International Journal of Computing Sciences Research (ISSN print: 2546-0552; ISSN online: 2546-115X)
Vol. 7, pp. 2158-2174
doi: 10.25147/ijcsr.2017.001.1.150
https://stepacademic.net

Short Paper*

Development of a System for Converting Recyclable Materials into Virtual Points

Paulo Cosio
School of Engineering, Asia Pacific College, Philippines
pauloc@apc.edu.ph
ORCID: 0000-0002-7645-9366
(corresponding author)

Stanley Glenn E. Brucal
School of Engineering, Asia Pacific College, Philippines
stanleyb@apc.edu.ph
ORCID: 0000-0001-5481-2803

Luigi Carlo M. De Jesus
School of Engineering, Asia Pacific College, Philippines
luigid@apc.edu.ph
ORCID: 0000-0001-7889-6044

Sergio R. Peruda Jr.
School of Engineering, Asia Pacific College, Philippines
sergiop@apc.edu.ph
ORCID: 0000-0003-4018-3094

Leonardo A. Samaniego Jr.
School of Engineering, Asia Pacific College, Philippines
leonardojrs@apc.edu.ph
ORCID: 0000-0002-1536-8428

Juan Miguel H. Villarroel
School of Engineering, Asia Pacific College, Philippines
juanmiguelv@apc.edu.ph
ORCID: 0000-0001-9435-6611

Einstein D. Yong
School of Engineering, Asia Pacific College, Philippines
einsteiny@apc.edu.ph
ORCID: 0000-0003-0591-9721

John Renzy D. Biron
School of Engineering, Asia Pacific College, Philippines
jdbiron@student.apc.edu.ph

Dominador S. Nevalasca III
School of Engineering, Asia Pacific College, Philippines
dsnevalasca@student.apc.edu.ph

Genesis T. Reyes
School of Engineering, Asia Pacific College, Philippines
gtreyes@student.apc.edu.ph

Jeremy Kyle B. Zamuco
School of Engineering, Asia Pacific College, Philippines
jbzamuco@student.apc.edu.ph

Date received: January 29, 2023
Date received in revised form: March 18, 2023
Date accepted:

Recommended citation:

Cosio, P., Biron, J. R., Brucal, S. G., De Jesus, L. C., Nevalasca, D. III, Peruda, S. Jr., Reyes, G., Samaniego, L. Jr., Villarroel, J. M., Yong, E., Zamuco, J. K. (2022). Development of a system for converting recyclable materials into virtual points. *International Journal of Computing Sciences Research*, 7, 2158-2174. https://doi.org/10.25147/ijcsr.2017.001.1.150

Special Issue on International Research Conference on Computer Engineering and Technology Education 2023 (IRCCETE 2023). Guest Associate Editors:* **Dr. Nelson C. Rodelas, PCpE (*Computer Engineering Department, College of Engineering, University of the East-Caloocan City; nelson.rodelas@ue.edu.ph*) and **Engr. Ana Antoniette C. Illahi**, PCpE *(Asst. Professor & Vice Chair, Department of Computer and Electronics Engineering, Gokongwei College of Engineering, De La Salle University, Taft Ave., Manila; ana.illahi@dlsu.edu.ph*).

Abstract

Purpose – The study aimed to develop a system that can turn recyclable materials such as PET bottles, papers, and metal containers into virtual point rewards in the form of RAMCoins that can be spent on.

Method – The system makes use of an object detection module with a modified dataset that includes PET bottles, paper, and soda cans as trash. This categorized into portions: trash detection, trash weighing, and transaction. The proponents conducted a survey to Asia Pacific College students and after the testing of the project, it had minor malfunctions that led to common problems that can be found in the system.

Results – The proponents aim to integrate a reward system for every trash thrown using Arduino tools and android as its supporting wallet. To achieve the functionalities of the project, these should be met: Accuracy for valuing RamCoins, Accuracy for comparing RamCoins to original price of trash, Efficiency of RamCoin generation, and lastly, the Usefulness of the GUI. The result from Accuracy (valuing RamCoins) and Accuracy (comparison on real price) indicated poor ratings. The Efficiency resulted to fair rating. Lastly, the Usefulness marked good rating.

Conclusion – The design functions implemented for the software, hardware and mobile application were able to perform accordingly in testing and collect satisfactory results. Upon testing, the system was able to consistently detect right trash and generate RamCoins.

