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Cleanique – A Smart Dustbin

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Abstract: *This study focuses on the innovative design and development of a Smart Dustbin system aimed at transforming waste management into an efficient, hygienic, and user-friendly process. The Smart Dustbin integrates advanced technologies such as IoT, sensors, and automation to provide features including automatic lid operation, waste sorting, mobility, and vacuum cleaning. The system addresses the growing need for sustainable and contactless waste disposal solutions, significantly reducing manual intervention while promoting hygiene. Through systematic testing and integration of components such as microcontrollers, ultrasonic sensors, and moisture detectors, this research establishes the functionality and applicability of the proposed system in diverse environments such as homes, offices, and public spaces. Furthermore, this paper explores potential future enhancements, including AI integration and solar charging, to advance the system's capabilities.*

Keywords: Smart Dustbin, Waste Management, IoT, Automation, Sensors, Sustainability of components such as microcontrollers

I. INTRODUCTION

The growth of urban population has indeed caused an avalanche of wastes, imposing a constraining need for sustainable and highly efficient waste management methods. Most traditional practices are rather manual, infrequent in collection, and not efficient in segregation, subjecting the environment and public health to the greater risk. Improper waste management contributes to air, water, and soil pollution and unhygienic methods expose workers and the public to various disease-causing pathogens.

The Internet of Things (IoT) and automation provide an opportunity to transform waste management in the many developing and developed nations. An IoT-enabled smart system could automate waste collection, optimize its disposal routes, and improve segregation efficiency, which creates economic savings and hygiene as well as environmental sustainability. Many smart waste management solutions have appeared in literature, but they often face challenges such as high-power consumption and heavy reliance on connectivity. Unlike previously proposed solutions, Cleanique Smart Dustbin enables real-time waste segregation, self-mobility for strategic disposal, and is thus suitable for the home and office as well as public spaces. The system integrates smart city initiatives for reducing the overflow of waste, manual intervention, and carbon emissions generated from conventional waste collection.

II. LITERATURE REVIEW

Effective waste management plays a vital role in promoting sustainable urban development. Conventional waste collection methods often encounter problems such as delays in pickups, overflowing bins, and insufficient segregation of waste. To tackle these issues, researchers have begun investigating IoT-based smart waste management systems that emphasize automation, real-time monitoring, and data-informed decision-making.

Smart Dustbin for Waste Management Using IoT, Shyam et al. introduced a Smart Dustbin designed for efficient Waste Management by employing RFID technology and various sensors to control lids automatically while detecting waste

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levels. Although this system improves hygiene standards and operational efficiency, it lacks the capability to separate wet from dry waste—a critical component of responsible waste management practices.

Intelligent Waste Management System with Smart Dustbin, Alamin et al. developed an intelligent waste management framework that incorporates smart sensors and cloud computing technologies. Their findings underscore the significance of data analytics in streamlining collection processes; however, the focus remains mainly on expansive citywide applications rather than solutions catered to individual user needs.

Automated Smart Waste Management Using IoT, Mohapatra et al. created an Automated Smart Waste Management System that integrates machine learning algorithms for effective categorization of different types of waste materials. By leveraging real-time data processing, they seek to enhance scheduling efficiency for collections but caution that increased computational demands might raise power consumption levels—potentially making this solution unsuitable for smaller-scale operations.

IoT-Enabled Smart Dustbins for Smart Cities, Ramana et al. investigated an IoT-driven Smart Dustbin specifically tailored for urban environments. This design employs Wi-Fi technology along with cloud storage capabilities to monitor fill levels effectively while signalling teams responsible for trash removal when needed. Nonetheless, heavy reliance on continuous internet connectivity may create obstacles especially in areas with weak network support.

III. METHODOLOGY

The Cleanique Smart Dustbin is designed to provide an automated, hygienic, and intelligent waste management system that integrates IoT, sensors, and mobility features. The system consists of hardware components for waste detection, segregation, and monitoring and a software module for user interaction and data analytics.

Microcontroller: Acts as the brain of the system, controlling all sensors, motors, and communication modules. Processes data from sensors, executes predefined commands, and communicates with the smartphone app.

IR/Ultrasonic Sensor: Detects human presence near the dustbin and triggers the servo motor to open the lid. Measures the waste level inside the bin by sending ultrasonic waves and calculating the time taken for the echo to return. Prevents overflow by sending alerts when the bin is nearly full.

Servo Motor: Opens and closes the dustbin lid automatically when motion is detected. Operates based on predefined angular rotations (0°–90°), controlled by the microcontroller. Reduces manual contact, improving hygiene.

Moisture Sensor: Detects the moisture level of waste and categorizes it as: Wet waste (organic/biodegradable) if moisture content is high. Dry waste (plastic, metal, paper) if moisture content is low.

