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Real Life Smart Waste Management System

[DRY, WET, RECYCLE, ELECTRONIC & MEDICAL]

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ABSTRACT

The problem of real-life smart waste management system can be solved using automatic waste segregation. In particular, the focus of the article is on the problem of detection (i.e., waste classification). In these 5 classes of waste are taken and segregated them into 5 categories namely dry, wet, recycle, electronic and medical. This system will automatically detect the waste object and segregate it into the respective category. The use of machine learning allowed improving the model with more accuracy. Convolutional Neural Networks (CNN) algorithm which is best used for image classification is used for object detection. The models that was trained are ResNet50, VGG16, InceptionV3 and MobileNetV2. Finally, when compared to the results of all these models, MobileNetV2 has given us the best and highest accuracy of about 98% and 99% respectively.

Keywords - Automatic Waste Segregation, Convolutional Neural Network, MobileNetV2, Computer Vision Library, Object Detection, Object Recognition, Object Classification.

I. INTRODUCTION

Waste Management:

Waste management refers to the various schemes to manage and dispose of wastes. It can be done by discarding, destroying, processing, recycling, reusing, or controlling wastes. The prime objective of waste management is to reduce the number of unusable materials and to avert potential health and environmental hazards.

Different activities include collection, monitoring, regulation, and disposal. Waste collection services are often provided for free by the local government. The collected wastes are disposed of by various methods, e.g., by landfill compaction and incineration. Solid wastes, most especially, are incinerated to reduce their volume by 80 to 95%, and

to convert them into gas, steam, ash, and heat.

However, air pollution is a concern when disposing of wastes by means of incineration.

Thus, other means are encouraged, such as recycling, reprocessing, and re-use. Organic wastes, especially those that are biodegradable, are allowed to be decomposed so that they can be used as mulch or compost in agriculture and the methane gas from

the biological degradation be collected and used for generating electricity and heat. Liquid wastes, such as waste water, undergo treatment producing sewage sludge that can be disposed of by incineration, composting, and landfill.

II. LITERATURE REVIEW

Waste segregation plays the vital role in today's era due this pandemic situation. By segregating the recyclable from non-recyclable wastes, so that we can easily notice, identify and separate the waste categories. Segregation of waste, i.e., sorting into waste categories, leads to reduced quantities of hazardous waste. Waste segregation is included in law because it is much easier to recycle. Effective segregation of wastes means that less waste goes to landfill which makes it cheaper and better for people and the environment. It is also important to segregate waste for public health. A literature review is a comprehensive summary of previous research on a topic. The literature review surveys scholarly articles, books, and other sources relevant to a particular area of research. The review should enumerate, describe, summarize, objectively evaluate and clarify this previous research. In the literature, many methods have been used for recognition of waste whether it is dry, wet or recyclable waste etc. They have been used the Machine Learning and Deep Learning techniques which are based on Supervised learning, a good training dataset is achieve the efficient and acceptable results.

[1]. Automatic Waste Segregation System using Machine Learning: [Myra Flores, Jose Tan published in 2019] They have been used the Intelligent Waste Separator (IWS) in Machine Learning and Spot Garbage in Deep learning. In IWS waste separation doesn't depend on the people it segregates the aluminum cans, plastic cutlery, and plastic bottles. Spot Garbage is 11 times faster than the naive window sliding and it predicts the tin cans, plastic bottles, paper etc. They got accuracy of 93% and 84% for these models.

[2]. Detecting glass and metal in consumer trash bags during waste collection using CNN: [Oliver Istad Funch, Robert Marhaug published in 2020] They presented the proof-of-concept method to classify the presence of glass and metal in consumer trash bags. They used the metal detector coil, proximity sensor, weight sensor, contact microphones, gopro camera. They used the custom-built test rig to mimic a real waste collection truck, test the sensors and build the datasets. They used the CNN to train the classification task. They got the accuracy of to 98%.