Recommendations – Throughout the project testing of the system, the proponents recommend the future researchers to integrate the RamWallet feature, the Earn and Receive system, as one for further simplification of the system. The camera detection through phone can be utilized so it will be more convenient for the users.

Practical Implication – The proposed project can help better address the waste disposal problem of every community since it will incentivize people participating the recycling of their trash.

Keywords – camera, recyclable, weight scale, virtual points, QR code

INTRODUCTION

It is true that improper waste disposal has persisted ever since. Apart from the pandemic, it might not be the most urgent problem humans are dealing with right now, but it still poses a threat to humanity. In essence, it stems from minor mistakes like poorly sorting non-biodegradable trash, throwing plastics in drainages, or even just leaving crumpled paper on the ground rather than in a trash can as it should be. It encompasses man's misunderstanding of proper waste disposal. A clean home or environment is important for our own public health (Skips, 2018). Because of this, having public trash cans and a waste disposal organization nearby greatly benefits a community. It is astonishing how one piece of paper, when disposed of properly, may have a positive impact on the environment (Wilson, 2016). Committing to excellent waste disposal practices, such as looking through everything that can be recycled or used again before throwing away all your old stuff and trash, is essential. The most prevalent waste kinds include recyclable, compostable, biodegradable, and non-biodegradable waste. What, in essence, makes appropriate waste disposal important? People are already aware of certain basic facts, such as how it benefits the environment or keeps the landscape clean, but they may not be aware that it also encourages good health and sanitation (Koop, 2021) which is crucial given the COVID-19 pandemic that is presently sweeping the globe (Skips, 2018).

Various studies and literature support the feasibility of the project incorporated with modern technology (Balagugan et.al., 2017, Singh et. al., 2017, Mittal et. al., 2016, Flores & Tan, 2019). Each of the presented study and literature is essential especially with giving ideas to develop the project EcoRam. Through local to foreign studies, these will be helpful in resolving issues on good waste disposal with the use of relevant technology like image processing and neural networks.

For local literature and local study, a study about public security threats object detection and classification using neural networks discussed the necessity of detecting and classifying public security threats (Guillermo et. al., 2020). In addition to local literature, analysis and classifying of garbage using image processing was explained as well as how neural networks came in handy – a topic that is to be applied in the development of EcoRam. As for the local studies, they discussed the country's state of solid waste management and risks surrounding bad waste disposal (Atienza, 2008, Castillo & Otoma, 2013, Romero, 2020, Moaje, 2021).

For the foreign literature and study, there was an autonomous trash collector based on object detection using deep neural network (Vinodha et. al., 2020). It presented the object detection and trash identification with the use of Neural Networks. A similar study (Mitra, 2020) was used to compare both of the researchers' ideas and learn from each. In addition, for the related foreign literature, a smart garbage system, Smart bin, (Hulyakar et. al., 2018) was discussed that used the algorithm of convolutional neural networks (CNN). CNNs use notably little pre-processing as compared to different photo category algorithms. This way, the proponents could learn to optimize the filters (or kernels) via computerized learning.

Conceptual Framework

Based on the cited conceptual framework, illustrated in figure 1, for the input, a weight scale that will be included into the system will be used to weigh trash once it has been scanned with the USB camera to determine how many RamCoins, a virtual points system, will be awarded. The process will be, starting, with the determination of the kind of trash that has been scanned. Next, the weight of the trash is kept in a threshold until the user runs out of things to scan. Then, the user may now deposit their earned RamCoins into their own accounts via a QR code. Finally, if the algorithm determines and weights the type of trash, the user will receive RamCoins. For the output from the system, initially, will include a summary of the types of materials that were disposed of, their weight, and the total number of RamCoins available for deposit to user's account. After completing the necessary steps, the user will be compensated with RamCoins based on the volume and weight of trash that a weighing scale and an integrated detecting module have detected.

