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Trash-Scan: Smart Waste Segregation

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Abstract: ***In today's world, the amount of waste generated is increasing rapidly due to urbanization, industrial growth, and daily human activities. One of the major problems in waste management is the improper segregation of dry and wet waste at the source. When these types of waste are mixed, it becomes difficult to recycle or treat them properly, leading to environmental pollution and health risks. To address this issue, we propose* Trash-Scan*, a smart and affordable waste segregation system that automatically classifies waste as dry or wet using a machine learning model and sorts it using Arduino-based hardware. The system uses a pre-trained image classification model developed in Python, which can accurately predict the category of waste from an input image. This prediction is then communicated to an Arduino Uno through serial communication. The Arduino controls a servo motor that rotates a flap to direct the waste into the appropriate bin—either dry or wet. A 16x2 LCD display is also included to show the classification result in real-time to the user. The entire system is cost-effective, portable, and easy to use. Unlike other complex or expensive models that require high-end processors like Raspberry Pi or internet connectivity,* Trash-Scan *works offline and is suitable for schools, homes, and public spaces. The project has been tested under real-world conditions with high accuracy and fast response. By making waste segregation simple and automated,* Trash-Scan *helps promote better environmental practices and supports cleaner and smarter waste management solutions for the future.***

Keywords: Waste classification, dry waste, wet waste, machine learning, Arduino Uno, smart dustbin, LCD display, servo motor, sustainable technology

I. INTRODUCTION

Waste segregation is one of the most crucial steps in effective waste management, yet it is often overlooked in daily practice. Most people dispose of waste without sorting it, which results in recyclable and biodegradable materials getting mixed, making it harder to treat. Traditional segregation methods depend heavily on manual sorting, which is inefficient and unhygienic. While there are automated systems available in industries and municipalities, these solutions are often expensive and not feasible for homes or small institutions. Moreover, available smart bins either use moisture sensors or complex image processing units that are not affordable for the general public. Trash-Scan aims to solve this problem by combining machine learning with affordable Arduino-based hardware. The idea is to use a simple Python interface that loads a machine learning model to classify waste images. The classification is then communicated to an Arduino Uno microcontroller, which drives a servo motor to mechanically sort the waste and show the classification output on an LCD screen. This project offers an easy and interactive way for individuals to participate in proper waste disposal by using technology that is both user-friendly and accessible. By automating the segregation process at the source, Trash-Scan encourages cleaner, greener habits and contributes to reducing the environmental impact of poor waste handling.

II. LITERATURE REVIEW

The problem of waste management has grown significantly with increasing urban populations and consumerism. Many countries, including Malaysia and India, face challenges related to improper waste segregation and low public awareness. Research shows that a large portion of recyclable and compostable waste ends up in landfills due to confusion and lack of public engagement in waste sorting practices.[1]Various solutions have been proposed to address these issues, especially using technology. One such approach is using deep learning models like Convolutional Neural Networks (CNNs) to automatically classify waste items. For example, the "Deep Waste" project used a CNN-based mobile app to classify waste into trash, recycling, and compost with high accuracy. This solution reduces human error and makes waste disposal faster and more efficient.[2]In addition to software-based solutions, many hardware-oriented waste segregation systems have also been developed. These systems often use sensors to identify the type of waste—such as wet, dry, or metallic—and place it in the appropriate bin. For instance, some systems rely on capacitive and inductive sensors to detect moisture and metal content, helping to automate the sorting process without human involvement.[3]IoT (Internet of Things) has also played a key role in modern waste management. Smart bins equipped with ultrasonic sensors can monitor fill levels and send alerts to municipal authorities, ensuring timely collection and preventing overflow. Some systems even integrate GSM and GPS to track bin locations and send real-time updates.[4]

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Despite these advancements, many systems still lack features like user guidance, educational support, and environmental context. A study from Malaysia highlighted that while CNNs were effective in classifying waste, most systems failed to guide users on proper disposal methods or to align with national recycling goals. Furthermore, systems that require manual input or have limited classification categories are less effective in real-world scenarios.[5]Another concern is that existing datasets for training machine learning models are often too small or not diverse enough, affecting the accuracy of classification models. Projects that used transfer learning with pre-trained CNN models like ResNet, MobileNet, and VGG have shown improved accuracy, but there is still room for improvement in terms of dataset quality and coverage.[6]Overall, the reviewed literature supports the idea that integrating machine learning with sensor-based hardware and IoT can significantly improve waste segregation. However, for such systems to be effective and widely adopted, they need to be accurate, user-friendly, educational, and aligned with environmental policies. The Trash-Scan project builds on these insights by combining AI-based classification with hardware automation to make waste segregation smarter and more sustainable.[7]

