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Development of an Improved Solid Waste Management System in Nigeria Using Smart IOT Devices

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ABSTRACT

Rapid rise in inhabitants across the globe has led to the inadmissible management of waste in various countries, giving rise to various health issues and environmental pollution. Waste management is a daily task in urban areas, which requires a large amount of labour resources and affects natural, budgetary, efficiency, and social aspects. Many approaches have been proposed and implemented in developed countries to optimize waste management, such as smart waste in and route optimization. However, these technologies are still new in developing countries and have been implemented fully. The waste-collecting trucks collect waste just once or twice in seven days. The poor and improper disposal of waste produces toxic gases, and radiation in the environment, which has adverse effects on human health. The agency managing waste in Nigeria lack proper coordination to ensure better result. These challenges motivated this research. The research develop an improved solid waste management system using IoT sensors. The robust web-based system, coordinate and manage all the trucks, drivers and revenue generated from waste disposal to ensure better result when compared with existing method. The methodology adopted for this system is Object Oriented System analysis and designed (OOAD) methodology for the web based system, and Embedded C++ is used for the algorithm that controls the sensor reading. However, the MQ5, MQ7, MQ135 and Load cell sensors were used for dumpsite monitoring. While Ardunino Controller and Sim808 Gate way are used for System connection and transmission. The result from the simulated work, shows that air quality and waste bin level can monitored concurrently, which boost the efficiency of the new system. Moreover, the incorporation of load cell sensor at the dumpsite also help the regulatory body to computing the efficiency of the evacuation process of truck drivers. The readings of gas sensors on air quality from simulated environment were compared with six-membership performance index (MID) of WHO air quality standard. The result shows that the simulated dumpsites were able to capture five out of the six MID. This represents 83.33% compliance to the WHO standard. The Improved solid waste management system developed in this work will help for proper coordination of waste collection and disposal, to ensure a clean and healthy environment that provides transparency in the business of waste management upon its implementation

Keywords: Development, Solid Waste, Management, Smart and IOT Devices

INTRODUCTION

Modern-day waste managers in cities all over the world face unprecedented levels of Municipal Solid Waste (MSW) as human populations grow. Various home activities generate garbage that must be

properly handled, stored, collected, and disposed of to protect the environment and public health [1]. The rise of the middle-class families contributed to increased solid waste generation and management concerns. New technology and commercial models are improving garbage management. Managing domestic waste refers to the proper handling and disposal of household waste materials. Current challenges and issues in domestic waste management include the lack of proper waste segregation and recycling facilities [2]. The increasing population and urbanization have resulted in a significant rise for waste generated, putting strain on existing waste management systems. WHO estimates that in 2019, some 37% of outdoor air pollution-related premature deaths were due to ischemic heart disease and stroke, 18% and 23% of deaths were due to chronic obstructive pulmonary disease and acute lower respiratory infections respectively, and 11% of deaths were due to cancer within the respiratory tract. Nigeria as one of the developing countries is not left out. Developments in technology systems have allowed waste managers to use data sources such as Global Positioning Systems (GPS) and Geographical Information System (GIS) systems to make the waste collection more efficient with mapping and path optimization [3]. The challenges identified necessitated this research, hence the need to have a better solution to manage the waste problems. The research tends to address the challenges by developing an improved IoT waste management system that will ensure proper coordination of waste collection and disposal activities in order to reduce the health risk of incessant dumping of waste.

AIM AND OBJECTIVES

The aim of this research was to develop an improved solid waste management system using IoT Devices. Specific objectives are to: develop a customized web-based system for waste management; develop database for data manipulation and storage; develop algorithm for data acquisition, transmission and analysis from IoTs at dumpsites; integration of gas and load cell sensors for monitoring of air quality and waste bin level respectively at dumpsites, and to develop equation for computation of waste evacuation efficiency of truck drivers.

METHODOLOGY

The methodologies used in this work are: Object oriented analysis and design methodology with HTML5, CSS, JavaScript, Nodej and Ajax was used for both front and backend design of the customized web-based system. MySQL database was used to design the database structure for data storage and manipulation. Embedded C-language and Thinkspeak API were used for development of algorithm for Data acquisition, transmission and analysis at the Cloud-based system. The IoTs Sensors used at dumpsites are MQ5, MQ7, and MQ135 for monitoring of air quality and Load cell for monitoring waste bin level. The Load cell sensor data was used to develop equation that calculates Evacuation efficiency of truck drivers.

