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Intelligent Waste Classification System Using Deep Learning Convolutional Neural Network

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***Abstract*: Waste management is an unavoidable issue at this time and is rising constantly with an ascent in urbanization. Waste management has lively impact on natural climate. Appropriate garbage removal at the unloading destinations has a fundamental part in arranging at the base level. Expansions in time and more labor supply is required to sort waste utilizing the conventional cycle. Arranging waste should be possible in different strategies and structures. Examining and grouping the trash utilizing picture handling can be an exceptionally useful method for handling waste materials. This paper intends to break down existing exploration introduced examinations all over the planet. This will empower to decide the issues, a calculation utilized and technique for those referred to studies. It can likewise evaluate the right calculation to be utilized in a future report. These papers discuss the various techniques and proposed frameworks where waste segregation occurred. These additionally discuss the disadvantages looked by the generally existing frameworks and calculations they utilized. With it, this paper offers a great deal of chances to deliver new information in making another framework.**

***Keywords*: Deep learning survey, trash datasets, waste detection, waste classification**

I. INTRODUCTION

Waste management is one of the biggest difficulties in the world. The Pollution Control Department (PCD) stated that the amount of garbage that cannot be managed in time is more than 27 million tons per year, while only 21% of the trash can be recycled. This is partly due to the labour-intensive and time-consuming nature of current garbage processing and managing methods. In most cases, the collected garbage from household, curb-side bins, etc. are unsorted, which would later require labour work to separate out each type of garbage to later dispose of it accordingly. The result of this report, which states that only around 35% total deposited garbage is processed correctly. Throughout the recent years, there has been an effort of tackling this problem by launching campaigns, promoting the act of separating trash into groups, often including recyclables, dangerous garbage, organic waste, and generic waste, beforehand. In many places such as schools, malls, and universities, there are also separate trash containers for the various kinds of trash. However, from observations One of the potential solutions in improving this problem is using automation, replacing the need for human labour while improving both speed and accuracy. An example of this implementation is the Refun Machine by Refun Corporation, using sensors to identify and validate plastic bottles before compressing it and storing it in its storage compartment.

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The system uses A.I and various ML algorithms to identify the garbage waste, this system in India is manual, labour based which is inefficient and slow, hazardous to labour involved in the segregation system.

The proposed Isolation framework sorts the disposal into 6 unique classifications. The working of the framework takes as follows, first and foremost camera snaps the photo of the waste to segregation and the image is broke down utilizing prepared information and then analysed using trained data the object is then identified using boundary algorithm. The venture use caffe the open-source profound learning instrument for because of its high velocity, operability with all operating system and solid outcomes. To work on the outcomes, we can utilize IOT, utilizing Arduino the exactness gets to the next level. This entire course of waste segregation is hazard free. In The present time CBO, enormously affect large scale picture grouping tasks and made it possible to achieve significantly higher accuracy than solutions based on classical image processing. There has been a steady improvement in the quality of picture recognition structures, and numerous new architectures were introduced, among which, few were recognized as reasonable for the waste grouping issue.

ML and DL methods empower numerous parts of modern society, similar to recommendation systems, text-to-speech devices, or objects identification in pictures.

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The waste management issue has drawn in a ton of interest, where the principal objective was to make a ML-based picture acknowledgment framework to sort litter most of the proposed approaches depend on deep learning algorithms utilized in the computer vision field.

EfficientNet-B2 consists of one input 3x3 convolution layer with input size of 224x224. Then, there are seven stages with mobile inverted bottlenecks MBCon with squeeze-and-excitation optimization that have jointly 16 layers. It ends with the 1ratio 1 CNN layer with a pooling and fully-connected layer. It is all scaled up with the compound coefficient $\phi = 2$. EfficientNetv2 provides faster training and better parameter efficiency. Moreover, to limit computational cost, the increase in resolution is limited. Waste management is an unavoidable issue in today's world and is rising ceaselessly with an ascent in

urbanization. The rising number in solid waste in the metropolitan region is turning into an extraordinary concern, and it would bring about ecological contamination and might be dangerous to human wellbeing if it is not properly organized. Breaking down and characterizing the trash utilizing image processing can be an exceptionally useful method for handling waste materials. It is critical to have a high level or insightful waste management system to deal with a variety of waste material. One of the main steps of waste management is the separation of the waste into the various parts and this process is normally done by handpicking.

