

Electronic Bin for Segregation and Classification of Plastic Waste Products using Deep Learning

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Abstract - In modern times, the usage, and the corresponding consumption, of plastic is drastically increasing because of its flexibility and scalability in packaging. Lack of sophistication in waste management, particularly in plastic segregation, is the major reason for rising difficulties in dealing with the increasing levels of plastic waste. Segregation and identification of plastic waste and materials makes the future processing and management of waste an easier task at hand. This work provides a ResNet (Residual Network) image classifier to predict brands of plastic waste products with a potential electronic bin (e-bin) design as an interface. The e-bin will be a physical interface for the user to submit the waste products and will use sensor-based feature extraction to segregate the plastic and non-plastic waste. In case of plastic being detected, the e-bin will predict the brand of the product using ResNet-based image classifier.

Key Words: Plastic Waste Segregation, ResNet, Plastic Wrapper Detection, Real-time Plastic Detection, electronic bin.

1. INTRODUCTION

1.1 Background

The plastics industry is one of the markets that is growing rapidly due to its application in a broad range of sectors such as automotive, transportation, electronics, healthcare, and textiles. Different government initiatives like Make in India, Skill India, Digital India and Swachh Bharat Abhiyan would further promote this evolution.

Source waste isolation combined with separated processing and transport were weak and inefficient mechanisms and links in the waste supply chain. Even though it is supposedly the initial step, it is often not considered. Due to the abundant amount of unsegregated waste, waste management issues eventually grow into larger issues in larger cities.

Without proper segregation mechanisms at the source, efficient SWM demands the adoption of decentralized methodology with segregation of dry-and-wet waste collection, especially in large cities. The next practical and technically feasible choice for plastic waste management is plastic recycling.

The approach utilizes multiple technological advances to generate a 2nd raw material supply chain.[1]

Recovery of secondary raw materials by recycling is a high priority following reuse according to the waste hierarchy. The two generalized recycling methods include primary and secondary recycling and other than that, tertiary recycling is favored for multilayered plastics (MLPs) where it is strenuous and economically infeasible to remove individual layers.

Recycling requires public involvement, and therefore needs people to isolate waste materials at source. Another possible usage method is waste plastics fuel production. Most of the current energy needs are met using fossil fuels. The conversion of waste plastics into fuel is advantageous, as it enables the removal of waste plastics but also offers the opportunity to establish another option other than fossil fuel.

Reports show that the 'methane level' of pyrolysis gasses is currently beneath sixty-five which is below the minimum requirement as per the European Union's and United States' requirements. [2] The non-recyclable plastic waste is used in a coordinated manner in processing of plastic waste in cement kilns. It applies to the reuse of waste which comes from different industries from which the form of energy and material is recovered.

1.2 Related Work

SWACHH: An effective real time solid waste management system for municipality Sanket, et al. in their work proposed a system having the capability to provide information about waste bins when they are full or the garbage level is reached. In this case, alerts are sent to the appropriate authorities to inform them about the immediate collection of the waste in the bin in order to keep the environment clean. This used ZigBee and GSM technology to allow the remote monitoring of solid waste bin in real-time mode, and to send notification of the status of the garbage bin to the appropriate authorities particularly when it is nearly full. Moreover, the drawbacks of the technologies used are disadvantages; for example, GSM is a lag in latency, Ultrasonic sensor accuracy is affected by changing weather conditions and ZigBee is known to have low transmission rate. All these factors affect the system's optimum performance. A web server that effectively

manages GUI and behavior can be built for the future as well as bins equipped with GPRS powered embedded device.[3]

N, S., Fathimal, P. M., R, R., & Prakash, K. (2019) paper proposes IoT (Internet of Things) based totally clever waste segregation and administration machine which assessments the wastes in the dustbins through the usage of Sensor systems and as soon as it detected the waste substances in it will be segregated with the assistance of sensors and right away this machine altered to cloud via IoT. We utilize the micro-controller as a mediator between the sensor devices and IoT system. Ultrasonic sensor is used to detect the presence of waste material. The moisture sensor's work is to detect the moisture in the waste, and if there is moisture present then the waste cannot be put in the dustbin. Metal sensor is used to separate the metal items and is separated into a section. Image processing is used to identify the plastics and degradable items and is separated into separate sections. The dustbin data are uploaded to the cloud database using IoT in real time.[4]

Limitation Existing system or research gap

Waste management systems here are mostly monitoring systems rather than managing systems.

