Smart Waste Management System for Societal Benefits

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Abstract**—** Nowadays certain actions are taken to improve the level of cleanliness in the country. People are getting more active in doing all the things possible to clean their surroundings. Various movements are also started by the government to increase cleanliness and waste management. IoT and machine learning based waste management systems are very effective systems nowadays for societal use.

In this paper we have discussed existing methods of segregation of waste, and how IoT and machine learning can be useful to solve major problems related to waste management. This paper guides about how to segregate biodegradable and non biodegradable waste and recycle biodegradable waste for making compost. Also we have discussed various relevant solutions proposed by various researchers in the related work.

Keywords— ***Waste management, Sensors, Segregation,***

I. Introduction

Waste collection is an essential societal service, yet existing waste management systems are resource-intensive, inefficient, and outdated. The Internet of Things (IoT) has the potential to greatly optimize collection services and reduce operational costs for cities. All humans produce solid waste, commonly known as trash or garbage, on a daily basis, yet essential waste collection systems in cities are often taken for granted by residents until a garbage bin overflows. Due to recent population growth and urbanization, waste production in cities has increased, and municipal waste collection operations need to adapt to be able to ensure a clean society.

With most existing waste management systems, a city collection service will travel a predefined route on a regular basis and empty trash and recycling receptacles, whether they are full or not. The fixed nature of this system creates the possibility of half-full bins being emptied, unnecessary fuel being spent, and excess use of city resources. Understanding of the waste generated, the availability of resources and the environmental conditions of a given society is essential for the development of an appropriate waste management system. Solid waste is defined as materials that no longer interest the original owner and are discarded. Good examples are organic waste (including kitchen waste and leftovers from garden pruning), paper, glass, metals, plastics, fabrics, and wood. Solid waste management is associated not only with generation control but also with the disposal of solid waste in a way that follows the best principles of health, economy and other considerations as to the environmental attitudes developed by citizens[3].

The current manual collection methods are highly resource-intensive. With the help of IoT, they can be transitioned into data-driven collection processes. Smart waste management solutions use sensors placed in waste receptacles to measure fill levels and to notify city collection services when bins are ready to be emptied. Over time, historical data collected by sensors can be used to identify fill patterns, optimize driver routes and schedules, and reduce operational costs. The cost of these sensors is steadily decreasing, making IoT waste bins more feasible to implement and more attractive to city leaders.

This work proposes an efficient and real-time waste management model for societies, focused on a citizen perspective. This proposed system has a smart dustbin to segregate waste, recycle the waste for making compost and prediction of air pollutants based on machine learning algorithms(KNN) and IoT[10]. The main contribution of this proposed system is

- A smart dustbin used for segregation of biodegradable and non biodegradable components using IoT sensors.
- Making compost using biodegradable waste.
- Non-biodegradable can be segregated using a conveyor belt.
- Prediction of air pollutants based on real time data.
- Supervised machine learning algorithm: KNN is used for classification and prediction of alert messages based on sample data.
- Sending an alert to municipal corporations using google messenger.

The rest of the paper is organized as follows. Section 2 describes the related work on IoT based waste management systems for societal benefits, mentioning the most relevant solutions available in the literature. Section 3 describes the proposed framework of this study, including the creation of hardware, software, and integration. Section 4 describes the methodology of the proposed system that is a solution that aims to optimize the waste management process.Finally, the conclusion and future work is described in Section 5.

II. RELATED WORK

Many research projects related to waste management are present in the literature. Researchers in **[4]** proposed the framework of a Smart City Garbage Collection and Monitoring System. In this , the smart bin is built on a microcontroller-based platform Raspberry Pi Uno board, which is interfaced with Global System for Mobile communication (GSM) modem and ultrasonic sensors and also a weight sensor, which is used for calculating the weight of the dustbins. Thus, the weight sensor is placed at the bottom of the dustbins, which will measure the weight of the dustbins, and the ultrasonic sensor is placed at the top of the dustbin, which will read the status of the dustbin. The Raspberry is programmed in such a way that when the dustbin is being filled, the remaining height from a threshold height will be displayed. When the waste achieves the limit level, an ultrasonic sensor will trigger a GSM modem, which will persistently caution the required expert until the trash in the dustbin is squashed.

