WASTE CLASSIFIER FOR SUSTAINABLE DEVELOPMENT WITH IMAGE RECOGNITION USING CONVOLUTIONAL NEURAL NETWORK

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Journal	Samvakti Journal of Research in Business Management https://www.samvaktijournals.com/sjrit e-ISSN : 2583-3979 Volume 6 Issue 1 (2025) Page No : 1 - 9
Discipline	Artificial intelligence and Machine Learning
Conference	**Innovating for a Circular Future: Strategies, Solutions and sustainability**
Conference Dates	Start Date: October 18, 2024 End Date : October 18, 2024
Institute Name	Royal School of Commerce, Federation of Industry & Commerce of North Eastern Region

Date Received	: February 22, 2025	**Publication Date**	: March 22, 2025
ID	: sjrit.2025.13	**Paper Type**	: Conference Paper

ABSTRACT

The "Computer Vision-based Waste Identifier" project seeks to transform traditional waste management practices by applying application of advanced technology. By leveraging image processing and machine learning algorithms, this project addresses the critical challenge of efficiently and accurately segregating recyclable and non-recyclable waste items. The system uses computer vision techniques to identify and classify waste materials, improving the precision of waste sorting and reducing human error. This innovation streamlines the recycling process and also contributes to environmental sustainability by enhancing the effectiveness of waste segregation, ultimately reducing landfill waste and promoting the recycling of valuable materials. This project opens the door to a cleaner and more effective future by realizing the promise for more intelligent and sustainable waste management techniques.

Keywords: Waste Classifier, Sustainable Waste Classifier, AI, ML, Computer Vision

INTRODUCTION

Waste management provides a pivotal role in the concept of sustainable development, particularly in mitigating environmental degradation through effective waste segregation and recycling. With the global surge in waste generation, there is an increasing demand for automated systems capable of efficiently classifying waste materials for recycling and disposal. Traditional methods of waste segregation, which depend on manual sorting, are both labour-intensive andsusceptible to human error, underscoring the need for more advanced technologies [1].

Convolutional Neural Networks (CNNs) have lately become a potent tool for automating trash sorting jobs, particularly because of their impressive visual recognition capabilities. CNN-based systems have demonstrated high accuracy in categorizing waste materials such as plastic, metal, glass, and paper, thereby reducing the need for manual intervention[2]. Indeed, studies reveal that CNN models could surpass more conventional machine learning algorithms like Random Forests and Support Vector Machines (SVMs) by achieving classification accuracies of over 90%[3].

These advancements in deep learning are driving improvements in waste segregation, contributing to sustainability by enhancing recycling efficiency and minimizing environmental impact. For instance, CNNs have been successfully applied to detect and classify waste in urban settings, proving their utility in large-scale waste management[4]. By incorporating deep learning-based systems into smart waste management infrastructures, real-time data on waste levels can be obtained, facilitating optimized resource allocation.

This paper proposes the implementation of a CNN-based waste classification system aimed at improving both the accuracy and efficiency of waste segregation processes. Through this approach, the system will support sustainable waste management practices and contribute to achieving global environmental objectives.

LITERATURE REVIEW

Numerous investigations are looking into the use of machine learning and deep learning techniques for trash classification automation, which is becoming an essential component for contemporary waste management systems. Within this field, Convolutional Neural Networks (CNNs) have stood out as the top approach for classifying waste through images, owing to their exceptional ability to identify and categorize visual data.

A notable study by Hulyalkar et al. (2018) developed a CNN-based waste classification model for SmartBin systems, which demonstrated high accuracy in classifying materials such as plastic, metal, glass, and paper. The system significantly reduced the need for manual sorting, highlighting the efficiency of CNNs in real-time waste classification [1]. Similarly, Khan et al. (2020) conducted a comparative analysis of machine learning algorithms, including SVMs, Random Forests, and CNNs, and found that CNNs achieved a classification accuracy of 90%, outperforming other models in recognizing different types of recyclable waste [2].

Deep learning techniques, particularly CNNs, have also been integrated with IoT-based systems for smart waste management. Majchrowska et al. (2022) implemented a CNN model to classify waste in urban environments, successfully detecting seven waste categories, including plastic, glass, and paper. This study demonstrated CNNs' adaptability to diverse environments, such as outdoor and underwater settings, though it noted challenges with detecting small objects like cigarette butts [3].

