Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 190(2) (2024) 170-184 EISSN 2392-2192

Design and construction of automated waste bin for efficient waste management

Francis John Uko* and **Ken Basil Anazodo**

Department of Mechatronic Engineering, Faculty of Engineering and Technology,
Alex Ekwueme Federal University Ndufu, Ikwo. Ebonyi State, Nigeria

*E-mail address: francouko@gmail.com

ABSTRACT

A major concern in our environment is in solid waste management which possess health challenges in communities, organizations, towns, schools, churches, etc. The adequate and systematic monitoring, detecting and managing of waste are a major problem in today's society. In the 21st century, automation cuts across different areas and sectors of life, hence the basis for this research. This project introduces a cost-effective smart waste container designed for efficient refuse collection in both residential and office settings using the IOT (Internet of Things) technology. By implementing advanced waste monitoring techniques, this solution saves time and resources. Unlike previous models where waste bins opened upon motion detection even when full, this project ensures that the bin remains closed until reaching full capacity, and it can only be opened manually at that point. It utilizes an ultrasonic sensor to detect the bin's fullness level and a PIR sensor for motion detection. Powered by an AT89S52 microcontroller (programmed using C), servomotor, and ultrasound sensors. In addition, I will be using a GSM module so as to enable the bin through the microcontroller to send SMS alert to the user when it is full and ready for pickup.

***Keywords*:** motion detection, sensors, ultrasonic sensor, machine learning algorithm, real time analysis, AT89S52 microcontroller

(Received 07 January 2024; Accepted 31 January 2024; Date of Publication 02 February 2024)

1. INTRODUCTION

Throughout history, humans have continuously sought to understand and harness parameters of our natural environment, including temperature, time, weight, distance, touch, light, motion, fluid, and more. This unconsciously brought about sensors. In the early stages of these quests, these parameters were primarily determined by observing celestial bodies, such as the sun and stars, or studying animals. As human understanding and technological capabilities evolved, measuring instruments emerged, enabling the quantification and analysis of various physical quantities and variables. We now find ourselves in the "silicon age," characterized by the integration of electronics into our daily lives.

In this age, electronic components, especially sensors, have become indispensable tools for measuring and interpreting environmental variables. These sensors, capable of detecting and quantifying a wide array of parameters, have played a pivotal role in the development of the Internet of Things (IoT). The IoT, in turn, has revolutionized how we collect, process, and utilize data to address myriad challenges (Khan, et al., 2021).

IOT is a network of physical objects integrated with different software, sensors, network connectivity (internet) to enable them receive and send data (Qureshi, Khan, Jamil, Sharma, & Jeon, 2023).

Furthermore, the IOT concept can be seen as the intelligent method of communication between networking, information processing, perception and non-digital entities. This has greatly eliminated the need for human control within the layer-three networks as regard humans, objects and services (Park, et al., 2022). Medically, clinic waste handling can be greatly enhanced with IOT technology (Singh & Misra, 2022).

Smart waste management is way we can control some challenges faced in the society in terms of pollution and diseases (Chenna, Govinda, Rami, & Nookala, 2022). This smart waste management has to be implemented to avoid adverse effect on nature and habitats (RadhaKrishna, 2022).

However, according to (Hong, et al., 2014), the present world's reliance on the internet for solving problems is undeniable. However, there remains vast untapped potential within the realm of IoT, suggesting that much more can be achieved through its continued evolution.

An important factor of the internet is its connection speed since a lot of processes depend on it to send and receive data at a very speedy manner. The IoT (Internet of Things) monitors and also controls the equipment used on a daily basis with the aid of sensors. These sensors convert raw physical data into digital signals and then transmit them to a specific control station (Venu, Arun, & Vaigandla, 2020).

Additionally, in hospitals, poor waste management has become a threat to the health of hospital employees and patients due to the method of disposal. (Ezeudu, et al., 2022).

(Ala, Guizani, Mohammadi, Aledhari, & Moussa, 2015) Stated that academic interests have been triggered by the need to integrate these sensors with communication technologies for the development of mobile devices. But so far among the numerous architectures that have been proposed, is three (3) layers architecture stands out and this consist of Network, Application and a Perception layer.

Managing trash bins, particularly in the context of waste collection, poses unique challenges due to their association with dirt and waste materials. This project focuses on the development of a "smart trash bin" equipped with motion sensors that detect the presence of an individual approaching to dispose of trash. Imagine the convenience of being able to discard

domestic waste without direct physical contact with the trash bin. This not only reduces the risk of germ and bacteria exposure but also contributes to improved living standards and public health.

