afriresearch.com *DOI:10.5281/zenodo.15449805*

Title

SMART WASTE MANAGEMENT SYSTEM USING INTERNET OF THINGS (IOT) FOR SUSTAINABLE ENVIRONMENT

Author

ZINENANI ZUZE

Co-Author

Mr. Joel Mulepa

Issue May 2025

Certificate AR2025YAY54W

ABSTRACT

Traditional waste management system operates based on daily schedule which is highly inefficient and costly. The existence of public bins have proved its ineffectiveness in the public as people do not dispose their waste properly. With the development of Internet of Things (IoT) the traditional waste management system can be replaced with smart sensors embedded into the system to perform real time monitoring and allow for better waste management. The purpose of this project is to develop a smart waste management system using microcontroller, ultrasonic sensor, global positioning system, Wifi module: ESP-01 and TensorFlow based deep learning model. Wifi module: ESP-01 and ESP-32 sends the sensor data and Tensorflow performs real time object detection and classification. Ultrasonic sensors will be embedded into waste bins to monitor the filling level of the waste. Global positioning system (GPS) module is integrated to monitor the location and real time of the bin. Wifi module: ESP-01 is used to transmit data about the location, real time and filling level of the bin. This system will be of great benefits such as; cost efficiency which will be achieved by optimizing collection routes based on actual fill levels rather than fixed schedule, improved cleanliness is another benefit, real time monitoring helps prevents overflow situations by ensuring timely collections based on actual need. The waste detection capabilities will allow waste management organisations to better understand what materials are being disposed of. Challenges that can be faced are; implementation cost since some of materials are not locally available on the market and user resistance to changes on technology.

KEYWORDS: Smart Waste Bin, Sensors, Microcontroller, IOT, Waste.

INTRODUCTION

The rise of human population in urban and cities of Malawi has resulted into poor waste disposal, and management. The inadequate waste management infrastructure has resulted in environmental pollution, health hazards, and inefficient resource utilization.

Waste is a great hassle for our health and the environment as it has many effects which are dreadful. Waste is the breeding ground for bacteria, insects, and flies. The bacteria, and flies causes food poisoning, typhoid, gastroentetritis, salmonella, and the insects such as mosquito cause malaria. Beside the flies and insects other animals that depends on wastes are rats and stray dogs that increases the rate of spreading diseases, the poorly managed garbage can also cause various respiratory diseases, like tuberculosis (TB) and Pneumonia.

Disposal of hazardous waste like the electronic items and plastics in water affect the aquatic life and indirectly the human beings. To address these pressing issues, there is a need for innovative solutions that leverage advanced technologies such as smart waste management systems using Internet of Things (IOT) for sustainable environment. The purpose of this paper is to develop a smart waste management

system using internet of things (IOT) and a TensorFlow based deep learning model.

Objectives

The primary objectives of smart waste management system utilizing Internet of Things (IoT) technology for a sustainable environment are multifaceted, focusing on reducing environmental impact, conserving resources, minimizing pollution, and promoting circular economy principles. This system aims at enhancing environmental sustainability by optimizing waste collection, processing, and diversion.

Smart waste management, powered by IoT, is crucial for addressing escalating waste production and contributing to sustainable urban development goals. By incorporating sensors and real-time data analytics, the system significantly reduce environmental impact compared to traditional methods, which are often inefficient and environmentally harmful.
The system optimizes collection schedules and routes using data-driven insights from IoT sensors. This optimization minimizes unnecessary waste collection trips, decreasing the frequency and distance traveled by collection vehicles. The resulting reduction in vehicle activity leads to lower fuel consumption and a corresponding decrease in carbon emissions. This shift from fixed, inefficient routes to dynamic, needs-based collection directly contributes to better air quality.

LITERATURE REVIEW

Malawi Environmental Protection Agency, (2023), *Challenges and Opportunities in Waste Management in Malawi.*

Discussion: Waste management is a critical issue in Malawi, with challenges such as inadequate infrastructure and limited resources for efficient waste disposal.

