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PhilCurrency Aid: A Mobile Application for Real-Time Detection of Philippine Banknotes and Coins for the Partially Blind Individuals

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Abstract: *Vision is the most critical of the five human senses, and individuals with blindness or low vision—referred to as Partially Blind Individuals (PBIs) often face significant challenges in daily life. According to the World Health Organization (2019), visual impairment is defined as vision that cannot be fully corrected with glasses or lenses and interferes with everyday activities. This includes low vision (visual acuity worse than 20/70) and legal blindness (20/200 or worse in the better eye or severely limited visual field). PBIs commonly struggle with routine tasks such as identifying money, medications, and clothing colors, and often encounter difficulties during financial transactions due to the challenge of recognizing banknotes and coins. While existing applications can detect general objects, currency recognition is particularly challenging due to variations in angles, lighting, and user handling. PBIs may not always position money optimally for recognition, necessitating a robust system that performs accurately regardless of orientation. This study addresses the issue by training models using augmented images (rotated, flipped, tilted) to enhance recognition from multiple viewpoints. Advanced deep learning techniques such as You Only Look Once (YOLOv8) and Convolutional Neural Networks (CNNs) are leveraged to detect and identify currency under varying conditions. The resulting application, PhilCurrency Aid, integrates image detection, processing, and recognition to accurately identify Philippine banknotes and coins. The system aims to enhance PBIs' independence, confidence, and financial engagement. Usability evaluation using the System Usability Scale (SUS) yielded a mean score of 75.5, with a median of 75 and quartile values (Q1 = 75, Q3 = 75.625), indicating consistent and favorable user feedback. Users highlighted the app's simplicity, speed, and reliability, underscoring its effectiveness in facilitating financial transactions without external assistance.*

Keywords: Visual Impairment; Currency Recognition; YOLOv8; Convolutional Neural Networks (CNN); Assistive Technology.

1. INTRODUCTION

According to the World Health Organization, approximately 2.2 billion people worldwide experience vision impairment or blindness, emphasizing the urgent need for assistive technologies that promote independence, particularly in financial transactions. In the Philippines alone, an estimated 12 million individuals live with some form of vision loss, including 500,000 who are completely blind [3].

Globally, various methods have been developed to help Partially Blind Individuals (PBIs) identify banknotes, such as differentiating by size, tactile or Braille markings, folding systems, and specialized AI-powered devices [4] Despite their usefulness, many of these solutions are limited by factors such as high cost, lack of portability, and limited availability—especially in low-resource settings. With the proliferation of smartphones and mobile computing, image processing and machine learning have enabled the development of mobile applications capable of real-time banknote recognition [23].

These tools offer a more accessible and scalable solution for PBIs. However, challenges remain. Many existing apps are either unaffordable, lack user-friendly interfaces, or fail to detect multiple banknotes in a single image, particularly when captured at different angles [5].

To address these limitations, this study explores the use of advanced artificial intelligence (AI) techniques for accurate and efficient Philippine banknote recognition. Leveraging technologies such as image classification and object detection, the system is designed to identify and interpret multiple banknotes from various orientations in real-time. As Murugan et al. (2024) highlight, modern AI models are capable of analyzing shaped data and recognizing distinct objects within complex images, paving the way for more robust assistive applications.

2. BACKGROUND OF THE RESEARCH

Recognizing banknotes and coins from various angles is essential for applications designed to assist visually impaired users. These individuals may not always position currency in a way that is optimal for camera detection, making it critical for recognition systems to operate reliably regardless of the money's orientation. To address this, machine learning models can be trained on augmented datasets that include rotated, flipped, and tilted images, enabling them to recognize currency from multiple perspectives [7] .

Advanced artificial intelligence models such as You Only Look Once (YOLOv8) and Convolutional Neural Networks (CNNs) have demonstrated strong performance in object detection tasks, even when objects appear in varied positions or lighting conditions [8]. These capabilities make them well-suited for developing applications that deliver consistent and accurate banknote and coin recognition, thereby enhancing the independence of Partially Blind Individuals (PBIs).

This study integrates image detection, image processing, and image recognition to accurately determine the value of Philippine banknotes and coins. Image detection analyzes patterns, shapes, and colors to locate relevant objects [4] Image processing involves enhancing and extracting meaningful features from visual input, treating images as two-dimensional signals to facilitate interpretation [9]. Once processed, image recognition systems can classify and identify objects in real-time, enabling applications to make actionable decisions based on visual data [10], Although image recognition has become increasingly powerful with advancements in computational resources, it still faces challenges such as algorithmic bias and data privacy concerns.

