EcoSort-Waste Segregation using ML and IOT

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Abstract - With the increase in the generation of waste, the maintenance and segregation of waste has become a tough and demanding job. Hence, various innovative and effective solutions need to be designed to deal with the environmental impact caused due to inappropriate waste disposal. The research paper "EcoSort -Waste Segregation using ML and IOT" presents a method for addressing the wastemanagement problem that combines Machine learning (ML) and Internet of Things (IOT) algorithms. Various deep learning models are trained on an image dataset to classify the images into their correct waste categories. The system also comprises smart bins wherein the sensors are used to efficiently segregate the waste into its respective category. The project offers an achievable solution to deal with the significant issue of handlingand disposing of garbage.

Index Terms - Waste Segregation, Machine Learning (ML), Deep Learning, Internet of Things (IoT).

I. INTRODUCTION

Urban waste management systems are facing challenges as a result of the population's rapid increase and the huge amount of waste it produces. Considering the cost and inefficient the current waste management system is, resourcewaste can be successfully utilized by combining the Internetof Things (IoT) with Deep Learning models.With the increasing rate at which resources are being consumed and the severity of environmental issues that are becoming more severe, it is essential that trash be identified and treated appropriately (e.g., composting, incineration, landfilling, recycling, etc.) for the various types of garbage. Classifying residential garbage is the responsibility of the residents under the traditional municipal waste management system. Relying solely on public awareness campaigns and publicity to guarantee proper garbage categorization at the source is challenging. The municipal solid waste management (MSW) system as a whole can become worthless if citizens do not sort their waste in accordance with the source sorting plan. Moreover, the most common traditional waste treatment techniques, such as incineration and landfilling, are increasingly expensive and energy inefficient.

Waste recycling is one of the techniques to reduce the impact on the environment and reduce the generation of waste. However, due to the ignorance of users and incorrect categorization of waste, this strategy does not yield favorableresults.IoT is the latest technology that is being developed to connect many things that will communicate with each other using sensors, embedded technology and wireless technology.[1] Wireless technologies can be wireless fixed networks or cellular. Our lives and habits are now simple andautomatic, thanks to Machine learning. It is a technology thathas advanced and had a significant impact alongside IoT. Computers or machines can learn supervised and unsupervised lessons from labeled or unlabeled data using machine learning. Some models and algorithms used in machine learning predict scientific research. With itsremarkable computational capabilities, the machine learningmovement has reached its peak.[2]. IoT combined with machine learning algorithms offers efficient waste management system results. These are the primary machine learning techniques that the waste management system depends on. These include decision trees, logistic regression, support vector machines, and linearregression. Garbage prediction and collection both use the above methods. [3]

II. RELATED WORK

A deep learning model was employed to create an innovative waste management system aimed at enhancing waste sorting and enabling real-time tracking of bin status within an Internet of Things (IoT) ecosystem. The primary objective was to develop a waste management solution harnessing deep learning techniques to optimize waste sorting while simultaneously providing the ability to monitor bin conditions in an IoT environment. For the task of waste classification and categorization, the SSD MobileNetV2 Quantized model was employed, which was trained on a diverse dataset encompassing paper, cardboard, glass, metal, and plastic waste materials. Utilizing this trained model, in conjunction with TensorFlow Lite and a Raspberry Pi 4, the camera module is employed to identify waste items accurately. Subsequently, a servo motor, affixed to a plastic board, facilitates the precise sorting of the identified waste into their respective designated trash bins [4].

TensorFlow Lite takes precedence over standard TensorFlow when utilized on resource-constrained mobile platforms. This preference is grounded in the fact that conventional TensorFlow models are typically designed with the expectation of a robust GPU for efficient object detection. However, the high-performance GPU requirement is incongruent with the specific demands of the smart bin project. TensorFlow Lite emerges as the optimal solution for enabling the deployment of object detection models on low- power mobile devices like the Raspberry Pi. In the TensorFlow repository, several pre-trained detection models, based on the COCO dataset, are readily accessible, offering a range of choices. Upon conducting a thorough assessment, the chosen object detection model is SSD MobileNetV2 Quantized 300×300, a model that has been trained using COCO data and seamlessly integrated into TensorFlow. This model, exemplifying the Single Shot MultiBox Detector (SSD) architecture, is purpose-built for real-time object detection, showcasing substantial enhancements in performance while concurrently reducing CPU resource utilization [5].

