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ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.86

IOT based smart trash management and response robot

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ABSTRACT

With the increasing need for efficient waste management, automation plays a crucial role in maintaining cleanliness in public and private spaces. The "Smart Dustbin and Auto Cleaning System" is designed to optimize waste collection and disposal by integrating smart technology. This system consists of a smart dustbin equipped with sensors to detect the waste level and an autonomous cleaning robot that collects waste when the bin is full. The smart dustbin uses IoT-based sensors to monitor waste levels and sends realtime data to a centralized system. When the dustbin reaches a predefined threshold, the auto-cleaning robot is activated. Using advanced navigation and obstacle detection, the robot moves towards the dustbin, collects the waste, and transports it to the designated disposal area. Additionally, the system features a detection mechanism that identifies whether the waste is dry or wet when placed on a plate above the dustbin. Once detected, the system differentiates and segregates the waste accordingly, ensuring efficient waste disposal. The system is built using various components, including RBS, servo motors, LCD displays, IoT modules, IR sensors, ultrasonic sensors, wet and dry sensors, ESP32, GPS for robot navigation, Arduino, robotic mechanisms, switches, and LCD screens. These components work together to enable seamless waste monitoring, sorting, and cleaning operations. By integrating IoT, automated navigation, real-time monitoring, waste differentiation, and a robust set of hardware components, this system enhances urban waste management, reduces human effort, and promotes a cleaner environment.

Keywords: Garbage Level Detection, Ultrasonic Sensor, Wireless Communication, Waste Segregation, Servo Motor Control

1. INTRODUCTION

In recent years, urbanization has drastically increased, resulting in growing challenges forcity planners and waste management authorities. The surge in population, coupled with an increase in consumerism, has led to the production of large amounts of waste, which puts immense pressure on existing waste management systems. Traditional waste collection methods, which often rely on manual labor and periodic collections, have proven to be inefficient and inadequate in addressing these challenges. Overflowing bins, poor waste segregation, and delayed waste disposal have become frequent issues in urban areas, contributing to environmental degradation and posing a threat to public health. The integration of advanced technologies, such as robotics, the Internet of Things (IoT), and smart sensors, into waste management systems has shown promising potential for addressing these issues. The Smart Bin Management and Response Robot system is a cutting-edge solution designed to automate the waste sorting process, monitor bin status in real-time, and optimize waste collection operations. By leveraging robotic technology and IoT connectivity, the system aim s to streamline waste disposal, reduce human intervention, and improve efficiency in urban waste management.

2. LITERATURE SURVEY

Pollak, etal(2024) explored the MARBLE project use of autonomous robots for smart waste management in urban areas. We identified that the lack of data on litter bin (LB) fill levels hindered efficient services. To address this, we implemented machine learning-based predictions for LB filling levels, achieving 82% accuracy with the XGBoost binary classifier. ByincorporatingthesepredictionsintoaSimulatedRebalancingapproach for route planning, combined with the Knapsack algorithm, we reduced operational time by 26% and energy consumption by 31% in our simulations for the James-Simon-Monbijoupark in Berlin. **[1] Abdullahi,etal(2024)**Thispaper,"DevelopmentofaSmartWasteManagementSystemwith Automatic Bin Lid Control,"presented a solution for optimizing waste collection in smart cities using the Internet of Things (IoT). The system featured intelligent waste bins with automatic lid control that opened only when the bin was not full, ensuring efficient waste disposal. By prioritizing bins based on real-time waste levels, it reduced unnecessary collection trips and improved operational efficiency. This approach provided city authorities with valuable insights for data-driven waste management, contributing to a cleaner and more sustainable urban environment. **[2] Zoumpoulis, et al (2024)** In the past, early smart waste collection systems focused on basic featureslikefill-level monitoring and IoT connectivity formor eefficient collection. However, they lacked advanced automation and material separation capabilities. Research highlighted varied approaches to waste sorting, with no standardized solutions. These early efforts laid the groundwork but revealed significant gaps in optimizing resource recovery and advancing sustainability in urban waste management. **[3] Oguejiofor, et al (2024)** smart waste management systems have been developed to improve efficiency and reducehuman intervention. Early prototypes incorporated sensors like ultrasonic devices to monitor waste levels, and micro controller- based systems such as Arduino were used toautomatetheopeningandclosingofbinlids. These systems also included features like GSM communication to notify waste collectors when bins were full ,reducing unnecessary collection trips. Such innovations aimed to optimize waste collection, minimize pollution, and improve environmental cleanliness by ensuring timely disposal without frequent manual checks.**[4]**. **Bithi, et al (2024)**smart waste management systems were developed to tackle waste disposal challenges and align with sustainability goals. Researchers used platforms likeArduino Uno andultrasonic sensor to design prototypes that could detect objects and automate the opening of bin lids. These early systems aimed to improve hygiene and efficiency by reducing human intervention. By creating hardware prototypes and testing their functionality, previous work laid the foundation for further enhancements in smart bins, offering solutions to waste management while contributing to health and sustainability goals.**[5] Shaneal(2024)**explored the potential of smart bins to promote waste reduction, particularly through systems like PAYT. Researchers surveyed populations, such as in Japan, to gauge publicresponsetosmartbinfeatureslikeautomatedwasteseparationandunscheduledpickups.
Findings revealed that younger individuals were more receptive to these technologies, while older generations showed less interest. Additionally, those who didn't engage in waste separation were less likely to support the idea of reducing plastic waste, even with smart bin assistance. This highlights that , along side technological advancements , strategies to encourage behavioural changes are necessary for successful waste reduction.**[6] Dimailig, et al (2024)** Focused on creating contactless, motion-activated trash bins to reduce the risk of indirect virus transmission through contaminated surfaces. Studies incorporated ultrasonic sensors for motion detection, demonstrating the feasibility of such systems. Prototypes were developed that could detect motion up to 60 cm with a response time of less than half a second,