Originally introduced in 2015, the YOLO model reconceptualized object detection as a regression task performed by a single neural network. Over the years, it has undergone multiple improvements, with YOLOv5 being one of the most widely adopted versions due to its high speed, detection accuracy, and customization options enabled by its PyTorch-based framework [11].

Despite the development of various assistive technologies, many current solutions fall short in recognizing multiple Philippine banknotes and coins within a single image especially when captured from different angles or under non-ideal conditions. This limitation significantly affects the financial autonomy of PBIs, forcing them to depend on tactile methods or external assistance. Most existing applications are designed for foreign currencies or require flat, front-facing views of banknotes, reducing their effectiveness in real-world scenarios where currency may be folded, wrinkled, or partially obscured.

Given these challenges, there is a pressing need for a perspective-aware, real-time, and locally relevant recognition system that can function reliably on mobile devices. This study seeks to address that gap by leveraging AI-based image recognition techniques to develop a cost-effective and user-friendly solution tailored to the Philippine context. The project also has the potential to support organizations like Resources for the Blind, Inc., by providing a scalable tool aligned with their advocacy for accessibility and inclusion.

Ultimately, by responding to the unique needs of PBIs in handling physical currency, this research aims to foster greater autonomy, confidence, and active participation in financial transactions—paving the way for more inclusive technological innovations in assistive tools.

3. PROBLEM STATEMENT

Visually impaired individuals often face significant challenges in identifying banknotes and coins, which hinders their ability to conduct financial transactions independently and confidently. Existing assistive technologies either lack support for Philippine currency, require ideal image conditions (e.g., flat, front-facing views), or are not optimized for real-time use on mobile devices. These limitations reduce the effectiveness of current solutions in real-world scenarios, where bills and coins may appear in various angles, orientations, and lighting conditions.

This study aims to address this gap by developing a mobile-based money detection application using the YOLO (You Only Look Once) algorithm. The application will be capable of recognizing multiple Philippine banknotes and coins simultaneously, even when captured from different angles and perspectives. It will feature a user-friendly interface designed to be accessible for visually impaired individuals, supporting their autonomy in payment and transaction-related activities. The ultimate goal is to provide a fast, reliable, and inclusive solution that enhances financial independence through real-time currency recognition.

4. METHOD

This study adopts the Design and Development Research (DDR) model, a structured approach that facilitates the creation of practical and user-centered technological solutions. The DDR framework ensures that the development process is both systematic and responsive to real-world needs—particularly those of visually impaired individuals.

The methodology is organized into five key phases:

Literature Review – This phase involves a comprehensive review of existing technologies, algorithms, and assistive tools related to currency recognition and visual impairment. It provides the theoretical foundation for system design.

Partial Survey and Data Analysis – Initial surveys and consultations with visually impaired individuals and stakeholders (such as educators or advocacy organizations) are conducted to identify user needs, common challenges, and desired features.

Dataset Preparation and System Design – A custom dataset of Philippine banknotes and coins is created, including images captured from multiple angles, rotations, and lighting conditions. The system architecture is designed, incorporating the YOLO object detection algorithm for real-time recognition.

Implementation and Experimentation – The mobile application is developed and tested using the prepared dataset. YOLO is trained and fine-tuned for optimal accuracy in detecting and identifying currency in varied real-world conditions.

User Survey and Review – The completed system is evaluated through usability testing with target users. Feedback is gathered using tools such as the System Usability Scale (SUS) to assess ease of use, accuracy, and user satisfaction.

Each phase contributes to the iterative refinement of the mobile-based currency recognition system, ensuring it is accurate, accessible, and effective in assisting visually impaired users with everyday financial tasks.

