INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue IX, September 2025

Image-Based Recognition for Recyclable Materials Using Convolutional Neural Network

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DOI: https://doi.org/10.51583/IJLTEMAS.2025.1409000073

Received: 25 Sep 2025; Accepted: 02 Oct. 2025; Published: 09 October

Abstract: This document presents the development of an intelligent mobile application that uses an Image-Based Recognition System that runs on a Convolutional Neural Network (CNN) to foster sustainable behaviors and promote environmental consciousness. The system will identify and sort different materials that can be recycled such as wood, plastic, fabric, cardboard, and metal using deep learning-based image recognition. The application allows users to take or post pictures of objects after which they are processed and analyzed to determine the type of material in real-time. After this identification, the system creates rule-based suggestions, which offer curated video tutorials and step-by-step instructions on potential upcycling projects. Such customized recommendations do not only prolong the life of materials, but also encourage users to implement creative, environmentally friendly solutions in their everyday life.

The application was developed on the basis of the Agile approach, which focuses on the iterative nature of development, flexibility, and constant feedback of real-life users. The data collection integrated both primary data collection techniques, including interviews and surveys to understand the preferences of the users, and secondary data collection techniques, including academic research and existing literature, to make the system consistent with the best practices in technology. The training data consisted of around 25,000 annotated images, namely around 5,000 images per material type, which was processed by the methods of normalization and augmentation to increase the recognition accuracy and reliability. Technically, the application is divided into three main parts: the input part where users post or take pictures, the processing part where the CNN-based classification takes place, and the output part where the users are shown personalized upcycling video suggestions. The front-end of the system was developed in JavaScript and React Native to provide a cross-platform mobile interface, and the back end was developed in Python and TensorFlow to provide machine learning features. PostgreSQL was used to manage databases in a reliable and secure manner.

Ethical aspects were given importance such as direct user consent, balanced data set creation, and energy-efficient model training to reduce the environmental impact. In the future, the project will map out the activities of thorough testing and evaluation to further improve the accuracy of detection, usability, and scalability before the full implementation. In general, this smart mobile app shows the possibilities of integrating artificial intelligence, user-centered design, and sustainability principles to solve environmental issues and spread the culture of responsible consumption.

Keywords: Artificial Intelligence, Convolutional Neural Network, Deep Learning, Image-Based Recognition, Machine Learning, Mobile Application, Recyclable Materials, Sustainability, Upcycling, Waste Management.

I. Introduction

Artificial intelligence and machine learning are much implemented today, they are suited for computers to perform work that would have otherwise called for intelligence from people. These studies are capable of mimicking brain functions like problem solving, learning, perception, and decision making. Machine Learning is a branch of Artificial Intelligence that deals with the study of making systems adapt and learn from experience through programming. It can enable the algorithms to learn from patterns and data and make predictions, which become more accurate with the amount of training data provided. These technologies are applied in different areas such as health care, business and industry, and education to simplify work and assist in decision making.

This study is about Image-Based Recognition for Recyclable Materials Using Convolutional Neural Networks. This study is designed for, development, and evaluation of a mobile application that can learn from images of reusable materials and suggest possible upcycling or repurposing ideas for them. This study uses a Convolutional Neural Network, a deep learning algorithm for image classification. This Algorithm can identify patterns, textures and shapes, and pinpoint what kind of material it will be used: wood, plastic, metal, fabric, or cardboard and if it is suitable for a best creative project.

This study will be implemented as an application for smartphones that will help users to take a photo of an object and then use Convolutional Neural Networks for image recognition to analyze it. When recognized, the application will provide recommendations for the most upcycling processes to employ. This study is useful for people of all ages, including crafters, learners, professionals, and proprietors of small businesses who participate in upcycling. Some designers that love new inventions may discover new ways to repurpose things found at home into new products, and students can use a mobile application to create environmentally friendly school projects.

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II. Review of Related Literature

A. Application of Image Recognition Algorithms in the Detection of Philippine Lime Diseases

In their study, Pelingon et al. (2023) demonstrated image recognition algorithms are applicable in the detection of diseases in Philippine lime (Calamansi) fruits. They compared K-Means Clustering, the artificial neural networks (ANN), the Support Vector Machines (SVM) and GrabCut techniques. GrabCut, color feature extraction and SVM gave highest accuracy and precision hence yielding the best results. Although their work was done on the detection of fruit diseases, we have applied the same concepts to our project except that we use Convolutional Neural Networks (CNN) to determine the type of material that should be recycled.

B. Sustainable waste management through eco-entrepreneurship: an empirical study of waste upcycling eco-enterprises in Sri Lanka

Jayasinghe et al. (2021), investigated an empirical study of Threes of waste upcycling eco enterprises in Sri Lanka through its contributions and challenges. The study found that these enterprises do social, economic, and environmental justice mixing through plastic waste upcycling (i.e. waste reduction and job creation). Additionally, they have limited funding and market access. It has been found in this study that eco-entrepreneurship is a critical method in advancing sustainable waste management practices and networking and partnership also significantly increase the likelihood of such companies' success. This is very relevant information for our project, which seeks to stimulate the recyclability of materials through technology.

