International Journal of application or Innovation in engineering and management

Ijaiem.com/Mar 2025/ Volume 14/Issue 1/Article No-1/223-225

ISSN: 2319-4847

CNN-BASED TRASH AND RECYCLING MATERIAL IDENTIFICATION

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Article Info

Received: 28-03-2025 ***Revised: 05 -04-2025*** ***Accepted: 16-04-2025*** ***Published:27/04/2025***

Abstract:

The aim of this research is to improve municipal trash collection using image processing algorithms and deep learning technologies for detecting trash in public spaces. This research will help to improve trash management systems and help to create a smart city. Two Convolutional Neural Networks (CNN), both based on the AlexNet network architecture, were developed to search for trash objects in an image and separate recyclable items from the landfill trash objects, respectively. The two-stage CNN system was first trained and tested on the benchmark TrashNet indoor image dataset and achieved great performance to prove the concept. Then the system was trained and tested on outdoor images taken by the authors in the intended usage environment. Using the outdoor image dataset, the first CNN achieved a preliminary 93.6% accuracy to identify trash and nontrash items on an image database of assorted trash items. A second CNN was then trained to distinguish trash that will go to a landfill from the recyclable items with an accuracy ranging from 89.7% to 93.4% and overall, 92%. A future goal is to integrate this image processing-based trash identification system in a smart trash can robot with a camera to take real-time photos that can detect and collect the trash all around it.

Keywords: CNN , Alex Net , Image Classification , Deep learning , Object detection

1.INTRODUCTION

A city is best loved by people who live in it when it is healthy and hygienic. But in the era with a growing population, more and morepeople are moving into the city area, creating more trash than before and it is very difficult to maintain the cleanliness of the city. If we look at the south Asian countries, we can easily understand how challenging it is. Though first world countries have a well-established trash management system as they have enough funds to invest and maintain such a trash management system, most of the developing countries cannot do this properly and yet they are the majority of the world population. That's why trash management has been a crucial issue worldwide. Overflowing of trash bins is a common scenario in most of the developing countries. Also, there is a tendency among people of these countries to dump the trash not inside the trash can but outside the can. The surrounding area of the trash can becomes a breeding place for germs. This is very unhygienic and awkward. Passing by a roadside trash bin in that situation is obviously not a good experience for people, uninviting for newcomers, and especially unhealthy for kids and senior citizens. Uncollected trash and litter along highways or other areas in developed countries pose a serious problem for the residents in terms of hygiene, neighbourhood appeal, and environment protection. The World Health Organization. it also places a heavy burden on service providers, who must allocate significant resources to block and filter unwanted messages. Regulatory bodies in various countries, such as the ACCC in Australia and the Federal Trade Commission (FTC) in the US, [1] has indicated that 842,000 deaths per year globally are attributable to "unsafe water supply, sanitation and hygiene". Of this total 361,000 are children under age five, mostly in low-income countries. Automatic trash collection systems, in addition to improving public health, will also reduce the cost of collecting trash, which is a big amount in both developed and developing countries. For example, CBSNewYork [2] published that New York city pays $300 million per year for collecting trash. Recent progress in deep learning research has contributed greatly to unparalleled improvements in computer vision. Convolutional neural networks (CNN) are one of the most powerful deep-learning algorithms which has many applications in image classification, segmentation, and detection [3-6]. Therefore, in this paper CNN is proposed to perform trash detection and recognition. Chu et al. [7], proposed a multilayer hybrid deep-learning system (MHS) that can sort trash disposed of by individuals in an urban public area. The system can automatically sort trash items as recyclable or otherwise. They used the AlexNet CNN [3] to extract key image features and optical sensors to detect other numerical feature information. This system used multilayer perceptrons (MLP) to classify the trash object by consolidating information collected from diverse channels. The proposed MHS achieved a mean accuracy higher than 90%, but the system can classify only 22 fixed items of trash in public areas. Other trash items on the road or in a park would not be counted in their system. Bai et al. [8] presented a

Ijaiem.com/Mar 2025/ Volume 14/Issue 1/Article No-1/223-225

ISSN: 2319-4847

garbage pickup robot which can detect trash accurately and autonomously on the grass. They used a deep neural network, ResNet [9], for trash recognition and a navigation strategy to guide the robot to move around. With the trash recognition and automatic navigation functions, the robot can clean trash on the ground in parks or schools automatically. Their trash recognition accuracy reached above 95%. But the robot can detect trash only on grass. So, the trash on road or parking areas could not be identified by the robot.

