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Next-Gen IoT Smart Waste Bin with Ultrasonic-IR Sensing and Real-Time Location Alerts

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ABSTRACT

Garbage bins remain uncollected for long periods of time putting the lives of marketeers at risk in an event that there is Cholera outbreak especially during the rainy season. This happens because the Kitwe City Council does not have a system that monitors the garbage levels and notifies the Central Office. In order to avoid such a situation, this project proposes the design and implementation of a GPS and IOT Based Garbage and Waste Collection Bin Overflow Management System using GPS and IOT technology in providing real time information on the status of the garbage bins, i.e. when they are full so that appropriate action can be carried out. The GPS-enabled smart trash management system with real-time location tracking describes a modern waste management solution. The system uses GPS technology to monitor and manage trash disposal efficiently. Real-time location tracking enables waste collectors to optimize routes and schedule pickups, reducing operational costs and environmental impact. The system's smart features enable automated notifications, ensuring timely waste collection and reducing overflow issues. By utilizing advanced technology, this system aims to enhance waste management practices and promote sustainability in urban environments. The system notifies the person (Truck Driver) in charge of garbage collection by sending alerts into the IOT server and telling them where the full bin is exactly located. This development will ultimately save a lot of time especially when the council does not have to go and check the level of garbage in the bin. Besides, it will timely prevent the overflow of garbage due to the fact that garbage will be collected on time.

Key words: Internet of Things (IoT), Global Positioning System (GPS), Smart Waste Management, Garbage Bin Monitoring, Real-Time Location Tracking, Waste Collection Optimization, Sensor-Based Monitoring, Smart City Applications, Overflow Detection, Route Optimization, Environmental Sustainability, Wireless Communication.

1. INTRODUCTION

We are living in an age where tasks and systems are fusing together with the power of IOT to have a more efficient system of working and to execute jobs quickly! With all the power at our finger tips this is what we have come up with.The Internet of Things (IoT) shall be able to incorporate transparently and seamlessly a large number of different systems, while providing data for millions of people to use and capitalize. Building a general architecture for the IoT is hence a very complex task, mainly because of the extremely large variety of devices, link layer technologies, and services that may be involved in such a system. One of the main concerns with our environment has been solid waste management which impacts the health and environment of our society. The detection, monitoring and management of wastes is one of the primary problems of the present era. The traditional way of manually monitoring the wastes in waste bins is a cumbersome process and utilizes more human effort, time and cost which can easily be avoided with our present technologies. This is our solution, a method in which waste management is automated. This is our IoT Garbage Monitoring system, an innovative way that will help to keep the cities clean and healthy. Today main issue for pollution is Garbage Overflow. It creates unhygienic condition for the people and creates bad smell around the surroundings this leads in spreading some deadly diseases & human illness.

To avoid all such situations we are going to implement a project called IoT Based waste management using smart dustbin. Implementation is done with the help of IoT concept. The Internet of Things (IoT) is a concept in which surrounding objects are connected through wired and wireless networks without user intervention. Objects communicate and exchange information. In this system multiple dustbins are located throughout the city or the Campus, these dustbins are provided with a sensor which helps in tracking the level and weight of the garbage bins and a unique ID will be provided for every dustbin in the city so that it is easy to identify which garbage bin is full. When the level and weight of the bin reaches the threshold limit, the device will transmit the reading along with the unique ID provided. In order to avoid the decaying smell around the bin harm-less chemical sprinkler is used which will sprinkle the chemical as soon as the smell sensors detect the decaying smell. Once the bins are full then user will not be able to access the bins. In such circumstances the bin displays the direction of the nearby bins on LCD display also generate the voice messages if the user place the waste on the floor. The status of the bin is accessed by the concerned authorities from their place with the help of Internet and an immediate action will be taken to replace overflowing bins with the empty bins.

