International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Smart Waste Sorting System Using Ai

Janani T[1], Jenifer Barbara J[2], Swetha K[3], Shanmugapriya L R[4], Mrs C Janani[5]

[1,2,3,4]UG Scholars, [5]Assistant Professor, Department of Computer Science and Engineering,
[5]Avinashilingam Institute for Home Science and Higher Education for Women, School of Engineering, Coimbatore, India

Abstract

In today's world, efficient waste management is crucial for environmental sustainability. This project proposes an automated waste segregation system using deep learning, computer vision, and embedded systems to classify waste into biodegradable and non-biodegradable categories. A Convolutional Neural Network (CNN) model is trained using a dataset of biodegradable and non-biodegradable waste images. The model is deployed with Python and OpenCV to automatically classify waste in real-time. The system is integrated with an embedded hardware setup that includes a NodeMCU microcontroller, an LCD display, and two ultrasonic sensors to monitor waste bin levels. Classified waste is directed to the appropriate bin, and the system continuously checks the bin levels, providing real-time updates via the Blynk IoT platform. When the bins approach their capacity, notifications are sent to users to ensure timely waste disposal. This smart waste segregation system aims to enhance waste management efficiency by reducing human intervention and promoting the proper disposal of waste, contributing to a cleaner environment.

Keywords: Automated Waste Segregation, Deep Learning, Computer Vision, CNN, IoT, NodeMCU, OpenCV, Waste Classification, Ultrasonic Sensor, Blynk IoT, Smart Waste Management, Embedded System.

1. INTRODUCTION

Effective waste management has become increasingly crucial in today's environmentally aware society. A key element of waste management is the appropriate separation of waste into biodegradable and non-biodegradable categories. Biodegradable waste, which comprises items such as food scraps and paper, can naturally decompose, while non-biodegradable waste, like plastics and metals, presents long-term environmental risks. Incorrect segregation not only undermines recycling efforts but also results in excessive use of landfills and environmental contamination. The manual separation of waste is a labour-intensive and time-consuming task that frequently leads to misclassification, resulting in inefficiencies in waste management. The rising amount of waste in urban regions heightens the necessity for automated solutions to support this process.

This project tackles the issues of waste segregation by utilizing deep learning, computer vision, and embedded systems to create an automated waste classification and monitoring apparatus. A Convolutional Neural Network (CNN) is employed to identify waste as either biodegradable or non-biodegradable through image recognition. Additionally, the system features an embedded setup that includes a

NodeMCU microcontroller, ultrasonic sensors, and an LCD display to track waste levels in bins, providing real-time notifications via the Blynk IoT platform when bins are full. By merging artificial intelligence with IoT-enabled waste monitoring, this system intends to enhance the efficiency and precision of waste segregation, encourage recycling, and contribute to improved waste management practices.

2. TECHNIQUES

A. Computer Vision

Computer vision represents a domain of artificial intelligence (AI) that enables machines to perceive and analyze visual data in a manner akin to humans. It includes techniques for image processing, object detection, pattern recognition, and classification to extract valuable insights from images or videos. By utilizing algorithms and deep learning models, computer vision equips systems to recognize objects, detect anomalies, and enhance decision-making procedures.This technology is widely applied in areas such as facial recognition, autonomous vehicles, medical imaging, and industrial automation. In this project, computer vision supports the waste segregation system by identifying and classifying waste items according to their visual characteristics, thus promoting accurate and efficient sorting.

B. Convolutional Neural Network

A Convolutional Neural Network (CNN) is a deep learning model designed specifically for image recognition and classification tasks. It learns to identify features in images independently, which makes it particularly effective for computer vision applications such as object detection and facial recognition. A CNN consists of multiple layers, including convolutional layers that recognize important features, pooling layers that reduce the size of the image while preserving key information, and fully connected layers that handle classification of the input data. Activation functions like ReLU and SoftMax support the network's performance.

C. Internet of Things

The Internet of Things (IoT) plays a crucial role in enabling real-time monitoring and smart control within the automated waste segregation system. The Blynk platform is used to create a user-friendly interface through a mobile app or web dashboard, allowing users to remotely track the status of waste bins. Integrated with the NodeMCU microcontroller, the system uses Wi-Fi communication to send real-time data—such as bin fill levels—directly to the Blynk cloud. This connectivity ensures that users receive timely notifications when bins are nearly full, allowing for prompt waste collection and maintenance. By leveraging IoT and the Blynk platform, the system enhances operational efficiency, reduces manual supervision, and supports a more sustainable and responsive waste management process.