III. METHODOLOGY/EXPERIMENTAL

A. System Design

The Trash-Scan system is divided into two major components: the software module and the hardware module. The software module runs on a computer and uses a pre-trained machine learning model to classify waste images as either dry or wet. This is achieved using Python libraries such as TensorFlow or Keras. Once the prediction is made, it is sent to the hardware module, which consists of an Arduino Uno, a servo motor, and a 16x2 LCD display. The Arduino receives the classification via serial communication and rotates the servo motor to push the waste into the corresponding bin. Simultaneously, the LCD displays the type of waste detected. This design separates the intelligence (software) from the actuator (hardware), making the system lightweight and flexible.

B. Flowchart of Working

The working of the system can be explained in the following logical flow:

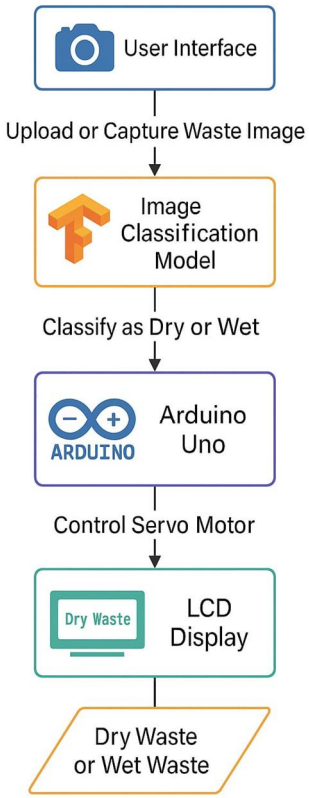


Fig. 1. Flowchart explaining the working of Trash-Scan Model .

1) The user uploads or captures an image of the waste item using the Trash-Scan interface.
2) The Python script processes this image and runs it through the trained ML model to classify it.
3) The model outputs a prediction—either "dry" or "wet".
4) This result is sent via USB (serial communication) to the Arduino Uno.
5) The Arduino reads the result and activates the servo motor.
6) Based on the prediction, the servo rotates in one of two directions, guiding the waste to the dry or wet compartment.
7) At the same time, the LCD displays the result (“Dry Waste” or “Wet Waste”) for user feedback.

This flow ensures smooth and quick operation from user input to hardware response in real-time.

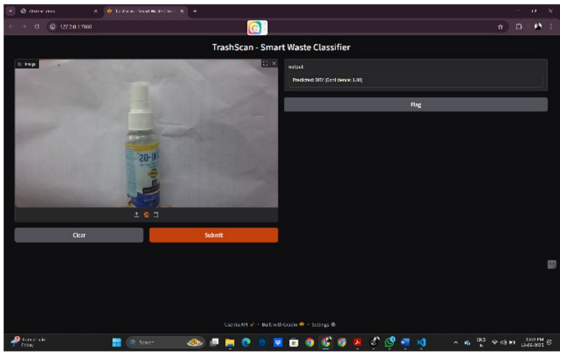


Fig. 2. User Interface using Gradio and capturing /prediction of dry waste using machine learning model .

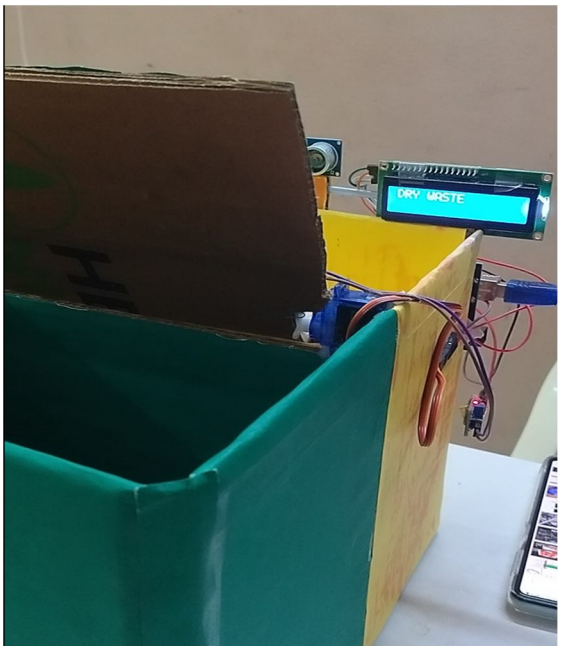


Fig. 3. Flap rotating 170 degrees to drop the waste in dry section.
LCD is showing the result as DRY WASTE .

