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Paper and Plastic Waste Segregator Using LJC18A3-H-Z/BY Capacitive Proximity Sensor and Ultrasonic Ranging Module HC - SR04

Rose Anne L. Reaño[a], Acer Jay Castillo[b], Feliciano Angelo C. Diaz[c], Maria Michaella Loren M. Garcia[d], Mark Lesther L. Lanto[e], Majella Reyes[f], Angelina L. Villagen[g], Alessandro R. Vispo[h]
[a-h]Electronics Engineering Program, Polytechnic University of the Philippines, Sto. Tomas, 4234, Batangas, Philippines

Abstract

A garbage bin that would detect and segregate the collected waste if it is a paper or a plastic using capacitive proximity sensor LJC18A3-H-Z/BY and ultrasonic ranging module HC-SR04 was created. It would provide a notification if the bin were full of garbage and segregated waste must be collected. It was tested by its accuracy in identifying the waste and the bin's fullness. Also, a repeatability and reproducibility test were performed to check the ability of the bin to separate paper from plastic waste. It could identify paper waste by 94.48% accurately, while plastic waste by 82.49%. The paper and plastic bin's fullness could also be identified accurately by 87.4% and 88.8% respectively. Over-all result of the repeatability and reproducibility tests were 85.6% and 67.8% for the paper and plastic waste segregation, respectively. The result of the experimentation showed that the detection of the waste was affected by the placement of the garbage in the bin. It was recommended to conduct additional calibration on the capacitive sensor to increase the accuracy in detecting plastic waste and to alter the bin's design to add more mechanical control in garbage placement inside the bin.

Keywords: paper waste, plastic waste, segregator, capacitive sensor, ultrasonic

1. Introduction

The World Bank estimates that the world's waste generation will increase from 2.01 billion tons in 2016 to 3.4 billion tons in 2050. The increase of waste generation may lead to multiple social or environmental problems if waste are disposed improperly. The implementation of reduce, reuse, and recycle project helps in managing wastes in the community. However, before recycling could occur, proper segregation of waste should be implemented. The garbage bin created in this paper would automatically identify if the thrown waste inside it wasa paper or a plastic using a capacitive proximity sensor. It would automatically place the identified waste to its corresponding bin. Lastly, it would identify if its bin were full by an ultrasonic ranging module and would notify the user through short messaging system (SMS). The segregation is limited only to the collected dry paper and plastic wastes. Identifying other wastes such as metals and biodegradable wastes is not within the capability of the created garbage bin. Also, placement of the garbage to the bin must be one at a time, and not both plastic and paper waste at the same time. The garbage bin created would help facilitate the separation of collected wastes but the authority still plays an important role in managing the sacked segregated waste. The accuracy of the identification of waste, and repeatability and reproducibility of the separation of the thrown waste between paper and plastic would be measured in this study.

2.Significance of the Study

The study would like to contribute in achieving a cleaner environment by avoiding conflicts like pollutants on the ground due to improper waste management. Proper separation of waste increases recycling rate so as to decrease the use of natural resources and increase environmental sustainability. The study will bring significant innovation on the method of waste management and will help develop a way of on-site segregation to reduce the overall cost of waste management and the time needed to properly dispose waste.

3. Review of Related Studies

For more than 50 years, global production and consumption of plastics have continued to rise. An estimated 299 million tons of plastics were produced in 2013, representing a 4% increase over 2012, and confirming an upward trend over the past years **(Le Guern, 2017).** Plastics are classified as Polyethylene Terephthalate Plastics, High-Density Polyethylene Plastics, Polyvinyl Chloride Plastics, Low-Density Polyethylene Plastics, Polypropylene Plastics, Polystyrene or Styrofoam Plastics, and Miscellaneous/ Unallocated Plastics **(Mertes, 2016).**

Bagdan, et. al. (2016) classified waste into solid waste and liquid waste. Solid waste is any garbage, refuse or rubbish that we make in our homes and other places. On the other hand, liquid waste is the waste generated in the kitchen, bathroom and laundry. **Hoornweg and Bhada-Tada** classified waste into six categories that can be used for general purpose of solid waste management planning. These categories of wastes are organic, paper, plastic, glass, metal and other type of waste. **Rogoff and Screve (2011)** found that paper accounts for 25% of landfill waste and about 30% to 40% by weight of the municipal solid waste stream, was typically represented by waste paper products, such as newsprint, corrugated paper (cardboard), and high-grade office paper (computer printout paper, tab cards, and ledger paper).