It only detects the presence of waste and the level of waste in the garbage bins. Once detected, the details are sent to the authorities using GSM which is a slow communication compared to the existing ones.

Separation is only done for metallic and non-metallic wastes, wet and dry wastes. The main challenges are that the information is not transferred real time.

Only metallic wastes are separated that means both plastic and bio wastes form in the category of non-metallic wastes. Hence there is a lack of garbage management system which effectively segregates plastics from garbage and identify them.[5]

1.3 Proposed Solution

The solution for the above mentioned problem is proposed in the form of an image classification model at a dedicated server with the corresponding database and an electronic bin capable of communicating with server. The proposed project has the following scope:

- i. Plastic waste segregation.
- ii. Garbage level monitoring and notifying pickup of garbage.
- iii. Detecting brands/companies of plastic waste products.
- iv. Create and update warehouse of time-variant and spatially categorized (region-based) data regarding plastic waste and different brands contributing towards it

With the help of this information an appropriate action on brands can be taken after which brands can make efforts to

replace plastic contents by some environment friendly material from their products. Also, owing to the current trend of using plastic as building-components for roads, portable washrooms, etc; a tool that helps as well as promotes collection of plastic waste products would be beneficial.

2. TECHNIQUES

2.1 Reason for choosing PyTorch as Framework?

Some of PyTorch's key benefits are: Simplicity: It is very pythonic and easily integrated with the rest of the Python ecosystem. Learning, using, extending and debugging are simple. Good API: The usability of PyTorch is shining thanks to better designed object-oriented modules, encapsulating all important data choices and model architecture choices. PyTorch's documentation is also great for beginners and helpful. Dynamic Graphs: Dynamic computer graphs are deployed by PyTorch. It ensures that, with little or no overhead, the network will change behavior as it runs. For debugging and also to create sophisticated models with minimal effort, this is extremely helpful. Enable the automatic distinction of PyTorch expressions.[6]

Along with PyTorch we will be using Fast.ai for training purposes. Fast.ai is an easy to use Python library with a large community that can be represented as a Research Laboratory. The library is packed in the most prominent profound learning and machinery libraries with a user-friendly interface for specific workflows. The top-down approach is followed.[7]

2.2 ResNet Model

We have used the ResNet34 (Residual Network) Model for Image Classification. Each of the ResNet layers is made up of multiple blocks. This is because ResNets typically increase the number of operations within a block when they get deeper, but the number of total layers is the same. An action refers, except the final working of a block which does not have the ReLU (Rectified Linear Unit), to a transforming batch norm and a revolution activation to an input.

ResNet solves an important problem commonly known as the vanishing gradient problem. This is because when the network is too large, after several implementations of the chain rule the gradients from which the loss function is measured quickly decrease to zero. This consequence is that weights never change their values and thus no learning is achieved. The gradients can flow from later layers to initial filters directly through the connections.[8]

3. METHODOLOGY

3.1 Proposed System

This project will consist of creating three important inter-dependent modules. They can be described as follows:

- E-bin (based on IOT)
- Android Application (UI)
- Server (Database and Deep Learning model)

Components of E-Bin are -

- Proximity Sensors (Capacitive and Inductive) for Plastic Detection
- Camera for Image Capture
- QR Code (Static/Digital Generator) to create session with user
- Raspberry Pi 3 for Upload Image and send session details to Server

Server: (Deep Learning Phase)

- Preprocess the input image from E-bin
- Process it in ResNet34 for Image and Brand Classification
- Update Statistics in Database for corresponding session with output results from DL model
- Send corresponding update to Android Application

Server (Database):

- Store User related details such as Name, IMEI, IMSI, Google Account ID
- Store results of submission with classified objects, date, time, location, user's name, etc.
- Database will be implemented using MongoDB/Firebase

Android:

- Provide User-Interface to user
- Generate session by QR-Code scanning
- Generate and maintain profile of user for submission details

