Journals Pub

International Journal of
Embedded Systems & Emerging Technologies
https://stmjournals.in/international-journal-of-embedded-systems-and-

ISSN: 2456-723X
Volume 10, Issue 1, 2024
DOI (Journal): 10.37591/IJESET

Review IJESET

Automated Garbage Bin Monitoring: An Embedded System Approach

Patrick Okot[1*], Oscar Okello[1], Geoffrey Okello[1] & Matthew Kica[1]

Abstract

Most cities today are faced with challenges of garbage management which are brought about by indiscriminate damping by the inhabitants. This has led to littering of garbage in the community hence, unhealthy living conditions. Such littering of garbage also leads to the spread of diseases. Currently municipal authorities are unable to sufficiently respond and collect the garbage due to constraints like lack of a notification system to remind them when the garbage cans are full or about to spill. This study sought to mitigate the above problems by developing an Automated Garbage Bin Monitoring System. In the system, the level of garbage is automatically detected by an ultrasonic sensor/humidity sensor and a notification is sent via SMS using a GSM connected to an Android Phone. After receiving the SMS on an application running on a Smartphone, a driver is dispatched to carry and empty the bin.

Keywords: Garbage Collection, Bin monitoring, Embedded System, SMS, Arduino, Gulu Municipality.

GENERAL INTRODUCTION

Introduction

Many times, cities and urban centers use garbage bins or dustbins placed at public places for collecting garbage. The garbage bins when filled up overflow and create unhygienic conditions for people as well as ugliness to that place leaving bad smells (Naregalkar, Krishna & Srivastava,[19]). Almost all human activities create waste in some form. Most individual items of waste, particularly wastes from homes and offices are not themselves a direct threat for public health, however it is the way these wastes are handled, stored, collected and disposed that can pose risks to public health. Clean and healthy living conditions in cities, Municipals and urban centers cannot be achieved without reliable and regular collection and disposal of generated solid waste (Aryagaruka, Otim & Kukundakwe, [4]). Uganda Constitution of 1995, Articles 39 and 41 provide that everyone has a duty to maintain and enjoy a sound environment. Every person in Uganda has a right to a clean and healthy environment and as such can bring action for any pollution or disposal of wastes

***Author for Correspondence**
Patrick Okot
E-mail: p.okot@gu.ac.ug

[1]Research scholar, Department of Computer Science, Faculty of Science, Gulu University, Uganda

Received Date: May 14, 2024
Accepted Date: June 18, 2024
Published Date: June 25, 2024

Citation Patrick Okot, Oscar Okello, Geoffrey Okello, Matthew Kica Design and Implementation of Circular Polarized Patched Antenna For 5G Applications. International Journal of Embedded Systems & Emerging Technologies2024; 10(1): 27–44p.

(Aryagaruka, [4]). According to Yashimera, Valerry & Benlot [22], today the most important subject that affects and worries mankind is the issues concerned with waste management. Waste management practices like the municipal solid-waste can differ for developed and developing nations, for urban and rural areas, and for residential, commercial, government institutions and industrial producers. Community participation has a direct bearing on efficient Solid Waste Management. The researchers are mainly concern with the social aspect of the implementation.

Background

Internet and its applications have become an integral part of today's human lifestyle. It has become an essential tool in every aspect (Naregalkar et al., [19]). Due to the tremendous demand and necessity, researchers went beyond connecting just computers into the web. These researches led to the birth of a sensational gizmo, Internet of Things (IoT). IoT, refers to the network of connected physical objects that can communicate and exchange data among themselves without the desideratum of any human intervention (Anitha, [3]). Communication over the internet has grown from user – user interaction to device – device interactions these days.

These open waste collection facilities have led to the spread of some diseases like typhoid as result of leakage finding its way to ground and surface water sources and contaminating it about these waste collection areas (Aijuka, [2]). 75% of life-years lost to premature death are due to ten preventable diseases (Sangeeta, Steve & Bonita, [20]). More to that, it is very easy for pathogen carrying organisms such as ies to get to these waste collection facilities in quest for what to feed on and move to nearby homesteads increasing the likelihood of spread of diseases to people staying around.

According to Aijuka [2], agricultural waste that result from abattoir after slaughtering animals, processing animal products and crops such as maize which generate maize cobs, fruits like mangoes whose seeds lead to infestation of the flies in the vicinity during harvest season of mangoes from majority of the city suppliers are some of the leading waste materials Industrial wastes that are generated from the industrial processes and manufacturing plants. These generate refuses which have been seen quite often join streams within the city even when they are not treated. This has led to increased toxicity in the natural water sources around town. Residential wastes, these in most cases are generated from homes after consumption of agricultural and industrial produces. He further argues that continued bad practices of solid waste management are most likely going to result into; Foul and bad odor near the storage bins, compost pits and collection centers; blocking of the drainage channels and water conveyance systems leading to waste water overflow; Leakage from solid waste has led to increased pollution of the surface and ground water. This has led to increased pathogen transmission by carrying agents because of poor disposal of the hospital wastes.

There are estimated 30,000 diarrheal deaths per year in Uganda exclusive of deaths attributed to cholera and bloody diarrhea (Bwire *et al*., [5]).

The existing problem is that most municipalities and urban centers use bins for temporary dumping of waste in a bid to maintain cleanness. However, these garbage bin points are always littered with waste due to spilling from the bins as a result of delayed collection of the garbage bin for proper disposal by the relevant authority. Towns in Uganda are able to collect only 40 percent of their garbage whereas 60 percent either rots on streets or perhaps gets washed away by running water up to wetlands and nearby rivers (Kato [14]), so there is need to develop an automated garbage monitoring system that sends an alert when the bin is full.

The main objective of the study was to develop an automated garbage bin monitoring system that informs garbage collection authorities of garbage level in bins for timely collection and neat maintenance of garbage-bin points. This was attained through; gathering requirements for the proposed system; designing of the system basing on the requirements gathered; implementing the system based on the design; and testing the effectiveness of the system.

The study was conducted in Gulu Municipality which is located in the Northern region. The study focused on 100 respondents in the bid to establish the underlying causes of poor waste management in Gulu and the study was both quantitative and qualitative in nature. The researchers reviewed documents, reports and collected data from 2015 to date. The data collected was able to illustrate whether with the

anticipation of the town becoming a city, the problem of poor waste management has reduced, remained the same or increased.

It is expected that if the purpose of the system was achieved, it would assist the community and other people in the following ways; providing real-time automated relay of garbage level in the bin to the relevant authority so that garbage gets picked up in time before it spills out; indirectly help avoid diseases like cholera, diarrhea since garbage spills in the streets will be avoided; and increased savings by individuals and government to treat such diseases above.

Literature Review

The trend of making the manually controlled things automatic has become a common practice these days. The process of making the things automatic is being exploited in almost all the major fields of life. Making things automatic reduces burden on the humans. The cost and effort used in manually controlled products is much higher than the automated systems. Considering the fact, that the problem of efficient waste management is one of the major problems of the modern times, there is an utmost need to address this problem. The proper waste management system is must for the hygienic society in general and for world as a whole. Solid waste which is one of the sources and causes of environmental pollution has been defined under Resource Conservation and Recovery Act as any solid, semi-solid liquid or contained gaseous materials discarded from industrial, commercial, mining or agricultural operations and from community activities (Ohri & Singh [1]). Many municipalities in low and middle-income countries use integrated solid waste management as the ideal principal concept for their waste management. However, different regions have different conditions that require them to determine the best approach for their situation (Klundert, [15]).