and self-dispose waste effectively with a capacity of 1 to 3 kg. These innovations addressed the need for hygienic ,efficient waste disposal , emphasizing the potential of sensor-driven solutions. Recommendations for future improvements included using higher- quality materials for better performance.**[7] Rahman, et al (2024)** researchers tackled inefficiencies in waste management by integrating IoT technologies like LoRa to improve coordination among garbage collection trucks. They focused on addressing fairness issues in transportation units ,which often led to varying active times. By designing a network for reliable data exchange, they framed the problem as a capacitated vehicle routing issue and proposed an objective function that balanced total distance with fairness. Simulations showed that this approach effectively minimized travel distances while ensuring fairness across the waste collection process.

3. PROPOSED SYSTEM

The smart Bin Management system comprises two primary sections: the Transmitting Section and the Receiving Section. Each section plays a vital role in the efficient handling, sorting, and collection of waste. The Transmitting Section is responsible for detecting and classifying the waste as it enters the bin. The Receiving Section focuses on waste sorting, collection, and transportation through an autonomous cleaning robot. This system integrates various components, including sensors, microcontrollers, robotic systems, and IoT connectivity, to provide a comprehensive and intelligent waste management solution.

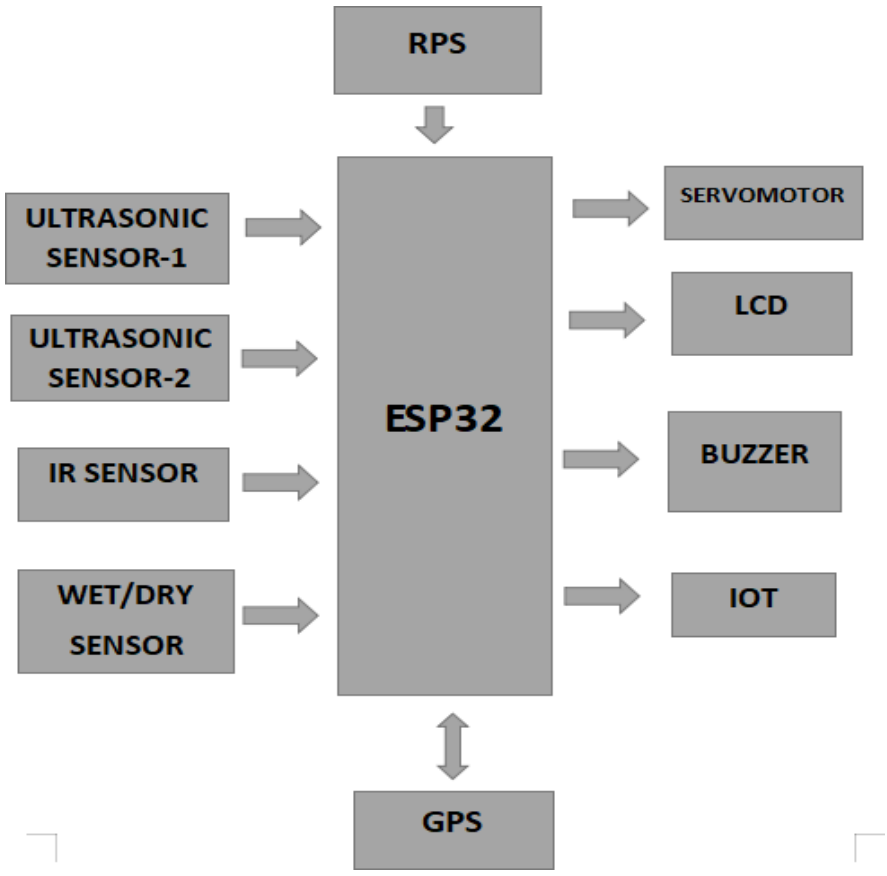

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Fig1: Block diagram of proposed system transmitting section