C. Achieving remanufacturing inspection using deep learning

Nwankpa et al. (2021) examined how deep convolutional neural networks (DCNNs) can be used to detect defects in remanufactured materials. Their vision system of inspection was very accurate in detecting pitting, rust and cracks on mild steel plates. The paper demonstrates that DCNNs are capable of automatizing inspection and eliminating manual labor and enhancing efficiency. This is despite the fact that we are working on remanufacturing yet it facilitates the objective of our project of using deep learning to automatically recognize images of the recyclable materials in the classification of material images.

D. Feasibility Study of an Integrated Waste Management Technology System for a Circular Economy in the Philippines

Langit et al. (2024) have carried out a feasibility study of an Integrated Waste Management Technology System (IWMTS) in the Municipality of Bay, Laguna, Philippines. Their results showed that the suggested system possesses a high potential of decreasing the amounts of waste, generating income, and producing favorable environmental effects. The paper has highlighted that IWMTS is cost effective and environmentally friendly. This underscores the need to invest in integrated waste management technologies in order to have sustainable practices that have long-term economic and ecological advantages.

E. The Impact of Solid Waste Management to the Economic Growth in selected OECD Countries and Philippines

Ella et al. (2022) reviewed how municipal solid waste (MSW) and recycling rates had an effect on the economic performance of chosen OECD countries, including the Philippines. Their results revealed that MSW positively and significantly influences GDP per capita and recycling has a positive impact on economic growth as well. The paper has shown the recursion nature of MSW, recycling and economic development and the significance of effective policies on waste management in promoting sustainable development of the economy and enhanced performance by the nation.

F. Functional Upcycling of Polymer Waste towards the Design of new Materials

Guselnikova et al. explored functional upcycling as a way to turn polymer waste into valuable new materials. Instead of breaking plastics down, they showed how common polymers like PET, polyethylene, and PVC can be modified to gain new functions, sometimes outperforming virgin plastics in uses such as sensors, catalysts, and electrodes. They also compared this method with traditional recycling, highlighting its environmental and economic benefits, while noting challenges and future research needs.

G. Generational Differences and Determinants of Purchase Behavior towards Sustainable Clothing in a Developing Economy

Valentin et al. examined the predictors of purchasing behavior toward sustainable clothing in the Philippines, focusing on Generations X and Z. Using data from 212 online survey participants and multiple regression analysis, the proponents found that both generation and environmental knowledge influenced the purchase of sustainable clothing. They also noted that Gen Z showed higher environmental awareness and a stronger tendency to buy sustainable clothing compared to Gen X. The study provides valuable insights on how promoting sustainable fashion choices can help reduce the environmental impact of the fashion industry.

H. Factors in enhancing environmental governance for marine plastic litter abatement in Manila, the Philippines: A combined structural equation modeling and DPSIR framework

In addition, Guilberto et al. examined the factors that influence environmental governance in addressing marine plastic litter (MPL) in Manila, Philippines. Using a hybrid structural equation modeling (SEM) and DPSIR framework, they analyzed data from 456 barangays through surveys, interviews, and focus group discussions. Results showed that COVID-19 waste management, community participation, socio-economic factors, and solution measures positively affected MPL abatement, while solid waste

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management policies and guidelines had a negative impact. Waste infrastructure, however, showed no significant link. The study highlights important policy implications to strengthen environmental governance for reducing marine plastic litter in Manila.

Table 2.1: Comparison of Accuracy to Similar Studies

Title	Accuracy
Developed a PET Bottle Collector using Image Processing and Deep Learning	94%
Introduced iWASTE, an Automated Waste Classification System Combining CNN and a Classifier	96%
Recyclable Waste Image Recognition based on Deep learning	95%
Trash and Recycled Material Identification using Convolutional Neural Networks (CNN).	93%
Individual model identification of waste digital devices by the combination of CNN-based image recognition and measured values of mass and 3D shape features	97%

Conceptual Framework

The conceptual framework demonstrates that the system employs the Convolutional Neural Networks (CNN) to identify and classify recyclable materials automatically out of images uploaded by users. The system does not require manual sorting, instead, identifying the material and proposing appropriate upcycling or restoring projects. This assists the users like students and entrepreneurs to convert waste into productive or innovative products. The system ensures environmental conservation by facilitating the speed and accuracy of the process and facilitates reuse of materials.

