Smart Disposal Machine
A Scientific Report on Automated Waste Compression and Segregation
“GREEN GUARDIAN”

Hostel ID- 84

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Contents

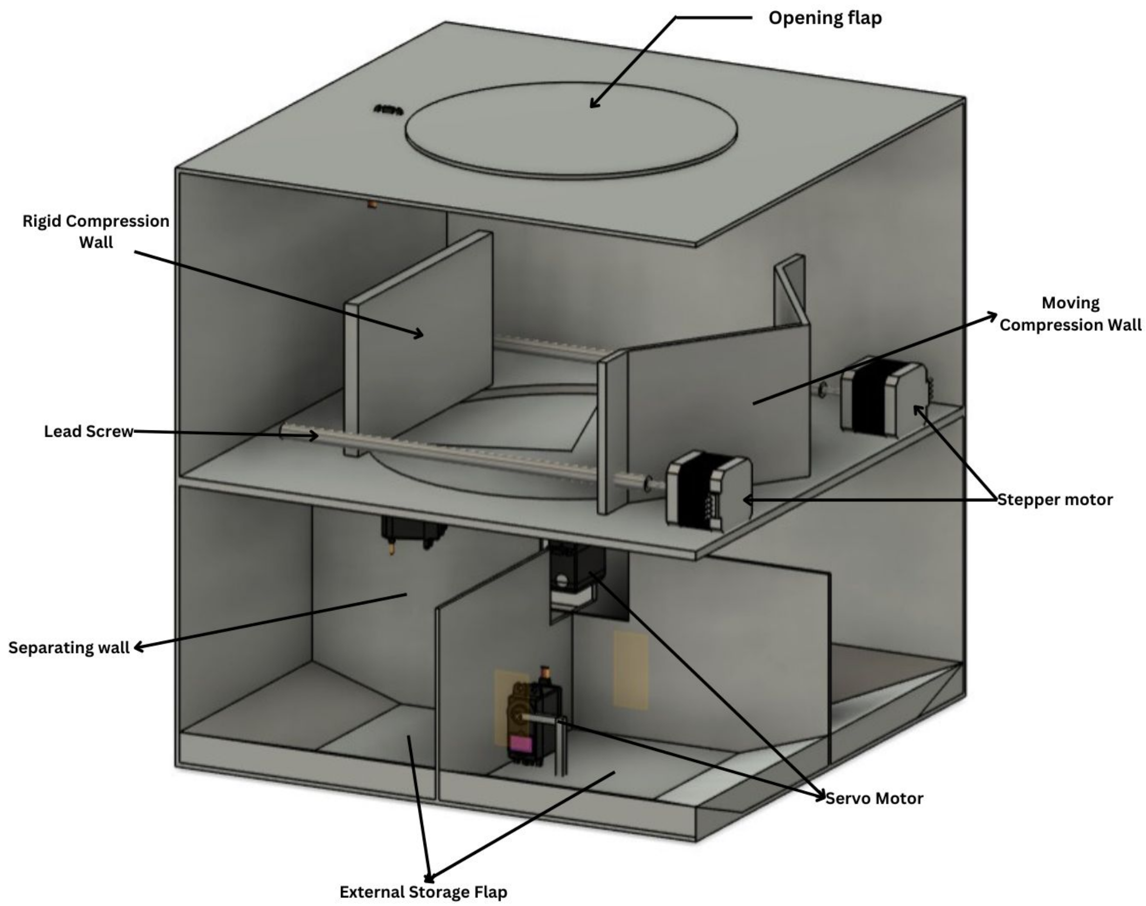


Figure 1:
Smart Disposal Machine

1 Abstract

The Smart Disposal Machine (SDM) is an advanced waste management system that incorporates AI-powered waste classification, real-time IoT monitoring, and automated mechanical segregation. This report describes the overall design of the system, focusing on the following key technologies: object detection using an SD Camera connected via USB, AI-based classification by -1.5 Pro refactor, and a lead screw-based compression mechanism to optimize waste storage and fill level monitoring via a streamlit dashboard.

A mathematical model has been designed to estimate storage efficiency, waste compression, and mechanical performance. SDM considerably improves operational efficiency, sustainability, and hygiene in waste disposal at a much faster rate.

