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Segregation of Plastic and Non-plastic Waste using Convolutional Neural Network

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Abstract. Due to industrialization and urbanization the rapid rise in the volume and amount of hazardous waste and the disposal of it is becoming a burgeoning problem that the world is facing today. One of the best ways out for this problem is to collect, sort and reuse or recycle these waste. So this paper proposes an architecture which sorts waste materials into plastic and non-plastic using Convolutional Neural Networks (CNN). CNN is one among the efficient machine learning techniques, which is able to provide maximum learning efficiency. This technique requires less parameter for training compared to the standard neural network. A dataset of waste materials required for our setup is collected. They are trained and tested using CNN. The proposed architecture with CNN gives an accuracy of 0.978. The proposed design also consists of a prototype, which acts as a real-time classifier. This system reduces the human efforts in separating plastics from non-plastics.

Keywords: Convolutional neural network, Solid-waste management, Rectified linear unit, Solid waste

1. Introduction

Solid waste is a very critical problem for all nations. SWM is a very challenging issue due to the rapid increase in the amount of SW with the increase in population. Statistics show us that SW generation is sharply increasing every year compared to the previous year [1, 2]. Most of the waste generated is dumped into water-bodies or as landfills. Biodegradable waste dumped into landfills are automatically decomposed but non-biodegradable wastes don't get automatically decomposed and hence pollute the environment and water-bodies and also waste disposed of in water-bodies pollute the drinking water and thereby reducing the available drinking water. Apart from all this these waste materials result in the release of toxic liquids which contaminate water-bodies and soil. They also result in the release of harmful gas like methane, which is one of the main greenhouse gases. Methane is an extremely dangerous gas that causes many changes in the climate, which also leads to a shift in our regular weather patterns.

So the only solution to all this is to recycle waste. The initial step for recycling is segregation. Segregation is the process of separation of biodegradable waste from non-biodegradable so that the waste material can be disposed of properly or recycled as the case may be. Segregation also helps us to save a lot of money by helping us to reuse certain materials, which we would otherwise throw away. Also if the waste is segregated, we can recycle them to some other useful products which will help us not only to keep the environment clean but also give huge revenue. Hence waste segregation is very important to save the environment. Traditionally picking and sorting of waste is done by rag pickers. But this can cause a lot of health issues like infections, skin cancer, respiratory problems etc. So, automatic waste segregation is very important.

There are so many techniques that are used to automate waste segregation. Some methods use image processing techniques to classify the waste. Size, colour, texture etc. of waste material is used to segregate them. Image processing has also been successfully used for other applications as in [3] and such systems are implemented using microcontrollers [5]. There are also waste segregation which works based on sensors. Different types of sensors such as capacitive sensors to detect plastic, glass,



wood, inductive proximity sensors to detect metals, gas detection and optical sensors for detecting food items etc. are used to segregate waste [2, 3]. Segregation of waste is also done using RFID. In this type of segregation, the RFID is attached on each type of material during manufacturing, so that classification becomes easier [6].

2. CNN layers

2.1. Convolution Neural Network (CNN).

It is a form of neural network commonly used for image classification. Unlike the other traditional network which has densely connected layers CNN shares weights between receptive fields. This reduces the number of parameters and CNN employs convolution mechanism with filters. CNN is a network that learns the filters to use i.e. the features to extract, in order to classify. The network takes input data, transforms it by calculating a weighted sum over the input and applies a non-linear for this transformed input to find an intermediate state. These three steps constitute a layer.

CNN constitute some combination of these three layers:

2.2. Convolution Layer.

This layer contains many filters and each filter produced an image containing a particular feature. So the output of a convolution layer will be a stack of images called Tensor.

2.3. Maxpool Layer.

This layer is used to reduce the size of the input by merging the neighbouring elements by taking the maximum value. Hence, a two-dimensional window is chosen and it is convolved over each image in steps. After each step we get values, which fall within the window, from these values, the maximum value is chosen and after all convolution steps a matrix of all these chosen values is formed which is of low dimension. This will help to reduce the number of parameters and hence the amount of computation.