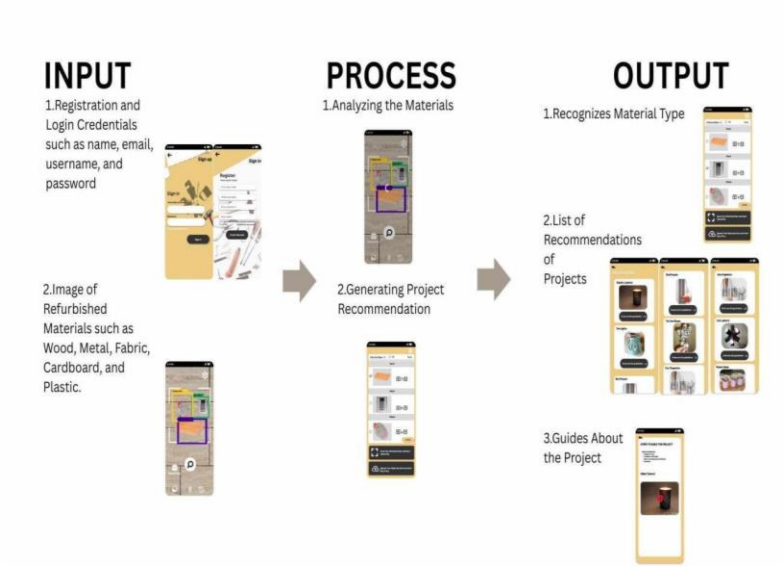

Figure 2.2: Input-Process-Output Model

Figure 2.2 gives the basic design of the study which is the blueprint of creating the image based recognition system of the recyclable and reusable materials. The model shows how Convolutional Neural Networks (CNN) analyze the input, which is indicated as images of the materials provided by the user to identify them automatically and classify them. The system scans the material and produces outputs as recommended recyclable or upcycling project options instead of manually sorting the material. The structure will make sure that the users, including students, entrepreneurs and craftspeople, are directed on how to turn waste into useful or creative products. The system helps in conservation of the environment by ensuring that the process is faster, more precise and more accessible, thus encouraging the re-use of materials that would otherwise be wasted.

Input Phase. The input phase starts with user registration and log-in during which the user inputs his/her credentials like name, email, username and a password to access the application. After completion of log-in, the user can upload or take a photo of the

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substance to which he/she wishes to classify or categorize. The system takes in the typical recyclable and reusable products like wood, metal, cloth, cardboard, and plastic. This is done so that correct input is made into the system to be further analyzed.

Process Phase. During the process stage, the image of the uploaded or captured material is analyzed with the help of the Convolutional Neural Network (CNN). The CNN determines the type of material based on its visual characteristics, i.e. texture, shape and color. Besides, the system checks the quality of the material to establish whether it can be reused. After being identified, the classified material is compared with the database of upcycling projects. According to this match, the system creates individualized suggestions, which are congruent with the input material given by the user.

Output Phase. The results of the analysis are presented in a user-friendly manner at the output stage. To identify the type of material, the system shows the type of recognized material. It then gives the user a list of suggested upcycling projects, depending on the material detected. All proposed projects are accompanied by guides, step-by-step instructions, and instructional videos to make users reuse the material in an effective manner. It will enable the user to recognize their materials and convert them into useful or artistic objects as well, which will encourage sustainable recycling..

III. Methodology

This chapter explains the methods used to design, build, and test the Image-Based Recognition system for recyclable materials using Convolutional Neural Networks. It not only describes the steps taken but also explains why each method was chosen to ensure the study's accuracy and reliability. The chapter covers the study design, the technology model followed during development, the ways data was collected, and the testing procedures used. Overall, it shows how the system was carefully developed and verified to make sure it works effectively in recognizing materials for upcycling projects.

A. Research Design

The Agile methodology is a collaborative and adaptable system development methodology that focuses on accomplishing tasks in small, manageable steps. This is broken down into a series of iterative cycles in which planning, designing, developing, testing, deploying, evaluating, and refining are done not in sequence but in parallel. This cyclic arrangement enables the team to be flexible to changes, factor in feedback regularly, and resolve any possible challenges earlier in the development process. Agile allowed the study to make the necessary adjustments during the development process, maintaining consistent progress and consistency with the goals of the project.

B. Technical Framework

The technical framework provides the system components, overall architecture, and technological tools that will be used to create the Image-Based Recognition System of recyclable materials. It describes the combination of artificial intelligence, mobile development, and database technologies to provide efficient classification, storage, and interaction with users. The system mainly employs Convolutional Neural Network (CNN) developed with the help of TensorFlow, which is an automated image recognition system that identifies patterns, textures, and shapes of recyclable materials like plastic, metal, fabric, cardboard, and wood.

The CNN model is made up of several convolutional and pooling layers, followed by fully connected layers with the activation functions of Rectified Linear Unit (ReLU) and Adam optimizer, and categorical cross-entropy as the loss function. This model was trained on a large-scale dataset consisting of about 4,000 to 5,000 valid image sets per subcategory of recyclable materials- giving a total of about 25,000 training images of plastic, metal, fabric, cardboard, and wood. The collection of these images was based on open-source data and locally obtained samples in various light conditions and settings to enhance diversity and avoid bias. Before training, all images were preprocessed by normalizing, resizing to 128x128 pixels, and data augmentation techniques, including rotation, flipping, and brightness changes to increase generalization and model robustness.

Figure 3.1: Agile Methodology

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1. Planning

The proponents initially identified the viability and extent of the system. The needs were collected via interviews and questionnaires to people who are well acquainted with the recycling process and sustainability efforts. The results showed that participants were highly supportive of an AI-based mobile application that could recognize materials and deliver educational information about upcycling. Following these findings, the developers found five target material categories, which are plastic, metal, wood, fabric, and cardboard. The training of the Convolutional Neural Network was carried out using open datasets and local sources (approximately 25,000 images (5,000 per category)).

2. Design

To visualize the architecture and the overall structure of the system in the CNN-based image recognition model, the proponents developed diagrams, workflows and mockups. The design phase consisted of creating the CNN model to do image classification, constructing a preprocessing pipeline to make sure that images are normalized prior to training, and defining the initial user workflow to use to interact with the system. These design outputs were blueprints that clearly showed how the system components would operate and how they would interrelate with other components.