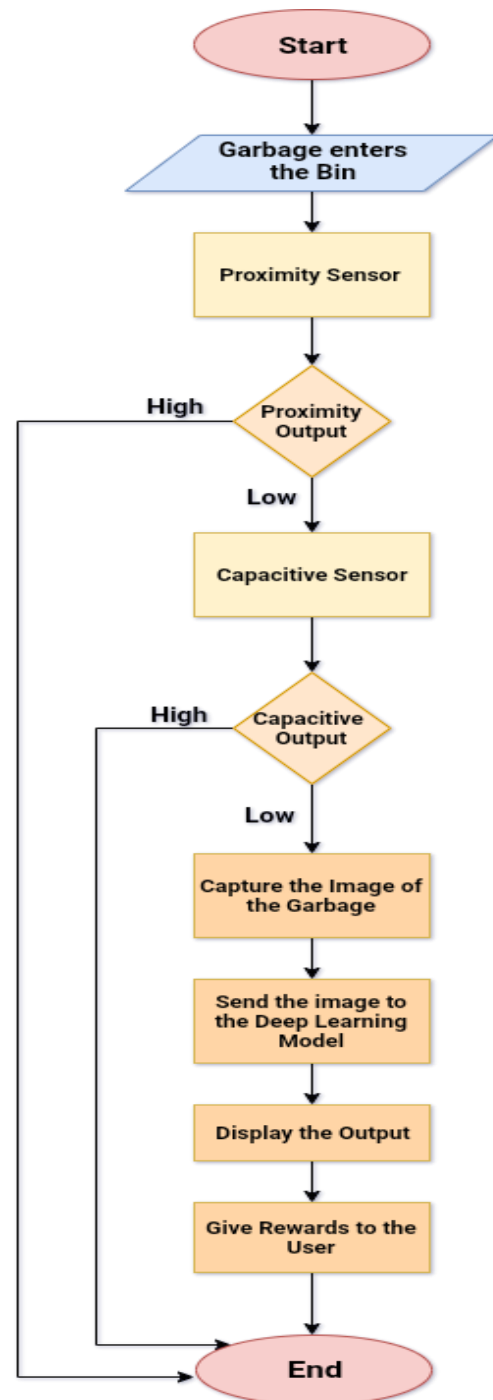


Fig -1: Front-end Flowchart

3.2 Proposed Workflow

- We have used sensor-based feature extraction which helps to detect waste as plastic waste.
- Image processing techniques are used as a preprocessing step for neural networks.
- For plastic brand classification we have used convolutional neural network in our approach. The convolutional neural network is a category of neural network that has been proven very efficient in image classification. The convolution neural

network learns about the filters which were hand-engineered in conventional algorithms.

- Camera modules along with Raspberry Pi modules are used to capture and transfer images from garbage bin to local server.

i. Sensor Based Feature Extraction

- Proximity Sensor:
An inductive proximity sensor can detect metal targets approaching the sensor, without physical contact with the target. If the waste scanned by the sensor gives an output as low then its further passed on for further processing.
- Capacitive Sensor:
Without physical contact with the target, a capacitive sensor can detect plastics which are approaching the sensor. If the waste scanned by the sensor gives an output as low then its further passed on for further processing.

ii. Capture Image and Transfer Image from Bin to Server

- The plastic waste detected from sensors will then be captured using a camera module which will be connected by Raspberry Pi module.
- The captured image will be sent to local server using Wi-Fi module connected on Raspberry Pi

iii. Plastic Product Classification

- After the image is received from the garbage bin image processing algorithm will be applied on it to crop and resize the image based on predefined parameters.
- The processed image is then fed into a convolutional neural network (CNN) for feature extraction and classification. As a result, this will help to detect the brand of plastic and update the entry of identified brands in the database.[9] [10]

iv. User Reward

- Users get rewards based on the type and number of submissions of the waste.

v. Garbage Bin Level Check

- After every submission bin will run a check to detect whether it has reached its full capacity or not. If yes then it will send a notification to garbage collection authorities for garbage pickup.