3. SYSTEM ANALYSIS

A. Existing System

The existing waste segregation systems primarily rely on manual sorting processes, where workers classify waste as it moves along conveyor belts. This method is often inefficient and slow, resulting in a high likelihood of human error, which can contaminate recyclable materials and increase costs. While some facilities have implemented basic automation, such as simple mechanical sorters, these systems still fall short of ensuring accurate classification and efficient waste processing. Additionally, they lack real-time monitoring and data analytics capabilities, making it difficult for waste management facilities to optimize their operations effectively.

B. Drawbacks of existing system

Waste sorting systems are crucial for managing waste, yet they have several disadvantages. A significant number depend on manual labor, resulting in a workforce-intensive process that raises operational expenses. Human error is a major concern, as incorrect classifications can contaminate recyclable items, diminishing efficiency. Furthermore, conventional sorting techniques tend to be slow, which restricts overall throughput and effectiveness. Another key issue is the absence of real-time monitoring, making it challenging to accurately assess waste levels and composition. This lack of advanced data analytics also obstructs informed decision-making, hindering the optimization of waste management approaches. Although automation can alleviate some of these challenges, it necessitates a considerable upfront investment, making it less attainable for all facilities.

C. Proposed System

The proposed waste sorting system combines deep learning, computer vision, and IoT technology to automate the separation of waste into biodegradable and non-biodegradable categories. By employing a Convolutional Neural Network (CNN) that has been trained on a varied dataset of waste images, the system effectively recognizes waste types in real time using a camera interface. It includes an embedded configuration with a NodeMCU microcontroller, which manages ultrasonic sensors for ongoing observation of bin fill levels and sends alerts through the Blynk IoT platform. An LCD screen offers immediate feedback on the results of waste classification, improving user engagement. This all-encompassing strategy not only simplifies the waste management process but also encourages sustainable practices by ensuring appropriate disposal and recycling.

4. FEASIBILITY STUDY

The technical issue usually raised during the feasibility stage of investigation includes the following:

- Does the necessary technology exist to do what is suggested?
- Does the proposed equipment have the technical capacity to hold the requirements to the use of the new system?
- Are there technical guarantees of accuracy, reliability, ease of access?

The automated waste segregation system is technically feasible, as it relies on existing and well-established technologies such as deep learning, computer vision, and embedded systems. Convolutional Neural Networks (CNNs) are widely used for image classification and have proven effective in waste recognition tasks. Python, OpenCV, and the Blynk IoT platform provide reliable frameworks for developing and deploying the system. The proposed equipment, including NodeMCU, ultrasonic sensors, and an LCD display, has the technical capacity to support real-time waste classification and bin level monitoring, ensuring smooth operation. Additionally, the system is designed to be scalable and upgradable, allowing for future improvements, such as enhanced AI models, better sensors, or integration with smart city waste management networks. The system also offers strong technical guarantees in terms of accuracy, reliability, and ease of access. The CNN model can be trained on diverse datasets to improve classification precision, while embedded components ensure stable performance. The IoT integration allows real-time monitoring and notifications, enhancing accessibility and user convenience. Overall, the system meets all necessary technical requirements and has the potential for future advancements, making it a viable solution for efficient waste management.

A. Operational Feasibility

Operational feasibility assesses whether the automated waste segregation system can function effectively in real-world conditions. The system is designed for easy deployment in various environments, such as homes, public spaces, and industries, requiring minimal human intervention. Its integration of deep learning and computer vision ensures accurate waste classification, while the use of NodeMCU, ultrasonic sensors, and the Blynk IoT platform enables real-time monitoring and notifications. The automated nature of the system reduces the need for manual sorting, improving efficiency and hygiene. Additionally, it requires minimal training for users and maintenance is straightforward, making it a practical and scalable solution for enhancing waste management.

B. Economic Feasibility

The Smart Waste Segregation system is a financially viable solution, as its benefits outweigh the initial investment. The primary costs involve purchasing hardware components like a microcontroller, sensors, an LCD display, and mechanical segregation mechanisms. However, these expenses are offset by reduced reliance on manual labor, leading to lower long-term operational costs. Additionally, the use of open-source platforms such as Python, OpenCV, and Blynk eliminates the need for costly software development. By improving waste sorting accuracy, the system enhances recycling efficiency, potentially generating revenue from recovered materials. Its scalable design allows for future upgrades without significant additional expenses, ensuring long-term sustainability. Moreover, as governments and organizations increasingly support smart waste management initiatives, funding opportunities or incentives may further improve affordability. Given its cost-effectiveness and long-term advantages, this system presents a practical investment in modern waste management solutions.