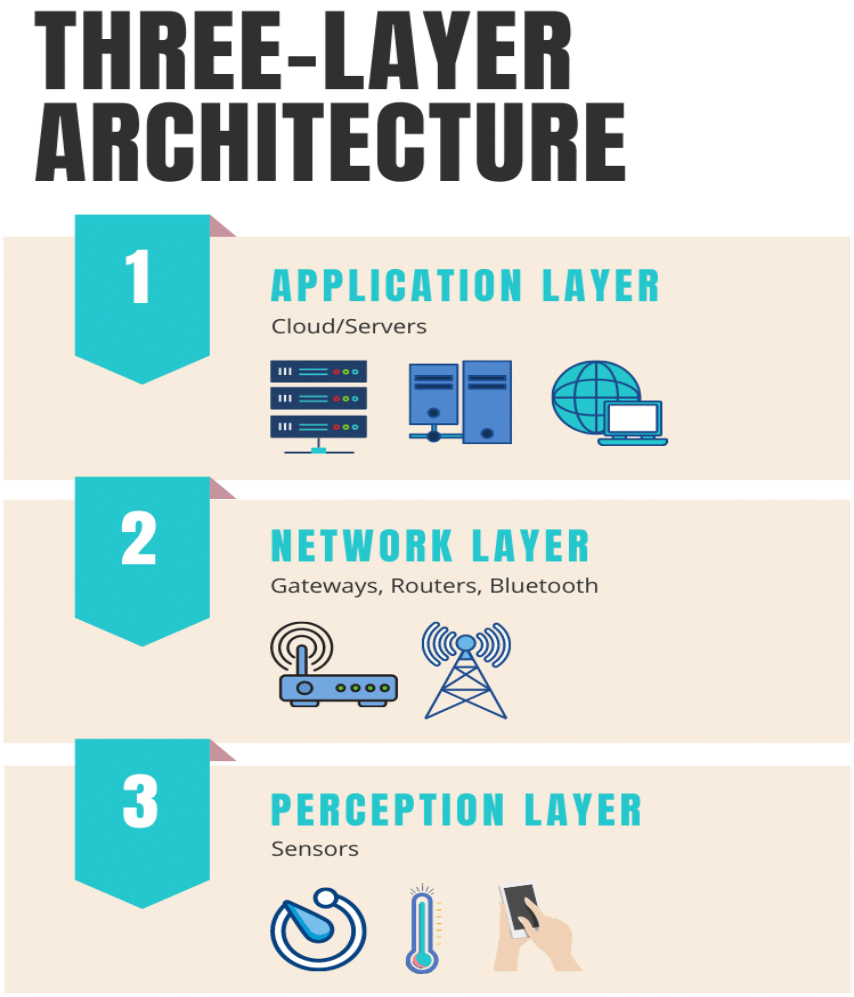

Figure 1. Three layers of architecture

Consider scenarios in public places such as schools and hospitals, where traditional trash bins require users to open a lid to deposit their waste. These bins may accumulate harmful microorganisms on their surfaces over time, as not all individuals are conscious of hand hygiene after using them. In some cases, there is no convenient access to water for handwashing. Consequently, some people resort to discarding trash on the ground or directly onto the lid of the trash bin to avoid manual contact. The smart trash bin, with its innovative design, offers a solution to this issue.

Furthermore, in Nigeria, industrialization and the increased use of packaged goods have led to a significant rise in daily waste generation. Waste comes in various forms, including mineral, organic/inorganic, radioactive, biomedical, agricultural, and domestic. Unfortunately, many trash bins are left unattended for extended periods, leading to overflowing and spillage.

Improper waste disposal poses health risks, as it creates breeding grounds for mosquitoes and other microorganisms that can lead to illnesses and diseases. This project introduces a smart trash bin system designed to save costs and time, particularly in smaller-scale applications such as parks, universities, and hospitals.

Improperly disposed garbage not only affects hygiene but also leads to unpleasant odors. Traditional waste collection methods often involve sending trucks to collect waste from locations with bins, but this approach proves inefficient, as bins do not fill up at the same rate. This results in wasted labor, time, and resources. Furthermore, bins that remain partially filled for extended periods invite rodents, mosquitoes, and insects, contributing to the spread of diseases and bacteria. The proposed smart system incorporates sensors, a GSM module, and an AT89S52 microcontroller to address these challenges. As the population of man becomes denser and coupled with man's exploitation of nature and its resources, significant amount of solid waste is generated daily. To ensure that the environment remains clean and healthy, it is required that garbage be disposed of properly. Improperly disposed garbage results in pollution, hazards, health related issues, and also affects the environment and micro-organisms. Pollution causes discomfort and disorder to the ecosystem and spoils the environment. Proper waste disposal improves health and also the well-being of citizens and the environment.

Collection of waste and disposal of this waste is a major environmental problem. It is then of high need to introduce a smart waste management system to tackle this problem and by so doing reduce cost, time and also manage resources. This can be done by applying smart devices using IoT technology. However, the application of this solution is very expensive but this project will explore a cheaper and less cost effective but efficient smart trash bin to serve small scale use such as universities, hospitals and offices.

The scope of this work is to implement a smart trash bin for waste management system using AT89S52 micro-controller for managing input and output. Motion sensor for motion detection, LCD lights to determine fill-level and finally a GSM module for sending text messages when the bin is full and ready for pick up. This GSM module will be connected to the micro-processor and will require 12V to power and a SIM card.

Numerous research projects have explored smart waste management systems, each contributing innovative solutions, for instance, (Hong, et al., 2014) study introduced an IoT-based smart garbage system to reduce food waste. Their battery-powered smart garbage bins used wireless mesh networks and various IoT techniques to reduce food waste by 33% in a year. In another research work by (Hassan, Hannan, & Shafiqu, 2013), integrated sensing and communication technologies to create a real-time waste monitoring system using sensor nodes, gateways, and a base station. This system significantly reduced fuel costs and optimized waste collection routes (Neha, Krishna, & Vinit, 2015).

(Parkash, Feb 2016), connected smart waste bins to the internet, using infrared radiation sensors and radio frequency modules to monitor bin status. These bins were distributed around cities and interfaced with a microcontroller-based system. Data was processed in the cloud, providing real-time status updates via a web browser. Also, (Navghane, Killedar, & Rohokale, IoT Based Smart Garbage and Waste Collection Bin, May 2016) implemented a real-time waste management system using smart dustbins equipped with weight sensors and IR sensors. This system allowed users to access information from all smart bins and reduce costs through efficient trash collection. (Priya, Lavanya, Samyukta Reddy, & Yarlaga, June 2015), proposed an RFID and load sensor-based smart waste management system to reduce waste management costs and automate waste identification.

