Chapter 83
Automatic Classification of Solid Waste Using Deep Learning

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Abstract Solid waste management is an essential task to be carried out in day-to-day life. So an automated recognition system using deep learning algorithm has been implemented to classify wastes as biodegradable and non-biodegradable. Efficient segregation of solid wastes helps to reduce the amount of waste buried in the ground, thereby improving the recycling rate, and safeguards the soil from pollution.

Keywords Waste · Glass · Plastic · Wood · Textile · Classification · Accuracy

Abbreviations

CNN	Convolutional Neural Network
R-CNN	Region Convolutional Neural Network

83.1 Introduction

Solid waste management has turned out to be one of the fundamental issues in both urban and rustic regions. The significant increase in municipal solid waste generation has been recorded worldwide. Most urban solid waste in Indian cities and towns is land filled and dumped. Currently there is no system for segregation of dry, wet and metallic wastes. An efficacious management needs to be materialized for replacing traditional way of dealing with waste. Current worldwide waste generation levels are roughly 1.3 billion tonnes for each year and are relied upon to increase around 2.2 billion tonnes every year by 2025. India produces 1,00,000 metric huge amounts of waste every day. Strong waste administration was made a need in the

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National Mission on Sustainable Habitat. The current refuse transfer framework in India comprises of unclassified waste gathered from homes which are then isolated at a station physically.

The segregation of solid waste done by manual labour can bring about many health hazards for the waste sorters in addition to being less efficient, time consuming and not completely feasible due to their large amount. In this project, an automated recognition system using Deep learning algorithm has been implemented to classify wastes as biodegradable (Agricultural Wastes, Food Wastes, Clothes, Paper, Mineral Wastes) and non-biodegradable (Plastics, Steel, Metal Cans), where the system once trained with an initial dataset, can identify objects real-time and classify them almost accurately. Efficient segregation of solid wastes helps to reduce the amount of waste buried in the ground, thereby improving the recycling rate, and safeguards the soil from pollution. Biodegradable waste is utilized for power generation, soil enrichment and food for animals. This process does not harm the earth but instead makes it valuable, ecologically safe and helps to protect the environment, ecosystem and human inhabitants in future.

83.1.1 Objective

The main objective of this project is to develop various computer vision approaches to classify garbage in an efficient manner into recycling categories to process waste. The images of a single piece of recycled material or garbage are taken and classified into six classes consisting of glass, paper, metal, plastic, cardboard and trash. A dataset that contains around 400–500 images for each class, which was hand collected, has been created. The model used is faster convolutional neural network (CNN). The performance of CNN was good; however, the CNN was not trained to its full capability due to trouble finding optimal hyperparameters.

83.1.2 Scope of the Proposed Methodology

The trend to instil automated waste segregation systems into new housing development projects is rising and serves for leading the way in implementing this type of technology. Statistics show that the UK produces 330 million tonnes of waste a year, and estimates show that in 2007, 480,000 tonnes of CO_2 were emitted due to separate collection and composting of 835,000 tonnes of organic waste. This shows us the need for segregating and composting garbage on a larger scale. Hence this project helps inefficient segregation of solid waste and provides the right path for decomposition. The major scope of this project is to make our

environment sustainable, to maintain a safe and green environment and to reduce the human work in classifying the waste as degradable and non-biodegradable.

83.2 Related Work

The prevailing garbage disposal system in India consists of unorganized waste collected from habitats which are then segregated at a station. The segregation is done by manual labour which has many health mishaps for the labourers and is time consuming and also requires financial share to the workers. Another concept uses a hardware component that can sort waste at the initial stage thus making waste management more powerful. The designed system sorts wastes into six different categories, namely, metal, plastics, paper, textile, wood and glass. An OpenCV, which acts as the heart of the system, is then used to observe the wastes and timing of all the subsections so as to sort the waste into the three primary categories. Literature survey considering various papers is summarized in Table 83.1.