State of the Art

Waste collection is an essential city service. Ample opportunity exists worldwide for smart technology to increase efficiency and improve the quality of waste collection services. Currently, most municipal waste collection operations focus on emptying containers according to predefined schedules. This is inevitably inefficient, with half-full bins being emptied, poor use of city assets and unnecessary fleet fuel consumption [6]. However, smart waste collection solutions on the market track waste levels and provide route optimization and operational analytics. Municipalities and waste service managers are realizing that these solutions can help them meet sustainability goals (such as zero waste), improve services for residents and reduce operational costs [6]. This section presents an overview of some of the Garbage collection systems developed in recent years. The overview pays attention to functionalities and principles of operations of these systems.[12]

Smart bin is an invention, which automatically sorts rubbish into recycling categories example tins, cartons, bottles, and cardboard for recycling. The bin, designed by start-up company Bin.E, recognizes different types of waste via a system positioned inside the bin which uses sensors, image recognition and artificial intelligence. Once waste is placed inside, the camera and sensors identify its type and place it in one of the smaller bins. Then it compresses the waste so it occupies less space [13].

Envac is the global leader in vacuum waste collection systems internationally recognized for revolutionizing the waste collection process by integrating it into the infrastructure of a building, a residential development, a town and even entire districts. The system addresses the perennial problem of waste management for large-scale residential and commercial developments by transporting waste using vacuum technology through an underground network of pipes (Envac, [7]). The automated and underground nature of Envac means that waste collection operatives no longer need to come into contact with the waste as it is stored and handled underground there are no smells associated with conventional

waste collection methods and no unsightly bins. This creates a cleaner environment that is less attractive to pests. Waste bins are not used in these system.

Sotkon is a global provider of underground waste recycling containers for use in public and private areas. The technology is very simple and cost effective and the system is extremely efficient. 3000 litre plastic containers are housed in a concrete bunker just below the surface. Usually in banks of 4 or 5, they enable the people using them to recycle and separate at source. This in turn enables the RCV to cover a much greater area as the containers need emptying less often than conventional containers. All that is seen on the surface is a smart stainless steel intake column which is similar in looks to a small bin with a lid (Environmental Expert, [8]).

Related Systems

A typical solid waste management system in a developing country displays an array of problems, including low collection coverage and irregular collection services, crude open dumping and burning without air and water pollution control, the breeding of flies and vermin, and the handling and control of informal waste picking or scavenging activities. These public health, environmental, and management problems are caused by various factors, which constrain the development of effective solid waste management systems [18].

Waste Pickers

The term “waste picker” was adopted at the First World Conference of Waste Pickers in Bogota, Colombia in 2008 to facilitate global networking. Waste pickers collect household or commercial/industrial waste. They may collect from private waste bins on the curb or from dumpsters, along the streets and waterways or on municipal dumps and landfills. Some rummage through garbage in search of necessities; others collect and sell recyclables to middlemen or businesses. Some work in recycling warehouses or recycling plants owned by their cooperatives or associations. What waste pickers have in common is that they do this work to earn a livelihood, and often help support their families (WIEGO, [21]). We therefore proposed a solution with added benefits such as - sending automated messages to local authorities that provides real time information on which garbage cans are filled/ready for collection to avoid problems like spilling/littering of garbage and waste of fuel and resources while tracking which garbage cans to collect.

Landfills

The idea of throwing daily waste directly in the landfills is the most common method of waste disposal used today. This method concentrates on burying the waste in the land. Landfills are very popular in developing countries. A process is carried out to vanish the odors and dangers of waste before it is placed into the ground (Greenlivingideas, [11]). From the above information, there exist some limitations to these systems, for example in an urban center like Kampala in Uganda, `Street A' could have it garbage cans filled and running over while `street B' could still have their cans empty. It wastes fuel and other resources for the local authority to track down where to head to next.

We therefore proposed a solution with added benefits such as - sending automated messages to local authorities that provides real time information on which garbage cans are filled/ready for collection to avoid problems like spilling/littering of garbage and waste of fuel and resources while tracking which garbage cans to collect.

Ugandan Context

In Uganda, the rapid population growth in the urban areas has greatly outpaced the ability of the urban authorities to provide adequate housing, roads, water supplies, sewers and collection of solid waste. Although the environmental problems associated with garbage do not disappear with collection, uncollected garbage exacerbates many of the environmental hazards associated with urban centers. Such hazards include fire, pests and disease vectors which create human health problems [16].

Uncontrolled disposal by dumping and burning can increase atmospheric and hydrologic pollution loads, clogs waterways and increase the danger of flooding, which has been experienced in some parts of the country [17]. Solid waste management in Kampala city, for example, is done by the Kampala Capital City Authority (KCCA) assisted by some private garbage collectors and in other towns; it's the responsibility of the Town Council or Municipal Council. Most of the waste is collected by garbage tracks and delivered to one central damping location [17]. Currently in Kampala, the dumping is done by the KCCA at Mpererwe, a landfill made in 1996 after the former one at Lweza and Lubigi (ERL, [9]). Kampala city generates about 1,200 - 1,500 tons of garbage on a daily basis and KCCA collects about 400-500 tons of garbage on a daily basis leaving about 60% of the garbage uncollected. The uncollected garbage to some extent results into indiscriminate disposal of garbage by the public as they have nowhere to put it (FortuneOfAfrica, [10]). Current challenges encountered by KCCA are issues of open dumping, lack of adequate transport receptacles and vehicles, lack of spare parts, corrosion of the waste containers [17].

Materials and Methods

The step-by-step methods of how one intends to achieve the objectives of the study/research are explained within an overarching methodology such as: Information Systems Development Life Cycle, Software Engineering Methods, etc. This section comprises of research/project design which describes the tools, instruments, approaches, processes and techniques, major algorithms and data structures to be employed in the research study, data collection, analysis, synthesis, design, and logical flow.

System development method

The system development approach used in this project was prototyping model. The Prototyping Model was chosen for because it is a Systems Development Method (SDM) within which a paradigm output (or an early approximation of a final system or product) is constructed, tested, and then reworked as shown in figure 1. This could allow us to easily debug and improved system's functionality since it was done till an appropriate paradigm was achieved to help develop the entire system or product.