2 Problem Understanding

2.1 Challenges in Waste Management

- **Inefficient Collection Schedules:** Conventional dustbins require frequent manual inspections to determine fill levels, leading to inefficiencies in waste collection.
- **Overflowing Bins:** High-traffic areas often experience overflowing containers, creating unsanitary and unhygienic conditions.
- **Hygiene Concerns:** Maintenance staff are exposed to unsanitary conditions during waste handling, posing health risks.
- **Lack of Automation:** Traditional systems lack real-time monitoring and automation, resulting in increased human intervention and operational costs.

2.2 Goals for the Smart Disposal Machine (SDM)

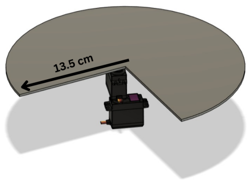
- **Smart Monitoring and Notification:**Use sensors to monitor fill levels in real-time and notify personnel or automated systems when bins are full.
- **Hygienic Operation:** Minimize user and staff exposure to unsanitary conditions during usage and maintenance.
- **Extended Operational Time:**Design the machine to extend the time between trash retrievals using compaction or additional storage slots.
- **Automation and IoT Integration:**Provide remote monitoring capabilities through a mobile app and improve automation to reduce human intervention.
- **Waste Segregation:**Automatically classify waste into categories such as biodegradable, recyclable, and non-recyclable.

3 Mechanical Module

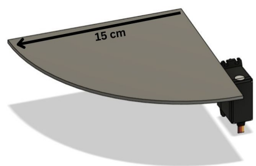
In this module in order to build the machine we have used acrylic sheets of thickness 3mm and 4mm

- **Lid Mechanism:** Infrared sensors are mounted onto the lid to detect motion which would cause the lid to open or close that is facilitated by a servo motor imitating a hinge mechanism.

- **Flap Mechanism:** The bottom flap comprises two sections: a three-quarter circular flap (A) and a quarter-circular flap (B) positioned beneath it.



Flap A



Flap B

Prior to compression, these two sections align to form a complete circular flap. Post-compression, flap (B) slides beneath flap (A), revealing a cavity strategically aligned with the designated chamber for waste segregation.

- **Compression Mechanism:** We have used a lead screw mechanism to compress the waste. A NEMA17 stepper motor which is controlled by a CNC shield that is connected from a Arduino Uno drives the lead screw forward when the waste is to be compressed and then moves it back to its original position. The speed and linear distance can be controlled by Arduino attached.

$$\text{Linear Distance (mm)} = \text{Steps} \times \frac{\text{Lead Screw Pitch (mm)}}{\text{Steps per Revolution}}$$

To calculate the number of steps required:

$$\text{Steps} = \text{Linear Distance (mm)} \times \frac{\text{Steps per Revolution}}{\text{Lead Screw Pitch (mm)}}$$

Lead Screw Dimensions- Length 20 cm and Diameter 8 mm

These formulas allow us to calculate the necessary movement of the piston to effectively compress the waste..