Waste management is crucial for maintaining a healthy environment, especially in countries like Australia, which generates a significant amount of waste.

(Wawale, et al., 2022) presented a suggestion that connecting RFID (Radio-frequency Identification) to IOT via fuzzy logic to monitor waste. Fuzzy logic is an approach to variable processing that allows for multiple possible truth values to be processed through the same variable. Additionally, (Waikhom, RamKumar, & Rajeev, 2014), designed an electronic system to address improper waste disposal. Bio-sensors, weight sensors, and height sensors were used to sense waste levels and gas emissions in trash bins. The system automatically sent messages to authorities to report bin status.

In another research done by (Zavare, Parashare, Patil, Rathod, & Babanne, 2017), on "Smart City Waste Management System Using GSM," developed a smart city waste management system using a sensor node connected to an Arduino microcontroller with a GSM module. The system detected bin fullness using ultrasonic sensors and transmitted data via Wi-Fi.

Another related work on wireless sensor network was carried out by (Singh, Mahajan, & Bagai, 2016). installed accelerometer sensors, humidity and temperature sensors, and ultrasonic sensors on bins to sense various aspects of waste conditions. Zigbee Pro micro-controllers were used to control the sensors, and data was transmitted to a central server.

(Navghane, Killedar, & Rohokale, IoT Based Smart Garbage and Waste Collection Bin, 2016), examined the use of weight sensors and three (3) IR (Infrared Radiation) sensors to determine the full level of the smart bin and send this data to a mobile phone using Wi-Fi network. ARM LPC2148 micro-controller board was used in this paper.

In a report conducted by (Ambrose, Ford, & Norris, 2015), which completely tackled the economic and power consumption problems facing the conversion of conventional outdoor trash bin to a smart trash bin. In the literature, u-blox C027-U20 micro-controller board was used, this had an in-built GPS module and cellular module. The ultrasonic sensor (HC-SR04) senses the full level and sends information to the controller, weather and fire alerts were measured using temperature sensors. The setup was done in a 2×4×6 plastic box, powered by a rechargeable lead-acid battery of 12V. The system was designed to produce an HTTP POST request using data gotten from the sensors. This data is then sent to a web application, which was built using Python and Flask framework on an SQLite database. The HTTP request is received by the web application and if the bin is full, it sends an SMS message using Twilio service. In addition, Leaflet JavaScript library is used to virtualize the collected data on a map. (Al-Maadeed, Madi, Kahraman, Hodzic, & Ozerkan, March 2012), proposed that the introduction of an integrated system combined with a web camera, GPS (Global Position System), Radio Frequency Identification (RFID), General Packet Radio Service (GPRS), and Geographic Information System (GIS) will offer solution to problems associated with solid waste. The performance of the system was actualized.

In research by (Islam , Arebey , Hannan , & Basri, 2012), argued that solid waste is one of the major challenges faced by urban areas throughout the world. They introduced an integrated system which consists of a GPS, RFID, GPRS, GIS and a web cam. All customer information and bin information are retrieved automatically using the RFID. Information about the locations of the bins is gotten via GPS which is updated using GPRS communication system. Truck monitoring is done using GIS server map. Here in this System, information of the bin, truck ID, time of waste collection, GPS co-ordinate information is developed and structured well. The data packet compiles the amount of waste from the bin's status. The GUI displays

real time image processing and other information about the bin. Basically, environmental pollution caused by poor waste disposal are all as a result of poor waste management. The solution to this is the development of smart waste bin (Ashwin, Alqahtani, & Mubarakali, 2021).

Also, (Hannan & Shafique, February 2012) described a system which uses two technologies, Zigbee and Global System for Mobile Communication (GSM). An ARM7 controller is used in this system and is mounted on a central station. When the bins get to fill level, signal is sent to the micro-controller. The controller then forwards the signal as data to a garbage collection truck as to which garbage bin is completely filled. The information is sent as an SMS using GSM technology.

Furthermore, (Mahajan & Chitode, July 2014) proposed a system that focuses on eradicating ugliness and disorder associated with waste. The smart trash uses two sensors which are IR (Infrared Radiation) sensor and gas sensor. The Infrared Radiation sensor senses the full level of the trash inside the bin and the gas sensor senses toxic gases in the trash bin. Once the trash is filled, the RFID (Radio Frequency Identification) placed inside the trash sends information to the corporation office. They also added that the existing garbage monitoring system throughout the country is manual. The garbage collectors visit the garbage bins at fixed time interval. This process possesses a lot of disadvantages because these trash bins don't get full at the same time depending on the number of residents in the area and this increases economic expenditures. They believe that this new automated waste monitoring system can solve the above problem effectively through the use of Arduino Micro-controller and Sensor based technologies.

Another work carried out by (Mamun, Hannan, & Hussain, 2013), Apartments, condominium or flat type residence were provided with smart garbage monitoring and management system. This system used ultrasonic sensor to measure waste levels and Arduino was used as the micro-controller. The ultrasonic sensor measures continuously the level of waste and notifies residents and garbage Collection Company when it is full. The notification is sent via SMS to the collectors when the bin is almost at full level. Indicators were also put to notify residence on when to deposit, stop depositing, or minimize deposition to avoid spillage.

