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Automated waste segregation system using Arduino Uno R3

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Abstract

This study presents the development and implementation of an Automated Waste Segregation System using Arduino Uno R3, aimed at enhancing waste management efficiency by segregating dry and wet waste materials. The system was developed and tested using moisture sensors, infrared obstacle avoidance photoelectric sensors, jumper wires, servo motors, cardboard, storage boxes, and breadboards through an applied research design. A total of 20 participants participated in the survey to evaluate the system's effectiveness and usability, providing valuable feedback for refinement. Results indicate that the system effectively segregates waste materials, demonstrating its potential for promoting sustainability in waste management practices. The Infrared Obstacle Avoidance Photoelectric Sensor and the Moisture Sensor can efficiently identify and segregate waste. Through experimentation, it was observed that the automated system effectively segregated dry and wet waste with higher accuracy and efficiency than manual segregation methods. The findings indicate that the automated system consistently sorted waste into appropriate categories, minimizing human error and ensuring proper waste management. This suggests that using Arduino Uno R3 for waste segregation can improve waste sorting processes, contributing to more sustainable and environmentally friendly practices in waste management systems. Future researchers are recommended to include further refinement of the system's features and scalability and explore additional functionalities to optimize waste segregation processes. This study contributes to advancing sustainable waste management practices through innovative technological solutions.

Keywords: waste management, Arduino-Uno R3, infrared obstacle avoidance photoelectric sensor, segregation, dry and wet waste

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1. Introduction

Waste management has become a major concern for society's health and well-being. The waste is manually separated into different categories by installing various bins to collect various types of waste, including wet and dry. However, this approach could improve many things, including how little attention most people pay to waste management. Due to improper segregation methods, large amounts of untreated waste are dumped in landfills. The plan is to create a garbage separator that can distinguish between different types of waste and automatically sort them into the appropriate bins. Implementing this type of project at the household level will lower the cost of waste disposal, the amount of manual labor needed for waste segregation, and the amount of waste that cannot be recycled or reused (Madankar et al., 2015).

Waste production has risen sharply in tandem with the growth of the global population. According to a recent World Bank report, cities are centers of garbage production, and the amount of garbage they produce is growing faster than their populations. This quickly becomes an environmental and economic catastrophe for cities in many developing countries. Globally, this poses serious problems for people's health. Proper waste management in urban and rural areas is crucial to maintaining a clean and healthy living environment. In an unclean and polluted environment, bacteria and viruses are primarily responsible for the spread of infections (Loaiza-Ceballos., 2022).

Despite having a strong environmental movement, the Philippines still has a trash issue. Out of the 178 LGUs in the Manila area, there are still 39.89% that do not adhere to the 10-year solid waste management plan, 27.53% that do not adhere to the regulations for source segregation, 23.03% that do not adhere to the regulations for segregated collection, 44.38% that do not adhere to the regulations for functional materials recovery facilities, and 10.11% that do not adhere to the regulations for approved disposal facilities (Flores & Tan, 2019). Due to the damage garbage poses to the environment, the dynamic rise in garbage production and the disgusting dumping of rubbish are becoming matters of concern. An automated trash segregator prevents this situation and makes recycling easier. Only after segregation do the importance and economic worth of garbage become apparent. Such a mechanism for separating dry and wet wastes has yet to be created. The idea suggests a spot automatic waste segregation device to solve this issue. A parallel resonance impedance system separates the trash, and capacitive sensors separate the wet and dry waste. The waste is more likely to be recovered due to this activity, as well as the occupational.

Thus, the researchers of this study aim to produce automatic waste segregation that uses an Arduino Uno R3 to separate waste into the appropriate bins, which will significantly aid in preventing environmental damage. With the help of this product, people will gain additional knowledge in sorting whether the trash is dry or wet. Additionally, sorting makes it easier for the local authorities to manage the waste. This lowers the risk of occupational injury for ragpickers while also speeding up the process of sorting the waste once it has been collected (Gangwani et al., 2019). This project aims to create a logical segregation system that benefits the environment. A central hub called the Arduino Uno controls all the sensors in this setup. The trash can keep track of the amount of waste it contains and opens or closes depending on how close or distant the user is. The sensors will be interfaced with a transporter (conveyor belt) camera to determine the sort of garbage. The garbage then moves and is placed in the appropriate bin, facilitating segregation (Kavithamani et al., 2023).

