# ESPYREAL: A Mobile Based Multi-Currency Identifier for Visually Impaired Individuals Using Convolutional Neural Network

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## ABSTRACT

Visually impaired person's faces many issues in handling money because they cannot differentiate different denominations especially in countries like the Philippines where both local and foreign banknotes are circulating together. This challenge may lead to various issues like the misidentification of paper money or coins, depending on others for financial matters, and being open to possible exploitation of finances. Therefore in this study the proponents implemented an image processing techniques that will assist visually impaired people in detecting and identifying money using convolutional neural network algorithm. The main objective of this application is to help the visually impaired individuals identify two different denominations that is commonly used in the contemporary time of the Philippines such as United States Dollar (USD) and Philippine Peso (PHP), making them feel secured and confident when they are conducting financial transaction alone. The application will be implemented as Android-based money detection app. The researchers utilize the AGILE and Tensoflow platform to build accurate and fast model. They collected diverse amount of Philippine Peso and United States Dollar banknotes and coins images, captured in different angles and lighting condition to achieve reliable model for Multi-Money Recognition Application. Furthermore, The proponents created a likert scale questionnaire that will use for survey and interview with visually impaired stakeholders in Pasay, Manila. Based on ISO/IEC 25010 evaluation, Espyreal achieved excellent ratings across functionality (4.74), usability (4.72), performance efficiency (4.64), reliability (4.60), and portability (4.58), with an overall weighted mean of 4.60. A 98 percent accuracy across all bills is achieve through diverse collection of bills datasets and aggressive training with Tensorflow platform. The results demonstrate that the system is functional, dependable, efficient, and user-friendly. The proponents suggest to upload the Espyreal to the Google Play Store for Easy access and download for the intended users.

**Keywords**: Tensoflow, Multi-Money Recognition Application, CNN.

## INTRODUCTION

Nowadays, technology is growing fast. By the use of technology, people are able to solve their problems within the small passage of time. Some applications are used in real life which includes currency monitoring systems, currency counting machines, currency exchange machines and currency recognition systems to help for blind or visually impaired people. Imaginative and perceptive no longer only facilitates us to carry out each day activities however also impact the behavior of the individual. Normal people can easily recognize the currency, but it becomes very difficult for the visually impaired to accurately recognize the currency. The blind or visually impaired people need to recognize and also adapt to differences among the note currencies

Tom [1] writes in his article that blind or visually impaired people must be able to distinguish their currencies swiftly and safely while paying and receiving change. In the U.S., all bills are the same size. Blind people can't tell denominations apart. Banknote sizes are different in several countries, such as India, Australia, Malaysia and Philippines, making money identification easier. Blind people may measure and identify money with a money identity card. When a currency is lined up with the card, tactile markings determine which bill to use. However, the blind individual needs help to determine money's value. Another way is blind people can fold

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money for specific denominations. However, they may have trouble sorting through many denominations while carrying multiple currencies. Tom said that identifying money varies by necessity and currency, and each choice has pros and cons. If people could distinguish banknotes by touch, life would be easier, improving and securing cash identification.

Therefore This study seeks to develop Espyreal: A Multi-Currency Identifier that will give a reliable, user-friendly, and accessible tool to the visually impaired sector in the Philippines. Through technology, including image identification and voice feedback, the system will be able to let the users properly identify banknotes by themselves without anyone's intervention. The significance of this study lies in its contribution to realizing financial inclusiveness, independence, and security of the visually impaired population, in compliance with the higher objective of accessibility and equal opportunity for all. This research aims to give a dependable and accessible solution that equips the visually impaired to handle money confidently and securely in day-to-day transactions.

**Related Studies**

According to [2], In India, nearly 12 million visually impaired people had difficulty in identifying the currency notes. Due to this problem the proponents in this study propose a solution called Coinnet. The proposed system is developed using TensorFlow and improved by selection of optimal hyperparameter value, and compared with existing well known CNN architectures using transfer learning. Based on the results it has been observed that the proposed model performs well over six widely used existing architectures in terms of training and testing accuracy.

A Study by Pathak, A. & Aurelia, S. [3] Stated that Around 37 million people Visually impaired individuals in India face challenges in checking the currency due to the lack of Braille systems and the similar sizes of each currency. To address this issue, a mobile-based Indian currency detection model is proposed, which uses image processing for feature extraction and a basic CNN for currency identification. This model is being developed into a mobile application, allowing visually impaired individuals to quickly check for potential frauds. The results are promising, around 80% of the visually impaired are relying on this application to identify banknotes.