To develop the interaction, we propose a sharp waste classification system, that has 3k-4k pictures having a place with 6 classes, This will enable to conclude the issues, a algorithm involved and procedure for those cited studies. In the present time, it's critical to have an estimation of biomass items, non-bio-mass products too, assessing the amount will help us in reusing the material.

The classifier is prepared in a semi-supervised design utilizing unlabelled images. This article gathers and summarizes past investigations and gives the results of authors' experiments on the introduced datasets, all planned to make a first replicable standard for litter recognition. EfficientDet-D2 is used to localize waste, and to group the recognized waste into six classes. The classifier is prepared in a semi-regulated design utilizing unlabelled images.

II. LITERATURE REVIEW

Machine Learning Approaches: Machine Learning makes a numerical model in light of preparing information to pursue expectations or choices without being unequivocally modified. The point of machine learning is to make a classifier or regression model through learning the training dataset and afterward use test dataset to examine the performance of the classifier or regression model. Machine learning can be ordered into the accompanying classifications in light of the idea of the preparation information. for example Supervised learning, Unsupervised learning, Semi-Supervised learning.

Deep Learning Approaches: The deep learning approach utilizes neural networks to take care of complicated issues in a creative manner.

At the point when you feed a neural network a progression of models, for example, pictures of people, It can perceive the highlights that are shared by those photos. At the point when we use layers of neural network next to each other, these layers perceive everything about the image to make a powerful model. After adequate preparation, a neural network becomes refined and equipped for ordering unlabelled images.

Hybrid Approaches: Every arrangement has its own assortment of constraints. Furthermore, it appears to be a decent answer for consolidate either at least two methodologies into the crossover approach where one supplements another. In the Hybrid approach, we generally combined machine learning, rule-based and deep learning ways to deal with make a powerful model.

Of the existing pre-trained models trained on ImageNet database, Alex Net, which won (ILSVRC) in 2012 is a highly competent architecture and proven to work efficiently on most image datasets. Afterward, the computerized order helps throughout the time spent on sanitation and implemented a CNN based system in order to classify the kinds of waste and open the dustbin when the waste is to be poured into the waste bin. designed robot model to counter the efficiently and effectively flow-free garbage accumulation in the river. The authors collected the images in Bing Image search and used the AlexNet model and achieved an accuracy of 87.69%. Sachin Hulyalkar et al. proposed a system that automatically segregates the waste at the source itself, thereby reducing physical effort. Convolutional Neural Network performed well over the mentioned Machine Learning algorithms. Their dataset is better compared to other researchers. Previous researchers used less than 1000 images whereas they have used more than 3000 images to train the model.

Studies Presented	Algorithm Used	Findings
Intelligent Waste Separator	Machine Learning	aluminium cans, plastic cutlery and bottles
Spot Garbage	Deep learning	Plastic Bottles, tin cans, paper, metals
IoT based Waste Collection System using Infrared Sensors	Azure Machine Learning System	No specified waste segregated
Adaptive and Interactive Modelling System	AI and Induction Algorithm	glass, metal, and

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III. METHODOLOGY

Classification is a method by which features are extracted from the dataset. This is achieved by splitting the knowledge into various clusters, based on the characteristics. A novel model is built which performs predictions and classifies it by training it on known data. The proposed system involves three basic modules such as pre-processing, image augmentation, and feature extraction.The model will be ready to catch a larger number of 'features' than previously and will ready to predict images much better. During feature extraction, the system characterizes the unlabelled data with maximum possible exactness.

1 Architecture of proposed system: Figure 1 displays pre-trained models that work on a given dataset. The pre-trained models train on Imagenet database are used for the extraction and classification of features after processing and data-augmentation.