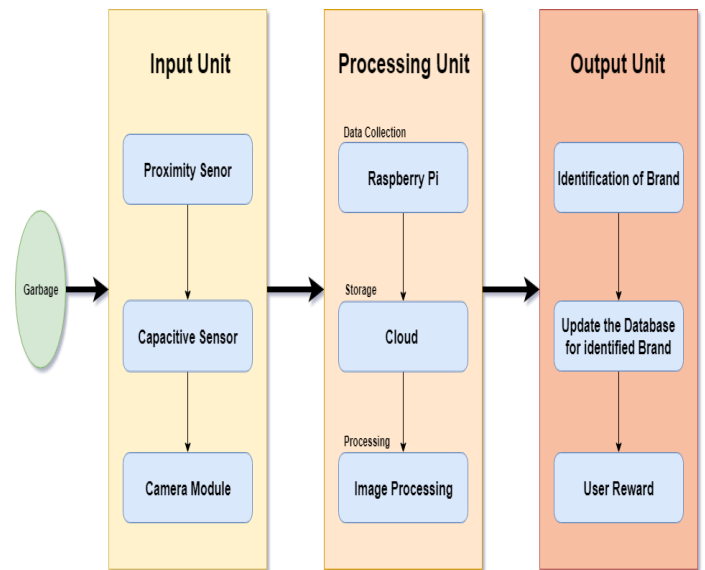


Fig -2: System Overview

3.3 Proposed E-Bin Hardware Design

The e-bin is dissected into two parts:

i. Head

- The plastic waste detected from sensors will then be captured using a camera module which will be connected by Raspberry Pi module.
- Consists of a slit to submit the garbage/waste.
- The Raspberry Pi 3 circuit with proximity sensors, camera module
- LED (Light Emitting Diode)
- 2 Flaps
- Motor (to rotate the flaps)

ii. Body

- Ultrasonic sensors for fill checking
- Wall partition for plastic and non-plastic waste
- Wheels

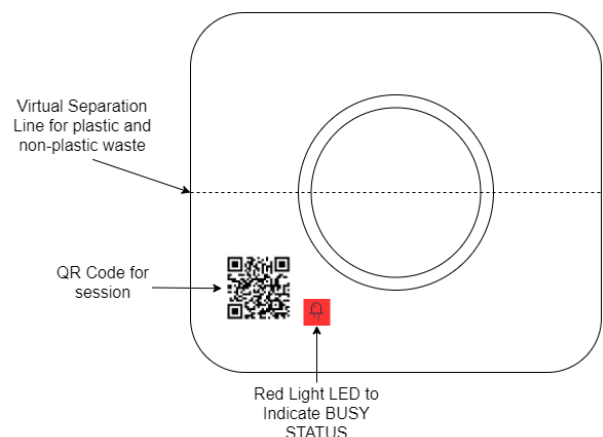


Fig -3: Top View of Bin (Demonstrates how the bin will look to the user from above)

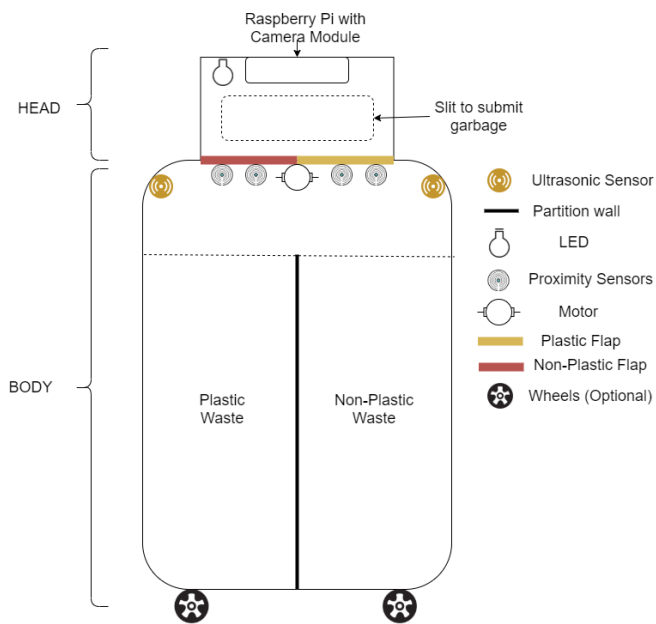


Fig -4: Internal Frontal View of Bin
(Exemplifies the inside view of the bin from the front of the user)

