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Smart Waste Collection System Using Mobile App

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ABSTRACT

The creation and management of solid waste, which is generally separated into hazardous and non-hazardous waste, is one of the most challenging environmental concerns. However, managing the process of collection remains a challenge. This study aims to develop a smart waste collection system for proper management of waste. An internet of things (IOT) based device was attached to the waste bin to measure the level of waste and transmit data automatically to the database and send SMS for waste collection, using ultrasonic sensor, Arduino microcontroller, and SIM800C GSM modules A mobile App was developed using React Native and Node JS to monitor the process from the collection stage to the conversion stage. The smart waste bin subjected to three iterations of test which completed 1 cycle of loading the smart bin, result showed that when the bin level is 0cm and percentage level is 0%, the status is Empty, when the bin level is 27cm and percentage level 80.8%, the status if FULL, when bin level is 29cm and percentage level 85%, the status is FULL, and 33.5cm and when the percentage level is 99%, the status level is FULL. While on the Mobile App the CPU usage gave an average of 1.49%, making it faster to load. This study concluded that the development of the smart waste collection system helps in monitoring the collection of waste. It is therefore recommended that the development of system should be adopted by waste management agencies.

Keywords: Smart Waste, Management, Waste collection, Mobil Application, Arduino microcontroller

I. INTRODUCTION

Waste creation can take many different forms, such as gas, liquid, or solid waste, and each can be managed in a different way [1]. It may be produced in industrial, biological, domestic, and unique circumstances where it could be harmful to human health. Human activities like factories extracting and processing raw materials result in the production of waste [2]. One of Nigeria's most difficult environmental challenges is the generation of solid waste, which is broadly divided into hazardous and non-hazardous waste [3]. Solid waste is produced by a variety of activities, including household organic trash, street sweepings, hospital and institutional garbage, commercial, agricultural, construction, industrial waste, sludge, treatment plants, plastic waste, and paper waste [1]. Nigeria, with a population of 220,686,96 [4] as of March 6, 2023, is one of the largest producers of solid waste in Africa. Nigeria generates more than 32 million tons of solid waste annually[5] [6] of which the larger part of it is either plastic waste or paper waste. This research focuses on paper waste. According to environmental statistics in Nigeria, 12.9 million tonnes of paper waste are generated annually, and only 25% of them are recycled or converted [7].

In recent years, there has been a persistent rise in the number of mobile devices due to the evolution of mobile technology. As of the year 2024, there were approximately 5.61 billion unique mobile subscribers out of which 66.2 percent (66.2%) were smartphone device [8] as compared to the year 2019 where the approximate number of unique mobile customer was 4.7 billion [9]. The advancement in the mobile industry has led to the using mobile device in waste management [10] for easy associability. In addressing the poor processes of waste collection adopting the mobile technology in waste collection process can go a long way to achieved the goal. This study aim at developing a smart waste collection system using mobile app.

II. OVERVIEW OF WASTE MANAGEMENT

Waste management has not been an exception to the procedures that have been streamlined and automated by smart city technology, and as a result, the industry has seen significant internet of things-based innovation. [11] asserts that the collection, processing, energy recovery, and disposal stages of the traditional waste management value chain will be the key beneficiaries of smart technologies. Waste management has been a topic of interest in operations research and has been shown that optimized route planning and scheduling in waste collection can lead to significant cost reductions [12].

As a result, the primary driver behind the development of intelligent waste collection systems has been route optimization. A radio frequency identification (RFID)-based monitoring solution is provided in [13], one of the first studies in smart bin monitoring. The system estimates the weight of the garbage cans' collected contents using load sensors, and then transmits that information to the collector's pocket computers (PDA).

A. Solid Waste (SW)

Any trash, junk, refuse, or abandoned materials that have "no economic value" or use for anyone are referred to as solid waste (SW) [14] . SW is broadly defined as any non-hazardous waste, or garbage, produced by various activities, including household waste, organic waste, street sweepings, hospital and institutional waste [15], commercial, agricultural, construction, and industrial waste, as well as the sludge produced by waste treatment facilities.

SW may be organic or inorganic (recyclable or non-recyclable) materials created by a variety of social activities that no longer have value to the original user. Depending on the kind and volume of consumption in each community, the SW components vary from one to the next. Examples include the rise in the amount of plastic and metal waste in urban areas and the rise in organic waste in rural areas. At both the local and global levels, improper disposal of SW contaminates all the essential elements of the living environment (air, land, and water). At the global, regional, and local levels, SW is an issue that is always becoming worse[16].