[3]. ContamiNet: Detecting Contamination in Municipal Solid Waste: [Ibrahim Khoury, Danielle A published in 2019] They developed ContamiNet, CNN to identify contaminating materials in residential recycling and compost bins. They done leveraging over 30,000 images each with up to 89 labels collected by Recology. They trained the model on subset of labels that meet a Minimum Frequency Threshold, ContamiNet bins. They used the CNN, Sensor, ANN, Sorting. They got accuracy up to 86%.

[4]. Automatic Waste Segregation using Image Processing and Machine Learning: [B. Dev published in 2018] They used the waste segregator is centrally partitioned movable bin that travels the area of interest and picks up any waste item in its path. They used the Image processing and embedded applications using Raspberry pi. They used the robotic arm which place the object on rotating flap attached over the two compartments. They used the Machine learning to identify the category of waste and artificial Intelligence to train the hardware. They used to train by dropping the waste item into respective compartment by rotating flap. They got the accuracy up to 92%.

[5]. Survey On identification and Classification of Waste for Efficient Disposal and Recycling: [M. Adhithya Prasanna, S. Kaushal published in 2018]

They used to sort, analyzing and classifying by using image processing technique. They used the models like George E Sakr's research, Spot Garbage, Mindy Yang et al research. They used the algorithms like CNN and SVM, Convolutional network and SVM. They got the accuracy like 94% and 83% for George model, 87% for Spot Garbage, 63% for mindy yang model.

[6]. A Study on object recognition using deep learning for optimizing categorization of radioactive waste: [Jeong-gukkim, Sung-Chan Jang published in 2020] They try to maximize the efficiency of categorization for ne or temporary workers instead of skilled workers by training the categorization using deep Learning. Here the waste management system based on deep learning technology was trained with total of 86084 images for 50 epochs with a subdivision of 8 and a batch of 128, which is extracted from the video data that were taken in a waste sorting site. The waste recognition was tested with a total of 21521 images. They got accuracy 99.67%.

[7]. Garbage detection using advanced object detection techniques: [Deep Patal, Vibha Patel published in 2021] They work proposes a garbage detection system using the object detection models to automatically detect the and locate garbage in real-world images as well as video. They used the five different models EfficientDet-D1, SSD ResNet-50 V1, Faster R-CNN ResNet-101 V1, CenterNet ResNet-101 V1 and YOLOv5M.They did the hyper-parameter tuning and evaluation, YOLOv5M achieved best results by achieving a Mean Average Precision value is 0.613.

[8]. Comparing deep learning and support vector machines for autonomous waste sorting: [G. Sakr, M. Mokbel published in 2016] They aim to automate waste sorting by applying machine learning techniques to recognize the type of waste from their images only. They used the two algorithms deep learning with convolution neural networks (CNN) and support vector machines (SVM). Each algorithm creates the different classifiers that separates waste in three categories: plastic, metal and paper using only 256*256 colored PNG image of the waste. They got accuracy of 94.8% for SVM and 83% for CNN.

[9]. SpotGarbage: Smartphone app to detect garbage using deep learning: [Gaurav Mittal, Kaushal, B. Yagnik published in 2016] They used the spotgarbage, which detects and coarsely segments garbage regions in user-clicked geo-tagged image. They trained the model on newly introduced garbage in images (GINI) dataset, achieving a mean accuracy of 96.8% in memory usage.

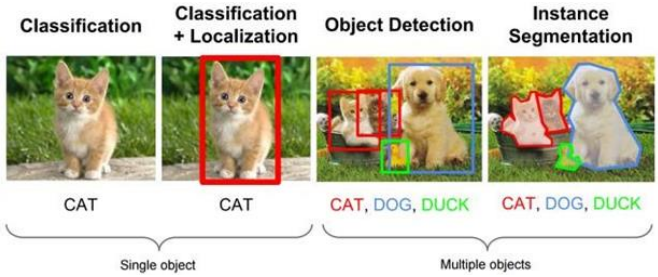
[10]. A comparison of several machine learning techniques for the centerline segregation prediction in continuous cast steel slabs and evaluation of its performance: [P. Nieto, E.G. Gonzalo published in 2018] They used the novel hybrid algorithm, based on SVM in combination with particle swarm optimization technique, for predicting the centerline segregation from the operation of input parameters determined experimentally in continuous cast steel slabs. They also used the Multilayer perceptron network (MLP) and a multivariate adaptive (POS) technique. They got accuracy of 0.97%