In their research entitled "Design on PLC based Automatic Waste Segregator", **Deepak et.al (2017)** stated that their system can segregate only one type of waste at a time as the solid waste material object moves on a conveyor belt one at a time behind each other. Moreover, they stated that automated waste segregation can be largely implemented in various municipal corporations, taking into consideration various factors such as reduction in manpower, avoid risk at hazardous places, improve accuracy, increase speed of waste management etc. In his research entitled "The Design and Implementation of Smart Trash Bin", **Samann (2017)** used Arduino Nano Board to operate and control his Smart Trash Bin. The size, weight, functionality and programming flexibility were his basis for choosing this microcontroller breadboard in implementing the Smart Trash Bin. **Ahmad, Mukhlisin and Basri (2016)** concluded that the capacitive proximity sensor is able to identify paper and plastic automatically without involving manual separation and is really suitable for sorting solid waste system because it can detect plastic due to its low permittivity value. Also, paper with the combination of paper and plastic with at least 10% of paper included.

4. Objectives of the Study

- To measure the accuracy in classifying the collected dry waste whether it is a paper or a plastic.
- To identify the collected waste bin's fullness.
- To conduct a plastic and paper segregation repeatability and reproducibility test.

5. Hypotheses of the Study

- The accuracy of identifying if the collected dry waste is a paper or a plastic is greater than 80%.
- The fullness of the collected waste bin could be identified.
- The result of the repeatability and reproducibility test in identifying the collected dry waste whether it is a paper or a plastic is acceptable.

6. Population and Sample

Three experiments were performed for this research. First, an experiment to check the accuracy of the bin in identifying the waste if it is a paper waste or a plastic waste. Then, the second experiment was for the accuracy of the bin in identifying if its waste container was full or has reached its limit in accepting paper or plastic waste. The third and final experiment was done to calculate the repeatability and reproducibility of the bin in segregating paper and plastic wastes.

Bin's waste identification accuracy was the ratio of the correctly classified collected waste (if either paper or plastic) with the total number of collected waste.

Percentage of Collected Paper Waste

$$= \frac{Number\ of\ Collected\ Dry\ Paper\ Waste}{Total\ Number\ of\ Collected\ Waste} \times 100\%$$

Percentage of Collected Plastic Waste

$$= \frac{Number\ of\ Collected\ Dry\ Plastic\ Waste}{Total\ Number\ of\ Collected\ Waste} \times 100\%$$

Moreover, the bin was full if the waste level reached 24 centimeters (cm) away from the sensor. Bin's fullness sensing accuracy was the ratio of the actual level of waste measured with the desired level of waste (24 cm).

Percentage of Identifying Bin's Fullness

$$= \frac{Actual\ level\ of\ waste\ measured\ (cm)}{Desired\ level\ of\ waste\ (24\ cm)} \times 100\%$$

It was set by the researchers that the percentage of the accuracy of identification of waste and bin's fullness must be both more than 80% for it to be acceptable. And repeatability and reproducibility of paper and plastic waste separation was measured through repeatedly placing paper or plastic wastes in the bin by three different people. 10 paper waste samples and 10 plastic waste samples were prepared. Each person will randomly place the samples in the bin with three trials. The Minitab 17 software will automatically generate the result of the test and decide if the value was acceptable or not.

6.1.Statistical Techniques Used in the Present Study

Graphical analysis was conducted by interval plots with two variables and 95% confidence interval (CI) to compare the accuracies of bin's identification of paper and plastic wastes and bin's fullness.

Measurement System Analysis (MSA) was conducted to evaluate the appraisal of the bin in separating paper and plastic wastes. The MSA measured the bin's repeatability and reproducibility by having tests per waste type with 10 samples, 3 trials, and 3 appraisers. Both the graphical analysis and MSA were generated using a software called Minitab 17.

