



IoT Enabled Smart Waste Management System using Machine Learning Techniques

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Abstract: Rapid population growth around the world has resulted in the improper management of trash in many nations, which has led to a number of health problems and environmental damage. Only once or twice a week are collected by the waste-collection vehicles. The garbage in the trashcan gets dispersed across the streets as a result of poor waste collection procedures. As a result, an effective solution for smart and effective waste management combining machine learning (ML) techniques and the Internet of things (IoT) is suggested in order to overcome this dilemma. The authors' suggested approach makes use of a moisture sensor, an ultrasonic sensor, and an Arduino UNO microcontroller. To calculate the trash index of a particular dumping site, image processing will be applied. Additionally, a hardware prototype for the suggested framework will be created. As a result, the proposed approach to effective waste management achieves the goal of creating clean, pollution-free cities.

IndexTerms: Arduino UNO, Dustbin, Internet of Things, Machine Learning, Smart Waste Management System, Smart cities.

I. INTRODUCTION

The waste management system primarily supports the treatment and disposal of various forms of garbage. Therefore, it protects people, animals, and the environment. Effective waste management practises may save costs significantly, improving air quality and reducing environmental pollution. The developed regions are simultaneously developing and putting into practise certain effective waste management strategies, producing incredibly positive effects. The existing state of affairs makes it difficult to handle such a massive amount of garbage in the ensuing five years. It is therefore preferable to take all the essential steps for the efficient management of garbage. Therefore, in order to effectively handle trash and maintain a healthy environment, we must employ the finest procedures and practises [1]. Daily trash generation has significantly increased around the world. A minimum of 35% of the 1.9 billion tonnes of garbage that are produced each year are not processed safely. According to statistics, each person produces between 0.17 and 4.67 kg of garbage each day. By 2055, it is projected that there will be more than 45 billion tonnes of trash worldwide, a growth rate that is more than twice as fast as today's. Waste production and income are directly inversely correlated [2].

Waste must be treated and disposed of as effectively as possible since it is a significant source of money. By 2050, trash creation in low- and middle-income countries is predicted to climb to 45%, whereas it may increase to 20% in high-income ones. Smart waste solutions are becoming more beneficial and will keep playing a bigger part in helping private companies and governmental organisation increase productivity and meet waste reduction goals. The authors' technique also does away with the danger of needless garbage collection, saving both staff time and gasoline. Globally, the rates of waste production are rising. By 2026, 2.5 billion tons of trash is anticipated to have been produced due to the rapidly increasing population [3].

With the help of the most recent technological advancements, we hope to provide in this work an intelligently improved solution to one of the most pressing social problems—the daily disposal of solid garbage across the city. Since the large garbage bin is usually the most crucial component to maintaining the level of hygiene in our community. Therefore, it is imperative to empty all of the large garbage cans before they become full or overburdened. This sensor will be placed over the trash can to help convey information about the level of rubbish inside it to the administrator in the form of digital signals. Based on this data, the clearing task could be started just when the bin's capacity is about to fill up. The potential of arranging the cleaning vehicle is optimised to ensure the city is clean and healthy once the rubbish load location of each and every waste-bin positioned throughout the city can be felt. The garbage cans are then emptied as soon as possible after that. The quality of life for the populace may increase, and the city will no longer be surrounded by unwholesome environments [4-5]. This technique allows for the reduction of the requirement for solid waste garbage bins and ensures that any bins that require immediate attention from sanitary staff are strategically recognised and tracked toward cleaning. how we can guarantee a clean smart city.

Waste Management Problems in Smart Cities: One of the main issues that cities deal with is waste management. The management of garbage in smart cities involves a sizable workforce of waste, including waste collectors, scrap dealers, and recyclers[4]. The largest informal sector in the nation, which consists of the unrecognised garbage collectors, is the part of the waste disposal system that is most affected. These garbage collectors often work in neighbourhoods with 50 to 70 houses, and every member of the family is active in collecting rubbish around the nation. All of the members of these families work as rubbish collectors, and they oversee between 15 and 20 percent of the city's waste [5].

- Lack of Awareness about Waste Management

- *Improper Classification of Municipal Waste*
- *Participation of Organized Sector for Carrying Out Efficient Management of Waste*
- *Lack of Technical Solution and Public-Private Partnership*
- *Transportation of Waste*

Solutions for Waste management Problems: The usage of an IoT and machine learning (ML) based waste management system is the most efficient way to combat the issue of environmental pollution. IOT and ML can give real-time garbage information and an optimal routing for waste collection vehicles, cutting down on costs and processing time overall.

