Content

Real-Time Waste Classification and Segregation Using CNN with A Automated Dustbin Lid Mechanism

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ABSTRACT
A practical method for sorting waste in real time has been created to encourage long-term waste management. Based on pictures it takes, the system uses a Convolutional Neural Network (CNN) to automatically sort waste into biodegradable and non-biodegradable categories. A webcam takes a picture of the trash, and the trained CNN model figures out what kind of trash it is. A microcontroller gets the classification result and turns on servo motors to open the lid of the right trash can, allowing for touch-free disposal. The method works well in homes, businesses, and public places because it is very accurate, quick to process, and flexible. It improves hygiene, helps recycling work better, and helps the environment by reducing the amount of waste that is thrown away. In the future, adding multi-sensor fusion could make it even more reliable to sort mixed waste materials.

KEYWORDS: Real-time waste segregation, Convolutional Neural Network (CNN), Smart waste management, Automation, Microcontroller, Image classification, Touch-free disposal, Biodegradable and non-biodegradable, Sustainable environment, Multi-sensor fusion.

INTRODUCTION
Waste management has become a critical concern due to the continuous rise in population and industrial growth. Improper segregation of waste at

the source leads to severe environmental and health issues, such as pollution, contamination, and inefficient recycling. Traditional waste handling methods often involve manual sorting, which is time-consuming, unhygienic, and prone to human error.

With advancements in Artificial Intelligence (AI) and computer vision, automated waste classification has become a promising alternative. Machine learning models, particularly Convolutional Neural Networks (CNNs), can effectively identify and classify objects based on visual features. By integrating deep learning with automation hardware, an intelligent system can be designed to classify waste and direct it to the correct bin without physical contact. Such automation not only promotes cleanliness but also supports sustainable and smart waste management practices in households, institutions, and industries.

LITERATURE REVIEW

Previous studies in waste segregation have primarily used sensor-based techniques such as infrared, ultrasonic, or metal detection to differentiate materials. These methods, while cost-effective, often fail to accurately classify complex or visually similar waste. Later approaches incorporated image processing and basic machine learning algorithms like Support Vector Machines (SVM) and Decision Trees, which required manual feature extraction and struggled under varied lighting or texture conditions.

Recent research demonstrates that Convolutional Neural Networks (CNNs) outperform traditional models by automatically learning image features from raw data. Several implementations have combined CNNs with embedded devices like Raspberry Pi and Arduino to enable low-cost, real-time waste classification. However, many of these systems rely on external sensors or mechanical components, which increase complexity. The present work focuses entirely on image-based recognition and database-driven automation using a microcontroller and servo motors for touch-free operation.

MATERIALS AND METHOD

The system is designed to perform real-time waste classification and segregation using computer vision and embedded control. The following table lists the materials used and the corresponding methods or functions performed by each component

Web Camera–Captures waste images in real time for analysis.
Python (TensorFlow,Keras,OpenCV)–Used for CNN model training and image processing.
Flask Web App–Displays classification result (biodegradable/non-biodegradable) in browser.
Database(MySQL/Firebase)–Stores image data, results, and timestamps.
Microcontroller(Arduino/NodeMCU)–Receives result signal and controls servo motors.
Servo Motors(2 Units)–Automatically open respective dustbins based on classification.
Laptop / PC–Main processing unit for model execution and communication.
Power Supply–Provides power to the microcontroller and motors.
Internet / Wi-Fi Module–Enables connection between the web app and microcontroller.

SYSTEM ARCHITECTURE

The architecture represents the operational flow of the intelligent waste segregation process. Captured images from the webcam are analyzed through a CNN model to determine the waste type. The classified output is stored in a database and transmitted to the microcontroller, which controls servo motors for automatic bin selection and disposal.

FUTURE WORKS

The proposed system can be further enhanced to improve efficiency, automation, and sustainability in the segregation and management of e-waste. Future developments can integrate advanced computer vision algorithms capable of detecting specific e-waste components such as circuit boards, cables, and metallic parts with higher accuracy. The camera module can be trained using an extended dataset, enabling the Convolutional Neural Network(CNN) to identify multiple waste categories beyond biodegradable and non-biodegradable classes. Once the type of waste is recognized, the trained model can send encoded signals to the microcontroller, which interprets and controls the servo motor to open the respective dustbin lid automatically. This enhancement eliminates manual intervention and ensures accurate sorting of multiple waste types, particularly electronic waste, in real time.

In addition, the system can incorporate Internet of Things(IoT) features for real-time monitoring and reporting. Each bin can be equipped with sensors and Wi-Fi modules that update fill levels, classification logs, and disposal patterns to a centralized cloud database such as Firebase or ThingSpeak. Authorities can monitor bin status remotely through a web dashboard or mobile application, improving waste collection efficiency and reducing manual labor. The integration of solar panels as a power source will make the system energy-efficient and self-sustaining, especially in outdoor or rural areas. The waste management process can be made smarter, safer, and easier to use with more improvements like predictive maintenance using machine learning, blockchain-based data transparency, and voice-assisted user interaction. The goal of all these improvements is to create a fully automated, smart, and environmentally friendly e-waste management system that fits with the vision of smart cities in the future.

ACKNOWLEDGEMENT
The authors would like to express their sincere gratitude to Mrs. Anitha, Assistant Professor, for her valuable guidance, continuous encouragement, and technical support throughout the completion of this work. Her insights and supervision were instrumental in achieving the objectives of this study. The authors also extend their appreciation to the Department of Artificial Intelligence and Machine Learning, Vels Institute of Science, Technology & Advanced Studies(VISTAS), for providing the necessary facilities and environment to carry out this research successfully.

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