4.1 Literature Review

This study draws upon existing research in four key areas: banknote recognition systems, assistive technology for the visually impaired, object detection models (particularly YOLO), and the use of the Design and Development Research (DDR) model in inclusive technology development. Several studies have explored the challenges faced by visually impaired individuals in recognizing currency, highlighting difficulties in distinguishing denominations and relying heavily on

tactile or external assistance [18] [9]. These challenges limit financial autonomy and emphasize the need for accessible, accurate, and real-time recognition tools.
Research into object detection technologies, particularly the YOLO (You Only Look Once) family of algorithms, demonstrates promising capabilities for recognizing currency through image classification [15]. YOLO's speed and accuracy make it well-suited for real-time applications, although earlier studies often struggled with limitations such as small training datasets, rigid image conditions (e.g., flat, front-facing images), and lack of support for local currencies.
Existing mobile-based solutions for the visually impaired have made significant strides in object detection and navigation but frequently fall short when applied to Philippine banknotes and coins [24]. Many are either costly, lack adaptability to different angles and lighting, or do not support multiple currency denominations within a single frame.
This study builds on these findings by integrating the YOLOv8 model, which offers improved detection capabilities and adaptability over its predecessors. Additionally, the DDR model is employed to ensure the system is not only technically robust but also centered around the specific needs of visually impaired users. By combining these approaches, the research aims to address current gaps such as insufficient real-time detection, angle sensitivity, and limited support for dynamic, multi-denomination recognition within a single image.

4.2 Partial Survey and Data Analysis

To ensure that the system aligns with the real-world needs of its intended users, a preliminary survey was conducted with visually impaired individuals in Taguibo, Butuan City. Five participants provided insights into their experiences in handling banknotes, their preferred modes of interaction with technology, and their expectations from an assistive mobile application. Feedback revealed a strong preference for real-time audio feedback, intuitive navigation, and minimal user input, emphasizing the need for simplicity and accessibility in the app's design.
For dataset development, the researchers collected a total of 428 images featuring various Philippine currencies, specifically the 5-peso and 10-peso coins, and the 20-, 50-, and 100-peso banknotes.
To ensure robustness and variability, images were captured under diverse lighting conditions, angles, and orientations. Additionally, video recordings of banknotes were converted into image frames to enrich the dataset with dynamic representations of currency in motion. Each image was manually annotated using bounding boxes and labeled according to the correct denomination to support supervised learning during model training. This annotated dataset served as the foundation for training the YOLOv8 model, enabling the system to recognize banknotes and coins in real-time and under realistic conditions.

4.3 Custom Dataset Preparation and System Design

Following data collection, the images underwent a data cleaning process to ensure quality and consistency. This involved removing duplicates, blurry frames, and incorrectly labeled samples. The resulting dataset provided a clean and reliable foundation for model training, directly contributing to improved detection accuracy.
The dataset was then divided into three subsets to support an objective evaluation of the model's performance: 88% for training, 8% for validation, and 4% for testing. This stratified approach enabled the model to generalize effectively while minimizing overfitting.

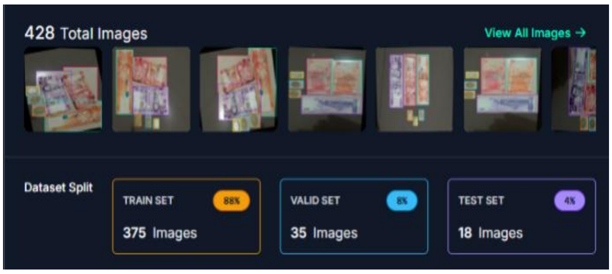

Figure 1. Dataset Annotation

The system architecture was designed around two core components:
Model Training (YOLOv8):
The YOLOv8 object detection model was trained using the annotated dataset. Emphasis was placed on optimizing both detection speed and accuracy to ensure real-time performance on mobile devices. The training process involved hyperparameter tuning and augmentation techniques (e.g., rotation, flipping, and brightness adjustments) to enhance model robustness across varying visual conditions.

Mobile Application (Android):
The mobile application was developed using Kotlin for the Android platform. It integrates the trained YOLOv8 model to perform real-time banknote and coin detection. Upon recognizing a currency denomination, the app delivers immediate audio feedback using Google Text-to-Speech (gTTS), ensuring accessibility for visually impaired users. The user interface was designed with simplicity and large touch targets to accommodate users with limited vision.
This modular design ensures that the system is scalable, user-friendly, and responsive to the specific needs of visually impaired individuals in real-world financial contexts.