3. Develop

The development stage was aimed at converting the system design blueprint into a fully operational application by writing a code that would mobilize all the necessary structures. The cross-platform mobile interface was created using React Native by the team, and it was designed in such a way that the users would find it easy to interact with the system, having a clean and responsive layout. The data handling, workflow management, and communication between system components processes were deployed at the back end. The analysis was made using the Convolutional Neural Network (CNN) model that is developed in the TensorFlow and that can analyze images and correctly identify materials as the central part of the system. This model was well incorporated in the system to allow automated recognition and classification. Parallel to this, a PostgreSQL database was created to store user and material data supporting safe storage, retrieval, and updates. All these elements have created a complete platform of a system that was user-friendly, effective in data management, and smart in image recognition, thus enabling the system to fulfill its purpose.

4. Testing

Figure 3.1.1: Stakeholder Testing and System Feedback Documentation

The proponents carried out a number of testing processes as they developed the material recognition system to make sure that the application did what it was supposed to do. Unit testing was done as the initial step to test each component separately and integration testing was done to test the compatibility between modules. Moreover, other stakeholders like local stores that manufacture products using recyclable materials were also included to give feedback on the system on its accuracy, usability and general functionality. Their feedback and suggestions were thoroughly considered to find potential ways that could be improved and to make the system fit real-life applications. This process guaranteed the system was not only working as intended but also gave credible output and recommendations on the project that were meaningful and contributed to sustainable practices and businesses making maximum use of recyclable materials.

5. Deploy

Once the application was tested successfully, it was released to live demonstration on the mobile platforms. Users are able to scan recyclable materials with their device camera or gallery, and receive tutorial suggestions. The deployment confirmed the effectiveness of the system in the real world and helps to raise environmental awareness at the community level.

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6. Review

In this continuous phase, the system undergoes regular review and evaluation based on user feedback and performance metrics. This ensures that the application remains reliable, efficient, and responsive to the needs of its users. Features are iteratively updated to introduce improvements, fix issues, and enhance overall usability. Furthermore, the Convolutional Neural Network (CNN) model can be retrained using new datasets to achieve better accuracy and adaptability over time. By refining both the technical components and user experience, the system is able to maintain long-term effectiveness and remain aligned with its goal of supporting sustainable material management.

C. Data Gathering Techniques

The two main methods were used in data collection about the study. The first one, interviews were carried out with the experts, who were chosen because of their knowledge and experience in the field of material properties and classification. The aim of these semi-structured interviews was to determine the properties of materials like wood, fabric, metal, and plastic, their reusability, as well as, the best practices and issues regarding classification. Secondly, a survey was also done on the potential users and beneficiaries including those individuals who were involved in the recycling of recycling or the sustainability of the environment. These surveys were able to give insight on the needs of the users, challenges and preferences of the users so that the mobile application can be created to be practical, user-friendly and relevant.

D. Sampling Methods

The stakeholders consisted of local stores that use recyclable materials for their products, while the respondents were crafters and small business owners engaged in upcycling practices. This selection is based on the primary users and their knowledge, experiences, and preferences in identifying materials suitable for reuse and repurposing. Purposive sampling was chosen because the participants needed to meet specific criteria relevant to the evaluation of the image-based recognition system for recyclable materials.

E. Data Analysis Procedures

The majority of the responses on the participants were gathered and processed to verify what should be enhanced or introduced. The findings revealed the necessity to diversify the material types, make the model more precise, and simplify the user interface to make it easier to use. These enlightenments will be a guiding force to develop the system further to be more efficient and effective in recycling and upcycling.

F. Validity and Reliability Measures

To determine the validity of the study, the system was tested on numerous occasions with real users that comprised crafters and small business owners that were involved in upcycling. The survey tools were also validated and constructed with clarity, relevance, and appropriateness to ensure that fruitful feedback is collected. The content validity was also strengthened as the analysis of user responses was performed relative to the desired functions and objectives of the system in order to make sure that the instrument measured what it was designed to measure. Reliability was also assured by first having repeated trials, in which the system had consistently given correct material recognition and project recommendations during the various test sessions. This consistency reflected the stability, reliability and reproducibility of the system thus making the study findings valid.

Ethical Considerations

The research was carried out in terms of ethical guidelines and procedures, so that all the system testing and feedback involvement was voluntary, with the participants being fully aware of the aims of the study as well as their consent having been received. The information gathered about the users was restricted to the images of the material needed to be identified and upcycled in accordance with the data reduction principle. To maintain security, confidentiality, and privacy, secure storage methods such as encryption and access controls were used so that access can be denied to unauthorized persons. Transparency was also ensured by notifying the users about the manner in which their information would be utilized as well as using simple and comprehensible language of information handling. Moreover, the application of information was limited to the pure purpose of the material identification and suggestion and no other irrelevant or inappropriate uses were made. These strategies guaranteed the responsible usage of technology and protection of user rights and data security.