Another related work was done by (Monika, Rao, Prapulla, & Shobha, 2016). Here a modem (GSM 900A) is used to send SMS messages. This consists of a GSM/GPRS modem that has standard communication interfaces such as Serial Port (RS-232) and a USB for easy connection to other devices. An ultrasonic sensor is used to determine the height of the full level at given time intervals. Arduino micro-controller is used in this system. An Interface is created by the GSM modem and the Arduino board by establishing a connection between the RX pin of the modem to TX pin of board. The TRIGGER and ECHO sensor pins are connected to digital pins 5 and 13 of the Arduino micro-controller board. The Arduino board uses 5V of power and the GSM modem takes 2A to power. The height of the threshold is fixed at 10cm. the threshold determines the difference between the full level. Whenever the difference is less than the threshold value, the GSM modem activates automatically and sends a signal to the authorities via SMS for pick up.

The disadvantages of this system include:

i) There was no provision for monitoring the status of the bin from a centralized system.
ii) The solution caters for monitoring one aspect of the bin status only, and that is the full level only.
iii) Other aspects including weight and Gas emission levels monitoring were omitted.

Ordinances and bye laws are implemented by the Urban Council as a responsibility. The central government makes policies while the Local Government implements these policies. They further pointed that the laws existing regarding waste management are not enforced effectively and this makes the law weak. Also, according to them waste management is financed poorly, as it is not the government's priority this can also be seen in Nigeria. They also pointed out that most households that are not provided with waste collection systems have developed their own methods of waste disposal, which include burning, backyard burying or dumping indiscriminately in the open. Furthermore, In East Africa these innovative methods for waste management have not been fully exploited and this is denying interested individuals the avenue to carry out such research projects in this area.

My project is set to design and implement a smart trash bin, explain the hardware parts used and how they are connected to function together. The fullness level of the bin is established by using an ultrasonic sensor to calculate the distance between the trash and the lid of the bin. I will be using ultrasonic range sensor to know the amount of garbage contained in the bin and the data will be sent through a GSM/GPRS 900A module to a set phone number present at waste management centers (WMC), but in this case I will be using my phone number. I will be using an AT89S52 microcontroller. The SMS will be sent via GSM/GPRS module and display the full level on the phone. Also, the ultra-sonic sensor will sense if any garbage is thrown on floor instead of in the dustbin.

2. MATERIALS AND METHODS

2. 1. Materials

- **Power:** the power can come either from an AC to DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1 mm center-positive plug into the board's power jack. The leads of the battery can be inserted in the GND and V-in pin headers of the POWER connector. The board operates on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may over heat and damage the board components. The recommended range is 7 to 12 volts.
- **Ultrasonic sensor**: this device measures the distance of an object with the aid of sound waves, it measures this distance by sending out a sound wave at a particular frequency and wait for the wave to bounce back. It is possible to measure the distance between the sensor and that object by recording the elapsed time between the sound wave being generated and the sound wave bouncing back. In other words, the sensor head emits an ultrasonic wave and receives the wave that is reflected back from the target. This distance can be calculated with the following formula:

$$Distance = \frac{1}{2} \times \mathrm{T} \times \mathrm{C}$$

where T is the time between the emission and reception, and C is the speed.
An ultrasonic sensor (HC-SR04) is used in this project to detect motion and presence of an object. This sensor measures between 2 cm to 400 cm with 3 cm accuracy. The sensor consists four pins which; VCC, Ground, Echo and Trigger. The sensor is powered

through the VCC and Ground, while operation is done by the Echo and Trigger connected to the Arduino.

- **A servomotor** can be defined as a linear actuator or rotary actuator that provides precise control of linear angular position, acceleration and velocity. It is attached to a sensor and controlled by a microcontroller (Suh, 2017). Let me take you through the actual setup and build process of the Smart Dustbin. First, I will start with the mechanism to open the lid. As you might have already guessed, I have used a Servo Motor for this purpose. In order to open the lid, I have fixed a small plastic tube (like an empty refill of a ball-point pen) to the servo horn (a single ended horn) using instant glue. For this mechanism to be able to open the lid of the dustbin, it must be placed near the hinge where the lid is connected to the main can. From the statement above you can see that I have fixed the servo motor. Also, make sure that the lifting arm is parallel to ground under closed lid condition. Other materials include;
  - Microcontroller (AT89S52)
  - GSM module
  - Servo motor
  - Capacitor
  - Passive infrared sensor (PIR)
  - Ultrasonic module
  - Transformer
  - Voltage regulator
  - Crystal oscillator
  - Resistor

MICROCONTROLLER (AT89S52**):** The AT89S52 microcontroller was chosen for its low power consumption, high performance, and cost-effectiveness. It operates at a 12 MHz clock speed, has 8KB of memory, and comes with 15 digital I/O pins.

Figure 2. Micro-controller AT89S52

G.S.M MODULE: The G.S.M module, is used in this work to send out SMS when the bin is full and needs to be emptied. The microcontroller will send a message to the set phone number via the GSM module.

