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Smart Waste Segregation Dustbin Using Arduino

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Abstract: Rapid growth in population and urbanization has resulted in a substantial increase in municipal solid waste, creating serious challenges in waste management and recycling processes. One of the major problems in existing waste management systems is the lack of segregation at the source, which leads to increased landfill usage, environmental pollution, and health hazards. Manual segregation is time-consuming, unhygienic, and inefficient. To address these issues, this project presents the design and development of a Smart Waste Segregation Dustbin using Arduino that automatically classifies waste into metal, wet, and dry categories..

Keywords: Arduino UNO microcontroller, IR sensor, moisture sensor, 28BYJ-48 stepper motor with ULN2003 driver module

I. INTRODUCTION

Waste management has become one of the most critical challenges faced by modern society due to rapid population growth, urbanization, and industrial development. The continuous increase in the consumption of goods has led to a proportional rise in the generation of solid waste. If this waste is not managed properly, it results in serious environmental issues such as land pollution, water contamination, air pollution, and health hazards. A major drawback of conventional waste management systems is the absence of segregation at the source. In most places, wet waste, dry waste, and metallic waste are collected together, making recycling difficult and inefficient. Manual segregation requires significant human effort, is time-consuming, and exposes workers to harmful substances and diseases. Therefore, there is a strong need for an automated waste segregation system that can reduce human involvement and improve recycling efficiency..

II. LITERATURE SURVEY

A literature survey provides an overview of existing research work and technological developments related to the proposed project. It helps in understanding the current methodologies, identifying limitations of existing systems, and justifying the need for the proposed solution. Several researchers have worked on automatic waste segregation, smart dustbins, and sensor-based waste management systems using microcontrollers, sensors, and IoT technologies. This chapter reviews relevant studies conducted in this domain.

Navghane et al. (2016) proposed an automatic waste segregation system using IR, moisture, and metal sensors to separate waste into wet and dry categories at the source level. The study emphasized improved recycling efficiency through early segregation, but the system lacked precise mechanical design and accurate rotational control[1]. Kumbhar et al. (2017) proposed an Arduino-based smart dustbin that detects and segregates waste using basic sensors to reduce human effort. However, the system relied on DC motors, resulting in limited angular precision and poor position holding[2].

Patil and Goudar (2018) presented an IoT-based waste management system using ultrasonic sensors to monitor bin status and optimize collection routes. While effective for remote monitoring, the system did not include automatic waste segregation[3].

Shukla et al. (2019) demonstrated waste segregation using moisture and inductive metal sensors to identify wet and metallic waste. Although segregation accuracy improved, mechanical alignment and repeatability issues persisted due to the lack of precise motor control[4].

Mane et al. (2020) developed an embedded-system-based garbage segregation system capable of classifying waste into multiple categories with moderate accuracy. However, increased system complexity and higher cost limited its suitability for small-scale applications[5].

Kumar and Rajesh (2021) introduced an automated waste sorting system using a stepper motor, achieving better positional accuracy than DC and servo motors. Nevertheless, the system did not integrate moisture-based waste classification[6].

III. METHODOLOGY

1) System Initialization: The process starts by initializing the Arduino controller along with all sensors (IR, metal, moisture) and the stepper motor.

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2) Object Detection: An IR sensor detects the presence of waste placed on the system. Once waste is detected, the segregation process begins.
3) Metal Detection: The metal sensor checks whether the waste is metallic. If metal is detected, the stepper motor rotates to the metal waste compartment and drops the waste. If no metal is detected, the system proceeds to the next step.
4) Moisture Detection: A moisture sensor measures the water content of the waste. If moisture is above a predefined threshold, the waste is classified as wet waste and directed to the wet waste compartment. If moisture is below the threshold, the waste is classified as dry waste and directed to the dry waste compartment.
5) Reset and Repeat: After placing the waste in the appropriate compartment, the motor returns to its home position and the system is ready to process the next waste item.