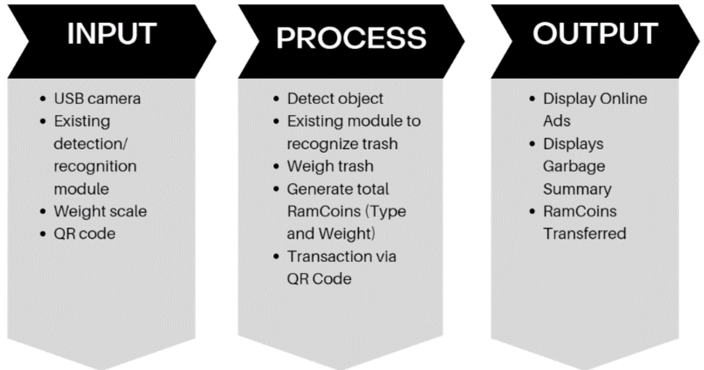

Figure 1. Conceptual Framework Flowchart for EcoRam

METHODOLOGY

A trash identification model and weight buildup are combined in the design concept. The proponents used the PyCharm IDE and TKinter tools to design and build a user and graphical interface for desktop PCs, which met the requirements for real-time trash identification, a weight scale, and finally the presentation of processed data and trash outcomes. The supplied IDE is used to create the frontend panel, which allows users to visualize and navigate the program to send RamCoins.

The recommended approach for taking RamCoins, on the other hand, is through a mobile application that reads the QR Code and presents it to the software after each detection and weight buildup. The proponents used the Android Studio and PyCharm tools to design and build the user and graphical interface for Smartphones, which met the requirements for Google authentication, QR code scanning, and, finally, saving RamCoins in an E-wallet. The provided IDE is used to create a frontend panel that allows users to visualize and navigate the program for the purpose of receiving and saving RamCoins for later use.

The project underwent three vital stages as shown in the flowchart in figure 2 with the trash to be converted into points alongside with the software design, hardware design, and the mobile application design.

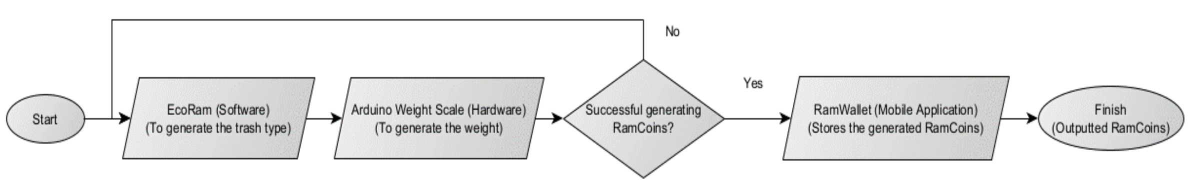

Figure 2. The Project Design Flowchart

Determining the Value of RamCoins

The proponents of the study based the accuracy of the generation on how the system rates the garbage detected by EcoRam. This determines how many RamCoins will be generated throughout each iteration of the system. The supporters relied on an internet source report that was an official study by The Environmental Management Bureau (EMB) on the cost of recyclable materials (NSWMC, 2016). Equation 1 is used to compute the value of RamCoins that will be generated, in which the price of recyclable materials per kilogram is divided across a thousand grams and then multiplied by the original weight of a recyclable item (Davis, 2021).

$$Generated\ RamCoins = \frac{Price\ of\ recyclable\ materials\ per\ kilogram}{Kilogram\ into\ grams} \times Orig.weight\ per\ material$$

Equation 1. Getting the generated RamCoins

Comparing the Generated Value of RamCoins to the Actual Price per Kilogram

$$Theoretical\ RamCoins\ per\ kilogram = \frac{Kilogram\ into\ grams}{Orig.weight\ per\ material} \times Generated\ RamCoins$$

Equation 2. Theoretical RamCoins Computation

$$Accuracy\ of\ original\ price\ to\ RamCoin = \frac{Theoretical\ RamCoinse\ per\ kg.}{Price\ of\ recyclable\ materials\ per\ kg.} \times 100\%$$

Equation 3. Accuracy of Original price to RamCoin using Comparison

The first stage, as mentioned in equation 1, is to value the number of RamCoins to be generated per waste; the second step is to determine the theoretical value by dividing a thousand grams by the original weight of the material utilized, and then multiplying it by the generated RamCoins, as shown in the equation 2. Finally, the accuracy is determined in the third phase by dividing the theoretical value over the original price and multiplying it by 100% to get the proportion of the original price to theoretical RamCoins, as presented in equation 3. This goal demonstrates how accurate the comparison of RamCoins values and original costs of recyclable materials that illustrate how much virtual points are comparable to actual money is. Table 1 shows the price of recyclables per kilogram wherein the first column refers to the types of recyclable materials that are available for object detection conducted by the EcoRam, as well as its limitations where only PET bottles, papers, and metal containers are permitted and the second column is directly applied from an EMB report (NSWMC, 2016), where each recyclable material was weighed down into kilograms and valued.

