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Research on Automatic Waste Segregation

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Abstract: ***With advancing urbanization, industrialization, and population rise, the global world is in the grip of a terrifying boom in municipal solid waste (MSW). Estimated global waste output is set to grow from 2.01 billion tonnes during 2016 to 3.40 billion tonnes by the year 2050, with an increase of nearly 70%, according to the World Bank. Of this, over 33% of waste is open dumped or uncontrolled landfilled, and this has a critical effect on air quality, soil fertility, and health. Landfills have grown now and are responsible for nearly 8–10% of the world's greenhouse gas emissions, and the situation is further worsened by the lack of segregation at the source. In addition to overloading city systems, it also exposes sanitation workers and stray animals to harmful substances.***

To counteract this growing issue, this paper proposes an Automatic Waste Segregation System to categorize domestic or industrial waste into metal, wet, and dry categories. The system is based on an Arduino Uno microcontroller, along with an IR sensor for dry waste, an inductive sensor for metals, and a moisture sensor for the detection of wet waste. A servo motor-controlled gate and rotor disc mechanism directs waste into respective bins based on sensor input. It is housed in a wooden box with PVC channels for ease of movement and protection.

Through minimized human contact and promoting effective, source-level waste separation, the system enables better safety in waste handling, reduced landfill burden, and enhanced recycling, delivering a low-cost, scalable solution for eco-friendly waste management in residential and institutional settings.

Keywords: Automatic Waste Segregation, Arduino Uno, Dry Waste, Wet Waste, Metallic Waste.

I. INTRODUCTION

As India is rapidly urbanizing and growing in population, the nation is now producing a whopping 62 million metric tonnes of Municipal Solid Waste (MSW) annually. Unfortunately, a lot of the waste is not being utilized productively. The remaining waste is just left to accumulate in ill-managed landfills, typically openly burned, causing severe health risks, environmental pollution, and unsustainable land use.

As per the Swachh Survekshan 2016 survey, carried out by the Ministry of Urban Development under the Swachh Bharat Mission, nearly 50% of Indian citizens are still suffering because of poor waste collection and disposal mechanisms. This is not just a figure—it is a sign of a serious breakdown in waste management at the point of origin, where segregation can make a huge difference in the reduction of the load on the entire waste handling chain.

Centre for Science and Environment (CSE) reports also show that India's excessive reliance on traditional landfill dumping is risky. Leachate from open landfills contaminates groundwater, and toxic gases released into the atmosphere lead to serious respiratory diseases. Sanitation workers and ragpickers are usually on the receiving end of this, with a very high chance of infection, skin infection, and even rodent bites while handling mixed waste with no or incomplete protection.

Though ragpickers constitute the backbone of India's unorganized recycling sector, their safety and health are at risk at all times. Hand segregation is also time-consuming, inefficient, and of low recoverability of valuable materials. Automatic waste segregation at the source, on the other hand, offers a smart, scalable, and much safer option. With the segregation of waste into wet, dry, and metallic streams at the disposal stage itself, this technology not only increases the extent of waste recycling efficiency but also improves the quality and worth of recyclable waste.

Our project serves as a solution to this pressing problem. We provide an economical, small, sensor-based Automatic Waste Segregation and Monitoring System for urban families and societies. It uses a mix of sensors—moisture, metal, and IR—to detect and segregate the types of wastes in real time. The reason behind choosing this project is its urgency and practicality. Since the waste management system of India is breaking down at its very foundation, we believe that smart segregation at the source is no longer a choice—it is a necessity. Not only does it minimize human contact with toxic waste, but it also makes it easier for recycling, composting, and energy recovery. Above all, it makes sustainable waste management a day-to-day, household reality.

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With the creation of this system, we hope to reduce human interaction with toxic waste, reduce reliance on human labor for segregation, reduce the burden of waste on landfills, and boost the overall recycling yield. Lastly, our project directly supports the vision of the Swachh Bharat Abhiyan. In the long term, this project can potentially alter the character of waste management in Indian cities—not only technologically, but culturally. By encouraging domestic-level responsibility and offering an affordable device for segregation, we make a significant step towards constructing cleaner, safer, and smarter cities.

II. PROBLEM STATEMENT

Industrial and domestic waste are the prime sources of waste. This project primarily focuses on domestic waste whose worth is unseen as individuals do not take the time to sort waste into their fundamental streams. Wet waste that is produced can be utilized for producing biogas, metallic and dry waste can be outsourced for recycling, if metallic waste is untreated then it turns into a danger to plant and animal lives.