III. Object Detection

Object detection is a computer vision technique that allows us to identify and locate objects in an image or video. With this kind of identification and localization, object detection can be used to count objects in a scene and determine and track their precise locations, all while accurately labeling them. Object Detection has been witnessing a rapid revolutionary change in the field of computer vision. Its involvement in the combination of object classification as well as object localization makes it one of the most challenging topics in the domain of computer vision. In simple words, the goal of this detection technique is to determine where objects are located in a given image called as object

localization and which category each object belongs to, that is called as object classification.

Object Classification:



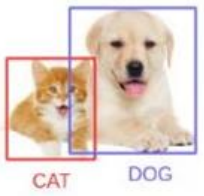
Object-based or object-oriented classification uses both spectral and spatial information for classification. Object-based classification is a two-step process, first the image is segmented or broken into discrete objects or features with and then each object is classified. Image classification involves predicting the class of one object in an image. Object localization refers to identifying the location of one or more objects in an image and drawing a bounding box around their extent. Object detection combines these two tasks and localizes and classifies one or more objects in an image.

Machine Learning using Python:

Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

Python is a general-purpose programming language, so it can be used for many things. Python is used for web development, AI, machine learning, operating systems, mobile application development, and video games.

Image Localization



Object Detection

Deep Learning using Python:

Image classification involves predicting the class of one object in an image. Object localization refers to identifying the location of one or more objects in an image and drawing abounding box around their extent. Object detection combines these two tasks and localizes and classifies one or more objects in an image.

Python is an interpreted, object-oriented, high-level programming language with dynamic semantics. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance.

IV. EXISTING SYSTEM

Algorithm:	CNN & SVM
Model:	AlexNet
Dataset:	Trashnet
Platform:	Kaggle
Categories:	0
Classes:	6

[Cardboard, Glass, Metal, Paper, Plastic, Trash]

Accuracy:	63%
Epochs:	50

V. PROPOSED SYSTEM

Algorithm:	CNN
Model:	MobileNetV2

Dataset: Custom

Categories: 5

[Dry, Wet, Recycle, Electronic, Medical]

Classes: 5

[Glass, Mango, Mask, Phone, Spoon]

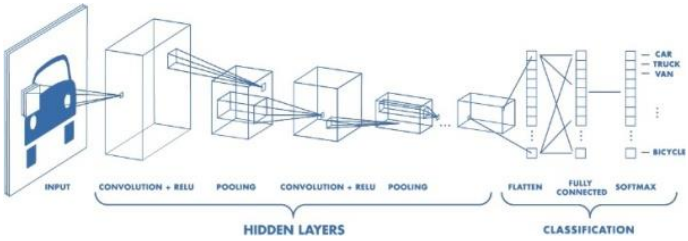
Accuracy: 98%

Epochs:10

VI. ARCHITECTURES

The various architectures which are used are, CNN architecture and MobileNetV2 architecture.

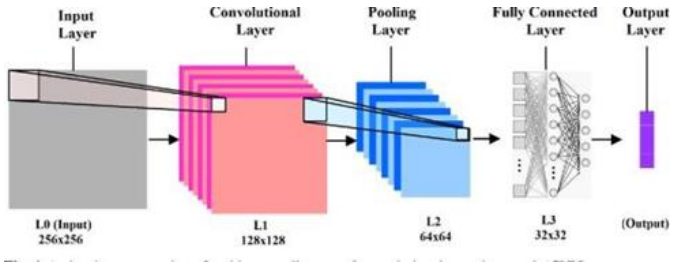
System Architecture:



CNN Architecture:

There are different layers in CNN

- Input layer
- Convo layer (Convo + ReLU)
- Pooling layer
- Fully connected (FC) layer
- SoftMax/logistic layer
- Output layer



Input Layer

Input layer in CNN should contain image data. Image data is represented by three-dimensional matrix. You need to reshape it into a single column. Suppose you have image of dimension 28 x 28 =784, you need to convert it into 784 x 1 before feeding into input. If you have "m" training examples then dimension of input will be (784, m).