A K-nearest neighbors (KNN) based application was developed for residential waste management, leveraging the capabilities of both IoT and machine learning. This application is designed to process various combinations of data from three sensors, specifically measuring the levels of biodegradable and non-biodegradable waste, along with toxic gas concentrations. To trigger an alert, a KNN machine learning algorithm is employed, which assesses the sensor data and generates an alarm message as appropriate [6]. This model carries substantial real-world implications for promoting environmental sustainability by facilitating the recycling and reutilization of household waste. This, in turn, contributes to the advancement of eco-conscious and technologically progressive businesses. As per the proposed framework, the front IR sensor of the intelligent trash can detects the user's proximity, enabling automated opening and closing of the lid through actuators. Inside the lid, there are two ultrasonic sensors diligently monitoring the fill levels in both the biodegradable and non-biodegradable bins located on level 1. These sensors calculate object distances by measuring the time it takes for sound waves to travel to the object and return to the sensor (T), factoring in the speed of sound (C) in the following formula:

"Distance = 1/2 * T * C (1)"

To detect hazardous gases like methane within the biodegradable compartment on Level 1, an MQ-4 gas sensor is effectively deployed. The monitoring of non-biodegradable waste segregation is achieved through the utilization of inductive proximity sensors and capacitive proximity sensors positioned beneath the Level 2 conveyor belt. The inductive proximity sensor identifies metal objects without physical contact, while the capacitive proximity sensor is adept at detecting plastic and wooden items. The Raspberry Pi serves as the central hub for collecting data from these diverse sensors. This data is then transmitted over Wi-Fi to the Adafruit IO web service. The Adafruit IO web service, in turn, establishes connections with the IFTTT (If This Then That) service and Facebook Messenger to execute predefined actions and convey messages as necessary. Comprehensive data tracking at different stages is accessible through mobile devices and the Adafruit IO graphical user interface (GUI). Adafruit.io, functioning as a cloud-based service, serves a dual purpose: storing and retrieving data and acting as a bridge between various web services, thus enhancing the utility of the data. Its dashboard functionality offers the capacity for data visualization, while Messenger is employed for dispatching alerts to the facility supervisor when the need arises.

The dataset comprises 100 samples categorized under the class 'Decision,' with possible values {'bleveli', 'nbleveli', 'pleveli'}. Among these 100 samples, 70 are allocated for training, while the remaining 30 are designated for testing purposes. To predict 'decisions,' the K-nearest neighbors (KNN) classifier is applied directly to the training dataset. Predictions for a new instance denoted as A{'bleveli', 'nbleveli', 'pgleveli'} involve searching the entire training set for the K most similar instances (neighbors) and aggregating the output variable for these K instances. In this comparative analysis, the focus is solely on the "n_neighbors" or "K" parameter. The KNN model demonstrates an overall accuracy of 93.3% when K is set to 3, 4, and 6. The resultant biocomposts derived from waste at the community level can serve multiple purposes, including maintaining the company's green spaces and generating revenue through compost sales.

III. ABOUT THE SYSTEM

A. System Design:

IOT Device Layer: This layer consists of IoT devices like Arduino Uno or Raspberry Pi deployed at waste collection points or bins. These devices collect data from the waste. The devices include cameras for capturing images of waste and environmental sensors (e.g., temperature, humidity) to gather contextual data. Data Processing Layer: The data gathered by Internet of Things devices is handled by the data processing layer. This layer is used to clean, format, and structure the raw data from IoT devices. This may include resizing and normalizing images, filtering out noise, and handling missing data. Machine Learning Layer: This layer implements the Machine Learning model required for waste segregation. In our project, a CNN based model using OpenCV is deployed, which is capable of classifying waste based on input data. Actuators and Sorting Mechanism: This layer consists of LED's which is used to indicate the particular bin in which the person has to put in waste according to the type classified by the above layers. [6]

B. Use of Machine Learning:

This project uses Convolution Neural Network (CNN) and OpenCV as a part of Machine Learning. The system capturesimages of waste items through IoT-enabled cameras, and OpenCV is employed for preprocessing tasks, including image resizing and noise reduction. A CNN model is trainedto classify waste items into distinct categories, enhancing theefficiency of waste segregation. Real-time inference by the CNN model guides the actuation of sorting mechanisms, efficiently segregating waste items into their respective categories.[2] This approach offers the advantage of automation, accuracy, and adaptability. Additionally, the system is designed for continuous learning, allowing themodel to improve its performance over time through feedback loops and additional training data. This integrated approach showcases a promising method for accurate and automated waste segregation, contributing to sustainable waste management practices. [7]

