IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

Autonomous Smart-Bin: An Outcome of IOT and Deep Learning

Vishal Gupta[1] & Mrs. Meenu[2]

M.Tech Student[1], Associate Professor[2]

Department Of Computer Science and Engineering[1, 2],

Madan Mohan Malaviya University of Technology[1, 2],

Gorakhpur, U.P., INDIA-273010

Abstract: With the quick developing world, the capacity of technological know-how and era has made viable the whole thing a human thinks of. By a decade ago, people had various issues with rising of Urbanization, results one such serious issue of discharge of municipal waste which affected the lives and health of every society. This paper presents a state-of-the-art autonomous smart dustbin i.e., a self-driving vehicular bin which facilitates a best way to overthrow the societal waste. The autonomous bin is capable of locate the rubbish trash containers correctly and autonomously with the aid of using a deep neural network for waste stuff recognition. In addition, the approach of ground segmentation to use a DNN (deep neural network) which is a totally precise navigation strategy is reckoned to guide the self-driving car to move around. This paper presents an artificial intelligence subset deep learning strategy to recognize waste and assess tidiness progressively. Firstly, a digital camera established at the autonomous automobile which gather the road lane images. Secondarily, processed data is transmitted to the information server to examine inside the network. At constant time, quicker RCNN i.e. (region with convolutional neural network) used to observe the road garbage's bin, pedestrian, building, etc. Also, RCNN perform classification of these categories to perform estimation of number of garbage's detected on digicam's frame. Finally, the result has pictured the containers detected on the road lane, which is convenient to regional municipality to allot a clean-up method to the street effectively. This smart approach when implemented, go to facilitate to form the society an improved place.

Index Terms: Computer Vision, Deep learning, Image processing, Convolutional Neural Network, Garbage Bin and Sign Detection, Internet of Things.

I. INTRODUCTION

With the beginning of 21st century, the lifestyle of human being has changed, resulting a more complex work environment with irregularity in time and physical labour. In this standpoint, people always find a way get relaxed and save their time. The manual cleaning as well as garbage-pickup is always a tedious, boring and repetitive task. Hence, a new concept of autonomous vehicles becomes an essential contender for this application. Several examples like floor-cleaner, aquaculture cleaner, wall-cleaners bots are manufactured for many years, whereas autonomous-bin that may operate the road lane still remains a difficult task because of the dearth of garbage and street recognition ability. As yet, various bulky cleaning devices are used for cleaning domestic and industrial waste. Focusing to avoid this boring task, an autonomous robot was proposed for cleaning purpose.

A Smart metropolis make use of distinct types of electronic Internet of Things (IoT) sensors to acquire records and after quick span of time use each little bit of records were given from that records to modify assets, resources, and businesses effectively. The diverse metropolitan attempts to enrol in records and correspondence development, and numerous bodily devices associated with the framework to propel the performance of town activities and administrations. To follow this motivation, there's still constant issues related to cleanliness to be sorted by metropolitan authorities or municipalities.
To beat these challenges, this article proposed an innovative learning approach for continuous garbage identification and tidiness methods. Initially, a tiny digital camera delivered on the street which collects the street photographs and transportable edge server is applied to keep the records withinside the cloud effectively. Moving further, organized records is transmitted to the server farm to examine withinside the system.

During the time, Quicker Region-CNN (Region-Convolutional Neural Network) used to understand the street wastes and ordering those instructions and verify the amount of garbage's bin as well as traffic signals on the road sides. The outcomes are dispatched to the street neatness community appraisal model for inspection.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

At last, the end result has anticipated the garbage bin diagnosed withinside the city, which accommodation to city municipality or NGO to precede neatness procedure.

Figure 1: A Simple Garbage Bin and Smart Garbage Truck

Contemporarily, the large avenues make the count of garbage on roads lanes. During the time, the system of garbage bin vicinity on lanes is not robotized and continuously calls for human help at each instance. Local citizens checking the location of garbage and dust physically and sends reviews to nearby municipality, at that factor town mayor coordinate close with the town team of workers to clean the garbage bins. A few city societies even install cameras on the junction of the roads to test whether or not there may be any garbage withinside the region. However, those manual preparations cannot take place at each avenues of the town in meantime. Therefore, the experts around the world are analysing a range of automated approaches using an automobile with mounting digicam to capture the avenue lanes automatically and acquire data, for example, street pictures, topographical area, date and time. Also, a remote cloud installed for storing existing object location calculations become aware of images. In the end, the location outcomes are sent via GPS to the metropolis administration for progress.