Convo Layer

Convo layer is sometimes called feature extractor layer because features of the image are get extracted within this layer. First of all, a part of image is connected to Convo layer to perform convolution operation as we saw earlier and calculating the dot product between receptive field (it is a local region of the input image that has the same size as that of filter) and the filter. Result of the operation is single integer of the output volume. Then slide the filter over the next receptive field of the same input image by a Stride and do the same operation again. Repeat the same process again and again until the whole image is gone through . The output will be the input for the next layer. Convo layer also contains ReLU activation to make all negative value to zero.

Pooling Layer

Pooling layer is used to reduce the spatial volume of input image after convolution. It is used between two convolution layers. If FC is applied after Convo layer without applying pooling or max pooling, then it will be computationally expensive So, the max pooling is only way to reduce the spatial volume of input image. In the above example, max pooling is applied in single depth slice with Stride of 2. Observe that the 4 x 4-dimension input is reduced to 2 x 2 dimension.

Fully Connected Layer (FC)

Fully connected layer involves weights, biases, and neurons. It connects neurons in one layer to neurons in another layer. It is used to classify images between different category by training.

SoftMax / Logistic Layer

SoftMax or Logistic layer is the last layer of CNN. It resides at the end of FC layer. Logistic is used for

binary classification and SoftMax is for multi-classification.Output Layer

Output layer contains the label which is in the form of one-hot encoded.

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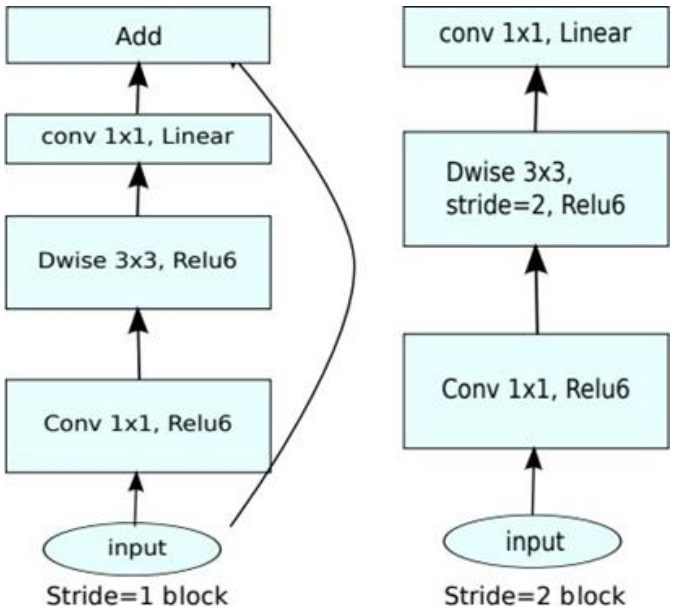
MobileNetV2 Architecture:

In MobileNetV2, there are two types of blocks. One is residual block with stride of 1. Another one is block with stride of 2 for downsizing.

There are 3 layers for both types of blocks.

- This time, the first layer is 1×1 convolution with ReLU6.
- The second layer is the depth wise convolution.
- The third layer is another 1×1 convolution but without any non-linearity.



It is claimed that If ReLU is used again, the deep networks only have the power of a linear classifier on the non-zero volume part of the output domain. And there is an expansion factor t. And t=6 for all main experiments. If the input got 64 channels, the internal output would get 64×t=64×6=384 channels.

Where t: expansion factor, c: number of output channels, n: repeating number, s: stride. 3×3 kernels are used for spatial convolution

- In typical, the primary network (width multiplier 1, 224×224), has a computational cost of 300 million multiply-adds and uses 3.4 million parameters. (Width multiplier is introduced in MobileNetV1.)
- The performance tradeoffs are further explored, for input resolutions from 96 to 224, and width multipliers of 0.35 to 1.4.
- The network computational cost up to 585M MAdds, while the model size varies between 1.7M and 6.9M parameters.
- To train the network, 16 GPU is used with batch size of 96.