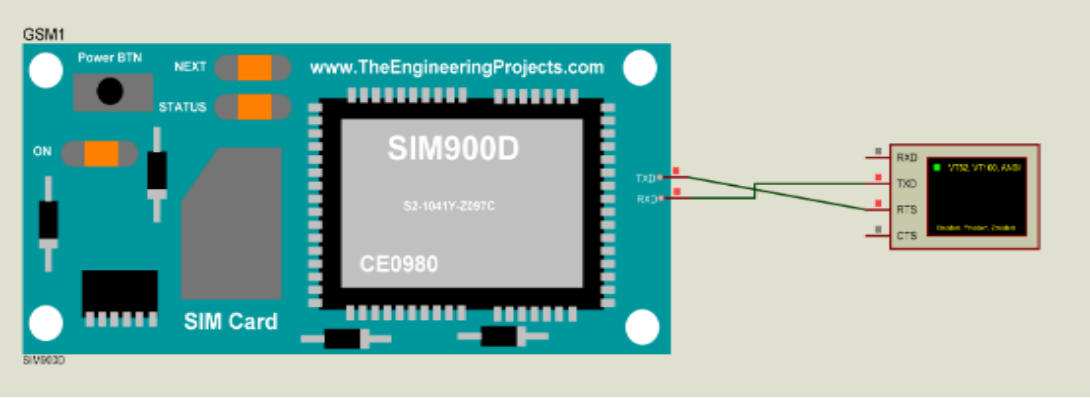

Figure 3. G.S.M module

PIR SENSOR: PIR sensors allow system to sense motion. They detect whether a human has moved in or out of the sensor's range. The PIR sensor is easy to connect to the microcontroller as ports are already installed for interfacing. The sensing range is between 5m and 12m.

