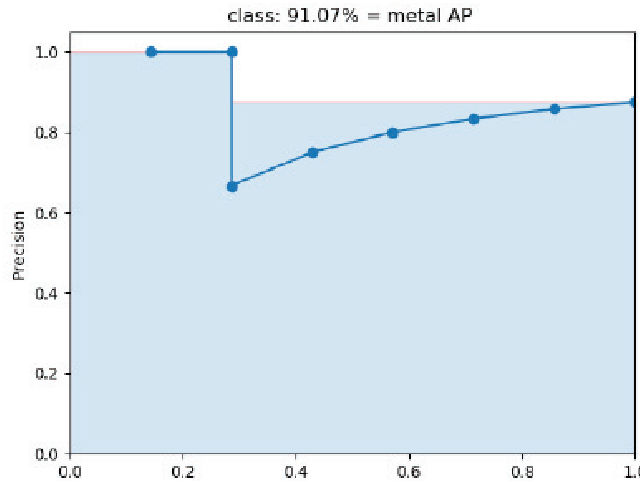

Fig. 5. Average Precision for the metal class by Yolov3 91.07%

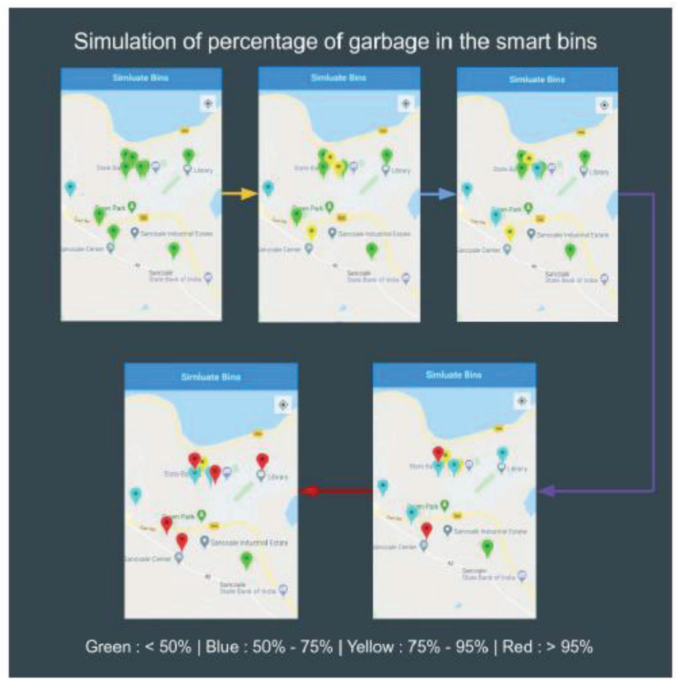

Fig. 6. Results : The flow of the image shows the simulation where the bins are getting filled in a locality. All the bins having color of yellow or red will be collected.

Now, we will be defining a term known as waste threshold. It is the level of waste inside the compartment of a bin, above which the bin will send a threshold-cross notification to the server that that compartment is ready to be collected. The purpose of introducing this threshold is to reduce overflowing of the bins. If a threshold-cross notification is sent before hand, then the bin will be emptied before it starts to overflow. For trial purpose, we defined the threshold as 75%, whereas, in practice, it should be determined on the basis of the amount of waste generated in each locality for the level based on the amount of waste generated patterns in the locality where bins are placed. Fig. 6

V. WASTE COLLECTION

We cannot send a truck to collect a single compartment , full of waste, each time we get a threshold-cross notification. So another threshold, know as the count threshold, is defined. It is the number of compartments, in a particular locality, which have sent the threshold-cross notification. This is done so that the efficiency of waste collection can be improved. As soon as the count threshold for a particular locality is reached, a garbage truck is assigned to the task of collecting the waste. The location of all the concerned smart bins are taken into consideration for generating the route. With the location of the bin nearest to the truck driver as the starting point and the recycling industry as the ending point, a route is generated using the Traveling Salesman Approach. The truck driver then collects the waste and delivers it to the recycling industry.