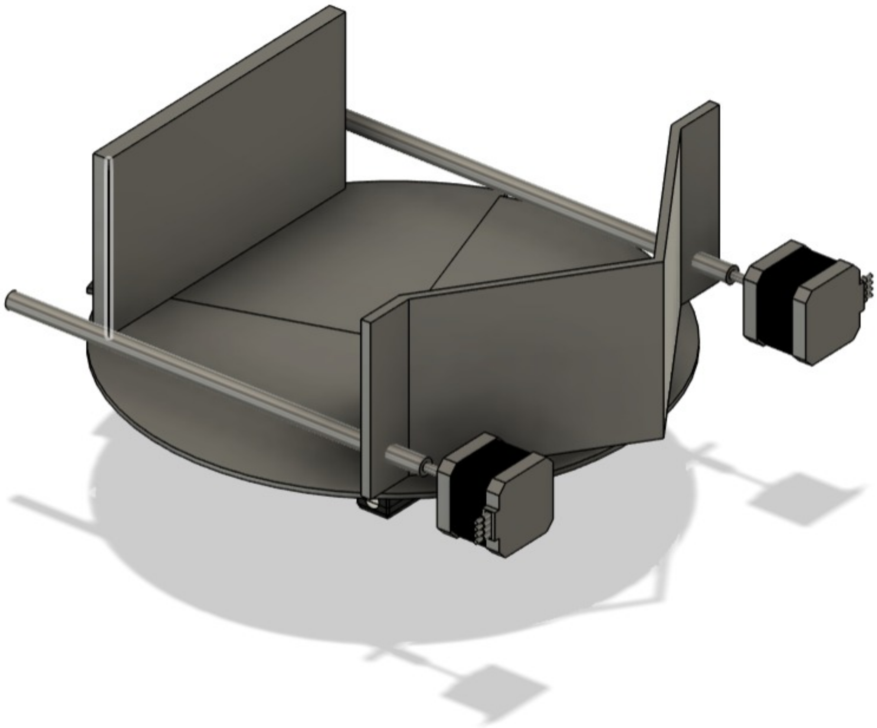


Figure 2: Compression Mechanism

- **Additional Storage:** In order to ensure hygienic waste collection an additional storage has been added that has a drawer mechanism which can be pulled out for waste collection.

Figure 3: Additional Storage

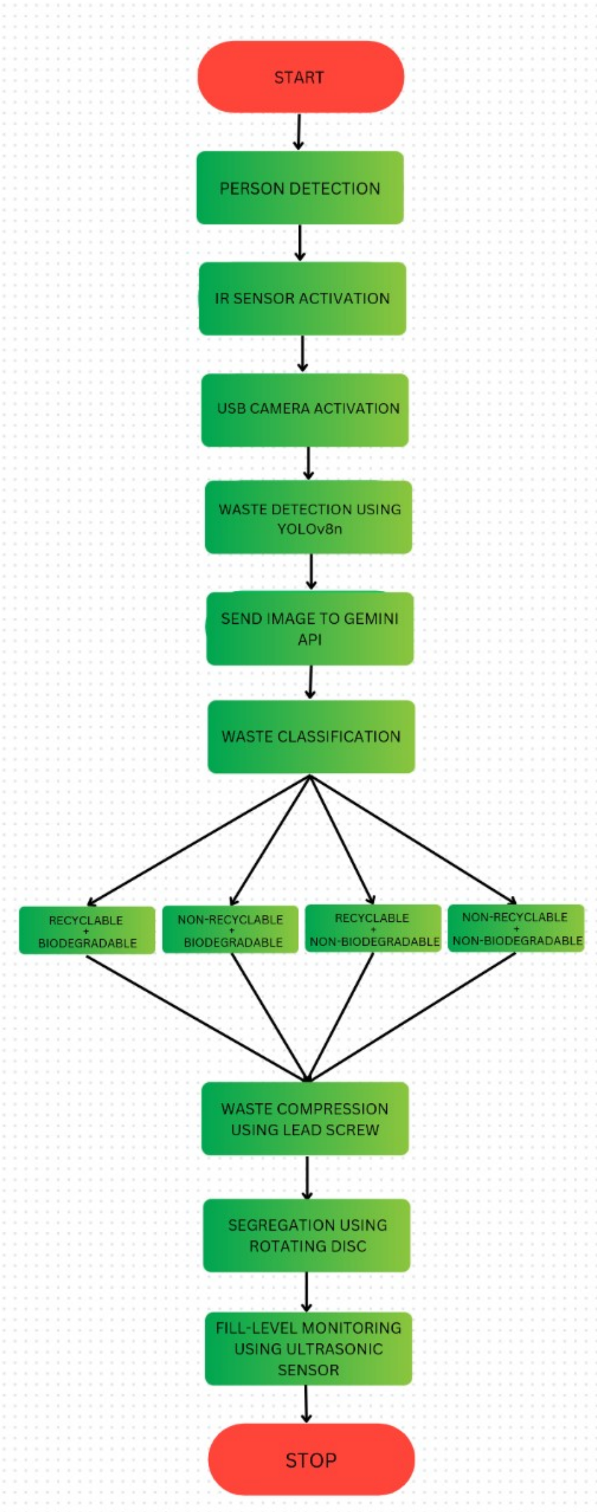


Figure 4: Flowchart for Mechanical System

4 Electrical Components

- **Embedded Processing Unit (Raspberry Pi 4):** The system employs a Raspberry Pi (R-Pi) as the central processing unit, orchestrating overall system control. In order to execute this commands an Arduino is used.