Table 1. Price of Recyclables per Kilogram

Recyclable Materials	Price per kilogram
PET Bottles	16.00 PHP
Papers	8.00 PHP
Metal Containers	50.00 PHP

Calculating the Efficiency of the System

Equation 4 depicts the efficiency rating of each point creation received by each user. The percentage rating was calculated by multiplying the number of appropriately generated RamCoins by the total number of generated RamCoins ready to be transacted.

$$Efficiency\ of\ RamCoin\ generation = \frac{no.of\ correctly\ generated\ RamCoins}{Total\ no.of\ RamCoins} \times 100\%$$

Equation 4. Efficiency of RamCoin generation

Getting Respondent Insights on the System UI

The project's proponents chose to conduct a survey to ask users if comprehensible and inviting visuals on the GUI that displays the benefits of trash disposal, classification summary, and transaction are useful; especially since the project will be implemented on a facility of a campus that is frequently busy and where students from all courses are present. Average scores were computed among the responses as presented in equation 5.

$$Average\ Score = \frac{User\ defined\ score\ on\ specific\ survey\ question}{Total\ score\ of\ specific\ survey\ question}$$

Equation 5. Usefulness of EcoRam via MS Forms

Sampling Method

Based on the results of the initial project testing method, the proponents conducted a stratified random sample in which students could test out the project in the cafeteria and they could gather at least 10 students from each school. Two days after the initial testing, proponents shifted to simple random sampling, due to constraints pertaining to the target respondent's availability. This is still acceptable for the project (Qualtrics, 2022) and the number of students who are available for face-to-face interaction during the whole week was chosen instead.

Software Design

The EcoRam system's backend is made up of machine learning using an existing YOLOv3 algorithm. Python was used as a high-level programming language and as a compiler by the proponents to build, debug, and execute the command code required to perform image processing tasks. The system is based on Maarten Sukel's existing OpenCV and YOLOv3 trash dataset/model, however, with an already provided trash dataset that contains more than 500 dataset components of random rubbish objects, it falls outside the scope of the project.

Figure 3 describes the EcoRam system flow. First, the system will be asking the type of recycled material and the weight of it. Next is the system will now compute the total price with the formula that was given to the system and after that, it will display the summary of the Total Generated RamCoims. Then, the system will be asking the user if the use wants to add more product, if the user clicked "Add more", it will go back to the second step where the system needs the recycled material and its weight, if the user clicked "Generate QR Code", the next step will be the system will generate a unique QR code until it ends.

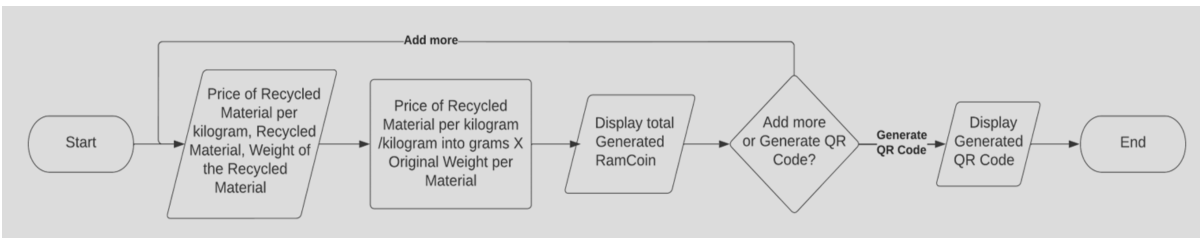

Figure 3. EcoRam Flowchart

Hardware Design

Figure 4 shows how the functionality of EcoRam, where its hardware is powered by an existing OpenCV and YOLOv3 module with real-time image detection in order to detect and identify what recyclable materials it is in real-time and for it to process in the Arduino and compute the weight that comes from the Arduino uno weighing scale, as shown in figure 5, to come up with a summarized result that has the total weight of the material and the total amount of points gathered in EcoRam.