Khan H, (2023), *Integration of IoT Devices with Deep Learning Models for Smart Waste Management.*

Discussion: Integration of IoT devices with deep learning models can enhance real-time monitoring of waste collection and processing, leading to more effective waste management practices.

Smith J., (2021), *Deep Learning Applications in Waste Management Systems*
Discussion: Deep learning techniques have been successfully applied in waste management systems to optimize resource allocation and improve environmental sustainability.

United Nations Development Programme (UNDP) (2020), (Report on Sustainable Development Goals Implementation in Malawi), *Community Engagement and Technology Adoption for Sustainable Waste Management Practices*
Discussion: Collaboration between government agencies, local communities, and technology experts is essential for implementing a deep learning-enhanced waste management system in Malawi.

Wang Lee, Et al, (2015), *Utilizing Deep Learning Algorithms for Waste Generation Analysis*

Discussion: Deep learning algorithms can analyze large datasets to identify patterns and trends in waste generation, enabling better decision-making for resource allocation.

METHODOLOGY

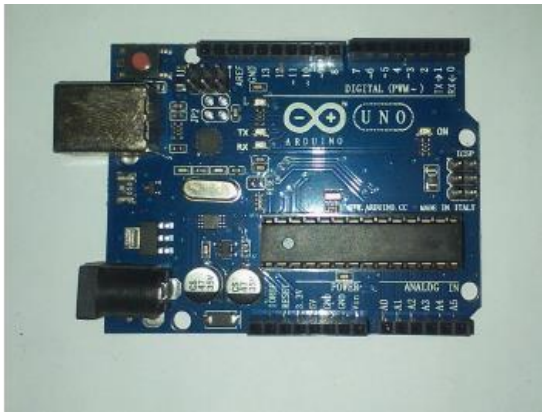
The Smart Waste Management System using IoT works by integrating waste bin, ultrasonic sensors, global positioning system, and a Wi-Fi module with an Arduino microcontroller. The sensors monitor waste fill level in real time and send data to the Arduino microcontroller for processing. This data is also transmitted to a mobile application and web application, allowing waste management organizations to monitor and optimize collection routes. The setup is tested and calibrated to ensure accuracy, then deployed in the residential and selected public areas.

Hardware Requirements

The requirements are categorized in two platforms namely Embedded platform and Server Platform.

Embedded platform requirements

Arduino Uno Ultrasonic Sensors ESP Wi-Fi Module Servo Motor
Global Positioning System GPS) Collection Bin

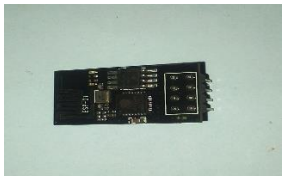


Figure; *Arduino Uno*

This is the microcontroller board, based on ATmega328P. Its features include: the 16MHZ quartz crystals, USB connector, ICSP header, six analogue inputs, a power jack and a reset button. It also has 14 digital inputs and out puts as well. This device processes the signals and transfers data to ESP (Wi-Fi module) remotely.

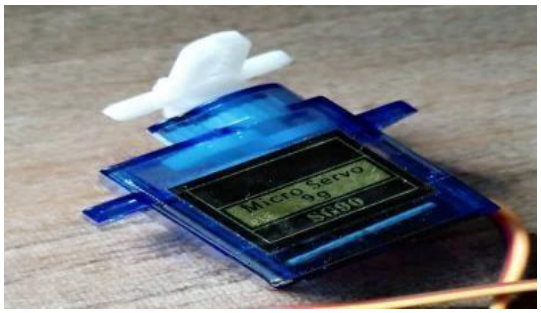
Figure; *Ultrasonic Sensor*

This is the device that responds to physical stimulus and transmits impulse to control system.



Figure; *WIFI Modules*

These are wireless platforms that allow devices to connect to internet using low-power, and wide area networking.



Figure; *Servo Motor*

Servo motor is used to automate lid operations. It is programmed to open and close the lid of the waste bin allowing hand free operations. The use of servo motor in a smart waste management system has shown a promising hygiene and user experience improvement, since there is no need to open bin lids manually.