A study by Kumar, K., et al. [4] a special mobile application designed for support of visually impaired people during identification of currency throughout transactions. By employing the Random Forest Classifier in conjunction with OpenCV, it correctly identifies many different currency notes. It does so through machine learning. The Text-to-Speech function tells people the identified amount, while also helping independence and swift payment.

According to the study of Vivien Agustin, et al [5] A visually impaired individuals face challenges in recognizing banknotes due to the similarity of paper texture and size between different categories. To address this, researchers have developed an Android-based money detection app called Eyessential, which uses image processing. The app is functional, reliable, helpful, efficient, maintainable, and portable. The developers suggest submitting the Eyessential Android app to Google Play for easy installation and compatibility with Google Assistant for blind users. A flashlight option is also proposed for user-friendliness. To accurately detect denominations, substantial data sets are suggested.

In the study of J. A. P. De Jesus, et al [6] Visually impaired people must have tools, assistant devices, or organizations that guide them throughout their lives but at a certain point, other visually impaired are lack of material especially in learning. Researchers in this study believed that having an environment that supports visually disabled people will serve as their great foundation throughout their lives.

**Conceptual Framework**

This part focuses on the structure framework of the application for better understanding and analyzing how the application works, and how it processes gathered information.

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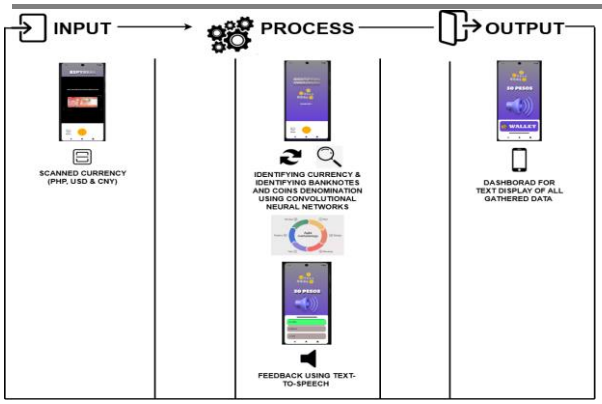


Figure 1: input-process-output model (IPO)

Figure 1 illustrates how Espyreal application workflow using input-process-output model, in the input stage, only needs a scanned currency, using the phone camera of the end-user to scan a banknote and coins.

The process stage consists of recognizing scanned currency and identifying banknotes & coins denomination using Convolutional Neural Networks, and feedback using Text-To-Speech. To identify the scanned currency, it needs to be compared by its key features such as patterns, color, size, etc. With the help of Convolutional Neural Networks to recognize and identify the scanned currency denomination and its type of banknote whether it is a Philippine Pesos and United State Dollars Then the system will start processing the gathered data and turn it into audio feedback using text-to-speech, the system will announce the scanned currencies type and denomination for more accurate currency identification. Additionally, the system will ask the end-user if they want to add the current banknote to the next scanned currency for easy and smooth transaction.

And in the output stage the application will announce the scanned currency denomination, type, and the current counted banknotes. Thereafter, the system will show a text display of all the gathered data of the application ensuring a secure user experience. This application encourages and empowers individuals with visual impairment to do transactions securely and confidently.

**Application Development**

For the application development, the proponents in this this adapt the AGILE Life Cycle Model due to the reasons that the the agile model was primarily designed to help a project adapt quickly to change requests which is suited for the application development and prototyping. The primary use of the Agile model in this study is to facilitate quick project completion. To accomplish this task, it is important that agility is required. Agility is achieved by fitting the process to the project and removing activities that may not be essential for a specific project. As a result, the propronents can ensure that their target users are satisfied with the quality of their work.