IV. Results and Discussion

Results

The survey involved 300 respondents in order to test Image-Based Recognition of Recyclable Materials with Convolutional Neural Networks (CNN). The evaluation included stakeholders like students, crafting enthusiasts, homeowners and small business owners, and the participants were also represented by Papelmelroti and the Mandaluyong Manpower and Youth Development Center, TESDA and Manila City Jail. The assessment was done in terms of the eight quality criteria of ISO/IEC 25010: Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability. The ratings were measured on a 5-point rating scale (1 = Poor to 5 = Excellent). Mean scores and visual graphs were used to summarize the

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results in order to have a better idea. In this section, the findings are presented and discussed in relation to the objectives of the study.

Results

A. Functionality

The General Weighted Mean of the system under Functional Suitability was 4.62 (Excellent). The respondents said that the app offers the required functionality to identify the recyclable materials, distinguishes between similar-looking objects, and recommends the appropriate upcycling options.

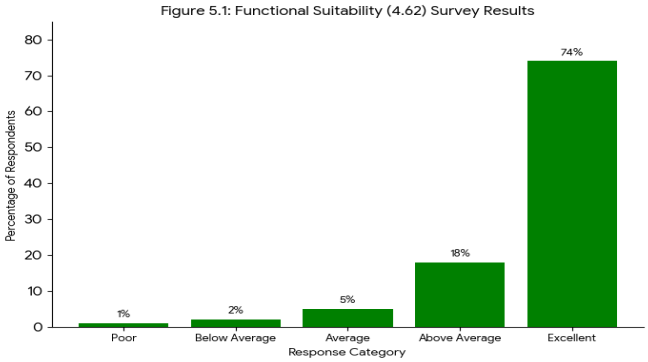

Figure 5.1: Functional Suitability Bar Graph.

The figure indicates that the majority of the respondents rated the app at 5 (Excellent) in all the items, especially in functional completeness and correctness. This proves that the recognition core features are extensive and precise with a minimal percentage of rating it otherwise.

B. Performance Efficiency

The system had a General Weighted Mean of 4.38 (Above Average) in Performance Efficiency. The respondents also added that the application takes only a few seconds to scan, and reacts instantly to user input and that the performance is smooth even when several results are stored in the history.

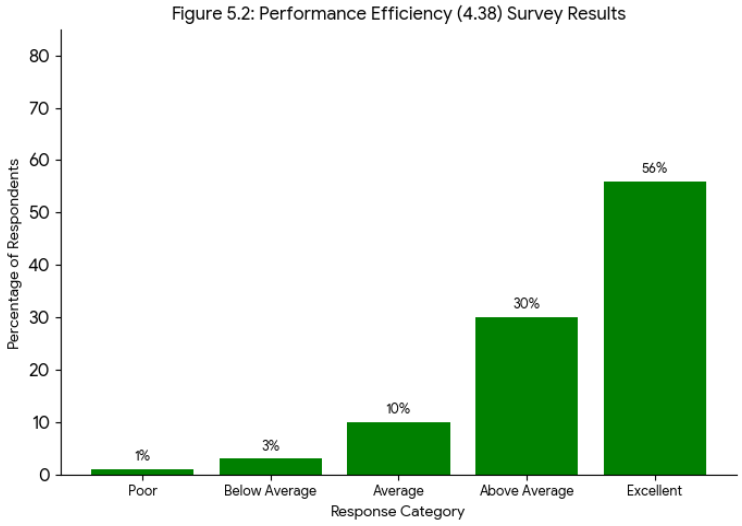

Figure 5.2 Performance Graph

It means that the application is capable of managing tasks without slowing down or crashing, which guarantees fast and stable recognition, which improves user experience. The respondents affirmed that it needs to have fast recognition and consistent performance to be used in everyday life.

C. Compatibility

The system received a General Weighted Mean of 4.41 (Above Average) on Compatibility. The users reported that the application is perfectly compatible with the device cameras and galleries, and they can upload photos stored in their devices without any failure, and the application does not conflict with other applications being used in the background.

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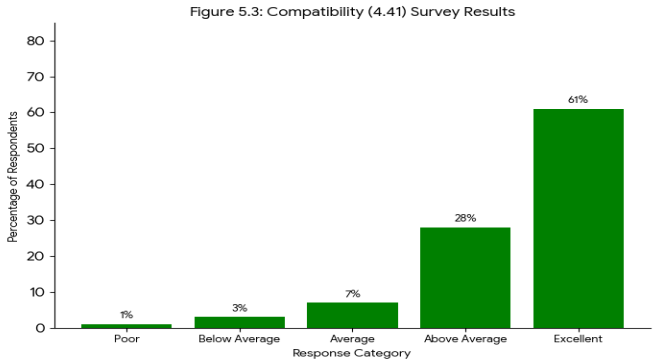

Figure 5.3: Compatibility Bar Graph.

This means that the system is compatible in the various device environments especially in the integration of scanning functions without interfering with other mobile processes. The respondents affirmed that compatibility makes the app flexible and easy to use**.**

D. Usability

The system scored a General Weighted Mean of 4.71 (Excellent) on Usability. The vast majority of the respondents highly rated that the application is easy to learn, easy to navigate, and visually appealing. There are also error warnings of unclear images that reduce the errors made in scanning.