Towards this exam heading, this article proposes a city avenue cleanliness appraisal version with the usage of flexible area registering and profound learning mechanism. The high-definition cameras brought at the automobile gather avenue pictures. In the meantime, the edge computing located at the brink of the gadget are applied to keep and process the street photo statistics briefly, and shifting next, this organized statistics is transferred to the remote cloud network through metropolis municipality or NGO. Quicker R-CNN (Region-Convolutional Neural Network) and IOT (Internet of Things) is applied to distinguish street garbage categories and take a look at the amount of garbage. The results are dispatched to the street cleanliness degree appraisal model for assessment. In the end, the technique picturizes street cleanliness degree, which offers rest to town directors to orchestrate employees in time.

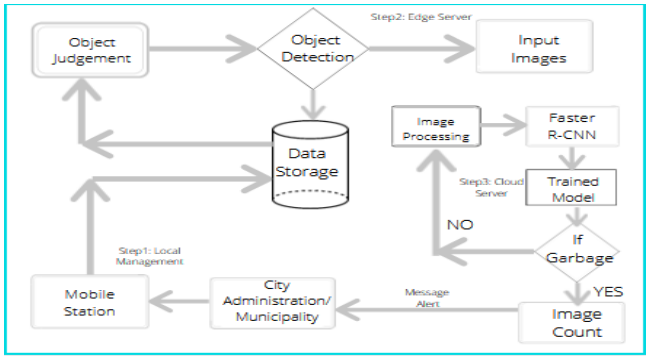

Figure 2: Deep Learning approach for real-time garbage detection and Cleansing evaluation.

Autonomous Vehicles is an example of Smart Waste Management system (SWMS) implementing elements of IOT (Internet of Things). The avenue waste transportation is optimised by enabling technology like SWMS for addressing the challenges. This allows each recycling trash-containers reporting its fill-level. The computerized system consisting advanced functionality will enable predicting the expected emptying time schedule of a recycling garbage-bin, i.e., before the garbage container's threshold value of filling level. Smart garbage-bin predicts over-filling level and help in avoiding redundant transportation. However, the efficiency of a Smart Waste Management system is achieved only with quality of fill-level predictions. The fill-levels are detected by sensors, which further transfer the data or message to the cloud server with help of MQTT protocol to the city administrative community for action.
To achieve a high quality prediction goal for the model, there are various technical challenges and the analysis of these challenges is a problem to operate and detect accuracy of a garbage-bin being unloaded using the quantification from a sensor mounted on top of the bin. Since it is demonstrated earlier, the correct detection of emptying container is knowledged by the quality of fill-level predictions and the inaccurate detections depreciate filling level predictions.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

Therefore, qualitative predictions are thought to be assessed when detecting bin emptying. Thus, this article applies and presented a great approach to the issue of the emptying detection of garbage-bin. At first, this study rules out the challenges as well as importance of the trash detection for the smooth working of Smart Waste Management systems.

II. RELATED WORKS

AutoML (Automated Machine Learning) is considered as newest research area in current scenario. Also, there is an extensive work needed to apply it in industrial applications. Hence, this segment tries focusing on the Smart Waste Management's present state-of-the-art techniques both in research as well as practical areas. The Smart Waste Management is a fast growing field and comprises many aspects in future.

A. Commercial systems:

The Clean technology and IOT (Internet of Things) when sums up their elements, resulting a Smart waste management system with a partial to quarter relating environmental issues. Also, there are number of commercial systems competing each other in the business.

Commercial systems are widely categorized into two i.e. retrofitted sensors and smart containers. There are specially manufactured bins e.g., smart dustbins or containers for plastic measuring the fill-degree at the same time as automatically compressing the plastic-board. The hotels, industries, metropolis, etc. generally use such small containers and dustbins. CleanCUBE by Ecube [7] and Big Belly [8] are instances of these commercial systems using smart-containers.