If waste is segregated at home level then they can be directly sent for recycling rather than sending them to industries initially for segregation which turns into a gigantic task and the waste doesn't get segregated properly. The techniques used for waste segregation in industries is dangerous for human health as it utilizes x-rays and infrared rays.The environmental hazards of improper waste disposal are well documented and recognized. Fly tipped waste can poison and harm children and animals and cause an eyesore.

Improper disposal of liquid wastes like solvents can seep into the ground water and pollute drinking water supplies. Landfills that are poorly planned and managed will produce a serious neighborhood disturbance, and where landfill gas and leachate are not adequately treated there will be a danger to the safety of residents in the locality. Those incinerators without sufficient pollution control equipment will emit intensely toxic dioxins.

Even recycling and composting plants can become a source of litter and bad odor if not sufficiently regulated. The main objective of the project is to sort out waste at source level to wet, dry and metallic so that waste is not wasted but their worth is realized and can be utilized as a source of energy, in a cost effective manner.

III.OBJECTIVE

1) To automate the segregation of waste into metal, wet, and dry types for efficient disposal.
2) To establish an environmentally friendly system that supports recycling and resource recovery.
3) To minimize human intervention and increase accuracy in waste segregation processes.
4) To produce a cost-efficient and scalable smart waste management solution.

IV.LITERATURE REVIEW

Padmakshi Venkateshwara Rao, Pathan Mahammed Abdul Azeez, 2020[1] introduces the “IoT based Waste Management for Smart Cities” to overcome the challenges in the environment such as inadequate waste collection, treatment, and disposal. Due to flooding of the dustbin causes unhygienic conditions are created, the dustbin is placed in the entire city; it is delivered with minimum cost embedded method to assist in tracking of the garbage, therefore the “Blynk app” is used to get the immediate SMS as early as garbage bin reaches its peak level. Therefore, instant action will be taken by the alarmed authorities once the status of a bin is notified through the internet. Ultrasonic sensor, node MCU, blynk app, and servo motor are used to develop the proposed system.

Nikolaos Baras, Dimitris Ziouzios, 2020[2] introduces “A cloud-based smart recycling bin for in-house waste classification” urban waste increases as long as modern lifestyle increases. Recycling is the best way to create a sustainable environment and also it needs the segregation of waste materials which is a tedious time-consuming task. It is the minimal cost and effective smart recycling bin that uses the power of the cloud in order with waste classification in personal in-house usage. A centralized Information System collects measurements in smart dustbins, the waste in each bin can be classified using Artificial Intelligence and also neural networks. And it is capable of classifying different types of waste with an accuracy of 93.4%.

Shashank Shetty, Sanket Salvi, 2020

[3] This introduces the SAF-Sutra: “A Prototype of Remote Smart waste segregation and garbage level monitoring system”, which can remotely monitor and is built at a very minimal cost. The design of the presented system considers the portability and ease of assembly of components as the essential factors during implementations. The demonstration shows the implemented system; its interaction with the user using the mobile along with the web application.

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Clude-Noel Tamakloe, Dr. Elena v. Rosca,[4] Introduces the Smart System and the Internet of Things (IoT) for waste management to provide an efficient and effective manner for waste disposal, improving the city's waste management. The proposed system is drawn and makes a prototype of a solar powered, compact smart garbage bin whose monitoring is done with server side applications. The smart garbage bin is capable of monitoring internal garbage levels, compacting them, and also free 25% of the space with each compactness. The bin detects and monitors the total weight and is capable of sending all the information to a secure server side application.

Rania Rizki Arinta, Dominikus Boli Watomakin, 2020[5] introduces the "Improves smart waste management to preserve tourist's attractions Yogyakarta in IoT environment", the main agenda is to make waste recycled, if it is not recycled, it will make the decomposition process more tedious. Therefore, the dustbin is integrated with the smartphone to find out information about the capacity of the garbage by using the ultrasonic sensor. The wi-fi module combined with the dustbin allows the sensor to send the data through the wi-fi module via smartphone.

