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INTRODUCTION

Efficient waste management is a major challenge in modern cities due to rapid population growth and improper disposal habits. Manual monitoring of dustbins is inefficient, unhygienic, and leads to overflowing bins, foul odour, and increased environmental pollution. To address these issues, this project implements an automated Smart Waste Bin that integrates IoT sensing, real-time data monitoring, and machine-learning-based waste classification.

The system uses an ESP32-S3 microcontroller equipped with ultrasonic, gas, and moisture sensors. The ultrasonic sensor measures the bin's fill-level, while the moisture and gas sensors detect wet or decomposing waste. When the bin is full or wet waste is detected, the system triggers LED and buzzer alerts and simultaneously updates the dashboard. The buzzer can also be remotely controlled through the web interface.

Additionally, a deep-learning model is integrated to classify organic waste through the device’s camera feed. Every few seconds, the model analyzes frames and determines whether the visible waste is organic. If confirmed, the system sends a signal to treat the waste as wet waste, improving segregation accuracy.

All sensor readings and model outputs are displayed live on a web dashboard using Flask. This approach ensures hygiene, reduces human involvement, prevents overflow situations, encourages proper segregation, and contributes toward smart-city waste automation and sustainable urban living.

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Problem statement

Waste collection in many cities still follows manual or scheduled routines, where garbage collectors visit bins without knowing whether they are full or empty. This outdated approach wastes time and resources and causes bins to overflow before collection arrives. Overflowing bins not only result in bad odour and unhygienic surroundings but also attract insects, stray animals, and contribute to environmental pollution. Wet waste in particular decomposes quickly, producing harmful gases and unpleasant smells, posing a health hazard for nearby residents and sanitation workers.

Another major issue is the lack of proper waste segregation at the source. Citizens often mix organic and recyclable waste, making recycling difficult and reducing its effectiveness. Most dustbins only serve as passive storage containers without intelligence to identify and sort waste. Without real-time monitoring, municipal authorities do not receive timely alerts, leading to late collection and inefficient waste transportation planning.

Therefore, there is a need for a **smart, automated waste monitoring and classification system** that can:

- Detect waste type (organic vs dry)
- Monitor bin fill level
- Give real-time alerts
- Trigger alarms for timely action
- Prevent overflow situations
- Improve hygiene and reduce manual dependency

This project aims to solve these problems using IoT sensors, AI vision, and real-time dashboard monitoring, enabling cleaner and more efficient waste management systems.

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Primary objective

The primary objective of this project is to automate waste monitoring and classification to make waste management smarter, cleaner, and more efficient. Traditional bins cannot differentiate between waste types or indicate when they are full. Our smart bin focuses on solving this by using **sensor-based detection and AI classification**.

First, the bin uses an **MQ-135 gas sensor**, **capacitive moisture sensor**, and **ultrasonic sensor** to identify wet waste and measure the garbage level. The goal is to classify waste at the source and avoid health hazards caused by decomposition gases and liquid leakage.

Second, a **machine learning model and webcam** detect organic waste visually. This cross-verification strengthens accuracy, ensuring even if one sensor fails, the bin still identifies wet waste correctly.

Third, by connecting the bin to a **Wi-Fi-enabled ESP32-S3 microcontroller**, the system sends real-time data to a web dashboard. Authorities or users can monitor gas levels, moisture, bin fullness, and waste type through a clean UI.

Another objective is to alert users when intervention is needed. A **buzzer and LED system** provides immediate notification for full bins or wet waste detection, ensuring timely disposal and maintaining hygiene.

Lastly, the aim is to build a platform that can scale for smart homes, institutions, and smart cities, reducing waste-collection inefficiency and encouraging better waste segregation habits.

Slide-4- methodology

The methodology of this smart waste bin system integrates IoT sensing, machine learning classification, and real-time web monitoring. The process begins with sensor data acquisition: the **MQ-135 gas sensor** detects harmful gases released by wet or decomposing waste, the **capacitive moisture sensor** identifies liquid content, and the **ultrasonic sensor** calculates the bin fill level based on distance measurements. These values form the first layer of decision-making for classifying waste as wet or dry and determining whether the bin is full.

Parallel to this, a **webcam captures images of incoming waste**, which are processed every few seconds using a **deep learning CNN model** trained on organic vs recyclable waste. The combination of visual classification and physical sensors increases reliability by cross-verifying decisions.

The ESP32-S3 microcontroller acts as the system hub — reading sensor inputs, interpreting logic, and sending structured JSON data to a **Flask server** hosted on a computer. This server updates a real-time dashboard, where the user can view metrics like gas levels, moisture, fill percentage, bin status, and ML prediction results. The UI also provides buzzer control to temporarily disable alerts.

When wet waste or full bin conditions are detected, **LED indicators and a buzzer** provide immediate audible and visual alerts. This structured pipeline ensures continuous sensing, AI-based classification, and real-time cloud connectivity, making the system efficient, intelligent, and scalable for smart city waste management.

Slide-5-innovations

Our project brings innovation by merging **IoT sensing and deep learning-based waste detection**, unlike most existing smart bins that depend on a single sensor. We use **gas sensors, moisture sensors, ultrasonic measurement, and a machine-learning vision model** to cross-verify waste type and bin status, improving reliability even in real-world messy waste scenarios.

An auto-calibration mechanism helps the device adapt to different waste bins and environments without manual tuning. The web dashboard shows live values, waste classification results, and even lets users control the buzzer remotely — a feature typically missing in small-scale IoT bins.

Together, these components create a **more intelligent, accurate, and interactive smart-waste system**, ready for smart campus and smart-city use.

Literature survey

Our system is built using a hybrid of machine learning and sensor fusion. We referenced a Kaggle CNN notebook for deep learning-based waste classification and combined it with real-world moisture, gas, and ultrasonic sensor methods. Capacitive sensor manuals helped us configure moisture thresholds reliably, and MQ135 tutorials provided gas baseline calibration logic. Finally, prior smart-bin ultrasonic works guided our bin fill detection and alert logic. This fusion approach improves accuracy and handles real-world waste conditions better than single-sensor systems.

Conclusion

Our project integrates IoT sensors with machine learning to automate waste detection and bin-monitoring. The system continuously checks moisture, gas levels, and distance to identify wet waste and detect when the bin is full. Meanwhile, a deep-learning model analyzes images from a camera to recognize organic waste. All this information is transmitted wirelessly to a real-time dashboard, and alerts are triggered through LEDs and a buzzer.
This setup reduces human effort, improves waste segregation accuracy, and enables smarter, more efficient waste-management in public and household environments. The project demonstrates how AI and IoT together can support cleaner surroundings and encourage responsible waste handling.