The waste management problems can be solved by details investigation of issues and challenges and proposing the efficient solutions using IoT and ML techniques. In this work we first understand the various existing solutions of waste management in cities. Then we propose the efficient solutions and a system is designed. Further we compare our proposed system with existing systems. Finally we develop the MATLAB framework using four ML models and performance analysis will be carried out.

The Contributions of our work are:

- Investigated the issues and challenges related to the waste management in cities
- Understood the various existing solutions of waste management in cities
- Identified the efficient solutions for effective waste management
- Proposed the Smart waste management system using IoT and ML
- Designed the hardware prototype of proposed system using IoT
- Carried out the comparison between my designed system with existing other systems
- Also carried out the simulation four ML models/algorithms using MATLAB
- Finally, carried out the performance analysis and comparisons of four ML models.

II. LITERATURE REVIEW

A review of the relevant literature on smart garbage collection and monitoring is conducted. In recent years, cities have grown in size and population, necessitating the development of smart services such as intelligent traffic, intelligent health care, intelligent trash collection, intelligent education, intelligent living, and intelligent energy. The amount of solid trash will rise, having an adverse effect on the environment, polluting the air and posing health risks. As a result, it is crucial to streamline the collection procedure and handle waste solids more effectively. Several studies have been conducted on various methods for managing solid waste, including generation, collection, and monitoring. Many researchers have provided specific guidance on various types of managerial, technological, and economic challenges for the collection of solid waste from cities in developing nations.

For a successful system, we should study about the research problem again and again. The question is "Is it possible to develop We should keep learning about the research challenge in order to build an effective system. The query is, "Is it feasible to construct Smart trash cans that alert the municipality when the trash cans are filled?" We examine a variety of research articles for the literature review to learn about the previous work. A weight sensor is used in various research publications for waste wastage detection [6-7]. This weight sensor informs the relevant authorities of the weight of the rubbish, so they may take the proper action.

Later, a new system with two functional components—a software component and special indication equipment—was presented by Andrei Brozdukhin and friends [8]. The distinctive indication apparatus is fastened to the trash sides. It consists of two components: the sensor and the receiver-transmitter. The sensor measures the amount of trash in the trash can and is connected to a transmitter that alerts the appropriate authorities that the trash can needs to be emptied.

Artificial intelligence algorithms are now responsible for determining the quickest route and closest truck driver to the relevant trashcan and notifying them of the garbage pickup. The prototype for the IoT/AI-based intelligent garbage waste management system was built around waste materials, a residential trash can, a garbage bag, and a garbage pickup truck [9]. The project begins with the flow of trash into the domestic bin and into the garbage can and ends with the garbage takeaway vehicles. Using RFID technology, a fresh trash bag is inserted into an integrated container. All the drawbacks of small-scale use, cheap cost, low fuel consumption, and a clean environment have been addressed by Arduino with IOT processes.

Many researchers have investigated into and developed novel applications for smart cities, particularly for waste management, taking the benefits of IoT technology into consideration. A straightforward system that determines the fullness of garbage cans was introduced, which gathered data and sent it using a wireless mesh network in order to minimise power consumption and increase operational time [10]. However, there are still some unclear issues with the concept in the system. Platform software for smart cities has been released in [11] to enhance trash management, but they primarily focused on data collecting, and their platforms were made up of technology from other firms.

III. PROPOSED SMART WASTE MANAGEMENT SYSTEM

We have proposed to design a smart waste management system using Internet of things. The block diagram of proposed system is shown in figure 1. In this diagram it has shown the interconnection of various hardware components with real time monitoring system. In this system the ultrasonic sensor is installed with smart dustbin to measure the distance or level of dustbin. A moisture sensor is connected to Arduino UNO to detect whether the waste is wet or dry. Also LED and buzzer are connected to indicate the output status. The GSM module and GPS module is connected to Arduino UNO to send the message to real time system about the dustbin status and location..