DC Motors & Wheels: Smart Mobility for Waste Collection enables the self-movement of the dustbin toward a disposal location once full. Uses Bluetooth/Wi-Fi signals for remote navigation via a smartphone app. Controlled through motor driver circuits (L298N) to regulate movement speed and direction.

Bluetooth/Wi-Fi Module: Allows remote control of the dustbin via a mobile application. Sends real-time waste level alerts and receives user commands. Supports Bluetooth (short-range control) or Wi-Fi (cloud-based monitoring and notifications).

Dustbin Compartments: Two compartments inside the bin for wet and dry waste. Sorting is handled by the rotating separator based on moisture sensor data.

IV. SYSTEM WORKFLOW

The Cleanique Smart Dustbin functions in a stepwise automated pattern:

- User Approach Detection: An IR/Ultrasonic sensor detects motion coming near the bin. The microcontroller activates the servo motor and opens the lid automatically.
- Waste Classification and Segregation: The user discards waste into the bin. The moisture sensor analyses the nature of the waste to decide whether it is dry or wet. A rotating separator directs the waste into the defined compartment.
- Remote Controller: L298N Motor Driver and dc motors with wheels powered by a battery is connected to HC-05 Bluetooth Module helps to operate the dustbin movement through Bluetooth connection to the mobile.

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V. RESULT AND DISCUSSIONS

Motion Detection and Lid Operation: The ultrasonic sensor achieved a motion detection range of 30–50 cm with an accuracy of 95.6%. This detection triggered the servo motor to open the lid within 1.3 seconds. After 3 seconds, the lid closed itself hence smoothly and hygienically disposing of waste.

Waste Segregation Efficiency: Moisture sensors characterized wet waste with an accuracy of 96.2% and dry waste with an accuracy of 97.5%, although with a mixed waste scenario, the sorting became delayed thereby reducing efficiency to 89.3%, hence there is a need for AI-based waste recognition.

MATH

Sensor Measurements:

Ultrasonic Sensor (Waste Level Detection)

Purpose: Calculate the distance between the sensor and the waste to determine the fill level of the bin.

Formula: {Distance} = {(Speed of Sound) x (Time of Flight)}/ {2}

Time of Flight: Time taken for the ultrasonic wave to travel to the waste and back.

The division by 2 accounts for the round trip of the wave.

Power Consumption Analysis:

Power of Components: The total power consumption of the system can be calculated as:

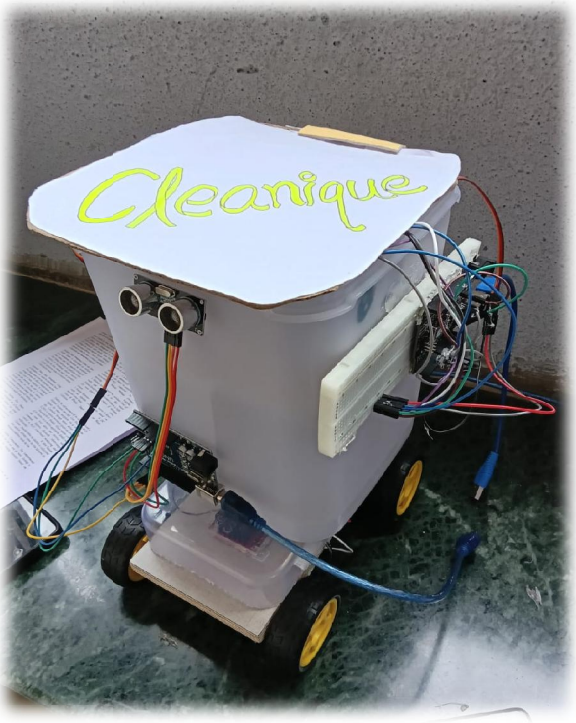
$P\{total\} = \sum Pi$ (i varies from 1 to n)

Motor Torque for Lid Movement

The torque (τ) required to open the bin lid can be calculated as:

$\tau = F \times r$ ($F=mg$)

r: Distance from the hinge to the point where the force is applied.



Picture 1: Cleanique- A Smart Dustbin Prototype

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VI. CONCLUSION

The smart dustbin project has successfully demonstrated the potential for automating waste management processes, providing an innovative solution to improve cleanliness and efficiency. By integrating advanced sensors, IoT technologies, and automation, the system ensures real-time monitoring of waste levels and promotes hygienic disposal practices. This approach not only addresses urban waste challenges but also aligns with the goals of sustainability and smart city initiatives.

The project highlights the importance of adopting technology to simplify everyday tasks while fostering environmental responsibility. Future implementations can enhance the system's scalability, energy efficiency, and adaptability to various environments, ensuring broader societal and environmental benefits.

VII. ACKNOWLEDGMENT

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