Researchers in **[5]** proposed the architecture which is primarily based on an intelligent compartment that is responsible for updating the system with volume information, the type of content present in its interior, and the environment surrounding the place where the compartment is inserted. The enclosure is equipped with a range of sensors that enable detection and communication with the cloud and are managed through a microcontroller, such as Arduino Yun or a Latte Panda card, which receives the collected data, aggregates the data and transmits them to the cloud. This range of sensors is basically composed of proximity sensors that provide neighborhood status data around the enclosure, such as information on restricted physical access for collection due to parked vehicles. There is a load cell that calculates the weight of the garbage available inside the compartment and updates the microcontroller. A humidity sensor is used to detect the level of dryness of the contents inside the compartment when it is not under usage for a long time, and the collection can be triggered when wet fragments are detected to avoid leakage. In addition, the compartment is equipped with a GPS that identifies your exact location. Also present is a lever-like drive key, which is used to detect open-lid physical events, generally due to over-filling of the tray. Complementing the solution, a mobile application is used by drivers of collection vehicles to determine the route and location of the bin within a collection schedule, and the application can be used by the public to control the disposal for a residence; QR code technology allows only registered users. The driver module inserted into the application ensures the implementation of dynamic routing by continuously monitoring the speed of the vehicle and its location. The cloud is the central processing unit of this system, which receives data pertaining to the management carried out by dumpsters. These data are aggregated and interspersed with weather conditions, rush time traffic, sporting events, and commemorative events with potential effects on the garbage truck route. The proposed system actively reacts to optimize waste collection routes.

Researchers in **[6]** bring a concept of intelligent disposal through a design that uses solar energy to feed the system and presence sensors for monitoring the amount of waste accumulated inside the enclosure. If necessary, the compartment can perform the compaction of the waste so that its volume can be reduced by up to 10 times, even before collection. Information about the fill level is sent via wireless communication to a cloud server where it is stored. The smart bin can act as a Wi-Fi hotspot, and it is easily adapted to any type of container, from small containers to large garbage containers such as underground containers. In turn, concessionaires access the system through a login and have access to data analysis, allowing fill level monitoring of smart bins, in real time, with notifications of need for collection through information that contains optimized routes for waste collection. This intelligent solution helps utilities reduce truck fleet, reduce fuel consumption, and maximize pick up time, minimizing operating costs by up to 80%.

Researchers in **[7]** proposed a smart garbage monitoring system which measures the garbage level in real time and alerts the municipality when the bin is full based on the types of garbage. This system uses ultrasonic sensors to measure the garbage level and an Advanced RISC Machines (ARM) microcontroller to control system operation, whereas everything is connected to ThingSpeak. This system can show the status of four different types of garbage, such as domestic waste, paper, glass and plastic, through LCD and ThingSpeak, in real time, storing data for future use and analysis, such as prediction of the peak level of garbage bin fullness.

Researchers in **[8]**, proposed an approach where monitoring not only occurs inside the compartment but also in the environment around it, in order to avoid waste disposal outside the container. The compartment is equipped with infrared sensors that play the role of detecting discarded garbage out of a bin, as well as measuring the compartment fill state. Garbage detected by the environment is delivered to an alarm system that is triggered to inform the person who disposed of the garbage improperly; this alarm will cause people to dispose of the garbage properly. A mechanical lift consisting of a rack, electric engine, pinion, gear shaft, and chain pulley that are driven by a master controller and collect accumulated waste around the compartment. The grouping of the rotating mechanical axis together with the elevation ensures the common area around the waste-free compartment providing a clean, hygienic, and healthy environment for society. When the internal sensor detects the garbage limit level, the system automatically sends a message to the corresponding authorities, notifying them of the need for collection.

