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Intelligent IoT Enabled Waste Segregation and Monitoring System

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Abstract

One of the significant issues contributing to environmental hazards is the ongoing accumulation of waste. As the global population continues to grow, waste is being discarded in single locations, mixing different types of refuse. In India, the total generated waste is projected to exceed 150,000 Mt/day. Waste is often scattered along roadsides, and the personnel responsible for management do not collect it regularly. This automated waste segregation bin project aims to enhance efficiency, utilizing IoT-based smart sorting and management to categorize waste as dry, metallic and wet using sensors such as IR sensors, ultrasonic sensors, inductive proximity sensors and moisture sensors. The microcontroller incorporates a Wi-Fi module alongside the Arduino to enable effective, closed-loop operations. Arduino manages sensor and servo motor functions, monitoring the entire waste process including levels and separation. This approach reduces open organic waste decomposition and subsequent microorganism growth. The proposed system divides waste into dry, metallic and wet waste. This application is a viable approach for waste management and sorting. Using a cloud server, data gathered by Arduino can be easily accessed by authorities, providing information on the garbage filling level without the need for manual checks.

Keywords: Automatic waste segregation and monitoring system, IoT based technology, sensor-based working, real time monitoring system, cost-effectiveness.

INTRODUCTION

Current waste segregation methods are inefficient due to manual handling. In domestic settings, the disposal process typically involves government authorities collecting waste from people's doorsteps, but waste is often improperly sorted, which negatively impacts later stages of segregation. Unprocessed waste can attract harmful microorganisms. When waste is not sorted, hazardous materials can end up in landfills or the environment, causing pollution of soil, water and air [1].

We introduce an effective system that automates waste sorting using a variety of sensors and a microcontroller. When waste is disposed of in the bin, an IR sensor detects it. The waste is then separated into dry, wet and metal categories. A different sensor identifies the type of garbage. According to the algorithm in use, if the waste is metal, the mechanism positions the metal collection bin under the tray, allowing the waste to drop into the metal bin with the aid of a servo motor. This proposed system offers a straightforward and efficient method for waste sorting, eliminating the need for human intervention during the segregation phase [2].

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Properly separating waste into categories like wet, dry and metal enhances its potential for recovery, recycling and reuse.

PROPOSED SYSTEM

The proposed method includes a comprehensive block diagram summarizing each component of the system. The system includes various sensors for the effective detection of dry, wet and metallic wastes [3].

Block Diagram

The primary component of the system is the Arduino UNO microcontroller board, which connects to all the input and output elements as shown in Figure 1. The Automatic Waste Segregation and Monitoring System uses Moisture, Ultrasonic, IR and Inductive Proximity sensors that feed data to the Arduino, guiding the operation of the servo motor and LCD display. All the connections are outlined in the block diagram. A relay driver supplies power to the servo motor. The inputs to the Arduino are Moisture sensor, Ultrasonic sensor, IR sensor and Inductive Proximity Sensor. The Arduino will be programmed with source codes using MatLab software. The compatible sensor devices are mentioned in the Block Diagram [4]. The Wi-Fi module used here is ESP8266. It provides internet connectivity to the system so that cloud server can send the real time information about the waste levels to the authorities.

Circuit Diagram

The automatic waste segregation system circuit combines various components to optimize the process as shown in Figure 2. Starting with the sensors, the Infrared (IR) sensor detects the presence of waste, the Moisture Sensor measures soil moisture to distinguish wet waste and the Inductive Proximity Sensor identifies metallic waste items. The LCD Display provides visual feedback about the waste segregation process. A Relay functions as a switch to control the Servo Motor, which sorts the waste into different bins [5].

The Arduino serves as the central controller, taking inputs from the sensors and making decisions based on programmed logic to control the Servo Motor and Relay. The ESP8266 enables internet connectivity, allowing for remote monitoring or data logging if needed. Power connections (VCC and GND) must be established for each component, while signal pins from the sensors should be connected to the appropriate digital or analog pins on the Arduino [6]. The programming on the Arduino is essential for interpreting sensor data, making decisions and executing actions to automate the waste segregation process efficiently. The programming on the Arduino is crucial, as it interprets sensor data, makes decisions and executes actions to automate the waste segregation process effectively.

