CA652 - Artificial Intelligence Group Assignment

Smart Waste Management using AI

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Link to the Meeting Logs: Group 5 - Meeting Logs

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Abstract:
In today's society, due to urbanisation, economic growth, and increasing population, the accumulation and disposal of household and commercial waste in open areas have become a significant problem. Research [1] states that, in the year 2016, 2.01 billion municipal solid waste was generated. To minimise its negative impacts on the environment or human health, waste must be managed properly. Artificial intelligence (AI) technology advancements offer a different way to achieve effective garbage collection, sorting, and recycling. We aim to propose a holistic AI-driven system that includes smart bins with RFID tags, Wi-Fi connection, and multiple types of sensors and cameras. These are connected to driverless autonomous trucks and all this would be managed through an app that will act as a central point of connection between different entities, smart bins, and trucks. By using a WasteNet dataset, the system could identify more items, thereby providing efficient segregation.

Keywords: Autonomous Trucks, Smart Bins, RFID, Sensors, Computer Vision, Artificial Intelligence

I. Introduction

AI is one of the most important tools for finding smart solutions to complex problems. One of the major issues the entire world is currently dealing with is improper waste management and disposal. As per the statistics given by World Bank [2], Waste generation will reach 3.40 billion tones by the year 2050. Effective waste management is crucial, but many nations struggle due to inadequate knowledge, poor management practices, and lax regulations. Urbanisation and population growth exacerbate environmental and health problems. AI is the solution to this problem. AI systems are able to optimise waste collection routes, track waste generation rates and composition in real-time, and find options for recycling and waste reduction. IoT solutions (sensors), on the other hand, give waste management authorities real-time information regarding bin levels, allowing them to optimise garbage collection and segregation procedures. AI and IoT can improve waste management, benefiting the environment and public health. Implementation requires significant investment and raises ethical concerns about data privacy and security. Despite challenges, AI and IoT-based systems have potential to address trash management problems.

AI can be used in each of the various processes that make up the waste management process. However, we have limited our research to the processes of trash collection, waste segregation, and waste disposal. We have covered our suggested system architecture and its elements, such as waste collection, waste segregation, and waste disposal, in the next section. We examined our proposed system in the final section and went over its benefits, drawbacks, and potential future development.

II. Related Work

There has been a significant amount of research done in the area of waste management. In paper [1], the authors have applied AI in waste management through models that consider population density, road network, and waste creation rate. Real-time monitoring and analysis of waste generation and collection rates along with composition can lead to better waste management choices. AI can also identify recycling opportunities. However, social and cultural elements can affect garbage generation and disposal behaviour, which may not be accounted for by AI. Investment in infrastructure and technology is necessary for AI to be effective in waste management.

In paper [3], Long Range (LoRa) technology and a TensorFlow deep learning model were used by the authors to develop a smart trash management system based on the Internet of Things. The system employs sensors to track the contents of the trash cans, and a LoRa gateway is used to transmit the

information to a central server. The suggested method has the potential to cut down on waste collection trips, lowering transportation expenses and greenhouse gas emissions in the process. The proposed technology, according to the authors, can be utilised to enhance waste management and collection procedures in smart cities.

In the study [4], the authors have proposed an AI based system for waste segregation using techniques such as image processing, AI and mechanical sorting for segregation at source into two categories namely organic and non-organic waste. Due to the inefficiency of mechanical segregation, they combined conventional techniques of mechanical sorting followed by computer vision and image processing using CNN for segregation and the system got an accuracy of 85%. This study only deals with the waste generated at places such as households, parks, universities etc.

The authors of [5] provide a method for localising the trash objects that employs a number of stages of segmentation namely scene-level and object-level segmentation, where the RGB intensity value and depth information from the image are employed to capture finer features. This approach has the benefit that it uses a depth camera to precisely determine an object's shape and placement, as opposed to using conventional RGB photos, and then uses that knowledge to train a deep learning algorithm.

Most of the research in waste segregation deals with a maximum of 2 to 3 categories for segregation such as organic non-organic; metal, glass, paper etc. Additionally, most of these researches use a small size of waste image dataset for training the classification model which can hamper the accuracy. Furthermore, the majority of these studies only deal with household waste but can be expanded to incorporate industrial waste. There were only a few studies [6] that used an autonomous truck to collect trash from smart bins in places as small as university campuses, nevertheless this application may be widened to include the entire city.

III. System Architecture

The previous models discussed don't have a complete system for autonomous garbage collection and disposal. This paper presents an architecture diagram of an autonomous system that deals with waste management from collection to disposal. The paper explains three processes to tackle waste management, which are described in detail in the following sections.