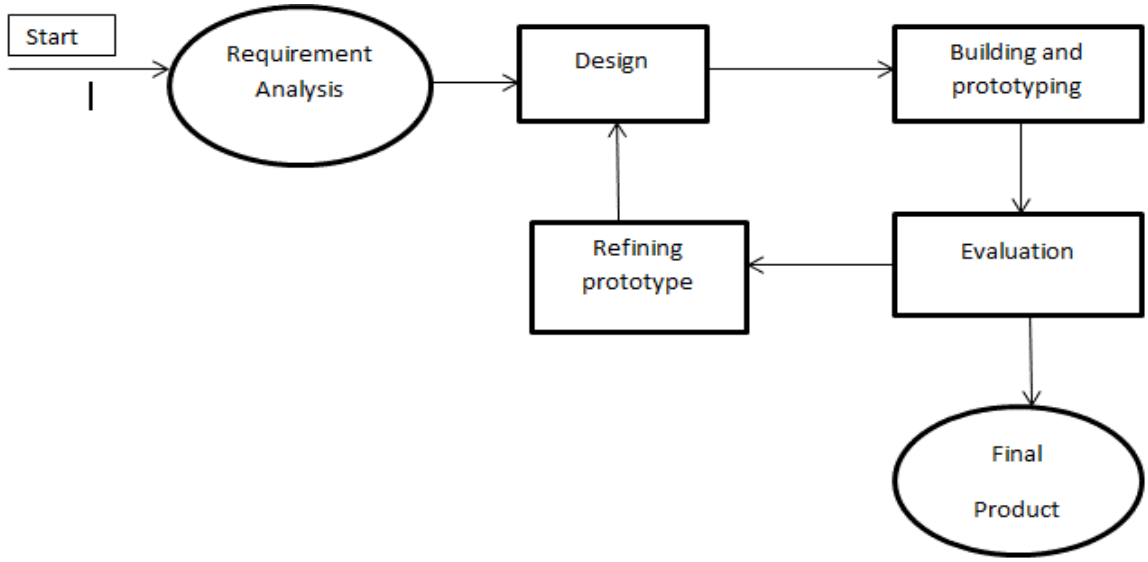


Figure 1: System Development Life Cycle

Requirement Analysis

This step involves gathering and understanding the very basics product requirements especially in terms of user interface. The more intricate details of the internal design and external aspects like performance and security can be ignored at this stage.

The techniques used at this stage were; Literature study, use of internet and interviews. This helped in the achievement of the first and the second objectives of the system design.

Design

This phase included designing the system including drawing the physical for hardware connections and flowchart which explained how software controls all the operations involved during monitoring processes by Arduino microcontroller.

This phase involved the use of pencil and paper, and the Computer (Microsoft Office Word), for drawing the diagrams like physical diagram and flow diagram for easy implementation. At this phase, the third objective was achieved.

Building and Prototyping Testing

During development process implementation (coding software) was done using Arduino, MYSQL, PHP, and JavaScript alongside testing to determine whether it was meeting the requirements. We basically used prototyping testing and then later carried out integration testing to compare for the overall operation of the system with the specification. This phase enabled the implementation and testing phases to be achieved.

Evaluation

At the evaluation stage, the system was tested to ensure that it was free from errors and that it met the user requirements where each component with defect was reported, tracked, fixed and tested, until the component reaches the quality standards defined. Unit testing was carried out. This phase enabled objectives set for the system to be achieved.

Refining the Prototype

This phase included correcting some errors that were in the system after it was first tested and the readings were shown.

Final Product

This is the final stage of development where after testing the system, it was accepted by users and thus it was ready to be used as a final product.

System Design and Implementation

This chapter describes the system study, analysis, design, strengths and weaknesses of the current system, Context level diagrams, Entity Relationship Diagrams and System implementation.

Study of the Current System

The study was carried out in Gulu Municipality. The main purpose of the study was to find out how information regarding garbage disposal and management within the municipality is sent to the relevant authorities in order for them to take action before garbage starts littering within the town areas. The system in use is the old ad-hoc system of manually checking whether the bins are filled up or not. There is no method of reporting to the Municipal authorities about the fill-up of waste bins.

Only when the garbage collection trucks move around and see that a certain garbage collection point is starting to get littered to they then take action. In most cases it’s already too late because the littered rubbish is washed away by rain and other factors.

System analysis

During the system study phase, the requirements of the automated garbage bin monitoring system were categorized into user requirements, system and hardware requirements.

Existing Garbage Bin Monitoring System

During the study, the researchers noted that the current system is still manual were garbage tracks have to physically move from point to point and monitor the garbage collection points. This had such disadvantages such as it was time consuming, tracks wasted fuel moving from place to place, at times, some garbage collection points were missed altogether and the littered garbage failed to be collected.

As per the statistics carried about 80% of the garbage point workers were not contented as it was time consuming to manually check garbage bin collection points. The users recommended that the proposed system should be user friendly, mobile based and be in real time to avoid wasting time.

Requirement specifications

After analyzing the data collected, the researchers formulated a number of requirements namely user requirements, system requirements and hardware requirements. This were grouped as user, functional, non-functional and systems requirements.

User requirements

Out of the analysis carried out, the following were identified as the user requirements of the system:

- System should be able to provide real time auto relay of garbage levels to the authorities.
- The system should help detect humidity levels in the garbage can and avoid air pollution.
- The system should be able to provide the GPS location of the garbage cans.

Functional requirements

The following was the desired functionality of the system:

- It measures garbage level in bins through ultrasonic, proximity and humidity sensors.
- It suggests that the garbage bins are full and ready for collection.
- It sends messages via a GSM module to recipient once condition is reached.
- It sends messages containing garbage bin location.

Non-functional Requirements

The operational requirements included:

- The system should allow room for expansion.
- The system should respond very fast to changes in garbage and humidity levels.
- The system should be able to run 24/7.

System Requirements

This section describes the hardware and software requirements that were needed for effective and efficient running of the system.

Hardware Requirements

The following components were used to design the hardware components

- Arduino Board
- Ultra Sonic Sensor
- Proximity Sensor
- Mobile phone
- GSM module
- Electronic components (resistors, jump wires, bread board)

Software Requirements

The following components were used as software requirements:

- Arduino programming platform
- Android IDE

System Design

This shows the different design undertaken in the system development which included; context diagram, use-case diagram, logical design, physical design, Entity relationship diagram.

Context Diagram

It is a diagram that shows the data flow from the users to the system.

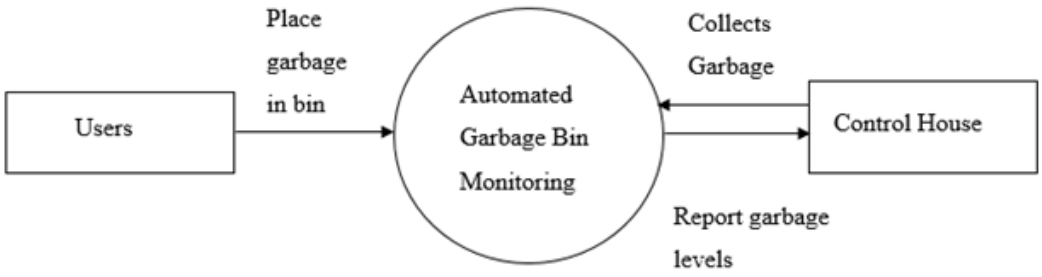


Figure 2: Context Diagram

In the above diagram in figure 2, users collect garbage in a bin. The garbage monitoring system detects the garbage level and its sensors relay information using a GSM module via the network, which is then received by the control house as a message.

Use-case Diagram

This describe a set of actions that some system or systems should or can perform in collaboration with one or more external users of the system (actors).