Chethan Kaushal, Anshu Singha, 2020[6] introduce the Architecture for garbage monitoring systems using integrated technology, proposed the novel architecture of waste management that utilizes the concept of IoT and digital image processing, the architecture acts as a surveillance system to monitor the over the flow of the garbage and delivers the message to the concerned authorities to take the necessary and instant action.

Singh et al.,[7] developed a smart waste bin that segregates waste into biodegradable and nonbiodegradable. Whenever a person approaches the bin with waste in front of the sensor, it detects and separates the waste (biodegradable or non-biodegradable). Subsequently, when the bin is full, a message will be sent to the person in charge to empty the waste bin. Many diseases are spread through improper disposal of waste. A cheap smart waste system was implemented to automatically separate wet and dry waste via a moisture sensor and then sent for further processing.

Saranya et al., [8] have made such a system that identifies and separates metallic waste from non-metallic waste via an RLC metal detector circuit. The bin itself is partitioned into two halves. The classification is based on the increase in inductance of the coil whenever an object is placed within the coil vicinity. If the inductance change is beyond a threshold, the object is classified as a metal and the plate tilts into one side of the partitioned bin. This proposed system is implemented using an Arduino and Wi-Fi powered by a 9v battery.

Kesthara et al., [9]. The proposed system sorts waste into three different categories specifically metal, dry and wet waste. This helps to optimize the collection schedule.

The various categories have been embedded with a rejection and acceptance rate system. In addition, sensors are incorporated to monitor the status of the waste bin, and at maximum capacity, instant messages are sent to the waste management authority to empty the bin. In this System, an Arduino microcontroller platform regulates the sensors (Ultrasonic sensor, Humidity sensor), GSM module, and Servo Motor. However, the waste level in the bin is measured by an ultrasonic sensor, if the fill level is more than a threshold value. The Arduino board prompts the GSM module to transmit a message indicating which specific part of the bin is filled (dry or wet).

Ssreejith et al., [10]. The proposed solution comprises waste level monitoring and at the filled level, the bin moves automatically to the designated collection area for the disposal of waste and is returned to its initial position via a two-axis robot. Also, a gas sensor has been incorporated to detect the odor and alert the people living within the location via a buzzer. In addition, a rain sensor is used to sense rain and automatically closes the lid of the bin when it senses rain. Furthermore, an Infrared sensor is interfaced with the microcontroller to monitor the waste level. The entire system is monitored on the web page via the Wi-Fi module.

V. RESEARCH METHODOLOGY

The automatic waste segregation project uses an Arduino Uno module to drive the segregation process. The waste is initially sensed by a sequence of sensors: an IR sensor for detecting dry waste, an inductive sensor to detect metal, and a wet sensor to detect moisture, thus identifying wet waste. Depending on sensor readings, the type of waste is shown on an OLED display. Then, a servo motor is engaged, which operates a gate system as well as a rotating disc. The mechanism guides the waste to one of three containers for metal, wet, or dry waste. The whole system is housed in a wooden compartment, with PVC pipes guiding the waste through the system smoothly.

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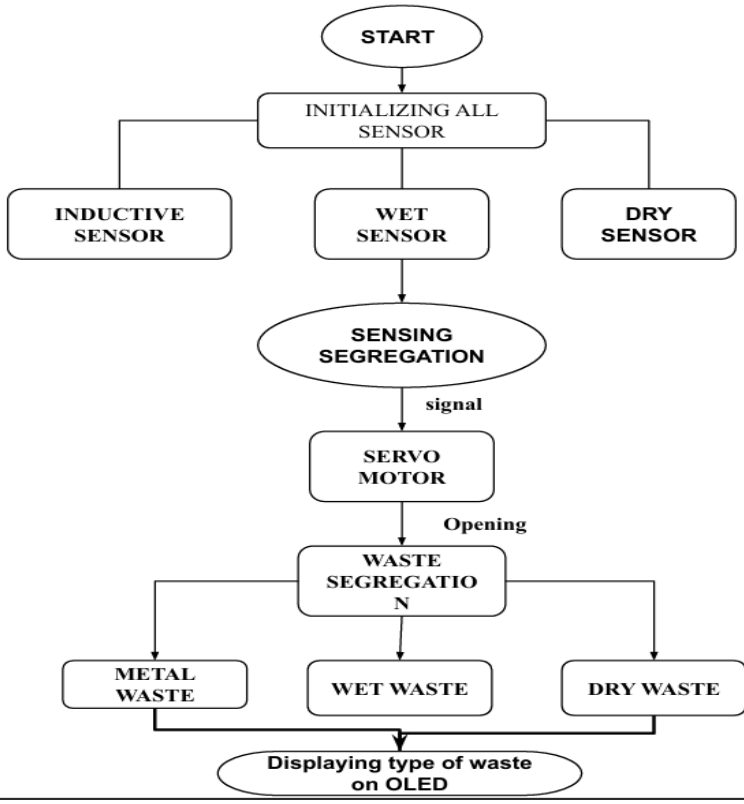


