Waste Management in Foundries- Real Time Smart Garbage System

Anindita Das Mondal
Brainware University, Kolkata

Abstract:
In a world grappling with the dual challenges of an exploding population and mounting waste generation, traditional waste management systems are proving to be inadequate and unsustainable. From foundries emits harmful pollutants, and waste collection processes are also inefficient. The "Smart Garbage Container System "presents an innovative solution that addresses the issue of waste disposal. The rapid growth of the global population has led to an alarming increase in waste production. Traditional waste management systems, based on outdated practices, are struggling to cope with this surge in waste. As a result, the environment is suffering from the toxic effects of waste disposal. Furthermore, the proposal comes at a time when the world is actively seeking cleaner and more sustainable energy sources to reduce our carbon footprint. This proposal is a comprehensive solution aimed at transforming the waste management landscape and simultaneously harnessing renewable energy. This ambitious initiative consists of the main component is to make Smart Garbage Container. The heart of the project is the Smart Garbage System, which incorporates advanced sensors and Internet of Things (IoT) technology to monitor and manage waste containers in real-time. These sensors are strategically placed within waste bins to detect fill levels accurately. The data collected is transmitted to a central control center, allowing for dynamic waste collection route optimization. All the units in the shop can access this data via mobile applications, facilitating efficient waste disposal and eliminating unnecessary pickups. An innovative aspect of the proposed model is the integration of a biogas generation plant into the waste management process. Organic waste of foundry industry collected from the Smart Garbage System is directed to the biogas plant. Here, through the process of anaerobic digestion, organic waste is converted into biogas. Biogas is primarily composed of methane, a potent energy source. This renewable biogas can be utilized for various purposes, including electricity generation, heating, and as an alternative fuel source for vehicles. The "Smart Garbage Container with Biogas Production" offers a multitude of advantages. Firstly, it significantly reduces the environmental impact of waste disposal. By diverting organic waste from landfills, it helps alleviate the strain on these overloaded sites. Moreover, the proposed model contributes to the global effort to mitigate climate change by substituting fossil fuels with biogas, a cleaner and renewable energy source. Additionally, the model presents economic benefits by optimizing waste collection routes, reducing fuel consumption, and decreasing maintenance costs for waste containers and trucks.

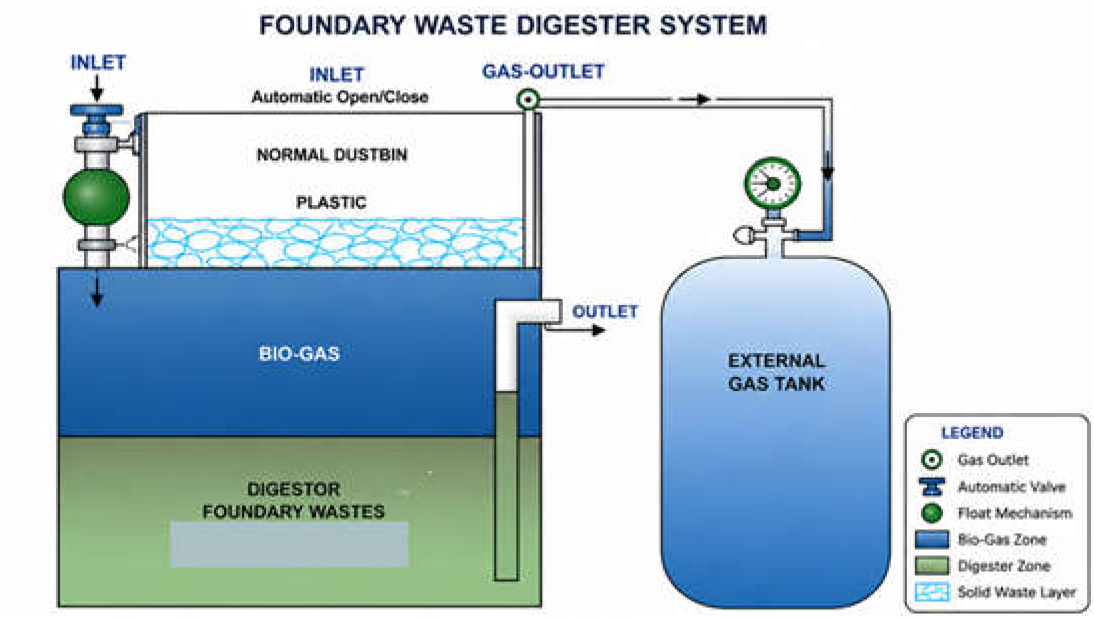
Keywords: Smart Garbage, Waste Management, IoT, Biogas production