5. PROJECT DESCRIPTION

In recent years, the rapid increase in urban population and consumption patterns has led to a significant rise in municipal waste generation. Traditional manual waste segregation methods are inefficient, time-consuming, and often lead to incorrect sorting, thereby affecting the recycling process and contributing to environmental hazards. To address these challenges, an intelligent waste management system has been developed that utilizes Artificial Intelligence and Internet of Things (IoT) technologies to automate the classification and monitoring of waste. The system ensures accurate segregation of biodegradable and non-biodegradable waste, minimizes human intervention, and supports real-time bin monitoring through a connected mobile platform.

A. Image Collection and Classification

To train the AI model, a comprehensive dataset of waste images was compiled. Each image underwent pre-processing techniques including resizing, normalization, grayscale conversion, and augmentation. These steps ensured consistency in input quality and helped the model perform accurately under varying conditions.

B. Deep Learning Model Implementation

A Convolutional Neural Network (CNN) was designed and trained using TensorFlow. The model was optimized using the Adam optimizer with a learning rate of 0.001 and achieved a test accuracy of 95%. It efficiently classified waste items based on visual features such as texture, shape, and color.

C. Integrating the Control Signals Using Embedded

The trained model was integrated into a hardware setup consisting of a NodeMCU microcontroller, a Raspberry Pi camera module, and an LCD display. The microcontroller managed sensor inputs, processed image data, and displayed classification results in real time.

D. Detection of Waste Bin Levels Using Ultrasonic Sensors
An HC-SR04 ultrasonic sensor was used to measure the fill level of the waste bin. It continuously calculated the distance from the sensor to the waste surface and determined whether the bin was empty, partially filled, or full. This allowed for efficient tracking and reduced overflow risks.

E. Bin Level Notification using Blynk App
The system was connected to the Blynk IoT platform through the NodeMCU. When the bin approached its capacity, real-time alerts were sent to a mobile application using Wi-Fi and MQTT protocol. This ensured timely waste collection without the need for manual supervision.

F. F. Local Feedback System
An LCD module displayed immediate feedback on the classification result and bin fill status. This feature improved user experience and made the system more interactive and informative on-site.

G. G. Testing and Evaluation
The system was tested in various scenarios involving different types of waste and lighting conditions. Evaluation metrics such as accuracy, precision, recall, and F1-score confirmed the reliability of the CNN model and the efficiency of the monitoring setup.

H. H. Environmental Impact and Future Enhancements
By automating waste segregation, the system contributes to cleaner surroundings, better recycling practices, and reduced exposure to hazardous materials. Future upgrades may include robotic arms for mechanical sorting, advanced object detection models like YOLO, and conveyor belt integration for industrial scalability.

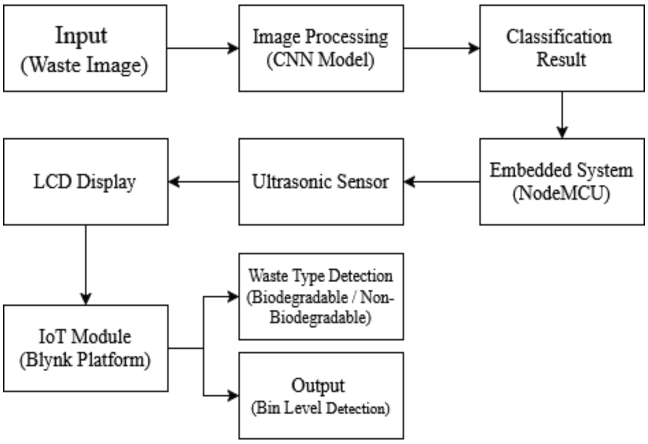

Fig 1. Block Diagram

6. CONCLUSION AND FUTUREWORK
The Smart Waste Segregator system developed in this project demonstrates an effective approach to automating the process of waste classification and real-time monitoring. By utilizing a Convolutional Neural Network (CNN), the system accurately distinguishes between biodegradable and non-biodegradable waste, achieving a high classification accuracy of 95%. The integration of IoT components, such as the NodeMCU, ultrasonic sensors, and the Blynk platform, allows for efficient tracking of bin fill levels and timely notifications to users, significantly reducing manual effort and the chances of bin overflow. This combination of AI and IoT offers a practical and scalable solution for improving waste management in residential, public, and industrial settings, contributing to cleaner and smarter environments.

To further enhance the functionality and efficiency of the Smart Waste Segregator, several advancements can be considered. The integration of an AI-powered robotic arm can enable autonomous physical sorting of waste items, reducing the need for human intervention entirely. Advanced object detection algorithms like YOLO (You Only Look Once) or Faster R-CNN could be implemented to increase the accuracy and speed of waste recognition across multiple categories, including recyclable materials. Additionally, incorporating a smart conveyor belt system would allow for continuous, large-scale segregation, making the system suitable for deployment in industrial or municipal waste processing units. These future developments would transform the current prototype into a fully automated, intelligent waste management solution adaptable to a wide range of real-world applications.

