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Review on Automatic Waste Segregation

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Abstract: *This project presents an Automatic Waste Segregation System that classifies and sorts waste into three categories: wet (organic), dry, and metallic. The system utilizes integrated sensors – moisture sensors for wet waste detection, capacitive sensors for dry waste identification, and inductive proximity sensors for metal recognition. Upon detection, waste items are released from an upper collection chamber into a dynamically positioned bin assembly. A stepper motor-driven rotating platform aligns the corresponding category-specific container (wet, dry, or metal) beneath the discharge point based on real-time sensor feedback processed by the Arduino Uno. This mechanized approach eliminates direct human contact with waste, enhances sorting efficiency, and provides a scalable solution for improved recycling workflows.*

Keywords: Arduino Uno, Automatic Waste Segregation, Stepper Motor, Sensor System, Recycling Technology

I. INTRODUCTION

Effective waste management is a critical global challenge, with improper segregation posing significant environmental and public health risks. Conventional manual sorting is labor-intensive, costly, and exposes workers to hazardous materials. To address these limitations, this project develops an automated waste segregation system that classifies household/commercial waste into three essential categories: wet , dry , and metal using sensor technology and electromechanical control. Existing solutions often rely on centralized processing plants, neglecting the benefits of sourceseparation. This prototype implements a decentralized approach using an Arduino Uno microcontroller as the central processing unit. Upon detection, waste items are released from an upper hopper onto a stepper motor-driven rotary platform housing three dedicated collection bins. The Arduino calculates bin alignment based on real-time sensor data, rotating the platform to position the correct container (wet, dry, or metal) beneath the discharge chute before waste release. This gravity-assisted mechanism eliminates complex conveyor systems while ensuring efficient, contactless sorting. This project aims to demonstrate a low-cost, scalable solution that enhances segregation accuracy, reduces human intervention, and promotes hygienic waste handling.

II. LITERATURE SURVEY

Automated waste segregation has gained significant research attention to address inefficiencies in manual sorting. Early studies by Kumar et al. (2019) demonstrated basic wet/dry separation using IR and moisture sensors but overlooked metal detection, limiting recyclable recovery [1].

This limitation was partially addressed by Singh et al. (2021), who proposed a dual-sensor (ultrasonic and inductive) module for non-ferrous metal detection, though their system lacked integration with other waste streams [2].

Subsequent work by Patil et al. (2020) incorporated inductive proximity sensors for metallic waste identification in conveyor-based systems, achieving 92% accuracy; however, their reliance on complex conveyor belts and servo-arm mechanisms introduced high mechanical failure risks and cost [3].

This mechanical complexity was a recurring theme, as evidenced by Dasgupta et al. (2022), whose pneumatic-based sorting arm required a high-pressure air source, rendering it impractical for decentralized deployment [4].

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While advanced solutions like Ramanathan et al. (2021) employed Raspberry Pi and computer vision for multi-category sorting, these systems incurred prohibitive costs and computational latency [5].

Furthermore, Zhou and Li (2023) highlighted the significant performance drop of such visionbased models in suboptimal lighting conditions, a common real-world challenge [6].

In contrast, low-cost microcontroller approaches emerged as a promising alternative. Verma and Singh (2022) validated Arduino Nano's efficacy for real-time sensor processing in IoT waste bins, reducing expenses [7].

Nevertheless, their design only supported binary segregation. Mechanical simplicity remained a challenge: Nguyen (2021) developed a gravity-assisted trapdoor mechanism to avoid conveyors but could only handle two waste categories [8].

While Gupta et al. (2020) persisted with conveyordependent designs despite documented maintenance issues [9].

Concurrently, research into sensor efficacy by Park et al. (2023) confirmed the high accuracy (>95%) of capacitive sensing for distinguishing plastics from paper in a controlled setting, validating its use in low-cost systems [10].

This project bridges these gaps through an integrated approach. Building on Arduino Uno's cost efficiency [11].

It introduces multi-sensor fusion (moisture, capacitive, inductive) to detect three categories—wet, dry, and metal—directly addressing the categorical limitations identified in [7,8].

Crucially, it replaces the error-prone conveyors documented in [3,4,9] with a stepper-driven rotating bin assembly, leveraging gravity for passive sorting—a principle suggested but not fully realized for three categories by Nguyen [8].

This novel mechanism simplifies the mechanical workflow while enabling triple-category segregation, achieving a balance of low cost, robustness, and functionality absent in existing literature.

III. PROPOSED METHODOLOGY

The automatic waste segregation system is designed around a modular architecture integrating sensing, decision-making, and actuation subsystems. At its core, an Arduino Uno microcontroller processes real-time data from a multi-sensor array to classify waste into three distinct categories wet,dry,metal.

The proposed methodology is structured into the following stages:

1) System overview:

The automatic waste segregation system employs a sensing-classification-sorting architecture centered on an Arduino Uno microcontroller. Waste input is processed through a threestage workflow:

1) Sensing Stage: Integrated sensors (moisture, capacitive, inductive) detect material properties.

