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Arduino Uno-based sound sensor system for waste sorting of metal and non-metal

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Abstract

This project's primary goal is to teach individuals about proper waste segregation. The incorrect sorting and disposal of garbage pose urgent problems, leading to contamination and inefficiencies in recycling operations. Innovative solutions supporting adequate waste segregation and disposal procedures are crucial to addressing these challenges. This study introduces an Arduino Uno-based sound sensor system to promote appropriate garbage disposal practices and enhance waste sorting efficiency. This method facilitates proper trash disposal by simplifying waste categorization into two types—metal and non-metal—and utilizing sound prompts. The study employed an applied experimental research design with four phases to develop and evaluate the product. Physical components, including cardboard, copper, and glue, were utilized alongside automation provided by an Arduino Uno R3, capacitive and inductive proximity sensors, a piezo buzzer, a servo motor, and wire. The researchers used essential software to configure the Arduino Uno to manage the system components. The evaluation included self-observation through trial and error and questionnaires from eight participants. Statistical analysis utilized the t-test for means and frequency distribution for descriptive analysis. Results indicate significant improvements in waste sorting convenience, particularly in public spaces, facilitated by the Arduino Uno-based sound sensor system. This study advances waste management technology by offering a practical approach to promoting appropriate trash disposal practices. The researchers' findings suggest designing trash bins to accommodate a large volume of garbage efficiently. Increasing the bin size provides adequate capacity for waste collection, reduces the frequency of emptying, and improves overall convenience.

Keywords: Arduino Uno R3, capacitive proximity sensors, inductive proximity sensors, waste segregation, trash bins

Arduino Uno-based sound sensor system for waste sorting of metal and non-metal

1. Introduction

The researchers' reason for creating this product came from the urgent need to address the problem of improper trash sorting management and to raise public awareness of appropriate waste segregation procedures. Considering the enormous difficulty of trash management, the researchers set out to lessen its adverse effects by implementing an Arduino Uno-based sound sensor system for waste sorting of metal and non-metal that can efficiently separate waste into its appropriate categories. The researchers decided to investigate the possibility of splitting metal and non-metal garbage together since they needed a complete system that could handle a variety of recyclable materials. The researchers hope to contribute to a more ecologically conscious and sustainable society by teaching people appropriate trash management techniques. In light of the research by Affandi et al. (2023), the material has been used and is no longer needed; it is a waste. Waste has to be disposed of and managed properly to lessen the issues in environmental contamination that can impact human health.

The rate of waste generation is increasing globally. According to World Bank Research (2022), the world produced 2.24 billion metric tons of solid waste in 2020, equivalent to 0.79 kg per person daily. The research predicts that annual garbage production will increase by 73% from 2020 to 3.88 billion metric tons in 2050 due to rapid urbanization and population growth. Unsustainable waste management has a more significant negative influence on citizens in developing countries—particularly the urban poor—than on those in wealthy ones. Over 90% of rubbish in low-income nations is frequently burned outdoors or dumped in uncontrolled landfills. These behaviors adversely affect the environment, public health, and safety. Poor waste disposal fosters the growth of disease-carrying insects, produces methane, fuels climate change, and may even incite urban conflict. Developing nations and cities often face difficulties effectively managing waste, a critical aspect of building sustainable and habitable communities. Studies by Flores & Tan (2019) indicate that the globe is facing widespread waste management issues that are worsening with increasing urbanization. Preserving the ecological environment necessitates proper waste management. The base-level sorting procedure at the dump sites depends heavily on proper garbage disposal. The conventional method of waste sorting requires more time and labor. Various techniques and formats exist for sorting garbage, with processing waste materials through image processing being particularly effective. Manila City, the capital of the Philippines, faces similar challenges, with 1.5 million citizens generating over 8,600 tons of waste daily.

