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Smart Dry Wet and Metal Waste Segregation System

Sahara Yogesh Dodake (Author)
Department of Electronics and Telecommunication Engineering
JSPM's Bhivrabai Sawant Polytechnic
Wagholi, Pune, India
dodakesaharaa@gmail.com

Aditi Anil Amate (Author)
Department of Electronics and Telecommunication Engineering
JSPM's Bhivrabai Sawant Polytechnic
Wagholi, Pune, India
aditi.amate2008@gmail.com

Ruturaj Santosh Ankushkar (Author)
Department of Electronics and Telecommunication Engineering
JSPM's Bhivrabai Sawant Polytechnic
Wagholi, Pune, India
ruturajankushkar2009@gmail.com

Yashraj Gokul Bharade (Author)
Department of Electronics and Telecommunication Engineering
JSPM's Bhivrabai Sawant Polytechnic
Wagholi, Pune, India
yashrajbharade@gmail.com

Prof. Sharma C.M. (Guide)
Department of Electronics and Telecommunication Engineering
JSPM's Bhivrabai Sawant Polytechnic
Wagholi, Pune, India
chetnasharma450@gmail.com

Abstract-

This paper presents the design of a Smart Dry, Wet and Metal Waste Segregation System intended to separate common waste at the point of disposal. Improper mixing of biodegradable waste, recyclable dry waste and metallic objects makes recycling difficult and increases the amount of material sent to landfills. The proposed prototype uses an object-detection sensor, a moisture sensor, a metal-detection sensor, a microcontroller and a motor-driven diverter to classify an item and direct it to one of three bins. The control sequence gives priority to metal detection, then checks moisture, and treats the remaining detected items as dry waste. This arrangement follows the general principle of source segregation and recovery described in Indian solid-waste management guidance.
. The design is modular and can be implemented with commonly available low-cost electronics. The paper describes the related work, design challenges, architecture, components, software logic and testing methodology. As this is a proposed design, performance values such as accuracy and throughput must be established through controlled prototype testing rather than assumed in advance.

Keywords-

Smart waste segregation, dry waste, wet waste, metal detection, Arduino, moisture sensor.

1. INTRODUCTION

Solid waste management is an important environmental and public-health issue. Waste generated in homes, educational institutions, offices and public places often contains food scraps, paper, plastic, glass and metal. When these materials are mixed, wet waste can contaminate recyclable materials and increase the effort required for sorting. Indian waste-management policy emphasizes segregation at source and the channeling of dry recyclable materials for reuse or recycling, while biodegradable waste can be directed toward composting or other suitable treatment.

Manual segregation requires time and exposes sanitation workers to mixed and potentially unsafe waste. An automated bin can reduce repetitive handling by using sensors to identify selected material properties and a mechanical mechanism to guide each item into a separate compartment. Earlier Arduino-based systems have explored moisture sensing for wet waste and inductive proximity sensing for metallic items, demonstrating the relevance of low-cost embedded systems to this problem.

The objective of this project is to propose a compact, affordable system that classifies incoming waste into three categories: wet, dry and metal. The system is intended as an educational prototype and a foundation for further development. It does not replace municipal collection rules or specialist handling for hazardous, biomedical or electronic waste.

2. LITERATURE SURVEY-

Research on automated waste segregation commonly combines a microcontroller with sensors and a sorting mechanism. An Arduino-based domestic waste segregator described in the IEEE conference literature uses proximity sensing to support source-level separation and bin-status monitoring.

This work indicates that a small embedded controller can coordinate sensor inputs and mechanical actions without requiring a high-cost industrial control system.

A sensor-based smart segregation dustbin study describes the use of a moisture sensor for distinguishing wet and dry waste and an inductive proximity sensor for identifying metallic waste. It also discusses audible indication and the potential to reduce direct worker contact with mixed waste .

These sensor choices are relevant to the present design because moisture and metallic properties provide practical, measurable signals for a first-stage prototype.

More recent research has also considered automated classification of wet, dry and metal waste using moisture, metal and object-presence sensors, with a servo-controlled mechanism directing items to separate bins.

A related smart-bin approach combines a sorting mechanism with tracking features, showing how the basic sorter can be extended toward connected waste management

. However, the reliability of any sensor-based design depends on calibration, waste condition, sensor placement and the range of objects tested.

Based on this review, the proposed system uses a simple rule-based classification sequence and a three-compartment collection unit. Its emphasis is on a clear, low-cost architecture that can be built, tested and improved by students.