2.4. Fully Connected Layer.

In this layer, we have many units. A unit is nothing but an activation function in a layer by which the inputs are transformed via a non-linear activation. In this layer, each unit is connected to every other unit of the succeeding layer. Fully connected layer map the data to a higher dimension. As the dimension increases, the accuracy of output also increases. The commonly used activation function is ReLu (rectified liner activation function).

2.5. Classification.

For classification, the fully connected layer output is sent through a sigmoid activation function. The fully connected layers absorb the non-linear kernel and sigmoid output 0 (plastic) and 1 (non-plastic).

The prediction loss is estimated using:

$$\text{loss}(pd, ed) = -\frac{1}{N} \sum_{i=1}^N [ed_i \log pd_i + (1 - ed_i) \log(1 - pd_i)] \quad (1)$$

Where pd is a vector of predicted probability for all samples in testing data set and ed is a vector of the expected class label, values are either 0 or 1.

Currently, different supervised learning techniques are used for a variety of applications [7]. In supervised learning, the dataset is labelled and the algorithm predicts the output from input data. The supervised learning algorithm learns to an inherent structure from input data. Traditional supervise learning techniques rely on feature engineering and feature selection techniques, this requires extensive domain knowledge. Recently, deep learning algorithms have performed well in comparison to traditional machine learning in various long-standing intelligence tasks which are related to computer vision, natural language processing, speech processing etc. They have the capability to learn optimal features by taking raw input samples. They pass the input data across many input hidden

layers and try to learn the abstract feature representation. The CNN is a type of deep learning algorithms. This has proved as one of the best classifiers in several computer vision tasks. In this work, we employ CNN for waste segregation.

3. Hardware setup components

3.1. Arduino UNO

The Arduino UNO microcontroller board works based on ATmega 328 datasheet. The board has 14 digital input/output pins out of this 6 are PWM output pins and 6 analogue pins. It can be powered by using a 9 v battery or by connecting it to a computer via a USB cable. It uses STK500 protocol for communication and ATmega 16U2 as a USB to serial converter [4]. Arduino can be coded by using C or C++.

3.2. Formatting author affiliations

Windshield wiper motor with an inbuilt permanent magnet is a most commonly used one in the automotive vehicle. . It is used to drive the wiper of the vehicle to provide a clear view to the driver. The rotation of a wiper motor makes the wiper to move back and forth. The motor works on an input voltage of 12 volts. The motor can work in two different speeds; they are single speed and two speed. When the motor works at a normal speed, it makes forty wipes per minute and when it works at high speed it makes sixty wipes per minute.

3.3. Stepper Motor

A stepper motor is a brushless DC motor. It has a small piece of iron in the Centre around which electromagnets are arranged. Permanent magnet stepper, Hybrid synchronous stepper and Variable reluctance stepper are the three different types of stepper motors. Stepper motor finds a wide range of applications in the field of lasers and optics. It is also used in commonly used devices such as printers, scanners etc.

3.4. Switching mode power supply

Switching power supply/Switching mode power supply (SMPS) transfers power from a DC or AC source to DC load. It is commonly installed in computers. The main advantage of SMPS is that it can supply three different voltage values i.e. 3.3v, 5v and 12v. As it receives power supply from AC/DC source, it can constantly supply the required voltage and will not get drained up like a battery. A fan is provided inside the SMPS to avoid the equipment getting heated up even when used continuously for a long time.

3.5. ULN 2003

ULN 2003 is most commonly used IC to drive a stepper motor. It has an array of Darlington transistors. This Darlington pair has two bipolar transistors, which can amplify current. Since there are two bipolar transistors, the current amplified by one is further amplified by the other resulting in double amplification. The IC has a total of 16 pins which includes 7 input pins, 7 output pins, 1 Vcc and 1 Ground Pin. The IC can withstand current of 500mA to 600mA.