1. Introduction:

Waste management is a pressing concern in today's urban environments. The conventional methods of waste disposal, relying on manual collection and disposal, have become increasingly unsustainable. Overflowing bins, unhygienic conditions, and the spread of diseases in urban areas have necessitated innovative solutions. Among these, the integration of automated garbage collection systems with biogas generation is emerging as a noteworthy paradigm shift in the realm of waste management. This literature survey delves into this innovative approach, comparing it with traditional waste disposal methods and exploring its implications. In conventional waste disposal practices, individuals manually deposit their waste into bins, which are emptied periodically. This process, while simple, has its limitations. When bins become full, there is a risk of overflowing waste, attracting pests, and creating unsanitary conditions. Maintenance issues, such as broken lids, can further exacerbate the situation. In neighborhoods and colonies, irregular bin emptying exacerbates these problems, fostering an environment conducive to various diseases.

Another traditional method involves the use of segmented bins for different types of waste. For example, green and blue bins are allocated for recycling. However, this approach, like the former, necessitates manual waste disposal. It aims to promote recycling but still encounters challenges like inefficient waste management, overflowing bins, and related hygiene issues.[1] In contrast, the integration of automated garbage collection systems with biogas generation represents a substantial leap in modern waste management [2]. This approach overcomes the limitations of traditional methods through the introduction of automation and technology.

2. Proposed Model:



created using ChatGPT and edited by the author

Fig 1. Foundary waste digester system

3. Real time implementation model:

Fig 2. Real time diagram Model

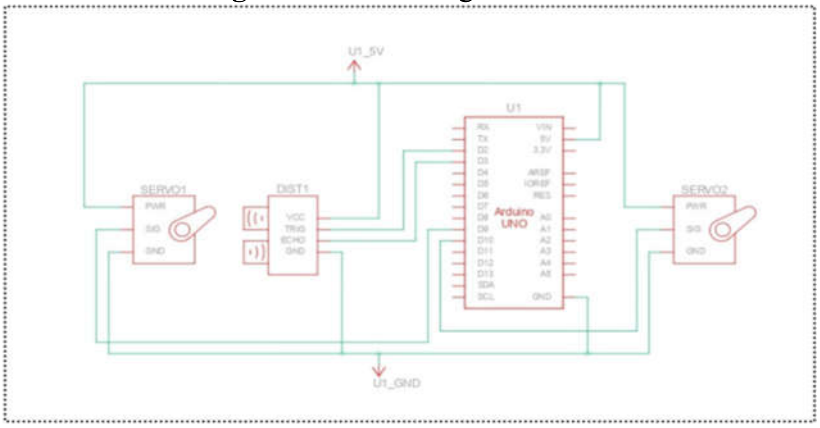


Fig 3 diagram of IOT implementation

Component details:

a) Arduino Uno Rev R3:

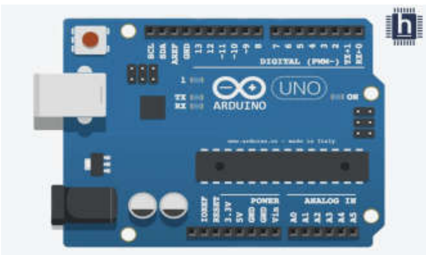


Fig 4 Arduino Uno

The Arduino Uno Rev R3 is a popular and versatile microcontroller board that serves as the brain of countless DIY electronics projects. It's based on the ATmega328P microcontroller, offering 14 digital input/output pins and 6 analog input pins. The Uno is known for its ease of use, with a simple, beginner-friendly development environment that enables users to write and upload code via USB.The board supports various sensors, shields, and modules, making it an ideal choice for makers, hobbyists, and students. It can interact with a wide range of components, such as sensors, displays, motors, and more, making it perfect for prototyping and creating interactive devices.With a focus on open-source hardware and software, the Arduino Uno Rev R3 has a strong community that continually contributes to its development. Whether you're building a robotics project, a home automation system, or an art installation, the Arduino Uno is an excellent starting point for your creative endeavors.

b) Ultrasonic Sensor:

Fig 5 Ultrasonic Sensor

The Ultrasonic Sensor is a versatile device used for non-contact distance measurement in various applications, such as robotics, automation, and object detection. It operates on the principle of sending and receiving ultrasonic waves. The sensor emits a high-frequency sound wave and measures the time it takes for the sound to bounce back after hitting an object. Using this time measurement, the sensor can calculate the distance to the object.Ultrasonic sensors come in different varieties, including single- and multi-element sensors, and they offer varying ranges and precision. They are known for their simplicity and reliability in measuring distances accurately within their specified range. Ultrasonic sensors are commonly used in robotics to detect obstacles, in industrial settings for level measurement, and in automotive applications for parking assistance systems.The sensor's non-contact nature and ability to work in various lighting conditions make it a popular choice for a wide range of distance-sensing needs.

c) Servo Motor:

Fig 6 Servo Motor

A Servo Motor is a rotary actuator that allows for precise control of angular position. It is known for its ability to rotate within a specific range of angles and hold those positions accurately. Servo motors are widely used in various applications, from robotics and automation to model aircraft and CNC machinery. The servo motor consists of a motor, a control circuit, and a feedback system. The feedback system, which is often a potentiometer, continuously provides information about the motor's current position to the control circuit. The control circuit adjusts the motor's position until it matches the desired position.Servo motors are popular for their ability to provide accurate and repeatable motion control. They come in various sizes and torque ratings, allowing them to be used in a wide range of applications. Their simplicity and precision make them essential components in projects that require controlled and precise movement, such as robotic arms, camera gimbals, and 3D printers.

4. IOT Implementation Procedure

Step 1: Hardware Setup

Begin by assembling the necessary hardware components. In your case, you're using an Arduino, an ultrasonic sensor, and other components. Connect the ultrasonic sensor to the Arduino, ensuring proper wiring and connections.

Step 2: Code for Ultrasonic Sensor: Write the code in Python for the Arduino to interface with the ultrasonic sensor. This code should enable the sensor to measure the distance from the top of the garbage to the sensor. When the measured distance is below a certain threshold, it indicates that the garbage level is reaching capacity.

Step 3: IoT Communication: Set up a communication protocol for your Arduino to connect to the Internet. You might use Wi-Fi or a similar technology to transmit data to a remote server. Utilize Python libraries like 'pySerial' or 'pywifi' to establish the connection.

Step 4: Server and Database: Create a remote server and a database to receive and store the data from your Arduino. You can use Python for server-side scripting and a database management system like MySQL or SQLite to store data.

Step 5: Real-time Monitoring: Develop a web interface or mobile app using Python, which connects to the server and displays real-time data. Users can check the garbage level remotely and receive alerts when it's time to empty the bin.

Step 6: Actuator Control: Integrate actuators, like a motor or a servo, to control the lid of the garbage bin. Write Python code that can be triggered by your IoT system when the garbage level reaches a certain threshold. This code will instruct the actuator to open the bin for garbage collection.

Step 7: User Interface: Create a user-friendly interface for your automated garbage collection system. Users can control and monitor the system through a web application or a mobile app. Use Python libraries for web development like Django or Flask.

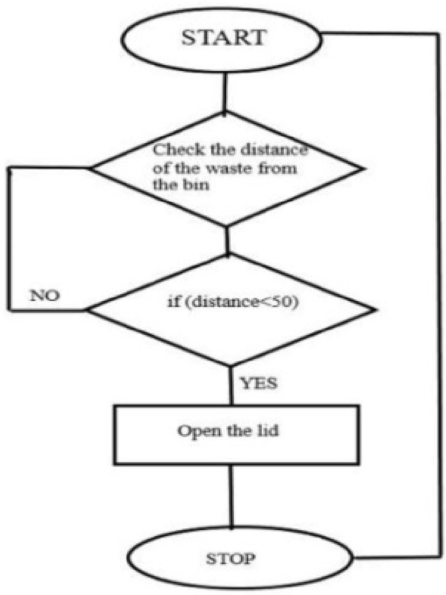
Step 8: Notifications: Implement notification features in your web or mobile app using Python libraries. When the garbage bin is full or when it's time for collection, the system should send alerts to the user.

Step 9: Testing and Calibration: Thoroughly test the entire system to ensure that the ultrasonic sensor, actuators, and IoT communication work seamlessly. Calibrate the system to ensure accurate garbage level measurements.