The retrofitted sensors are from time to time taken into consideration as Smart Recycling system. Some examples of commercial systems are 'Smart Waste with the aid of using Citibrain', Sensoneo, Enevo, CleanFLEX with the aid of using 'Ecube', and Smart Bin. Amidst those systems, Smart Recycling ® system does not often admit CleanFLEX under itself because CleanFlex additionally predicts fill stages of it.

B. Smart Waste Management research:

The Smart Waste Management is an area encompasses a Smart Waste Management system's whole life cycle. The various fuel economies collect the garbage-bin by garbage vehicles of areas which are also connected to the Smart Waste Management.

Here, Garbage-bins construction is described taking into account their container's structure, how they are collected, and what could be the various sensing techniques. There are various aspects to make it functionally efficient such as

- Collection of data in an energy-efficient manner
- Strategies also learned using data-driven techniques
- Queries related to brace computing performance of a system.

Currently, the Smart Waste Management researchers are focusing over IOT as an enabling technology. The problem of Smart Waste Management needed several technical implementations and studies which are shown in [9].

C. Work and Approaches:

The Entity detection technology may be defined as the foundation of numerous Artificial intelligence's subset i.e. Computer Vision research. The object detection helps in to find the location, to perform tracking, and have a look at all viable items in images. It is realized that conventional object detection is commonly perceived consistent with the feature classification and steps of location preference. There are style of feature extraction operators and classifiers such as "Histogram of oriented gradients" [10], Scale Invariant Feature Transform (SIFT) and 'Local binary pattern' (LBP) algorithm [11] and the classifiers like Support Vector Machine (SVM), Adaboost algorithm [12], etc. Furthermore, traditional goal detection technique's generalization functionality which is a feature of man-made design may be very weak and the outside environmental factors making it effortlessly suffer. The deep learning methodology researches given rise to object detection which shifted implementation based totally on CNN (Convolution Neural Network). The other well-known implementations of DNNs are R-CNN [13] and single-shot detector (SSD).

The entity detection with the use of deep learning making a halt by placing the target photo feature with limit of artificial setting. The attainable features of the target object are automatically learned with the help of CNN which make the accuracy as well as robustness of object detection substantially stronger. Although, CNN based many object detection strategies need high computing power, which makes deployment of portable devices which is a real-time situation unfavourable. There are various researchers and professionals in the past years had paid interest in object detection performance including Faster R-CNN and YOLO [13] which are best well-known object detection algorithms. The self-driving cars, human detection, traffic signal detection, etc. are the examples of target detection in automobile environment which are majorly focused by various research communities.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

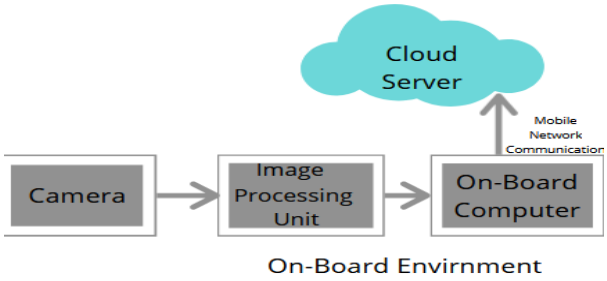

Figure 3: Hardware Deployment

III. METHODOLOGY

This paper experimentally applies the object detection algorithm to the garbage bin mounted automobile for tracking in addition to data statistics. The paper contains deployment of the hardware as well as software program in the view of design to meet the desired approach.

A. Hardware Deployment: The hardware deployment scheme may be interrupted by the factors comprising computing power, energy consumption, range of devices, etc. in the special environment of smart garbage-bin. The various parameters like deflecting the digicam on automobile, transmission mode of the data and the computing performance at the layout of the software program level affects The IPU (Image processing unit) of this article. In Figure 3, a scenario of the typical hardware deployment for this paper is proven.
To document the automobile's vicinity and fuel level, various garbage bin automobiles have assembled pc device with a feature of cellular network communication. In this article, a water resistant digicam and an IPU are mounted on the autonomous vehicle.

Hardware used:

- Camera with 640 × 480 resolution (preferred)
- Chessis
- Wheels
- Raspberry Pi
- Raspi-Cam
- Battery
- Ultrasonic Sensor
- Garbage bin, etc.