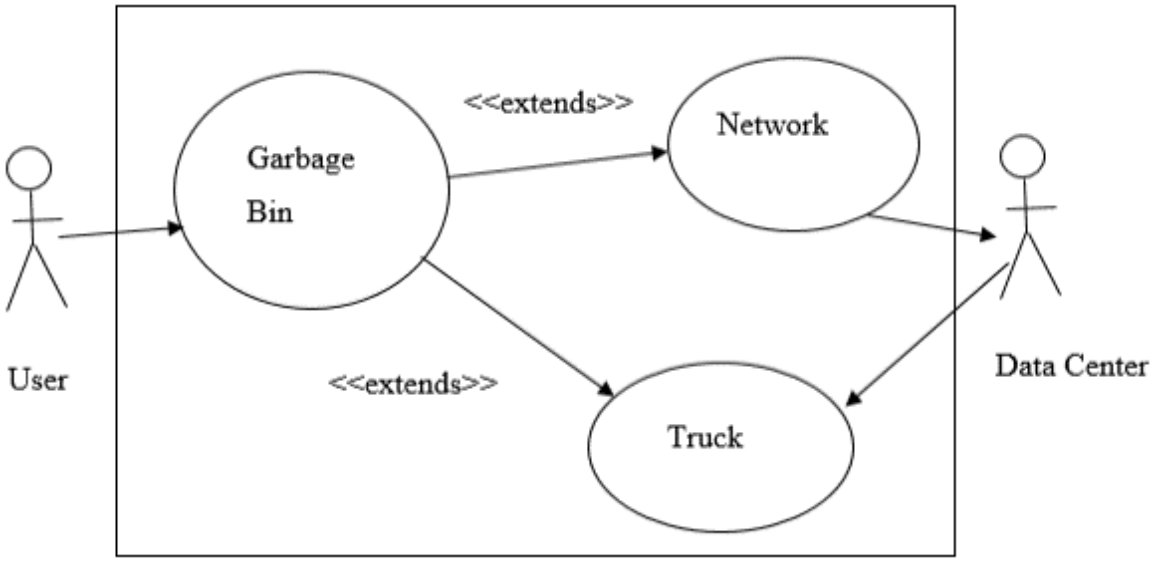


Figure 3: Use-Case Diagram

In the above diagram in figure 3, the user dumps garbage in the garbage bin. When the level of garbage reaches threshold, a message is sent to the data center via network. The data sends a truck to pick the garbage.

Logical Design

The logical design shows an abstract/graphical representation of the system processes and the flow of data into and out of the processes shown in figure 4.

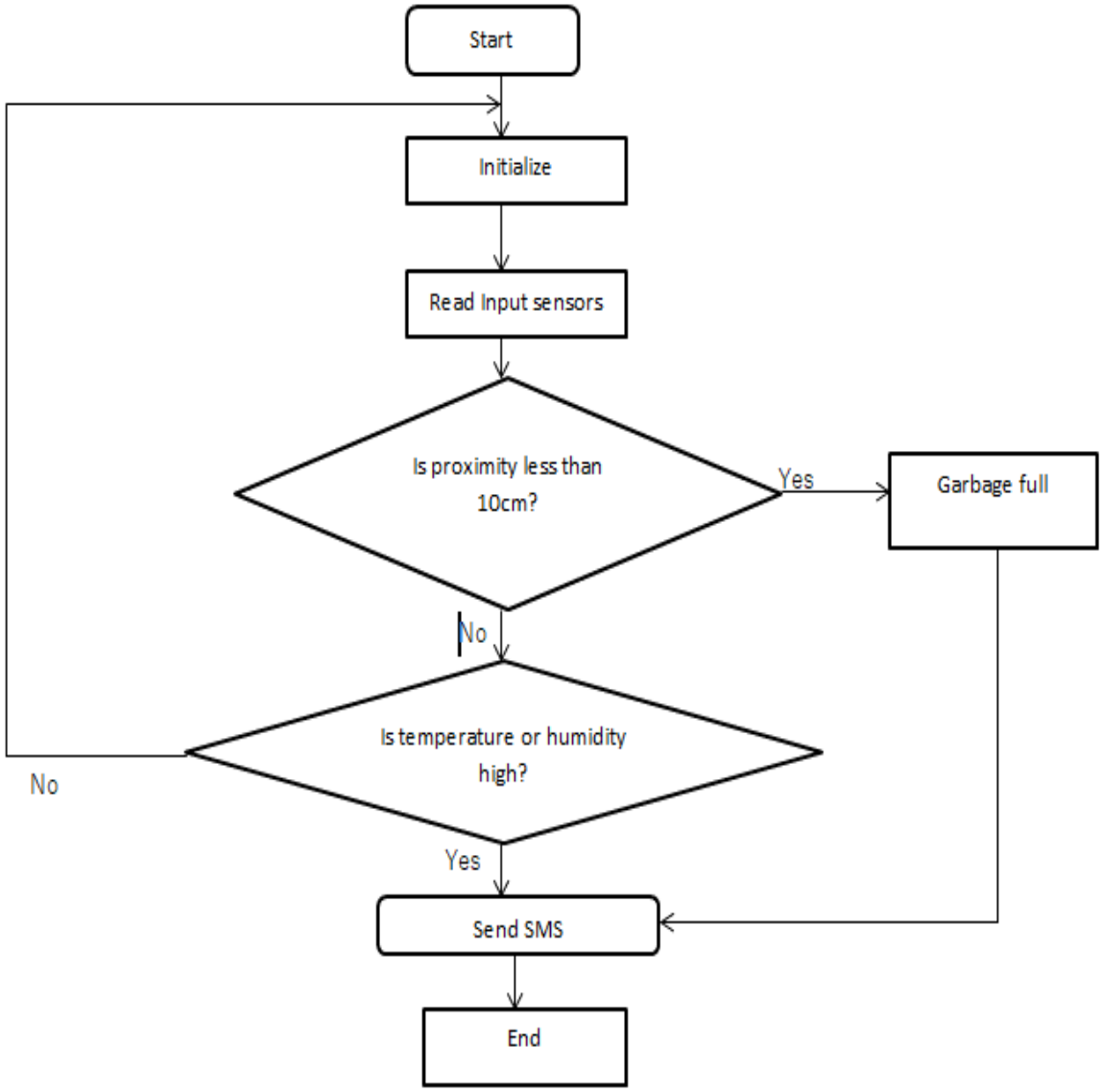


Figure 4: Logical Design

Figure 4 shows the logical design of the system where it begins from the start when the system is mounted on the bin, it start by reading the input sensors, first it determines if the proximity between the ultrasonic sensor and the garbage has reached threshold meaning the garbage is full then a message is sent to the data center. When the first condition is not meant, it then in turn determines if either the temperature or humidity is high, if met a message is sent to the data center. But if all the conditions are not met, the process goes back to the initial stage.

Physical Design

The physical design in figure 5 shows an abstract/graphical representation of the system processes and the flows of data into and out of the processes.