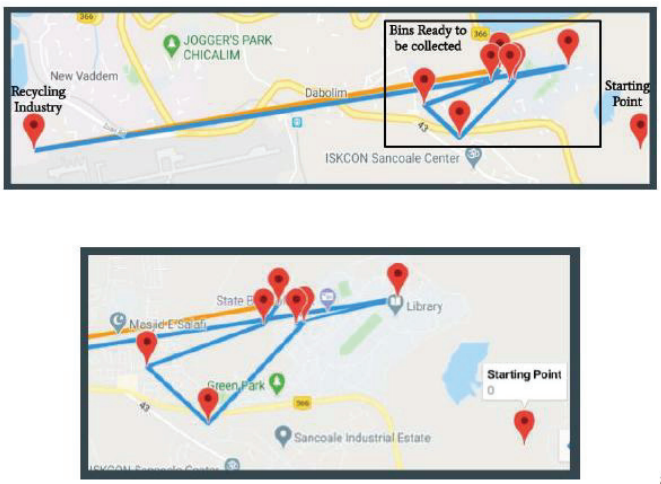

Fig. 7. Results showing the nearest bins.

Traveling Salesman is an optimal and dynamic solution to the classic problem of path finding. Traveling Salesman takes two parameters into consideration, first the start point and the end point. The path is to be found between all the points from the source to the destination. By using Travelling Salesman Problem, we are saving up on fuel and increasing the efficiency at which the waste is collected.

VI. WASTE DISPOSAL AND GEO-FENCING

The waste once collected by the truck driver is delivered to the recycling industries for recycling. It is found that there are many homemakers who make use of recycled products for making artifacts. Thus, we have also built a marketplace where the home makers can buy recycled waste and also sell the products online.The benefit of having such a market place is providing a platform for effective and easy communication for buying and selling of products.

The user of the application can also search for smart bins near his/her location. A geo-fence of 10 km is created, inside which the application returns the nearest 10 bins from the person's location. Fig. 8

VII. CONCLUSION

The paper concludes that with modernization and advancement in technologies, we improve the existing archaic methods used for waste classification, collection and disposal. By efficiently applying the knowledge of Neural Networks we trained the models for automating the task of waste classification. Also by using the genetic algorithms like Travelling Salesman Problem we can overcome the age old problem of waste collection in our country. The simulation of the entire idea over an app makes it user friendly and easily available for use by the masses. The overall implementation of Smart Bins with efficient recycling of waste will contribute towards a healthier and clean environment.

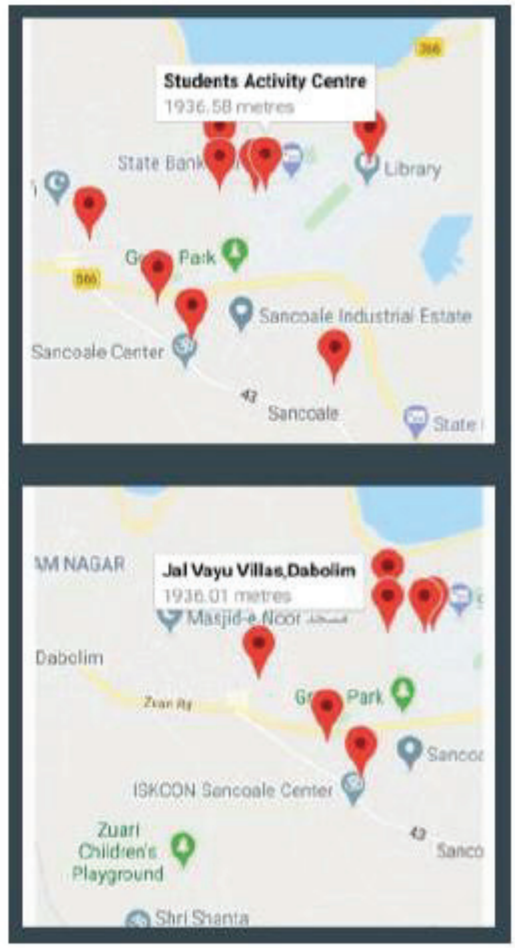

Fig. 8. Results showing the nearest bins.

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