2. LITERATURE SURVEY

The idea of smart garbage bins and systems have been in discussion for quite a long time. The technologies used at disposal to develop this smart system have also evolved, Internet of Things (IoT). Each idea seems to be similar but is slightly different at its core and our proposed work is no exception from the same. After the IoT field, finding its hold in our lives, this is our original plan for designing a smart garbage collection system which has provision for citizen participation and analysis of data for better decision making. At hardware level, the smart system is a garbage bin with IR sensor, a micro-controller and Wi-Fi module for transmission of data. The worldwide implementation of Internet of Things is possible with a Cloud centric vision. This work exploits the future possibilities, key technologies and application that are likely to drive IoT research. But a strong foundation to our work is provided, where the basics and applications of ESP32 board is explained . It is quite interesting as it implements a GAYT (Get As You Throw) system concept as a way to encourage recycling among citizens. As we would discuss further, the citizen participation part of our system is quite influenced by their work Solid waste management (SWM) is the process of collecting, handling, and disposing of no longer in use solid objects that are discarded[1]. In today's world, typical solid waste management includes large outdoor waste bins, waste pickup trucks, and scheduled pickup routine by the related party. Manaf et al. [2] explain that solid waste is categorized into three categories, each is handled by different authorities. the categories of solid waste and the related party that's responsible for handling the waste. In London, solid waste collection is carried out based on selective collection requirements. Different color of garbage bags and/or garbage bins are used for different categories of solid waste. The examples of this color categorization are the yellow container for hospital waste, the red container for toxic waste and black container for household waste [3]. Pardini et al.[4] On the other hand, smart solid waste management system (SSWMS) is a smart system that links smart waste bins (as smart objects) to web-based and/or mobile-based application through cloud servers using Internet-of-Things (IoT) technologies [12]. IoT allows traditional, physical objects to communicate among each other by transforming them into "smart objects" using several essential technologies such as embedded devices, sensor networks, and Internet protocols [13]. The overall concept of IoT is depicted in Figure 1 which shows an example of domains suitable for IoT services. In a SSWMS, the smart waste bins are integrated with several sensors (e.g., proximity sensor, weight sensor, temperature sensor, etc.). Example of working

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smart waste bin is produced by ZAN Compute Inc. called Smart Garbage Bin, as patented by Shahabdeen[14]. These sensors then collect related real-time data regarding the solid waste inside the bin before the microcontroller embedded on each bin transfer the data to Cloud servers. Next, the Cloud servers communicate with specially developed mobile-based and/or web-based applications for monitoring and management purposes.This SSWMS is important as its efficiency is proven to be better than the traditional waste management procedures. The aim of this system is to assist the waste management team to carry out their work more efficient in terms of (but not limited to) monitoring, scheduling and cutting operational cost. For example, the implementation of Bigbelly Solar Waste &Recycling System (BSWRS) in smart cities such as Hamburg and New York City has managed to help these cities reducing their number of waste pickups up to 80% while also reducing the waste collection costs around 75% [15].There is no universal solution on how SSWMS should be planned and implemented as it is a complex task. Therefore, several factors and aspects need to be considered and analyzed. IoT is an integral part of any development and implementation of SSWMS. According to Dorsemaine et al.,[16]Internet-of-Things (IoT) is a group of infrastructures interconnecting linked objects and permitting their management, data mining and access to the information they generate. The interconnection between objects is realized by having an Internet connection and/or cloud server as its gateway. To understand the IoT concept further. Components of IoT Component Examples IoT Identification Object ID, object's address IoT Sensing Smart actuators, sensors, wearable sensing devices IoT Communication 6LOWPAN IoT Computation Fog Computing IoT Semantics Extraction of knowledge wisely by different systems IoT Services Identity-related services, collaborative-aware services, ubiquitous services, information aggregation services SSWMS is one of many services that any Smart City can implement in order to provide an environment that is more sustainable.

3. PROPOSED SYSTEM

The proposed IoT-enabled smart monitoring and automation system is designed to perform real-time sensing, data processing, remote communication, and automatic control operations for intelligent waste management and monitoring applications. The overall architecture consists of sensing modules, communication interfaces, processing units, and actuator components interconnected through an embedded control framework, as illustrated in Figure 1. The system operation begins with the setup phase, where the microcontroller configures the input and output pin modes, initializes the 16×2 LCD display, and establishes Wi-Fi connectivity for IoT communication with the remote server. After initialization, the system continuously executes the main loop operation to monitor sensor inputs and control system behavior dynamically.