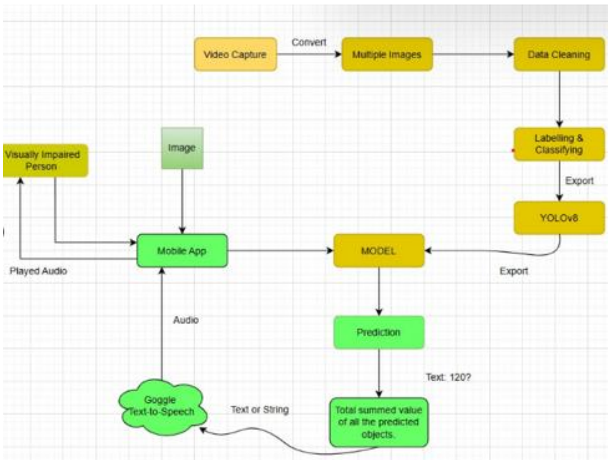

Fig. 2 System Architecture Diagram

Figure 3 illustrates the system workflow, beginning with image capture and progressing through the YOLOv8-

based processing pipeline to deliver audio output. The diagram is color-coded for clarity: the green section represents the components of the mobile application, while the yellow section highlights the model training process.

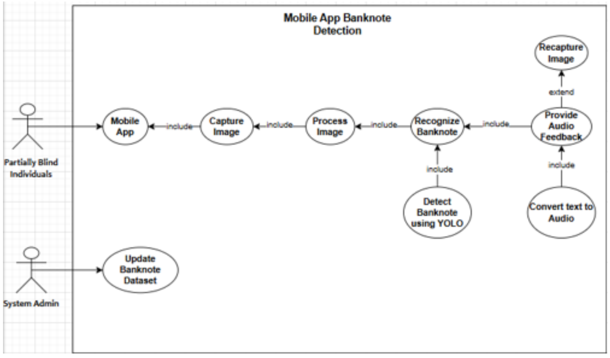

Fig. 3 Use Case Diagram

The diagram illustrates the user interaction flow, detailing how visually impaired individuals initiate the application, capture images of banknotes, and receive spoken feedback. It also highlights key accessibility features such as voice command support and haptic feedback, which enhance usability and user experience.

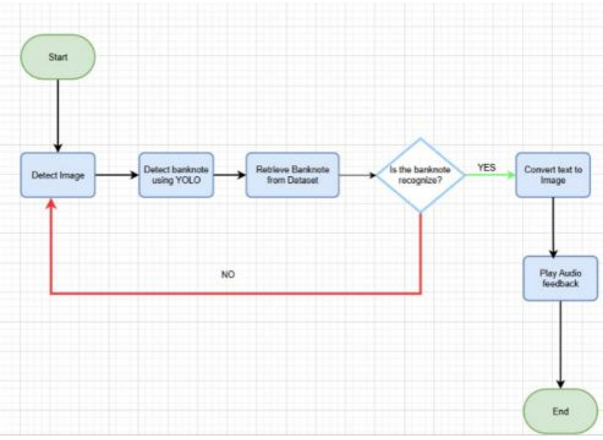

Fig. 4 Flowchart

Figure 4 presents the step-by-step process flow of the mobile-based banknote recognition system tailored for visually impaired individuals. It outlines the sequence of operations—from image capture to the delivery of audio feedback—demonstrating how the system interprets and responds to user input in a clear and accessible manner.

4.4 Experimentation and Analysis

The Central Processing Unit (CPU) is designed for handling basic computational tasks and general-purpose operations. While it provides sufficient performance for routine activities such as web browsing, word processing, and standard application usage, it lacks the efficiency required for high-performance machine learning workloads. In contrast, the Graphics Processing Unit (GPU) is optimized for parallel processing and excels in performance-intensive tasks, making it ideal for training deep learning models.

For this study, a GPU is essential to meet the computational demands of training a YOLOv8 model. Specifically, an NVIDIA GPU with a minimum of 8GB of memory is recommended to ensure smooth handling of large datasets and complex computations. This setup significantly accelerates model training and enhances overall system responsiveness, supporting the development and deployment of real-time object detection applications.

Fig. 5 Experimentation on datasets

Figure 5 presents an experiment designed to evaluate the robustness and adaptability of the trained object detection model under real-world conditions. To simulate common challenges encountered by visually impaired individuals, the dataset was intentionally augmented with various transformations applied to Philippine banknote images. These modifications included horizontal and vertical flipping, rotation at multiple angles, and crumpling to replicate the irregularities of everyday cash handling.

The results were encouraging. The mobile application retained high recognition accuracy across all transformed images. Flipped banknotes were correctly identified, rotated bills were accurately classified across a range of angles, and even crumpled banknotes—with complex textures and non-uniform surfaces—were detected with consistent reliability. This experiment validated the system's ability to generalize beyond clean, flat images, demonstrating its practical applicability in uncontrolled, real-world environments.