Fig1. Flow chart of Automatic Waste Segregation

VI. WORKING

The Automatic Waste Segregation system has been programmed to sensibly monitor and segregate the waste into three categories of metal, wet, and dry. The equipment comprises a regular waste bin with an installed series of sensors and a microcontroller for processing, sensing, and communication of data. The waste type is determined using a specific sensor: a metal sensor senses metallic items, a moisture sensor senses wet waste according to moisture content, and an IR sensor is employed for sensing dry waste. An Arduino Uno acts as the core microcontroller, programmed via the Arduino IDE, while the whole system is simulated using Proteus software to check circuit behavior and logic. When the system is initialized, all sensors turn on. When the waste is inserted, the corresponding sensor identifies the material type. Depending on the sensor signal, the servo motor turns on and opens the right garbage bin lid for disposal. An OLED display module is embedded in the system to visually show the detected type of waste in real time, like "Metal Waste Identified," "Wet Waste Identified," or "Dry Waste Detected." After depositing the waste, the bin lid closes on its own, finalizing the segregation process. The following figure illustrates the design and component layout of the proposed Automatic Waste Segregation system:

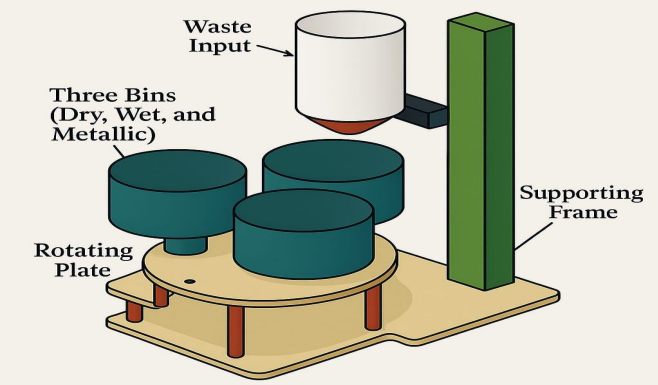


Figure 2: Layout of Waste Segregator

VII. RESULTS

The Automatic Waste Segregation System designed was tested for several experimental runs to ensure it could detect and sort waste into three different types: metal, wet, and dry waste. The system uses an Arduino control unit coupled with an inductive sensor, moisture sensor, IR sensor, servo motor, and OLED display to provide automated segregation.

1) Metal Waste Detection: When metallic items were introduced into the system, the inductive sensor effectively sensed their presence. After sensing, the sensor signal was processed by Arduino Uno, which in turn enabled the specified servo motor to open the metal waste can. In parallel, the OLED display furnished real-time feedback, showing the message: "Metal Waste Detected."

2) Wet Waste Detection: The sensor for moisture correctly detected wet or organic waste materials. The system, once activated, processed and made the servo motor rotate to the wet waste container. The OLED display presented the following message: "Wet Waste Identified."

3) Dry Waste Detection: For dry waste materials like paper or plastic, the infrared (IR) sensor reacted well. After detection, the control unit performed motor rotation to direct the waste to the corresponding dry waste bin, while the OLED showed: "Dry Waste Detected."

4) Accuaracy: High detection accuracy, with a classification success rate of more than 95% in controlled environments.

5) System Performance: Fast response time from sensors to actuation (<1 second latency).

VIII. DISCUSSION

The findings confirm the efficacy of sensor-based waste segregation systems for small-scale operations. The integration of real-time sensing, precise classification, and automated bin sorting plays a key role in enhancing waste management efficiency. These aspects render the system appropriate for possible implementation in residential societies, schools, hospitals, and small-scale industries, facilitating source-level segregation and increasing recyclability.