Researchers in **[9]** proposed system which includes sensors installed in a compartment that determine the level of residues present internally through the distance measured from the cover and the beginning of the deposited garbage. The Authors use sonar devices like the HC-SR04 and consider the battery-optimization process, which can be achieved through optimized waste detection rates in conjunction with Wi-Fi. This is a factor with strong influence on energy consumption that can raise the life of the device. The data obtained through the sensors installed in the trash can be transmitted to a MySQL database via the Internet and then passed through optimization algorithms to calculate the best collection path. Associated with artificial-intelligence-based (AI) approaches, future waste levels can be predicted and properly associated with information from landfills, and a lower route of disposal can be determined. Every day, workers in the collection system update the paths on their navigation devices based on an essential feature of this system, which is to improve previous experience and to decide not only the status of the daily level of the compartments but also the foreseeable future state and other related factors, such as congestion, blockages, and parking area to receive the fleet at the end of a journey. Based on historical data on dumps and future projections it is possible to anticipate the occurrence of exhaustion of the landfills and, thus, plan new localities assuming less distance from the waste generation center.

Researchers in **[11]** proposed waste management through smart bins. The presented model defends specific dumps applied to each type of waste and considers the following elements: wet/biodegradable paper; paper/clothing/wood; glass/metal, chemical/medical and hazardous waste. In each compartment, there is a coupled GPS module that determines the exact location of the compartment, an infrared sensor to determine the compartment fill level, a gas sensor to detect harmful gases, a temperature and humidity sensor, and a sound sensor for noise pollution monitoring. All the sensors are managed by a microcontroller with a LoRa coupled communications module that is used to transmit the information obtained from the smart bin. A Linux-based gateway device (Raspberry pi) with LoRa module receives data from smart bins and, in the sequence, sends it to the cloud through a LAN/Wi-Fi connection using an MQTT message broker as the application layer protocol. The cloud layer includes data storage with a NoSQL database, event processing, and data analysis with alerts sent to the garbage trucks for collection when the boxes are full. These messages are received in an application that determines the best route for the truck to collect the waste.

Researchers in **[12]** proposed a Web browser, a way for the garbage collection agencies to obtain information on filling of the containers and thus to plan their collection routes in an optimized and pre-scheduled manner, as well as facilitating the insertion of data to be made available to users, such as the collection schedule or out-of-service notifications for maintenance purposes.

Researchers in **[13]** proposed a IoT-based solid waste management system in which, a DHT22 temperature sensor, MQ-135 gas sensor, IR sensor, passive infrared, PIR sensor, and load cell are used to monitor the temperature and humidity, presence of harmful gas, amount of garbage, presence of user, and weight of garbage respectively. LoRa communication is used to transmit data to a gateway, and the data are sent to a cloud for cloud monitoring. The system uses a total of five waste bins to handle five different types of wastes, with each bin having its own set of sensors, which ultimately increases the overall cost of the system.

Researchers in [14] proposed a smart recycling bin which uses Raspberry Pi 3 and Xilinx PYNQ-Z1 FPGA board together with pretrained ResNet-34, a convolution neural network containing 34 pretrained layers to perform waste classification. The data collected from the bin are transmitted using a LoRa communication network from a sensor node to the gateway. The system obtained a detection accuracy of 92.1% with an average processing time of 1.82 seconds. However, the system does not perform any form of waste segregation after waste classification.

Researchers in **[15]** proposed an automated approach to segregate recyclable material. The recycling bin is equipped with four types of sensors, namely inductive sensors to detect plastic, a capacitive sensor to detect metal, a photoelectric sensor to detect paper, and a proximity sensor to detect motor position. When waste is inserted into the recycle bin, three types of sensors connected to Arduino Uno operate to detect the type of material. Once the detection is completed, the circular plate holding the waste will be rotated by the direct current motor to the respective material's compartment. A pusher then pushes the recyclable material to the separation bin. The proposed system relies on several sensors that can add up to the maintenance and manufacturing cost of the recycling bin.

III. PROPOSED SYSTEM

Waste is constantly generated in one's apartment complex or office building. It is important to dispose of it appropriately and responsibly. Segregating waste before disposing of it makes it simpler to recycle.

Pre-process requirements:

Dividing the waste into the categories by which they need to be segregated.