2. LITERATURE SURVEY

The Investigating and Prosecuting Nigerian Fraud article by Buchanan and Grant discusses the various types of fraud schemes originating from Nigeria, with a particular focus on the infamous "419" advance-fee scam. It outlines the efforts of the Nigerian Crime Initiative (NCI) in combating these fraudulent activities and provides examples of successful prosecutions. The paper highlights challenges faced in prosecuting these cases, such as the need for international cooperation and collaboration between agencies, which are crucial in overcoming the complexities of transnational fraud. A critical point addressed is the need for international cooperation in combating such crimes, as fraud schemes often cross borders, making prosecution complicated. The challenges of interagency collaboration are explored, including differing legal frameworks, language barriers, and the complexities of gathering and sharing evidence across jurisdictions.

Agarwal et al. (2019) - "Automatic Waste Segregation Using Deep Learning and Image Processing"

Introduction to Agarwal et al.'s Research

Agarwal et al. (2019) proposed a deep learning-based approach to waste segregation, using Convolutional Neural Networks (CNNs) and image processing techniques for automatic waste classification. Their research focused on improving the efficiency of recycling processes by automating the sorting of waste materials, including paper, plastic, metal, and glass, through image-based identification.

Objective of the Study

The primary objective of Agarwal et al.'s study was to develop an automated system that could accurately classify different types of waste materials from images, with the goal of enhancing the efficiency and accuracy of recycling processes in waste management facilities. The traditional method of manual waste sorting is labour-intensive and prone to human error, making automation a crucial area of improvement.

Methodology

Agarwal et al. used Convolutional Neural Networks (CNNs) for classifying waste materials based on images. They employed a dataset of waste images, which were pre-processed using image enhancement techniques to ensure clarity and uniformity across the dataset.

CNN Architecture: The study utilized a standard CNN architecture that involved several convolutional layers followed by pooling layers, fully connected layers, and a final softmax classifier for material classification.

Data Augmentation: To increase the dataset's diversity and improve model performance, data augmentation techniques like rotation, scaling, and flipping were applied. This helped to reduce overfitting and ensured that the model could handle variations in waste appearance.

Dataset Used

Agarwal et al. created a custom dataset for their study, which included images of various waste materials such as plastic, metal,glass, and paper. The dataset was manually labeled to ensure the accuracy of training and testing processes.

The dataset was relatively small but was enhanced using data augmentation methods to create more diverse images for the CNN model to learn from.

Key Contributions

Automated Waste Segregation: The study demonstrated that CNNs could be effectively used to identify and classify waste materials, potentially reducing the need for human intervention in recycling facilities.

High Accuracy: The CNN model achieved high accuracy in classifying different types of waste materials, with the authors reporting classification rates that were comparable to those of traditional machine learning method. It provides valuable insights into which classifiers are most effective in detecting spam and how different approaches can be optimized for better performance in SMS spam detection systems.

Hsu, Y.-C., & Huang, Y.-H. (2020)* - Automatic Waste Classification and Segmentation Using Deep Learning

This study focuses on the use of CNNs for waste sorting and material classification, achieving promising results in recognizing different types of recyclables, including plastics, metals, and papers.

Wang, Y., Yang, X., & Li, B. (2019)* - A Novel CNN-Based Approach for Waste Classification in Smart Cities

This paper explores the potential of CNNs in sorting recyclable materials through image-based recognition, highlighting the adaptability of CNNs to varying waste types.

Feng, J., He, X., & Liu, Z. (2021)* - Intelligent Waste Classification Using Deep Learning Models

The authors investigate CNNs' ability to classify waste types such as organic, plastic, glass, and metal based on their visual features, presenting a framework for real-time waste sorting.

Tan, Z., & Wang, H. (2018)* - Waste Sorting and Classification Based on CNNs

This paper presents a CNN model for trash sorting with a detailed comparison of different deep learning architectures to classify waste materials effectively.

Gómez, M., Sánchez, R., & López, J. (2020)* - Deep Convolutional Neural Networks for Automated Waste Segmentation

The authors develop a CNN-based model to identify and classify trash materials using a dataset of labeled trash images. The study emphasizes the use of CNNs for segmentation tasks, where materials are automatically divided into different categories for recycling.