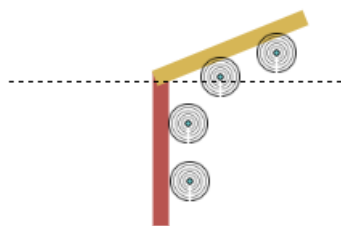


Fig -5: Flap arrangement when Plastic Waste is detected

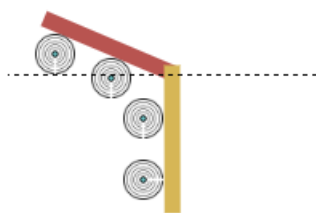


Fig -6: Flap arrangement when Non-Plastic Waste is detected

Fig -3 gives the top view of the E-Bin which describes how the bin will look to the user from above. A QR Code is present on the top. This QR Code can be scanned to generate the session between the user's Android client and the e-bin. The user can then submit their waste through the slit as shown in Fig -4. Fig -5 gives a representation of how the flaps will be arranged when plastic is detected. Fig -6 conveys similar information for when non-plastic waste is detected.

3.4 Android UI Screens

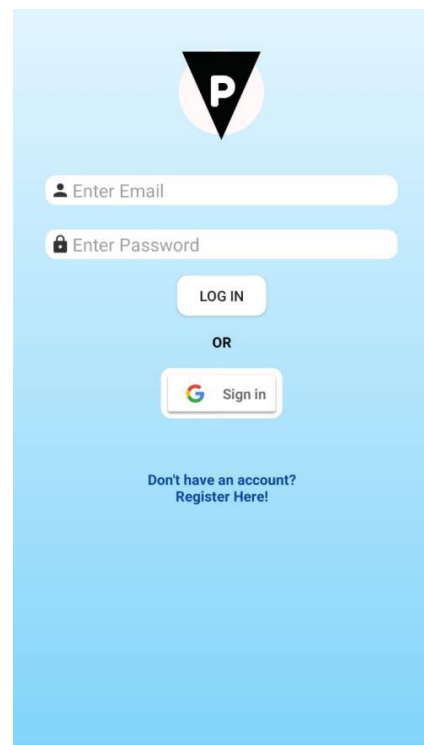


Fig -7: Login Screen
(Initial Launch Screen that requires the user to log-in or register for authentication)

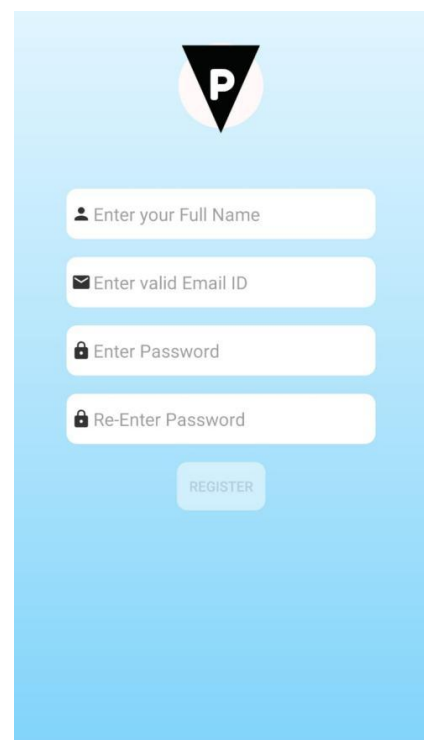


Fig -8: Registration Screen
(Registration Form required to be filled by New Users)

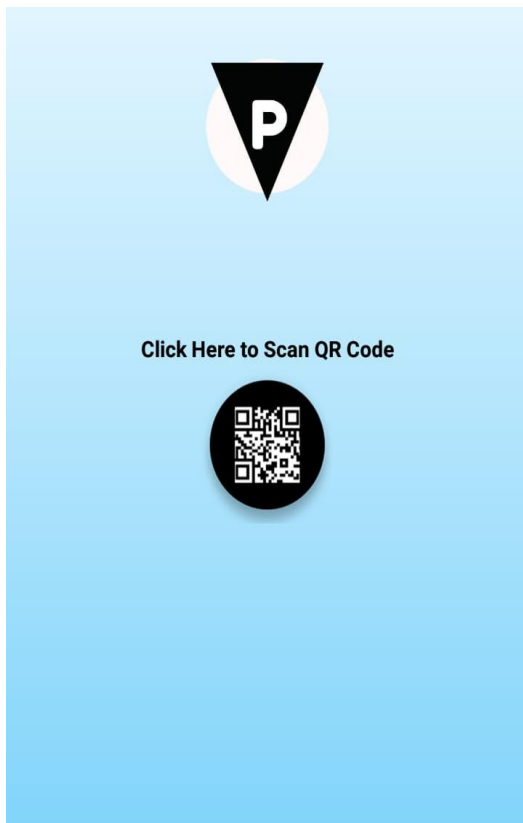


Fig -9: Home Screen

(User can press the Scan Button to scan the bin QR Code)