IX. CONCLUSIONS

The Automatic Waste Segregation System presents an economical solution which is both scalable and environmentally friendly for addressing present-day waste management issues. The system uses Arduino control and servo-actuated technology with inductive sensors and infrared and moisture sensors to automate the identification and segregation of dry and wet and metallic waste types. The system provides high accuracy and responsiveness through its OLED screen feedback and sensor-actuator communication system which cuts down human involvement and recyclable contamination risks. The system's modular design using PVC pipes and wooden frames enables its deployment at homes and businesses and community waste collection sites. The system demonstrates an advanced intelligent waste management technology which shows promise for supporting sustainable waste management and source-level segregation.

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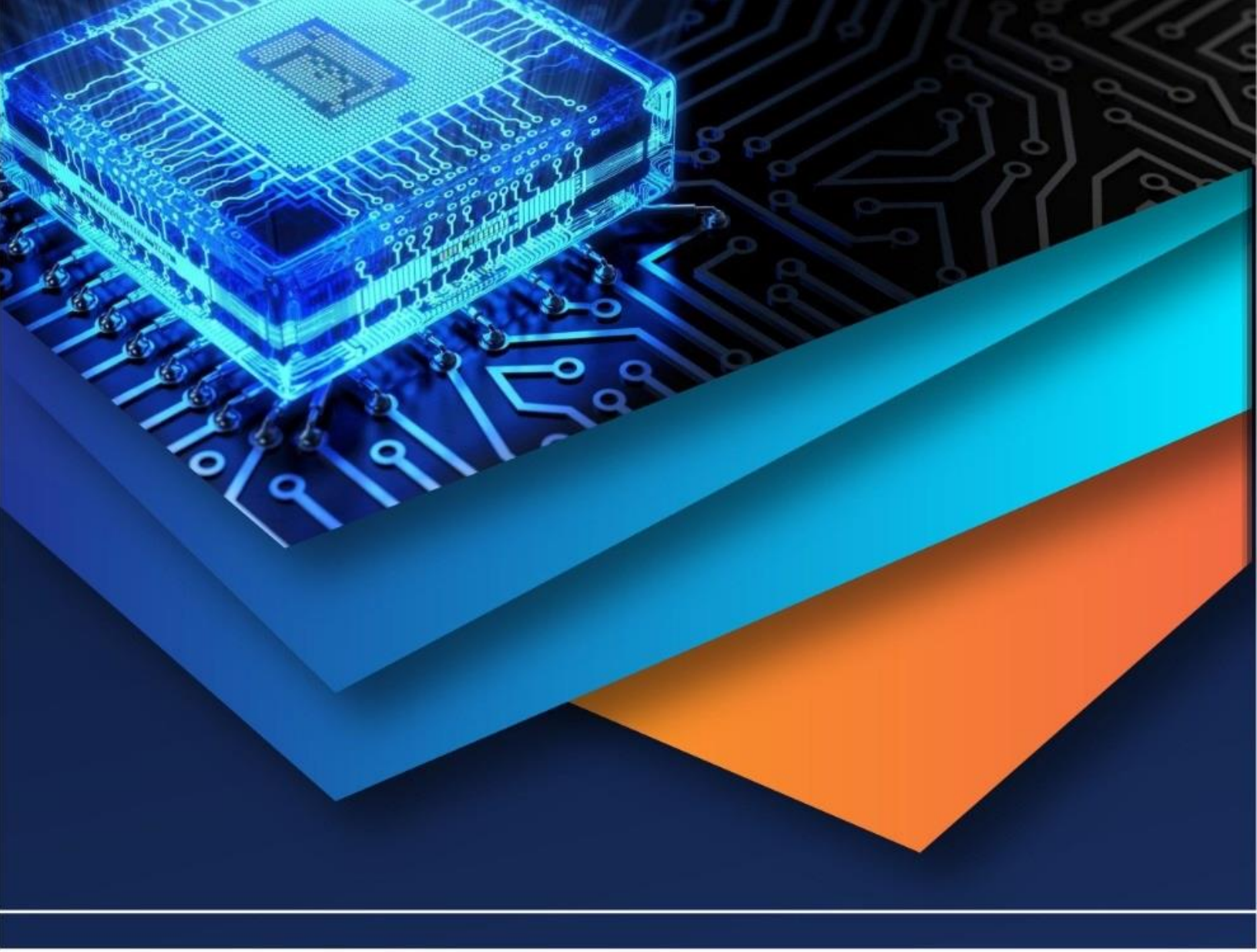
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