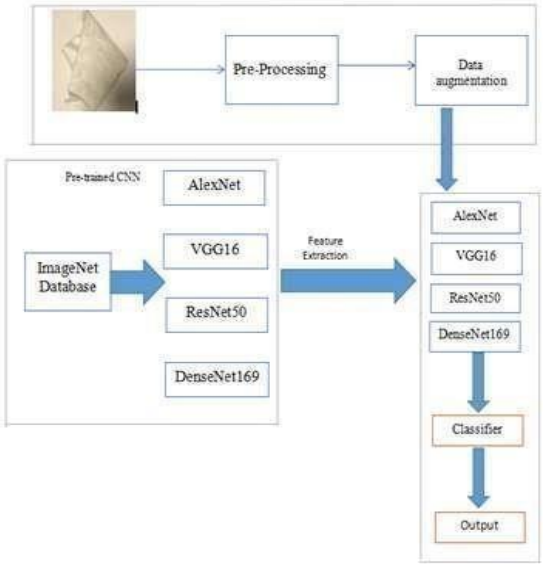

Figure. 1. Methodology of proposed work

2 Pre-processing and data augmentation: The dataset is little for pre-trained models to think about. Overfitting can be a concern. Thus, a couple of stages ought to be taken before the training model. Dataset size is duplicated by adding pictures from the Google pictures. Besides, certain methods of increase like random Re-sized crop, Irregular Level Flip, are used.

3 Convolutional Neural Network: Convolutional Neural Network(CNN) is prominently used for picture analysis. Its hidden layers called convolutional layers to make it more special. Each convolutional layer contains a bunch of filters. These filters perceive designs in the pictures. A simplest CNN has the going with layers: 3.1 Convolutional layer: A convolutional layer removes components of pictures by using filters. filters are little matrices of aspects of our desire loaded with random values. These filters recognize patterns by stepping over the input pictures after which we get the resultant 24 feature map which is passed to the following layer.

3.2 Pooling layer: In this layer, a window normally a size of 2x2 is placed over the feature map and the max value is selected in the window neglecting all other values. It results in a decreased picture scale.

3.3 Fully connected layer: The actual image recognition and classification happen in this sheet. The shrink images are taken and inserted into a single vector. This vector is compared and the image is classified with the vectors obtained from the trained images. Below are the CNN architectures that are used in this research.

4 Network Training: The dataset is split into 80% training set and 20% testing set. Google Colab is used for this project as it provides GPU free of cost. Google Colab has 1000s of cores running simultaneously. It provides with 12.72 GB RAM and 358.27 hard disk spaces in one run time. We took advantage of Fastai library to train CNN models. The Learning rate is determined after plotting learning rate vs loss graph (Figure 2). From the graph, suitable learning rate is selected and each CNN model is trained for 50 epochs using data augmentation.

5 Problems Addressed: The two key concerns that were found most are: 1. The dataset is too small to train. So there can be a problem of insufficient training. 2. There is a problem of overfitting because of less data. Image Scraping and removal of misclassified images is performed to combat these problems.

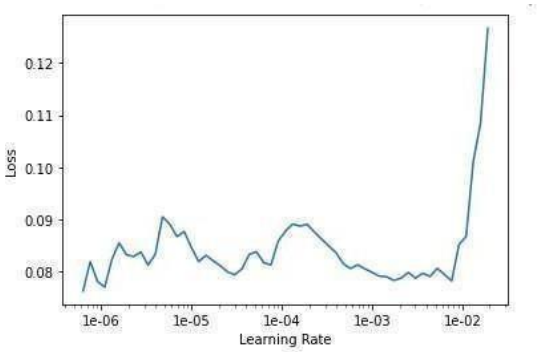

Figure. 2. Loss vs Learning rate for DenseNet169

6. Image Scraping: The models performed considerably well. Still, there is a scope to increase accuracy. To improve the model's accuracy, image scraping is done to increase the dataset set, and some of the most misclassified images are removed. We need to be more precise when looking to get more images that are linked and match best.

7 Removing the most misclassified images: One is the elimination of the most misclassified images. Therefore, the

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top 20 most misclassified images are removed from the dataset and instead of them 16 images are newly added during web-scraping

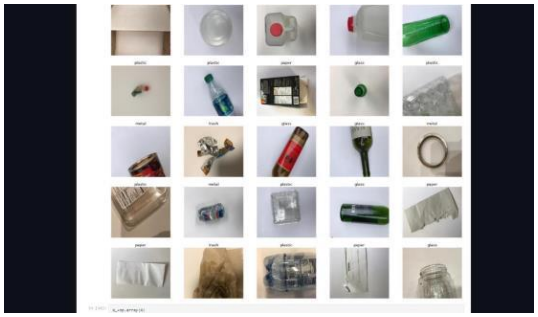

Figure 3. Types of Dataset

IV. RESULT

Once model is built, the next step is to evaluate the result of developed model using some evaluation metrics. The following metrics were used for performance assessment. It is a simple ratio of correctly predicted samples to total number of samples.