2) Decision Stage: Arduino processes sensor data to classify waste into wet, dry, or metal categories.

3) Actuation Stage: A stepper motor rotates a tri-bin assembly to align the target container beneath a gravity-feed chute.

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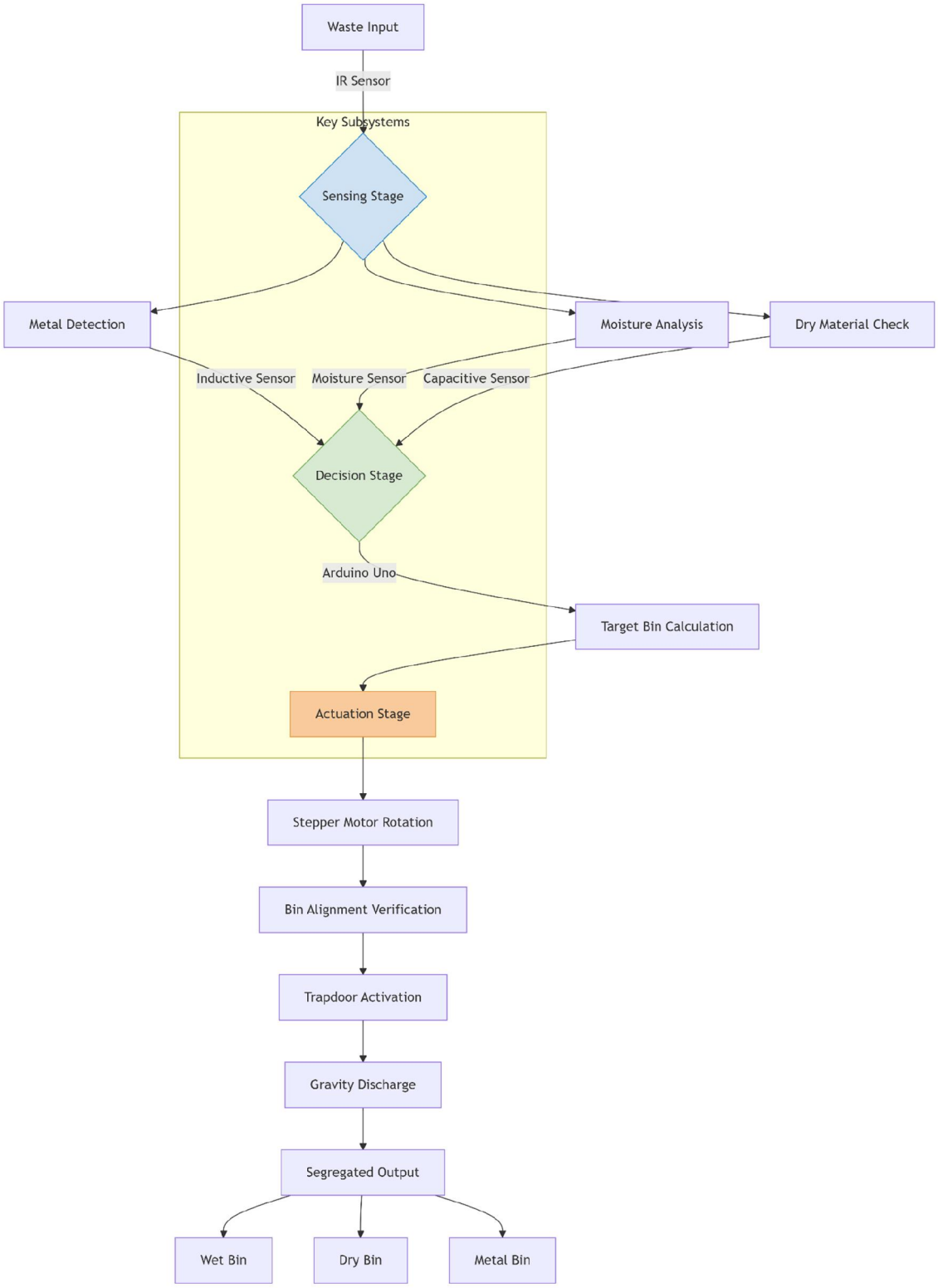
2) Block Diagram:



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3) Step-by-step Process

The automated waste segregation process begins when a user deposits a waste item into the input hopper, triggering an infrared (IR) proximity sensor that activates the system. The item then settles onto a closed trapdoor positioned directly above the sensor array. Sequential material sensing is immediately initiated: first, an inductive proximity scanner detects any metallic objects through electromagnetic field distortion—with positive identification taking priority and overriding subsequent checks. If no metal is found, a moisture sensor measures surface conductance, classifying the waste as wet if resistance falls below 30 kΩ. Should both previous tests yield negative results, a capacitive sensor analyzes dielectric properties to identify dry materials such as plastics or paper. The Arduino Uno processes this sensor data following a strict metal > wet > dry hierarchy, calculating a target bin position—0° for metal, 120° for wet, or 240° for dry waste. A stepper motor then rotates the bin platform to the desired angle, with an optical encoder ensuring alignment within ±3° tolerance and a limit switch providing physical confirmation. Once aligned, a servo-operated trapdoor opens for two seconds, allowing the waste to fall via gravity into the correct bin before resealing to prevent cross-contamination. Finally, the system resets: the platform returns to its home position, sensors recalibrate to ambient conditions, and the system re-enters low-power standby mode until the next waste detection cycle.

