Waste Segregation Using Deep Learning

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Abstract: In the year 2019, Marine drive turned into a necklace of trash incident and constant flooding of areas due to chock up in pipelines is constantly asking us to pay attention to our waste management system. The health issue of clean- up workers in India is increasing day by day hence the need for an automatic waste management system has increased. The traditional method involves collecting waste from household and surroundings and then manual segregation of waste at a station or dumping areas. This method is time-consuming, less efficient and increases health issues. YOLO (you look only once) deep learning algorithm is used to segregate waste as wet, dry, metallic, non-metallic, sanitary, hazardous waste respectively. This method is an Eco-friendly, less time consuming and efficient. Once the waste is segregated properly then the decomposition or recycle and reuse of waste can be easily done.

Keywords: Deep learning, object recognition, YOLO algorithm, COCO dataset, Machine learning, RCNN, SSD, Retina, Artificial intelligence, kaggle dataset.

I. INTRODUCTION

Waste is any substance which is unwanted or defective to a human being. Garbage is a waste which is discarded by human beings. It includes different food items, plastic, paper, sanitary, hazardous, metallic, non-metallic, electronic, industrial, agricultural waste, etc. As per the survey in the year 2018, out of 8.3 billion tonnes of plastic produced, 6.3 billion tonnes have been discarded and nearly 13 million tonnes of plastic waste are mixed in oceans. It contains 1 million plastic drinking bottles which are purchased every minute and 5 trillion disposable plastic bags used every year [1].

Waste generated by 377 million urban people living in 7,935 towns is 62 million tonnes of solid waste per annum out of which only 43 million tonnes of waste is collected, 11.9 million tonnes of waste is treated and 31 million tonnes of waste gets dumped in landfill sites. Waste management is a universal issue which matters to every single human being on this planet. In the year 2016, 5% of global emission was generated by solid waste management excluding transportation [2].

This shows that waste segregation and then waste management is of very much importance. Hazards affecting all forms of life leading to contamination of air, water, and soil which in turn causes dangerous diseases to human beings are the effects of improper disposal of garbage.

Segregation manages the waste at landfills which in turn reduces the air, water, soil pollution. The trend to introduce automated waste segregation systems into new housing development projects is rising and serves for leading the way in implementing this type of technology.

II. OBJECTIVE

The existing waste segregation method in India involves collecting waste from every house and then at a station the waste is segregated by rag pickers manually. This leads to various health issues of rag pickers as well as consume a lot of time.

The main aim of this paper is to proffer an automated waste segregation method which will help to reduce the health issue and fasten the process of waste segregation. The waste will be segregated as dry, wet, hazardous and bio-medical waste.

Due to the accumulation of waste various greenhouse gases like methane, carbon monoxide is released the intensity of these gases can be reduced by properly segregating waste daily. The depth of the existing landfills will be also curbed, thereby cutting down whatever is toxic to the environment.

III. EXISTING SYSTEM

As per traditional waste disposal system in India, waste collected from household by waste collectors reaches transfer stations then manually to the landfill sites. Solid waste is segregated manually by rag pickers, in the end, to be fed to a waste-to-energy plant but in most cases, they are just land- filled. Manual segregation of waste results in various health mishaps of rag pickers consumes a lot of time and also requires financial share.[3][4]

An Automated Waste Segregator (AWS) was designed to sort the waste into metallic waste, wet waste, and dry waste using rotating disks and various sensors. The rotating disks use a moisture sensor to detect wet waste, the proximity sensor detects metallic waste and accordingly the waste detected stays on the same disk while the remaining waste is passed on to the next disk. The laser test performed to detect the various types of plastic. This segregation method must be under observation of an adult while performing in houses as involves the laser-related risks.[5]

A Smart robot was designed using an IC controller and DC motors to separate degradable and non-degradable waste using image processing techniques to perform various movements. It has two process modes manual mode and auto mode. In manual mode, the user will give command manually from PC GUI and through USB to TTL the command will be received from PC, be given to PIC controller. According to command robot will act. In auto mode, waste will be segregated using image processing; the camera is attached in front of the robot. PC will give a command to robot to start moving forwards until an the obstacle is detected using the obstacle the sensor will continue to move forward. After detecting any obstacle robot will stop and the camera will turn on to capture garbage image. MATLAB will process it and according to garbage detected, the robotic arm will dump it in a respective bin. If any valuable or useful object found as an obstacle to robot then it will throw it in dustbin so it cannot be used at a household level[6].