$$\text{Accuracy} = \frac{\text{Correctly predicted samples}}{\text{Total number of samples}}$$

(Or)

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

True Positives (TP): These are correct predicted values which mean the sample which belongs to a particular class is predicted that it belongs to original class. For example, if an object belongs to the paper class, it is correctly predicted by the algorithm / model. True Negative (TN): These are correctly predicted negative values. When a sample is not really part of a class, the. For instance, if an object does not belong to the paper class, the predicted class correctly classifies the same thing. False Positives (FP): When a sample is from a negative class and the. prediction model incorrectly classified as positive. False Negatives (FN): When a sample is from a positive class and the prediction model incorrectly predicted as negative. True positive and true negatives are correctly predicted samples whereas false positives and negatives are incorrectly predicted values and the confusion matrix is shown in Table 2. So, we need to minimize false positives and negatives to build a better model. Precision: It measures how good the model is at assigning positive events to the positive class. Precision = **T**P/**(TP** + **FP**) Recall: Recall measures how good the model is in detecting positive. eTherefore, the formula for recall is the same as sensitivity.

Recall = **TP** /(**TP** + **F**N)

Figure. 4. Prediction of model

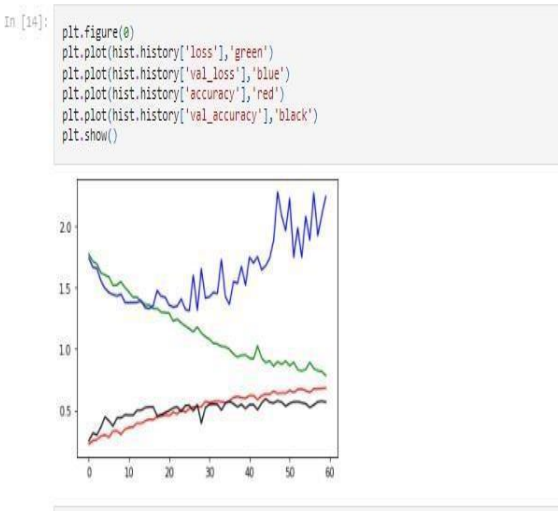

Figure. 5. Some of the mis-classified images

V. CONCLUSIONS

Various steps and methods of efficient waste management and disposal have already been researched and carried out by many researchers and research enthusiasts. Many devices have also been designed in order to carry on this process efficiently. Hardware components such as raspberry pi have been used along with various algorithms to achieve the goal. Images of objects are scanned using the device in order to classify them accordingly. But a major shortcoming of such devices is that all these devices work with maximum accuracy only on images containing single objects to be recognized and classified. Convolution Neural Networks is considered to play a very important role in the process of object detection and can be said to be the major step towards the development of such methods. Methods and steps that consider the shape and size of objects for their recognition and classification have also been developed, but they can be used only on objects that can be said to stay in a specific shape or size, which seems to be a bit difficult when it is wastes and scraps. Physical reflectance properties of various objects and also a classification of objects based on their materials have also been used earlier to propose methods to classify images accordingly. Previous researches have been more about single object recognition and classification, and moreover, different algorithms were implemented on the same datasets in order to calculate and evaluate the precision of algorithms used to demonstrate the importance and application of the specified algorithm with respect to the kind of datasets used. The major drawbacks of these already existing systems are that they aim to classify an only single object in an image. In a real-world scenario, it is very difficult to separate individual objects from a garbage pile and then classify them as the amount of garbage present will be in the magnitude of millions of tons and it will be very time consuming. Hence there is a need to recognize and segregate images. Also in the current models, the number of categories in which wastes are classified is very less. Wastes are usually classified as recyclable and compost.

Recyclable materials consist of paper plastic metal etc. and each of it is recycled 36 separately in a different way. Hence to classify the recyclable materials from garbage and wastes into different categories would make the recycling process better and easier. From the past decade, there is a huge increase in the use of electronic gadgets, which can be attributed to the explosive growth in computer and technology. The average life of an electronic gadget like a smartphone is around 2 years. In the next few decades, the number of electronic wastes generated will increase drastically. It will be very difficult to recycle these components as each part are made of made of different materials and each of these materials has to be recycled in different ways. Therefore, an efficient method to recycle electronic gadgets and their spare parts is needed. With this, a study to conduct new wastes segregation is a must.Image processing capability must be high in order to determine and segregate recyclable materials.

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