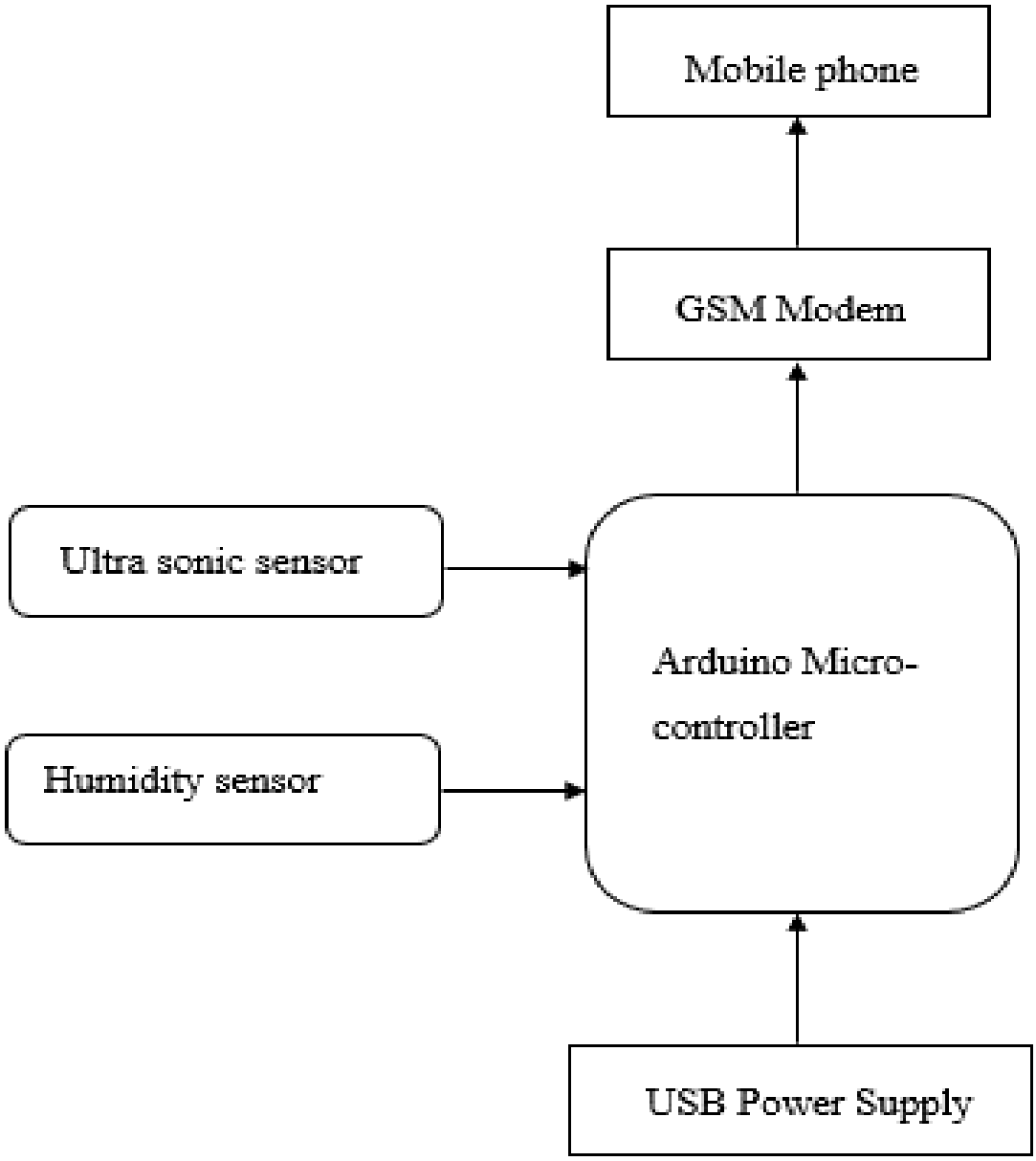


Figure 5: Physical design

The sensing elements comprise of an ultrasonic/proximity sensor and a humidity sensor. Their purpose is providing the notification signal in case of an increase in the humidity or the garbage levels.

The GSM acts as an interface between the mobile phone and the Arduino board and it has a SIM card. The Arduino controller provides processed data that sends instructions to the GSM module.

The mobile phone receives the final information that is sent by the GSM. For the entire system to work, it receives power preferably via a USB connected to a computer. The USB also helps interface with the Arduino software in the computer.

Entity Relationship Diagram

The result of the conceptual design is the Entity Relationship (E-R) Diagram in figure 6 which describes the relationships among the various entities used in the design of the database.

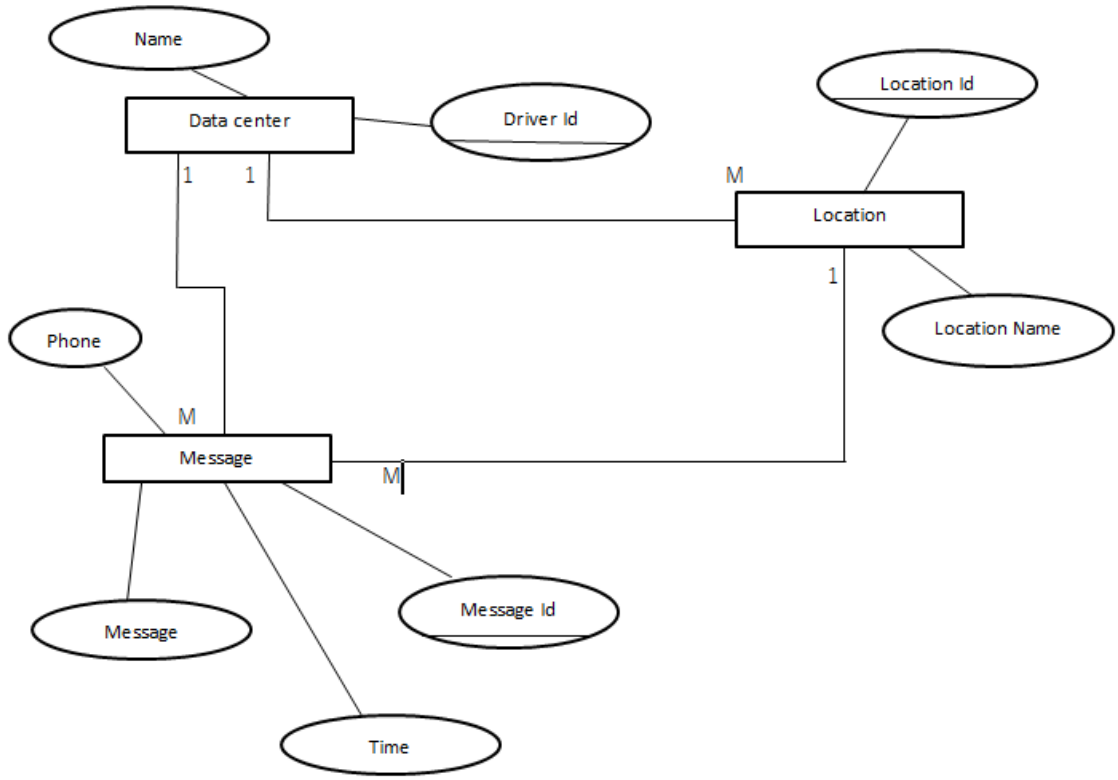


Figure 6: Entity Relationship diagram

Data Dictionary

This section contains information describing the contents, format and structure of the database including the relationship between its elements used to control access to and manipulation of the database as discussed in table 1.