Waste segregation using IOT was designed wherein STM32 was the heart of the system. It used various sensors to detect the type of waste and drop it into its corresponding section. The level in each section was detected using a level detecting sensor and then the message was sent to the user using the cloud. Bacteria sensor tracks the microbial activities. Odor controller is used for minimizing the unpleasant odor by spraying chemicals. This segregation method cannot be used in an area having poor internet connections as it requires the internet to inform the user about the filling of a section so that user can vacant that section else it leads to an overflow of the garbage from a bin. [7]

The automatic waste management system uses artificial intelligence and deep learning technique to classify waste into biodegradable and non-biodegradable. The proposed system uses Caffe model and was based on the SSD algorithm which is an aggressive object detector i.e. it can detect multiple objects but can make more mistake [8].

IV. PROBLEMS

The non-segregated waste dumped in landfill discharges poisonous gases and leach into the air and soil respectively. When this poisonous gas gets mixed with air or water bodies it affects the health issues, increases the pollution and blockage of a drainage system which increases the amount of flood occurring. This affects the aquatic life[9].

Waste collected by these waste pickers contains hazardous medical waste, sanitary waste; biological waste that gets disposed into general waste which may act as an exploitative system. Workers face various injuries, cuts, respiratory problems, stomach problems, musculoskeletal disorders (MSD) in many body parts. Since they climb and carry heavyweights of collected waste they face MSD[10].

Majority of wastes generated consists of plastic, which is non-degradable i.e cannot be absorbed or recycled. When oceanic creatures and birds consume plastic inadvertently, they choke on it which causes a steady decline in their population [11].

V. DEEP LEARNING

Machine learning is used to analyze, understand and identify a pattern in the data. Machine learning helps the machine to make decisions on its own without any human intervention using its experience. To understand the relationship between input and output it uses data to feed an algorithm. Deep learning also is known as deep structured learning or hierarchical learning is a subset of machine learning which makes use of deep neural networks because it mimics the network of neurons in the brain.

Deep learning can be supervised, unsupervised or semi- supervised. Deep learning can be used in a task involving adaptive learning like computer vision, image recognition, speech recognition, natural language processing medical image analysis, etc. as well as in cognitive learning such as learning the features, characteristics, and attributes with the help of good algorithms which can learn on its own. Deep learning architecture is deep neural networks, deep belief networks, recurrent neural networks and convolutional neural networks that represent probability hierarchy. [12]

In convolution neural network architecture layers are stacked upon each other, this help to solve problems of classification and representation through constant learning. Each layer learns minute details from the picture then the next layer combines the previous layer knowledge to make complex information. Feature extraction is done here by using a filter; the filter finds the matching features from the picture hence it is automatic.

To learn data representation it processes multiple layers through computational models. The back propagation algorithm is used to discover complex structures in huge data sets and represents variation in inner parameters of a machine that are used to determine the representation of each layer from the depiction of the previous layer. Weights used for recognizing any objects are combined in perceptron. [13][14]

A. OBJECT DETECTION

It consists of recognition, localization, and detection of multiple objects within an image. It can be implemented using various ways like Feature-Based Object Detection, Viola-Jones Object Detection, SVM Classifications with HOG Features, Deep Learning Object Detection.