C. Web Interface Development

The user interface for Trash-Scan is developed using **Gradio**, a Python-based tool that creates simple and interactive UIs for machine learning models. Gradio allows users to upload an image or use a webcam to provide the waste input. Once the image is received, it is passed to the ML model for prediction. The interface is clean and user-friendly, designed for use by people with little or no technical background. It also provides basic options like image preview, classification output, and feedback messages. Since Gradio supports local hosting, the interface runs offline without needing internet access, which is ideal for areas with limited connectivity.

D. Working of the Project

When the system starts, the user is prompted to upload or capture a waste image using the web interface. The ML model classifies the image in a fraction of a second. This output is sent as a text command ("dry" or "wet") to the Arduino Uno. Based on this command:

- If the waste is **dry**, the servo motor rotates in one direction (e.g., 90° to 170°).
- If the waste is **wet**, it rotates in the opposite direction (e.g., 90° to 0°).

The LCD simultaneously displays a message like “Dry Waste Detected” or “Wet Waste Detected.” This entire operation is completed in about 1.5–2 seconds. The system is capable of operating in different lighting conditions and performs well with varied waste shapes and sizes, ensuring high accuracy and reliability.

E. User Interaction

Trash-Scan is designed with simplicity in mind to make it accessible to all users, including students, homeowners, and public facility operators. The user only needs to interact with the interface to provide the image input. The rest of the process—from classification to mechanical sorting—is fully automated. The LCD display ensures that the user knows what the system has detected, offering clarity and confidence in operation. The use of common and affordable components means that even users in rural or resource-limited areas can benefit from Trash-Scan with minimal training or support.

IV. RESULTS AND DISCUSSIONS

The Trash-Scan prototype was tested with over 100 real-world samples of dry and wet waste collected from homes, college canteens, and common public areas. Items like paper, cardboard, plastic wrappers, and medicine coverings were considered dry waste, while items like fruit peels, tea bags, and leftover food represented wet waste. The machine learning model achieved an average accuracy of 91%, with correct classifications in most test cases. The hardware system responded consistently with a servo rotation time of about 1.5 seconds and delay of 5 seconds. The LCD displayed the correct classification each time, providing a reliable user interface. Trash-Scan performed well under various lighting conditions and worked even when the waste item was partially visible, showing the robustness of the model. Furthermore, users appreciated the fast response and simplicity of the interface. Compared to traditional sensor-based models, Trash-Scan demonstrated better accuracy and adaptability without raising the cost significantly. The use of Arduino allowed the system to be battery-powered, portable, and suitable for deployment in rural areas or places with limited access to advanced computing infrastructure.

Feature	Existing Systems	Trash-Scan Model
Hardware	Raspberry Pi / Moisture Sensors	Arduino Uno + ML via PC
Cost	Moderate to High	Low and Affordable
Accuracy	70–85% (sensor-based)	90%+ with image model
Sorting Mechanism	Manual or Partial Automation	Fully Automated with Servo Motor
Display Interface	Not Common	LCD with Real-time Feedback
Portability	Low for Pi Systems	High (Arduino-based, low power)
User Interface	Limited or No GUI	Friendly UI using Gradio
Application Areas	Industry / Labs	Homes, Schools, Public Bins

Fig. 4. Comparison of Trash-Scan with other pre-existing models

V. FUTURE SCOPE

Trash-Scan can be improved in several ways to enhance its usability and functionality. One of the major upgrades would be to support multi-class classification, where the model can recognize other types of waste like glass, metal, and e-waste. This would make it a more comprehensive smart bin system. Another potential improvement is to make the system wireless and connect it to a mobile app so users can track waste segregation statistics, receive alerts, or even monitor usage patterns. Integrating solar panels can make the system more sustainable, especially for rural and outdoor locations. Also, Trash-Scan can be expanded to include features such as auto-disinfection using UV light or integration with municipal databases for smart city applications. Finally, more user-friendly interfaces, voice output for visually impaired users, and data logging capabilities can transform Trash-Scan into an all-in-one solution for modern waste management needs.