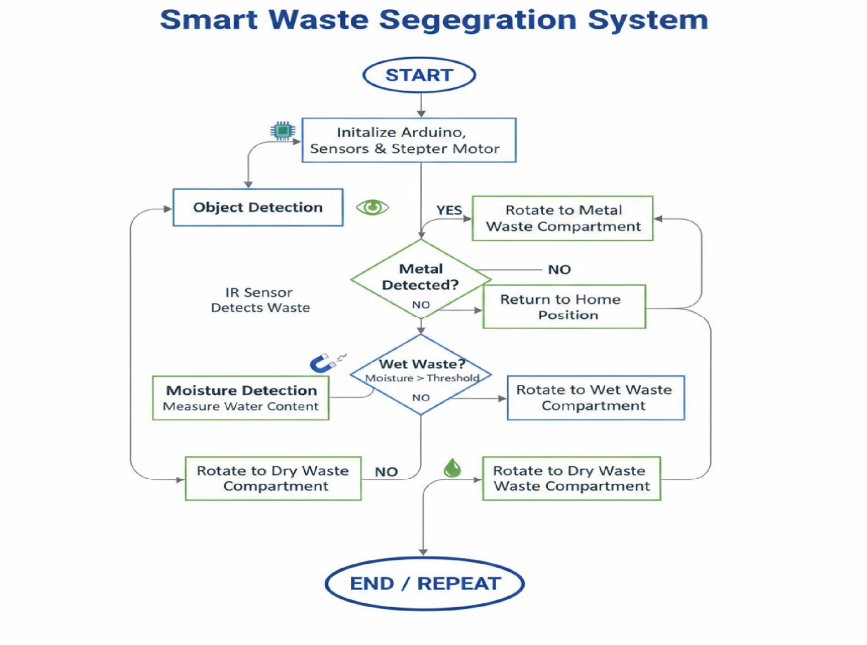


Fig no 1. Flow chart smart waste segregation system

Block Diagram:

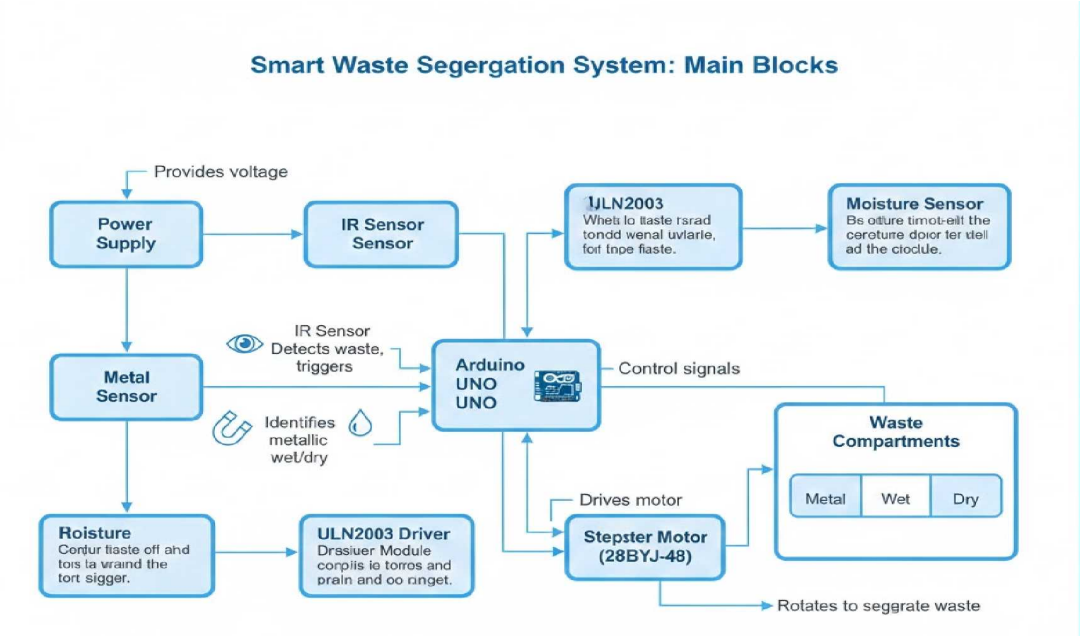


Fig no 2. Block diagram smart waste segregation system

The Working of Smart Waste Segregation System

The Smart Waste Segregation System is powered by a regulated power supply that provides the required operating voltage to all system components, including sensors, Arduino UNO, ULN2003 driver, and the stepper motor. Initially, the Arduino UNO initializes all connected sensors and the stepper motor and remains in an idle state. The system continuously monitors the inlet of the dustbin for waste insertion. When waste is placed near the inlet, the IR sensor detects its presence and sends a trigger signal to the Arduino UNO. This activates the segregation process and ensures the system operates only when waste is detected, thereby reducing unnecessary power consumption.