B. OBJECT DETECTION ALGORITHMS

Different algorithms are available for object detection in deep learning

RCNN*:* Region-based Convolutional Neural Network Selective Search algorithm is used to scan input image and generate 2000 region proposals, convolutional neural net (CNN) runs above all the region proposal. Output of each CNN uses SVM to classify region and linear regressor is used to tighten bounding box of objects.[15]

SSD: Single Shot Detector It runs a Convolutional network is run on input image only one time to computes a feature map. It uses anchor boxes at a variety of aspect ratio comparable to Faster-RCNN and learns the off-set to a certain extent than learning the box. In order to hold the scale, it predicts bounding boxes after multiple convolutional layers. Since every convolutional layer functions at a diverse scale, it is able to detect objects of a mixture of scales.[16]

RetinaNet: It is a one-stage dense object detector whose two crucial building blocks are featurized image pyramid and the use of focal loss. To assign more weights on hard, easily misclassified examples and to down-weight easy examples focal loss is designed. The featurized image pyramid is the backbone network for RetinaNet. Featurized image pyramids provide a basic vision component for object detection at different scales by following image pyramid approach in SSD.

YOLO: You Only Look Once are a popular object detection algorithm which not only predicts the category of an object also detects its location. It applies a Single Neural Network to the Full Image which divides the images into regions and predicts bounding boxes and probabilities for each region. Predicted probabilities are used to find the weights of these bounding boxes. [17] YOLO is faster and more accurate compared to Single Shot MultiBox (SSD) object detection algorithm. Use of OpenCV for YOLO:

- Supports python
- Easy integration with OpenCV application
- The CPU version of OpenCV is 9x times faster [18].

VI. PROPOSED SYSTEM

This proposed system will identify and segregate waste without human involvement. The proposed system mainly focuses on identification, classification, and segregation of waste using YOLOV3 algorithm. The sample data set is a combination of various kaggle dataset, converted in coco format. The proposed system uses custom dataset containing 2000 images of dry waste, wet waste, hazardous waste and plastic waste. Out of 2000 images model uses 1000 images for training and 500 images for testing. The proposed system uses Darknet an open source neural network framework, to train custom dataset. Sample data set used is shown in Fig1. It has an auto update facility i.e. when a new object is found then based on the previous predictions it will find probability and classify it.

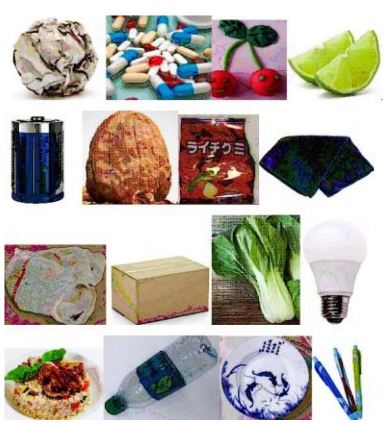

Fig. 1. Sample images of Coco dataset

A. ALGORITHM

Step 1: Start
Step 2: Accept the input image or video
Step 3: Perform an analysis of the captured images by comparing it with trained data.
Step 4: Objects are classified then localized using YOLOV3 object detection algorithm
Step 5: Combination of classification and localization results in the identification of an object
Step 6: Based on identification predictions are made and probability is found.
Step 7: The prediction having the largest probability will be the output.
Step 8: The output tells the type of waste.
Step 9: Stop

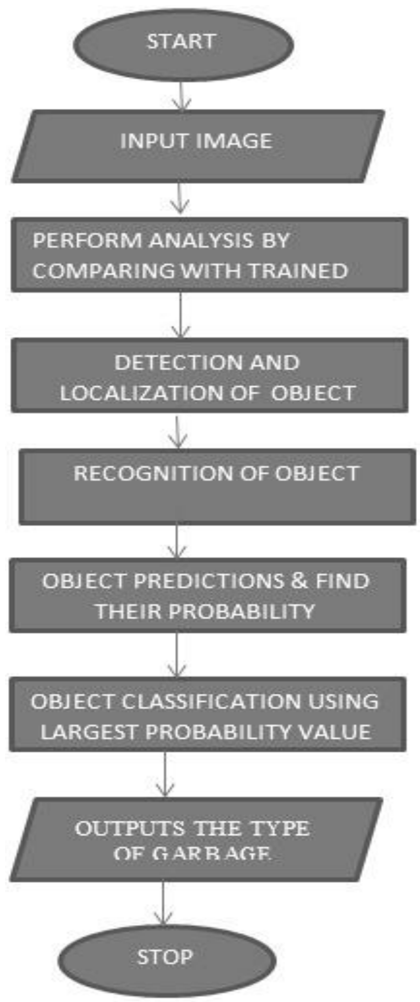

Fig. 2. Flowchart of Object detection and classification

VII. IMPLEMENTATION

Based on the accuracy and speed to detect object we are using YOLOv3 algorithm for waste detection and segregation.