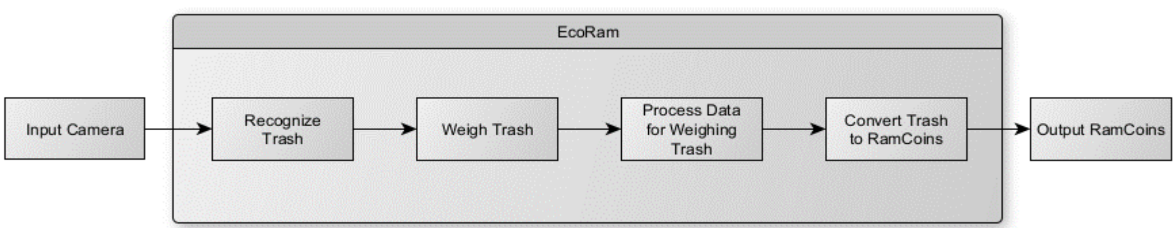

Figure 4. The EcoRam Function Flow

Figure 5. Project Prototype

Mobile Application Design

The RamWallet's backend system is built with the Java programming language and the Android Studio IDE. Most of the application will be written in Kotlin, with Google Authentication integrated into the mobile app to ensure a safe and secure account. The RamWallet's user interface will likewise be created in Android Studio from the ground up. The RamWallet can use the camera to recognize QR Codes as well as Earn and Spend RamCoins.

EcoRam User Interface

The Tkinter package, a standard Python interface GUI toolkit, was used by the proponents. The software may appear obsolete to some, but the creators made effort to use creative graphic styles for the GUI's canvas, buttons, and so on. The image above depicts the EcoRam windows that the user will encounter while running the application. The user will see the loading screen, as shown in the first panel of the figure 6, followed by the home screen panel, which has a start button that, when pressed, will move to the second panel, an information button where the user will see more information about the project, and finally an exit button where the project will be terminated.

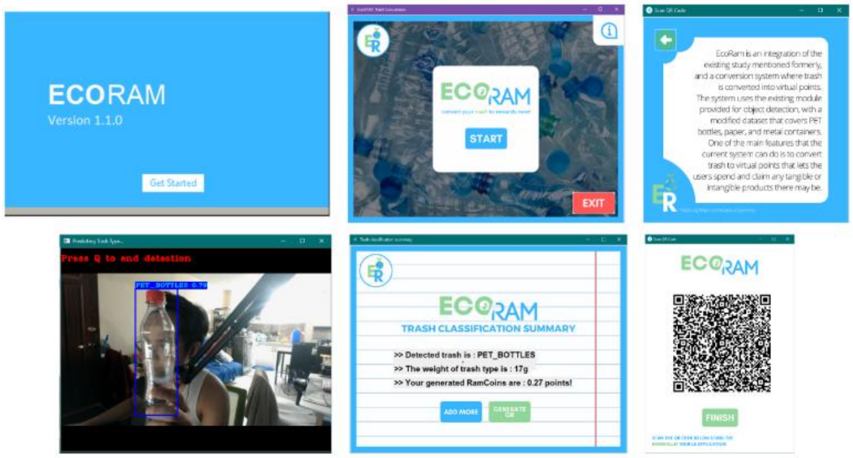

Figure 6. EcoRam GUI Overview

RamWallet Graphical Design

Figure 7 demonstrates how the RamWallet works when it is utilized by the user. In the first panel, the user was directed to the Login/Signup screen. This is where the user decides whether to join or merely login. When the user is given the option between the two, a Google Authenticator will pop up to help the user into the RamWallet software. The user will be taken to the home screen on the third panel, where they will see their total RamCoins, Transaction History, and the three buttons Earn RC, Spend RC, and Scan RC (RC = RamCoins). When the user presses the Earn RC button on the next panel, the RamCoin will turn on its camera to detect a QR code provided by the EcoRam. On the fifth panel, the Spend RC, the software will also turn on its camera to scan QR codes and pay for products using RamCoins. When the user selects Earn RC by QR Code on the last panel, RamCoin will supply its own QR Code for it to pay for retailers.

Figure 7. RamWallet GUI Overview

Google Sign-In Options for RamWallet

The RamWallet's proponents favor the usage of a Google account provided by the user for sign-in and account creation. In this manner, a user may readily access his or her account by simply logging in with Google; it also guarantees protection for the user and the RamCoins he or she holds.

SQLite Database for Storing User Accounts with Points

The SQLite database was used by the proponents to store the values that can be obtained through Google Authentication; required values such as the unique user ID as the main key, the user display name, and the user email. Another database column, 'user points,' has been added to serve as a container for the user's RamCoins. The database is also used to determine which QR codes can be used and are scannable. Because the supporters do not wish to tolerate several scans of a single QR code, which could fool the system, each QR code that is scanned records a unique ID that is saved to our database.

RESULTS AND DISCUSSION

The proposed EcoRam design was put to test to demonstrate the functionality in terms of meeting the design specifications, design objectives and its metrics; accuracy for the generation of RamCoins, accuracy in comparison of the generated RamCoins to the real price, efficiency for determining if QR Scanner properly passing generated RamCoins, and usefulness to assess how inviting our graphical user interface is.