Figure 4. PIR sensor

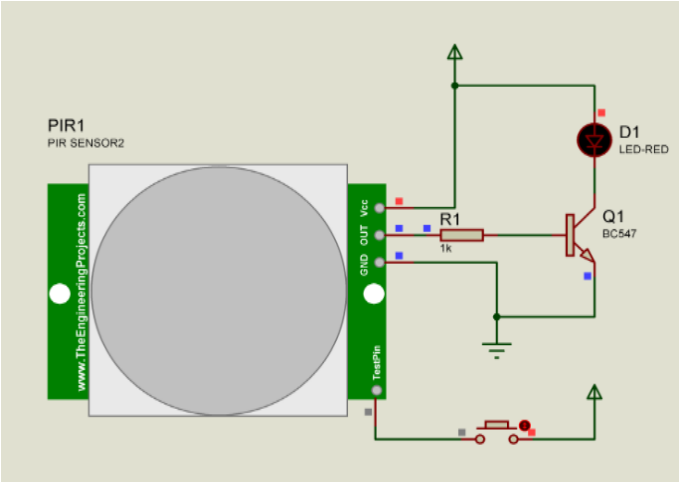

Figure 5. Simulating PIR sensor operation

The LED is off because no motion detected

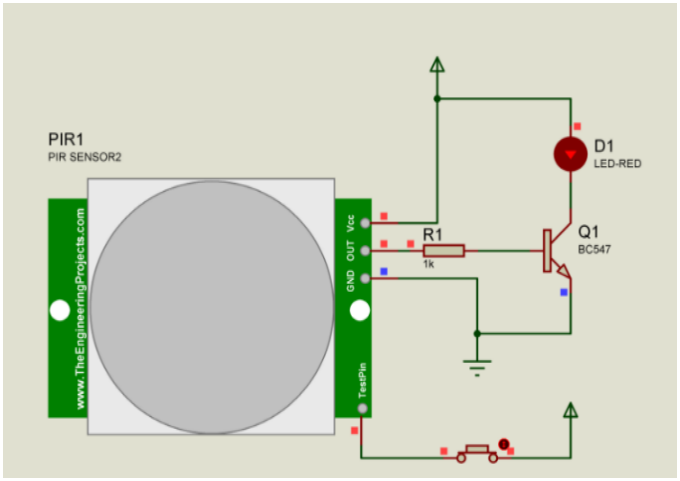

Figure 6. Simulating PIR sensor operation

2. 2. Methods

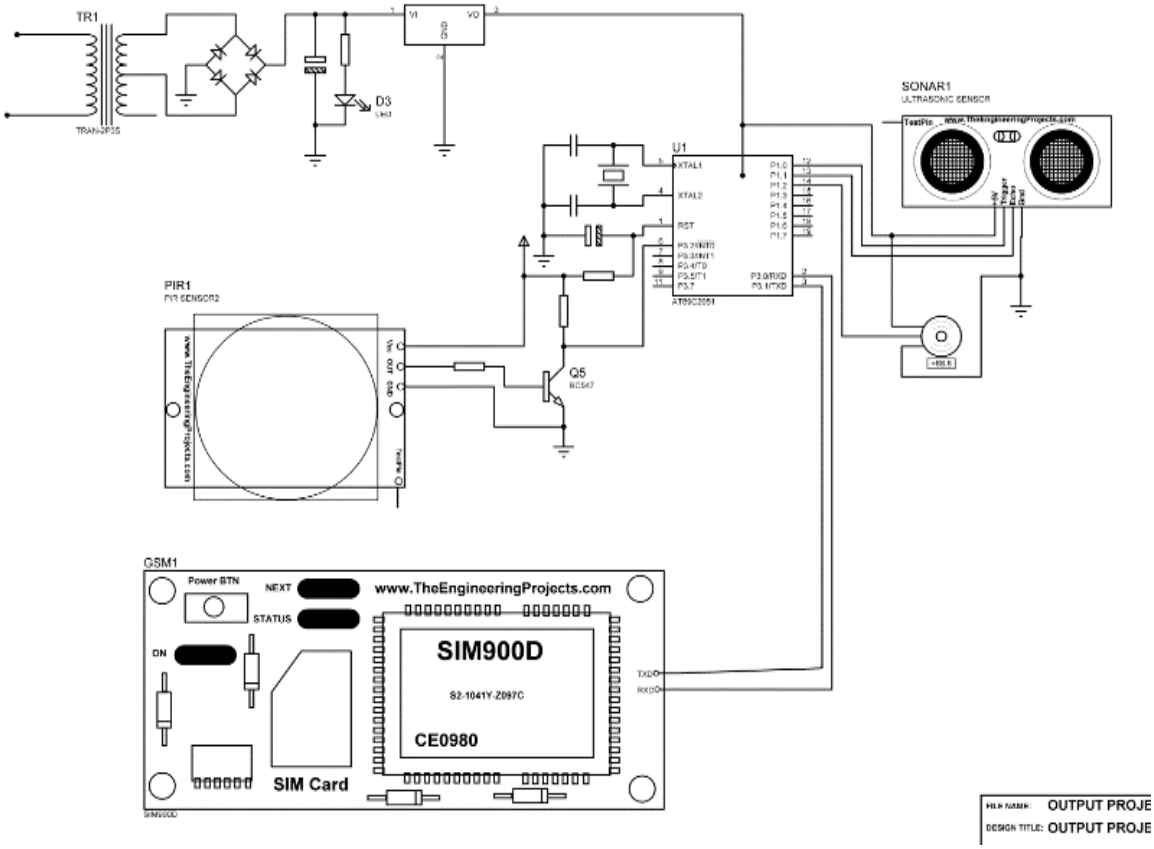

Figure 7. Circuit diagram of the smart waste bin

The system relies on the AT89S52 microcontroller with 12MHz clock speed, 2KB SRAM, 1KB EEPROM, and a 5V voltage. The microcontroller features 15 digital I/O pins, with 6 providing bidirectional output and 2 external interrupt pins.

The following instruments and methods were utilized:

1. Ultrasonic Sensor: This sensor detects the fullness level of the bin and has a sensing range of 20 cm to 400 cm at a 15-degree angle. This is gotten by the following formula:

$$V_t = V_o + N * T$$

where, V_t = velocity of sound at temperature
V_o = velocity of sound at 0 ℃
N = rate of change of velocity per rise in degree temperature
T = temperature

To calculate the distance, we use:

$$d = (V_t * t)/2$$

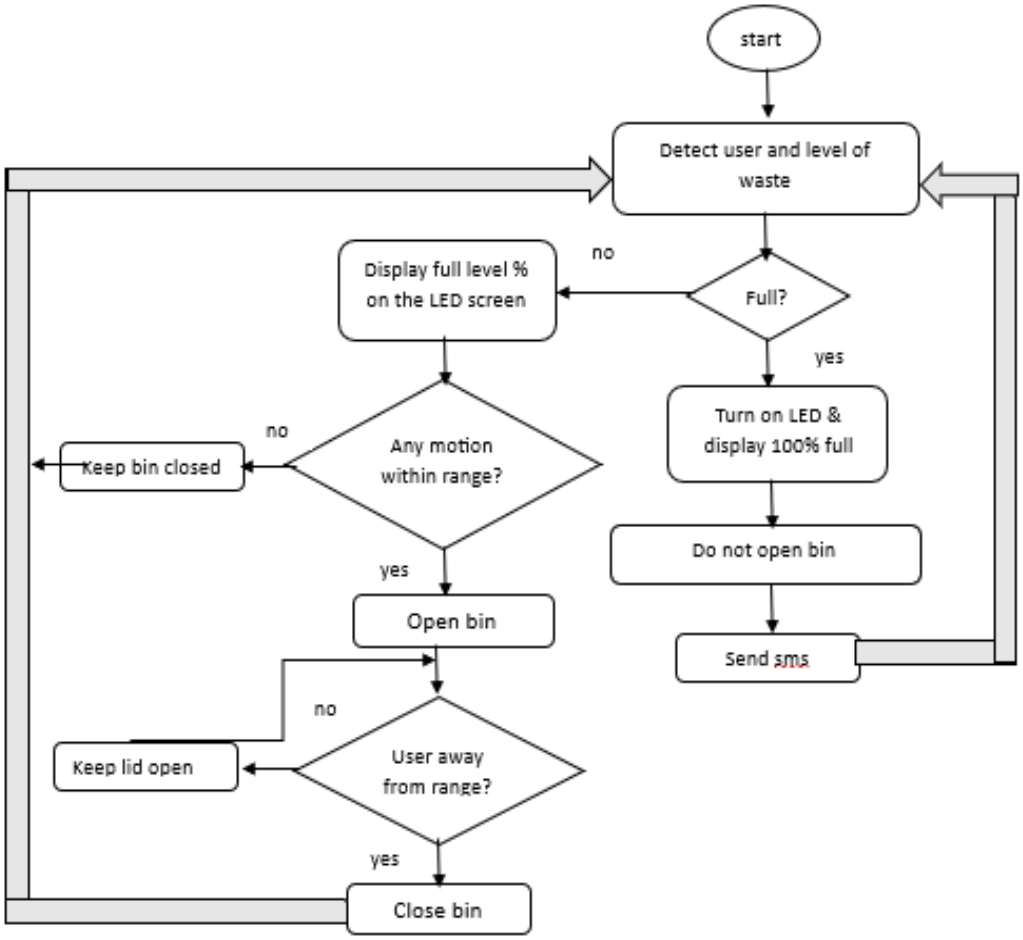

Figure 8. Program flowchart

2. Microcontroller Program: The entire program is developed using the M IDE-51. It relies on four main memories for communication with various modules. These memories are Software Serial memory for communication with the GSM module, Interrupt memory for communication with the PIR module, and others.
3. Setup Function: The controller program's Setup function first defines the used pins as outputs or inputs. It sends AT commands to the GSM module to enable text mode, local time/date stamp, and other settings on the GSM module. The time/date stamp is stored in CSV files during events. This function also retrieves phone numbers and SMS alert text from text files, making it easy to change parameters without altering the program.
4. Interrupt Pin: Digital pin 3 is initialized as an interrupt pin to connect the output pin of the PIR module. This pin is used to check the presence of a human in front of the waste bin when motion is detected.