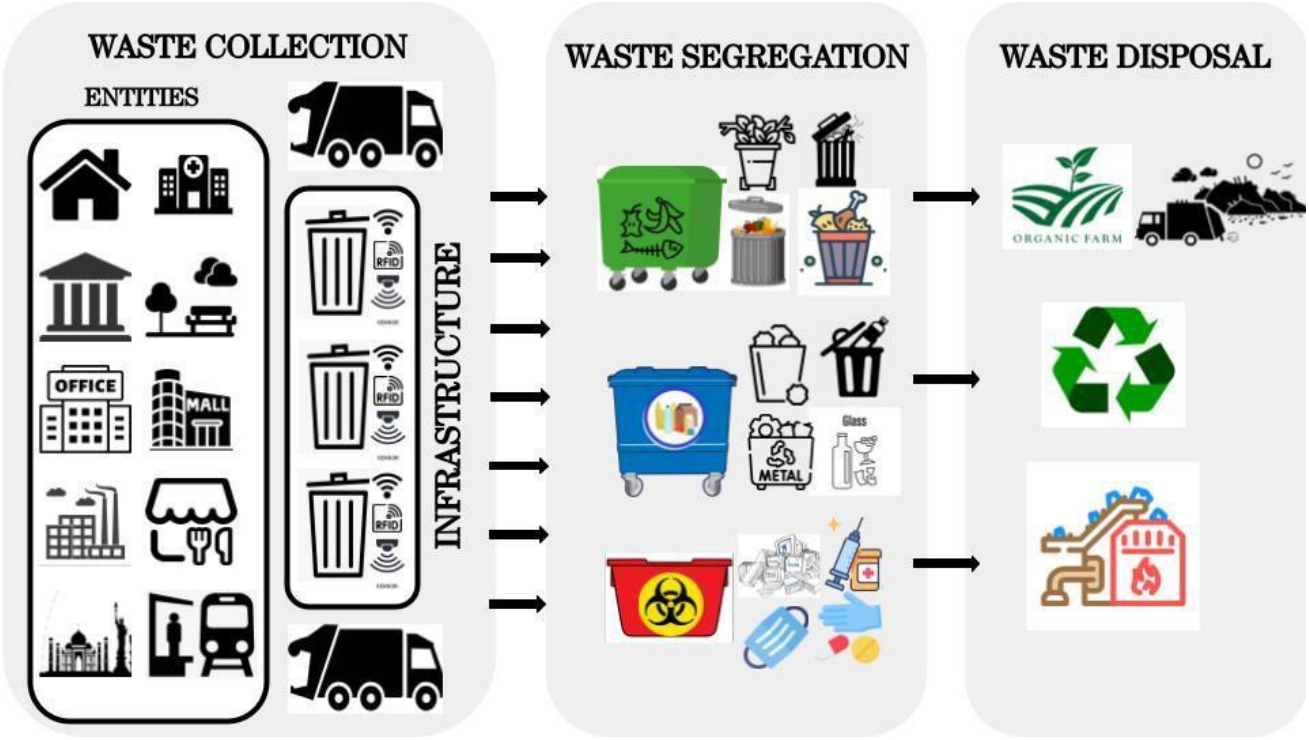

Fig 1: Architecture diagram for autonomous waste management system

a. Waste Collection

Effective waste management starts with proper source management. When waste is separated at the source, it becomes easier to dispose of it using fewer resources and efforts. AI plays a crucial role in creating a smart network for managing waste at the source. Here's a simplified architecture for the waste collection mechanism.

Fig 2: Waste Collection Mechanism

All endpoints in the proposed autonomous system are interconnected to form a fully autonomous system, as listed below:

1. ***Entity:*** All premises where garbage can be generated are considered as an entity. The prominent premises include: residentials, universities / schools / colleges, private / government workplaces, industries, tourist places, hospitals, parks / public spaces, malls / entertainment zones, restaurants, bus / train stations /airports.
2. ***Smart Bins:*** Each premise will have a collection of smart, fully automated bins well equipped with RFID tags, Wi-Fi connection, GPS, moisture, thermal and pressure sensors and camera.
3. ***Autonomous trucks:*** These will be of two types, on-premise and transport trucks. They will be driverless and will be equipped with RFID tags, GPS and an auto-pilot system.
4. ***App:*** The app acts as a coordinating agent for the other three endpoints. The app will be owned by stake owners on various premises.