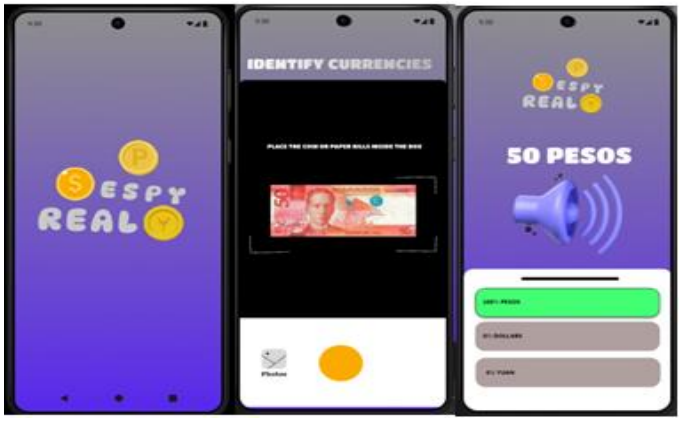


Figure 2: Espyreal Prototype

Figure 2 shows how will the system work after the development, First the when the user first launch the application it will directly go to the loading screen or splash-screen where all Philippine peso model and United

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States Dollar Model will load during that time where in approximately 2-3 seconds. After that, the application will immediately proceed to the identifying section where in the users have accessible button and medium view camera, if the users click or push the capture button it will capture the image and passed to the model, the model will identify what is the denomination of the bills and give the result to the screen with audio announcement. The big buttons and easy navigation of the application was intentional because the main target of the application is visually impaired, making the application user-friendly and reliable.

**Requirements Gathering**

The agile first phase is requirements. In this phase, the proponents must identify and gather the key requirements needed to develop the project and understand what the customer or end-user needs by interacting with them through surveys or interviews to make sure that everyone is on the same page.

This phase also holds the planning of how much time and effort the developers should give to assess if the project is technically possible and whether it is worth the investment from both technical and economic standpoint.

Furthermore, The proponents must learn deep learning techniques such as Convolutional Neural Network (CNN) for recognition and identification of the currencies and a subfield of Natural Language Processing (NLP) which is for the text-to-speech feature for audio feedback which is required to build the Espyreal. And conduct a survey and interview to identify the needs of the visually impaired when it comes to handling and managing money. Additionally The proponents must gather and study different platforms and tools that will use in the development of the application. In this phase the proponent decided what features of the application can help the visually impaired and what features and functionality they will need to make the Money Identifier application more accessible and usable to them.

**Design**

The agile second phase is design, in this step, the proponents will create a plan or design for the application or system based on the gathered requirements. The proponents will use a user-flow-diagram to discuss how the application works, it is shown in the Conceptual Framework figure number 1 the IPO or the input process output. Figure 2 illustrates the appearance of the money identifier application. Once the app is open, it requires no input from the user and directly navigate to the identifying screen, which will be easily accessible to the visually impaired. The planned design of the user interface is done in this phase, this shows how the application will look and how the end-users will interact with it, ensuring it is user-friendly and easy to navigate.

As for the user interface, the proponents designed a simple but interactive UI/UX that will meet the needs and satisfaction of the end-users, and to do this, the proponents will use Figma for prototyping due to it being the best option for designing and simulation of the application,

For the developing an interactive mobile-based application the proponents decided to use react-native to achieve the modern and clean looking UI/UX. Espyreal is designed to be straightforward ensuring it is an easy to use tool for the visually impaired.

**Development**

The agile third phase is the development, in this step, the developers will start developing the core components of the application based on the gathered requirements and planned design. In this phase of the development model happens the actual programming and building of the application to make it functional and accessible when it moves on to the next phase.

The proponents start by establishing the needed datasets and build the foundation and core frameworks of Espyreal such as the system algorithms, specifically the Convolutional Neural Network (CNN) that will classify and identify the currencies and polish all errors that will occur in the application. This phase also holds the creation of the user interface that will allow the end-users to use the functionalities of the application with ease that will meet the needs and satisfaction of the visually impaired individuals.

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The proponents use old phone camera and new phone camera to capture PHP and USD bills and coins, this approach ensure that the result of the model is accurate on all devices whether the user phone is old and new. After gathering the datasets is normalize in google-collab and apply medium to light augmentations to achieve accurate results in real-world usage. The proponent's will maximize the Teachable machine capabilities to train the datasets because it allows the proponents to build and test the model in short period of time. Moreover the proponent's will use React Native to build the pipeline and image processing functions to ensure that the image that will capture of the application is correctly passed down into the models. In addition the React Native will be used to create the design, functionalities and user interface. These include the Loading screen, identification section, Audio Announcement Integration and offline capabilities. The Espyreal Application will be developed on Lenovo Ideapad Slime one 8GB ram Laptop with AMD Ryzen 3 5300U with Radeon Graphics.

**Testing**

The agile fourth phase is the testing, it is the most fundamental part of the agile model for the reason that iteration development happens in this phase, ensuring that the quality of the product is at its best ensuring to deliver a reliable product for the target audience of the study.