Statement of the Problem - This study aimed to develop an Automated Waste Segregation System using Arduino Uno R3. It seeks to answer the following questions: (1) What is the level of effectiveness of an automated waste segregation system using Arduino Uno R3 in terms of accurate detection and duration of detection? (2) What is the performance level of the Automated Waste Segregation System Using Arduino Uno R3 in terms of using

infrared obstacle avoidance photoelectric sensor and moisture sensor and choosing the appropriate waste and disposal location? (3) Is it effective to use a Moisture Sensor with a light indicator in an Automated Waste Segregation System Using Arduino Uno R3 for identifying and sorting wet waste? 4) Is there a significant difference between using an ultrasonic sensor and an infrared obstacle avoidance photoelectric sensor in terms of the effectiveness of proper segregation? (5) Is there a significant difference between using the automated waste segregation system using Arduino Uno R3 and manual waste segregation in terms of proper segregation?

Significance of the Study - The segregating machine efficiently sorts waste into categories, promoting recycling and minimizing landfill waste. Its advanced technology ensures accurate separation, making it a crucial tool for a sustainable and eco-friendly future, promoting recycling and reducing landfill waste. The results and findings of this study will be beneficial to the following: For the students of DWCSJ, the machine might provide young students with more information to study and grasp the significance of trash segregation, and they can go deeper into this topic to fully realize various types of segregation methods. For the employees of DWCSJ, this invention can result in direct cost savings by reducing labor and sorting time. It can relieve human laborers of a portion of their workload. This enhances the effectiveness and precision of recycling operations and reduces the labor shortage in this industry. This segregating machine will help the community segregate its waste and introduce new strategies to make the place a low-waste community. The segregating machine can contribute to reducing landfills. To hospitals, the device can be beneficial in handling and disposing of medical waste more efficiently and safely. This can contribute to managing toxic medical wastes effectively, such as corrosive chemicals. To the companies, this invention will gain companies as their trash will be appropriately sorted into several categories. It can aid in reducing the work-related stress of employees who manually sort waste. It also has a significant impact on lowering environmental pollution. To business enterprises, this segregating machine might refrain from improperly disposing of all garbage since doing so exposes them to legal action from authorities if any damages occur. It can reduce operational costs, decrease potential fines and penalties, boost staff morale, lean performance, and high production rates. This could also lead to improved adherence to environmental laws, such as sustainability goals or green building certifications. For the individuals, we will be more knowledgeable about appropriate segregation practices. People won't have to worry or trouble about their waste with this device. They can quickly sort their waste into many categories according to the machine's effective segregation and directions. Additionally, this technology will support recycling efforts and prevent contamination, creating a cleaner and more environmentally friendly environment for people. Lastly, for future researchers, the invention can be beneficial in enhancing the codes and materials necessary for their study to appropriately segregate things like plastics and papers further to increase the capabilities of this autonomous trash segregation system. Using the study's findings, researchers can find a more straightforward examination of the effects of improper waste and pollution disposal on the ecosystem and any possible health issues.

Scope and Delimitation of the Study - The general intent of the study is to produce an automatic waste segregation system using Arduino Uno R3. Because people frequently improperly dispose of their trash, it results in dry and wet waste getting mixed up. The scope of this study focused only on segregation issues and lightening the workload of those responsible for segregating waste one piece at a time. This study consumed a week and a half of preparation on our part. However, this machine requires the correct code for this Arduino to function. There are a few specific delimitations within the proposed project. It is important to note that waste should be disposed of one item at a time to ensure the system's proper functioning and maintain the integrity of waste separation. Nothing must obstruct the infrared obstacle avoidance photoelectric sensor within its reach regarding wet and pressure waste applied to the sensor. This study is limited to school premises, but after it is tested, it may be possible to use it with a larger population. It is only intended to separate dry and wet materials. Wet metals are programmed to be placed in a particular bin.