7. RESULT ANALYSIS

The AI-powered Smart Waste Segregator showcased commendable results in both waste identification and real-time monitoring functionalities. Its CNN-based classification model reached an impressive accuracy of 95% when tested on varied waste samples including plastic, paper, metal, and organic material. Essential pre-processing steps—like grayscale conversion and noise filtering—helped boost the model's precision and consistency. Evaluations using metrics such as precision, recall, and F1-score further reinforced the system's ability to deliver accurate classification across different conditions.

Beyond classification, the system's embedded IoT infrastructure effectively monitored bin levels using the HC-SR04 ultrasonic sensor. Real-time status updates were displayed via an LCD, while the NodeMCU microcontroller connected to the Blynk IoT platform ensured that timely alerts were pushed to users when the bin approached capacity. The lightweight MQTT protocol enabled smooth data transmission, making the solution practical for real-world waste management needs. Overall, the system's automation, accuracy, and smart monitoring capabilities point toward a scalable and sustainable approach to urban waste handling.

Metric	Value (%)
Accuracy	95.0
Precision	94.2
Recall	95.5
F1-Score	94.8

Table 1. Comparison Table

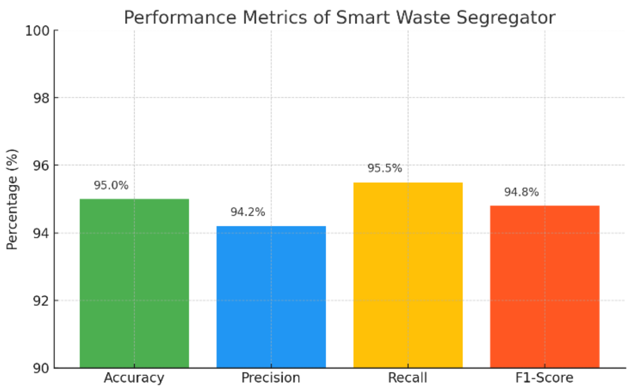

Fig 2. Comparison graph

REFERENCE

1. Ohtani, K.; Baba, M., “A Simple Identification Method for Object Shapes and Materials Using an Ultrasonic Sensor Array”, in Proceedings of the IEEE on Instrumentation and Measurement Technology Conference, IMTC, pp. 2138 - 2143, April 2006, 24-27.
2. M. O. Rahman, A. Hussain, E. Scavino, H. Basri and M. A. Hannan, "Intelligent computer vision system for segregating recyclable waste papers," Expert Systems with Applications, vol. 38, no. 8, pp. 10398- 10407, 2011.
3. Suwon Shin, Kaiyuan Fan, “Smart Automatic Recycling Trash Basket”, 2012.
4. Jiu Huang, Pretz, T., Zhengfu Bian, “Intelligent solid waste processing using optical sensor-based sorting technology”, in: Proceedings of 3rd IEEE International Conference on Image and Signal Processing (CISP), Vol.4, pp.1657-1661, October 2013, 16-18.
5. Yann Glouche, Paul Couderc, “A Smart Waste Management with Self-Describing Objects”, in Proceedings of Leister, Wolfgang and Jeung, Hoyoung and Koskelainen, Petri. The Second International Conference on Smart Systems, Devices and Technologies (SMART'13), June 2013, Rome, Italy. 2013.
6. Madan Kumar, L., Pavan, B., Kalyan, P.V. Paul, N.S., “Design of an embedded based control system for efficient sorting of waste plastics using Near Infrared Spectroscopy”, in: Proceedings of IEEE International Conference on Electronics, Computing and Communication Technologies (IEEE CONNECT), January 2014, pp. 1-6
7. T. J. Lukk, T. Tossavainen, J. V. Kujala and T. Raiko, "ZenRobotics Recycler-Robotic sorting using machine learning," Proceedings of the International Conference on Sensor-Based Sorting (SBS), 2014.
8. S. Sudha, M. Vidhyalaskhmi, K. Pavithra, K. Sangeetha and V. Swathi, "An automatic classification method for environment: Friendly waste segregation using deep learning," IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), pp. 65-70, 2016.
9. N. Sivakumar, A. R. Kunwar, S. Patel, S. Kumar, and S. P. Mala, "Design and development of an automatic clustered, assorted trash segregation system," IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), pp. 409-413, 2016.
10. A. Shaukat, Y. Gao, J. A. Kuo, B. A. Bowen, and P. E. Mort, "Visual classification of waste material for nuclear decommissioning," Robotics and Autonomous Systems, vol. 75, pp. 365-378, 2016.