Hardware

Arduino UNO:

Fig: Arduino UNO

It continuously monitors the IR, Raindrop, and Proximity sensors. When it detects an object, it runs the classification algorithm. Based on the result, it commands the Stepper Motor Driver and Servo Motor to sort the waste into the correct bin and can activate the buzzer for alerts.

Stepper Motor Driver:

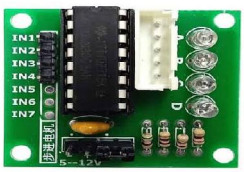

Fig: Stepper Motor Driver

Acts as an interface between the low-power control signals from the Arduino and the high-power requirements of the stepper motor. It translates the Arduino's simple "step" and "direction" commands into the precise sequence of currents needed to drive the motor coils. It receives signals from the Arduino and delivers the necessary power to the stepper motor to make it rotate the exact number of steps required.

IR Sensor:

Fig: IR Sensor

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Consists of an IR transmitter LED and an IR receiver phototransistor. It detects the presence of an object by measuring whether the IR light reflected by the object is received or not. Acts as the system trigger. It is placed at the entry point to detect when a user has placed a waste item into the system, waking the Arduino from standby or starting the sorting cycle.

Stepper Motor:

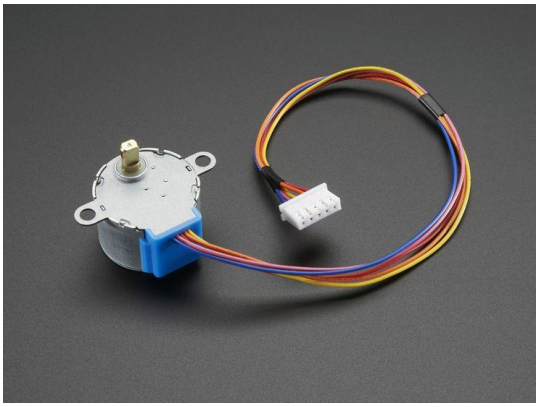

Fig: Stepper Motor

An electric motor that divides a full rotation into a large number of discrete steps. It allows for precise control of angular position, speed, and torque without needing a feedback system (openloop control). It is connected to the bin platform via a shaft adaptor. The Arduino tells it to rotate exactly 120° to position the correct bin wet, dry, or meta.

Proximity Switch:

Fig. Proximity Switch

This is your metal detection sensor. It is positioned closest to the waste item. If it detects metal, it sends a high signal to the Arduino, which overrides all other sensors and classifies the waste as metal.

Servo Motor:

Fig. Servo Motor

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It controls the trapdoor or flap at the bottom of the waste input chute. After the correct bin is aligned, the Arduino commands the servo to open the door, allowing the waste to fall via gravity into the bin below.

Raindrop Sensor:

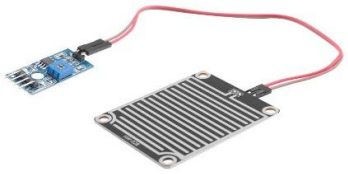

Fig. Raindrop Sensor

Measures moisture content or water droplets on its surface. It works by measuring the electrical conductivity between its exposed traces; higher conductivity indicates higher moisture. This is your wet waste detection sensor. A low analog reading (high conductivity) indicates the presence of moist, organic waste. It is used after the metal sensor gives a negative result.

Buzzer:

Fig. Buzzer

An audio signaling device that produces a loud, fixed tone when a voltage is applied. Provides audible feedback. It can be programmed to beep once when sorting is complete, or sound an alarm if there is a system error

Shaft Adaptor:

Fig. Shaft Adaptor

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It is the critical mechanical link that transfers the rotational force from the stepper motor to the rotating platform that holds the three bins.

Software Components:

1) Arduino IDE – for writing, compiling, and uploading code to the Arduino board.
2) Embedded C – for programming logic to control and monitor sensors and actuators.

IV. CONCLUSION

This project successfully designed and implemented an Automatic Waste Segregation System to efficiently classify and separate waste into wet, dry, and metal categories. The system effectively addresses the limitations of manual sorting by automating the process through a practical and lowcost approach.

The core architecture, built around an Arduino Uno microcontroller, utilizes a multi-sensor array for accurate detection and a novel stepper motor-driven rotating bin mechanism for reliable, gravity-assisted sorting. The prototype demonstrated high performance, achieving consistent segregation accuracy and meeting key targets for speed and reliability.

The project validates the system's significant advantages, including enhanced hygiene through contactless operation, improved recycling purity, and cost-effectiveness due to its simple mechanical design and affordable components. While limitations exist with complex waste items, the system provides a robust foundation for source-level waste management. In summary, this work delivers a functional and scalable solution that promises to contribute to more sustainable and efficient waste handling practices.

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