Waste can be segregated as

1. Biodegradable
2. Non-biodegradable

Biodegradable waste includes organic waste, e.g. kitchen waste, vegetables, fruits, flowers, leaves from the garden, and paper.

Non-biodegradable waste can be further segregated using a conveyor belt. Conveyor belt separates household waste just as precisely and effectively as plastics, glass, scrap metal and electrical waste.

We are proposing Smart Dustbin system which does the following:

- Segregation of biodegradable and non biodegradable waste using sensors
- Making compost using Biodegradable waste.
- Non-biodegradable can be segregated using a conveyor belt.
- Placed sensor on top of the garbage bin for detecting the total level of garbage inside it based on bin size.

- Classification and Prediction of air pollutants using real time data
- Notification alert will be activated and sent to the corporation's office using messenger, when the garbage will reach the maximum level.
- After receiving notification action will be taken by the corporation's staff for empty the bin.
- Better approach to clean the city.

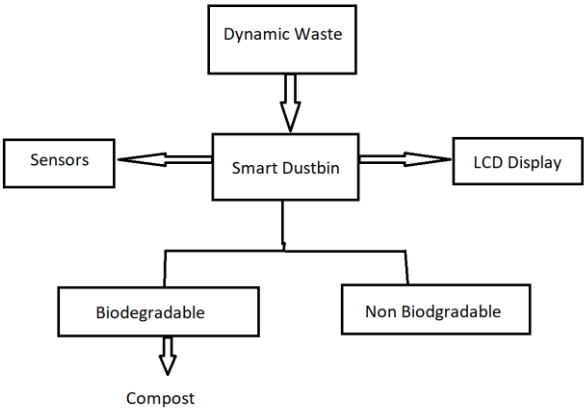

Figure 1: Proposed System

IV. Methodology

As shown in the figure 2 Block Diagram represents how the sensors are being connected to the system.

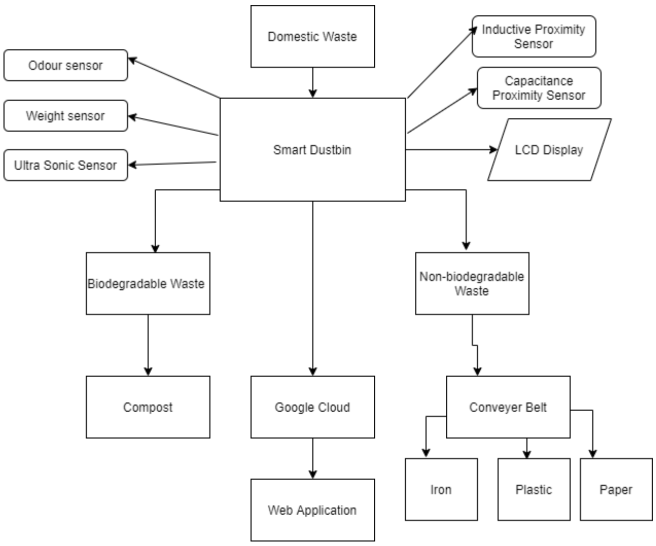

Figure 2: Smart Dustbin Methodology

Hardware Component used: Sensors, Actuators

According to the proposed framework,

1. The IR sensor on the front side of the smart dust bin senses the proximity of the user and opens and closes the lid automatically.
2. Actuators are used to control the linear motion required to open and close the lids of the smart dust bin.
3. The two ultrasonic sensors on the inner side of the lid continuously monitor the level of garbage in biodegradable as well as non biodegradable compartment of the dustbin..
4. Segregation of non-biodegradable is monitored by proximity inductive sensors and capacitance proximity sensors fixed under the conveyor belt.
5. The inductive proximity sensor detects the metal object without any physical contact with the object which is fixed under the conveyor belt.
6. The capacitance proximity sensor can be used for sensing the plastic as well as wood and is located below the conveyor belt.