In this stage, the proponents conduct an iterative system testing to evaluate and review the system performance and ask for a second opinion with the application target audience for any refinements.

After the application is done, the proponents will first test the model in the teachable machine testing area, where the proponents feed the new images of banknotes and coins into the model to test its accuracy and once it is accurate in the teachable machine, the model is exported and eventually integrated into the application where in the proponents will test the model on the banknote and coins from different conditions, if there is any color shifting, and if there are any changes to the quality of the banknote, and as for the coins the proponents will check the size and if there is deformation,

Moreover, the proponents prepare a likert scale interview questionnaire for the intended users in Philippine national School for blind in Pasay to evaluate and test the application, the questionnaire is also based on the ISO 9126 criterion to make sure both models and application satisfy the user needs and demands.

This study uses purposive sampling to select visually impaired participants based upon their own availability and willingness for participation. One hundred Fifty (150) visually impaired individuals in the Philippine National School for blind were selected to test the functionalities and accuracy of the application.

**Deployment**

In the fifth phase is the deployment part, in agile this phase where finished software is made available to end-users in a production environment. It is a crucial phase due to the reason that it allows the developers to get feedback from users. This phase of agile methodology ensures that the software or application is stable and ready for users.

After the testing and evaluating the system performance and checking any vulnerable part of this system application, the proponents will deploy it first using a link provided by the react native platform, the intended users can download application through qr code or link, if is easy to install, once the user download the apk in the link, he/she can install it immediately to identify both USD and PHP. The proponents suggest to submit the application in the google play store so that visually impaired can download it, anywhere and anytime. Additionally, the users are required to have internet connection they want to download it, but once it installed, the functions and identification that are available in the app is offline.

**Review**

In the last stage, review is the last phase of the agile methodology. In this phase, the developers will review the process helping ensure that the team and stakeholders are aligned on the product vision and objectives.

After the deployment the proponents will review system performance based on the target audience feedback,

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and make any changes to the application to ensure stability of the system functionality and adaptability, meeting end-users satisfaction.

### Espyreal Algorithm

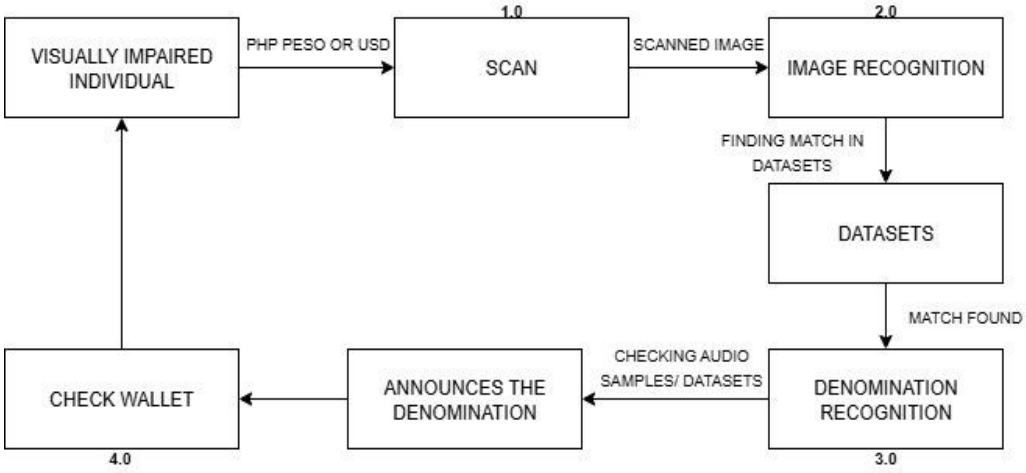


Figure 3 : Dataflow Diagram of Espyreal

The Data Flow Diagram (DFD) of the Espyreal Application as shows in the figure 3, shows the application flow and process under the hood, These process involved several steps such as scanning and identifying the money of the visually impaired user once it captures image. The algorithm will start running once the visually impaired user scan the money, the application will detect the images and feed the images into the model. After that the Tensorflow.js model will process the image and try to identify the image, once the model correctly identify the image, it will give the result back to the application. Then the application will start process that result into the User interface of the application with loud and clear voice announcement. It displays how the applications identify the money of visually impaired users under the hood.


Figure 4: Generated Sample Money Identification (a)-(e) True Positive Results (f) True negative.