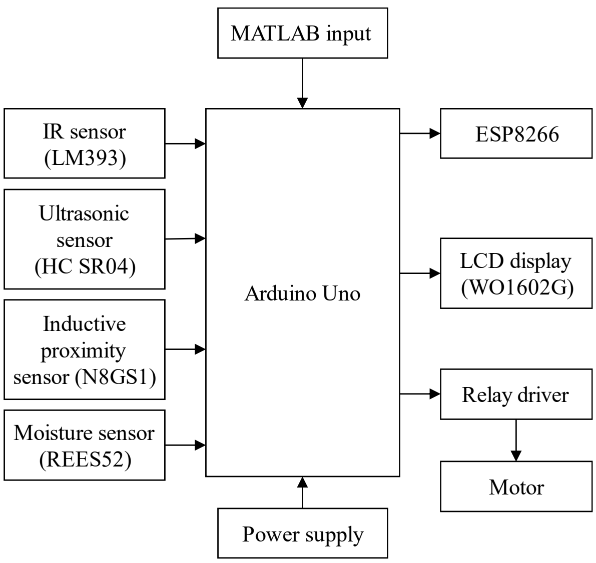

Figure 1. Block diagram of the system.

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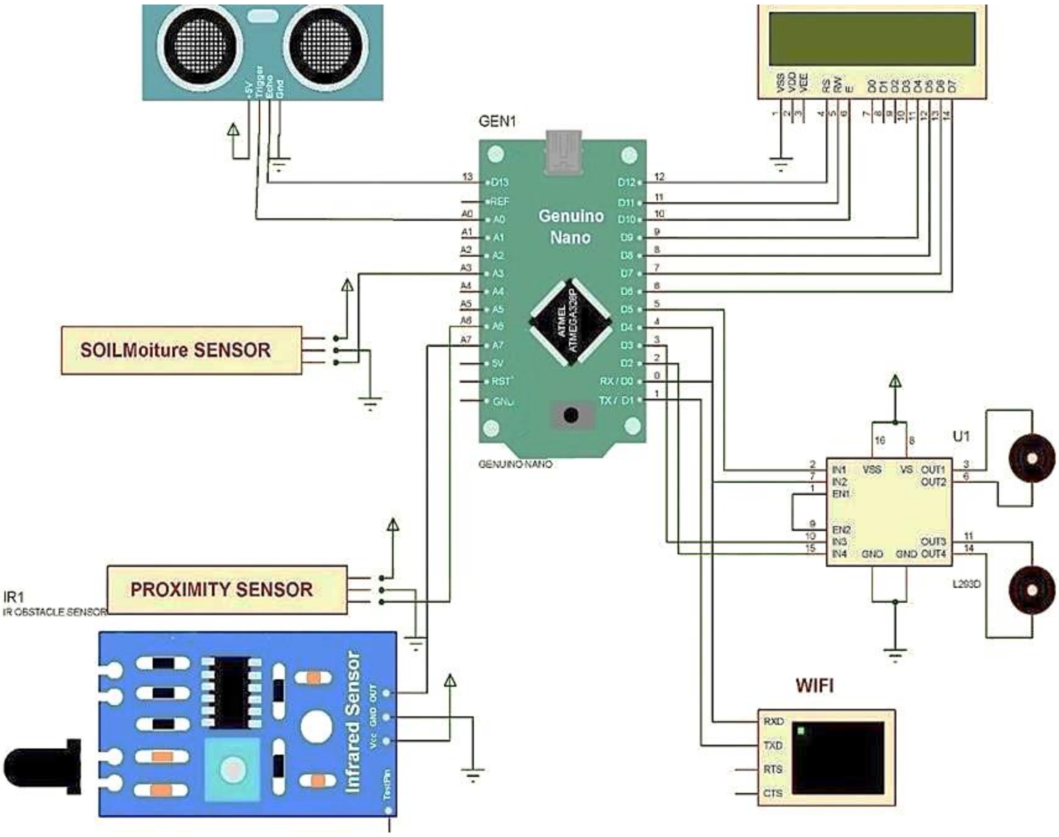

Figure 2. Circuit diagram.

WORKING

The Arduino UNO plays a crucial role in our system. A metal detector, IR sensor and moisture sensor are connected to the Arduino board, with the IR and moisture sensors connected to the digital pins. The moisture sensor is linked to servo motor 1, which controls the opening of the collector trash slot and an ADC is connected to the moisture sensor to convert its output signal to DC form. The metal detector is attached to an analog pin. The two servo motors, connected to the digital side, are essential for sorting waste into the appropriate bins, while another motor manages the opening and closing of the top [7]. Three separate waste bins segregate wet, metal and other waste, each connected to a motor. An ADC linked to the metal detector converts its analog signal to digital inside the UNO board. The system uses an external power source instead of batteries because servo motor 2, which rotates the dust bin, requires high voltage. An adapter provides the necessary power because the moisture sensor cannot supply enough.

When waste is thrown into the bin, the sensors on the surface identify the type of waste. If metal waste is detected, it becomes entangled in the magnetic field of the inductive proximity sensor, which sends an input to the Arduino for the appropriate bin to collect the metal waste [8]. Similarly, the moisture sensor identifies wet waste, while the IR sensor detects dry waste. An ultrasonic sensor measures the garbage level inside the bin. An IoT module enables the system to connect to the internet and provide real-time updates on the garbage level through Wi-Fi connectivity.