The data from the various sensors is collected by Raspberry pi and then sends messages according to the programming and performs the required action. The data at various stages is also monitored on the mobile as well as ad fruit IO GUI. Adafruit.io is a cloud service and can be connected to the Internet. It is used for storing and then retrieving data.It connect the two web services. It also makes storing data useful. With the help of dashboard features we can visualize the data. Messenger service is used to send the alert message to the concern officer

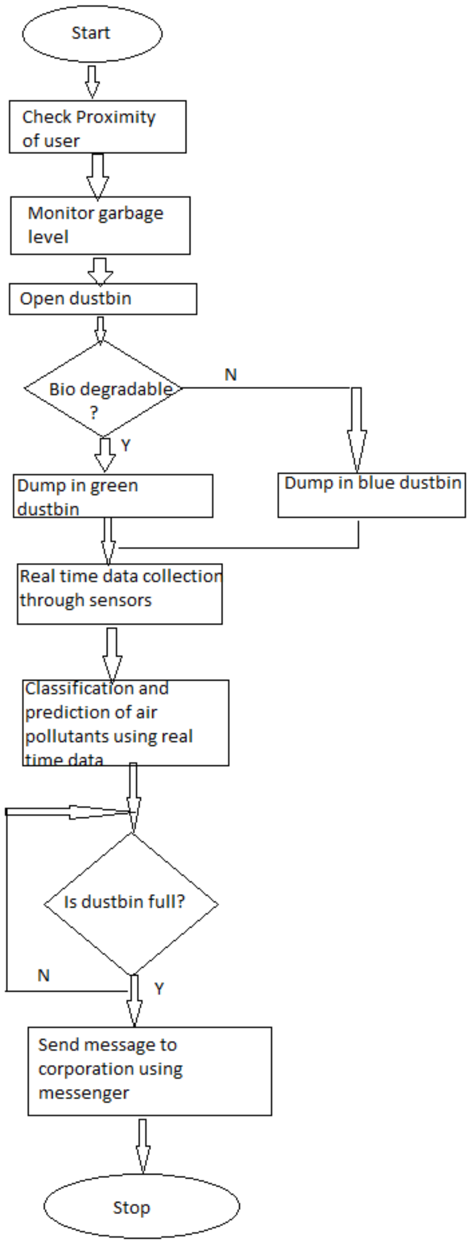

Figure3: Flowchart of proposed work

Figure 3 shows flowchart of the proposed work. The steps to achieve proposed work are mentioned below:

- Checks the proximity if someone comes near the dustbin
- Two types of dustbins can be placed - one for Biodegradable(Green) and other for Non-biodegradable(Blue)
- Garbage level is monitored
- Dustbin will be opened.
- Checks if the garbage is biodegradable or not.
- If biodegradable then user will dump the garbage in to green dustbin
- If is it non-biodegradable, user will dump the garbage in the blue dustbin
- Real time data is collected and monitored using sensors and based on the prediction of air pollutants can be done using KNN machine learning algorithm.
- If the dustbin is full, message is sent through google messenger

For Biodegradable waste the following procedure can be done for making compost: Composting is a biological process in which micro-organisms like fungi and bacteria, convert degradable organic waste into humus-like substance . Vermicomposting has become very popular in the last few years. In this method, worms are added to the compost and it helps to break the waste. Preferably the pit should be lined with granite or brick to prevent nitrate pollution of the subsoil water, which is known to be highly toxic. Each time an organic matter is added to the pit it should be covered with a layer of dried leaves or a thin layer of soil that allows air to enter the pit thereby preventing bad odor. At the end of 45 days, the rich pure organic matter is ready to be used[16].

Non biodegradable waste can be segregated into metals , plastic or glass using a conveyor belt. These waste can be segregated and placed in various coloured dustbins, few of the color codes and given below in the figure.

Figure 4: Waste Management Color Code

V. Advantages

- It will stop overflowing the dustbins along roadsides and localities as bins are managed in real time.
- It also aims at a clean as well as green environment around our society.

VI. Conclusion and Future Scope

The purpose of this paper is to make the society a smart society which is environmentally sound and healthy. Waste management system using IOT and machine technique helps in monitoring the levels of biodegradable waste and non-biodegradable waste. This technique uses a machine learning algorithm (KNN) to send alert messages to concern authority. It also segregates the societal waste and minimizes the actual waste by recycling biodegradable waste to make compost .

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