Residential, commercial, institutional, construction and demolition areas, municipal services, treatment plants and sites, agricultural, and biomedical are common categories into which solid wastes are broken down. [17]

1) Residential: The majority of solid waste comes from residences and dwellings where people live. Food waste, plastics, paper, glass, leather, cardboard, metals, yard debris, ashes, and special wastes including large home objects like electronics, tires, batteries, old mattresses, and used oil are all included in the garbage from these locations. Most homes have trash cans where residents can dispose of their solid wastes. A garbage collection business or individual then empties the can so it can be treated.

2) Industrial: One of the main sources of solid waste is recognized to be industry. Construction sites, fabrication factories, canning plants, power plants, and chemical plants are among them. They also comprise light and heavy manufacturing enterprises. These businesses generate solid waste in the form of ash, construction and demolition waste, special waste, medical waste, and other hazardous wastes.

3) Commercial: Today, commercial buildings and facilities are additional producers of solid waste. In this context, "commercial structures and facilities" includes lodging establishments, shops, dining establishments, and office buildings. Plastics, food scraps, metals, paper, glass, wood, cardboard materials, special wastes, and other hazardous wastes are only a few of the solid wastes produced in these locations.

4) Institutional: Solid waste is also created in institutional settings such government buildings, jails, military barracks, and educational institutions. Glass, rubber waste, plastics, food waste, wood, paper, metals, cardboard, electronics, and various hazardous wastes are a few of the main solid wastes that can be found here.

5) Construction and Demolition Areas: Sites of construction and demolition also add to the issue of solid waste. Sites for new building and road construction, road maintenance, and building refurbishment are all included in the construction and demolition category. Steel, concrete, wood, rubber, plastics, wires made of copper, glass, rubber, plastics, and rubber are only a few of the solid wastes generated in these locations.

6) Municipal services: The solid waste dilemma that exists today in the majority of nations is also greatly exacerbated by urban areas. Street cleaning, garbage from parks and beaches, wastewater treatment facilities, landscaping wastes, and waste from recreational areas are some of the solid wastes produced by municipal services.

7) Treatment Plants and Sites: Both light and heavy manufacturing facilities generate solid waste. Refineries, power plants, processing facilities, mines, and chemical plants are among them. These facilities produce a variety of wastes, including industrial process wastes, undesirable goods that don't meet specifications, polymers, and metal components, to name a few.

8) Agriculture: Other sources of solid waste include feedlots, vineyards, dairies, orchards, and crop farms. Agricultural wastes, damaged food, pesticide containers, and other dangerous materials are some of the trashes they produce.

9) Biomedical: Hospitals, biomedical equipment, and chemical production companies are all mentioned here. Several kinds of solid waste are created in hospitals. Syringes, bandages, used gloves, pharmaceuticals, paper, plastic, food scraps, and chemicals are a few examples of these solid wastes. All of these need to be disposed of properly or they will have a serious negative impact on both the environment and the residents of these facilities. [18].

B. Solid Waste Management

Solid Waste Management (SWM) is defined as the application of techniques to ensure an orderly execution of the various functions of collection, transport, processing, treatment, and disposal of municipal solid waste [19]. Municipal solid waste management (MSWM) encompasses planning, engineering, organization, administration, financial and legal aspects of activities referring to the generation, storage, collection, transfer and transport, processing, and disposal of municipal solid wastes (household garbage and rubbish, street sweepings, construction debris, sanitation residues, etc.) in an environmentally compatible manner adopting principles of economy, aesthetics, energy, and conservation [20]

According to Ramachandra in [21] solid waste management is concerned with keeping waste generation under control as well as its storage, collection, transfer, and disposal. This is done while adhering to the best practices for public health, economics, engineering, conservation, aesthetics, public opinion, and other environmental considerations. Choosing and implementing the proper technical solutions for garbage collection, transfer, recycling, and disposal is a difficult undertaking that requires coordination and cooperation between individuals, groups of people, private businesses, and municipal authorities [22], [23].

III. SMART WASTE COLLECTION MODEL

The smart waste bin system and model consists of hardware, backend, and mobile App as shown in Figure 1 and Figure 2.

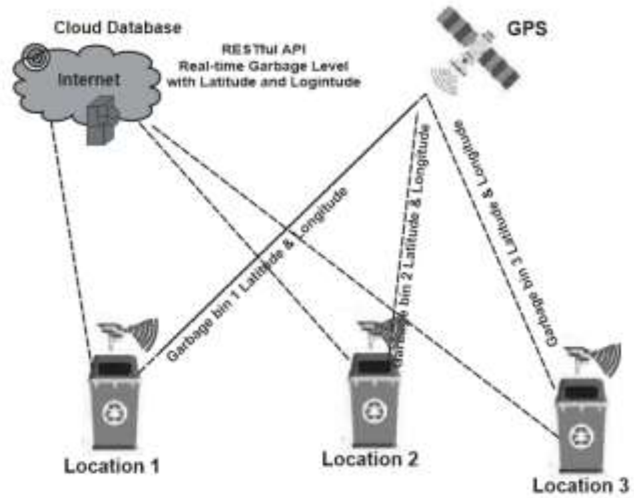

Figure 1. Smart Waste Bin system (Researcher's Model)