IMPLEMENTATION

Hardware Implementation

One of the key components of this system is the implementation of sensors for monitoring different aspects of waste. The inclusion of an Ultrasonic sensor allows for precise measurement of the garbage level within a waste bin. By utilizing sound waves, the Ultrasonic sensor can accurately determine the distance to the surface of the waste, providing real-time data on the fill level of the bin. This information is crucial for optimizing waste collection routes and schedules, thereby reducing operational costs and environmental impact. IR sensor is employed to detect the presence of garbage within the bin. This sensor emits infrared radiation and measures the reflection or absorption of this radiation to determine the presence of objects, such as waste, within its range [9]. By continuously monitoring for the presence of garbage, the system can trigger alerts or notifications when the bin needs to be emptied, ensuring timely waste collection and preventing overflow or littering. Moisture sensor is integrated into the system to detect the moisture content of the waste. This sensor utilizes probes or electrodes to measure the conductivity or dielectric properties of the waste, providing insights into its moisture level. By monitoring moisture content, the system can identify and segregate wet waste. Inductive proximity sensor is utilized to detect the presence of metal objects within the waste. This sensor generates an electromagnetic field and detects changes in this field caused by the presence of metallic objects as shown in Figure 3.

Define Requirements

Clearly outline the requirements of your waste segregation and monitoring system. Define the specifications for the parameters you want to track (such as waste level, quantity and types of waste), specify the placement of sensors and detail the actions the sensors should perform.

Select Sensors

Choose appropriate sensors for monitoring the type of waste dumped. Consider factors such as accuracy, reliability, power consumption and compatibility and durability with IoT platforms. Choose IR sensor for detecting the presence of dry waste, moisture sensor for wet waste, inductive proximity sensor for metal waste and ultrasonic sensor for measuring the waste level inside the bins.

IoT Platform Selection

Select an IoT platform that enables data collection, storage, analysis and visualization. Well-known platforms include AWS IoT, Microsoft Azure IoT, Google Cloud IoT and open-source options like Arduino IoT Cloud or ThingsSpeak. For this project it is better to use the ThingSpeak IoT platform.

Data Transmission

Set up a communication protocol (such as MQTT, HTTP or CoAP) to securely and safely transfer data from sensors to the IoT platform. Implement encryption and authentication methods to safeguard data privacy and integrity.

Software Implementation

Embedded C programming is used to write code for the microcontroller and Wi-Fi module. The program evaluates and processes sensor readings according to set conditions to monitor the type of waste disposed of in the bin using different sensors and actuators in an Arduino-based system. It is always better to use embedded C while programming microcontrollers especially for this type of uses [10].

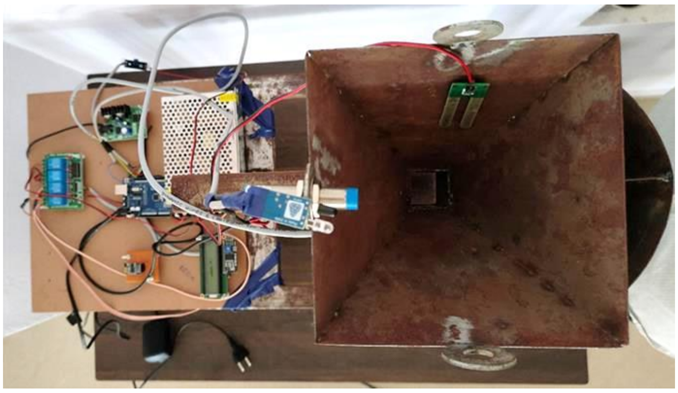

Figure 3. Hardware implementation.

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Installing Required Libraries

The code uses libraries to interface with hardware components like the LCD, various sensors and communication modules. It also defines several global variables that store sensor data and system states.

IoT Interference

Using the cloud platform ThingSpeak, graphical visualization of sensor parameters can be achieved. ThingSpeak supports real-time data collection and visualization through its features. Data can be securely transmitted to the cloud for analysis and visualization via MATLAB. Actions based on the received data can also be set up. ThingSpeak offers RESTful and MQTT APIs for efficient data communication and is compatible with devices like Arduino, ESP8266/ESP32 Wi-Fi modules, Raspberry Pi and others.

RESULTS

When a metal waste is thrown, LCD display shows "METAL WASTE DETECTED" and corresponding graph and data is also shown in the IoT interface. The Segregation system rotates the bins and chooses the one for the metal waste to dump it.

The details shown in the IoT interface for the metal waste are shown in Figures 4 and 5. It includes a graphical representation and an icon for the metal waste. The graphical representation depicts the details of metal wastes dumped with respect to time.

