IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 7, May 2024

Camera Vision Based Trash Classification and Detection System using Deep Learning

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Abstract*: Trash generally refers to discarded or waste materials that are no longer considered useful or valuable. It encompasses various items and substances that individuals or organizations dispose of, typically with the intention of discarding or recycling them. The term trash is often used interchangeably with terms like garbage, waste or rubbish. Improperly managed waste contributes to environmental issues, including pollution and the release of harmful substances, impacting ecosystems and public health. Existing waste management faces challenges in sorting and disposal practices, leading to inefficiencies in the overall process. The increasing volume of waste in urban areas poses a growing challenge, demanding innovative solutions to handle the scale and complexity of modern waste streams. In response to these challenges, the Trash AI project leverages advanced technologies such as Convolutional Neural Networks (CNNs) and Temporal Convolutional Networks (TCNs) to introduce a smarter and more efficient waste management system. These technologies provide the foundation for accurate trash classification, real-time detection, and intelligent waste segregation. The goal is to revolutionize waste management, automating and optimizing processes for accurate trash classification, real-time detection, and intelligent waste segregation. Through the development of a Municipality Web App, Trash AI centralizes monitoring and decision-making, facilitating a more sustainable and efficient approach to waste management. This initiative is poised to transform urban waste handling, promoting environmental consciousness and sustainable practices for smarter, cleaner cities*.

Keywords: TCN: Temporal Convolutional Networks, CNN: Convolutional Neural Network.

I. INTRODUCTION

In a recent study, the World Bank estimated that the amount of trash made around the world every year is 2.01 B tonnes. Because of how quickly the population is growing, it is expected to grow by 70% and reach nearly 3.40 billion tonnes by2050 [1]. These figures have a big effect on how society's work. The more trash we generate, the more diseases we spread. The main problem for both developed and developing countries is how to deal with waste. The World Health Organization (WHO) says that improper waste management causes deadly diseases like respiratory tract infections, carbon monoxide poisoning, nausea, diarrhea, malaria, dengue, and tuberculosis. Also, improper disposal of hazardous electronic and medical waste can cause lung and skin infections, HIV/AIDS, and the Hepatitis B and C viruses. The WHO says that dirty air is "the new tobacco" and a "silent public health emergency. "Proper waste management is essential for garbage collection, disposal, and recycling/reusing [2].In the past, lack of waste management led to inefficient garbage collection, bins that overflowed, a lack of information, low rates of recycling, and a lot of gas, insects, and houseflies. In this age of new technologies, we need Smart (automation) Waste Management, which is cloud-based software that links fleets, bins, customers, and central management [3].The goal of smart waste management is to improve waste management, and fleet management, increase efficiency, lower labor costs/use fewer people (by only going to bins that are empty), Increased transparency, and make streets cleaner. With smart IoT-based hardware and a cloud-based software solution, smart cities can also cut waste collection costs by up to 50% [3].Using SWM, the city's managers can keep track of bins, keep an eye on how full they are and how full they have beenin the past, check the battery levels, optimize collection routesbased on collection history, geographic locations, responsetimes, fire events, the status of bins that are overflowing, and other factors. With an algorithm for machine learning, we can predict the analysis as we gather data. Also, the machine learning algorithm will learn from the patterns of waste production to see what will happen up to 24 hours from now. This lets the collection routes be optimized and makes more efficient routes than using real-time data [4].In comparison to earlier research, ongoing work on intellect-gent waste management is accelerating. Still, there is a lack of systematic literature reviews that have gone unaddressed. Therefore, this research work will contribute to the systematic literature review part as this study will be helpful for the upcoming research work within the field. This research work was motivated by the gap in previous studies; the primary motive of this systematic literature review on 'Smart Waste Management with the use of MachineLearning (ML) is to introduce smart-waste-management system SWM. The secondary objective of this study is to systematically acquire, understand and synthesize all previously available research and explore the area for specific keywords that somewhat satisfy the study area to summarize the previous work.

II. LITERATUREREVIEW

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[5] The research includes developing the research procedure, benchmarking research inclusions and exclusions, researching research standards established on the right benchmark, data extraction, and synthesis. The review gathers, compiles, andanalyses 50 papers on smart waste management published in the finest journals and conference proceedings from January2017 to May 2022. The study follows the standards of systematic literature review defined by the author Kitchenhamin their base study

[6]. This research shows that smart waste management is gaining popularity and that certain tools and methodologies are beneficial in creating and implementing smart waste management using machine learning. On the contrary, it's lauded that current research focuses so much on some disciplines, such as systems and tool development, while ignoring others, like smart waste management adoption. This research provides study criteria to support the topic.