After waste detection, the metal sensor checks whether the waste contains any metallic material.

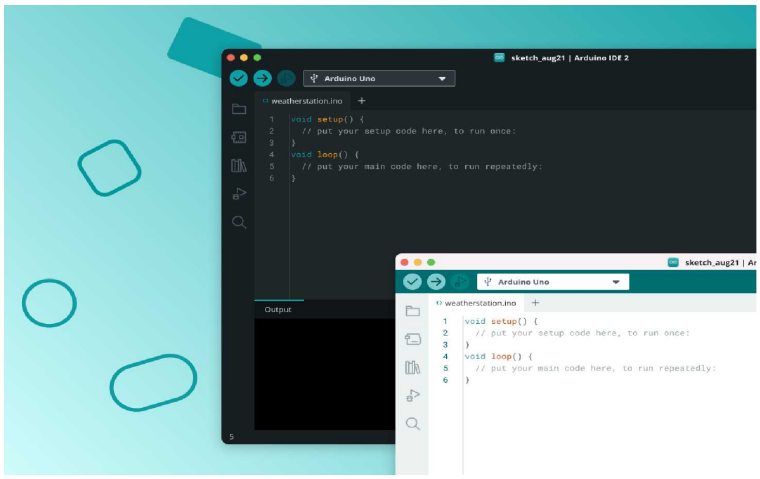
- If metal is detected, the Arduino immediately classifies the waste as metal waste.
- The Arduino sends control signals to the ULN2003 driver, which drives the 28BYJ-48 stepper motor.
- The stepper motor rotates the dustbin mechanism to align with the metal waste compartment, and the waste is deposited.

If the waste is non-metallic, the system proceeds to moisture analysis. The moisture sensor measures the water content of the waste and sends the analog signal to the Arduino UNO. The measured value is compared with a predefined threshold programmed in the controller.

- If the moisture content is higher than the threshold, the waste is classified as wet waste.
- If the moisture content is below the threshold, the waste is classified as dry waste.

Based on this classification, the Arduino generates appropriate control signals to the ULN2003 driver, which rotates the stepper motor to the respective wet or dry waste compartment. The waste is then dropped into the selected compartment. After successful deposition, the stepper motor returns the system to its home position, making it ready for the next waste input. This entire process repeats automatically for every new waste item, enabling real-time and efficient waste segregation.

IV. SOFTWARE DESCRIPTION



The Smart Waste Segregation System uses the Arduino IDE and Embedded C (Arduino programming) for software development. The Arduino framework provides easy hardware interfacing and rapid prototyping support. A Stepper Motor Library is used for precise motor control, while the Serial Monitor helps in debugging and sensor calibration.

The software follows a sequential and event-driven architecture, where sensor inputs are continuously monitored and actions are performed based on predefined conditions. The program is divided into modules such as sensor initialization, data acquisition, decision making, motor control, and system reset.

The algorithm starts by initializing all sensors and the stepper motor. The IR sensor detects the presence of waste, after which the metal sensor checks for metallic content. If metal is detected, the waste is sent to the metal bin. Otherwise, the moisture sensor classifies the waste as wet or dry based on a threshold value, and the motor rotates to the respective bin. After deposition, the motor returns to the home position and the cycle repeats.

The 28BYJ-48 stepper motor is controlled using predefined step positions for accurate bin alignment. Sensor calibration is performed to ensure reliable detection and minimize false triggering.

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The software operates through the Arduino setup() and loop() functions, enabling real-time response. Overall, the software design is simple, modular, reliable, and easy to debug, making it suitable for automatic waste segregation applications.