2. Methodology

Research Design - This study aimed to develop an automated waste segregation system using Arduino Uno R3 using a developmental evaluative experimental research design. The researchers aimed to evaluate the

usefulness of their experimental product. The device's effectiveness in employing an Arduino was the basis for researching and investigating relevant literature and studies. Using this design, the researchers could weigh the advantages and disadvantages of the Arduino-powered automatic waste segregation machine. As the study's primary source, the researchers conducted experiments and tests to compare the Arduino's performance and effectiveness as an additive to the typical components of a waste segregation machine. This allows the researchers to define and contrast the outcomes to ascertain whether employing an Arduino instead of a waste segregation machine is more reliable.

Data Gathering Procedure - With the help of a randomly chosen group of people to test the device, the researchers collected the information required to assess the accuracy of the device. This research experiment involved 20 individuals (employees and students) around the campus carrying wet and dry waste and an automated waste segregation system using Arduino Uno R3. Before starting the experiment, the researchers must ensure they agree with the participants. The individuals placed their waste inside the gadget and observed the detection process. Afterward, the individuals answered the questionnaire given. The researchers then gathered the individuals' responses within 2-3 days, calculated them, and consolidated the information.

Research Process: Stage 1 Preparation and Gathering of Materials - The production of the Automatic Flood Water Level Sensor uses the following materials to work correctly:

- For Experiment: Arduino Uno R3, Servo Motor, Infrared Obstacle Avoidance Photoelectric Sensor, Moisture Sensor and Jumper wire.
- For Casing and Accessories: Storage box, Breadboard and Cardboard.

The researchers used the Arduino, the familiar controller kit in Divine Word College of San Jose. Primary materials, such as the Arduino Uno r3, Infrared Obstacle Avoidance Photoelectric Sensor, Moisture Sensor, and Servo Motor, were bought online. The researchers looked for low-cost materials that students could afford. The estimated cost for the materials alone is PhP 1,500, and the total cost of the product's shipping is 150.

Stage 2: Building and Development of the Project - Using an Arduino Uno R3 to create an automated waste segregation system offers an affordable way to quickly and accurately identify dry and wet waste. The Arduino Uno R3 functions as the brain of the device, receiving and transmitting code to the different parts of the apparatus. The waste that requires identification will be placed into the lid, which is also attached to the servo motor. As seen from the design, the machine is composed of different parts that work together to carry out the intended mechanism of the product. The researchers created the device and its intended output for the experiment by building a waste segregation machine with an Arduino UNO R3. It can determine whether the waste is wet or dry by using an infrared obstacle avoidance photoelectric sensor to detect its presence in the moisture sensor. Once the moisture sensor indicates the waste is dry, the lid is twisted to the right using a servo motor. When the waste is wet, the lid is twisted to the left. Developing and coding to run the waste segregation system using an Arduino Uno R3 consumed approximately two weeks of programming and testing for 1-2 weeks.

Stage 3: Experimental Stage, Observation and Data Recording - The researcher experimented with the accuracy and effectiveness of the automated waste segregation system using Arduino Uno R3 to detect motion, accurate segregation, and detection length. To begin with, the researchers developed and encoded the system program using the Arduino IDE application for two weeks. They used a “trial and error” method to determine the accurate timing of the sensors’ detection and movement. Next, the infrared obstacle avoidance photoelectric sensor, IR sensor, servo motor, and moisture sensor are attached to the Arduino Uno R3. The encoded and programmed data is applied to the Arduino Uno R3 to execute and evaluate the system. Finally, the sensors and wires were all attached to the bins. The researchers then conducted a test to measure the machine's accuracy in categorizing the waste. Lastly, the researchers observed its efficacy and accuracy in detecting motion, accurate segregation, and length of detection for two weeks. Furthermore, the researchers collected the test objectives to be conducted on the end product of the outcome. The researchers documented every stage of the machine's construction, including the

preparation of necessary materials and checks to ensure the sensors were operating as intended. All of the images and videos taken during the machine's construction were done to demonstrate that the researchers were the ones who created it. Following the machine's completion, the researchers assessed the machine's dependability and functionality. They also take note of and monitor the machine's operating lifespan. Moreover, this study utilized a researcher-made evaluation checklist and was validated by an expert in science and technology at Divine Word College of San Jose.