## RESULTS AND DISCUSSION

### Philippine and United States Dollar Recognition

The developers have created a simple yet modern GUI or Graphical User Interface. The use of the Espyreal Application is simple and straight forward, once the application runs, it is ready to identify the bills and required

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no input to the visually impaired users, making the application both accessible and easy to use. Multiple test have been implemented in the testing phase of the application, the bills is captured in every direction and angles visually impaired might identify. As shown in figure 6. In addition the figure clearly shows the equivalent percentage in accuracy form. As shown, the results is promising, from (a)-(e) the results shows 99% percent of accuracy. Although the application is challenge if the bill is far way from the camera. Furthermore in order for the model to have accurate results, at least half of the bill should be seen in the camera. In addition the application allow the users to scan the bills in natural, dim, and dark lighting due to the capability of the application to enable the flashlight or torch functions on the phone. The proponents were able to achieve (90-99%) of accuracy on both PHP and USD bill datasets especially on the 20pesos, 50pesos, 100pesos, 200pesos, 500pesos, 20 dollars, 5 dollars, 1 dollars, 50dollars, 100 dollars. Moreover the application is limited only to the USD and PHP bills and coins due to the datasets and financial limitations.

**Evaluation based on ISO 9126-1 criterion**

A survey of 150 visually impaired individuals in Philippine national school for blind was conducted, sixty two (62) of them are utterly blind, eighty eight (88) of them are partially blind. The ISO 9126-1 survey questions were created to evaluate if the application actually help them to identify common currencies that circulating in the Philippines and also if the application make their day-to-day transaction safe and easier. In addition by creating this questions it also allows the proponents to gather feedbacks and improve the application catering their needs and satisfaction. Goggle forms were use to analyze and quantified the data gathered answers from the visually impaired participants, ensuring the data is clear and accurate.

**Functionality**

Functionality refers to the application's usefulness or efficiency. The app received 4.74, 4.74, 4.76, 4.72, and 4.58. Mean scores for criteria 1 to 5, respectively, as clearly shown in the table below

| CRITERIA | GENERAL WEIGHTED MEAN | INTERPRETATION |
|---|---|---|
| **1. Functionality** | 4.74 | Excellent |
| ESPYREAL successfully identifies all currency denominations I need to recognize. | 4.76 | Excellent |
| The currency identification results are consistently accurate and precise. | 4.74 | Excellent |
| The app's functions are well-suited for visually impaired users' needs. | 4.72 | Excellent |
| **2. Performance Efficiency** | 4.64 | Excellent |
| The app identifies currencies quickly enough for practical real-world use. | 4.66 | Excellent |
| ESPYREAL uses device resources efficiently (battery, memory, processing). | 4.64 | Excellent |
| | | |
| The app maintains consistent performance across extended use. | 4.62 | Excellent |
| **3. Compatibility** | 4.56 | Excellent |
| ESPYREAL works well alongside other accessibility applications. | 4.58 | Excellent |
| The app integrates effectively with device accessibility settings. | 4.54 | Excellent |
| **4. Usability** | 4.72 | Excellent |
| It is clear that ESPYREAL is designed for currency identification. | 4.75 | Excellent |
| The app is easy to learn and use, even for first-time users. | 4.74 | Excellent |
| All functions can be accessed effectively using gestures/voice/audio. | 4.72 | Excellent |
| The app prevents errors and provides clear guidance. | 4.71 | Excellent |
| The audio interface and overall user experience are pleasant. | 4.70 | Excellent |
| ESPYREAL fully supports screen readers and visual impairment levels. | 4.70 | Excellent |
| **5. Reliability** | 4.60 | Excellent |
| ESPYREAL rarely crashes and performs consistently. | 4.62 | Excellent |
| The app is always available when needed. | 4.60 | Excellent |

Table 1: User Evaluation Summary

1. Overall, the weighted mean is 4.60, which is equivalent to Excellent. These results indicate that the majority of respondents found the application highly functional, efficient, reliable, and user-friendly.

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**Performance**

The system gained a mean of 4.64 (Excellent). Participants highlighted that the application identified currencies quickly enough (less than one second) for practical real-world use while consuming minimal. device resources such as battery and memory.