As seen in the research study conducted by Chakraborty et al. (2020), the environment constantly has problems with cleanliness and hygiene due to the growing population. In most cities, overflowing trash cans create an unpleasant environment that encourages the development of various diseases. Unhygienic conditions lower our standard of living. The researchers must develop an intelligent garbage disposal system prototype to combat this situation. If the trash can is incomplete, it will automatically detect and open it. This system creates separate areas for biodegradable and non-biodegradable garbage. It helps create a waste management system that safeguards the environment from contamination caused by incorrect rubbish disposal, raising our living standards. Following the study by Amin & Faiz (2021), the amount of trash produced is rising. Waste management is a topic that has gotten much attention. This tactic is a means of achieving this noble goal. The smart trashcan is built on the Arduino Uno microcontroller platform and connected to a servo motor and an ultrasonic sensor. A top-mounted ultrasonic sensor measures the height of the trash bin with a specified threshold height. The Arduino activates the servo motor and opens the lid when a human approaches the trashcan, allowing the user to dispose of waste. Adopting these intelligent bins and replacing our existing standard bins could help control garbage more effectively, preventing excessive accumulation of trash by the roadside. These rotting wastes have gone untreated for a long time due to government neglect and public carelessness. The environment could suffer long-term consequences as a result of this. An automatic hand sanitizer dispenser and

garbage disposal with a sound sensor system are also incorporated.

This research aimed to produce an Arduino Uno-based sound sensor system for sorting metal and non-metal waste. It proposes employing Arduino Uno-based sensor devices to speed up garbage cleaning and sorting. The waste management procedure was improved by adding sound effects for the environment. This phase focuses on developing creative solutions to tackle waste management challenges, especially in sorting metal and non-metal waste. They also represent a comprehensive strategy for updating waste management procedures and improving waste disposal.

Statement of the Problem - This study aimed to produce an Arduino Uno-based sound sensor system for waste sorting of metal and non-metal that alerts individuals to put their trash in the correct category. Arduino Uno-based proper segregation with sound effects helped to create a cleaner environment by encouraging proper trash disposal procedures and lowering contamination. It aimed to address the following inquiries: (1) What is the level of effectiveness of an Arduino Uno-based sound sensor for waste sorting of metal and non-metal in terms of efficiency, convenience, and accuracy? (2) Does using sound effects improve the effectiveness of the Arduino Uno-based sensor system in sorting metal and non-metal waste? (3) Is there any significant difference between using the Arduino Uno-based sound sensor system for waste sorting metal and non-metal and a traditional trash bin?

Significance of the Study - Due to increased global concern regarding improper waste management, developers are creating new solutions to address the challenges of waste management systems. The invention of an Arduino Uno-based sound sensor system for waste metal and non-metal significantly contributes to preserving the environment. This study enhances the lives of numerous individuals. The study aimed to assist all individuals and corporate entities: For local governments, this study's effective garbage sorting will save them money in the long run by lowering the cost of processing and waste disposal. This study can reduce environmental damage by educating people and incorporating the community into waste sorting. For food corporations, this study could enhance the sustainability and efficiency of food firms' waste sorting operations. For companies, this study can minimize the manual labor of the workers because of automatic waste sorting. It leads to an increase in productivity and cost savings for companies that use our product. Companies can also benefit from this study due to its effect on their environmental sustainability, as this product will enhance it. This study can help communities by lessening health risks and improper waste segregation, which leads to water source pollution and disease transmission. This study can help improve school waste segregation and prevent trash from being left on school property. Since the study and product relate to their strand, incorporating it into the STEM curriculum can promote experiential learning in electronics and programming. This study can help households segregate the waste in their homes. Utilizing automatic garbage can decrease the manual labor required by households for garbage sorting, resulting in increased cost savings and productivity. This study can also teach the family in the household correct waste sorting management. This study can be helpful for future researchers as a guide for conducting research similar to that of investigators.

Scope and Delimitation of the Study - This research aimed to produce an Arduino Uno-based waste sorting system for metal and non-metal waste that could be implemented in homes and other environments where waste segregation has become an issue. This research distinguishes between standard waste products, including glass, metal, paper, plastic, and organic rubbish using sensor capabilities. Listening to the sound lets People determine whether the trash is correctly sorted. A sound indicates that the garbage is in the correct category, while no sound indicates it is in the wrong category. Furthermore, this study aids in cleaning up and rectifying incorrect waste segregation in homes, workplaces, communities, and other areas. Additionally, this study helped clean up and rectify incorrect waste segregation in homes, workplaces, communities, and other settings. The system could collect data on waste composition and provide valuable insights for waste management strategies. It could educate people about waste segregation and promote sustainable waste management practices. The study's limitations were that it limited the waste categories to those often used and included only the metal and non-metal categories. The system might have required a constant power source, limiting its usability in remote locations. It might not have

been able to handle hazardous waste or other specialist rubbish types. By defining the scope and delimitations in this way, the research is intended to significantly contribute to producing an Arduino-based waste sorting system under the exact parameters of the study's constraints. The researchers conducted this science investigatory project at the Divine Word College of San Jose, Occidental Mindoro. It started in August 2023 and is to be completed in April 2024.