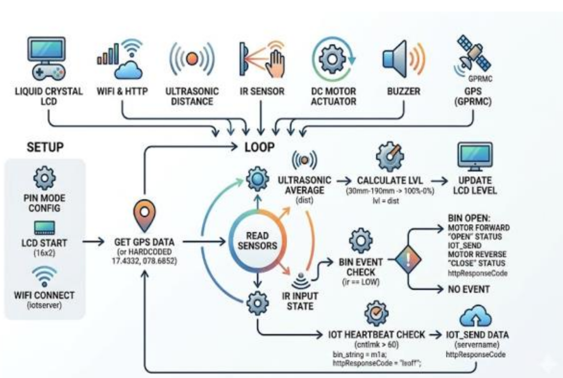

Figure 1 : The proposed IoT-enabled smart monitoring and automation system

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The architecture integrates multiple hardware modules including an ultrasonic distance sensor, IR sensor, GPS module, DC motor actuator, buzzer alert system, LCD display, and Wi-Fi communication interface. The ultrasonic sensor continuously measures the distance level inside the monitoring container and calculates the fill level percentage based on the measured distance values. Simultaneously, the IR sensor detects the presence of objects or user interaction events near the system, which helps determine bin activity and event triggering conditions. The GPS module provides real-time location information using GPRMC data, enabling location-based monitoring and tracking functionalities. All sensed information is processed by the embedded controller, which acts as the central processing unit responsible for sensor data acquisition, decision-making, and actuator control.

Based on the sensor readings and event conditions, the system performs automatic control operations using the DC motor actuator to open or close the bin mechanism. If an object detection event is identified by the IR sensor, the controller activates the motor in the forward direction to open the bin and later reverses the motor operation to close the bin automatically after a predefined condition is satisfied. The buzzer module is used to generate audio alerts and notifications during important operational events or abnormal conditions. The LCD display continuously updates the system status, fill level information, and operational messages for local monitoring purposes. In addition, the Wi-Fi and HTTP communication modules enable IoT-based cloud connectivity, allowing the system to transmit sensor data and operational status to a remote monitoring server. The IoT heartbeat checking mechanism continuously verifies communication availability and periodically sends monitoring data to the cloud platform for real-time remote supervision and analytics. Overall, the proposed architecture provides an efficient embedded IoT automation framework capable of intelligent monitoring, automated control, remote data transmission, and real-time smart waste management operations.

4. RESULTS AND DISCUSSION

The proposed IoT-based smart waste bin system was successfully implemented and tested under different operating conditions. The ultrasonic sensor accurately monitored the garbage fill level, while the IR sensor effectively detected user presence and triggered automatic lid operation through the DC motor. When the bin reached the predefined threshold level, the ESP32 controller transmitted real-time alerts along with GPS coordinates to the IoT server, enabling efficient monitoring and timely waste collection. The LCD display continuously provided fill-level information and system status, while the buzzer generated alerts during critical events. Experimental results demonstrated reliable sensor performance, accurate location tracking, and seamless wireless communication, thereby reducing manual inspection efforts and improving the overall efficiency of waste management operations.