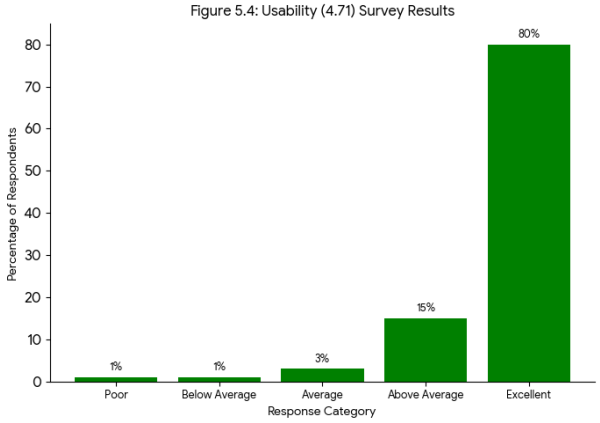

Figure 5.4: Usability Bar Graph.

This means that the system is user-friendly and can be readily embraced even by the novices. Respondents affirmed that it is convenient to use in daily life due to the easy-to-use interface and simple functions.

E. Reliability

The Reliability of the system was rated with a General Weighted Mean of 4.46 (Above Average). The respondents noted that the application is always accurate, scan history is stored in a secure place, and the application is stable even after extended usage.

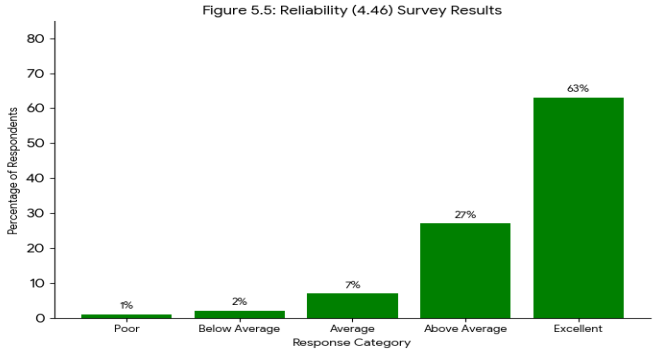

Figure 5.5: Reliability Bar Graph.

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This means that the system has reliable operations and that user data is maintained. Respondents affirmed that reliability is essential in the development of trust and constant usage of the application.

F. Security

The General Weighted Mean of Security in the system was 4.59 (Excellent). The respondents indicated that they were confident that the application secures their data with the help of secure authentication, adequate permissions, and clear management of personal information.

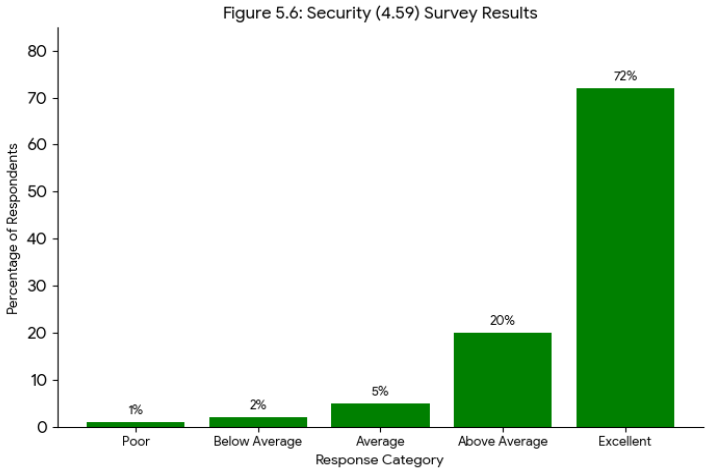

Figure 5.6: Security Bar Graph

This implies that the system protects the privacy of users and ensures integrity of findings. The respondents affirmed that security measures make them have confidence in using the app on a regular basis.

G. Maintainability

The General Weighted Mean of 4.32 (Above Average) was achieved in the system in Maintainability. Users felt that updates can be made in a smooth way without interfering with the features already available and that the error messages are clear and understandable in terms of recognition problems.

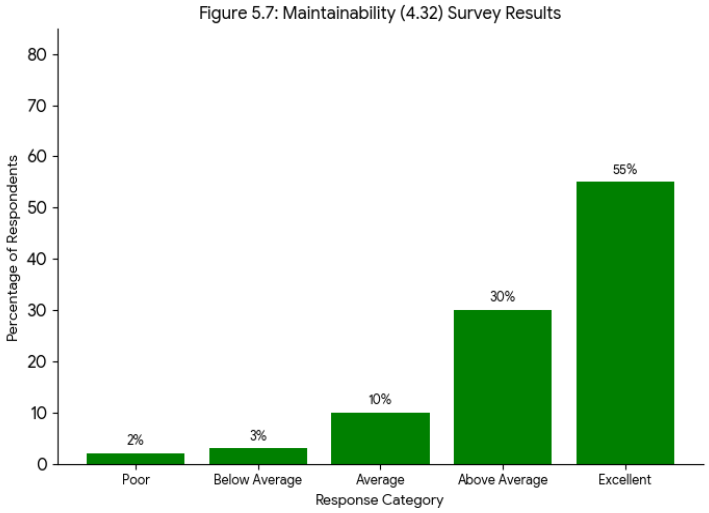

Figure 5.7: Maintainability Bar Graph.