These are the 3 layers in MobileNetV2 model in two stride blocks.

MobileNetV2 model is the fastest and lightest model in which using this we can easily deploy it in low powered computational devices and mobile applications.

DATASET USED

A data set is a collection of data. Training dataset is the actual data set used to train the model for performing various actions.

There are two types of datasets used.

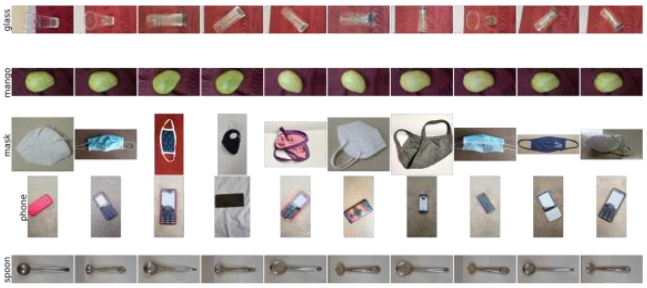
Existing dataset
Custom dataset

Existing Dataset

Kaggle – Garbage Classification Classes:
[Cardboard, Glass, Metal, Paper, Plastic, Trash]

Custom Dataset

Custom Created Dataset
Classes:
Dry – Spoon Wet – Mango
Recycle – Glass
Electronic – Phone Medical – Mask



This is the proposed dataset.

VII. TECHNOLOGY & METHODOLOGY

The Technologies and Methodologies used are .

- CNN
- MobileNetV2

CNN Algorithm

Artificial Intelligence has been witnessing a monumental growth in bridging the gap between the capabilities of humans and machines. Researchers and enthusiasts alike, work on numerous aspects of the field to make amazing things happen. One of many such areas is the domain of Computer Vision.

The agenda for this field is to enable machines to view the world as humans do, perceive it in a similar manner and even use the knowledge for a multitude of tasks such as Image & Video recognition, Image Analysis & Classification, Media Recreation,

Recommendation Systems, Natural Language Processing, etc. The advancements in Computer Vision with Deep Learning have been constructed and perfected with time, primarily over one particular algorithm that is a Convolutional Neural Network.

MobileNetV2 Model:

MobileNetV2 is a convolutional neural network architecture that seeks to perform well on mobile devices. It is based on an inverted residual structure where the residual connections are between the bottleneck layers.

MobileNets are small, low-latency, low-power models parameterized to meet the resource constraints of a variety of use cases. According to the research paper, MobileNetV2 improves the state-of-the-art performance of mobile models on multiple tasks and benchmarks as well as across a spectrum of different model sizes.

VIII.SOFTWARE USED

Google Colab:

Google have released Colaboratory - a web IDE for python, to enable Machine Learning with storage on the cloud. This internal tool had a pretty quiet public release in late 2017, and is set to make a huge difference in the world of machine learning, artificial intelligence and data science work.

Colaboratory or Colab allows anybody to write and execute arbitrary python code through the browser, and is especially well suited to machine learning, data analysis and education. With Colab you can import an image dataset, train an image classifier on it, and evaluate the model, all in just a few lines of code. Colab notebooks execute code on Google's cloud servers, meaning you can leverage the power of Google hardware, including GPUs and TPUs, regardless of the power of your machine.

Python:

Python is a high level, dynamically typed language developed by Guido Van Rossum in the early 1980s. It is a dynamic, interpreted (bytecode-compiled) language. There are no type declarations of variables, parameters, functions, or methods in source code. This makes the code short and flexible, and thereby

lose the compile-time type checking of the source code. Python is used for web development, AI, machine learning, operating systems, mobile application development, and video games. Python is widely considered one of the easiest programming languages for a beginner to learn, but it is also difficult to master.