B. Software Design: In this segment, the object detection algorithm and dataset set up are described and represented respectively.

Software used:

- Anaconda Navigator
- Python v3 and above
- Google Colab
- OpenCV library
- Keras library
- Tensorflow library
- Udacity Self-driving Car Simulator
- Git and Github
- Real-Time Operating System e.g. Ubuntu, etc.

B.(i) Dataset: As it is earlier depicted, supervised learning method is used for object detection in training of model that constructs a dataset with labels tag. Firstly, the picture attributes of garbage-bin are examined and then distinguish them accordingly to the distinct varieties of attributes like garbage bins, pedestrians, site visitor's signs, and so on throughout the avenues.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

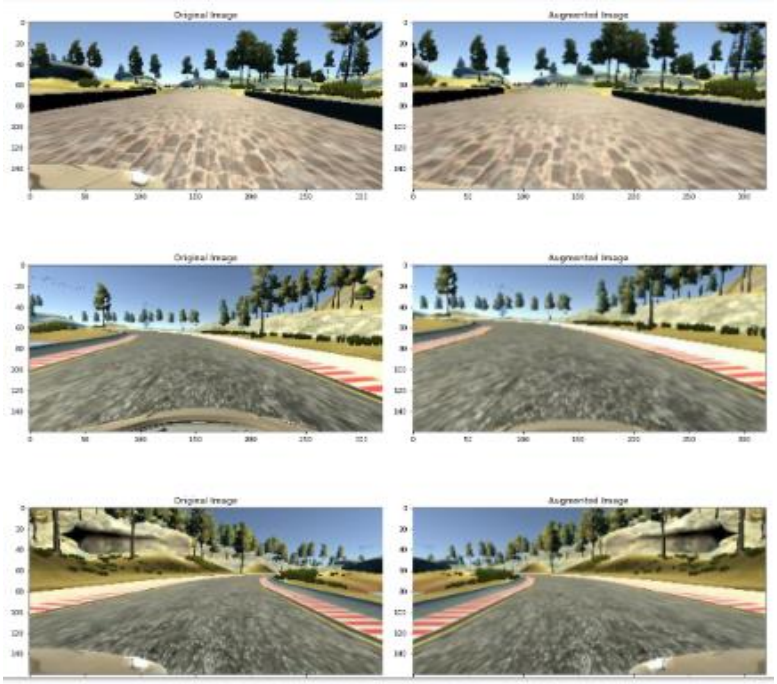

Figure 4: Dataset of Training model

B.(ii). CNN Model: The object classification and detection algorithm used in this paper is CNN (Convolution Neural Network). CNN [13] may be outlined as deep learning model to process data that has a mesh pattern, like pictures. CNN has automatic and adaptive learning scheme i.e. it can learn spatial hierarchies of characteristics, from low-to-high-level patterns which is motivated by the consortium of animal visual cortex.

Figure 5: CNN Architecture Flowchart

CNN is composed of three types of layers e.g. convolution layer, pooling layer, and fully connected layers. The convolution and pooling layers do characteristic extraction procedure, whereas a fully connected layer performs classification. In mathematical operations, a convolution layer performs convolution i.e. linear operation. The pixel standards are recorded into a two-dimensional (2D) mesh in digital images. A 2D mesh is also called an array of numbers. A kernel is a little mesh of parameters. At each image position, a kernel acts as optimizable feature extractor. This feature makes Convolution Neural Networks (CNNs) highly efficient for image processing. In CNN, one layer carries its output into the next layer. Also, the complexity of taking out from an image features hierarchically and progressively is very high. Hence, backpropagation algorithm is performed where training is needed to reduce the difference between outputs and ground truth labels and help in optimization. Afterwards, Gradient descent (GD) is performed among others.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