2. Methodology

Research Design - The researchers employed an applied experimental approach to produce a sound sensor system for sorting waste metal and non-metal through an Arduino Uno. The focus was on elucidating its components' collaborative functionality to create an efficient sound sensor system tailored for waste sorting. It aimed to develop and apply practical solutions for correctly disposing of their waste items in the appropriate categories. Applied experimental research aims to tackle a particular issue or offer innovative solutions to problems impacting a person, a community, or society. Because it employed the actual application of scientific procedures to real-world issues, it was frequently referred to as a scientific method of inquiry or contractual research.

Data Gathering Procedure - The researchers chose to observe and conduct experiments to compare the effectiveness of the Arduino Uno-based sound sensor for sorting waste with the traditional method of using recyclable trash bins for sorting metal and non-metal. The researchers aimed to gather firsthand data to determine if their product significantly outperformed the traditional approach. By observing and analyzing these two methods, the researchers sought to evaluate the product's accuracy, efficiency, and overall effectiveness. This directed comparison provided valuable insights into whether the Arduino Uno-based sound sensor for metal and non-metal waste sorting offered superior performance in accurately sorting waste. The product development phase began on March 30, 2024, while the coding started on January 17, 2024, and was tested on April 3, 2024. The subsequent experimental phase, employing a trial-and-error methodology, occurred from March 22, 2024, to April 4, 2024. In addition, the evaluation checklist made by the researchers was validated by an expert to determine the effectiveness of this device. The eight researchers answered the survey. It took one day to answer the survey.

Research Process: Stage 1 Preparation and Gathering of Materials - The project emphasized advanced components that improved the Arduino Uno-based sound sensor system for metal and non-metal waste sorting. Every component required to build the device was purchased online, specifically from MarkerLab Electronics, and the total cost of these materials was PHP. 3,025. The following supplies, selected by the researchers from affordable products and reliable sources, are optional for the study.

For the electronic device:

- Arduino Uno R3 -12V Battery - Breadboard - Capacitive Proximity Sensor

- Inductive Proximity Sensor - Jumper Wires -Piezo Buzzer - Power Bank

- Servo Motor

B. For the device housing

- Cardboard - Copper Wire - Trash Bin

Stage 2: Building and Development of the Project - This product's construction and development phase involved assembling the trash bin's components. Next, the researchers created and programmed the code to integrate the piezo buzzer, servo motors, jumper wires, capacitive proximity sensor, inductive proximity sensors (metal sensors), and 9V batteries onto the breadboard for power supply. After inputting the functional codes, we

systematically arranged the components inside the trash bin and placed the cover on once all the components were set up. The final step involved observing and documenting the system's performance.

Figure 1. Actual Product of Arduino Uno-Based Sound Sensor System for Waste Sorting of Metal and Non-Metal

Stage 3: Experimental Stage, Observation and Data Recording - The researchers investigated whether the Arduino Uno-based sound sensor system for waste sorting of metal and non-metal was operational by assembling the product and utilizing an Arduino IDE application for product testing and coding. The researchers aimed to evaluate the precision and effectiveness of an Arduino Uno-based sound detection system incorporated into a waste sorting prototype. The project's main objective was to assess the system's accuracy and responsiveness in sound detection. By putting different kinds of trash close to the sound sensor and seeing how well the system detects and categorizes the waste based on the sound, the researchers intended to test the sound sensor's programming. This creative waste sorting method enhanced the effectiveness of recycling operations by automating the sorting based on a unique sound signature. Ultimately, this project may empower people by offering an automated and more efficient waste sorting system, promoting a more environmentally friendly and sustainable environment. The researchers methodically gathered data regarding the preparation and processing of the product during the different phases of its application. The researchers tested for almost two weeks using a trial-and-error methodology, meticulously recording subtitled variables about the product's precision, efficiency, and reliability. This approach aimed to help gain a thorough understanding of the product's functionality by allowing for an in-depth analysis of its performance in various situations. The researchers closely observed and documented all the essential data.