Ultimately, the test confirmed that the application is resilient to common distortions and capable of supporting visually impaired users in accurately identifying currency during financial transactions, regardless of the physical state or orientation of the banknotes.

5. RESULT SUMMARY AND FUTHER ANALYSIS

The images and videos used for model training were originally captured using a mobile device. For data collection, each location was allotted five minutes of video recording time. These videos were subsequently converted into .png image format to facilitate training. The video files were uploaded to Roboflow, where they were processed into individual frames per second, enabling the extraction of a diverse and comprehensive set of training images.

Fig. 6 Captured Images and Videos

After the conversion process, the researchers annotated each frame using custom classes labeled ‘100’, ‘50’, and ‘5’. Once annotation was complete, the dataset was enhanced through data augmentation techniques, including automatic orientation correction and size normalization. The custom-trained model demonstrated excellent performance in detecting currency bills. With confidence and overlap thresholds set at 50%, the model achieved a precision of approximately 99.7%, indicating a high rate of correct predictions. It also attained a recall of 99.5%, reflecting its ability to identify nearly all relevant instances in the dataset. The overall effectiveness, measured by mean average precision (mAP), was 99.2%, underscoring the model’s robustness and reliability across different bill denominations.

Model evaluation included integration with video files under varied conditions such as different angles, lighting scenarios, and orientations. These tests were conducted to assess the model’s accuracy and processing efficiency on mobile devices.

Table 1 Performance of the Mobile-based application Detection Model

Test Condition	Denomination	Performance
Well-lit (Daylight)	5-peso coin	Excellent
Well-lit (Daylight)	50-peso bill	Excellent
Well-lit (Daylight)	100-peso bill	Excellent
Low light (Indoor)	5-peso coin	Good
Low light (Indoor)	50-peso bill	Good
Low light (Indoor)	100-peso bill	Good
Partial Obstruction (folded)	50-peso bill	Fair
Angled (45-degree tilt)	100-peso bill	Good

The proponents initially utilized the YOLOv8-large model; however, its high processing time of approximately 30,000 milliseconds (ms) per frame rendered it impractical for mobile deployment. Consequently, the YOLOv8-nano model was selected due to its substantially faster detection speed. This model was further optimized by employing high-resolution inputs and extending the training epochs to maintain accuracy. The optimized YOLOv8-nano demonstrated excellent performance, achieving near-instantaneous detection times of approximately 200–250 ms per frame, making it well-suited for real-time applications on mobile devices.

To complement the system evaluation, a usability test was conducted with five participants who have partial visual impairment to assess the application’s effectiveness and usability in real-world scenarios.

Table 2 Usability Test Conducted.

Participant No.	Gender	Age Range	Visual Impairment Status
1	Male	45–60	Partially Blind
2	Male	45–60	Partially Blind
3	Female	45–60	Partially Blind
4	Female	45–60	Partially Blind
5	Male	30–35	Partially Blind

A total of five participants took part in the study, comprising three males and two females. Four participants were aged between 45 and 60 years, while one was between 30 and 35 years old. Among them, three regularly engaged in daily activities involving monetary transactions, whereas the remaining two participants had limited experience with money handling tasks, offering valuable insight into the app’s accessibility for less frequent users.

The System Usability Scale (SUS) scores were calculated based on responses to 10 items, each rated on a five-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree). For scoring, responses to positively worded items (1, 3, 5, 7, and 9) were adjusted by subtracting 1, while responses to negatively worded items (2, 4, 6, 8, and 10) were adjusted by subtracting the score from 5. The sum of these adjusted scores was then multiplied by 2.5 to yield a final usability score ranging from 0 to 100. The findings indicated that most participants selected responses between Agree and Strongly Agree, reflecting an overall positive evaluation of the application’s functionality and performance.

However, items 2 and 6 showed comparatively higher disagreement levels, suggesting specific areas that may require improvement, possibly related to usability or detection accuracy. In contrast, items 8 and 9 received the most favorable feedback, with the highest proportions of Agree and Strongly Agree responses, indicating strong user satisfaction—likely in aspects of reliability and ease of use. Instances of Strongly Disagree were minimal across all items, further underscoring the generally favorable perception of the application. Although Strongly Agree responses were present, they were moderate in frequency, indicating potential for further enhancement. Overall, the data suggest that users perceive the mobile banknote detection application positively while identifying opportunities for targeted improvements.