3. CHALLENGES-

- Mixed or overlapping waste: a single item may be wet and metallic, or may contain multiple materials. The prototype therefore needs a defined decision priority.
- Moisture variation: food waste, damp paper and surface water can produce similar sensor readings. A threshold must be calibrated using representative samples.
- Metal detection limits: inductive sensors detect suitable metallic targets within a limited sensing distance; small, thin or poorly positioned objects may be missed.
- Sensor contamination: moisture, dust and food residue can affect readings, so the sensing area must be accessible for cleaning and maintenance.
- Mechanical jams: irregular objects can block a flap, chute or rotating platform. The mechanism should be tested with different object sizes and shapes.
- Power and electrical safety: motors can draw more current than a microcontroller pin can supply. Motors should use suitable drivers and a stable supply with a common signal reference.
- Cost and scalability: a student prototype can demonstrate the concept, but a public-use unit requires a durable enclosure, safe moving parts, larger bins and maintenance planning.
- Validation: accuracy should be measured across a documented test set; it should not be inferred from a few successful demonstrations.

4. REVIEWED SYSTEM ARCHITECTURE-

The proposed system contains five functional blocks:

(1) waste input and object-presence detection,
(2) material sensing,
(3) microcontroller-based decision logic,
(4) motorized diversion,
(5) three separate collection bins.

The object-presence sensor signals that an item is available. The controller then reads the metal detector and moisture sensor. If metal is detected, the item is directed to the metal bin. If no metal is detected but the moisture value exceeds the calibrated wetness threshold, the item is directed to the wet bin. Otherwise, it is directed to the dry bin. This rule sequence is consistent with sensor combinations explored in previous segregation prototypes.

Block flow (conceptual): Waste inlet → Object sensor → Metal sensor → Moisture sensor → Microcontroller decision logic → Servo/diverter → Metal / Wet / Dry bins.

Priority is important because an item can trigger more than one sensor. For this prototype, metal detection is given first priority; moisture is checked second. This is a practical design choice, not a universal classification rule.

In a real deployment, special cases and local waste categories would need additional handling. The architecture can optionally include an LCD, buzzer, bin-level sensors or a wireless module.

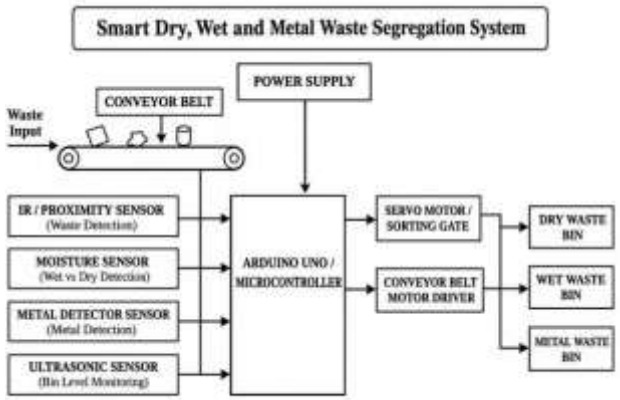


Fig.1 Hardware block diagram of the reviewed system

5. HARDWARE AND SOFTWARE IMPLEMETATIONM-

The system uses cost-effective, high-reliability commercial component chosen for low power consumption and harsh outdoor environments**.**

1 Hardware Architecture and Component selection

A. IR sensor / Proximity sensor

The IR (Infrared) Sensor is used to detect the presence of waste on the conveyor belt. When a waste item comes in front of the sensor, the sensor sends a signal to the Arduino UNO. The Arduino then starts or coordinates the next step of the process. For example, when a plastic bottle reaches the sensor, it detects the bottle and helps the system begin the waste identification process.



Fig.1 IR sensor / Proximity sensor

B. Moisture sensor

The Moisture Sensor measures the moisture level in waste and helps distinguish wet waste from dry waste. For example, food scraps and vegetable peels usually contain more moisture, while dry paper and some plastic items generally contain less moisture. The sensor sends its readings to the Arduino UNO, which uses the programmed moisture threshold to classify the waste. The sensor must be properly positioned and calibrated for reliable results because some materials can give misleading readings.



Fig.2 Moisture sensor

C. Metal detector sensor

The Metal Detector Sensor is used to identify metallic objects in the waste. It can detect suitable metal items, such as certain metal cans and metal pieces, depending on the type of sensor used. When metal is detected, the sensor sends a signal to the Arduino UNO. The Arduino processes this signal and commands the servo motor to direct the waste toward the Metal Waste Bin. The detection range and the types of metal detected depend on the sensor specifications.