RELATED LITERATURE

The emergency of the Internet of Things (IoT) is changing the way field data is collected for many environments. [4] define a 'smart city' as a collection of disparate smart objects, heterogeneous networks and systems which are networked together, allowing for the collection and processing of data from connected smart city assets for city managers. IoT devices are being used within smart cities environments to provide new data sets with specially designed support networks, message protocols, data distribution services and data storage. Numerous research case studies have shown that IoT devices can provide data using multiple sensors. First case study by [5] shows that it is possible to use multiple sensors on an IoT device to deliver environmental data from waste bins to waste managers. A second case study shows that raw environmental data from IoT sensors can have machine-learning algorithms applied to it, and useful predictions can be determined. The predictions allow waste managers to determine the optimal time and route for waste bin collections [6]. The recent development in the use of IoT within Smart Cities is the conceptual model of Fog (also known as Edge) computing. The idea behind the Fog model is using neighboring wireless devices (typically) to perform computational operations for the required function. Fog computing has many benefits over tradition IoT networks as much of the computing is done locally near the IoT devices. Therefore, the computing latency is reduced. As newer high bandwidth low latency networks such as 5G [7], transmitting higher volumes of data through to city managers is possible. Using IoT architecture models and smart city networks, smart city managers can govern city infrastructure by implementing new services and policies that were not previously achievable. Ultimately, IoT and smart city technologies allow managers to gain awareness of the conditions within a city that need managing through the acquisition of relevant data. IoT and smart cities bring unique sets of standards, challenges and opportunities. From the reviewed literature, the

research discovered that many researchers focus is on using IoTs to either monitor air quality or waste bin level at the dumpsites. Some researchers in developed countries researched on route optimization of waste disposal. The literature discovered that researchers have not used a hybrid technology approach (monitoring both waste bin level and air quality at dumpsites, integrated into a customized web-based system) for waste management. Moreover, the cloud-based system used by many researchers have been only on analysis of uploaded data from dumpsite. Hence, this gap necessitated this research.

ANALYSIS OF THE EXISTING SYSTEM

From the research, the existing system is a smart waste bin, which uses IoT sensor to alert the waste managers the status of the waste bin and upload the real-time data on a web-based system. Here is the analysis of the workings of the system. The analysis is on the work of [7], which uses Ultra Sonic sensor with Arduino UNO as the microcontroller to interpret data from sensors received and transmit it using an attached Wi-Fi module. Data obtained from the waste bin sensors is sent to main server/client continuously with a time interval of 3 minutes so current situation of bin can be analyzed. Data flashed on server does not only show verbal status of bin but also gives data continuously displaying data log and status of dustbin on web server. The smart waste bin does its work by gathering the real –time data from the waste bin and then processed them through Arduino UNO microcontroller. The controller then deduce the amount of garbage in bin with respect to its predefined ranges. For instance, if the height of garbage is around 30cm, then it will match it with predefined programming and will display 30 percent full on main server to client. Then It'll check again, if amount of garbage is same it will return same value but if amount of garbage is increased, let's say to 40cm, then it will display 40 percent is full and so on.

Weaknesses of the Existing System

It is obvious that there are certain factors that prevent this environmental factor from developing and flourishing. The following are the weaknesses identified on using the existing system. The system determines only the waste bins that are filled up for collection; it checks the quantity of waste at dumpsite but does not monitor the quality of air which small quantity of waste can cause environmental pollution. The focus of the system being on waste readiness for evacuation does not incorporate monitoring of the disposal van activities. The system lack proper accountability on waste truck drivers activities and payment plan. The existing system web-based does not create public-mass/Agency and Stake holders interactions. To enable individuals report issues to the stakeholders or contact them through the web-based system.