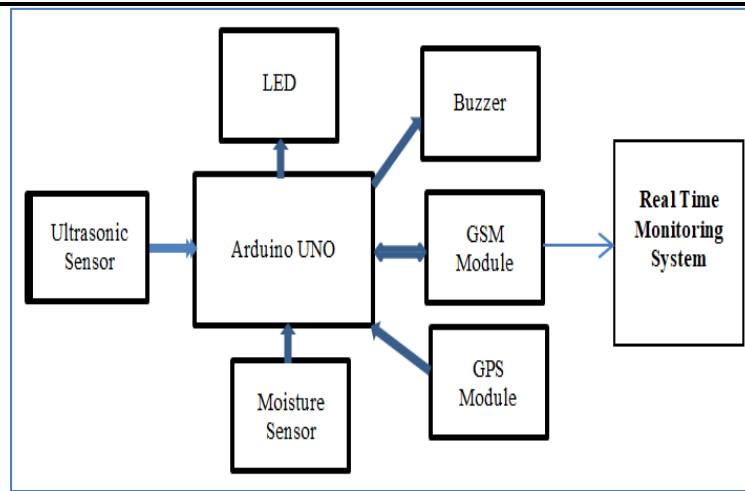


Figure 1: Block diagram of IoT enabled Smart Waste Management System

Waste management and collection are sometimes perceived as low-tech tasks. However, IoT and ML-based solutions have the ability to turn a single trash can into a network of smart, interconnected devices. In order to gather information about dumper truck ID, meeting date, meeting time of garbage collection, etc., a dumper truck database has been generated in the provided system. This system enables timely garbage collection and also allows vehicle tracing through a database using automation of the Global Positioning System (GPS). It also maintains track of all the truck driver's actions and the waste gathering system of waste management. The simulation of four ML models/algorithms using MATLAB is proposed and performance analysis and comparisons of four ML models proposed to carry out.

The Arduino is programmed according to proposed logic using Arduino integrated development environment (IDE). The IDE is written in java language. The IDE editor is used to compose the required code and compiler is used to assemble and transfer the project code into the arduino module.

Proposed Design and its benefits

- This study demonstrates smart trash management through the use of the IoT. Utilizing this technique guarantees that waste is removed as soon as it reaches the maximum amount. As a consequence, the system will generate reliable reports, increasing its effectiveness.
- Our goal is to develop a smart waste management system based on the idea of integrated, sustainable waste management. Public health may be impacted by the closing of landfills owing to a number of possible risks. The burning of unwanted rubbish and open junkyards can cause environmental damage and numerous dangerous diseases.
- A system that can efficiently monitor trash disposal, collection, and control the overall expansion of unnecessary garbage should exist.
- Compared to existing approaches, the system we propose effectively gathers and processes waste. Additionally, it saves time and money on fuel. The technology also tracks the garbage collection vehicles, providing real-time information on the whereabouts of the trucks and boosting productivity.
- All previous waste management models have prioritized increasing sustainability while minimizing the time and expense of the entire system. Our trash management method, on the other hand, is environmentally friendly and cuts down on setup time and expense.
- The system forecast the trash index of a certain dumping site using image processing. The garbage-collecting vehicles will gather rubbish in accordance with the priority, which significantly reduces time.

IV. RESULT ANALYSIS

The designed system will identify the dustbin which is filled and indicate the system. The entire communication of devices will be through IoT framework. The implemented system will provide the optimized path for efficient waste collection. On the sender side, information on how many garbage levels have been filled is communicated to the recipient. On the receiver side, a mobile application provides the user with an indicator. He can tell how much of the garbage level has filled based on the signals he got.

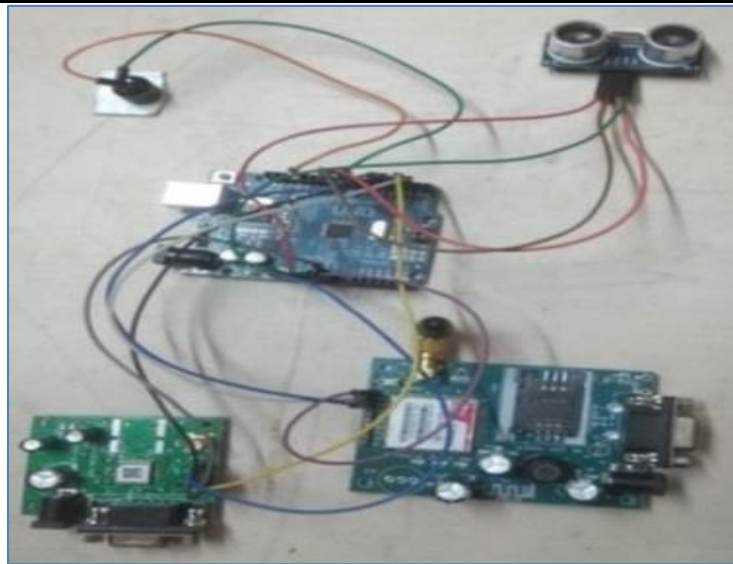


Figure 2 Smart Waste Management System using IoT

From the results analysis it is seen that the proposed system will reduce cost of infrastructure, rating, and maintenance up to 30%. Also we see that smart bins have outperformed ordinary garbage cans. There is an up to 80% decrease in the number of waste pickups.