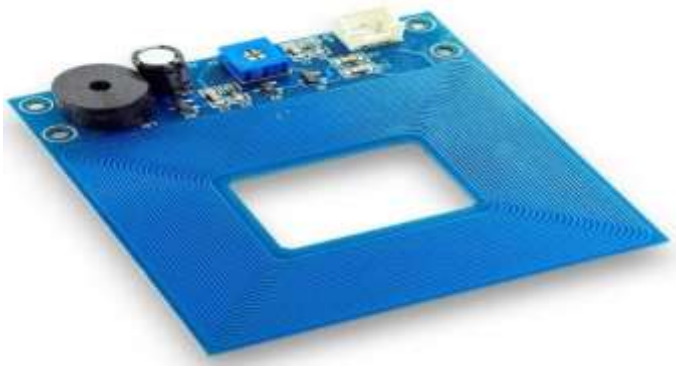


Fig.3 Metal detector sensor

D. Ultrasonic Sensor

The Ultrasonic Sensor measures distance using high-frequency sound waves. In this project, it can be installed above the waste bins to monitor their fill levels. It measures the distance between the sensor and the waste surface. When a bin becomes nearly full, the distance changes, and the Arduino can provide a warning or stop the process if the program is designed for that function. This sensor monitors the bin level; it does not identify the type of waste.



Fig.4 Ultrasonic sensor

E. Arduino UNO microcontroller

The Arduino UNO is the brain of the waste segregation system. It receives signals from the IR Sensor, Moisture Sensor, Metal Detector, and other connected sensors. It processes this information according to the program uploaded to it and determines which output action is required. For example, when metal is detected, the Arduino sends a control signal to direct the waste toward the metal bin. It also coordinates the conveyor belt motor and servo motor. Thus, the Arduino connects and controls the different parts of the system.



Fig.5 Arduino UNO microcontroller

F. Motor driver (L298N)

The Motor Driver is used to control the conveyor belt's DC motor. The Arduino sends low-power control signals to the motor driver, and the driver supplies the required motor current from the motor power source. Depending on the circuit, it can start or stop the motor and control its speed or direction. For example, the conveyor belt can be stopped temporarily when a waste item reaches the sorting position. The motor driver helps the Arduino control the motor without driving it directly.



Fig.6 Motor driver (L298N)

G. Servo motor (sorting gate)

The Servo Motor rotates to a specific angle and is used to operate the sorting gate. Based on the signals from the Arduino UNO, the servo moves the gate toward the appropriate waste bin. For example, if the system identifies metal waste, the gate moves toward the Metal Waste Bin. Similarly, it directs wet waste toward the Wet Waste Bin and dry waste toward the Dry Waste Bin. The gate's mechanical design and the servo's programmed angles determine how accurately the waste is separated.



Fig.7 Servo motor (sorting gate

- Microcontroller board (for example, Arduino Uno): reads sensors and controls the sorting sequence.
- Object-presence sensor (IR or equivalent): detects an item at the input position and starts a classification cycle.
- Moisture sensor: provides an analogue or digital signal related to surface moisture; its threshold must be calibrated for the chosen sensor and waste samples.
- Inductive proximity sensor or metal detector module: identifies metal objects within its specified sensing range.
- Servo motor or motorized diverter: positions a flap or chute toward the selected bin.
- Three-bin enclosure: separate compartments for wet, dry and metal waste.
- Power supply, motor driver if required, jumper wires, mounting hardware and protective enclosure.
- Optional LCD and buzzer: provide the detected category and an audible/visual status indication.

5.2 Software implementation

The control program can be developed in the Arduino IDE using a rule-based sequence. First, the controller waits for the object sensor. After an item is detected, it allows a short settling interval, reads the metal sensor and moisture value, chooses a category, moves the diverter to the relevant position, and allows the item to fall into the selected bin. The actuator then returns to its standby position. A timeout and a clear standby state help prevent repeated triggering while the same item remains in the sensing area.

Illustrative pseudocode:

START
Initialize sensors, motor position and status indicators
Wait until object-presence sensor detects an item
Read metal sensor
IF metal is detected: select METAL bin
ELSE read moisture sensor
IF moisture value crosses calibrated threshold: select WET bin
ELSE: select DRY bin
Move diverter to selected bin and release item
Return diverter to standby; display or signal category
Repeat

Sensor outputs and motor timings should be confirmed against the actual modules used. The metal sensor may have an active-low output, while a moisture module may produce an analogue reading whose direction depends on the board. These details must be handled in the program rather than assumed. Motor power should not be drawn directly from a microcontroller I/O

6. METHODOLOGY-

- Requirement analysis: define the three target categories, expected item size, bin dimensions and operating environment.
- Component selection: select a controller, compatible metal and moisture sensors, object detector, actuator and power supply.
- Mechanical design: build the input chute and a stable diverter that aligns with the three bins.
- Circuit assembly: connect sensor outputs to suitable digital or analogue inputs and connect the actuator through an appropriate power arrangement.
- Programming: implement object detection, sensor sampling, classification priority, motor positioning and return-to-standby logic.
- Calibration: collect readings from dry items, wet organic samples and metal objects. Select a moisture threshold based on observed readings and document the conditions.