Step 10: Deployment: Once testing and calibration are complete, deploy the system. Install it in the target environment, whether it's a household, neighborhood, or urban area. Ensure a reliable power source and internet connectivity.

This step-by-step implementation allows your automated garbage collection system to measure garbage levels, communicate real-time data, and remotely control the garbage bin's lid. Users can efficiently monitor and manage waste while promoting sustainability through biogas generation. Python is instrumental in interfacing and managing the various components in this IoT solution.

5. Workflow of the proposed model



Main coding follow up steps:

1. Start the program.
2. Initialize serial communication at 9600 baud rate.
3. Wait for 50 ms.
4. Send ultrasonic pulse through Trigger pin.
5. Receive reflected pulse through Echo pin.
6. Calculate distance in centimeters.
7. Store distance value.
8. Display distance on Serial Monitor.
9. Check if any control action is required based on distance.
10. Repeat the process continuously.

This block representation is suitable for inclusion in a project report, repository documentation, or presentation on an IoT-based Smart Dustbin or Ultrasonic Distance Measurement System.

Coding Details:

1. Import Libraries:
Import the necessary libraries for working with the Raspberry Pi GPIO, such as RPi. GPIO, and time for time-related functions.
2. Set Up GPIO:
Set the GPIO mode (BCM or BOARD) and configure the GPIO pins for the ultrasonic sensor's trigger and echo pins, as well as the servo motor's control pin.
3. Initialize Servo Motor:
Initialize the servo motor, usually through PWM (Pulse Width Modulation), with a specific frequency (e.g., 50 Hz). The servo motor is started with an initial duty cycle (e.g., 0) to set it to an initial position (e.g., 0 degrees).
4. Main Loop:
Enter a continuous loop that repeatedly performs the following steps.

5.Trigger Ultrasonic Sensor:
Send a very short pulse to the trigger pin of the ultrasonic sensor and then turn it off. This triggers the sensor to send out an ultrasonic wave.
6. Measure Distance:
Calculate the time it takes for the ultrasonic wave to return (echo). The duration can be measured by detecting the rising and falling edges of the echo signal.
7. Calculate Distance:
Use the duration of the echo signal to calculate the distance to the nearest object. This calculation is often based on the speed of sound (approximately 343 meters per second) and the time taken for the sound wave to travel to the object and back.
8. Control Servo Motor:
Check the calculated distance. If the distance is less than 20 cm, change the duty cycle of the servo motor to move it to a specific position (e.g., 180 degrees) that corresponds to the desired action (e.g., avoidance). If the distance is greater than or equal to 20 cm, change the servo's duty cycle to another position (e.g., 0 degrees) to return to its initial state.

9. Clean Up and Error Handling:
Implement proper error handling to ensure the program exits gracefully when interrupted by the user or if any exceptions occur. Stop the servo motor and clean up the GPIO resources.
This algorithm outlines the logic for controlling a servo motor based on the distance measured by an ultrasonic sensor. Actual code implementation may vary depending on the programming language and hardware used.

Future Scope:
The future scope for kitchen waste-based biogas production systems is promising and includes several potential developments and opportunities:

i. **Advanced Technology:** Continuous advancements in biogas technology, including compact and efficient digesters, could make kitchen waste biogas systems more accessible and user-friendly.
ii. **Integration with Smart Homes:** Integration with smart home systems could enable users to monitor and control biogas production and usage remotely, optimizing energy management.
iii. **Waste-to-Energy Microgrids:** Integration of kitchen waste biogas systems into local energy grids or microgrids could enhance energy distribution and resilience in communities.
iv. **Urban Farming:** The nutrient-rich residue from biogas production can be used for urban farming and gardening, supporting local food production and sustainability.
v. **Circular Economy Initiatives:** Kitchen waste biogas systems can be part of broader circular economy initiatives, emphasizing waste reduction, reuse, and recycling.
vi. **Economic Opportunities:** Entrepreneurs and businesses can explore opportunities in manufacturing and installing kitchen waste biogas systems, creating jobs and contributing to sustainability.
vii. **Environmental Regulations:** Increasing environmental regulations and incentives for waste management and renewable energy could drive the adoption of these systems.

viii. **Educational Programs:** Educational programs and awareness campaigns can promote the benefits of kitchen waste biogas production, encouraging more households to adopt the technology.

ix. **Research and Development:** Ongoing research can lead to innovations in materials, processes, and efficiency, making these systems even more effective and affordable.

x. **Global Sustainability Goals:** As countries work towards sustainability goals and reducing greenhouse gas emissions, kitchen waste biogas systems align with these objectives and may receive support and funding.