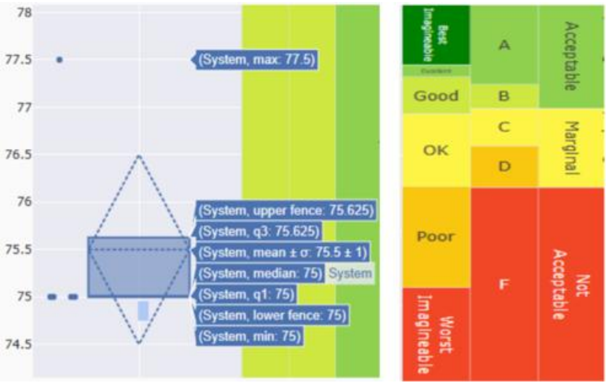

Fig. 7 System Usability Scale Box Plot Analysis

Figure 7 illustrates the usability evaluation of the Mobile Banknote Detection Application based on the System Usability Scale (SUS). The first image depicts the SUS grading scale, categorizing scores from Best Imaginable to Worst Imaginable, with corresponding letter grades from A to F. The second image presents the computed SUS scores using a box plot. The application achieved a mean SUS score of 75.5 with a standard deviation of ±1, placing it in the Good to Acceptable range according to the SUS interpretation chart. The median score was 75, with the first quartile (Q1) and third quartile (Q3) at 75 and 75.625 respectively, reflecting consistent and favorable user feedback.

These results suggest that the Mobile Banknote Detection Application offers a high level of usability, effectively supporting visually impaired users in accurately detecting and identifying banknotes. Users highlighted satisfaction with the app's simplicity, speed, and reliability, emphasizing its significant assistance in daily transactions without requiring external help. One participant remarked, "The app makes recognizing money easy and quick, which is a big help when I'm alone." Additionally, the real-time voice feedback and straightforward interface were particularly praised for enhancing user independence.

With a SUS score of 75.5—above the median of 75 and accompanied by a low standard deviation of 1.12—the application's usability is classified as Good (letter grade B) and Acceptable overall. Falling within the third quartile further indicates above-average performance compared to other systems evaluated with SUS. Overall, these findings affirm that users perceive the application as functional, user-friendly, and reliable.

5.1 Further Testing and Evaluation

The system was tested under various conditions, including different lighting environments (dim and bright) and partial obstructions such as folded or partially covered banknotes.

The performance of the mobile money detection application was evaluated under various lighting and positioning conditions using Philippine currency. Qualitative assessment of success rates showed excellent recognition in well-lit environments, particularly with flat and clearly visible denominations. For instance, the 5-peso coin and both 50- and 100-peso bills were accurately identified under daylight conditions, despite minor challenges such as blurring or reflections.

In low-light indoor settings, performance slightly declined but remained within the good range. The application reliably detected coins and bills, although occasional misses occurred due to shadows, dark spots, or glare, especially on crumpled notes.

Table 3 Conducted testing under several conditions

Test Condition	Banknote Denomination	Recognition Performance	Avg. Response Time (ms)	Failure Cases	User Feedback Summary
Well-lit (Daylight)	5-peso coin	Excellent	320	5 (blurred)	Audio was clear and instant.
Well-lit (Daylight)	50-peso bill	Excellent	350	8 (folded)	Easy to position the bill
Well-lit (Daylight)	100-peso bill	Excellent	340	6 (reflection)	Recognize even when tilted.
Low-light (Indoor)	5-peso coin	Good	420	17 (shadowed)	Sometimes missed the coin
Low-light (Indoor)	50-peso bill	Good	450	15 (dark spot)	Slower but mostly accurate
Low-light (Indoor)	100-peso bill	Good	440	13 (glare)	Struggled with crumpled notes
Partial Obstruction	50-peso bill (folded)	Fair	500	22 (hidden)	Needs better edge detection
Angled (45-degree tilt)	100-peso bill	Good	380	12 (cut-off)	Works if held steadily

Recognition accuracy decreased to fair when bills were partially obstructed, such as being folded. These conditions introduced challenges including hidden features and difficulties with edge detection, highlighting areas where algorithm improvements are needed. However, when bills were tilted at a 45-degree angle, performance remained good, demonstrating robustness in handling perspective variations as long as the object was held steadily.

Overall, the application exhibited strong reliability under controlled conditions and moderate robustness in more challenging real-world scenarios. User feedback noted acceptable response times but recommended enhancements to improve detection under occlusion and low-light glare.

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