Specifications:

- CPU: Quad-core Cortex-A72 (ARM v8) 64-bit @ 1.5GHz
- RAM: 2GB, 4GB, or 8GB LPDDR4
- GPU: VideoCore VI
- Ports: 2x USB 3.0, 2x USB 2.0, Gigabit Ethernet, HDMI (dual micro-HDMI)
- Wireless: Wi-Fi 802.11ac, Bluetooth 5.0
- Power: 5V/3A via USB-C

Figure 5: Raspberry Pi

- **IR Proximity Sensor:** Infrared (IR) proximity sensors offer a convenient and hygienic way to automate lid operation. By emitting an invisible beam of infrared light and detecting its reflection, these sensors can determine when a hand or object approaches. This triggers a mechanism to open the lid without any physical contact, enhancing convenience and reducing the spread of germs. Similarly, the sensor can detect when the object moves away, prompting the lid to close automatically.
  Specifications:
  - Detection Distance: 2-30 cm
  - Detection angle: 35 deg
  - Operating voltage: 3.6-5 V

Figure 6: IR Sensor

- **Camera Module:** For enhanced waste segregation capabilities, a USB camera has been integrated into the lid assembly. This camera captures images of waste deposited into the receptacle, enabling identification and classification through the utilization of Google's Gemini 1.5 model.
  Specifications:
  - Resolution: 720p or 1080p
  - Frame Rate: 30fps
  - Interface: USB 2.0
  - Focus: Fixed or Auto

Figure 7: Camera

- **Ultrasonic Sensors:** Used to measure fill levels of storage compartments using ultrasonic sound waves.
  Specifications:
  - Power Supply +5V DC
  - Working Current 15mA
  - Output Signal Electrical frequency signal
  - Ranging Distance 2cms – 400 cms
  - Resolution 0.3 cm

  Ultrasonic Sensor calculates distance of nearby objects as follows:

$$\text{Distance} = \frac{\text{Speed of Sound} \times \text{Time Taken}}{2}$$

Figure 8: UltraSonic Sensor

- **Servo Motor SG90:** Specifications:
  - Operating Voltage: 3 - 7.2V
  - Rotation Degree: 180 deg
  - Torque rating: 1.2-1.6 kg.cm
  - Stall Torque @ 4.8V: 1.2 kg.cm
  - Stall Torque @ 6.6V: 1.6 kg.cm

Figure 9: Servo Motor SG90

- **Servo Motor MG995:** Specifications:
  - Operating Voltage: 4.8 - 7.2 V
  - Rotation Degree: 180 deg
  - Torque rating: 10-12 kg.cm
  - Stall Torque @ 4.8V: 10 kg.cm
  - Stall Torque @ 6.6V: 12 kg.cm

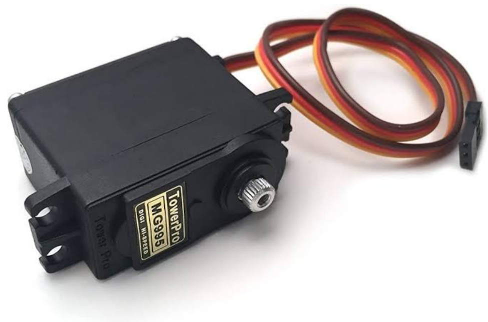


Figure 10: Servo Motor MG995

- **CNC Shield:** Specifications:
  - Compatible with Arduino Uno
  - Supports: 4 Stepper Drivers (A4988, DRV8825)
  - 3-axis control, microstopping, end - stop pins

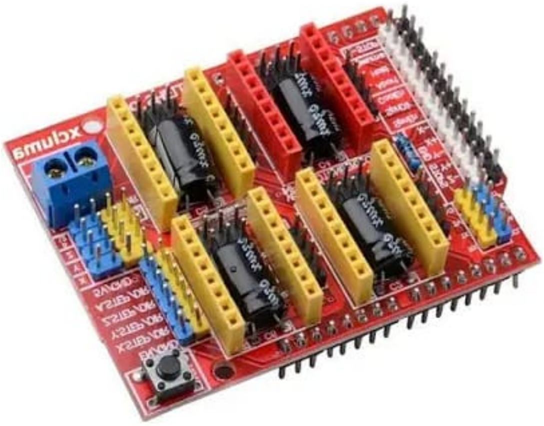


Figure 11: CNC SHIELD

Figure 12: A4988 Stepper Driver

- **Stepper Motor NEMA17:** Specification:
  - Shaft Type: D Type
  - Step Angle: 1.8
  - Holding Torque: 4.2kg-cm