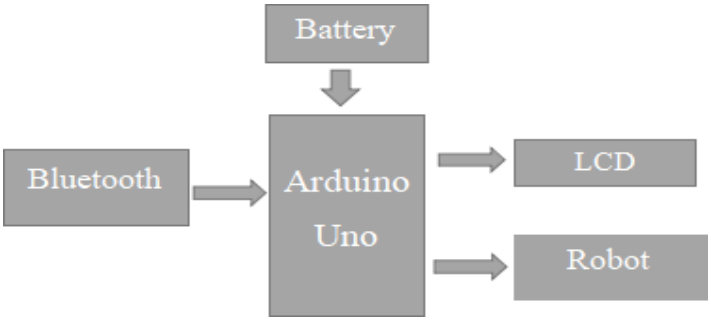

Fig2: Block diagram of proposed system receiving section

The Smart Bin Management and Response Robot system utilizes ESP32 and Arduino to automate waste management and robotic assistance.The ESP32 processes data from multiple sensors ,including ultrasonic, IR, and wet/dry sensors, to monitor bin fill levels, detect objects, and determine waste type.It communicates with an IoT module for real-time data updates and activates outputs like LCD ,buzzer and servomotor to indicate bin status oroperate mechanical components. A GPS module helps track bin locations. Meanwhile, the Arduino-controlled response robot receives commands, powered by a battery, and connected via a router for network communication. A switch in itiates the robot' movement, enabling it to perform tasks such as waste collection or navigation to designated bins. The system ensures efficient waste disposal, remote monitoring, and automated robotic intervention, enhancing smart city waste management.