Figure; *Global Positioning System (GPS).*

The global positioning system on the smart waste management system using IOT, offers a powerful solution for optimizing waste collection, reduce costs, and improving efficiency

Figure; *Collection bin*

A collection bin is a device where all waste management system hardware requirements are embedded to. Its main functions include; waste level monitoring, giving alerts if the bin is full, and provision of locations.

Server platform requirements

1 machine with following minimal needs will be needed:
CPU: Intel 2 GHZ
Memory: 2 GB

Disk: 40 GB
Display : 15 inch color

Network: Internet interface / WIFI Enabled Input
: Keyboard and Mouse

Software Requirements
Embedded platform software requirements

Coding : Python
Platform : Arduino 2.1

Development Tool: Arduino Development Kit
Operating Systsem: Windows

SYSTEM ARCHITECTURE

The system architecture of a smart waste management system utilizing the Internet of Things (IoT) is designed to enhance operational efficiency, sustainability, and responsiveness in urban waste collection. This architecture integrates various components, including sensors, communication networks, cloud platforms, and data analytics tools.

At the core of this architecture are ultrasonic sensors installed in waste bins that monitor fill levels in real-time. These sensors operate by emitting sound waves and measuring the time it takes for the echo to return, allowing them to accurately determine how full a bin is. The data collected by these sensors is crucial for optimizing waste collection routes and schedules.

DATA FLOW DIAGRAM

Data flow diagram is a graphical representation of the flow of data through an informed system. They are used for the visualization of data processing structured design. On a data flow diagram, data items flow from an external data source or internal data store to an internal data or external data sink, via an internal process. The data flow diagram shows how the system is divided into sub-systems each of which deals with one or more of the data flows to or from an external agent, and which together provide full all functionality of system as a whole.

DISCUSSION

A waste management system using internet of things (IoT) uses sensors and network connectivity to monitor and optimize waste collection. This approach involves real-time data collection from waste bins, enabling efficient route planning, resource optimization, and improved environmental performance. Internet of things based solution enhance waste collection, and reduce costs associated with waste management.

The components of this system are the smart bins equipped with ultrasonic sensors to monitor waste level and other relevant data, internet of things platform which collects and analyses data from smart bins, providing insights into waste generation patterns, and data analytics, this component enables waste management teams to optimize collection routes, predict waste generation, and identify areas of improvement.

Benefits of smart waste management system using IoT, may include waste collection routes optimization, waste management cost reduction. Another benefit is that it enhances public health. Timely waste collection and disposal minimizes the risk of disease transmission and maintain a clean environment. Lastly it improves environmental sustainability.

This system will be applicable in in residential areas and some selected public spaces such as streets and parks.

The system may have the following challenges: infrastructure, the system will need regular upgrading to support IoT technology. Another challenge is cost: implementation and maintenance of the system is expensive since its devices are imported. Lastly, data security, ensuring the security and integrity of data collected is crucial.

CONCLUSION

Smart waste management system for sustainable environment using internet of things (IoT) has the potential to revolutionize waste management practices, leading to significant improvements in resource allocation and environmental sustainability. By leveraging the power of Artificial Intelligent, the system can; reduce waste generation and disposal costs, increase resource recovery, promote environmental sustainability, and enhance public awareness and engagement.

However, the successful implementation of such a system requires careful planning, collaboration, and investment. It is crucial to address challenges related to data availability, infrastructure development, and public acceptance. By overcoming these hurdles, Malawi can pave the way for a more sustainable and environmentally responsible future.

REFERENCES

1. Smith, John A. 2023, *Deep Learning Applications in Waste Management Systems*. Aligah, India
2. Brown, Sarah L. 2023, *Optimizing Resource Allocation in Waste Management Using Deep Learning Techniques*.
3. Johnson, Robert M. 2020, *Environmental Sustainability Through Deep Learning- Enhanced Waste Management Systems.* Basel, Switzerland
4. Zhang, Y., Luo, X., & Wang, Y. (2020). *Smart Waste Management System Based on Deep Learning.* IEEE Access.
5. Min, J., & Lee, D. (2019). *Deep Learning-Based Intelligent Waste Management System*. IEEE Access: Practical Innovations.