Statistical Treatment of the Data - The researchers used frequency distribution for descriptive analysis. The trial-and-error observation produced successful waste segregation with the sound sensor. An Arduino Uno-based sound sensor verified the correct sorting and disposal of waste. The researchers employed a statistical treatment, a T-Test: Paired for Two Samples for Means to quantify and compare the performance of these two waste sorting methods. This method is frequently applied in hypothesis testing to determine whether the means of two groups are significantly different or if a specific procedure or treatment genuinely impacts the population under investigation. In the context of this research, the T-test serves as a robust analytical approach to evaluate the efficacy of waste sorting between the manual trash bin and the Arduino Uno-based sound sensor system.

3. Results and Discussions

Table 1 shows the performance and user experience of an Arduino Uno-based sound sensor system designed for waste sorting for metal and non-metal. The greater the weighted mean score, the more positive the evaluation. The result shows that the system performs well in error frequency, scoring 3.88, indicating that errors occur infrequently during garbage sorting. The system is straightforward to engage with during waste disposal, as demonstrated by a score of 3.63. The system's ability to accurately sort things achieves a commendable 3.50 rating. With a weighted mean of 3.67, the system receives a high agreement grade, indicating that it performs

well across all evaluated variables, making it a dependable and user-friendly option for garbage sorting. The analysis conducted by Alvianingsih et al. (2022) shows that as Indonesia's population grows, the increasing amount of landfill garbage necessitates effective classification to maximize resource utilization, reduce disposal volume, improve living environments, and mitigate groundwater pollution. This research designs an automatic garbage classification system using Arduino Mega 2560 and a binary tree algorithm, incorporating ultrasonic sensors, servo motors, and proximity sensors. Performance tests show a 33.3% error rate for the ultrasonic sensor, 100% success for inductive proximity sensors in detecting metal, and 85.7% for capacitive proximity sensors in detecting organic waste, resulting in an overall system success rate of 86.6% across 30 experiments.

Table 1

Mean Level of Effectiveness of an Arduino Uno-based Sound Sensor for Waste Sorting of Metal and Non-Metal

Indicators	4 (SA)	3 (A)	2 (DA)	1 (SDA)	Weighted Mean	Descriptive Indicator
The Arduino Uno-based sound sensor system made errors in frequency during waste sorting of metal and non-metal.	7	1	0	0	3.88	Strongly Agree
Interacting with the Arduino Uno-based sound sensor system during waste disposal of metal and non-metal is convenient.	6	1	1	0	3.63	Strongly Agree
The Arduino Uno-based sound sensor system correctly sorts the items.	5	1	1	0	3.50	Strongly Agree
Overall Mean					3.67	Strongly Agree

Legend: 3.26 - 4.00 Strongly Agree, 2.51 - 3.25 Agree, 1.76 - 2.50 Disagree, 1.00 - 1.75 Strongly Disagree

Table 2

Mean Level of Effectiveness of Sound Effects for Waste Sorting of Metal and Non-Metal

Indicators	4 (SA)	3 (A)	2 (DA)	1 (SDA)	Weighted Mean	Descriptive Indicator
The Arduino Uno-based sound sensor system made errors in frequency during waste sorting of metal and non-metal.	8	0	0	0	4.00	Strongly Agree
The Arduino Uno-based sound sensor system correctly sorts the items.	4	1	3	0	3.13	Agree
Overall Mean					3.57	Strongly Agree

Legend: 3.26 - 4.00 Strongly Agree, 2.51 - 3.25 Agree, 1.76 - 2.50 Disagree, 1.00 - 1.75 Strongly Disagree

Table 2 shows the effectiveness of sound effects for metal and non-metal waste sorting. The weighted average of 3.57 indicated that opinions on the effectiveness of sound integration in the waste-sorting process were largely favorable. It implies that incorporating sound effects enhances the performance and user satisfaction of the waste-sorting system. It highlights the critical role of sound-based features in improving waste

management procedures' effectiveness and user experience, offering valuable insights for future efforts to refine and enhance them. As shown by the research by Ibrahim & Osten (2022), the design of the automatic garbage monitoring system utilizes a buzzer for message alert purposes to trigger it to surpass predefined threshold values for both weight and level metrics. This buzzer functions as a notification mechanism, effectively alerting individuals to refrain from adding further garbage to the system. Notably, the piezo buzzer, also called an Arduino Uno buzzer, plays a pivotal role in this setup. As confirmed by the study by Khan et al. (2021), it served as a compact speaker directly interfaced with the Arduino Uno platform, generating audible signals through the piezoelectric effect.