Entity	Field Name	Data Type	Description
Data Center	Driver Id	Varchar(15)	Stores up to 15 characters
	Name	Varchar(20)	Stores up to 20 characters
Location	Location Id	Varchar(10)	Stores up to 10 characters
	Location name	Varchar(40)	Stores up to 40 characters
Message	Message Id	Varchar(30)	Stores up to 30 characters
	Time	Int(5)	Stores up to 5 characters
	Message	Varchar(40)	Stores up to 40 characters
	Phone	Int(10)	Stores up to 10 characters

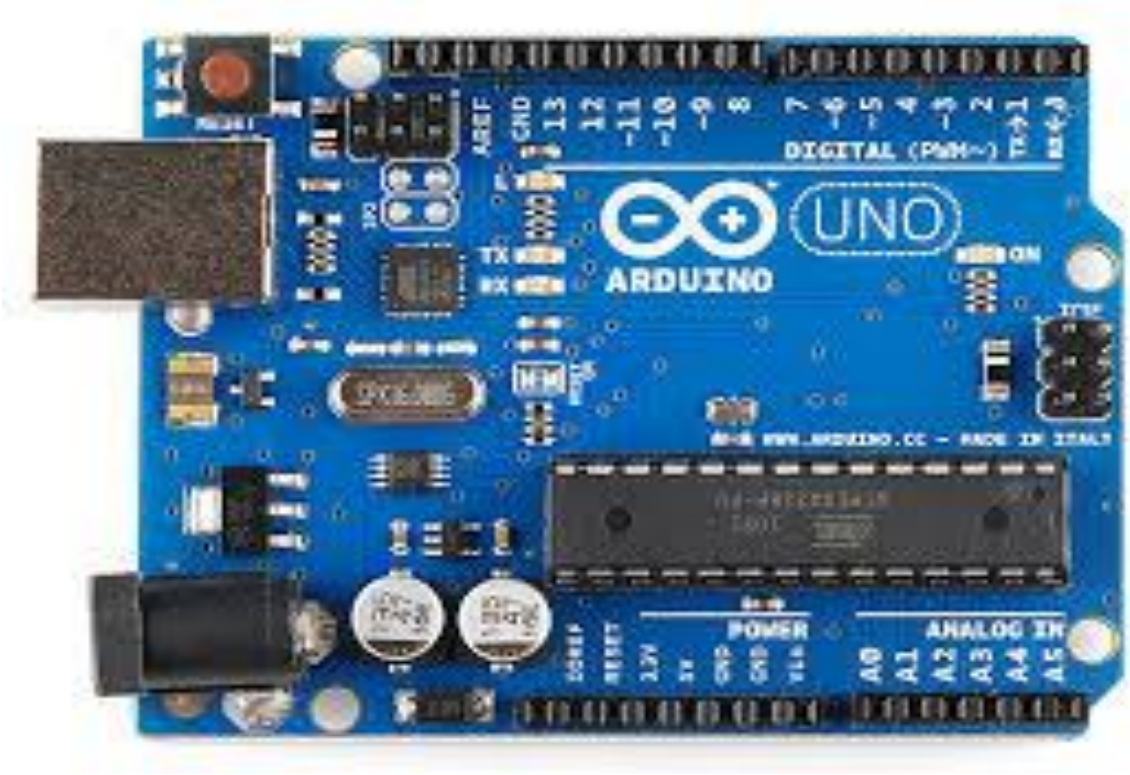
Table 1: Data dictionary

Physical Implementation

The following components were used in the physical implementation of the system

Arduino Board

Arduino board (Microcontroller) was able to read inputs, light on a sensor, a finger on a button, or a Twitter message and turn it into an output activating a motor, turning on an LED, publishing something online as shown in figure 7.



GSM Module

Figure 8: GSM module

GSM/GPRS module was used to establish communication between a computer and a GSM-GPRS system as shown in figure 8.

Mobile Phone

Figure 9: Mobile phone

This was to deliver information to the local authority that the bin is full as shown in figure 9.

Ultrasonic Sensor

Figure 10: Ultrasonic sensor

An ultrasonic sensor measures distance as shown in figure 10. It was be attached to the lid indicating the quantity of garbage.

Jump Wires

Jump wires (also called jumper wires) for solder-less bread-boarding can be obtained in ready-to-use jump wire sets or can be manually manufactured as shown in figure 11. The latter can become tedious work for larger circuits. Ready to- use jump wires come in different qualities, some even with tiny plugs attached to the wire ends. Jump wire material for ready-mad be or homemade wires should usually be 22 AWG (0.33 mm2) solid copper, tin-plated wire - assuming no tiny plugs are to be attached to the wire ends. The wire ends should be stripped 3/16 to 5/16 in (4.8 to 7.9 mm). Shorter stripped wires might result in bad contact with the board's spring clips (insulation being caught in the springs). Longer stripped wires increase the likelihood of short-circuits on the board. Needle-nose pliers and tweezers are helpful when inserting or removing wires, particularly on crowded board.

Figure 11: Jump wires used for connecting the sensors to the board.

Relationship of the Physical Design Components

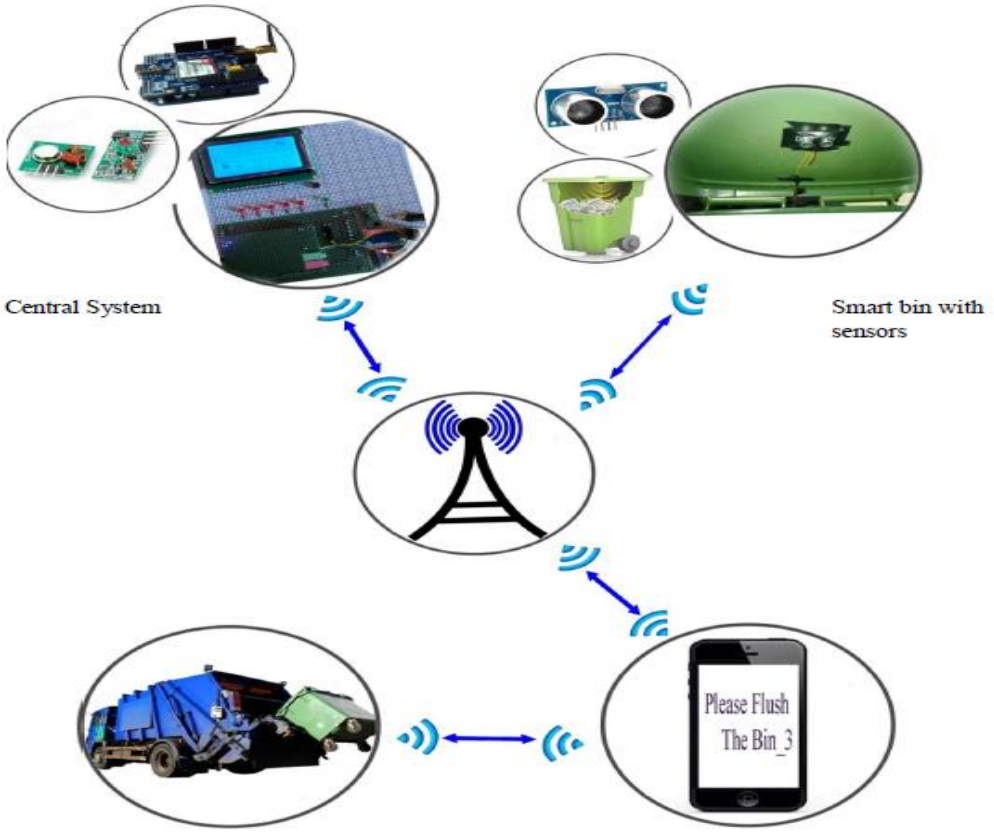


Figure 12: Relationship of the physical design components

Figure 12, shows the ultrasonic sensor works detects the bin level and sends the information to the Arduino board and the Arduino sends information to the GSM module which in turns sends the message to the mobile phone and the LED light blinks when the bin level reaches threshold.