Further advancements have been made using transfer learning to enhance CNN-based waste classifiers. Poudel and Poudyal (2023) applied transfer learning techniques to identify if a waste commodity is biodegradable or not.

leveraging pre-trained models like VGG19 and InceptionV3. This method improved classification accuracy while requiring fewer labelled data, making it more suitable for real-world applications [4].

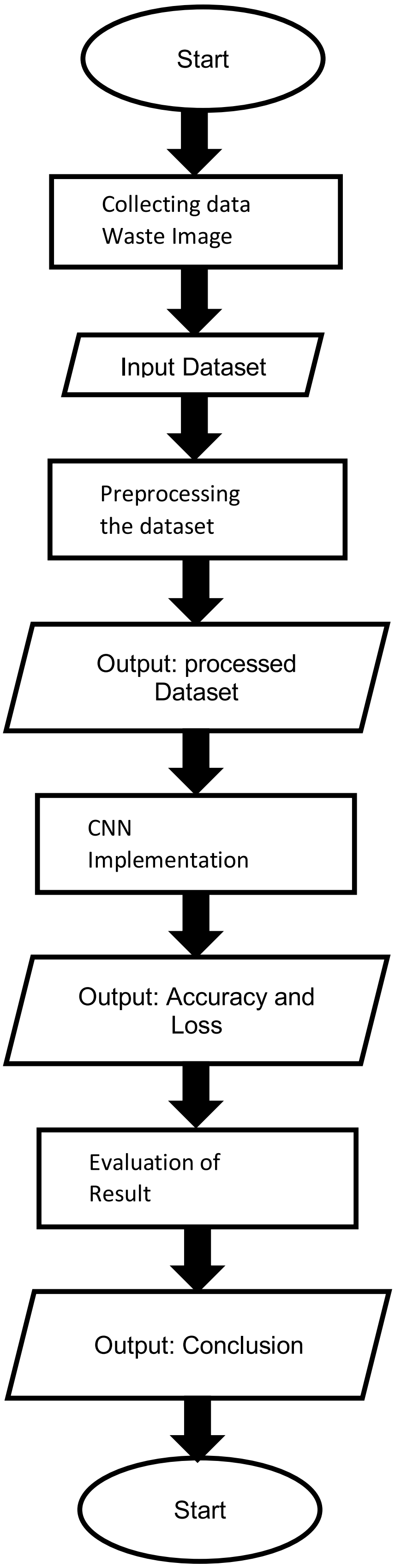
Moreover, Dookhee (2022) proposed a domestic waste classification system using CNNs, emphasizing the importance of real-time classification in household waste management. This study further validated CNNs' robustness in handling diverse waste categories in domestic settings [5].

Comparative studies, such as that by Sakr et al. (2016), have shown that CNNs not only outperform traditional algorithms but are also more scalable for complex classification tasks in waste management systems. Their study demonstrated that CNNs outperformed SVMs in autonomous waste sorting, solidifying CNNs as the preferred choice for such applications [6]. Additionally, Mittal et al. (2016) developed a mobile application, Spotgarbage, which utilized CNNs to detect and classify garbage using a smartphone camera, providing a practical solution for real-time waste management [7].

While the current literature emphasizes the effectiveness of CNNs in automating Classification regarding Waste, it also points to ongoing challenges, such as the need for larger, more diverse datasets and improved small-object detection. Addressing these limitations through techniques like advanced image processing and enhanced dataset collection will be essential for developing more robust and scalable waste management solutions in the future.

OBJECTIVES OF THE STUDY

- Increase the trash segregation's accuracy
- Minimize human mistake when sorting garbage
- Increase the effectiveness ofrecyclingtosupportenvironmental sustainability.
- Encourage improved recycling of valuable resources to reduce landfill waste.