Table 83.1 Literature survey

Paper name	Problem solved	Demerits
An automatic classification method for environment: Friendly waste segregation using deep learning	A proposition for a system that automatically classifies waste using deep learning	Cannot classify medical waste and e-waste due to government restrictions
Comparing deep learning and support vector machines for autonomous waste sorting	To use SVM model to classify waste into plastic, paper and metal	Small amount of images is used in the training set
Automatic waste classification using computer vision as an application in Colombian high schools	Integrating computer vision into developing an application to classify waste automatically into the IEAB	The wrong classifications, the reduced waste and the images in the database indicate that this technique is not enough to carry out the classification in a system of the real scale
Municipal solid waste classification using microwave non-destructive testing technique	This paper presents basic researches of the variation of microwave signal propagation characterization to verify microwave is suitable for MSW classification	Resolution of microwave non-destructive detection of MSW is not always high enough and can be improved only by using stronger microwaves
Smart recycle bin: A conceptual approach of smart waste management with integrated web- based system	A smart recycle bin that caters for recycling glass, paper, aluminium cans and plastic products that automatically evaluate the value of the wastes thrown and accordingly provide 3R card	It is not a very energy-efficient process when the scale of the project is increased

83.3 Methodology

The proposed idea mainly concentrates on the classification and identification of the waste that is being dumped into the garbage. Usually, unsegregated waste is dumped in a landfill and they are made to decay which however takes thousands of years in the case of non-biodegradable waste. This project proposes an idea where a computer system on its own is able to identify the waste without any human intervention based on the material of the waste item, irrespective of its shape, colour and size, and classify them. The proposed system can learn by itself and hence can constantly update itself in case of new waste materials. The advantage of this proposed system is that it would include easy classification of solid wastes, decomposition of wastes, reduced health hazards and faster process that requires only a negligible initial investment for this to carry out. The block diagram of the proposed system is shown in Fig. 83.1.

83.3.1 Dataset Collection

Different types of wastes from the Internet are collected. To remove all the redundancies from those images, pre-processing will be done followed by training those datasets and finally developing a model and classifying the waste as biodegradable (textile, paper, glass, wood, waste, agricultural waste, food waste) and non-biodegradable (plastics, steel, metal cans).

The dataset collection process was done by capturing the waste images manually because there were no publicly available sites for datasets pertaining to waste materials. Initially the waste images collected from Google were used. However, these images do not accurately represent the kind of waste even after more research and progress on recycling wastes and the state of recycled waste goods. This is unlikely in recycled waste materials since they are treated as waste because they are unclean, improper, arbitrary shaped, crushed, etc. So the waste images were collected manually.

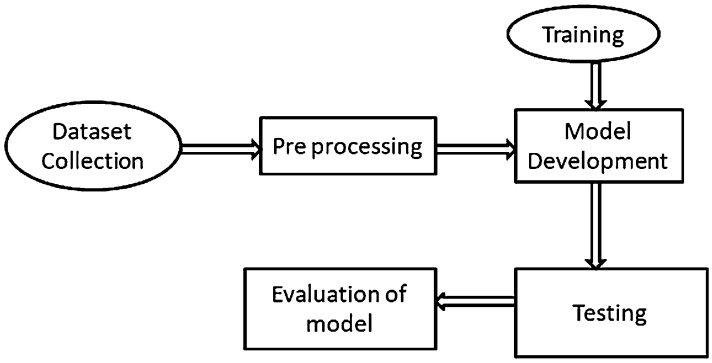

Fig. 83.1 Block diagram of the system

83.3.2 Processing Datasets

Few images of waste datasets are hand collected by us and the rest are taken from the Internet. The dataset contains images of solid waste objects across 7 classes with about 200–300 images in each type of waste, totalling about around 1100 images. The dataset collection process involved using a white paper as a background (even normal background is supported) and taking pictures of waste. The intensity of light and position for each image is not the same, which introduces variation in the dataset. Figure 83.2 shows example images of few classes of datasets. Various image transformation techniques were chosen to account for the different positions of recycled material which ultimately helps in increasing the quality of dataset.

Fig. 83.2 Types of wastes

83.3.3 Types of Wastes

The dataset contains seven classes that are mutually exclusive and the images are small, are clearly labelled and have no noise. The seven various types of wastes used are food waste, paper waste, plastic waste, metallic waste, wood waste, broken glasses, rubber and textiles. Some types of wastes are depicted in Fig. 83.2.

83.4 Implementation

83.4.1 Algorithm Used: Convolution Neural Network

A convolution neural network (ConvNet or CNN) is one of the most popular algorithms for deep learning, a type of machine learning where a model learns to perform the task of classification directly from text, images, videos or sound. CNNs are specifically useful for finding the patterns in images to detect and recognize objects, faces and poses.