A. TRAINING YOLOV3

1. Download and built Darknet environment on Linux operating system using command git clone and make Darknet
2. Load pre-trained yolov3 weights on device.
3. Create a folder of custom data containing images folder, names file, yolov3.cfg file, train.txt, test.txt and pre- trained weights.
4. The proposed system uses labelImg to create annotations for input images, export annotation in Yolo format.

```
15 0.501901 0.500000 0.996198 0.989583
```

Fig. 3. Format of yolov3 annotation

5. The Fig 3. shows the format of yolov3 annotation as follows object-class-id it refer to id associated with each class and its ranges from 0 to classes-1, x-center i.e. x- center=x/width, y-center=y/width ,width height where x and y are center coordinates of bounding boxes
6. Upload images and annotations in images folder, store the location of training and testing images in train. txt and test.txt files
7. Place one label per line in names file.
8. Update convolution layer and Yolo layer present in yolov3.cfg file as 0number of filters=(number of classes+5)*3
9. Number of classes represents the number of labels; the proposed system uses 4 labels wet waste, dry waste, hazardous waste and plastic waste.
10. Create detector.data file and store number of classes, location of train.txt, test.txt and names file, a backup file which will store new weights created during training model as shown in Fig 4.

```
classes=3
train=custom_data/train.txt
valid=custom_data/test.txt
names=custom_data/custom.names
backup=backup/
```

Fig. 4. Create detector file

11. Train dataset by running command: history=model.fitgenerator(aug.flow(xtrain, ytrain,batchsize=BS),validationdata=(xtest, ytest), stepsperepoch=len(xtrain) // BS, epochs=EPOCHS, verbose=1), where epochs represents number of iteration required to train dataset
12. The new weights of trained model are stored in backup file.

B. WORKING WITH YOLOV3

1. Load the contents of custom data file containing yolo3.weights (weights of trained model in backup folder), yolov3.cfg , and names files.
2. Initialize the parameters like input height, input width, the confidence threshold value, non-maxima suppression (NMS) threshold value.

<u>**Note:**</u> If NMS is too low then it won't detect overlapping objects of the same or different objects whereas if it's set too high then it can detect multiple objects of same or different classes.

3. Load the model and class (yolov3.cfg, yolov3.weights, coco.names) file.
4. Take input using a camera or load image or video.
5. Input frame read from image or video is passed to blobFromImage function where an input image is con- verted into a the required format called as a blob.
6. An input image is divided into SxS grid cells size of cells is input height, input width size.

7. Each grid cell predicts n bounding boxes in images and confidence.
8. Accuracy of the bounding box is represented by confi- dence i.e. the object is present inside the bounding box or not (Irrespective of class).
9. YOLOV3 predicts the classification score for each box for every class in training.
10. To find the probability of each class being present in a predicted box combine both the classes.
11. The number of predicted boxes is SxSxN boxes
12. The process of eliminating the predicted bounding boxes with the low confidence value is called as non-maxi- mum suppression.
13. To remove the predicted boxes having the low value set a threshold level of confidence as 30%.
14. This will eliminate the boxes having confidence value higher in another cell.
15. Draw the boxes around the filtered boxes and assign class labels and confidence scores.
16. To add more objects to be detected as per your choice. Garbage detection is done similarly as object detection and model is trained to classify an object as wet, dry, metallic, non-metallic, sanitary, medical, hazardous waste.