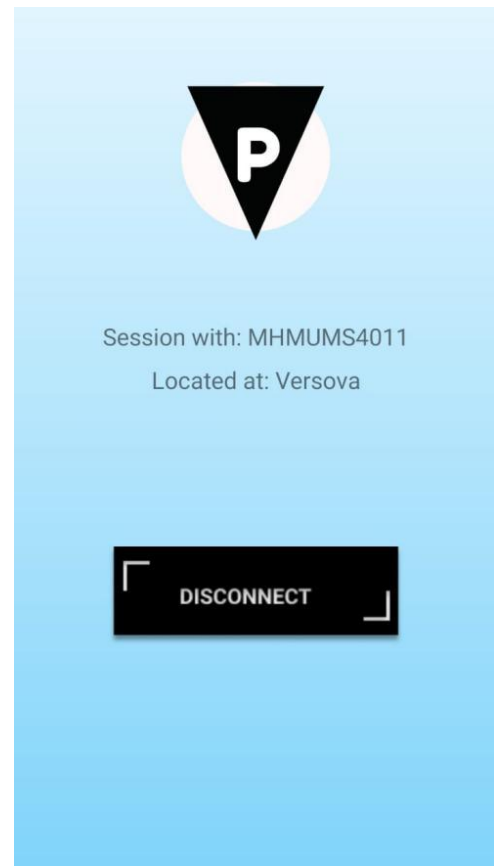


Fig -11: Home Screen

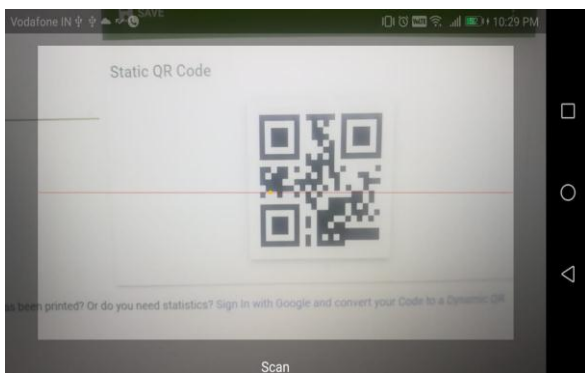


Fig -10: QR Code Scanner
(To scan QR Code on the E-bin)

4. RESULTS

77	0.057498	0.415276	0.925234	01:16
78	0.061770	0.410107	0.925234	01:19
79	0.055125	0.441170	0.925234	01:18

Save the best accuracy 0.59813
 Save the best accuracy 0.76636
 Save the best accuracy 0.84112
 Save the best accuracy 0.86916
 Save the best accuracy 0.87850
 Save the best accuracy 0.89720
 Accuracy is eq, Save the lower loss 0.33602
 Save the best accuracy 0.90654
 Save the best accuracy 0.93458
 Accuracy is eq, Save the lower loss 0.33396
 Save the best accuracy 0.95327