Testing of the Objective for Accuracy for Valuing RamCoins

The system testing to achieve accuracy for valuing RamCoins is shown in table 2 Accuracy Test for Valuing RamCoins. The admin must keep an eye on whether the RamCoins-based system is appropriately valued based on the trash that has been detected by the module. The proponents revised the checklist that lessened the number of accuracy to 3 due to lack of dataset features that can detect certain trash details like a PET bottle that has been crushed, or like a piece of paper that is crumpled.

Table 2. Accuracy Test for Valuing RamCoins

Accuracy Test	Accuracy 1 Rating Percentage	Remarks
Able to accurately value empty PET bottles (water and soda bottles) that are not crushed	89.29%	Poor
Able to accurately value papers (copy/bond and pad papers) that are not crumpled	100%	Excellent
Able to accurately value soda cans that are not crushed	67 %	Poor

Testing of the Objective for Accuracy (Comparison on Real Price)

The table 3 shows the accuracy in calculating the percentage of difference between the computed quantity of RamCoins and the generated RamCoins. The users were able to collect 25 testing data from PET bottles, 13 data from papers, and 12 data from soda cans.

Table 3. Accuracy tests for trash types in general

Accuracy Test	Accuracy 2 Rating Percentage	Remarks
Able to accurately compare earned RamCoins for all tested PET Bottles	98.66%	Very Good
Able to accurately compare earned RamCoins for all tested Writing Papers	94.66%	Fair
Able to accurately compare earned RamCoins for all tested Soda Cans	78.85%	Poor

Testing of the Objective for Efficiency

The proponents gathered data for the testing of the efficiency objective and presented in Table 4. From what the proponents observed, the system was able to achieve 99.85% accuracy on PET bottles' high efficiency that has its cap on, and 98.83% on generating its own for standard 300 ml bottle of water. The system was able to accomplish 94.48% on crumpled paper, 93.88 on printed paper, and 98.46% on clean papers for the papers. Finally, non-crushed cans were able to achieve a high efficiency rate of 86.19%.

Table 4. Efficiency Testing for different test cases

Accuracy Test	Accuracy 1 Rating Percentage	Remarks
Able to generate a high efficiency rate of 90% and above after x iterations for PET Bottles with the cap on	99.85%	Very Good
Able to generate a high efficiency rate of 90% and above after x iterations for standard sized 300ml PET Bottles	98.93%	Very Good
Able to generate a high efficiency rate of 90% and above after x iterations for standard 500ml PET Bottles	99.76%	Very Good
Able to generate a high efficiency rate of 90% and above after x iterations for non-crumpled papers	94.48%	Fair
Able to generate a high efficiency rate of 90% and above after x iterations for printed/written papers	93.98%	Poor
Able to generate a high efficiency rate of 90% and above after x iterations for clean papers	98.46%	Very Good
Able to generate a high efficiency rate of 90% and above after x iterations for non-crushed soda cans	86.19%	Poor

Evaluation of the Objective for Accuracy (Valuing RamCoins)

The table 5 describes the target for accuracy by comparing the real price to created RamCoins. The number of RamCoins generated per trash is valued first in the equation; then, the theoretical value is computed by dividing 1,000 grams over the original weight of the material used, then multiplying it by the generated RamCoins; and finally, the accuracy is computed by dividing the theoretical value over the original price, then multiplying it by 100 percent to get the percentage of accuracy. As you can see, the last column displays the average comparison rating calculated by taking the entire average of all user trials.

Table 5. Evaluation of 1st Accuracy Objective

Number of Trials	How many were converted to RamCoins?	Average Rating
50	48	96%

CONCLUSIONS AND RECOMMENDATIONS

The proposed EcoRam design was put to test to demonstrate the functionality in terms of meeting the design specifications, design objectives and its metrics; accuracy for the generation of RamCoins, accuracy in comparison of the generated RamCoins to the real price, efficiency for determining if QR Scanner properly passing generated RamCoins, and usefulness to assess how inviting our graphical user interface is. The accuracy on the generation of RamCoins was based on the calculation where the price of recyclable materials per kilogram over a thousand grams is multiplied to the original weight of a recyclable material. As for the second accuracy, the equation starts where the theoretical RamCoin value is divided over the original price of each recyclable material and multiplied by 100% to get the percentage of the comparison. The percentage rating was calculated by multiplying the number of correctly generated RamCoins by the total number of generated RamCoins that were ready for transactions. The equation was taken from a related study, PicaTree (Minoru, et. al, 2019) to assess consistency. For the usefulness metrics the proponents chose to conduct a survey to ask the users if comprehensible and inviting visuals on the GUI that displays the benefits of trash disposal, classification summary, and transaction is useful.