6.2.Data Analysis and Interpretation

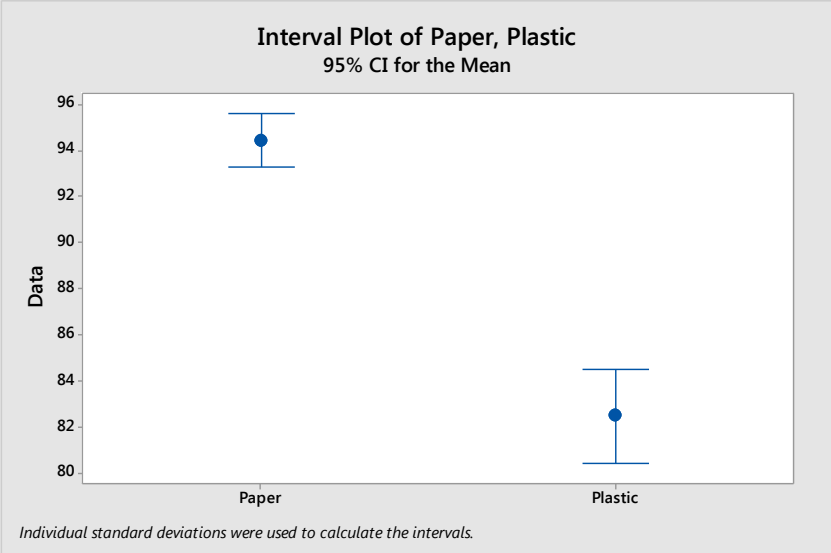
Waste Identification Accuracy

During experimentation, a total of 1,747 wastes at the designated paper bin were collected and 1,650 of those wastes or 94.48% were paper wastes. While 556 out of 674 or 82.49% of the total collected wastes at the designated plastic bin were plastic wastes. Both percentages were above 80%, however, the bin could detect paper waste more accurately than plastic waste.

Table 1. Percentage of Correct Collected Paper and Plastic Wastes

Test No.	Percentage of Correct Paper Waste Collected (%)	Percentage of Correct Plastic Waste Collected (%)
1	94.08	83.58
2	96.48	84.13
3	96.15	81.16
4	91.98	81.25
5	96.86	81.69
6	93.21	78.13
7	93.68	83.33
8	93.19	79.91
9	94.87	82.86
10	94.05	88.73
Mean	**94.48**	**82.49**

Figure 1. Interval Plot of the Percentage of the Correct Collected Paper and Plastic Waste



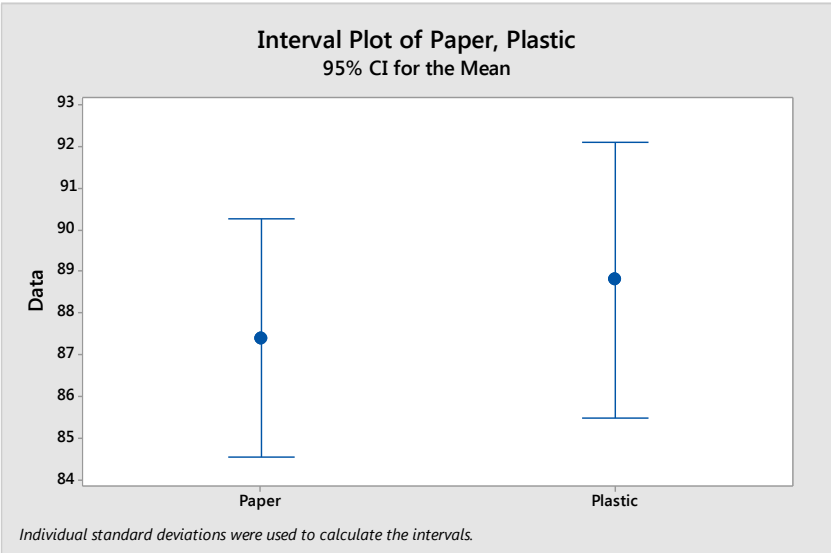
Bin's Fullness Sensing Accuracy

The bin had detected that the paper waste bin was full by 87.4% correctly. And it had detected that the plastic waste bin was full by 88.8% correctly. Thus, both the paper and plastic bin fullness was detected correctly by more than 80%.

Table 2. Percentage of Correct Indication of Paper and Plastic Waste Bin Fullness

Test No.	Percentage of Correct Indication of Paper Bin's Fullness (%)	Percentage of Correct Indication of Plastic Bin's Fullness (%)
1	86	88
2	84	82
3	92	88
4	94	98
5	86	84
6	84	94
7	88	86
8	86	88
9	82	90
10	92	90
Mean	**87.4**	**88.8**

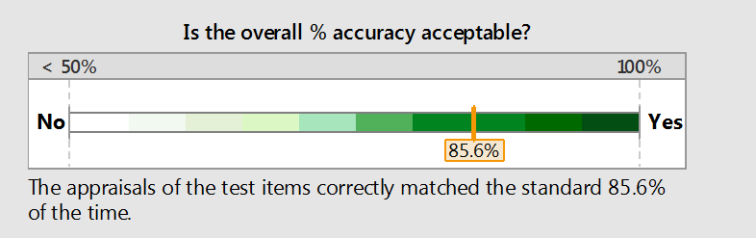
Figure 2. Interval Plot of the Percentage of the Correct Indication of Paper and Plastic Bin Fullness