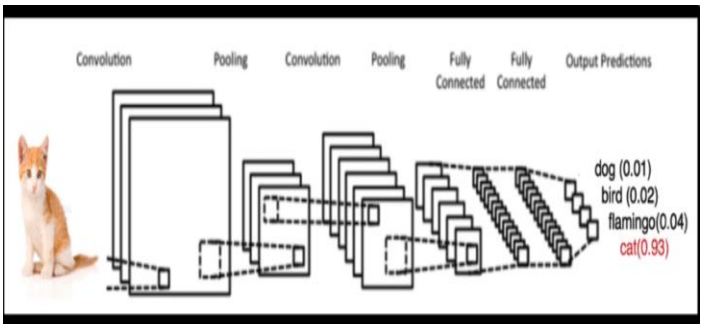

Figure 6: Categorisation of animal using CNN

B.(iii). Data Statistics: In Figure 7, the method of creating the smart garbage bin is decided with the aid of using whether or not there's a garbage bin withinside the frame-boundary of digicam and the data statistics is shown below. The entity or object detection algorithm i.e. CNN (Convolution Neural Network) perform the detection of garbage-bin in a picture-frame. The time, when there is a change in movement garbage-bin seemed mean the designated program is working whilst the object detection application can't discover the garbage bin withinside the screen, it indicates that the method of moving forward and stop the bin after an interval. Meanwhile, the quantity of garbage bin targets in a body is the quantity of garbage bin.

Seeing that the digital camera installed on smart garbage bin contains rear-feeding garbage it's far vital to differentiate among the objects encountered while moving. The experiment discovered that the change of the varying x-coordinate of the garbage bin target in the course of the complete avenue and continuously distinguishing diverse images on the street with the use of CNN classification. Afterwards, the classified pictures are examined in the system automatically and the data transmitted to the cloud storage.

At end most of the filling bin, a Serial port or COM port carries the data statistics of the garbage bin sent by IPU (image processing unit) to on-board PC. The on-board PC will locate whether or not there may be any required operation consistent with the data caught. During the time, the data are uploaded to the cloud server via the cellular network as a record to the city administrators.

B.(iv). Training CNN model:
In this segment, the procedure of training the model is displayed.