Throughout the one-week project testing in Asia Pacific College cafeteria, the proponents were able to encounter problems and the thus, recommend the future researchers to add the following features to the existing project. First is the RamWallet's two features, Earn & Receive. These two can be merged into one since it's only the same feature, so it is clarified that both features only contain one single function which is to scan a QR code. Aside from having three types of trash, the proponents recommend having more trash types, since there are different recyclable materials that can be found not just within the campus but also in the streets. The proponents would like to recommend a way for the system to achieve faster processing of points by upgrading the GPU for

GPU/hardware acceleration; this will create a faster way to load the GPU acceleration libraries, as well as to increase the FPS of the real-time detection to cater more trash to be converted into RamCoins. The proponents would like to jump into real time saving of the database from local saving of the database. Instead of using Google Authentication, it would be much more in line and easier when students at Asia Pacific College will use their Microsoft account email when logging in to RamWallet. Improving the mechanics and reminding the users of the rules in converting their carrying recyclable trash into virtual points. A simple remedy to this issue is by creating an interactive way of visualizing how trash should be registered (e.g. in-app tutorial videos). Creating a logic to be able to detect if the trash is empty or not (written or clean for papers) would solve a current weakness of the system which was to manually monitor every trash. The team's recommendation to solve the weakness of input trash being weighed again to double the output RamCoins, was to create a hardware system, like a robot that automatically collects the trash after the RamCoins are weighed.

ACKNOWLEDGEMENT

The proponents would like to sincerely thank everyone who contributed to making this research endeavor possible, especially to the community of Asia Pacific College for providing the required support system. Also, thanks to the families of the proponents for their constant support and inspiration.

DECLARATIONS

Conflict of Interest

All authors declare that they have no conflicts of interest.

Informed Consent

The authors ensure their full consent to have the photos included in this research published in an international journal.

Ethics Approval

The conducted research uses only the researchers' photos and did not include others hence, it does not violate any ethical issues.

REFERENCES

Atienza V. A. (2008, July 18). *A breakthrough in solid waste management through participation and community mobilization: The experience of Los Banos, Laguna, Philippines*. Semantic Scholar. Retrieved September 16, 2021, from

https://www.semanticscholar.org/paper/A-Breakthrough-in-Solid-Waste-Management-through-of-Atienza/c4de4b68609f03685f28d0037d3b148f0ca1c342
Balagugan, Raja S., Maheswaran T., & Savitha S. (2017). Implementation of automated waste segregator at household level. *International Journal of Innovative Research in Science*, *6*(4), 5389-5394. doi: 10.15680/IJIRSET.2017.0604039
Castillo, A., & Otoma, S. (2013). *Status of solid waste management in the Philippines*. Semantic Scholar. Retrieved September 16, 2021, from https://www.semanticscholar.org/paper/Status-of-Solid-Waste-Management-in-the-Philippines-Castillo-Otoma/2cafc3855ba4339ae1fcb18a37b33586397eaf2c
Davis B. (2021). *How much do 4 sheets of paper and an envelope weigh?* MVOrganizing. Retrieved November 3, 2021, from https://www.mvorganizing.org/how-much-do-4-sheets-of-paper-and-an-envelope-weigh/
Flores, M., & Tan Jr, J. (2019). Literature review of automated waste segregation system using machine learning: A comprehensive analysis. *International Journal of daviSimulation: Systems, Science & Technology, 20*(S2), 15.1-15.7. doi:10.5013/ijssst.a.20.s2.15
Guillermo, M., Tobias, R. R., Carlo De Jesus, L., Billones, R. K., Sybingco, E., Dadios, E. P., & Fillone, A. (2020). Detection and classification of public security threats in the Philippines using Neural Networks. *2020 IEEE 2nd Global Conference on Life Sciences and Technologies (LifeTech)*. 320-324. doi:10.1109/lifetech48969.2020.1570619075
Hulyakar S., Deshpande R., Makode K. & Kajale S. (2018). Implementation of smartbin using convolutional neural networks. *International Research Journal of Engineering and Technology (IRJET), 5*(4), 3352-3358
Koop, F. (2021). *Why is recycling so important? the dirty truth behind our trash*. Retrieved September 28, 2021, from https://www.zmescience.com/other/feature-post/why-is-recycling-so-important-the-dirty-truth-behind-our-trash/
Minoru R. B., Verterra J. D. V. & Zacarias C. A. (2019). Development of a mobile application for tree species identification with location. Asia Pacific College, Makati
Mittal G., Yagnik K. B., Garg M. & Krishnan N. C. (2016). *SpotGarbage: Smartphone app to detect garbage using deep learning*. Retrieved September 28, 2021, from https://dl.acm.org/doi/10.1145/2971648.2971731
Moaje M. (2021). *QC 'trash for cash' to help residents earn, save environment*. Philippine News Agency. Retrieved October 23, 2021, from https://www.pna.gov.ph/articles/1141557
NSWMC. (2016). *Price of recyclables (Based on sales of EMB Central Office MRF)*. NSWMC.ph, Quezon.
Qualtrics. (2017). *Simple random sampling: The ultimate guide*. Retrieved November 3, 2021, from https://www.qualtrics.com/uk/experience-management/research/simple-random-sampling/?rid=ip&prevsite=au&newsite=uk&geo=NO&geomatch=uk
Romero, P. (2020). *PHL facing garbage crisis; 16.6 million metric tons of waste this year*. Retrieved September 28, 20201, from https://www.onenews.ph/phl-facing-garbage-crisis-16-6-million-metric-tons-of-waste-this-year-can-fill-99-philippine-arenas
Singh S., KR M., Ragothaman S., Zacharia S., Krithika R. D. & A. N. (2017). *Waste segregation system using artificial neural networks*. Retrieved September 21, 2021, from