VIII. RESULTS & DISCUSSIONS

During training of 1000 images on YOLOV3 model present in dataset, a graph is plotted between training and validation to graphically represent the accuracy and loss of data shown in Fig 5 and Fig 6 respectively. The following results are obtained by using YOLOV3 algorithm on coco data set. The proposed system is trained to detect four types of waste i.e. wet waste, dry waste, hazardous waste and plastic. We have tested our model on 500 images, sample tested images are shown in Fig 8 to 11. The below listed figures display the type of waste and accuracy. The proposed model have detected plastic fork as plastic waste with accuracy of 0.9811, sandwich as wet waste with accuracy of 0.9782, knife as hazardous waste with accuracy of 0.9976 and broken tennis racket as dry waste with accuracy of 0.9971.

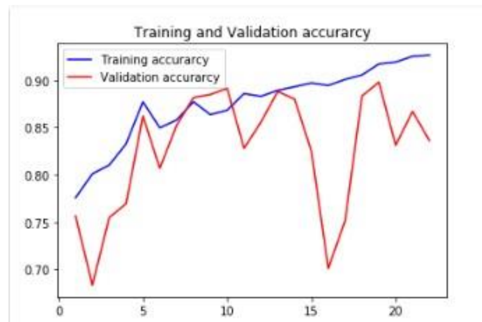

Fig.5. Training and validation accuracy representation

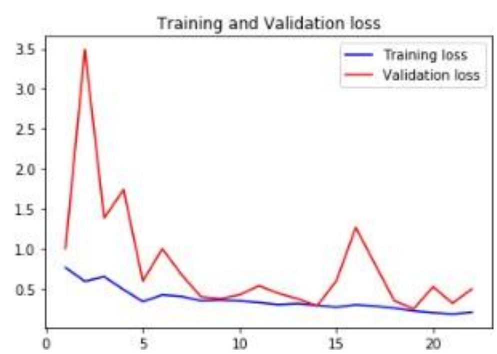

Fig. 6. Training and validation loss representation

```
[INFO] Calculating model accuracy
154/154 [==============================] - 13s 86ms/step
Test Accuracy: 83.6038961038961
```

Fig.7.Accuracy percentage

Fig. 8. waste detection as plastic waste

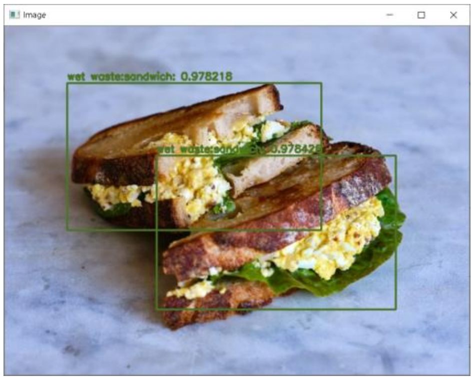

Fig. 9. waste detection as wet waste

Fig. 10. Waste detection as hazardous waste

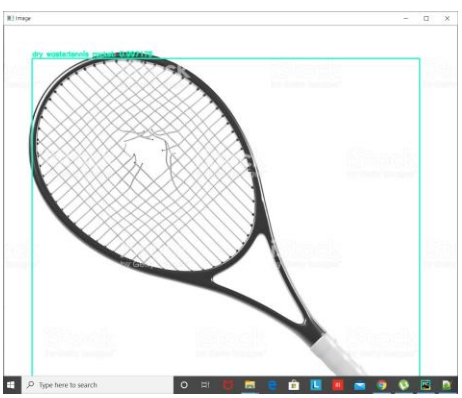

Fig. 11. waste detection as dry waste

IX. CONCLUSION & FUTURE SCOPE

Thus using the fastest deep learning algorithm YOLOV3 on custom CoCo dataset we have achieved an accuracy of 83.60% in identifying the type of waste correctly as shown in Fig 7.

This concept can be used at small scale like restaurants, residential areas, and schools to segregate waste.

This concept can be further extended as robotic arm to segregate waste. In landfills robotic arm or a robot can use this method and segregate heaps of mixed waste. It will reduce the task and risks related to rag pickers lives. The dataset can be further extended to classify sanitary waste, medical waste, e-waste, metallic waste, non-metallic waste, etc.

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