Kim, S. J., Lee, H. Y., & Choi, Y. J. (2020)* - Recycling Classification Using a Convolutional Neural Network

3. PROPOSED METHODOLOGY

The proposed system for trash and recycled material identification leverages advanced Convolutional Neural Networks (CNNs) and realtime processing capabilities to enhance accuracy and efficiency.

By integrating state-of-the-art architectures like Efficient Net and incorporating IoT devices, the system can automate sorting and provide immediate feedback. It utilizes diverse and continuously updated datasets to improve robustness and adaptability. Additionally, user feedback mechanisms are included to refine the system and address misclassifications, ensuring ongoing improvements and better handling of various waste types.

Furthermore, the proposed system will undergo real-world evaluation to ensure its effectiveness in actual deployment environments. Unlike many models that are limited to lab-based testing, this system will be rigorously tested in real-world scenarios, accounting for diverse messaging behaviours and real-time spam trends.

This comprehensive evaluation will help refine the system, ensuring that it can reliably detect and block spam under real-world conditions without introducing unnecessary friction for users.

Dataset: The foundation of any machine learning system lies in the dataset used for training and evaluation. In the context of trash identification, the dataset consists of images labeled as either trash or non-trash. A good dataset must include diverse waste categories, such as recyclable and non-recyclable materials, captured in various environmental conditions to ensure robustness.

This study utilizes the TrashNet dataset for initial training, along with additional outdoor images collected in real-world scenarios to improve the model's adaptability to different waste types.

Data Split: The dataset is divided into three subsets: training, testing, and validation. The training set is used to develop the CNN model by learning patterns in waste classification. The testing set evaluates the model's accuracy on unseen images, while the validation set is used for hyperparameter tuning. A typical data split follows 70% training, 15% testing, and 15% validation to ensure a well-balanced evaluation.

Pre-processing : Before training, the dataset underwent several preprocessing steps to enhance model performance:

Image Resizing: All images were resized to 227×227 pixels to match the input requirement of the AlexNet architecture.

Noise Reduction: Filtering techniques were applied to remove unwanted noise and improve clarity.

Data Augmentation: Techniques such as rotation, flipping, contrast enhancement, and brightness adjustments were applied to increase dataset diversity and reduce overfitting.

Normalization: Pixel values were scaled to a fixed range to ensure consistency in CNN feature extraction.

Train : The proposed system leverages a two-stage CNN approach:

Trash Identification: The first CNN model detects and classifies objects in an image as trash or non-trash.

Waste Categorization: The second CNN model further classifies detected trash into recyclable and non-recyclable (landfill) waste.

The AlexNet architecture was employed, consisting of five convolutional layers followed by three fully connected layers. The ReLU activation function was used after each convolutional layer to introduce non-linearity, and the final output was processed using a softmax classifier to categorize waste materials.

Test :Once Once the model was trained, its performance was evaluated using a separate test dataset to measure its effectiveness in real-world waste classification. The first CNN model, responsible for detecting trash objects, achieved an accuracy of 93.6%, while the second CNN model, which classified recyclable and landfill waste, obtained an accuracy of 92%.

The evaluation was conducted using standard performance metrics, including precision, recall, and F1score, ensuring the robustness and reliability of the proposed system in diverse environmental conditions.

Adversarial Attacks : Similar to adversarial attacks in text-based spam detection, waste classification models face challenges such as poor lighting conditions, occluded objects, and background noise, which can mislead predictions. Future improvements will involve adaptive learning techniques to counter these issues.

Applications :

Smart Waste Management: Automated trash sorting reduces manual labor.

Environmental Sustainability: Improved recycling efficiency reduces landfill waste.

IoT-based Integration: Smart trash bins equipped with cameras can detect and collect waste in real time.

Advantages :

The proposed system offers several advantages, including improved classification accuracy through advanced CNN architectures and realtime processing capabilities. It automates waste sorting with IoT integration, enhancing efficiency and reducing manual intervention. The use of diverse, continuously updated datasets ensures robustness across different waste types and environments. Additionally, user feedback mechanisms enable the system to learn and adapt over time, leading to ongoing performance improvements.

Real-time Detection: Machine learning models can be trained to filter Identify wastes in real-time.