Bin's Paper Waste Repeatability and Reproducibility Test

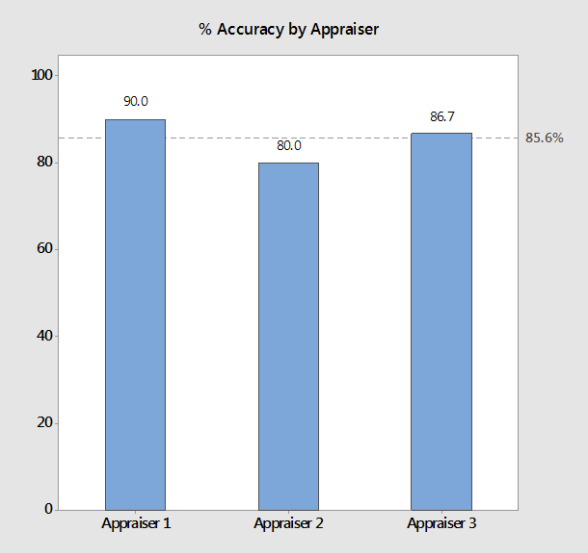
The judgement of the bin correctly matched the set 10 paper waste samples 85.6% of the time. Thus, the result of the test was acceptable.

Figure 3. Over-all Result of Bin's Paper Waste Repeatability and Reproducibility Test



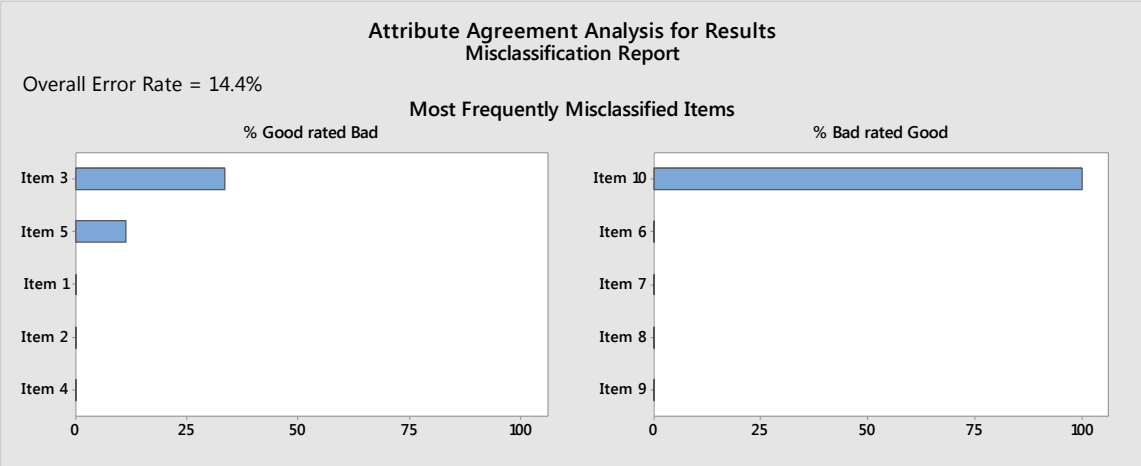
The over-all percentage was affected by the low rate of the second appraiser. Thus, the bin's identification was affected by the method of placement of the waste.

Figure 4. Percent of Accuracy per Appraiser



Also, the over-all percentage was affected by waste sample number 10 which was consistently identified as a paper waste even though it was not.

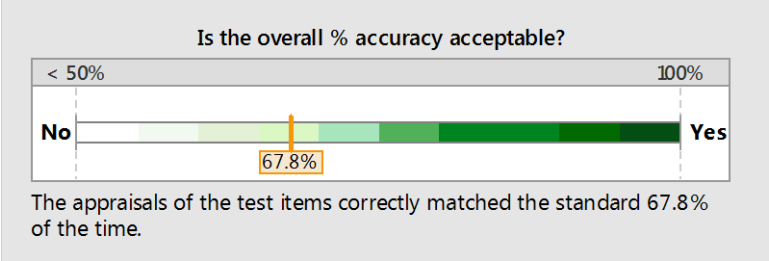
Figure 5. Bin's Paper Waste Repeatability and Reproducibility Test's Misclassification Report