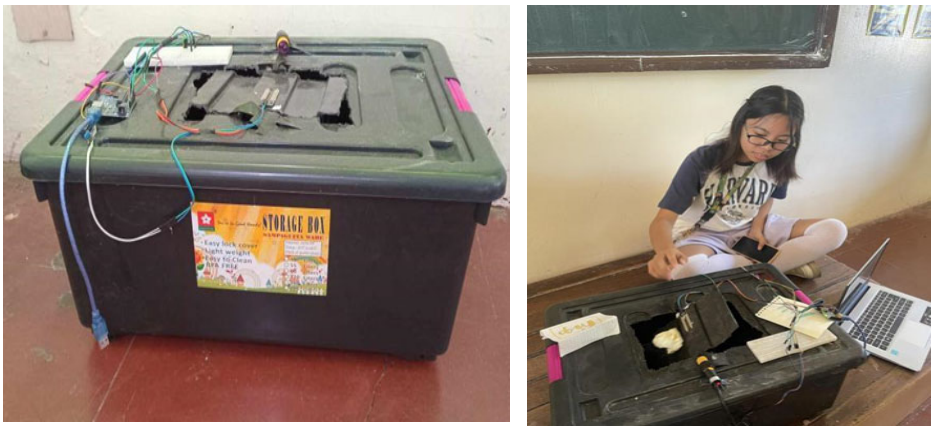

Figure 1. Actual Product of Automated waste segregation system using Arduino Uno R3

Statistical Treatment of the Data - The researchers employed descriptive statistical treatment using a weighted mean to determine the level of effectiveness of the device. The researchers can calculate the device's accuracy and efficacy in classifying wastes. To determine the significant difference between the automated waste segregation system using an Arduino Uno R3 and manual trash segregation, the researchers conducted a t-test to compare the two groups' means. It is frequently employed in hypothesis testing to ascertain whether two groups are distinct or whether a procedure or treatment genuinely affects the population of interest.

3. Results and Discussions

Table 1

Mean Level of Effectiveness of an Automated Waste Segregation System using Arduino Uno R3 in terms of Accurate Detection and Duration of Detection

Indicators	Weighted Mean	Descriptive Indicator
1. The automated waste segregation system can detect the waste accurately.	3.47	Strongly Agree
2. The system was able to detect the waste in a duration of time	3.26	Strongly Agree
Overall Mean	3.37	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

The accuracy of the Automated Waste Segregation Machine is displayed in Table 1, along with its task-functioning capabilities and waste category detection accuracy. The participants strongly agreed that the automated waste segregation system could accurately identify and distinguish between dry and moist trash, as indicated by the overall weighted mean of 3.37. Additionally, they firmly agreed that the machine could identify waste within the allotted time. These findings aligned with the research conducted by Tan et al. (2020), which found that waste classification is not a variable when considering the time required for the system to segregate waste and that the system could obtain precise data with an accuracy of 83.54% in their experiments.

Table 2

Performance level of the Automated Waste Segregation System Using Arduino Uno R3 using an Infrared Obstacle Avoidance Photoelectric Sensor and Moisture Sensor

Indicators	Weighted Mean	Descriptive Indicator
1. The Infrared Obstacle Avoidance Photoelectric Sensor, Moisture Sensor, and Arduino Uno are effective in the segregation system of disposing of waste.	3.50	Strongly Agree
2. The Automated Waste Segregation System is effective in choosing the appropriate waste and disposal location	3.35	Strongly Agree
Overall Mean	3.43	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

The information in the table above demonstrates the performance level of the automated waste segregation system using an Arduino Uno R3 and an ultrasonic and moisture sensor. The infrared obstacle avoidance photoelectric sensor can detect material waste on top of the trapdoor, while the moisture sensor can recognize if the material is wet. The participants strongly agreed with the effectiveness of both sensors. The findings proved that the infrared obstacle avoidance sensor, moisture sensor, and Arduino Uno R3 effectively developed the device. This result is supported by Xiaohua et al. (2020), who stated that the photoelectric sensor asserts effective signals in detection platforms in their Automobile Electronic Detection. Moreover, they also discussed that the photoelectric sensor was their core architecture in building their machine.