III. METHODOLOGY SECTION

1. Data Collection

- Source Selection: Identify sources for trash images, such as online repositories, datasets, or proprietary collections.
- Data Acquisition: Collect a diverse range of trash images covering various categories like plastic, paper, metal, organic waste, etc.
- Data Labelling: Manually label the collected images with appropriate categories to create a labeled dataset for training.

2. Pre-processing

- Image Cleaning: Remove noise, resize images to a standard size, and enhance quality if necessary.
- Data Augmentation: Increase the dataset size through techniques like rotation, flipping, and adding noise to improve model generalization.

3. Model Selection

- Architecture Choice: Select a suitable deep learning architecture like Convolutional Neural Networks (CNNs) due to their effectiveness in image classification tasks.
- Transfer Learning: Leverage pre-trained models like ResNet, VGG, or MobileNet and fine-tune them for trash classification to benefit from learned features.
- Framework Selection: Use frameworks like TensorFlow or PyTorch for model development and training.

4. Training

- Data Splitting: Divide the labelled dataset into training, validation, and testing sets for model evaluation.
- Hyperparameter Tuning: Optimize hyperparameters such as learning rate, batch size, and optimizer settings through experimentation.
- Model Training: Train the selected model on the training dataset while monitoring performance on the validation set to prevent overfitting.
- Evaluation Metrics: Measure model performance using metrics like accuracy, precision, recall, and F1-score on the test set.

5. Model Deployment

- Deployment Environment: Choose a deployment environment based on requirements, such as cloud platforms (AWS, Azure) or edge devices (Raspberry Pi, mobile devices).
- Model Optimization: Optimize the trained model for inference speed and resource efficiency, considering hardware limitations for edge deployment.
- Integration: Integrate the AI model into a user-friendly interface or application for real-time trash detection and classification.