IX. PYTHON PACKAGES & LIBRARIES

- TensorFlow
- Keras
- Matplotlib
- NumPy
- OpenCV

X. ACCURACY GRAPHS

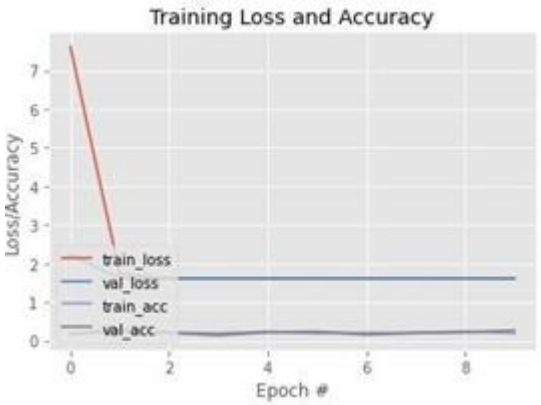
The dataset was trained and tested with 4 different types of models and got the accuracies respectively.

The 4 models are:

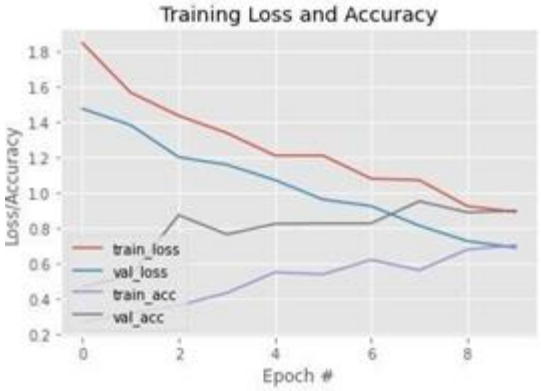
- ResNet50
- VGG16
- InceptionV3
- MobileNetV2

The model was trained up to 50 epochs.

MobileNetV2 got the best and highest accuracy by running just 10 epochs. Even when compared to all the models, MobileNetV2 is the fastest model which runs epochs in less time but with more accuracy while testing.

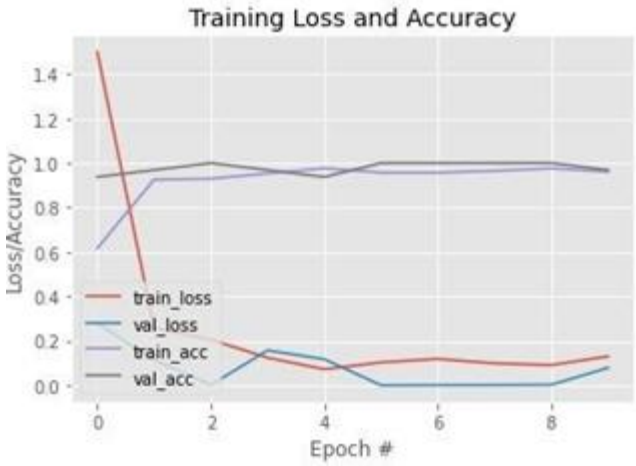


ResNet50



VGG16

InceptionV3



MobileNetV2

XI. RESULTS

Pre-trained model MobileNetV2 was used on 5 category classes of custom dataset because it has clearly identified the objects very faster with an accuracy of 98% and 99% respectively.

Using the code, the objects was predicted with the following steps:

- Image of the object
- Bounding box around the object
- Name of the class label of the object
- Confidence score of the object
- Category of the object

Wet Waste

Dry Waste

Recycle Waste

Electronic Waste

Medical Waste

These are the results obtained after testing.

Here, 5 classes was taken and classified them into 5 categories. They are:

Spoon → Dry Waste Mango →

Wet Waste Glass → Recycle

Waste Phone → Electronic

Waste Mask → Medical Waste

Best results and highest accuracy was got for two classes. They are:

Dry – Spoon = 99% and Medical – Mask = 98%

XII. CONCLUSION

After analyzing the results as shown in the accuracy comparison graphs, it is clearly concluded that MobileNetV2 turned out to be the best model for object detection, prediction and classification of the waste objects using CNN algorithm.

MobileNetV2 model has given us the highest accuracy of 98% and 99% just by running 10 epochs.

XIII. FUTURE WORK

In the future works, we can do so many things to get good results such as:

- Adding more layers to CNN algorithm.
- Using other different models.
- Training for more epochs on various models.
  - Including some more images of the waste objects into the dataset.
  - Extending the project for deployment into a device using sensors.

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