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844: Use
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/10
300/300 [==============================] - 373s 1s/step - loss: 0.1098 - val_loss: 0.0604
Epoch 2/10
300/300 [==============================] - 373s 1s/step - loss: 0.0731 - val_loss: 0.0503
Epoch 3/10
300/300 [==============================] - 371s 1s/step - loss: 0.0657 - val_loss: 0.0428
Epoch 4/10
300/300 [==============================] - 372s 1s/step - loss: 0.0592 - val_loss: 0.0371
Epoch 5/10
300/300 [==============================] - 395s 1s/step - loss: 0.0557 - val_loss: 0.0357
Epoch 6/10
300/300 [==============================] - 411s 1s/step - loss: 0.0508 - val_loss: 0.0375
Epoch 7/10
300/300 [==============================] - 411s 1s/step - loss: 0.0491 - val_loss: 0.0324
Epoch 8/10
300/300 [==============================] - 369s 1s/step - loss: 0.0481 - val_loss: 0.0301
Epoch 9/10
300/300 [==============================] - 370s 1s/step - loss: 0.0457 - val_loss: 0.0305
Epoch 10/10
300/300 [==============================] - 369s 1s/step - loss: 0.0442 - val_loss: 0.0281
```

Figure 7: Training model showing Loss value and Validity loss

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

IV. EXPERIMENT

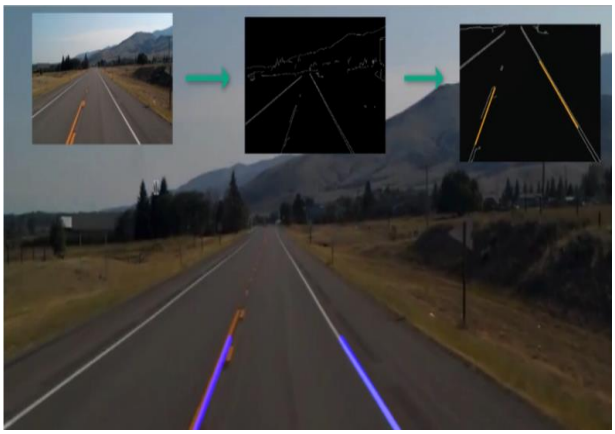

Figure 8: Computer Vision of Finding Lanes

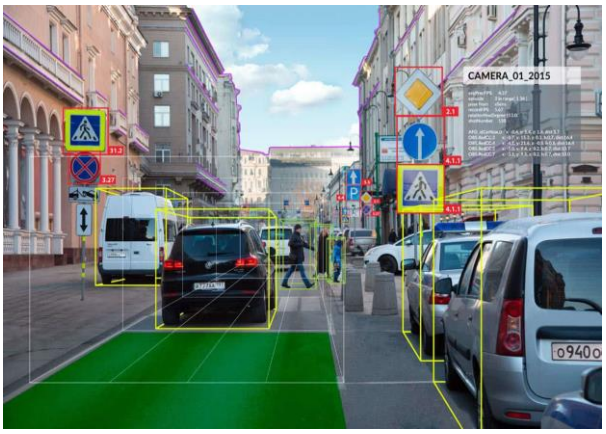

Figure 9: Sample Picture to visualize Real-Time Object Detection e.g. Cars, Traffic signs, Pedestrians, Garbage Bins.

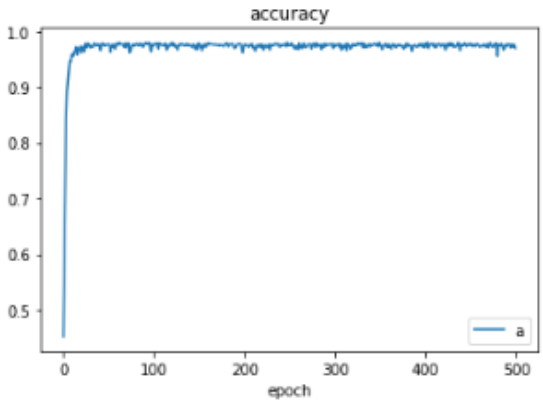

Figure 10: Accuracy value of Training model

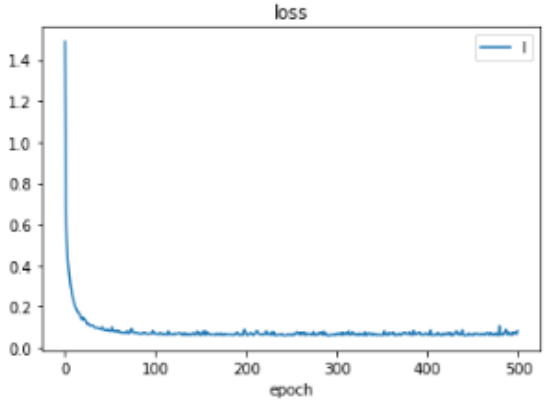

Figure 11: Loss value of Training model

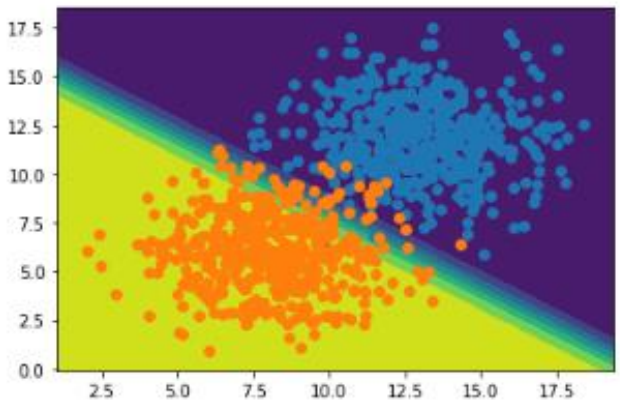

Figure 12: Decision Boundary for the Investigated classification algorithm.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

Mathematical Equation [14]**,**
Class-specific confidence scores is given by

$$Pr(Object) * IOU_{pred}^{truth} * Pr(Class_i|Object) = Pr(Class_i) * IOU_{pred}^{truth}$$

Where**, IOU** = Individual box confidence predictions
Pr = Conditional class probabilities

During training, the following loss function is optimized by

$$\lambda_{coord}\sum_{i=0}^{S^2}\sum_{j=0}^{B}\mathbb{1}_{ij}^{obj}\left[(x_i-\hat{x}_i)^2+(y_i-\hat{y}_i)^2\right]$$
$$+\lambda_{coord}\sum_{i=0}^{S^2}\sum_{j=0}^{B}\mathbb{1}_{ij}^{obj}\left[\left(\sqrt{w_i}-\sqrt{\hat{w}_i}\right)^2+\left(\sqrt{h_i}-\sqrt{\hat{h}_i}\right)^2\right]$$
$$+\sum_{i=0}^{S^2}\sum_{j=0}^{B}\mathbb{1}_{ij}^{obj}\left(C_i-\hat{C}_i\right)^2$$
$$+\lambda_{noobj}\sum_{i=0}^{S^2}\sum_{j=0}^{B}\mathbb{1}_{ij}^{noobj}\left(C_i-\hat{C}_i\right)^2$$
$$+\sum_{i=0}^{S^2}\mathbb{1}_{i}^{obj}\sum_{c\in classes}(p_i(c)-\hat{p}_i(c))^2$$

V. RESULTS