Fig -12: Training Result

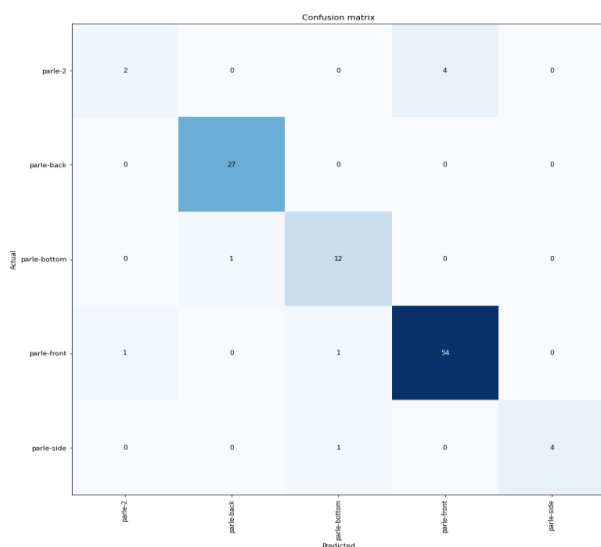


Fig -13: Confusion Matrix



Fig -14: Prediction Result

In Fig -12 we can see that over-fitting takes place after 75 iterations. We can increase the dataset and add more variations for further iterations. Also, the weights with the best accuracy were saved. Fig -13 is the confusion matrix representing the True-Positives, True-Negatives False-Negatives and False-Positives. The diagonal in the matrix represents all True-Positives (Predicted and Actual values are same). Fig -14 gives the prediction results with lowest confidence interval.

5. CONCLUSIONS

In the presented paper we have developed only the software of the system along with proposed hardware design and framework analysis to build IOT equipped smart bin which can segregate waste into plastic and non-plastic. The dataset generated for the training the ResNet model comprised of more than 2000 images containing variations of different angles, scales, noise, light, etc. Since, a single wrapper (product) has different features from different angles of

viewing, we segregated the dataset as top, bottom, front and back classes (4 classes for single product). This improved the accuracy for predictions as the back of the product and front-side of the same have different features which may lower the confidence interval in certain cases. An accuracy of 95% was recorded after the training. Also, as seen in Fig. 12, majority of the small packets (parle-2) were predicted as large packets concluding that different sizes of products can be classified as the same class. The model can be further trained for more plastic products with the same logic of separating the different faces/sides of the product as different classes.

REFERENCES

- [1] R. R. N. Sailaja Bhattacharya, Kaushik Chandrasekhar, M V Deepthi, Pratik Roy, and Ameen Khan Plastic Waste Management in India - TERI, May 30, 2018.
- [2] Neha Dasgupta, "India shelves plan on countrywide ban on single-use plastic products" 1 Oct. 2019, <https://www.reuters.com/article/us-india-pollution-plastic/india-shelves-plan-on-countrywide-ban-on-single-use-plastic-products-idUSKBN1WG43W>.
- [3] Ghate, Sanket S. and Sangeeta Kurundkar. "SWACHH: An Effective Real Time Solid Waste Management System for Municipality." International Journal of Computer Applications 149 (2016): 44-48.
- [4] N, S., Fathimal, P. M., R, R., & Prakash, K. (2019). Smart Garbage Segregation & Management System Using Internet of Things (IoT) & Machine Learning (ML). 2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT).
- [5] Technovation, "Smart Garbage Monitoring System Using Internet of Things (IoT)." Jul 28, 2017 <https://www.instructables.com/id/Smart-Garbage-Monitoring-System-Using-Internet-of-/>.
- [6] P. Mishra, "Fine-Tuning Deep Learning Models Using PyTorch," PyTorch Recipes, pp. 151-164, 2019.
- [7] Paszke, Adam and Gross, Sam and Massa, Francisco and Lerer, Adam and Bradbury, James and Chanan, Gregory and Killeen, Trevor and Lin, Zeming and Gimelshein, Natalia and Antiga, Luca and Desmaison, Alban and Kopf, Andreas and Yang, Edward and DeVito, Zachary and Raison, Martin and Tejani, Alykhan and Chilamkurthy, Sasank and Steiner, Benoit and Fang, Lu and Bai, Junjie and Chintala, Soumith PyTorch: An Imperative Style, High-Performance Deep Learning Library, Advances in Neural Information Processing Systems 32, pp 8026-8037, 2019.
- [8] K. He, X. Zhang, S. Ren and J. Sun, "Deep Residual Learning for Image Recognition," 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Las Vegas, NV, 2016, pp. 770-778.
- [9] A. Mahmood, M. Bennamoun, S. An and F. Sohel, "Resfeats: Residual network-based features for image classification," 2017 IEEE International Conference on Image Processing (ICIP), Beijing, 2017, pp. 1597-1601.
- [10] F. Sultana, A. Sufian and P. Dutta, "Advancements in Image Classification using Convolutional Neural Network," 2018 Fourth International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), Kolkata, India, 2018, pp. 122-129.