Flow Chart 1: Working Models

RESEARCH METHODOLOGY

Although evaluating the classification model's accuracy objectively is the primary goal of the study, qualitative factors like the model's generalizability across various waste types and environmental conditions are also taken into account. To ensure a scrupulous assessment with regard to how well the model works, the evaluation method entails examining classification performance using statistical. The paper also highlights the noteworthiness of preprocessing methods and dataset quality, both of which are critical for improving model robustness and lowering bias. To improve the generalization capabilities of the model, a sizable dataset comprising a variety of waste types is used for training. Rotation, flipping, and brightness modulation are examples of data augmentation techniques that further increase the dataset's variety and enable the model to function successfully in real-world scenarios.

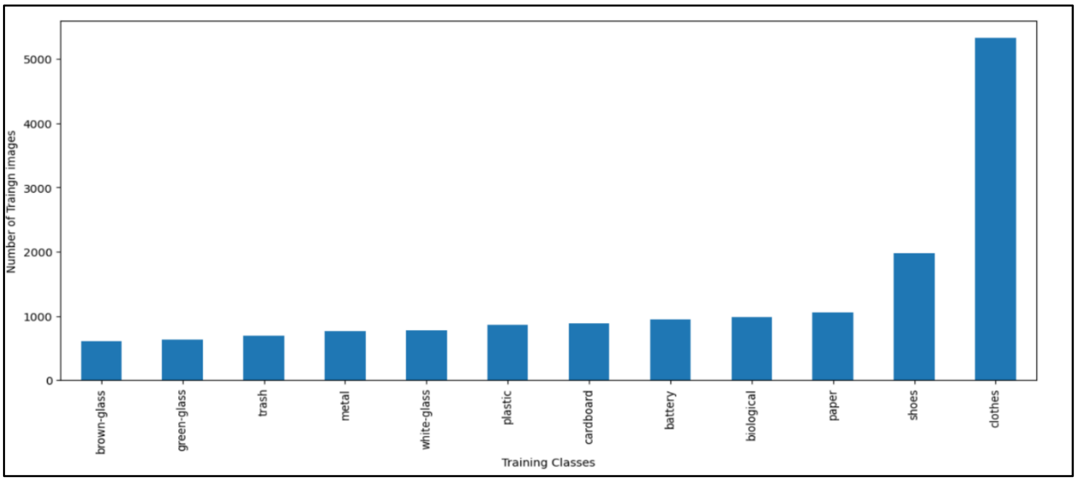
The study employs a systematic methodology that encompasses data gathering, preprocessing, training, assessing, and implementing the model. The study intends to create a scalable and effective trash classification system that can be incorporated into automated waste management solutions by utilizing Convolutional Neural Networks (CNNs). Each stage in the process is broken down in detail in the following sections, which also emphasize how important each step is to obtaining high- precision waste classification.

DISCUSSION/ANALYSIS

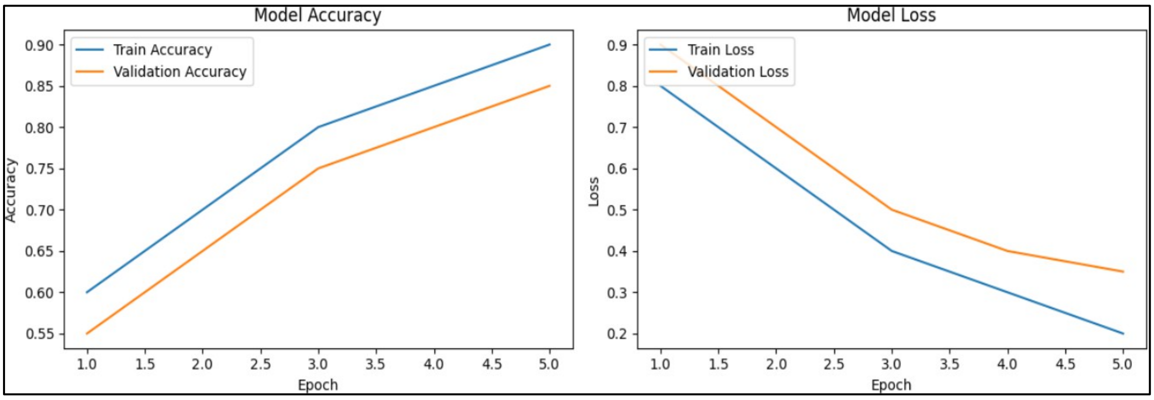
This model is trained to classify images of waste into 12 categories, including plastic, glass, paper, and metal, using a dataset of over 12,000 images. The system leverages data augmentation techniques to enhance training robustness. It also includes early stopping mechanisms to prevent overfitting