Similarly, for dry and wet wastes a graphical representation will be shown in the IoT interface with respect to the time they are thrown, as shown in Figures 6–9.

Figure 4. Graphical representation of metal wastes.

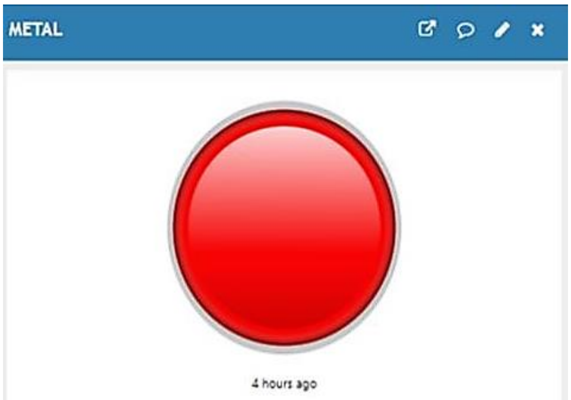

Figure 5. Icon for metal waste.

For Dry Waste

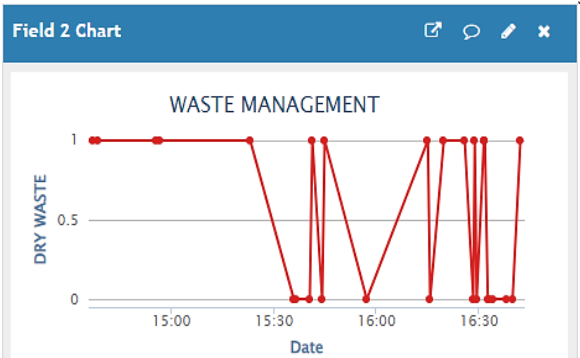

Figure 6. Graphical representation of dry wastes.

Figure 7. Icon for dry waste.

For Wet Waste

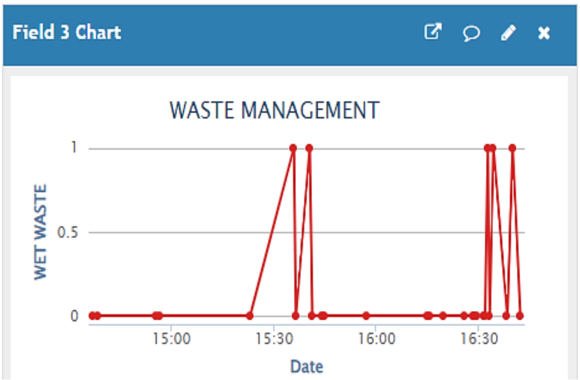

Figure 8. Graphical representation of wet wastes.

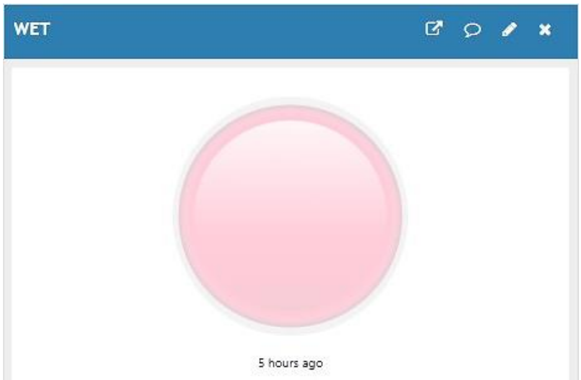

Figure 9. Icon for wet waste.

CONCLUSION

This study represents a substantial advancement in waste management practices. By integrating advanced technologies such as inductive proximity sensors, IR sensors and moisture sensors, along with the flexible ESP8266 module, the project offers a comprehensive solution with extensive benefits. The results of the implemented project are already given in this study. When a waste material was thrown, it accurately differentiated its type and when one bin was full, it gave an alert by turning the icon color red and also it was shown in the LCD display. The accuracy in waste segregation not only boosts recycling efforts but also aligns with global sustainability goals by minimizing landfill waste and supporting a circular economy. Real-time monitoring and data-driven decision-making enable waste management authorities to optimize resource allocation, leading to cost savings and reduced environmental impact. Associated mobile apps and web interfaces increase public awareness and involvement, promoting responsible community behavior and sustainable waste disposal practices. Additionally, the scalability, adaptability and over-the-air update features of the ESP8266 contribute to the system's durability and ongoing relevance. This system presents an innovative approach to current waste management issues and serves as a robust, forward-thinking framework ready to adapt to the evolving demands of urban environments. In essence, the IoT-based automatic waste segregation and monitoring bin project goes beyond traditional waste management, embodying technological innovation, environmental responsibility and community participation and setting a standard for smart city initiatives. As cities increasingly embrace sustainable living, system serves as a guiding light toward a cleaner, more efficient and technologically advanced future in waste management.

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