4. Result analysis

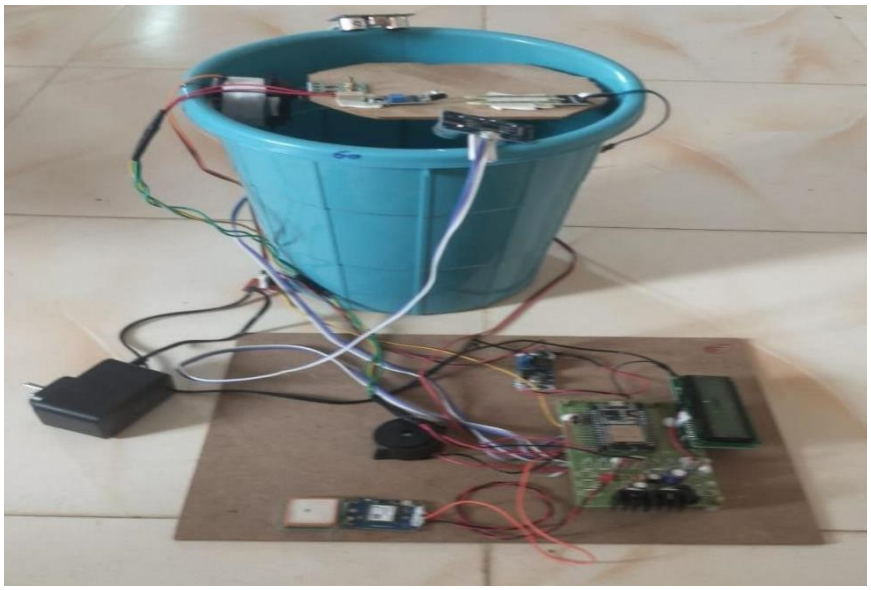

Fig 3: smartbin setup

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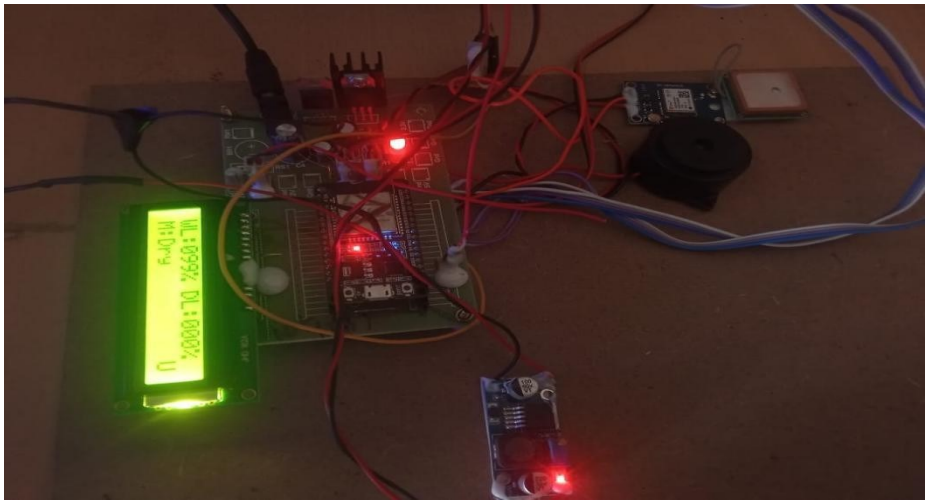
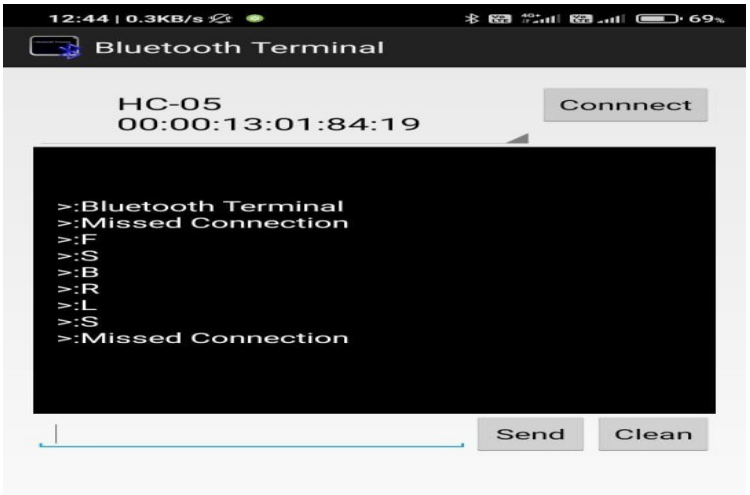


The figure 3 image shows the transmitting section of your smart bin project, featuring sensor- based waste segregation with an ESP32controller, ultrasonic and IRsensors ,an LCD display, and GPS for IoT-based monitoring.

Fig 4: Title Display in LCD

The figure 4 displays the control circuit of the IoT Smart Bin Management system, featuring an ESP32 microcontroller, LCD display, power regulation module, and connected sensors for waste monitoring and segregation.



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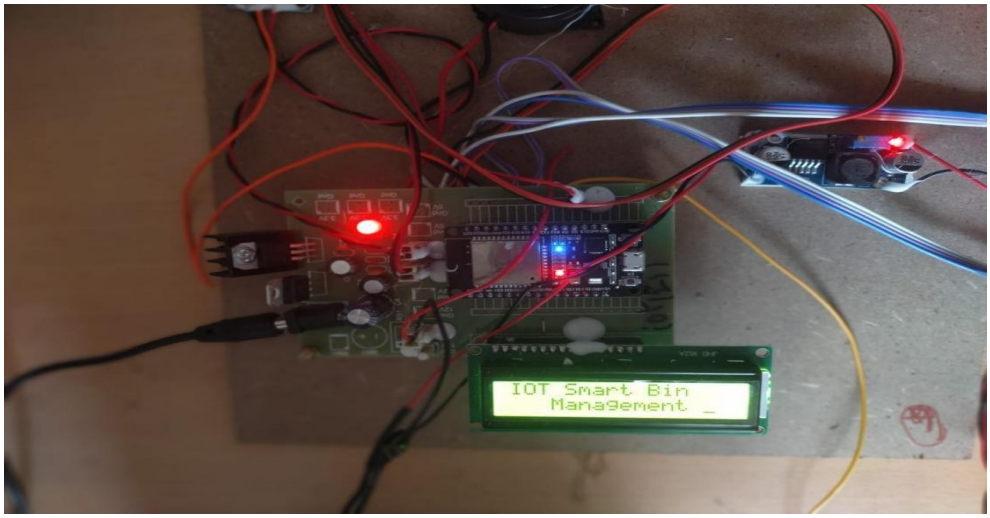

Fig.5: Robot commands

The figure 5 shows the Bluetooth Terminal apposed for controlling the Smart Bin robot via the HC-05 Bluetooth module, displaying movement commands like Forward (F), Backward (B), Left (L), Right (R), and Stop (S) along with connection status.

5. CONCLUSION

The Smart Dustbin and Auto Cleaning System represents a significant step toward modernized waste management solutions. By integrating smart technology, real-time waste level monitoring, automated waste collection, and waste segregation, this system provides a sustainable and efficient approach to maintaining cleanliness. As cities and communities continue to embrace smart solutions, this system has the potential to play a crucial role in shaping the future of waste management, promoting environmental conservation, and ensuring healthier living conditions for all.

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