Table 3

Correlation Analysis on the Effectiveness of using a Moisture Sensor for identifying and sorting Wet Waste and p-value for H01

Independent Variable	Dependent Variable	R-value	R^2(Effect Size)	t-value	P value	Interpretation
Moisture Sensor	Identifying and Sorting Waste	0.246	0.61	10.0001 35	0.000	Highly Significant

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

Table 2 shows the correlation analysis between the effectiveness of using a moisture sensor for identifying and sorting wet waste and the p-value for H01. A test was conducted using seven trials to determine the use of a moisture sensor with a light indicator in an automated waste segregation system using Arduino Uno R3. Trials are observed using a wet plushie toy to see if the light indicator from the moisture sensor will be able to detect the waste. Five trials were conducted using a moist plush toy, in which the light indicator worked while properly segregated. On the other hand, two trials in which the light indicator did not work were not properly segregated. Overall, it shows that it is effective to use a moisture sensor with a light indicator in an automated waste segregation system using Arduino Uno R3 to identify and sort wet waste. This result is supported by Limin et al. (2021), who affirmed that moisture sensors are functional in detecting damp objects, specifically wet soil. Moreover, the findings reveal a p-value of 0.000, less than 0.05 alpha level, which means it is highly significant. This signifies that the null hypothesis is rejected, indicating a significant relationship between the independent and dependent variables. The given results correlate with the study of Salleh et al. (2024), which emphasizes that the moisture sensor signals a high when it finds moisture level; the garbage is classified as "wet waste" by the system, which then drives the servo motor to place the wet trash can in front of the individual. Thus, they also proved the moisture sensor's accuracy and credibility in waste detection by separating municipal solid wastes.

Table 4

Difference Between Using an Ultrasonic Sensor and an Infrared Obstacle Avoidance Photoelectric Sensor in the Effectiveness of Proper Segregation

SUMMARY (Anova: Single Factor for Hypothesis (2)						
Groups	Count	Sum	Average	Variance		
Column 1	5	3	0.6	0.3		
Column 2	5	3	0.6	0.3		
Column 3	5	5	1	0		
Column 4	5	2	0.4	0.3		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F critical
Between Groups	0.95	3	0.316667	1.407407	0.277103	3.238872
Within Groups	3.6	16	0.225			
Total	4.55	19				

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

Table 4 shows an Anova: Single Factor for Hypothesis (2) to show the difference between using an ultrasonic sensor and an infrared obstacle avoidance Sensor in the Effectiveness of Proper Segregation. An ultrasonic sensor and an infrared obstacle avoidance photoelectric sensor for segregating objects under dry and wet conditions were experimented with across five trials. The Infrared Obstacle Avoidance Photoelectric Sensor generally performed more consistently, segregating objects properly in most trials regardless of the dry or wet condition. This finding contradicts the study by Burke (2023), in which the infrared obstacle avoidance photoelectric sensor couldn't detect dry waste. In contrast, the ultrasonic sensor's performance was more variable; sometimes, it performed well, while others did not in the same conditions. While both sensors had some trials where they did not segregate properly, the Infrared Obstacle Avoidance Photoelectric Sensor appeared to be the more reliable overall. Moreover, it clearly stated that the F-value is 1.40 while the computed F-critical value is 3.24, meaning it is less than the F-critical value. On the other hand, the computed P-value is 0.277, which is greater than the 0.05 alpha level. Thus, this indicates that the null hypothesis is accepted, and there is no significant difference between using an ultrasonic sensor and an infrared obstacle avoidance photoelectric sensor in terms of proper waste segregation. This finding aligns with the study by Kumar and Dhadge (2018), which details the highly successful use of IR sensors to detect object motion compared to standard inductive sensors. This indicates that the null hypothesis is accepted, and there is no significant difference between using an ultrasonic sensor and an infrared obstacle avoidance photoelectric sensor regarding the effectiveness of proper segregation.