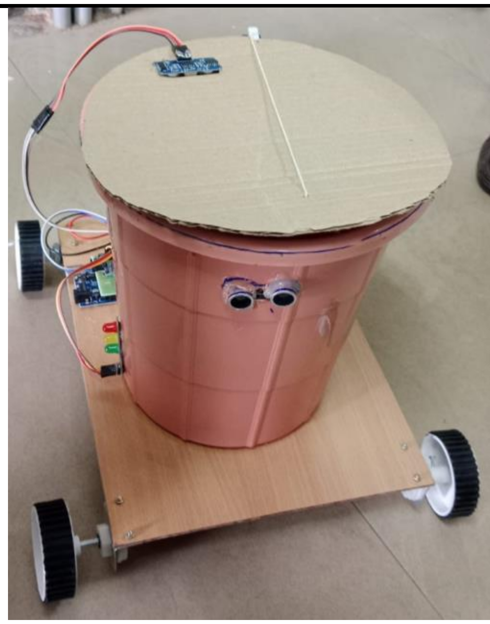

Figure 2: Prototype Implementation of the IoT-Based Smart Waste Bin System

Figure 2 shows the developed prototype of the proposed IoT-based smart waste bin system. The prototype consists of a waste collection bin mounted on a mobile platform integrated with an ultrasonic sensor positioned on the front side for monitoring the garbage fill level. The system incorporates an ESP32 microcontroller, Wi-Fi communication module, indicator LEDs, and a motorized mechanism for automated operation. The circular lid at the top represents the smart bin cover, which can be controlled automatically based on sensor inputs. The mobile base with wheels demonstrates the concept of efficient waste transportation and collection, while the embedded electronics enable real-time monitoring, GPS-based location tracking, and IoT server communication. The successful hardware implementation validates the feasibility of the proposed smart waste management system for intelligent and automated garbage collection applications, as illustrated in Figure 2.

Figure 3: Automatic Lid Operation and Ultrasonic-Based Smart Waste Bin Prototype

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Figure 3 illustrates the developed IoT-based smart waste bin prototype during its automatic lid-opening operation. The ultrasonic sensor mounted on the front side of the bin detects the presence of a user or object and triggers the motorized mechanism to open the lid automatically, enabling contactless waste disposal. The prototype integrates an ESP32 microcontroller, indicator LEDs, and wireless communication modules for real-time monitoring and control. The green status LED indicates normal system operation, while the sensor continuously monitors bin activity and garbage levels.

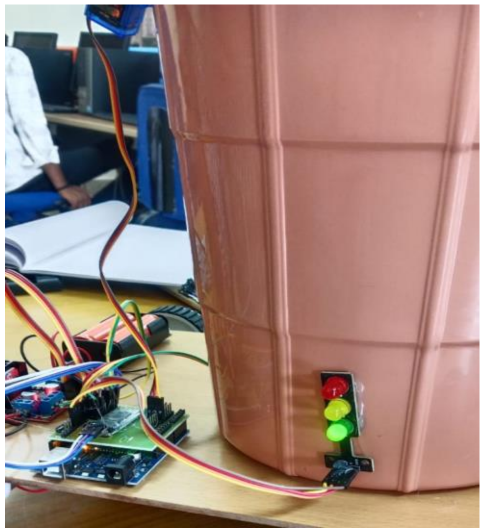

Figure 4: Status Indication and Embedded Control Unit of the IoT Smart Waste Bin

Figure 4 presents the embedded control section of the proposed IoT-based smart waste bin system, highlighting the status indication module and microcontroller interface. The prototype incorporates a three-color LED indicator system that visually represents the garbage fill level and operational status of the bin, where the green LED indicates normal operation, the yellow LED signifies a medium fill level, and the red LED alerts when the bin approaches or reaches its maximum capacity. The control circuitry, including the ESP32/Arduino-based processing unit and communication interfaces, is responsible for acquiring sensor data, processing fill-level information, and transmitting updates to the IoT server. The real-time status indication enables quick local monitoring, while the integrated wireless communication module supports remote supervision and timely waste collection. This implementation enhances operational efficiency by providing both visual and IoT-based alerts for intelligent waste management applications.

5. CONCLUSION

The system is able to monitor the garbage level in the bin, avoid the overflow of garbage by notifying the collector via an IoT message and give the precise location. The system provides an efficient and effective way of garbage collection. this project proposes the design and implementation of a GPS and IOT Based Garbage and Waste Collection Bin Overflow Management System using GPS and IOT technology in providing real time information on the status of the garbage bins, i.e. when they are full so that appropriate action can be carried out. The GPS-enabled smart trash management system with real-time location tracking describes a modern waste management solution. The system uses GPS technology to monitor and manage trash disposal efficiently. • Inclusion of the control room will effectively help monitor the garbage level from the Central Office • Integrating the system with an application based website to have an exact location on the map. In this project we designed automatic alerts to garbage collection team using IOT

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server alert. That is, the council will collect garbage only when it is time to do so rather than routine where even half-full bins are collected.

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