RESULTS

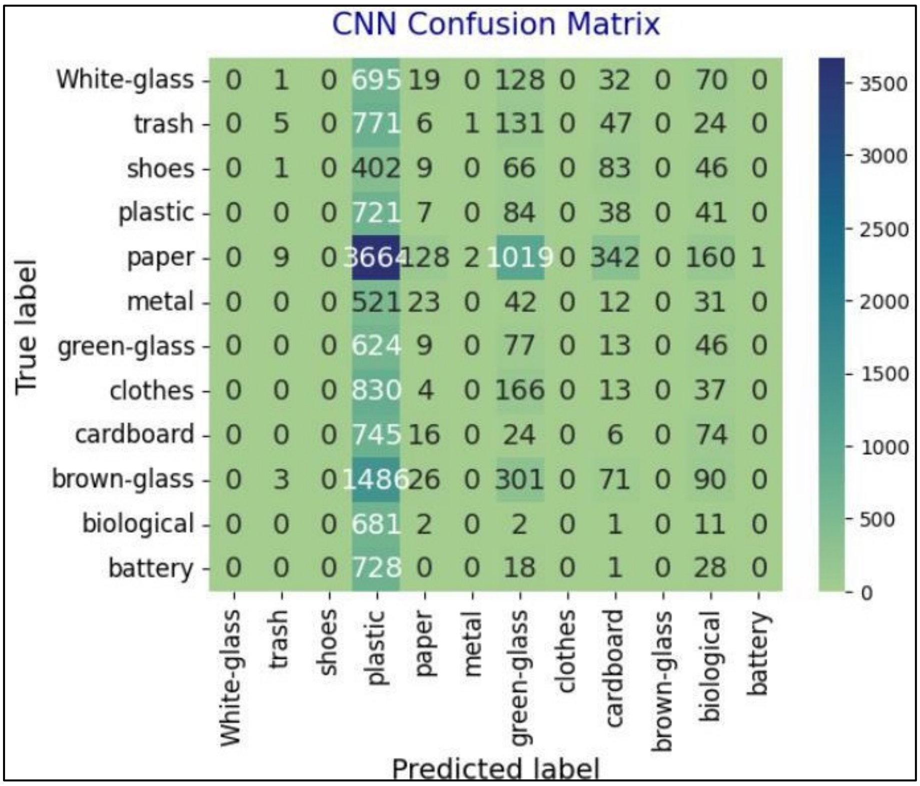
- A training accuracy of 78.5% after 36 epochs.
- A validation accuracy of approximately 76% with early stopping enabled to avoid overfitting.



Graph 1 : Dataset



Graph 2 : Model Accuracy and Model Loss



Graph 3 : CNN matrix

Figure 1: identification of the waste

The model's results demonstrate effective classification for the majority of waste categories, with potential improvements needed in classifying more ambiguous or overlapping categories like different types of glass or plastics.

CONCLUSION

Automated waste classification is a critical advancement in addressing the challenges of waste management, especially within the framework of sustainable development. Convolutional Neural Networks (CNNs) have proven to be an exceptionally efficient approach, offering superior accuracy in classifying various types of trash materials. The ability of CNNs to perform real-time classification with minimal human intervention makes them an ideal choice for large-scale waste management systems.

The incorporationof deep learning techniques, such as CNNs, with Internet of Things (IoT)-based infrastructures can significantly enhance the efficiency of waste segregation and recycling processes. This technology not only reduces human error but also optimizes resource allocation by providing real-time data on waste levels. Furthermore, the adoption of methods like transfer learning has shown promise in improving classification accuracy, even with limited labeled data.

Despite the notable advancements in CNN-based waste classification systems, there remain challenges, particularly in detecting smaller objects and handling diverse environments. Addressing these limitations through improved image processing techniques and more comprehensive datasets will be essential for further progress.

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