ANALYSIS OF THE PROPOSED SYSTEM

The new system aimed at improving the existing system by developing a robust IoT-web based system that will enable three (3) category of users to access the site; 1) the Web Management Agency, 2) the Government agency and 3) public individuals. The web-based system will capture all dumpsites areas within all communities, which will enable public to know areas to dump their waste. It will provide a communication channel between the waste management agency, Government Agency and public on matters concerning waste in their areas. The Waste management Agency will login to the site to view status of dumpsites, reported cases from individuals, and manage the truck driver's activities. Four (4) IoT sensors integrated for the design are: MQ5, (gas sensor for methane), MQ7 (sensor for Carbon II oxide), MQ137 (Sensor for ammonia) and a load cell sensor for checking the weight of waste bin at the dumpsites. These sensors are powered through 5V battery for monitoring and uploading real-time data from dumpsites to the cloud through Arduno Microcontroller and Sim 808 gateway.

Air-Quality Monitoring IoT Devices

Due to the presence of gases emitted from the waste dumpsite, such as methane and carbon dioxide. With small amounts of nitrogen, oxygen, ammonia, and sulfides. The three gas sensors; MQ5, MQ7 and MQ137 sensor will be mounted on the dumpsite, to monitor excess level of Methane, carbon II oxide, and ammonia respectively. Each node will have gas sensors and the load cell connected to Arduno board, and Sim 808 Gateway through the Cloud Based API.

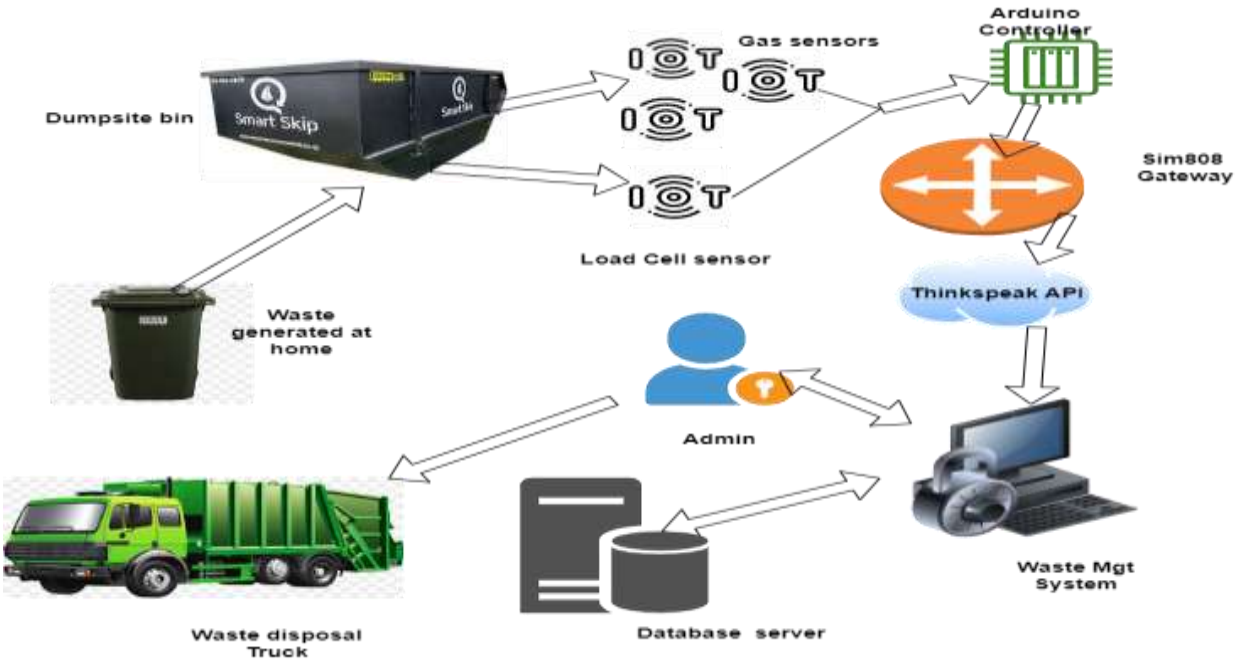

Figure 1 Architecture of the new system

RESULTS

The use of hybrid technologies (Gas sensors, Load cell sensors and a customized website) in this work shows better result when compared with the existing system which is 1out 3 of the new system, making the new system 100% better than the existing system. The use of Load cell sensor at dumpsite helps the waste management regulatory body to determine the efficiency of every disposal truck. This was achieved by using the developed equation for evacuation efficiency, which is the expected time of evacuation divided by actual time of evacuation (the result of data transmitted from Load cell sensor). The result gives 100% efficiency for the computation of work efficiency of truck drivers. Moreover, the readings of gas sensors on air quality from simulated environment were compared with six-membership performance index (MID) of WHO air quality standard. The result shows that the simulated dumpsites data captured five out of the six MID. This represents 83.33% compliance to the WHO standard. The Improved solid waste management system developed in this work will help for proper coordination of waste collection and disposal, to ensure a clean and healthy environment that provides transparency in the business of waste management upon its implementation