C. Use of Internet of Things:

In this project, we use two IoT platforms, Raspberry Pi and NodeMCU, to advance waste segregation practices. These IoT devices serve as essential components for data acquisition and transmission in our waste management system. Outfitted with various sensors, including cameras, weight sensors, and environmental sensors, Raspberry Pi andNodeMCU enable real-time data collection, encompassing critical waste item attributes such as type, weight, and environmental conditions. [8]. Raspberry Pi and NodeMCU function as pivotal data hubs, seamlessly relaying this information to the central system. This data forms the foundation of our machine learningalgorithms, which make data-driven decisions concerning waste categorization. The versatility and cost-effectiveness of these IoT platforms render them adaptable for integration into existing waste collection infrastructures, thereby fostering more streamlined and sustainable waste segregation procedures.

D. System Integration:

This research paper focuses on the seamless integration of Machine Learning, employing CNN and OpenCV, with Internet of Things devices, specifically Raspberry Pi and NodeMCU to revolutionize waste segregation practices. This integration is at the core of our waste management system, merging the strengths of advanced data analytics with real- time sensor data acquisition. The IoT devices, Raspberry Pi and NodeMCU, function as the sensory nervous system of the system. They capture critical data, including images of waste items, weight measurements, and environmental parameters, providing a holistic understanding of the waste disposal environment. This data is then pre-processed using OpenCV, optimizing it for ML analysis.

The ML component, powered by CNN, is responsible for classifying waste items into distinct categories based on their visual features. This real-time classification forms the foundation for subsequent actions, ensuring efficient waste segregation. The integrated system offers not only accuracy and automation but also adaptability, as the IoT devices can be seamlessly incorporated into existing waste management infrastructure. Our project highlights the significance of this ML-IoT fusion in waste segregation, demonstrating its potential to enhance waste management processes, increase recycling rates, and promote environmental sustainability. The successful integration of ML with IoT represents a paradigm shift in waste segregation methodologies, underscoring the importance of data-driven, technology-driven solutions in addressing contemporary environmental challenges. [9]

IV. METHODOLOGY

The waste sorting method used in this research highlights thelinked advantages of Machine Learning (ML) and the Internetof Things (IoT). IoT devices, namely Raspberry Pi and NodeMCU, are strategically placed at waste collection sites,equipped with cameras and sensors to capture comprehensive data about waste items. This data encompasses visual attributes, weight measurements, and environmental conditions, forming the foundational dataset for our waste segregation system. Subsequently, data preprocessing is conducted utilizing OpenCV to ensure consistent and high- quality input for ML analysis. The following phase involves meticulously training a Convolutional Neural Network (CNN) model with a labelled image dataset so that it can identify and classify waste products with the highest level ofaccuracy and precision. The model which is trained is deployed onto IoT devices to facilitate real-time inference, thus allowing swift and precise decision-making. An intelligent decision logic system processes the CNN's predictions, leading to actionable outcomes such as the automated sorting of waste into their respective bins. Moreover, the system's adaptability and continuous learning capabilities are ensured through feedback loops and periodic model retraining, thereby enhancing the sustainability ofwaste segregation practices.

This research methodology represents an innovative and comprehensive approach to waste segregation, addressingcritical challenges in waste management. The fusion of IoT'sdata gathering capabilities with ML's pattern recognitionprowess not only automates the segregation process but also elevates its precision and adaptability. The incorporation of edge computing within IoT devices ensures rapid responses to waste categorization, contributing to real-time decision- making. The system's ability to continuously learn and adapt signifies an ongoing commitment to refining its performance,reducing misclassifications, and ultimately advancing theefficiency of waste segregation. This methodology stands as a transformative solution, offering practical, data-driven strategies for efficient and sustainable waste segregation—a pivotal contribution to contemporary environmental and sustainability imperatives.