The goal is to design a method where each premise is made up of smart bins placed at predetermined locations. Each form of garbage, including wet, dry, hazardous, and recyclable waste, would have its own bin. The sensors in the bins would measure the amounts of moisture and heat in the garbage, alert the relevant parties of the unsegregated waste that was identified, and label the bin on the RFID with a warning. On the other hand, the pressure sensors will be in charge of determining how much rubbish has been thrown into the bin and will alert the trucks if they are about to reach their capacity.

When the bin is full, it uses its RFID tag to transmit a signal to the app, which then picks up the signal from the tag and the GPS and instructs the on-premise truck to collect the bin. The on-premise vehicle will be completely autonomous and collect the bins when they are full, empty them and collect the garbage at a dedicated location of that premise. The app will then determine how much trash was gathered for that specific location in a single day, and will inform the transport trucks of the quantity of each category of garbage that was gathered along with the GPS signal.

These trucks will have both manual and automatic transmission. The program creates an efficient path for each truck based on GPS signals obtained from locations across the city and accesses the truck via the RFID Tag and GPS signal.

b. Waste Segregation

The proposed system segregates waste at different points, like at the source or at the conveyor. When the trash is put in smart bins, AI sensors would recognize the type of waste and notify the stake owners if there is a mix-up in recyclable, biodegradable, or hazardous waste.

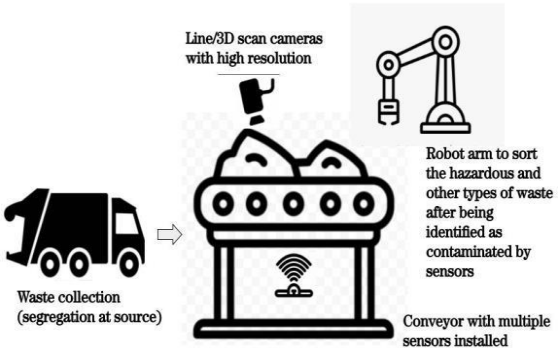

Fig 3: Waste Segregation Mechanism

After the collection of waste from the smart bins, it is sent to management facilities or recycling centres. Typically, there is human intervention at this step. If waste is not adequately collected at the source, it is manually sorted to separate materials like paper, metals, glass, and organic waste. This method could be time-taking, laborious, and even dangerous if waste is polluted and contains sharp objects.

AI can be employed for sorting waste by implementing computer vision and ML algorithms. To do this, waste should be passed through cameras and sensors and photographed as it moves along the conveyor belt. Images can then be processed by an AI model like the YOLO V5 and classify different materials based on their characteristics like shape, colour, and texture. A mechanical arm can then be used to segregate the waste based on the images received. This can improve the efficiency and accuracy of waste sorting, reducing manual work and giving high percentages of waste that can be recycled or reused.

c. Waste Disposal

For biodegradable waste, they will be brought to landfills or composting facilities where they get composted, which involves mixing the waste with other organic materials and allowing it to decompose. This process creates nutrient-rich soil that can be used for landscaping or agriculture. AI can help by using predictive analytics to optimise the composting or anaerobic digestion process [9]. For example, AI can analyse data on temperature, moisture, and other variables to determine the optimal conditions for composting or anaerobic digestion. This can lead to more efficient processing, better quality compost or fertiliser, and reduced greenhouse gas emissions.

Recyclable waste can be sent to Material Recovery Facilities (MRFs), where the waste is sorted, cleaned and processed. This may involve shredding, crushing, or melting the materials down to their basic components. The processed materials are then used to manufacture new products. AI can be used to optimise recycling processes, such as identifying the best recycling methods for specific materials or predicting equipment maintenance needs to prevent breakdowns.

With regards to hazardous waste, they get disposed of in special facilities that are designed to safely manage and treat it. Depending on the type of hazardous waste and its level of toxicity, it may be treated through various processes such as incineration, chemical stabilisation, or bioremediation. The final disposal of hazardous waste is usually in specially designed landfills that are lined with multiple layers of protective materials to prevent leaching of the waste into the surrounding soil and groundwater. AI can also be used to develop predictive models that can forecast potential accidents or spills in hazardous waste storage and transport, allowing companies to take proactive measures to prevent them [10]. Additionally, AI can help optimise the hazardous waste disposal process by identifying the most efficient and safe ways to dispose of the waste based on various factors such as the type of waste and its chemical properties.