This article has used real-world dataset and captured significant pictures for training of the model because it is the preliminary input value of the model. After 300 epoch instance of iterations, the loss value parameter dropped from 0.10 to 0.02. Also, the learning rate of lane detection, sign and object detection as well as accuracy drastically improved from 87% to 96.5% approximately. As it is demonstrated that training sets consists of Validation sets and Test sets. In fig.9 indicates the numerous categories of garbage bin and signal detection precision. The X-axis suggests garbage's categories. The Y-axis suggests the correct recognition of examined images. From the Figure10, the accuracy of garbage bin can attain the accuracy of 95%, pedestrian on roads can be 96%, and traffic sign reaches 84% accuracy.

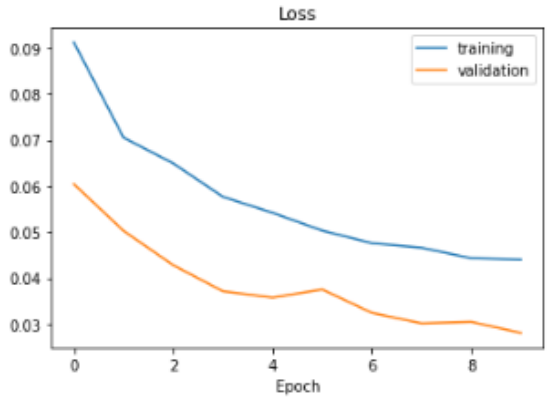

Figure 13: Loss value during Training vs Validation

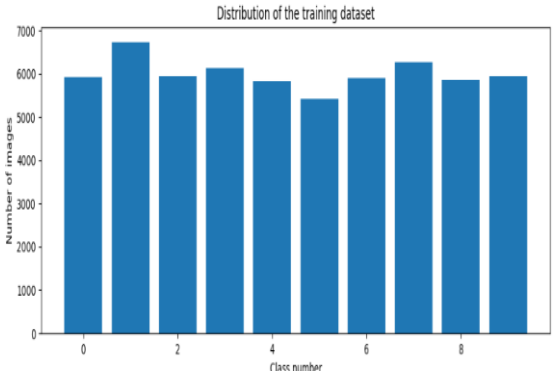

Figure 14: Distribution of Training Dataset using images

VI. CONCLUSION

The article presents an innovative autonomous system for cleansing the trash on the street with automated vehicles. The CNN is the powerful deep neural networks which propose smart-bin automobile to detect and pick-up the trash without any human assistance. Also, smart supervision is an effective way and workload statistical data of trash automobile primarily based totally on computer vision is initiated.

The on-board computing and communication equipment are established on the smart garbage-bin. A smart automobile also mounted and set up digicam and an IPU (Image processing unit) over it. The image generated via a digicam give rise to a dataset which is mounted at the garbage-bin and with the idea of utilizing trained model to carry out the object detection. The recorded data of the smart-bin help to initiate move/stop process of the smart garbage bin.

This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 5, May 2021

DOI 10.17148/IJARCCE.2021.105121

There is a great difference between the modern-day model and the conventional RFID model. The proposed approach of this paper has made much less deployment and maintenance costs on the model. The experimental consequences depict that the approach proposed on this paper has an accuracy rate near 97% with a frame rate more than 25 Frames/Sec beneath appropriate light conditions. Although, when the light condition turn out to be worse the total performance of the method can be remarkably affected

This mechanism is an enhanced cleansing method for cleansing the trash on the avenues and can replace street sanitation vehicles as well as vacuum cleansing robot.The dataset obtained from the models shows that the accuracy of existing manually engineered model is approx. 80% but a poor recall of 57.9 %. However, the call of the deep neural network engineered model gives accuracy approx. 97.5%, which is an improved version, optimized and obtained by training dataset of model parameters.

Thus, the smart garbage-bin's accuracy and efficiency could target and recognize the trash which proved this approach experimentally successful. This type of autonomous automobile is a powerful cleansing tool for the wastes on the streets of towns or metropolitans.

REFERENCES