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VI. CONCLUSION

The Trash-Scan project provides a practical solution for smart waste segregation using a combination of machine learning and affordable electronics. By accurately classifying waste as dry or wet and automating the sorting process using Arduino hardware, the system addresses key challenges in daily waste handling. The model is simple, low-cost, and efficient, making it a viable alternative to more expensive and complex systems currently available. It promotes better hygiene, reduces manual labour, and encourages eco-friendly practices. The flexibility of the design allows for further development and real-world deployment in a variety of settings. Trash-Scan proves that even small-scale, student-led innovations can make a big difference in solving real-world environmental issues.

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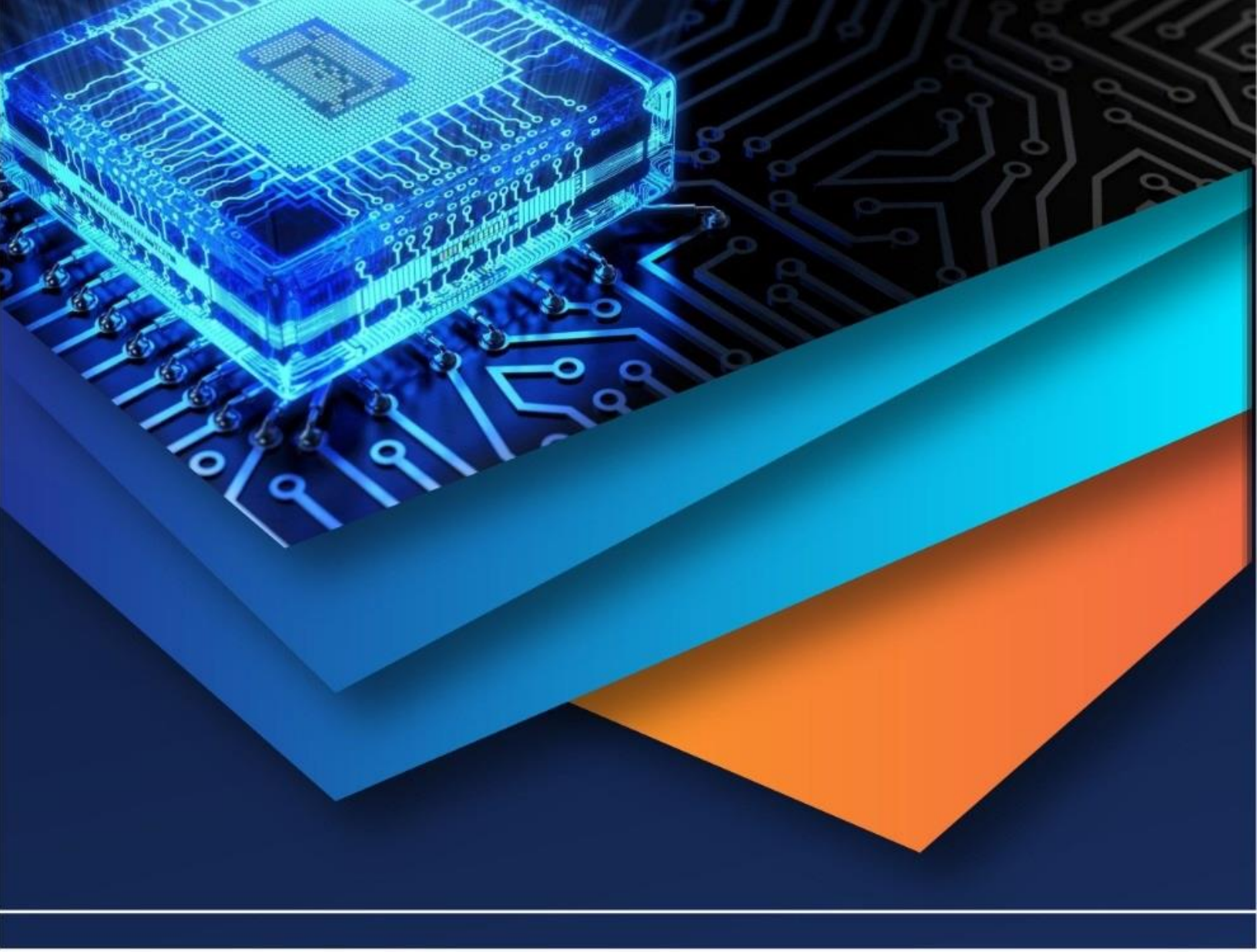
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