Table 3

t-Test Results in Distinguishing Between Arduino Uno-Based Sound Sensors and Traditional Trash Bin for Waste Sorting of Metal and Non-Metal

t-Test: Two-Sample Assuming Unequal Variances		
	Arduino Uno-Based Sound Sensor (Variable 1)	Traditional Trash Bin (Variable 2)
Mean	3.3671875	2.8671875
Variance	0.19468471	0.123256138
Observations	8	8
Hypothesized Mean Difference	-0.126534259	
Df	0	
t Stat	7	
P(T<=t) one-tail	2.366431913	
t Critical one-tail	0.024933615	
P(T<=t) two-tail	1.894578605	
t Critical two-tail	0.049867231	

Legend: *Highly Significant at p≤0.01, *Significant at p≤0.05

Table 3 shows the t-test results distinguishing between Arduino Uno-based sound sensors and traditional trash bins for metal and non-metal waste sorting. The result shows that the Arduino Uno-based system's mean sound sensor reading was 3.37, compared to 2.87 for the traditional trash can. A two-tailed test's critical value is 2.36, and the computed t-statistic of 2.37 is outside of it. It implies a significant difference in the sound sensor readings between the two systems. Therefore, the results suggest that, compared to a traditional trash bin, the Arduino Uno-based system typically records higher sound sensor values. As a result, the researchers reject the null hypothesis, showing that the two systems' products differ significantly. Thus, there is no significant difference between an Arduino Uno-based sound sensor system for sorting metal and non-metal and a traditional trash bin. As documented by Anwar & Aeie (2018), managing solid waste is a big concern because it affects our health and the environment. One of the biggest challenges today is finding, tracking, and dealing with all the waste we produce. With new technology, it can circumvent the sluggish handling of traditional trash bins. The traditional trash bin takes a lot of people's time, unlike the device developed by the researchers.

4. Conclusions

The Arduino Uno-based sound sensor device revolutionizes trash management with its remarkable efficiency, accuracy, and convenience. Low error rates, high user satisfaction, and precise sorting capabilities make it ideal for waste management. This system enhances user interaction and boosts engagement and sorting accuracy by utilizing carefully chosen sound effects. Compared to conventional garbage bins, the Arduino Uno-based offers superior effectiveness, promising a future of more efficient waste management and resource recovery. This sustainable approach promotes recycling, fosters a cleaner environment, and transforms sorting into an enjoyable process. Ultimately, the Arduino Uno-based sound sensor system represents a significant

technological advancement with the potential to shape a more sustainable and environmentally friendly future.

4.1 Recommendation

In line with the inspection by the researchers and the results of the experiments, various trash bins customized to different types of waste are recommended for an optimal waste management setup, allowing for effective sorting and disposal operations. Consider placing an alcohol dispenser near the bins to encourage users to practice good hygiene and cleanliness. To improve system reliability, include a piezo buzzer that makes a distinct sound when the sensor incorrectly detects trash, ensuring exact functionality. Because battery draining is a concern, investigating alternate power sources or integrating energy-efficient components may extend battery life, reduce maintenance requirements, and increase sustainability. The researchers' findings suggest designing trash bins to accommodate a large volume of garbage efficiently. Increasing the bin size provides adequate capacity for waste collection, reduces the frequency of emptying, and improves overall convenience. Furthermore, reinforcing the lid mechanism may be considered to ensure the bin's durability and functionality. Strengthening the lid will allow it to withstand the pressure the servo applies, ensuring a tight closure even when the bin is nearly complete. The researchers suggested using an innovative garbage monitoring system called the Internet of Things (IoT); it is a new way to manage intelligent and efficient waste; with this system, waste management is more accessible, cleaner, and better for everyone's health.

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