http://helix.dnares.in/2018/03/14/waste-segregation-system-using-artificial-neural-networks/

Skips L. M. (2018). *10 reasons to commit yourself to proper waste disposal*. Retrieved September 21, 2021, from https://www.lakemacquarieskips.com.au/10-reasons-tocommit-yourself-to-proper-waste-disposal/

Vinodha D., Sangeetha J., Sherin C. B. & Renukadevi M. (2020). Smart garbage system with garbage separation using object detection. *International Journal of Research in Engineering, Science and Management (IJRESM)*, 3(5) 779-782.

Wilson D. C. (2016). *Responding to the global waste management crisis*. Retrieved September 27, 2021, from https://wasteaid.org/responding-global-waste-management-crisis/

Authors' Biography

Paulo Cosio is a licensed Electronics Engineer. He is now pursuing his graduate degree at St. Joseph College. He is a Full-Time Faculty Member at Asia Pacific College's School of Engineering.

Stanley Glenn E. Brucal earned his BS Electronics Engineering from Adamson University (2003) and a Master of Engineering major in Electronics and Communications Engineering from De La Salle University (2006). He is a Professional Electronics Engineer (PECE), an ASEAN Chartered Professional Engineer (ACPE), and currently the Registrar of Asia Pacific College.

Luigi Carlo M. De Jesus is a Master of Engineering Major in Computer Engineering graduate of Asia Pacific College. He is a licensed Electronics Engineer, Electronics Technician (2nd Placer), and the current Engineering and Science Laboratory Office (ESLO) Head of Asia Pacific College - School of Engineering.

Sergio R. Peruda Jr. is a Professional Computer Engineer. He is currently the Program Director of Computer Engineering at Asia Pacific College.

Leonardo M. Samaniego Jr. holds an Electronics Engineer license. He also holds a Master of Engineering degree with a major in Electronics Engineering from MAPUA Institute of Technology. He is currently the Executive Director of Asia Pacific College's School of Engineering.

Juan Miguel H. Villarroel holds an Electronics Engineer license (3rd Placer). He is now pursuing his graduate degree at MAPUA Institute of Technology. He is currently a Full-Time Faculty Member at Asia Pacific College's School of Engineering.

Einstein D. Yong is a Professional Computer Engineer. He is currently an Associate Professor at Asia Pacific College's School of Engineering.

John Renzy D. Biron is a student at Asia Pacific College pursuing a Bachelor of Science in Computer Engineering.

Dominador S. Nevalasca III is a student at Asia Pacific College pursuing a Bachelor of Science in Computer Engineering.

Genesis T. Reyes is a student at Asia Pacific College pursuing a Bachelor of Science in Computer Engineering.

Jeremy Kyle B. Zamuco is a student at Asia Pacific College pursuing a Bachelor of Science in Computer Engineering.