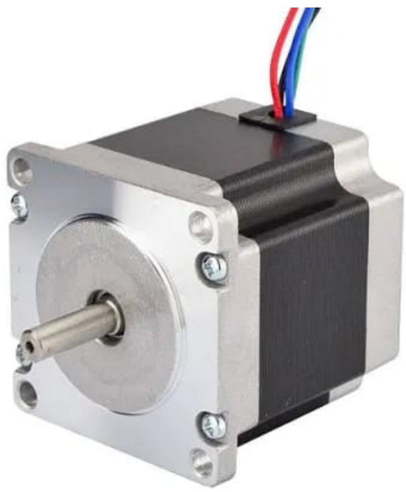


Figure 13: Servo Motor MG995

The working is shown in the flowchart below-

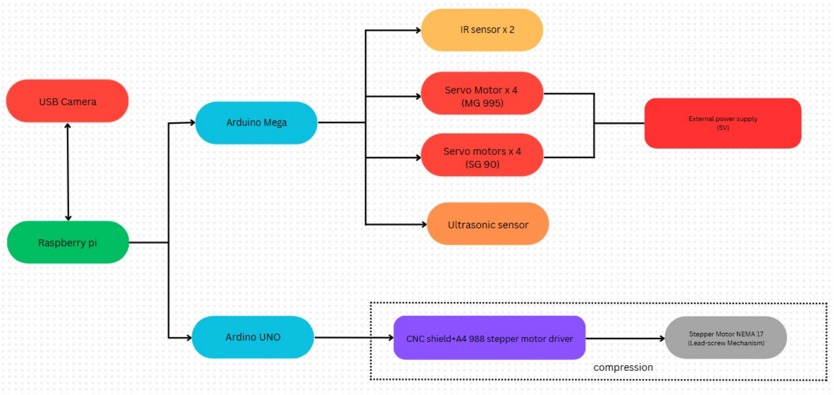


Figure 14: Flowchart for Electronic System

5 Approach

5.1 Fill-Level Monitoring

The fill level of the dustbin is monitored using an ultrasonic sensor, which captures readings over a specified period.These readings are used to calculated the percentage of the compartment that is filled. Later this is done for all the 4 compartments and the overall percentage fill is calculated.

5.2 Notification System

The notification system is designed to provide real-time alerts based on the fill levels of the dustbins. When the overall fill percentage of a bin exceeds 80%, a notification is triggered to prompt timely waste collection. Once the fill level drops below 80%, the notification is automatically removed. This system ensures efficient waste management by preventing overflow and optimizing collection schedules. Additionally, the dashboard visually highlights bins that require attention, enabling swift decision-making.To enhance monitoring, the bin includes LED indicators that display the bin's status as empty, half-full, or full.

5.3 Waste segregation

To enable effective segregation of waste for disposal, the SDM has four compartments for segregation, which are **divided on the basis of biodegradability and recyclability**. The **Gemini 1.5 system uses a USB camera mounted on the lid, which is used to recognize and sort items based on the above factors**. After sorting, the system computes which lid to open, thus ensuring that the waste is loaded into the correct compartment. Additionally, **a built-in compression unit compresses the waste before segregation, thus increasing the disposal volume before the bags are full**.

5.4 Hygiene Operations

The dustbin system is designed with user convenience and hygiene in mind. It features a contactless disposal mechanism i.e**a motion sensor-based opening, to minimize direct contact and enhance cleanliness**. The surfaces are made easy to clean, and the waste compartments are detachable, allowing for effortless emptying and maintenance.

6 AI Model Performance Evaluation

A comparative analysis was conducted to evaluate different AI models for waste classification. The following table summarizes their performance metrics.