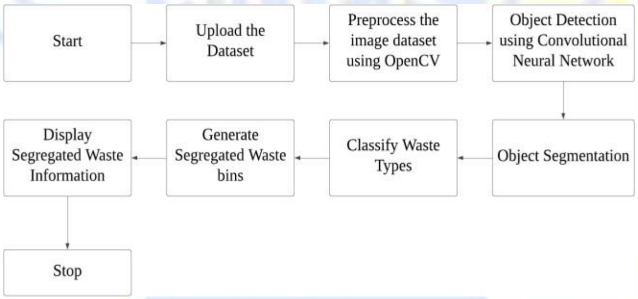

Figure 1- Machine Learning Flowchart

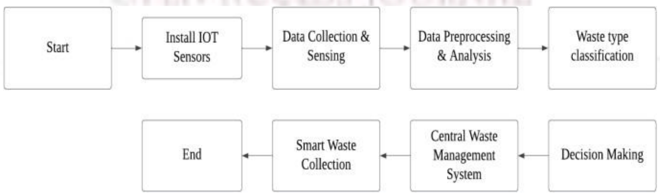

Figure 2- IOT Flowchart

V. FUTURE SCOPE

The proposed waste management system, integrating machine learning (ML) and Internet of Things (IoT), presents a foundation for promising future developments. Firstly, the system exhibits scalability potential, enabling its deployment in larger urban areas and an increased number of waste collection points. This scalability aligns with the vision of smart cities, offering a comprehensive waste management solution at an urban scale. Future research could focus on enhancing the ML models employed in waste classification, exploring more advanced deep learning architectures or ensemble methods to further elevate accuracy and efficiency. Additionally, the incorporation of real-time monitoring through IoT devices opens avenues for predictive analytics, optimizing waste collection routes, and proactively addressing logistical challenges. The development of a user- friendly mobile application could foster user engagement and education, providing real-time feedback to encourage better adherence to waste segregation practices. Collaboration with companies developing smart bins with built-in sensors offers the potential to automate waste segregation further. Exploring the integration of blockchain technology for transparent waste tracking could enhance accountability in the waste disposal process. Despite these future prospects, it is crucial to address limitations such as data quality, cost, user compliance, security concerns, maintenance, and regulatory considerations to ensure the success and ethical implementation of such advanced waste management systems.

VI. LIMITATIONS

The proposed waste management system integrating machine learning (ML) and the Internet of Things (IoT) exhibits considerable promise, yet several limitations must be considered for its successful implementation. Firstly, the efficacy of the ML model heavily relies on the quality and diversity of the training data. Inadequate representation or lack of diversity in the dataset may hinder the model's ability to generalize to real-world waste scenarios, particularly with less common items. The implementation costs associated with deploying IoT devices, including cameras and sensors, may pose a significant financial challenge, potentially limiting widespread adoption, especially in economically constrained regions. User compliance is a critical factor, and ensuring consistent adherence to proper waste disposal practices may prove challenging, requiring extensive public awareness campaigns. Security concerns related to unauthorized access and potential cyber threats must be addressed to safeguard the integrity of waste data and the proper functioning of the system. Ongoing maintenance of IoT devices is essential for sustained operation, but it may lead to operational disruptions if neglected. Compliance with local regulations and waste disposal policies is crucial and may involve time-consuming approval processes. Technical challenges, such as interoperability issues and system integration complexities, need to be overcome for successful deployment. Ethical considerations, including data privacy and responsible technology use, should be prioritized to gain public acceptance. Scalability to larger urban areas may present challenges related to managing an extensive network of IoT devices and increased data processing demands. Finally, integrating the proposed system with existing waste management infrastructure may require modifications and adaptations, necessitating careful consideration of compatibility issues and potential resistance to change from established practices. Acknowledging and addressing these limitations is imperative to enhance the practicality, effectiveness, and social acceptance of the waste management solution.

VII. CONCLUSION

In conclusion, the proposed waste management system offers a progressive solution to the problems arising from garbage collection, classification and management. The system classifies recyclable waste into different categories and achieves high accuracy in waste classification at the point of garbage collection by utilizing deep learning-based classifiers and IOT approaches. The utilization of state-of- the-art convolution neural networks (CNN), particularly MobileNetV3, demonstrates impressive classification accuracy, compact storage size, and efficient processing times. An efficient municipal waste management solution must also include the integration of Internet of Things (IoT) devices for real-time monitoring, which improves the system's capacity to optimize equipment deployment, maintenance and garbage collection . Overall, this innovative system showcases the potential to reduce costs and enhance the efficiency of waste management processes, offering a promising model for future implementations in urban areas.

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