This shows that the app is sustainable in its structure and it can sustain long-term improvements. The respondents affirmed that maintainability assists in ensuring that the system will keep on evolving with the needs of the users.

H. Portability

The Portability was rated at 4.67 (Excellent) in the system. The respondents concurred that the app is simple to install, scales well to various screen sizes and works reliably across Android devices.

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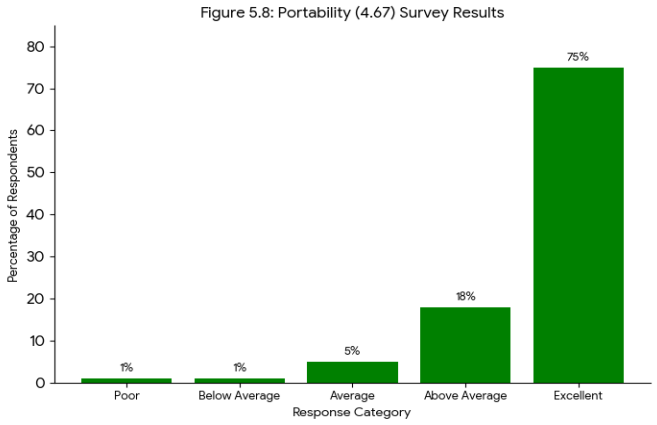

Figure 5.8: Portability Bar Graph.

This implies that the application can be applied easily in various devices and therefore it is accessible to a large group of stakeholders. The respondents affirmed that portability guarantees flexibility and easy adoption.

I. Evaluation Metrics

Criteria	General Weighted Mean	Verbal Interpretation
Functional Suitability	**4.62**	**EXCELLENT**
The app offers all functions required for recognizing recyclable materials.	4.61	EXCELLENT
The app accurately identifies the type of recyclable material in each scan.	4.63	EXCELLENT
The app's suggested recycling/upcycling options are relevant and useful.	4.62	EXCELLENT
The app successfully recognizes and provides information for the established set of core recyclable material categories it is designed to cover.	4.6	EXCELLENT
The app successfully differentiates between similar-looking materials when scanned.	4.64	EXCELLENT
Performance Efficiency	**4.38**	**ABOVE AVERAGE**
The app processes image recognition results quickly.	4.36	ABOVE AVERAGE
The app's performance remains consistent and fast even after the user has accumulated a large history of saved scan results.	4.41	ABOVE AVERAGE
The app's interface responds immediately to user input.	4.35	ABOVE AVERAGE
The app maintains performance without causing my device to lag or crash.	4.4	ABOVE AVERAGE
Compatibility	**4.41**	ABOVE AVERAGE
The app's camera function and scanning process do not conflict with or interrupt the use of my device's default camera or gallery apps	4.4	ABOVE AVERAGE
The app allows for the seamless uploading of pre-existing photos from my device's gallery for material recognition.	4.42	ABOVE AVERAGE
The app does not interfere with device notifications or other background apps.	4.44	ABOVE AVERAGE
The app accepts images from different sources (camera, gallery) without issues.	4.39	ABOVE AVERAGE
The app's image scanning process does not interrupt or freeze other apps that rely on the internet connection.	4.4	ABOVE AVERAGE
Usability	**4.71**	**EXCELLENT**
The app is clear what it is designed to do when I first open it.	4.72	EXCELLENT
The app teaches me how to scan and use the features quickly.	4.7	EXCELLENT
The app's navigation through the app is simple and intuitive.	4.73	EXCELLENT
The app warns me when I perform an action incorrectly (e.g., bad image quality).	4.69	EXCELLENT
The app's colors, fonts, and layout make it pleasant to use.	4.71	EXCELLENT
Reliability	**4.46**	**ABOVE AVERAGE**
The app consistently provides an accurate scan result or error message instead of freezing or failing silently.	4.45	ABOVE AVERAGE
The app is available and responsive whenever I want to use it.	4.48	ABOVE AVERAGE
The app recovers smoothly after an error or failed search.	4.47	ABOVE AVERAGE
The app saves my scan history so I don't lose important data.	4.46	ABOVE AVERAGE
The app remains stable even after prolonged use without restarting	4.45	ABOVE AVERAGE
Security	**4.59**	**EXCELLENT**
The app clearly explains how my personal data is handled, ensuring its privacy and secure storage.	4.61	EXCELLENT
The app ensures scan results and user inputs are not altered improperly.	4.58	EXCELLENT
The app maintains logs of my activities securely if needed.	4.6	EXCELLENT
The app's account management screen allows the user to securely change their password and contact information.	4.57	EXCELLENT
The app requires appropriate permissions and authentication when accessing device features.	4.33	EXCELLENT
Maintainability	**4.32**	**ABOVE AVERAGE**
The app receives regular updates that improve functionality.	4.33	ABOVE AVERAGE
The app's new features are added without affecting existing ones negatively.	4.31	ABOVE AVERAGE
The app's error message clearly indicates what went wrong (e.g., poor light, unsupported material) when it fails to recognize a material.	4.32	ABOVE AVERAGE
The app is flexible and evolves to include requested features.	4.34	ABOVE AVERAGE
The app's design makes it possible to test the image recognition output independently of the user interface display.	4.3	ABOVE AVERAGE
Portability	**4.67**	**EXCELLENT**
The app successfully performs image recognition and displays results correctly across different models and manufacturers of Android devices I have used.	4.66	EXCELLENT
The app downloads, installs, and starts up on the Android testing devices without requiring complex configurations or troubleshooting steps.	4.68	EXCELLENT
The app's core functions (e.g., image recognition) work immediately and correctly after a clean installation on a new device.	4.67	EXCELLENT
The app's interface adapts properly to different screen sizes (phone and tablet).	4.65	EXCELLENT
The app requests only the necessary permissions (e.g., camera access) during the installation or first launch.	4.69	EXCELLENT