We implemented and simulated the ML approaches that use previous input data to forecast the likelihood of collecting rubbish in the real world. The four classifiers are simulated using MATLAB tool and results in terms of mean accuracy and percentage accuracy are obtained. These values are presented in table 2 and it is seen that the accuracy of random forest classifier is 96.5%, Naïve Bayes Classifier is 80.4%, Neural Network Classifier 95.5% and Support Vector Machine Classifier is 88.5%. The performance of neural network classifier is almost equal to random forest classifier and better than other two classifiers. Further it is seen that the performance for random forest classifier is better than other three classifiers.

Table 1: Comparison of proposed System with Existing Systems

Proposed System	Existing Systems
Smart waste management system using IOT and ML	Integrated Linear Model, Advanced Locality Model, Mixed Integer Goal Programming Linear Model and Integer Programming Model.
The design of this system incorporates GSM, GPS, IoT, and ML approaches.	All these systems are designed using old technologies
Dumper truck database has been generated	No generation of dumper truck database
Tracking of truck drivers activates and waste gathering system	Tracking not available
This system offers timely garbage collection and vehicle tracing.	This system does not provide on time waste gathering and automobile tracing
reduces the price of fuel	Does not reduce fuel price
This system ensures practical consequences and Good green environment	This system does not ensure practical consequences and Good green environment

Table 2: Comparison of Accuracy of different ML techniques

ML Classifiers	Mean Accuracy	Accuracy (%)
Random Forest Classifier	0.965	96.5
Naïve Bayes Classifier	0.804	80.4
Neural Network Classifier	0.955	95.5
Support Vector Machine Classifier	0.885	88.5

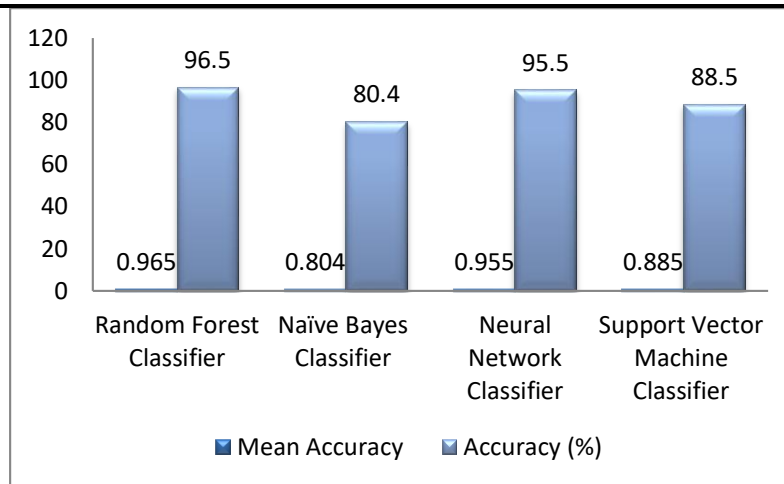


Figure 3 comparisons of Accuracy of different ML techniques

The figure 3 presents about the mean accuracy and percentage accuracy obtained after simulation of 4 different ML techniques. It is seen that Random forest classifier outperforms over other three techniques. The Smart Garbage Monitoring System's primary goals are to improve the city's smart vision while utilizing less resources and labor-intensive processes. The atmosphere is made clean and sanitary by employing a sensor and GSM, which also guarantees environmental cleanliness. The improper storage and disposal of domestic garbage leads to pollution and public health issues. An IoT-based smart waste monitoring system was created employing an ultrasonic sensor as a distance measuring sensor, GPS to convey the location of the trash can, and GSM to send a message to the local government with the current location. The Arduino IDE as an IDE tool and the Google API as a software tool were used to construct the Smart Garbage Monitoring System utilizing IOT.

When creating a smart city, this Smart Dustbin may make a significant contribution to a clean and sanitary environment. It aids in preventing rubbish overflow in the neighborhood. As a result, the intelligent waste monitoring system increases the efficiency of garbage collection. Garbage might include undesired items that have been left behind by a city, a public space, a society, a college, a home, etc. This project is based on the "Internet of Things" and is connected to "Smart Cities" (IOT). Cleanliness is therefore necessary for a wise lifestyle, and cleanliness starts with the garbage can. However, because the technology is new in India, adequate public awareness should be raised before it is widely utilized. Otherwise, delicate equipment like sensors might be harmed by users' rough behavior.

V. CONCLUSION

The proposed system is designed successfully using IoT and ML. Comparisons of designed systems with other existing systems are carried out. The system collects and efficiently treats the waste as compared to other existing models. This system saves time and fuel costs as well and the system tracks garbage collecting trucks which provides real-time trucks, positions, thereby increasing work efficiency. The concept suggested in this project is intended to integrate the various waste management system stakeholders, such as smart bins, sensors at the source area, and vehicles, with regard to the infrastructure in India. Since smart bins, collection trucks, and routes are dynamically updated, the system is efficient and effective.

VI. REFERENCES

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