IV. System Evaluation

Pros:

- Because all previous contributions have concentrated on a single area of the waste management process, there has never been a holistic system developed that addresses trash collection, waste segregation, and waste disposal.
- The kinds of trash that can be controlled have also been lacking. In addition to the fundamental classification of merely dry and wet trash, this system also deals with industrial, hazardous, hospital, and recyclable garbage.
- Because all previous contributions have concentrated on a single area of the waste management process, there has never been a holistic system developed that addresses trash collection, waste segregation, and waste disposal.
- The kinds of trash that can be controlled have also been lacking. In addition to the fundamental classification of merely dry and wet trash, this system also deals with industrial, hazardous, hospital, and recyclable garbage.
- Additionally, the user-friendliness that this system offers will empower the stakeholders to suggest waste controlling solutions by allowing them to access the waste caused by having current statistics.
- Also, all of the previous process lacked a wider sense of waste classification using Computer Vision as the dataset was not inclusive enough. With the help of Wastenet dataset [13] more than 3 million waste items can be identified.

Cons and Solutions:

- The suggested system necessitates a substantial initial investment in technology and equipment, followed by maintenance costs.
- However, by comprehending the productivity vs. long-term profitability and putting it into practice under a revenue model, the cost may be reduced.
- Utilising simulation tools to assess latency, trash collection rate, and performance before comparing it to alternative approaches, as stated in [12], is one way to achieve route optimization. It would be necessary to validate the system's functionality and stability.
- Utilising ongoing stakeholder feedback is another way to enhance the system.
- Every endpoint in the system can be powered with renewable sources of energy to cut down on maintenance and expenditures.
- This ongoing information seeking from the stakeholders, the surroundings, an understanding of the truck routes, and the classification of the garbage based on the images acquired, will be the performance improvement aspects of the system.

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SELF-ASSESSMENT

Student Name: Sayali Randive		**Student Number: 21265052**	
Rating / **Criteria**	Poor	Satisfactory	Excellent
Completion of assigned Task			✓
Peer Interactivity			✓
Overall Performance			✓

Student Name: Tripti Bharadwaj		**Student Number: 22260190**	
Rating / **Criteria**	Poor	Satisfactory	Excellent
Completion of assigned Task			✓
Peer Interactivity			✓
Overall Performance			✓

Student Name: Minh-Khoi Pham		**Student Number: 22270044**	
Rating / **Criteria**	Poor	Satisfactory	Excellent
Completion of assigned Task			✓
Peer Interactivity			✓
Overall Performance			✓

Student Name: Mrunmayi Bhide		Student Number: 22263299	
Rating / Criteria	Poor	Satisfactory	Excellent
Completion of assigned Task			✓
Peer Interactivity			✓
Overall Performance			✓

Student Name: Bharath Raju		Student Number: 22267838	
Rating / Criteria	Poor	Satisfactory	Excellent
Completion of assigned Task			✓
Peer Interactivity			✓
Overall Performance			✓

TASKS PERFORMED

SAYALI RANDIVE:

- Brought initial ideas like Virtual Reality for autistic kids to the table
- Also, researched about the previous works done for waste management before
- Kept logs of the meetings
- Designed the system architecture and the waste collection
- Scripted the waste collection and the evaluation sections
- Presented the topics in the lecture on behalf of the team
- Initiated discussions and forum topics
- Formatted the report alignments

TRIPTI BHARADWAJ:

- Conducted research on previous work on waste management.
- Played a role in formulating the abstract of the proposed waste management system.
- Worked with the team to identify key objectives of the system, its scope and benefits it could bring to the community.
- Worked on waste segregation designing and implementation process of proposed system
- Gave inputs on the evaluation of the system
- Integrated all the components and organized the reports

MINH-KHOI PHAM:

- Propose initial idea about “Driver monitoring system”
- Conduct research about previous works on application of AI in waste management business.
- Help on ideas about designing architecture diagrams for the system
- Worked on scripting the “Waste Disposal” section

- Suggested an input for evaluation of the system: using WasteNet

MRUNMAYI BHIDE:

- Came up with the topic of Waste Management using AI.
- Gathered research papers for Waste Segregation and wrote a detailed summary for each paper.
- Worked on Introduction and Related Works part of the report.
- Gave Inputs for the evaluation of the system and the design.
- Collaborated with the team to discuss the scope, methodologies and outcomes over the forums and on call meetings.
- Maintained the Reference List
- Worked on the formatting of the report as well as on modifications where necessary.

BHARATH RAJU:

- Brainstormed initial ideas for the assignment.
- Conducted a literature search to find related work for the finalised topic.
- Analysed and evaluated the literature that were found.
- Collaborated with a team to identify the critical objectives of the system.
- Added forum topics and discussions.
- Worked on the waste collection part of the introduction and related work.
- Provided inputs for system evaluation.