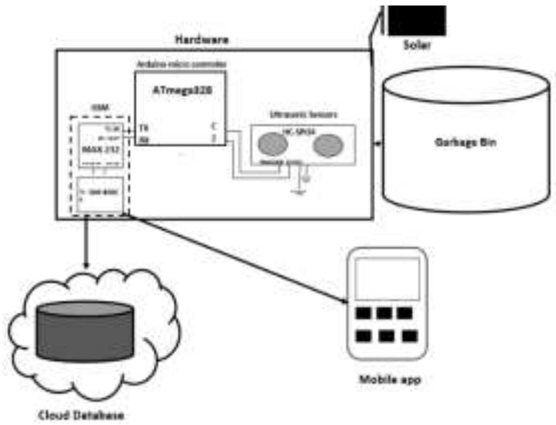

Figure 2. Smart Waste Collection System Model (Researcher's Model)

The hardware: A microprocessor, an HC-SP04 ultrasonic sensor, a SIM800C GSM module, a solar panel, and a resistor make up the hardware. The ATmega328 contains 6 analog inputs, an inbuilt resonator, a reset button, 14 digital input/output pins (of which 6 can be used as PWM outputs), and mounting holes for pin headers. It is a microcontroller with 16 bits. Two 16-bit and one 32-bit timer/counter are included. The ultrasonic sensor HC-SR04 is connected to the microcontroller using timer 1. Moreover, this microcontroller has Tx and Rx ports for serial connection. With the built-in MAX 232IC found at the GSM module, these pins are connected to the device. As illustrated in figure 3.1, the ATmega328 microcontroller uses TTL logic whereas the GSM module runs at RS232. MAX 232IC is used to convert the logic from TTL to RS232.

The Backend: The backend offers an interface via which cloud database management businesses make computing resources, including memory and computation, available. The online database management system is utilized to save the trash level record for later use.

The Mobile App: The phone serves as an interface via which waste management staff or the garbage analyzer receives a warning or alert from the trash can, prompting the filled-level warning and the requirement for the trash collection team to remove the trash from the cans.

A. Flowchart Diagram for Smart Waste Bin

Figure 3 is the flowchart representing the Smart waste collection system.

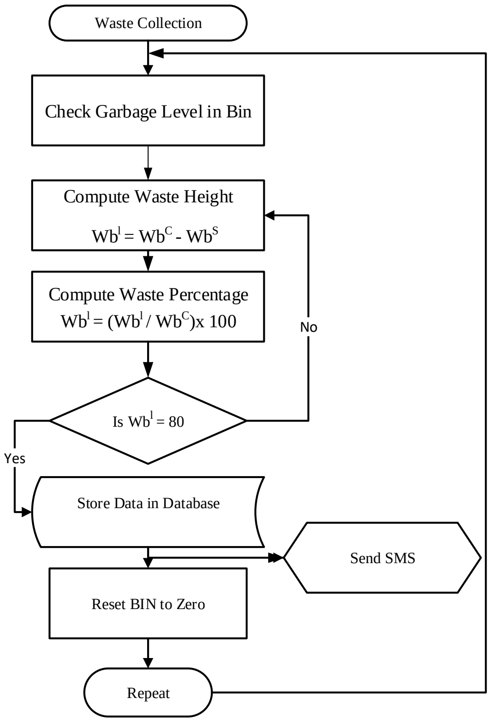

Figure 3. Flowchart Diagram for Smart Waste Bin

B. Smart Waste Bin Use Case Diagram

This diagrammatically represents all actions that can be performed by the smart waste collection system. The use case is shown in Figure 4.