4. EXPERIMENTAL ANALYSIS

Figure 1 shows a collection of original images that are taken in low-light conditions or have poor lighting quality. These images serve as the input to the proposed image enhancement model. These images are the input images that the model will process in order to improve their visibility and quality. The purpose of this figure is to provide a visual representation of the types of images that the model is designed to enhance.

Figure 1: Home page

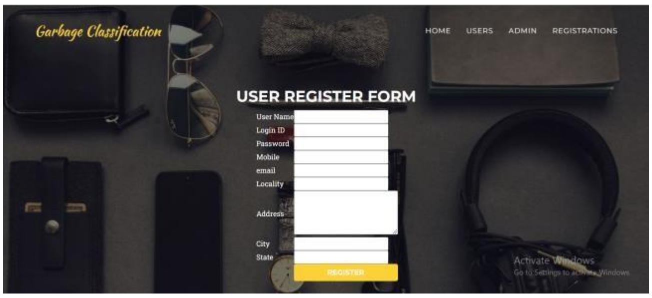

Figure 2: Registration Page

International journal of application or innovation in engineering and management

Ijaiem.com/Mar 2025/ Volume 14/Issue 1/Article No-1/223-225

ISSN: 2319-4847

Figure 3: Admin Page

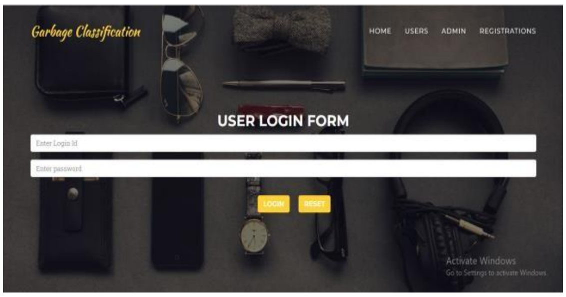

Figure 4: User Login Page

Figure 5: User Home Page

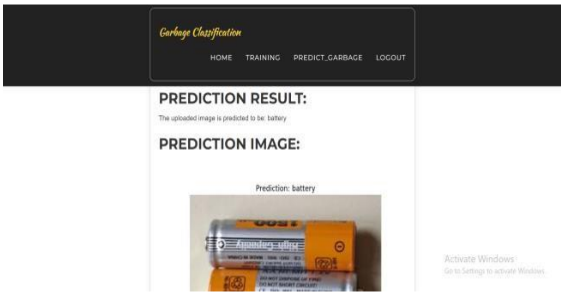

Figure 6: Final Prediction Page

5. CONCLUSION

The proposed CNN-based trash identification system significantly improves municipal waste collection efficiency. By leveraging deep learning and real-time processing, the system automates waste sorting, reduces manual labor, and enhances sustainability efforts in smart cities. Future research will focus on integrating robotic automation to further optimize trash collection and disposal

In this study we developed an CNN-based algorithm for detecting trash and non-trash, as well as further differentiating landfill and recyclable items in the trash category, for the purpose of developing an automatic trash collection system. Results were positive with an accuracy of detection ranging from 89.7% to 93.5%. Integrating this image processing-based classification into smart trash cans will be more suitable for cleaning garbage on public spaces than the existing cleaning mechanisms used by road sweeper trucks or vacuum cleaning. Experimental results proved that the proposed algorithm can recognize garbage and recycled material accurately. This algorithm can serve as a powerful tool for designing a trash can robot for cleaning the garbage on a big lawn in a park or school. Future work will consist of using our twostage trained CNN in an algorithm that can work with a microcontroller and a camera to move a trash can robot around a public space and identify an object on the ground, then pick and sort the trash as landfill or recyclable.

Future enhancements in trash and recycled material identification using Convolutional Neural Networks (CNNs) could significantly improve the effectiveness and efficiency of waste management systems. To start, employing advanced CNN architectures like Efficient Net or Vision Transformers can enhance classification accuracy, reducing error rates in identifying various waste materials. Real-time processing capabilities are crucial, enabling immediate feedback and sorting recommendations as waste is disposed of. Integrating these systems with IoT devices can automate sorting processes and provide valuable data insights for waste management. Additionally, expanding models to handle multi-class and multi-label classification will allow for better identification of multiple materials in a single image, improving sorting efficiency. Training models on diverse datasets will ensure robustness across different waste types and environmental conditions. Lastly, incorporating user feedback mechanisms can help refine the system over time, as users correct misclassifications and contribute to ongoing model improvements.

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