Table 5

T-Test Results in the Effectiveness of Using the Automated Waste Segregation System Using Arduino Uno R3 and Manual Waste Segregation

t-Test: Two Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	0.727272727	0.363636364
Variance	0.218181818	0.254545455
Observations	11	11
Hypothesized Mean Difference	0	
df	20	
t Stat	1.754116039	

P(T<=t) one-tail	0.047361041
t Critical one-tail	1.724718243
P(T<=t) two-tail	0.094722081
t Critical two-tail	2.085963447

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

The effectiveness of appropriate segregation using an automated waste segregation system using an Arduino Uno R3 and manual waste segregation were compared in a test. For an hour, both segregation processes were observed. Regarding manual waste segregation, the researchers found that some individuals tend to dispose of their waste carelessly, resulting in inaccurately separated waste in both wet and dry garbage bags. According to Manegdeg et al. (2021), using manual labor to segregate waste properly can cause illness. Based on the data and findings, the Automated Waste Segregation System with Arduino is more efficient at precisely separating waste and avoiding the release of hazardous chemicals into the ground waste system, which can result in pollution, illnesses, and diseases.

Table 5 presents the results of a t-test to analyze the effectiveness of using the automated waste segregation system using Arduino Uno R3 and manual waste segregation. The p-value being greater than 0.05 proves that the null hypothesis that says there is no significant difference between using the Automated Waste Segregation System using Arduino Uno R3 and other waste segregation is accepted. Assuming unequal variances between the two methods, the t-test was performed. The null hypothesis is accepted because the t-statistic value of 1.75 is significantly less than the critical value of 2.09. This indicates that there is no significant difference between the automated waste segregation system using Arduino Uno R3 and other waste segregation systems. This result lines up with a study by Wang (2024), which highlights the high error and environmental risk associated with the classification of garbage types carried out under human supervision and the suggested approach of using an automated way to accurately identify waste types with 98.81% and 99.01 percentiles. Additionally, the high processing speed of an automated waste segregator makes it appropriate for real-time scenarios. This proves that the machine increases the efficiency, accuracy, and speed of classifying wastes compared to the manual segregation process.

4. Conclusions

Based on the gathered data, the researchers came to the following conclusions: the automated waste segregation system using an Arduino Uno R3 equipped with an infrared obstacle avoidance photoelectric sensor and moisture sensor demonstrated strong performance. Both the Infrared Obstacle Avoidance Photoelectric Sensor and the Moisture Sensor can efficiently identify and segregate waste. The system can accurately guide waste to the correct disposal locations with its sensors. The Automated Waste Segregation System is a reliable solution for waste management. It can help reduce the volume of waste being sent to landfills while also reducing waste processing costs. The automated waste segregation system requires minimal human intervention. Thus, this makes it a cost-effective and efficient solution for organizations that need to manage large volumes of waste.

Recommendation - Based on the conclusions drawn from the findings, the researchers recommend the following: The researchers discovered that programming is a crucial factor in determining the machine's performance. Users may use simpler code with advanced commands, the machine's capabilities can be improved, and errors can be reduced. This product could see enhancements with the availability of more efficient materials like sensors and servo motors. This could encourage users to adopt automatic waste segregation systems over manual ones. The researchers found that certain materials are more effective for waste segregation than those commonly used. The machine can currently detect and select the correct waste and disposal location. It could be enhanced by adding features to detect when the bin is full and to display the type of waste that needs to be detected on an LCD screen. The machine can detect wet waste when pressure is inserted in the two probes of the moisture sensor. It can be further improved by adding a conveyor belt and a robot hand pressure that will help to

position wet waste in the moisture sensor precisely. This machine can segregate dry and wet wastes. Future researchers should add other waste types that can be segregated, such as metal, biodegradable, and non-biodegradable.

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