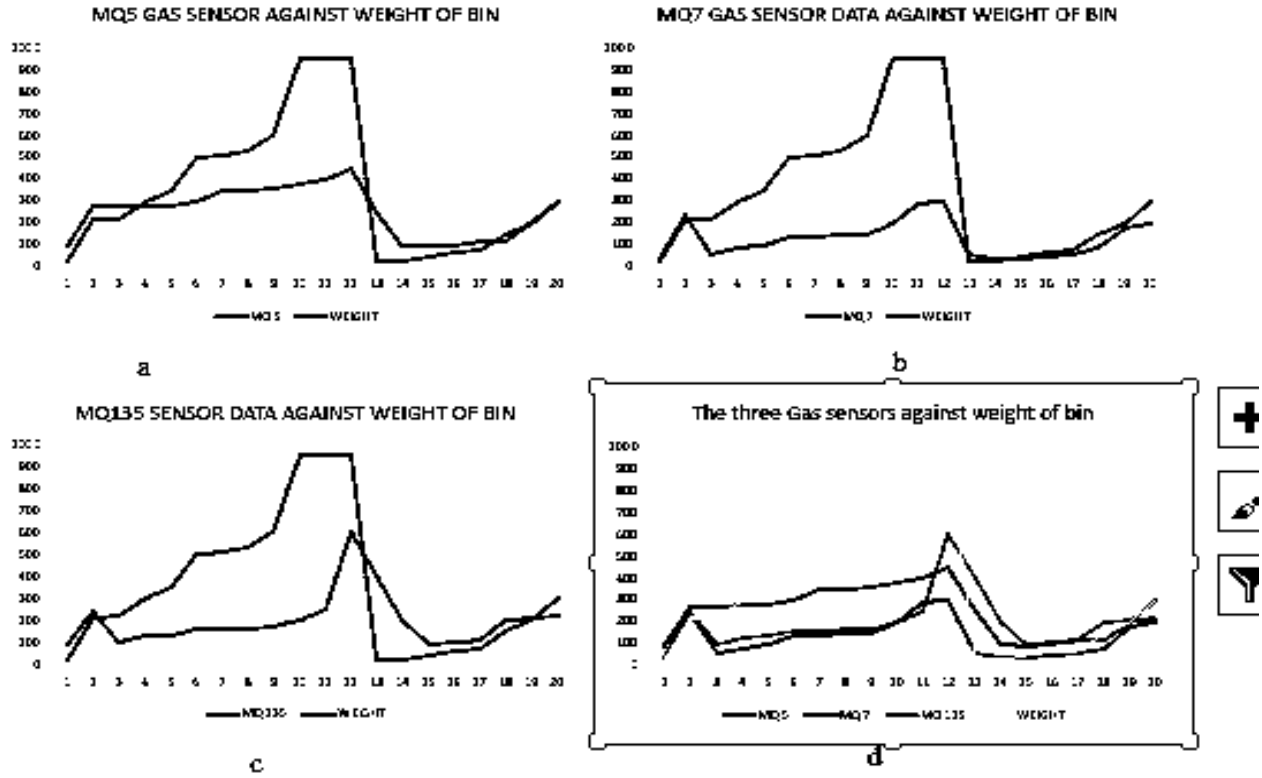

Figure 2: Graph of gas emission against level of waste in waste bin.

CONCLUSION

The result from this work shows that the use of a hybrid technology in this work proved better result because both waste bin level and air quality are monitored concurrently to determine when the air quality at the dumpsite is conducive or not. Moreover, the research also discovered that the use of load cell sensor at dumpsite served as regulatory measure in monitoring of evacuation activities of truck drivers. The data generated from the load cell sensor was used to also compute the efficiency of truck drivers to determine their reward for the job or penalty as case may be.

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