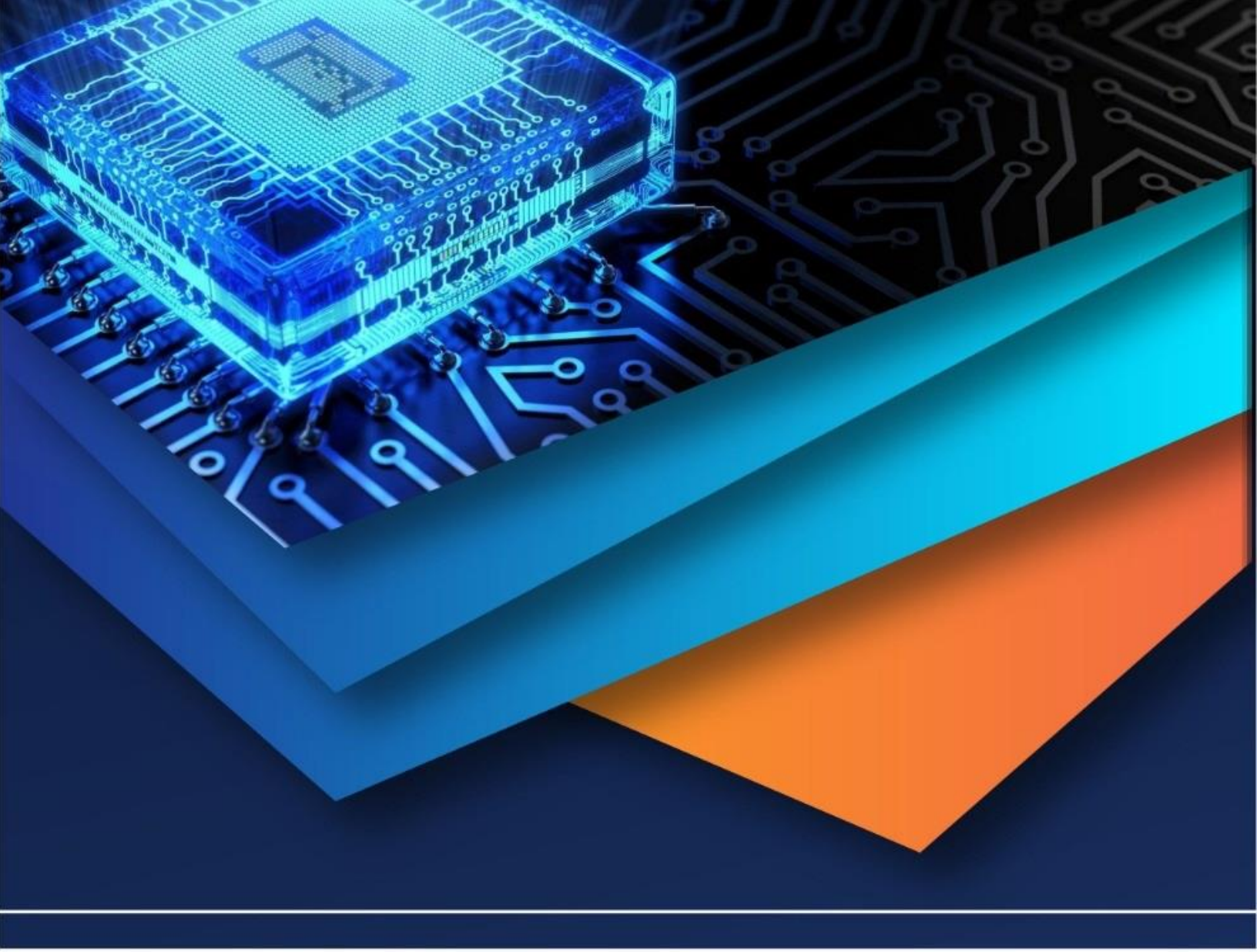
V. CONCLUSIONS

The Smart Waste Segregation Dustbin using Arduino proves to be an effective solution for automatic waste classification. The integration of sensors with a microcontroller and stepper motor enables precise, reliable, and hygienic waste segregation. The system is cost-effective, easy to implement, and suitable for small-scale applications such as homes, colleges, offices, and public places. This project demonstrates how embedded systems can contribute to sustainable and intelligent waste management solutions.

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