[1] J. Bai, S. Lian, Z. Liu, K. Wang and D. Liu, "Deep Learning Based Robot for Automatically Picking Up Garbage on the Grass," in IEEE Transactions on Consumer Electronics, vol. 64, no. 3, pp. 382-389, Aug. 2018, doi: 10.1109/TCE.2018.2859629.

[2] Rutqvist, David & Kleyko, Denis & Blomstedt, Fredrik. (2019). An Automated Machine Learning Approach for Smart Waste Management Systems. IEEE Transactions on Industrial Informatics. PP. 1-1. 10.1109/TII.2019.2915572.

[3] A Real-Time Garbage Truck Supervision and Data Statistics Method Based on Object Detection by Xuanyu Zhang, Yining Gao, Guangyi Xiao, Bo Feng and Wenshu Chen Wireless Communications and Mobile Computing Volume 2020, Article ID 8827310, 9 pages https://doi.org/10.1155/2020/8827310

[4] International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 08 | Aug 2020 www.irjet.net p-ISSN: 2395-0072 A Deep Learning Approach for Real-Time Garbage's Detection and Cleanliness Assessment by Ashok S, Arun Kumar HN Niranjan J, Shekar A Arun Kumar DR ,Department of Computer Science and Engineering, SJB Institute of Technology, Bengaluru, India-560060.

[5] T. Anagnostopoulos et al., "Challenges and Opportunities of Waste Management in IoT-Enabled Smart Cities: A Survey," in IEEE Transactions on Sustainable Computing, vol. 2, no. 3, pp. 275-289, 1 July-Sept. 2017, doi: 10.1109/TSUSC.2017.2691049.

[6] Zhang, Qi & Hongyang, Li & Wan, Xin & Skitmore, Martin & Sun, Hailin. (2020). An Intelligent Waste Removal System for Smarter Communities. Sustainability. 12. 6829. 10.3390/su12176829.

[7] "Ecube Labs - Smart waste management solution," https://www.ecubelabs.com/, [Online; accessed 27-May-2018]. [Online]. Available: https://www.ecubelabs.com/

[8] "Bigbelly - Smart City Solutions," http://bigbelly.com/, [Online; accessed 27-May-2018]. [Online]. Available: http://bigbelly.com/

[9] J. W. Lu, N. B. Chang, L. Liao, and M. Y. Liao, "Smart and green urban solid waste collection systems: Advances, challenges, and perspectives," IEEE Systems Journal, vol. 11, no. 4, pp. 2804–2817, Dec 2017.

[10] N. Dalal and B. Triggs, "Histograms of oriented gradients for human detection," in 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05), vol. 1no. 12, pp. 886–893, San Diego, CA, USA, 2005.

[11] T. Ojala, M. Pietikainen, and T. Maenpaa, "Multiresolution gray-scale and rotation invariant texture classifification with local binary patterns," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 7, pp. 971–987,2002.

[12] Younghyun Lee, David K. Han, Hanseok Ko, "Reinforced AdaBoost Learning for Object Detection with Local Pattern Representations", The Scientific World Journal, vol. 2013, Article ID 153465, 14 pages, 2013. https://doi.org/10.1155/2013/153465

[13] Internet Source: RCNN, YOLO https://towardsdatascience.com/r-cnn-fast-r-cnn-faster-r-cnn-yolo-object-detection-algorithms-36d53571365e

[14] Zhao ZQ, Zheng P, Xu ST, Wu X. Object Detection With Deep Learning: A Review. IEEE Trans Neural Netw Learn Syst. 2019 Nov; 30(11):3212-3232. doi: 10.1109/TNNLS.2018.2876865. Epub 2019 Jan 28. PMID: 30703038.

This work is licensed under a Creative Commons Attribution 4.0 International License