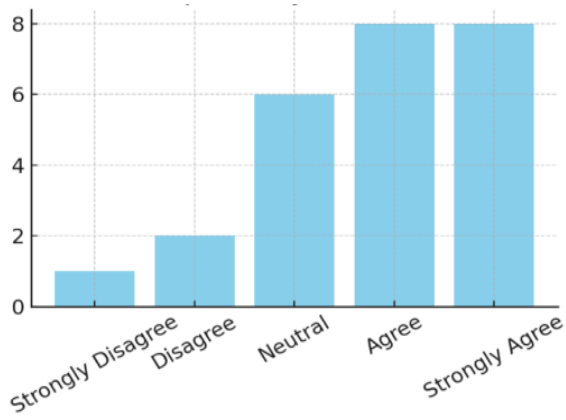


Figure 5: Bar Graph of Performance Criteria

2. The figure 5 clearly shows the the summary of the answers of the users based on their experience while using the application. This confirms that Espyreal is not only accurate but also efficient in execution, even on mid-range smartphones.

**Compatibility**

*3.* Compatibility refers to the quality of the Eyessential money identifier application's ability to work effectively alongside other accessibility applications and integrate seamlessly with device accessibility settings. The first criteria under Compatibility received a weighted mean of 4.58, which corresponds to Excellent, as shown in Table 1. The weighted mean for the second criteria was 4.54, also achieving an Excellent rating.

According to the respondents, the application works well alongside other accessibility applications without conflicts or interference. Users reported that the app integrates properly with their device's existing accessibility settings and features. The application demonstrates strong compatibility with various assistive technologies that visually impaired users commonly rely on. Respondents appreciated that they could continue using their other essential accessibility tools while benefiting from the currency identification features..

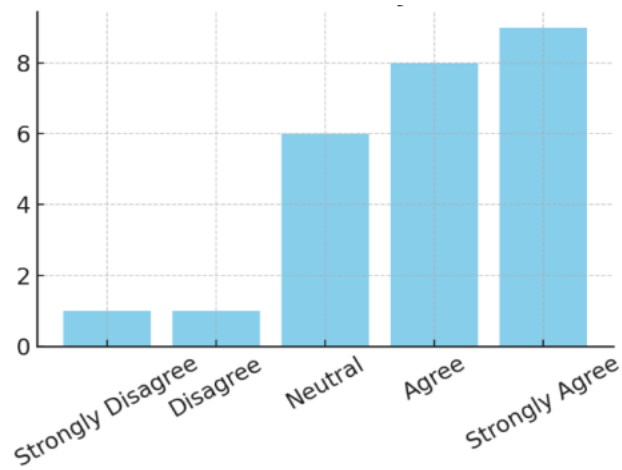


Figure 6: Bar Graph of Compatibility Criteria

4. Users expressed confidence in the application's ability to function as part of their broader accessibility toolkit. With an average mean of 4.56, as shown in figure 6. Most respondents assessed the Espyreal application as

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excellent in terms of Compatibility, indicating that the app successfully meets the interoperability needs of visually impaired users in their daily digital environment

**Usability**

Usability refers to the ease of use and user experience quality of the Eyessential money identifier application for visually impaired users. The criteria under Usability achieved weighted means of 4.75, 4.74, 4.72, and 4.70, all corresponding to Excellent ratings, as shown in Table 1.

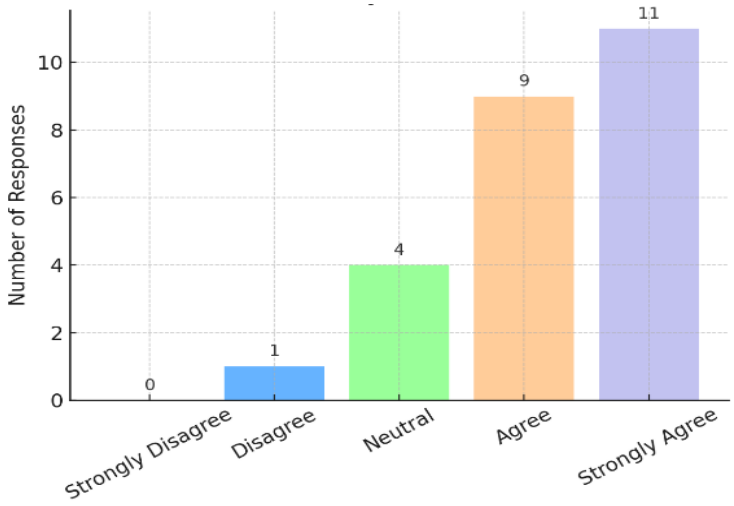


Figure 7: Bar Graph of Usability Criteria

5. Respondents found the application's interface simple, appealing, and straightforward to understand. Users can operate the app with minimal effort and reported that navigation is intuitive for the target population. The app is easy to learn and use effectively for first-time users, with clear audio feedback and logical gesture-based controls.