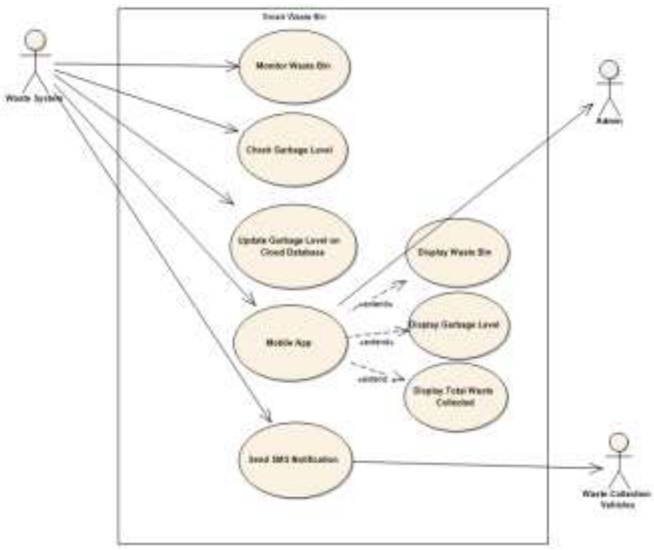

Figure 4. Use Case Diagram for the Smart Waste Bin

IV. IMPLEMENTATION OF THE SMART WASTE COLLECTION SYSTEM

Figure 5 and 6 shows hardware implementation of the smart waste bin. The hardware device for the smart waste bin is placed at the top of the bin in order to measure the level of garbage filled in the waste bin. The waste bin is having two levels which are listed as follows EMPTY level and FULL level. EMPTY level is equal to 0%, and the FULL level is between 80% to 100%. The monitoring and measurement stages is divided into four. The first stage of the smart waste bin is the combination of ultrasonic sensor, GSM module and Arduino microcontroller generate a unique ID and then INSERT into a document on the cloud database.

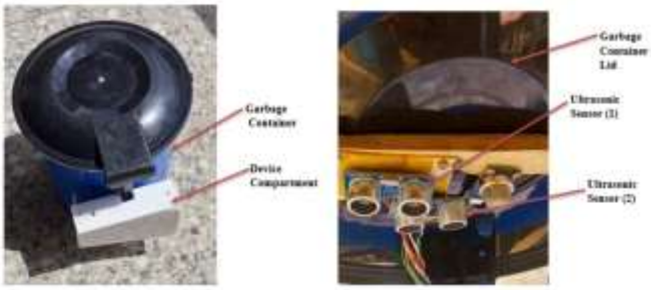

Figure 5. Smart Waste Bin

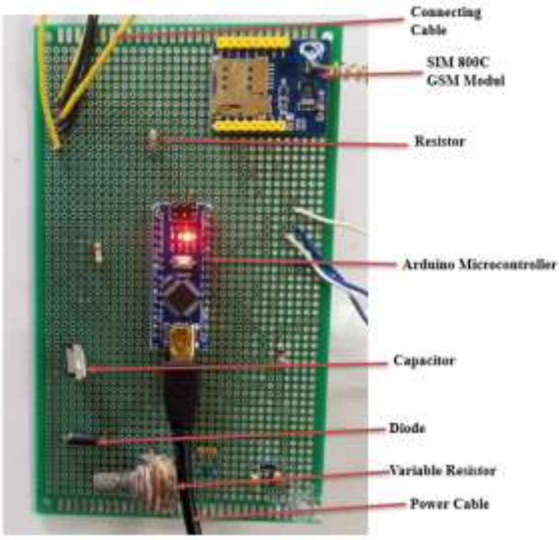

Figure 6. Smart Waste Bin Monitoring Device

C. Hardware Testing for the Smart Waste Bin

Three (3) test were carried out on the system which completed 1 cycle of loading the garbage bin, in Babcock University Ilisan Remo Ogun State as show in Figures 7, 8, 9 The empirical outcome of the test is shown in Table 4.2, 4.3, 4.4 and 4.5 representing the filling level of the ultrasonic sensor place at the top of the bin. The garbage level with respect to height was tested. When the bin was empty the height was Zero present “0%”, gradually we loaded the bin with garbage, at a point when the bin was full an SMS was sent to the phone notifying the garbage level is full. The height of the bin is 34cm and equation 4 was used to calculate the percentage level.

Figure 7. Experiment test one (1) on Smart Waste Bin

Figure 8. Experiment test one (2) on Smart Waste Bin

Figure 9. Experiment test one (3) on Smart Waste Bin

TABLE I

Experiment one (1) data from several tests run of the prototype

Test	Bin Height (cm)	Bin Space (cm)	Bin Level (cm)	% Level	Status
1	34	34	0	0	Empty
2	34	7	27	80.8	FULL

TABLE III

Experiment two (2) data from several tests run of the prototype

Test	Bin Height (cm)	Bin Space (cm)	Bin Level (cm)	% Level	Status
1	34	34	0	0	Empty
4	34	5	29	85	FULL

TABLE III

Experiment three (3) data from several tests run of the prototype

Test	Bin Height (cm)	Bin Space (cm)	Bin Level (cm)	% Level	Status
1	34	34	0	0	Empty
5	34	0.5	33.5	99	FULL

TABLE IV

Experiment one (1) data from several tests run of the prototype

Experiment	Bin Level (cm)	%Level	Status
1	0	0	Empty
2	27	80.8	FULL
4	29	85	FULL
5	33.5	99	FULL

CONCLUSION

In conclusion, it is possible to achieve a more efficient system than the existing ones by using sensors to monitor the fullness of bins. Our idea of "a smart waste collection system using mobile App", mainly concentrates on managing the collection waste. By implementing this project, the environmental condition in the urban and rural areas of the country will be improved.

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