83.4.2 Steps Involved

Step 1: Start
Step 2: The system is powered on. The OpenCV comes up on the screen. The waste image is shown in front of it.
Step 3: Camera takes pictures of the objects to be identified. The interest points in the images are marked by a rectangle.
Step 4: Training data is used to analyse images. Only the marked points of test image are analysed with the training data.
Step 5: Detection and localization of objects by boundary algorithm that finds out the features in the images that could identify the image easily.
Step 6: Object identification takes place. The image is identified using the Fast R-CNN algorithm.
Step 7: Prediction: The prediction of type of waste is based on the identification and a probability index studied.
Step 8: Arriving at output: The prediction with highest probability is regarded as the output.
Step 9: Classification of object: The object is then classified to the type of waste it belongs to.
Step 10: Stop.

83.4.3 Flow Chart (Fig. 83.3)

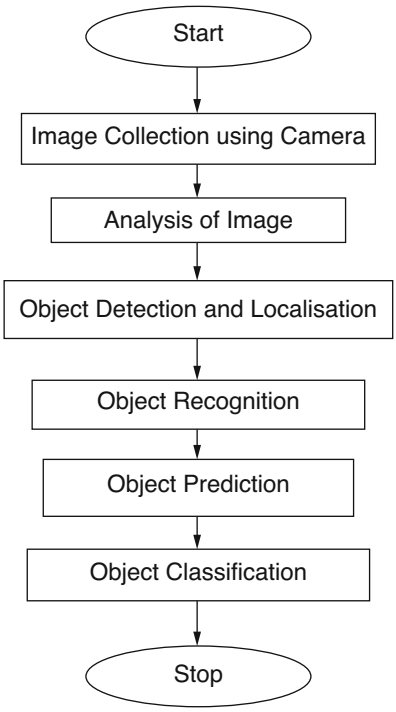

Fig. 83.3 Flow chart

83.4.4 Model Development

Training is the first step to be practised after the collection of dataset. A large number of inputs have to be given to train the network. Here for the purpose of recognizing images, train a layer of features that receive input from the pixels of the image. The edges present in the image are recognized using Edge detection algorithm. Next, object parts are identified from various image processing algorithms such as feature extraction by faster R-CNN, Finally, objects are identified.

83.5 Experimental Results

The developed system could identify all the types of wastes both when shown individually as in Fig. 83.4 and also when they are mixed up together as in Fig. 83.5.

Fig. 83.4 Glass identification

Fig. 83.5 Mixed waste identification

Table 83.2 Result analysis

S.no.	Type of waste	Accuracy
1	Glass	99
2	Wood	67
3	Paper	97
4	Textile	70
5	Metal	70
6	Plastics	97

Table 83.2 Accuracy obtained on showing various types of wastes to the system.

83.6 Conclusion

The proposed system for the management of wastes is more efficient and time saving than the currently employed method that the municipality employees perform. Though this system is simple in concept, it is very valuable and affordable. Hence to ensure being automated, a system which takes a huge dataset with lots of images as input without human intervention and also has the capacity to think by itself offers the best solution. It acts as an aid for reducing pollution levels and in the long run focuses on the development of a nation and restoration of our ecosystem. Thus this project holds value as an important asset to the society.

References

1. Abdel-Hamid O, Mohamed AR, Jiang H, Penn G (2012) Applying convolutional neural networks concepts to hybrid nn-hmm model for speech recognition. In: Proceedings of the IEEE international conference on acoustics, speech and signal processing (ICASSP), pp 4277–4280
2. Taigman Y, Yang M, Ranzato M, Wolf L (2014) Deepface: closing the gap to human-level performance in face verification. In: Proceedings of the IEEE conference on computer vision and pattern recognition, vol 4, pp 1701–1708
3. Ciresan D, Meier U, Schmidhuber J (2013) Multi-column deep neural networks for image classification. In: Proceedings of the IEEE international conference on computer vision and pattern recognition (CVPR), IEEE conference, vol 8, pp 3642–3649
4. Smola A, Vishwanathan SVN (2008) Introduction to machine learning, vol 1. Cambridge University Press, Cambridge, pp 16–25
5. Chandramohan A, Mendonca J (2014) Automated waste segregator. In: Texas instruments India educators' conference (TIIEC). IEEE, Bangalore
6. Desai Y, Dalvi A (2009) Waste segregation using machine learning. Int J Res Appl Sci Eng Technol (IJRASET) 6:5
7. Vipin Upadhyay JAS, Poonia MP (2012) Solid waste collection and segregation. Int J Eng Innov Technol (IJEIT) 1:3
8. Aronszajn N (1950) Theory of reproducing kernels. Trans Am Math Soc 68(3):337–404
9. Krizhevsky A, Sutskever I, Hinton GE (2012) Imagenet classification with deep convolutional neural networks. Adv Neural Inf Proces Syst 2:1097–1105