**Reliability**

Reliability refers to the ability of the Eyessential money identifier application to perform consistently and maintain stable functionality over time. The criteria under Reliability achieved weighted means of 4.62 and 4.60, both corresponding to Excellent ratings, as shown in Table 1.

Based on the respondents answers the application rarely crashes and performs consistently during use. Users found the app to be dependable and always available when needed for currency identification tasks. The application maintains stable performance across extended usage periods without significant errors or interruptions.

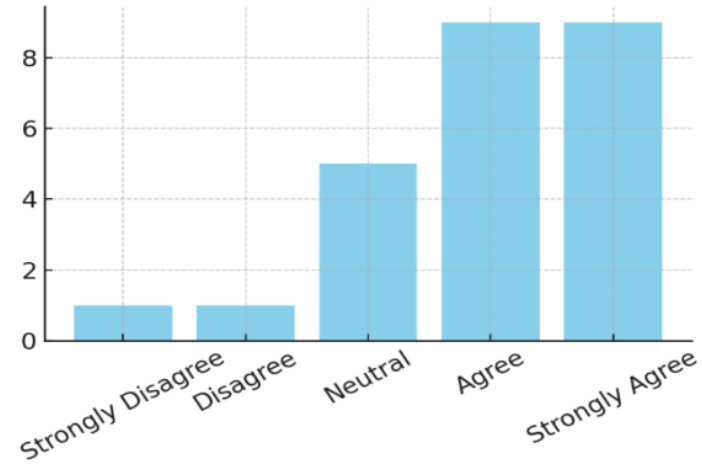


Figure 8: Bar Graph of Reliability Criteria

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6. As shown in figure 8, in terms of Reliability the application 4.60 (Excellent) reflecting that Espyreal was always available when needed and was able to recover smoothly from interruptions such as temporary permission issues.

**Security**

Espyreal obtained a mean of 4.52 (Excellent). Although slightly lower compared to other criteria, this still falls under Excellent.

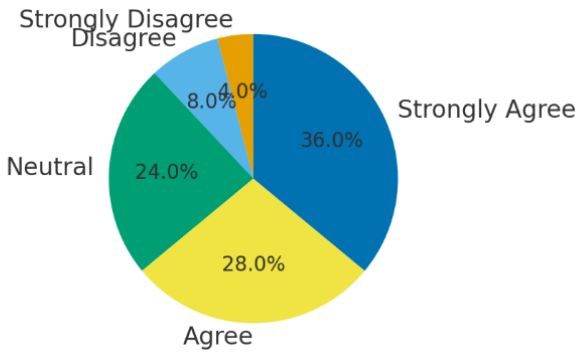


Figure 9: Pie Chart of Security Criteria

6. Respondents acknowledged that the application protected their privacy since no sensitive data was collected and all detection processes were performed locally. This offline-first design reassured participants that their usage was secure and confidential

**Maintainability**

Although it was rated at the lowest among the other categories, (4.48). Respondents still recognized that while the system can be updated and adapted to new currencies, there remains room for improvement in providing clearer diagnostic information and feedback

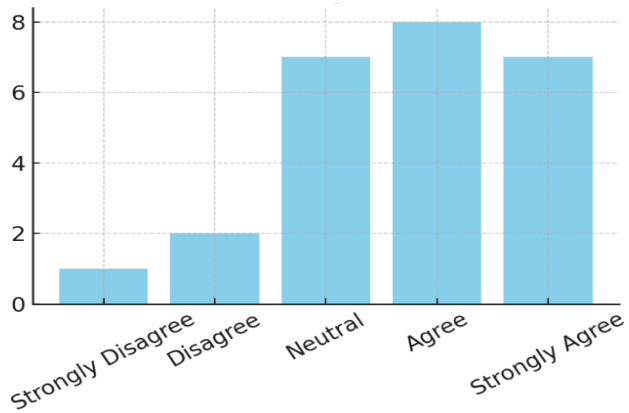


Figure 10: Bar Graph of Maintainability Criteria

7. Nevertheless, the modular design of Espyreal ensures that updates and improvements can be implemented without disrupting existing features.