3. RESULTS AND DISCUSSION

The servo motor is attached to the hinge of the bucket so that when it opens it can be accessed fully. The ultrasonic sensor is mounted inside the waste bin on the roof of the bucket cover faced down to monitor the fullness level. When the bin is full, it does not open unless manually this is also sensed using the ultrasonic sensor. The PIR sensor is mounted outside the waste bin to monitor when a body approaches it. The threshold variable source voltage value is set at -250V. When the voltage is below the threshold, we noticed the on the virtual terminal that the dustbin is not yet full. After ensuring that all the pins are connected properly, we upload the code into the microcontroller and execute.

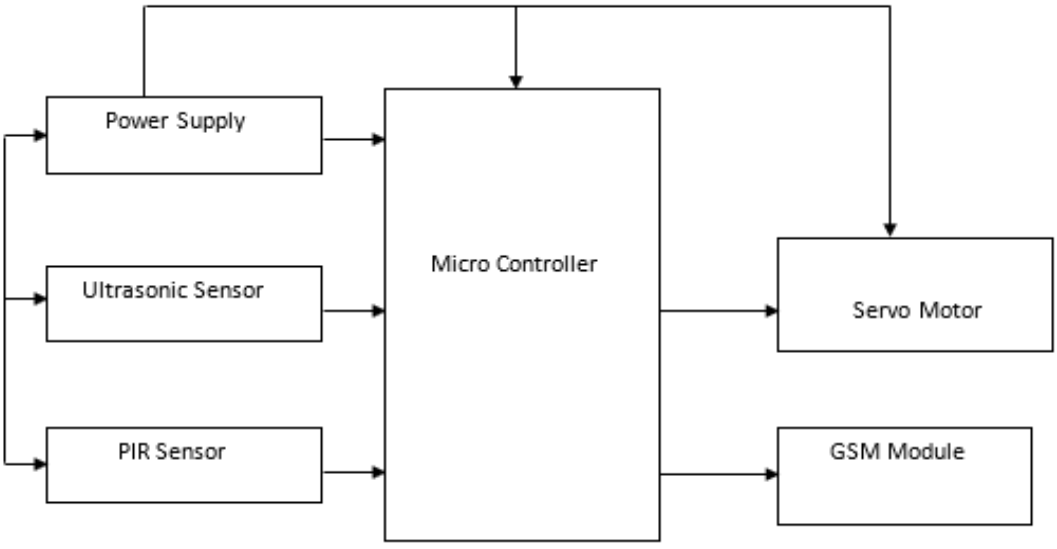

Figure 9. Block diagram of the smart waste bin

Previous work had issues with the bin still opening when full; this project effectively addressed this issue by introducing the PIR sensor for human motion detection. Additionally, the compact and energy-efficient microcontroller used in this work has several advantages.

For future work, the report suggests several improvements:

1) Weight Measurement Sensors: Install sensors to measure the weight of the refuse in the bin, preventing light materials from triggering alerts prematurely.
2) Smell Sensors: Research and implement sensors capable of detecting odors, ensuring immediate pick-up of smelly waste.
3) Expansion to Outdoor Waste Management: The system can be applied for large outdoor waste collection points, such as neighborhoods, streets, and factories where significant waste accumulation occurs.

The smart waste bin underwent testing both indoors and outdoors, revealing some interesting results:

1) PIR Sensor Issue: Initially, the PIR sensor encountered problems as it would frequently switch off due to exposure to direct sunlight. This issue was resolved by placing the bin in the shade and repositioning the PIR sensor to the side of the bin rather than the top. This ensured more reliable motion detection.
2) Power Consumption: The system demonstrated a power usage of 400 mA, with the GSM module utilizing 2W/5V of power. The GSM module's sleep mode effectively reduced its current consumption to 1.5 mA during idle periods, contributing to power efficiency.
3) Servo Motor Challenges: The servo motor faced challenges in opening the smart bin as intended, leading to the need for a motor replacement. Additionally, the code required rewriting to reduce unnecessary delays, which had been hindering the system's responsiveness.
4) Cost Analysis: In terms of cost, the mobile network subscription was found to be cost-effective, offering 100 SMS messages per 400 airtime units.

4. CONCLUSION

This solution has been tested and it works effectively. The sensors were able to interact with the micro-controller to measure and transmit the required parameters and SMS alerts were sent to notify the user when full. With this, waste can be managed more effectively and timely too.

ACKNOWLEDGMENTS

I will like to thank my HOD Engr. Dr Benjamin for his guide which lead to the completion of this research paper. I am also thankful for the resources provided by the university that facilitated the research and development process.

References

[1] Ala, A.-F., Guizani, M., Mohammadi, M., Aledhari, M., & Moussa. (2015). Internet of Things. *A Survey on Enabling Technologies, Protocols, and Application IEEE Communication Surveys & Tutorials,* 17(4), 2347-2377

[2] Al-Maadeed, M., Madi, N. K., Kahraman, R., Hodzic, A., & Ozerkan, N. G. (March 2012). An Overview of Solid Waste Management and Plastic Recycling in Qatar. *Springer Journal of Polymers and the Environment*, 20(1), 186-194

[3] Ambrose, T., Ford, C., & Norris, M. (2015). *Smart City Trash Cans.* California: California Polytechnic State University.