Bin's Plastic Repeatability and Reproducibility Test

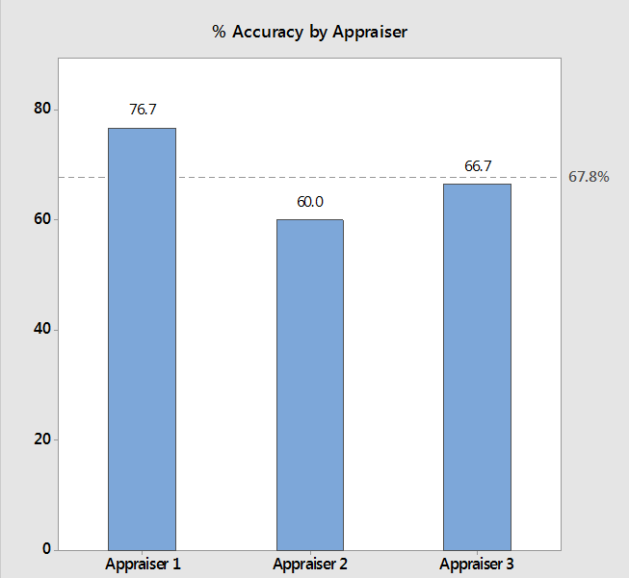
The judgement of the bin correctly matched the 10 plastic waste samples 67.8% of the time. The over-all rate of the test was marginally acceptable, or improvements should be done to help increase the rate.

Figure 6. Over-all Result of Bin's Plastic Waste Repeatability and Reproducibility Test



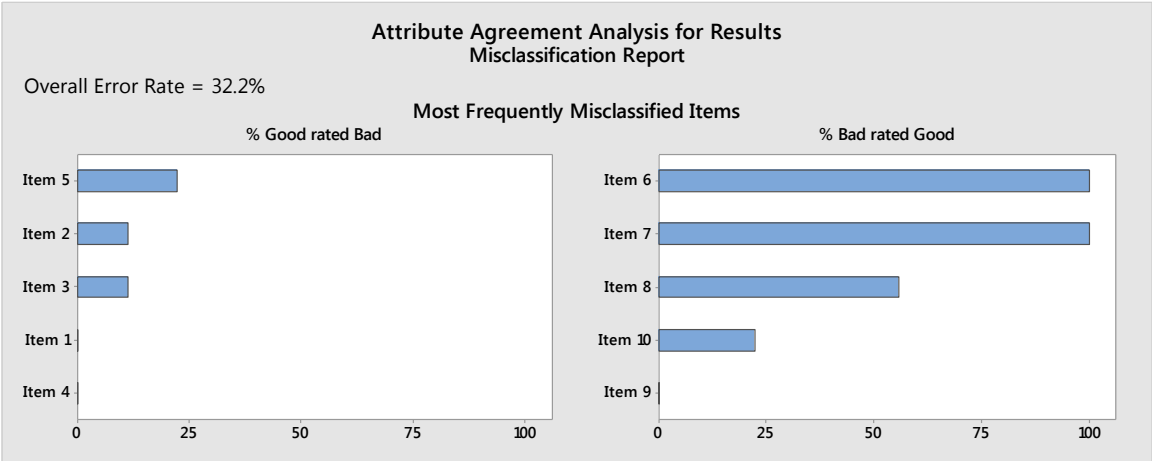
Also, the rate of the second appraiser affected the over-all result of the test. Thus, identification of plastic waste was affected by the method of placement of the waste in the bin.

Figure 7. Percent of Accuracy per Appraiser



The bin misclassified sample number 6 and sample number 7, 100% of the time, sample number 8, 50% of the time, and sample number 10, 25% of the time. They were classified as plastic wastes even though they were not.

Figure 8. Bin's Plastic Waste Repeatability and Reproducibility Test's Misclassification Report



Comparison between the Bin Segregator's Paper and Plastic Repeatability and Reproducibility Test
The bin can separate the paper waste 85.6% of a time, while it can separate the plastic waste 67.8% of a time. The Minitab 17 software identified the 85.6% rate of paper waste segregation as an acceptable value. However, the 67.8% rate of the plastic waste segregation was a marginally acceptable value. The bin could correctly separate paper wastes more than plastic wastes.

Table 3. Result of Repeatability and Reproducibility Test

Type of Waste	Percentage of Repeatability and Reproducibility of Segregation (%)	Remarks
Paper	85.6	Acceptable
Plastic	67.8	Marginally Acceptable

7.Recommendations

- Proper mechanical design for the collection of waste and location of sensors would help improve the accuracy of waste identification.
- Waste samples should be varied enough to properly test the device.

8.Conclusion

The research was successful in creating a garbage bin that could automatically differentiate a dry paper waste from a dry plastic waste. Identified wastes were automatically placed in its designated bin. It could detect if the bin were full and would notify the user for its fullness. However, the bin could detect paper waste more accurately than the plastic waste. Additional capacitive sensor calibration was recommended to increase the accuracy of detecting plastic waste. The placement of the waste also affected the appraisal of the bin. Thus, it was also recommended to add more control in the collection of waste.

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