• Functional testing: test each category individually, then test mixed sequences and objects with different sizes, shapes and moisture levels.

• Performance evaluation: record the number of correct classifications and total trials for each category. Calculate classification accuracy as (correct classifications ÷ total test items) × 100. Also record misclassification, jams and average sorting time.

• Improvement: adjust sensor placement, thresholds, delay or mechanical geometry based on test observations.
No experimental measurements are claimed in this manuscript. A final project report should insert the actual prototype photographs, circuit diagram, sensor calibration table and measured test results after the hardware is assembled and evaluated.

7. ADVANTAGES-

• Separates selected waste categories at the point of disposal, supporting source segregation.
.
• Can reduce repeated manual sorting of common dry, wet and metallic items.

• Uses widely available embedded-system components and a straightforward control algorithm.

• Modular design allows individual sensors or the actuator to be replaced or upgraded.

• Can support demonstrations and awareness activities in schools, colleges, homes and small offices.

• Metal recovery can improve the collection of recyclable material when items are correctly identified and handled.

• Optional indicators can make the sorting action easier for users understand.

10. APPLICATIONS-

Potential applications include college laboratories and project exhibitions, household waste points, office cafeterias, small commercial premises and controlled demonstrations at community awareness events. At larger facilities, multiple units could be combined with bin-fill sensors and a collection dashboard.

. Such extensions should be evaluated against local waste-management arrangements and the official rules applicable at the time of deployment

9. FUTURE SCOPE AND ENHANCEMENTS-

• Internet of Things (IoT) connectivity to report bin fill level, fault status and collection needs to a dashboard.

• Ultrasonic sensors for bin-level monitoring and alerts when a compartment is nearly full.

• Came ra-based classification or machine-learning models to recognize a wider range of materials, subject to suitable datasets and privacy-aware deployment.

• Improved sensor calibration, repeated sampling and filtering to reduce unstable readings.

• Jam detection, motor-current monitoring, emergency stop and guarded moving parts for safer operation.

• Data logging to record category counts, misclassifications and average sorting time.

• Solar-assisted power or energy-efficient standby operation for suitable outdoor installations.

• Additional sorting stages for glass, paper, plastics or hazardous items, only where the handling method is safe and clearly defined.

Future development should focus first on reliability and safety. Network connectivity or artificial intelligence cannot compensate for poor mechanical design or uncalibrated sensors; each added feature should be validated using measurable tests.

10. CONCLUSION-

The Smart Dry, Wet and Metal Waste Segregation System proposes an embedded, sensor-based approach for sorting common waste into three separate compartments.

The design combines object detection, metal sensing, moisture sensing, a microcontroller and a motorized diverter.
.
It is informed by previous sensor-based segregation studies and by the general policy goal of separating waste at source for suitable recovery and treatment.
The concept is suitable for a student prototype because its operation can be explained through a clear decision sequence and its components are modular.

The system's practical value will depend on calibration, mechanical reliability, maintenance and measured performance. The next step is to assemble the prototype and publish test results, including category-wise accuracy, sorting time and observed failure cases. With further validation and appropriate safety improvements, the design could be extended with bin monitoring and connected reporting.

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BIOGRAPHIES



Prof. Sharma C.M. (Guide) is a Lecturer in the department of Electronics and telecommunication Engineering , JSPM's Bhivrabai sawant polytechnic , Wagholi, pune, India.

Email: chetnasharma450@gmail.com



Aditi Anil Amate (Author) is a student in the Department of Electronics and telecommunication Engineering , JSPM's Bhivrabai sawant polytechnic , Wagholi, pune, India.

Email: aditi.amate2008@gmail.com



Ruturaj Santosh Ankushkar (Author) is a student in the Department of Electronics and telecommunication Engineering , JSPM's Bhivrabai sawant polytechnic , Wagholi, pune, India.

Email: **r**uturajankushkar2009@gmail.com



Sahara Yogesh Dodake (Author) is a student in the Department of Electronics and telecommunication Engineering , JSPM's Bhivrabai sawant polytechnic , Wagholi, pune, India.

Email: dodakesaharaa@gmail.com



Yashraj Gokul Bharade (Author) is a student in the Department of Electronics and telecommunication Engineering , JSPM's Bhivrabai sawant polytechnic , Wagholi, pune, India.

Email: yashrajbharade@gmail.com