**Portability**

8. Espyreal was successfully tested across different Android versions (9 to 14) and phone models, showing strong portability. With a mean of 4.58, showing that the system works effectively across different smartphone models and operating system versions.

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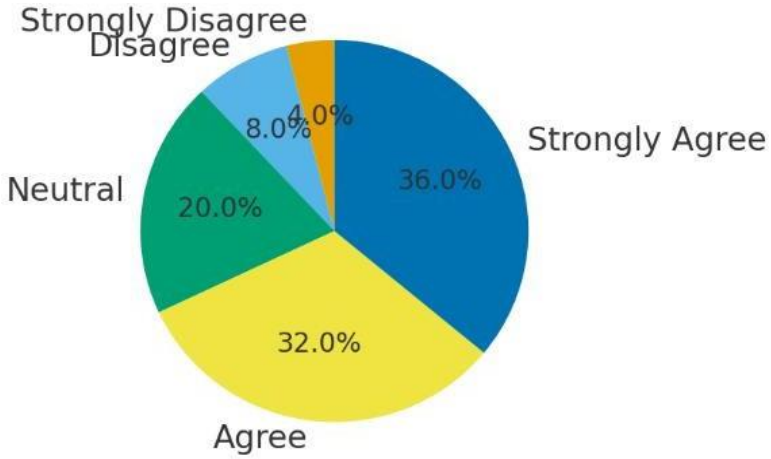


Figure 11: Pie Chart of Portability Criteria

8. Participants found the application easy to download, install, and set up, especially with audio-assisted guidance during installation.

**Data Availability**

The datasets generated and analyzed during this study are not publicly available due to participant privacy and confidentiality considerations involving visually impaired individuals from the Philippine National School for the Blind.

The survey responses contain sensitive information about participants' accessibility needs and experiences. However, anonymized summary statistics and evaluation results are presented in this manuscript.

Raw image datasets of Philippine Peso and United States Dollar banknotes used for model training are not shared to prevent potential misuse for counterfeiting purposes. Aggregated data supporting the study's conclusions may be available from the corresponding author upon reasonable request and with appropriate institutional approval.

**Ethical Consideration**

Informed Consent: Espyreal ensures that all users, especially those with visual impairments, understands the reason why the study is conducted, how it was done, and see if there are any possible risks or benefits by using the app.

Accessibility: Ensures that users can easily access the Espyreal regardless of the level of their visual impairment. It is also accessible for users regardless of their age, technical proficiency, and educational background. All of these ensure that the Espyreal system is accessible regardless of the status of the user.

Reliability and Accuracy: The app ensures the stability and consistency of the system, minimizing errors and inaccurate results. A clear reminder should inform users of the possible identification errors and encourage verification when necessary.

Fairness: Espyreal recognizes every banknote regardless of the condition, whether it is old, worn-out, or crumpled. Ensuring that the recognition is accurate for all users and banknotes.

Transparency and Accountability: Espyreal informs users that it does not recognize counterfeit bills and should not be taken upon for financial transactions. The users will have an easy way to report bugs or errors, considering it for future improvements.

User Consent: The users do not have the option, thus not required to provide personal data to use the full functionality of the app, Espyreal is designed to be accessible to all users with visual impairments without any difficulties.

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## CONCLUSION

Based on the findings, Espyreal successfully met its objectives of providing a reliable, fast, and accessible solution for currency identification among visually impaired users. The integration of Convolutional Neural Networks (CNNs) with audio feedback ensured accurate recognition and improved financial independence. The high evaluation scores across all quality attributes demonstrate that Espyreal is not only functional and efficient but also adaptable for future updates, making it a practical tool for real-world application. The study concludes that Espyreal is a dependable assistive technology that can significantly improve the financial autonomy and security of visually impaired individuals.

## RECCOMENDATIONS

1. Expand Currency Support – Extend the model to include additional currencies commonly encountered by Filipino users to enhance versatility.

2. Counterfeit Detection – Incorporate security features such as watermark or UV detection modules to safeguard against counterfeit bills.

3. Broader Testing – Conduct larger-scale user testing in multiple regions to improve generalizability and inclusivity of results.

4. Continuous Updates – Regularly update the system to accommodate new banknote designs released by central banks.

5. Future Research – Explore the integration of haptic and auditory cues for a multimodal accessibility experience, further improving usability for different levels of impairment.

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