The future of the project is closely tied to authors collective commitment to sustainable practices and the development of technologies that enable more efficient and widespread adoption. As these systems become more commonplace, they have the potential to play a significant role in reducing foundry waste and contributing to renewable energy production.

Conclusion:

In conclusion, this model represents a significant step toward a more sustainable and environmentally responsible future. By implementing a smart garbage container system that can able to address critical issues of waste management in foundries. As we move forward, the potential for reducing landfill waste, mitigating environmental pollution. The future scope of the model offers a path to cleaner, more efficient urban living and the opportunity for rural communities to harness renewable energy while managing waste effectively. By embracing this innovative technology, authors contribute to a greener world, where economic, environmental, and social benefits onverge for a more sustainable tomorrow.

References:

1. Telugu Maddileti, Harish Kurakula, ”Iot Based Smart Dustbin, International Journal Of Scientific & Technology Research “, Volume 9, Issue 02, (February 2020).

2. Guerrero, L.A., Maas, G., Hogland, W, “Solid waste management challenges for cities in developing countries”, Journal of Waste Management (2012)

3. Harshlata S. Punse et al, “Smart Waste Management with Biogas Production,”, JETIR, June 2019, Volume 6, Issue 6 (2019)

4. Dattatray Waghole et al, “Smart Bin for Waste Segregation and Energy Generation using IoT,” International Journal of Engineering Research & Technology (IJERT), Vol. 10 Issue 04, (April-2021).

5. Poddar, H., Paul, R., Mukherjee, S., & Bhattacharyya, “Design of smart bin for smarter cities,” (2017, April).

6. Abeygunawardhana. A. G. D. T et al, “AI-Driven Smart Bin for Waste Management, conference on Advancements in Computing (ICAC),”IEEE, DOI: 10.1109/ICAC51239.2020.9357151 (2020).

7. Salma A. Iqbal et al, Anaerobic digestion of kitchen waste to produce biogas, 10th International Conference on Mechanical Engineering, ICME (2013).

8. Sharma,SN., et al., "Predictive Analytics for Waste Management Using Machine Learning,", Artificial Intelligence Applications for a Sustainable Environment, 2025 – Springer.

9. W Zhao, JL Hao, G Gong, T Fischer, Y Liu," Applying digital technologies in construction waste management for facilitating sustainability", Journal of environmental, 2025, Elsevier.

10. Dawar, I., Srivastava, A., Singal, M. et al. "A systematic literature review on municipal solid waste management using machine learning and deep learning." ,Artif Intell Rev 58, 183 (2025). https://doi.org/10.1007/s10462-025-11196-9.

11. Sosunova and J. Porras, "IoT-Enabled Smart Waste Management Systems for Smart Cities: A Systematic Review," in *IEEE Access*, vol. 10, pp. 73326-73363, 2022, doi: 10.1109/ACCESS.2022.3188308.

12. A. Arroub, B. Zahi, E. Sabir, and M. Sadik, "A literature review on smart cities: Paradigms, opportunities and open problems," in *Proc. Int. Conf. Wireless Netw. Mobile Commun. (WINCOM)*, Oct. 2016, pp. 180–186, doi: 10.1109/WINCOM.2016.7777211.

13. M. S. Chaudhari, B. Patil, and V. Raut, "IoT based waste collection management system for smart cities: An overview," in *Proc. 3rd Int. Conf. Comput. Methodologies Commun. (ICCMC)*, Mar. 2019, pp. 802–805, doi: 10.1109/ICCMC.2019.8819776.

14. G. Soni and S. Kandasamy, "Smart garbage bin systems—A comprehensive survey," in *Proc. Int. Conf. Intell. Inf. Technol.*, 2018, pp. 194–206, doi: 10.1007/978-981-10-7635-0_15.

[15] M. Topaloglu, F. Yarkin, and T. Kaya, "Solid waste collection system selection for smart cities based on a type-2 fuzzy multi-criteria decision technique," *Soft Comput.*, vol. 22, no. 15, pp. 4879–4890, Aug. 2018, doi: 10.1007/S00500-018-3232-8.