Presentation and Discussion of Results

This chapter presents implementation of the system, and displays the screens that contain different information that were used in the implementation of the system. The purpose of system implementation was to make sure that the correct application is delivered to the end user. Besides that, this chapter also emphasizes on how the testing is done to meet the user requirement

Demonstration of the System

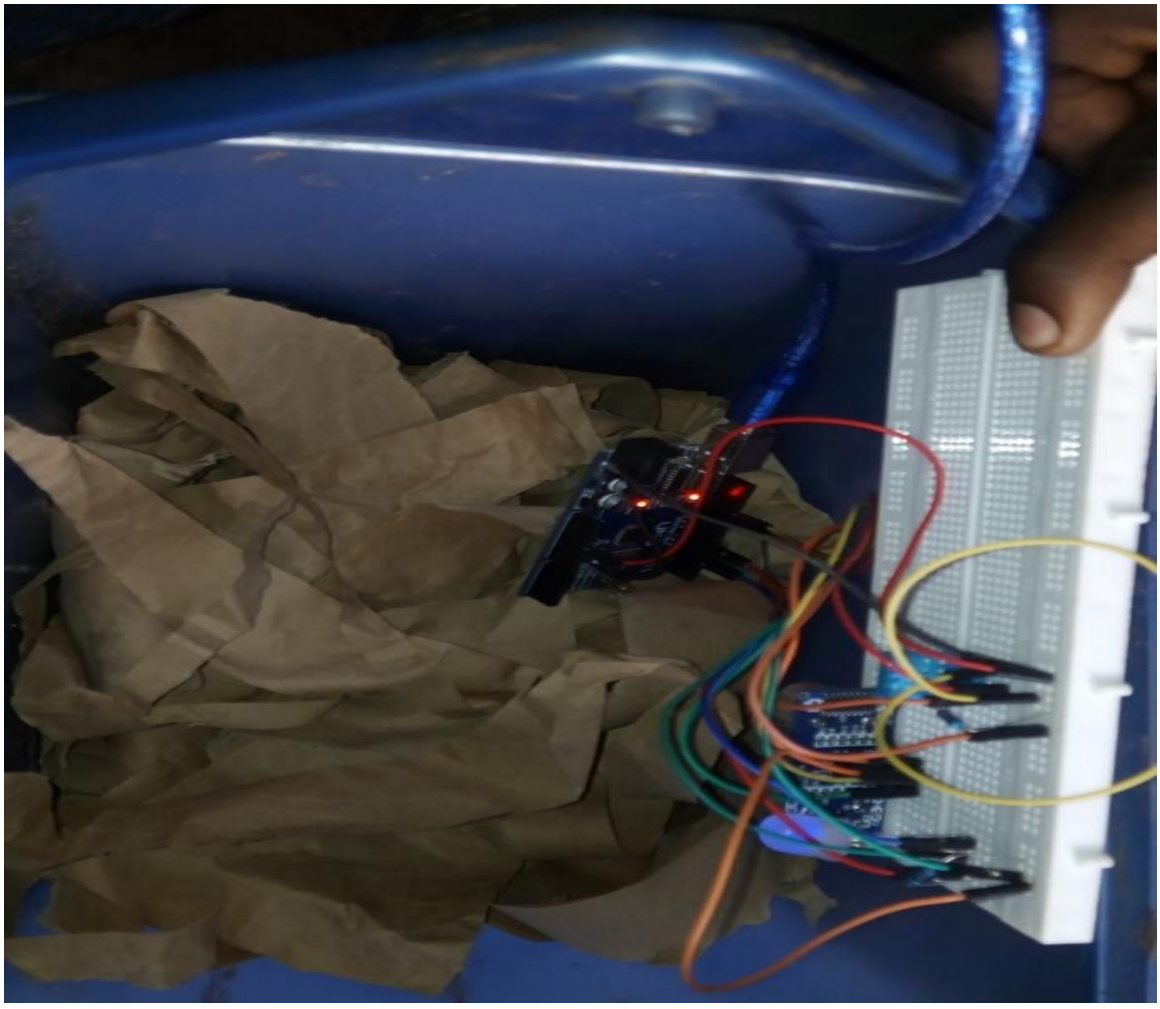


Figure 13: System mounted into the bin

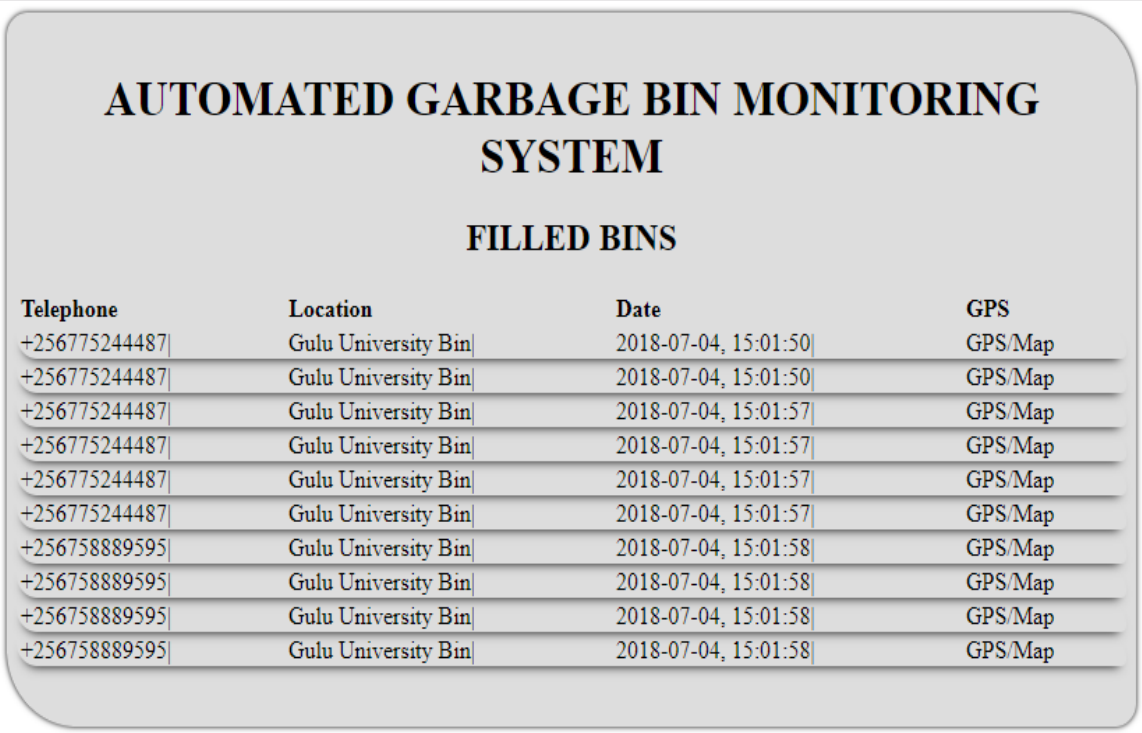
Figure 13, shows the Arduino Board, the ultrasonic sensor, RGB LED light and the temperature and humidity sensors are mounted on the dustbin. When the ultrasonic sensor detects that the bin has reached threshold, it sends an information to the Arduino Board which processes the information and triggers the LED that produces the blue light and the message sent via the GSM to the mobile phone to the local authority, and when the temperature and the humidity becomes high it caters for rotting, a message is sent to the Arduino Board which processes the information and triggers the LED that produces the green light and the message sent via the GSM to the mobile phone to the local authority.

GPS Location of the Bin

Figure 14: Sample location of the dustbin

Figure 14, shows the geographical position system (GPS) of the dustbin that needs to be emptied.