Figure 5.9 Overall Summary Survey

This study garnered an exceptionally positive overall assessment across all quality characteristics, resulting in a majority of categories achieving an Excellent rating and the remainder being rated as Above Average. Specifically, Usability (4.71), Portability (4.67), Functional Suitability (4.62), and Security (4.59) all surpassed the 4.50 threshold for Excellent interpretation, proving the application is user-friendly, functionally robust, secure, and widely accessible. The remaining categories Reliability (4.46), Compatibility (4.41), Performance Efficiency (4.38), and Maintainability (4.32) all fell into the high end of the Above Average range (3.50, 4.49), collectively indicating that the system is highly effective, stable, and ready for integration into daily use with strong core features and a minimal need for immediate improvement.

V. Discussion

The survey results of the system, based on the high General Weighted Means (GWMs), provides a strong, positive affirmation of the students' hard work and the application's overall quality. The results weren't just good; they were excellent in key areas, proving that the team didn't just build an app that works, but one that people actually enjoy using.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue IX, September 2025

The most exciting news for the student team lies in the four criteria that hit the Excellent rating (GWM 4.50). The top score for Usability (4.71) is a triumph, confirming that the interface is simple and intuitive, making it easy for anyone, even a total novice, to pick up and use instantly. This success in user-friendliness is matched by the high Functional Suitability score (4.62), which validates that the app's core job identifying and differentiating materials is precise and effective. Furthermore, the students successfully delivered on modern expectations for Portability (4.67) and Security (4.59), ensuring the app works reliably across different devices and builds user confidence regarding data privacy.

While the other four categories—Reliability (4.46), Compatibility (4.41), Performance Efficiency (4.38), and Maintainability (4.32) were rated Above Average, they still reflect strong, dependable performance. The students proved the app is fast, stable, and plays nicely with the device's camera and other background apps. The Reliability score, in particular, is extremely close to the Excellent threshold, suggesting that the system is highly dependable. Moving forward, the students have a clear path for refinement: focusing on the slight margin of improvement in Maintainability will ensure the app's structure is future-proof, allowing for smooth, hassle-free updates down the road. Ultimately, the survey gives the student team overwhelming validation that they successfully built a high-quality, practical, and well-received mobile solution.

VI. Conclusion and Recommendations

Conclusion

The study, "Image Based Recognition for Recyclable Materials Using Convolutional Neural Network," is a significant achievement for the student proponents. It successfully applies machine learning theory to a practical, real-world solution. The project aims to address a major challenge: many people struggle to identify reusable materials and find personalized upcycling ideas, which often results in valuable items being thrown away. The students achieved their goal by creating a mobile application that uses a Convolutional Neural Network (CNN) to recognize materials and suggest specific upcycling projects.

The final evaluation provided strong support for the system's quality. The high General Weighted Means (GWMs) showed that the complex technical elements, like the CNN, were well integrated into a functional tool. The system received an Excellent rating in four important areas, especially in Usability (4.71) and Functional Suitability (4.62). This proves that the app's image recognition is precise and that the interface is easy and intuitive for anyone to use. All other criteria, including Reliability and Performance Efficiency, also scored as highly Above Average, reassuring users that the app is stable, fast, and reliable.

In summary, the students have met their academic and technical goals, offering a practical solution that connects artificial intelligence technology with environmental sustainability. This project is more than just an academic exercise; it provides a high-quality tool that benefits students, crafters, and the broader community by encouraging creative reuse, reducing waste, and fostering a more sustainable approach to resource management. The study not only meets their degree requirements but also establishes a strong, practical foundation for future developers in the growing field of smart, eco-friendly technologies.

Recommendations

To improve the performance of the system and user satisfaction further, a few improvements are suggested according to the criteria that scored relatively lower mean scores. On one hand, the overall functionality of the app proves to be very strong; on the other hand, the indicator related to the responsiveness of the system in the condition of a long-term usage (4.34) and the performance of the application after several scans (4.36) indicate the need to optimize the memory management and the background processing; the enhancement of the application resource management will allow maintaining the speed and stability after a long time of use. Second, the criterion related to processing unsupported or low-quality images (4.33) notes that the more effective notification system should be provided to ensure that the users are informed when the material is not recognized and given the clear guidelines of how to re-take or improve the input. Third, offline scanning and recognition performance (4.36) can be improved by adding some offline functionality or offline caching processing, such that it becomes more usable in low-connectivity settings. Finally, since the user will rely on a smooth interaction process, features must be optimised to reduce when a system freezes or slows down when scanning processes, especially when it involves multistage operations. Performance tuning in these areas, better user guidance and better offline handling will improve the reliability of the system and overall user experience in the future.

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