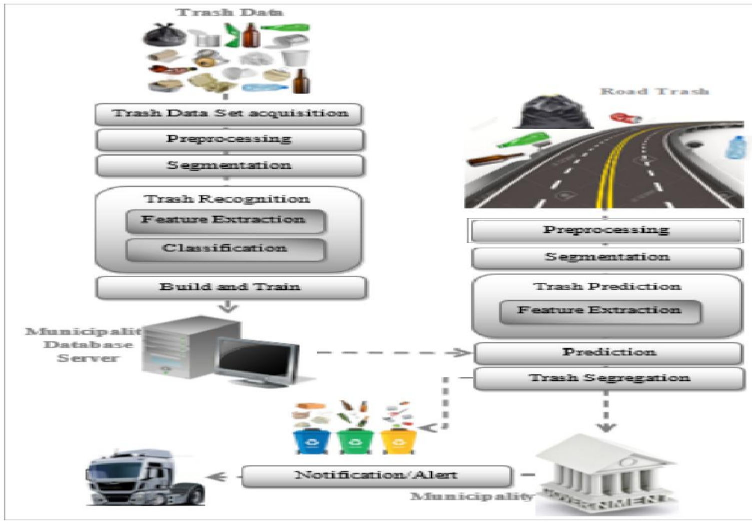

Fig 1. System Architecture

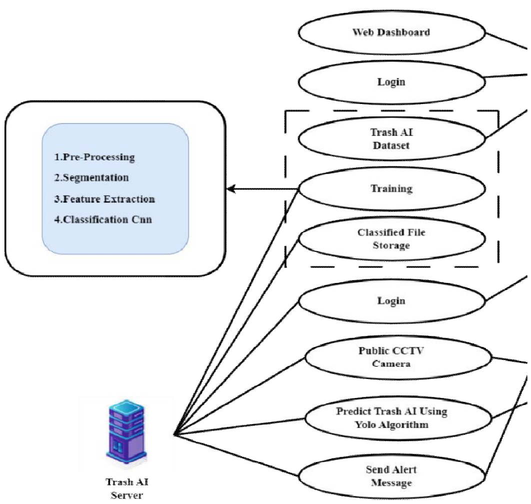

Fig 2.Use Case Diagram

IV. EXPERIMENTAL RESULTS

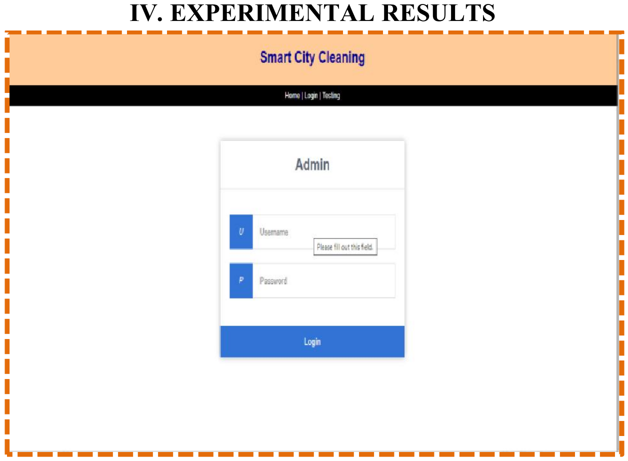

Fig 3: Admin Login

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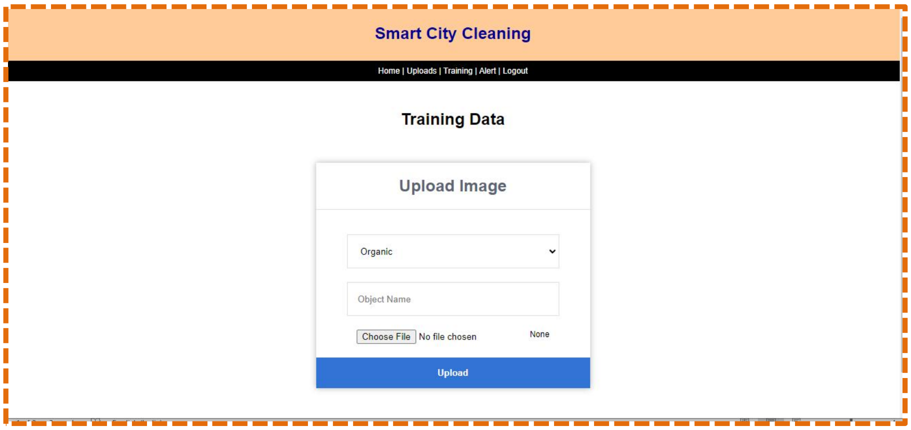

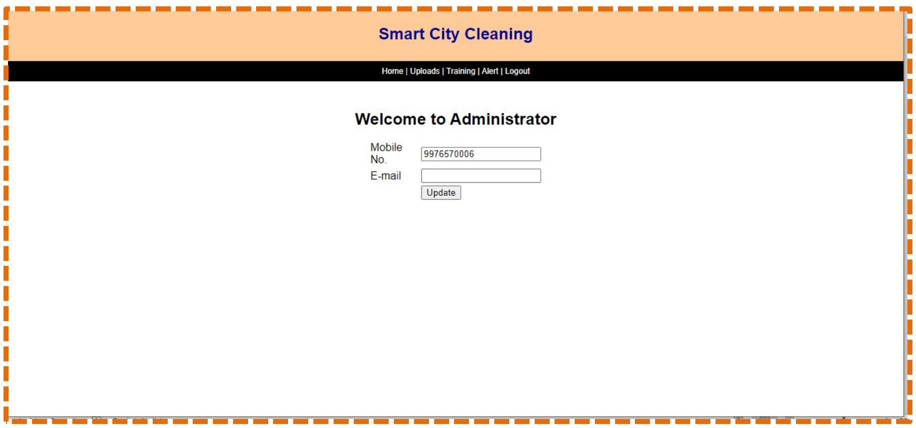

V. CONCLUSION

In conclusion, the TrashAI project represents a significant step towards modernizing waste management practices through the application of artificial intelligence and machine learning technologies. By addressing existing challenges and embracing emerging opportunities, the project paves the way for a more sustainable and efficient approach to waste management in urban environments. Throughout the project, significant milestones were achieved, including the development of a robust Municipality Web App, successful construction and training of the TrashNet model, and integration of real-time trash detection and segmentation capabilities. The system's ability to accurately classify and segregate waste items, coupled with proactive alert generation, demonstrates its potential to enhance waste management efficiency and environmental sustainability. Despite the achievements, several challenges were encountered during the project lifecycle, such as fine-tuning model parameters for optimal performance, addressing technical issues during system integration, and ensuring scalability and adaptability to diverse waste management setups. These challenges underscore the complexity of implementing AI-based solutions in real-world environments and emphasize the importance of iterative development and continuous improvement. Looking ahead, the TrashAI system holds immense potential for expansion and refinement. Future efforts should focus on enhancing model accuracy through additional data collection and augmentation, leveraging advanced algorithms for more sophisticated trash detection and segmentation, and incorporating feedback mechanisms to iteratively improve system performance.

VI. FUTURE ENHANCEMENT

To advance waste management, integrating IOT sensors into waste collection points can provide real-time data on fill levels and environmental conditions, optimizing collection routes. A mobile app can empower residents to report issues and stay informed about waste schedules, fostering community involvement. Implementing smart sorting stations

DOI: 10.48175/IJARSCT-18605

enhances recycling by automating the segregation process. Aligning with broader smart city initiatives amplifies the impact of Trash AI, promoting urban sustainability.

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