Display of the results



AUTOMATED GARBAGE BIN MONITORING SYSTEM

FILLED BINS

Telephone	Location	Date	GPS
+256775244487	Gulu University Bin	2018-07-04, 15:01:50	GPS/Map
+256775244487	Gulu University Bin	2018-07-04, 15:01:50	GPS/Map
+256775244487	Gulu University Bin	2018-07-04, 15:01:57	GPS/Map
+256775244487	Gulu University Bin	2018-07-04, 15:01:57	GPS/Map
+256775244487	Gulu University Bin	2018-07-04, 15:01:57	GPS/Map
+256775244487	Gulu University Bin	2018-07-04, 15:01:57	GPS/Map
+256758889595	Gulu University Bin	2018-07-04, 15:01:58	GPS/Map
+256758889595	Gulu University Bin	2018-07-04, 15:01:58	GPS/Map
+256758889595	Gulu University Bin	2018-07-04, 15:01:58	GPS/Map
+256758889595	Gulu University Bin	2018-07-04, 15:01:58	GPS/Map

Figure 15: Display

In Figure 15, it shows an extract from the system of the telephone numbers used to call the local authorities, location of the bin, date and time, and the GPS of the bin.

Conclusion and Recommendations

Conclusion

As discussed in the previous chapters, the problem that the researchers discussed was concerned with garbage monitoring using Arduino sensors. The project implemented based on the objectives stipulated in earlier chapters. The system is effective in informing the municipalities about the level of the garbage in various garbage bin locations when the garbage bin is full. Measuring the level of garbage and informing the truck drivers via the local authorities is the main feature that is developed in the project which makes the system more reliable and efficient. The motion detection mechanism is done by an ultrasonic and humidity sensor that sends waves to detect the presence of an object and gives feedback to the sensors.

There were some problems encountered during system design which included, amongst others, limited time to finish the work and limited access to the internet. During data collection, the respondents were not fully open in providing information that was required by the researchers. There were also other financial constraints in conducting the research. With this system, the problem in the problem statement has been met.

Limitations of the Study

There were some problems encountered during system design which included amongst others, limited time to finish the work and limited access to internet.

During data collection, the respondents were not fully open in providing information that was required by the researchers. There were also other financial constraints in conducting the research.

With this system, the problem in the problem statement has been met.

Some of the services not provided by the system included the humidity sensor giving false information in case when there is heavy rain but the garbage is not dump or rotten.

Recommendations

In the world of technology, more so, in the use of computers and electronics, newer systems are being developed to enable easier sharing of information. Although the development of the garbage bin monitoring system is good, there are things recommended to be worked on in future to improve its performance. The interface and software of this project can be modified or redeveloped according to the requirements of the system for different municipals or town councils using further research to boost its efficiency and performance. It is recommended to add a camera to the system that can capture the image of the surrounding in order to provide a visual feedback to the authorities for more clarification.

Members should also be trained to get familiar with the new system. For the efficiency of the garbage monitoring system, users of the system need to be educated about how the sensors work.

During the course of this project, the researchers were able to understand what goes on during garbage monitoring and collection. This was effectively done through reading of research and literature. The researchers plan to incorporate this system and plan it to facilitate more user-requirement

References

1. Ohri, A. & Singh, P.K. (2010). Development of decision support system for municipal solid waste management in India: A review. India: International Journal of Environmental Sciences. pp. 440-453;

2. Aijuka, N. (2017). Menace of Waste Management in Kawempe Division Kampala- Uganda. Kampala, Uganda: Lap Lambert Academic;
3. Anitha, A. (2017). Garbage monitoring system using IoT. Uganda: Materials Science and Engineering;
4. Aryagaruka, M., Otim, M. & Kukundakwe, W. (2006). Environmental Impact Statement for the Proposed Waste Composting Plant and Land_ll in Aminit Village. Soroti, Uganda: Enviromental assessment;
5. Bwire, G., Mugagga, M., Maskery, B., Kim, Y., Mogasale, V. & Levin, A. (2013). The Burden of Cholera in Uganda. PLoS Negl Trop Dis;
6. Christina, J. (2017) IoT and Smart City trends boost smart waste collection market. Retrieved from https://www.greenbiz.com/article/iot-and-smart-city-trends-boost-smart-waste-collection-market accessed on the 21/05/2018;
7. Envac (2017). Stationary vacuum systems. Retrieved from http://www.envacgroup.com/products/our products/envac-stationary-vacuum-system, accessed on 21/04/2018;
8. EnviromentalExpert (2017). SOTKEN waste systems. Retrieved from https://www.environmental-expert.com/companies/sotkon-waste-systems-35442, accessed on 22/04/2018;
9. ERL (2008). Background of domestic waste management in Kampala. Retrieved from http://www.angel_re.com/nc/namicol/backgd1.html, accessed on 23/04/2018;
10. FortuneofAfrica (n.d). Waste management in Kampala. Retrieved from http://fortuneofafrica.com/ug/waste-management-in-kampala/,accessed on 12/04/2018;
11. Greenlivingideas (2017). Different Ways of Waste Disposal. Retrieved from https://greenlivingideas.com/2017/07/03/different-ways-waste-disposal/, accessed on 20/04/2018;
12. Joshua, K. (2007). Garbage: Will NEMA get rid of the menace? Retrieved from https://www.newvision.co.ug/new vision/news/1219737/garbage-nema-rid-menace, accessed on 28/04/2018;
13. Katie, M. (2017). 'Smart bins' are coming to the UK and could spell the end of hand-separating recycling. Retrieved from https://www.telegraph.co.uk/news/2017/08/29/smart-bins-coming-uk-could-spell-end-hand-separating-recycling accessed on the 22/05/2018;
14. Kato, J. (2018). Hoima dirtiest town in Uganda. Retrieved from http://www.monitor.co.ug/News/National/Dirtiest-towns-Uganda-named/688334-4343790-1hav6pz/index.html, accessed on 19/04/2018;
15. Klundert, A.V. D., Anschutz, J. (2001). Integrated Sustainable Waste Management – The Concept: Tools for Decision Makers, Experiences from the Urban Waste Expertise Program (1995, 2001) WASTE. Gouda, The Netherlands;
16. Kunzmann, K. R. (2014). Smart Cities: A New Paradigm of Urban Development. Crios. pp. 9-20;
17. Lucy, S. (2017). Uganda Waste Management and Disposal Providers. Retrieved from http://dlca.logcluster.org/display/public/DLCA/3.7+Uganda+Waste+Management+and+Disposal+Providers;jsessionid=10E50656D174184E352015 accessed on the 27/05/2018;
18. Moritz, B. (2012). 3 Alternative Ideas for Waste Management in Developing Countries. Retrieved from https://www.ifu.com/knowtheow/2012/3-alternative-ideas-for-waste-management-in-developing-countries accessed on the 28/05/2018;
19. Naregalkar, P. R., Krishna, K. T. & Srivastava, R. (2007). IOT Based Smart Garbage Monitoring System. Maharashtra, India: International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering; Vol. 6, Issue 5;
20. Sangeeta, R., Steve, W., & Bonita, B. (2000). Uganda Logistics Systems for Public Health Commodities. Uganda: An Assessment Report;
21. WIEGO (2017). Waste pickers. Retrieved from http://www.wiego.org/ informal economy /occupational-groups/waste-pickers accessed on the 25/05/2018;
22. Yashimera, M., Valerry, R., & Benlot, M. (2010). Solid waste management: a university social concern on attitude, perception and willingness. Uganda: An Assessment Report.