Model	Accuracy(%)	Inference time (sec)	Feasibility
DETR(deta-swin-large)	50-60	1.2	Computational intensive
YOLOv8n	40-50	0.02	Fast but less accurate
Google cloud vision API	75-85	1-3	Cloud dependent
Gemini 1.5	85-95	1-3	Optimized for real-time deployment

Table 1: Comparison of Models

7 User Interface

In order to achieve real time monitoring the SDM is equipped with website url.

Features of the site include:

- All the dustbins are further displayed on the map so as to provide more data regarding dustbins in close vicinity that requires/would require waste collection simultaneously so that the process is done efficiently.

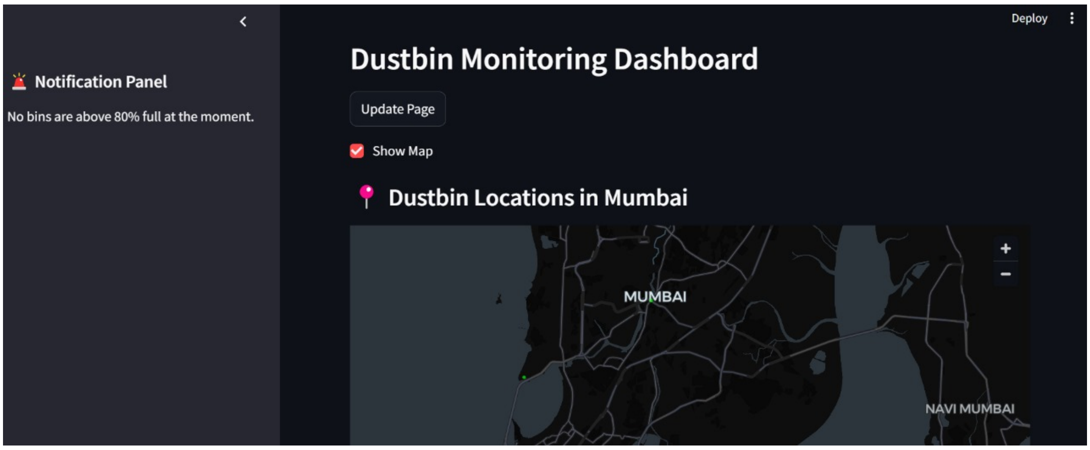


Figure 15

- Each dustbin is given a unique identification code which is displayed on the website.

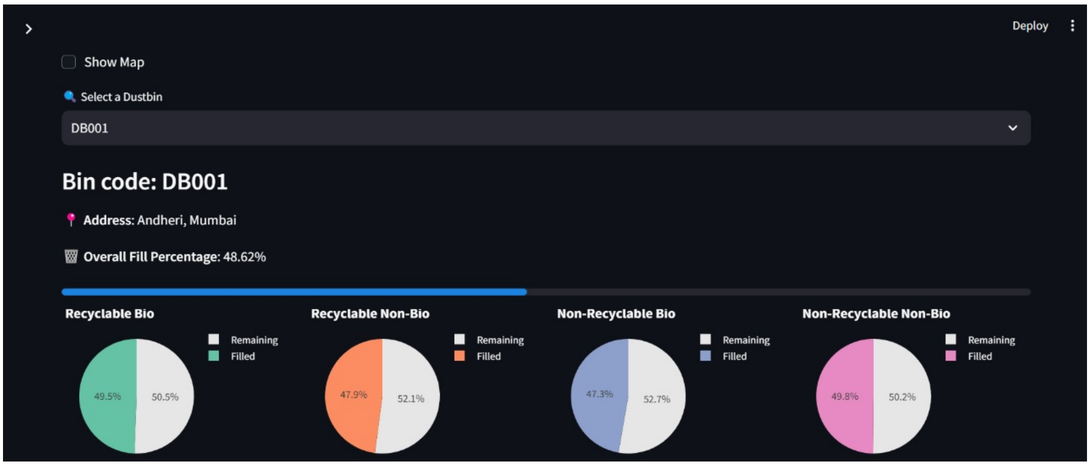


Figure 16

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- The website displays overall as well as individual percentage of waste filled in each compartment.