3.6. Webcam

The webcam is used to capture a stream of real-time images or videos. It can be connected to the computer through a USB. These cameras find a wide range of applications in the areas of security, health monitoring, traffic control, in houses for making video calls etc.

4. Hardware setup and its working



Figure. 1. Hardware setup for segregation

The hardware setup consists of a conveyor belt, which is run by a windshield wiper motor, a camera, a gate which is moved by a stepper motor. The motor is controlled using a motor driver ULN 2003 and an Arduino board. The power supply required for the entire system is given by a switching mode power supply. The waste material to be segregated is placed on the conveyor belt such that it is captured by the camera.



Figure. 2. A plastic object in the conveyor belt

The image captured by the camera is sent to the CNN code for pre-processing and classification as plastic or non-plastic. The grouping of a picture is done in framework utilizing convolution neural network (CNN), CNN comprises of two hidden layers and one completely associated layer which give the outcome whether the picture is plastic or non-plastic. The output is given as probability value. If the probability value is more than 0.5 then the waste material is plastic and if the probability value is more than 0.5 then the waste material is non-plastic.

If the system identifies the material as plastic that is if the probability value obtained is greater than 0.5, a character (e.g. 'o') is sent (serial communication) to the Arduino board. The board immediately switches on the stepper motor which moves the gate to an angle of 45 degrees (i.e. 25 stages) with a speed of 60rpm. And after few seconds the motor returns back to its default state.



Figure. 3. Use of a motor to dispose of plastic wastes to the bin

Now if the system identifies the material as non-plastic that is if the probability value obtained is less than 0.5, then the gate will be in the open state and the material over the belt moves straight to the end and falls to the bin.



Figure.4.Non-plastic disposal

5. Results

Table 1. Detailed result of CNN model.

Dataset	Accuracy	Recall	Precision	f1Score
1	0.978	0.913	0.979	0.945

Table 2.Detailed statistics of CNN model

Layer (type)	Output Shape	Parameters
conv2d_1 (Conv2D)	(None, 32, 56, 56)	896
activation_1 (Activation)	(None, 32, 56, 56)	0
conv2d_2 (Conv2D)	(None, 32, 54, 54)	9248
activation_2 (Activation)	(None, 32, 54, 54)	0
max_pooling2d_1 (MaxPooling2)	(None, 32, 27, 27)	0
dropout_1 (Dropout)	(None, 32, 27, 27)	0
conv2d_3 (Conv2D)	(None, 64, 27, 27)	18496
activation_3 (Activation)	(None, 64, 27, 27)	0
conv2d_4 (Conv2D)	(None, 64, 25, 25)	36928
activation_4 (Activation)	(None, 64, 25, 25)	0
max_pooling2d_2 (MaxPooling2)	(None, 64, 12, 12)	0
dropout_2 (Dropout)	(None, 64, 12, 12)	0
flatten_1 (Flatten)	(None, 9216)	0
dense_1 (Dense)	(None, 128)	1179776
activation_5 (Activation)	(None, 128)	0
dropout_3 (Dropout)	(None, 128)	0

Layer (type)	Output Shape	Parameters
dense_2 (Dense)	(None, 1)	129
activation_6 (Activation)	(None, 1)	0

Table 3.Detailed statistics of data set.

Total parameters	Trainable parameters	Non-trainable parameters
1245473	1245473	0

6. Conclusion

The objective of the paper was to build an automatic waste segregator and test its performance using a CNN. The model was tested with different waste materials and the accuracy of 97.8% is obtained. It can be further improved by increasing the dataset size. The setup can be expanded for multi-class waste sorting and be implemented in hardware set up with more number of trash cans. In future, it is easy to add up more images in the dataset and hence we can retain the same model.

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