[4] Amr El-Mougy, M. I. (2015). Software- Defined Wireless Network Architectures for the Internet-of-things. *40th Annual IEEE conference on Local Computer Networks*, 804-811.

[5] Ashwin, M., Alqahtani, A. S., & Mubarakali, A. (2021). Iot based intelligent route selection of wastage segregation for smart cities using solar energy. *Sustainable Energy Technologies and Assessments*, (p. 46).

[6] Chenna, K., Govinda, C., Rami, R., & Nookala, V. (2022). Chemical Reaction, Heat and Mass Transfer Effects on MHD Peristaltic Transport in A Vertical Channel Through Space Porosity And Wall Properties. NeuroQuantology.

[7] Ezeudu, O., Ezeudu, T., Ugochukwu, U., Tenebe, I., Ajogu, A., Nwadi, U., & Ajaero, C. (2022). Healthcare waste management in Nigeria.

[8] Hannan, M., & Shafique, I. M. (February 2012). An Overview for Solid Waste bin Monitoring System. *Journal of Applied Science Research,* 8(2), 879-886.

[9] Hassan, B., Hannan, M. A., & Shafiqu, M. (2013). Integrated Sensing and Communication Technologies for Automated Solid Waste Bin Monitoring System. International Conference on Research and Development.

[10] Hong, I., Park, S., Lee, B., Lee, J., Jeong, D., & Park, S. (2014). IoT-Based Smart Garbage System for Efficient Food Waste Management. *The Scientific World Journal*. 1, 646953

[11] Islam , M. S., Arebey , M., Hannan , M. A., & Basri, H. (2012). Overview for solid waste bin monitoring and collection system "Innovation Management and Technology Research" (ICIMTR). *International Conference*, (pp. 258 – 262). Malacca.

[12] Khan, R., Kumar, S., Srivastava, A. K., Dhingra, N., Gupta, M., Bhati, N., & Kumari, P. (2021). Machine Learning and IoT Based Waste Management Model. *Computational Intelligence and Neuroscience*. Volume 2021 | Article ID 5942574 |

[13] Mahajan, K., & Chitode, J. S. (July 2014). Waste bin monitoring system using Integrated Technology. *International Journal of Innovative Research in science Engineering and Technology,* 3(7).

[14] Mamun, A., Hannan, A. A., & Hussain, A. Real Time Solid Waste Bin Monitoring System Framework Using Wireless Sensor Network. *2014 International Conference on Electronics, Information and Communications (ICEIC)*, Kota Kinabalu, Malaysia, 2014, pp. 1-2

[15] Monika, K. A., Rao, N., Prapulla, S. B., & Shobha, G. (2016). Smart Dustbin-An Efficient Garbage Monitoring System. *6*(6), 7113–7116.

[16] Navghane, S. S., Killedar, M. S., & Rohokale, V. M. (2016). IoT Based Smart Garbage and Waste Collection Bin. *International Journal Advanced Research Electronic Communication Engineering, 5*(5), 1576–1578.

[17] Navghane, S. S., Killedar, M. S., & Rohokale, V. M. (May 2016). IoT Based Smart Garbage and Waste Collection Bin. *The International Journal Of Advanced Research in Electronics and Communication Engineering, 5*, 1576 - 1578.

[18] Neha, G., Krishna, K. Y., & Vinit, K. (2015). A review on current status of municipal solid waste management in India. *Journal of Environment Sciences*, 206-217.

[19] Park, H. S., Jang, S. C., Kang, I. S., Lee, D. J., Kim, J. G., & Lee, J. W. (2022). A detailed design for a radioactive waste safety management system using ICT technologies. *Prog Nucl Energy* , 149.

[20] Parkash, P. V. (Feb 2016). IoT Based Waste Management for Smart City. *The International Journal Of Innovative Research in Computer and Communication Engineering, 4*, 1267-1273.

[21] Priya, B. K., Lavanya, T., Samyukta Reddy, V., & Yarlaga. (June 2015). Bin That Thinks. *The International Journal Of Science and Technology, 3*, 218-223.

[22] Qureshi, K.N., Khan, A., Jamil, S.U.U. *et al.* Internet of Things enables smart solid waste bin management system for a sustainable environment. *Environ Sci Pollut Res* 30, 125188–125196 (2023).

[23] RadhaKrishna, K. (2022). Application of IOT on Intrusion Dectection System with Deep Learning Anlysis. *International Jourfor Innovative Engineering and Management Research,* 11 (06), 227-232.

[24] Singh, A. P., & Misra, D. C. (2022). waste management issue and solutions using IOT. *International Journal Science Arch.*, 260-282.

[25] Singh, T., Mahajan, R., & Bagai, D. (2016). Smart Waste Management using Wireless Sensor Network. *International Journal Innovative Research Computer Communication Engineering, 4*(6), 10343-10347.

[26] Waikhom, R., Ram Kumar, S., & Rajeev, K. M. Sensor Unit for Waste Management : A Better Method for Frequent Data Updating System. *2014 International Conference on Science Engineering and Management Research (ICSEMR),* Chennai, India, 2014, pp. 1-5,

[27] Wawale, S., Shabaz, M., Mehbodniya, A., Soni, M., Deb, N., Elashiri, M. A., . . . Naved, M. (2022). Biomeical waste management using IOT tracker and fuzzy classified integrated technique. *Human-centric Computing and Information Sciences* 12: 32

[28] Zavare, S., Parashare, R., Patil, S., Rathod, P., & Babanne, P. V. (2017). Smart City Waste Management System Using GSM. *International Journal Computer Science Trends Technology, 5*(3), 74-78