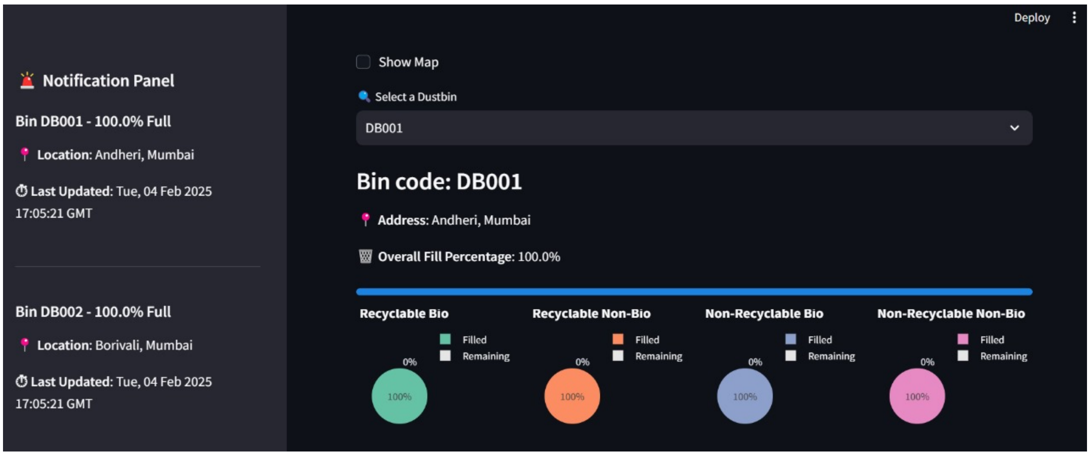

Figure 17

- The website also employs a colour scheme to indicate different levels of waste filled in the dustbin. Green is for low or no waste filled, yellow for moderate and red indicates that more than 80 of the dustbin has been filled.

Figure 18

- A notification panel is also added to make it user friendly

8 Future Scope

- The sustainable disposal system can be scaled to diverse settings like office buildings, factories, hospitals, airports, schools, fairs etc.
- Advanced machine learning models can be integrated for improved classification.
- The project can be further developed so as to fully automate waste collection and disposal.
- Expanding detection capabilities for hazardous and electronic waste.
- The disposal system can be further integrated with smart city initiatives for sustainable living.
- The extendable storage can be automated so as to open up as soon as the waste reaches the critical amount.

9 Existing Smart Disposal Technologies and Comparison

Several smart waste disposal technologies currently exist, utilizing various automation and monitoring features. Below is a comparison of existing systems and how our Smart Disposal Machine (SDM) surpasses them.

Our SDM improves upon existing solutions by incorporating AI-driven automation, real-time monitoring, optimized storage, and enhanced hygiene measures. This ensures better waste management, cost efficiency, and sustainability.

Feature	**Existing Technologies**	**Our SDM**
Fill-Level Monitoring	Uses ultrasonic sensors but lacks real-time IoT alerts	Utilizes ultrasonic and infrared sensors with IoT integration for real-time updates
Waste Segregation	Basic segregation using weight-based classification	AI-based segregation using Gemini-1.5 Pro Refractor for precise categorization
Compression Mechanism	Limited or no compression, leading to frequent emptying	Lead screw-based compression to optimize storage capacity
IoT and Automation	Some systems provide IoT features but with limited remote access	Full remote monitoring and control via a mobile app
Hygiene	Manual handling required in most existing solutions	Contactless operation
Cost	High initial costs with limited automation	Cost-effective with enhanced automation and smart analytics

Table 2: Comparison of Existing Technologies vs. Our Smart Disposal Machine

10 Conclusion

The Smart Disposal Machine (SDM) is a revolutionary waste management technology that integrates AI-based classification, automatic sorting, and real-time IoT monitoring. Utilizing the application of Gemini-1.5 Pro for high-accuracy waste classification, the SDM provides efficient sorting, thereby ensuring maximum recycling potential and minimizing contamination across various waste streams.

The innovative design of the SDM features lead screw-based compression technology, which optimizes storage capacity and facilitates more effective space utilization. This feature has the potential to decrease waste collection frequency, resulting in reduced transportation costs and a reduced environmental impact.

Integration with IoT enables real-time waste tracking and alerts, facilitating valuable insights for proactive management and informed decision-making. By resolving core challenges inherent in current waste management systems, the SDM paves the way for more intelligent and sustainable waste management strategies for more urbanized cities.

11 References

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