MONEY DETECTOR FOR VISUALLY IMPAIRED USING RASPBERRY PI

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Abstract: Financial independence is a cornerstone of a secure and fulfilling life, yet for visually impaired individuals, identifying and handling currency presents a significant obstacle, hindering their ability to confidently navigate daily transactions. This study addressed this challenge by designing and developing a user-friendly Money Detector utilizing a Raspberry Pi. The core functionality employs a robust vision system, equipped with a Raspberry Pi camera and advanced image processing algorithms, to achieve accurate denomination reading of Philippine currency. User testing validated the system's effectiveness, demonstrating a high accuracy rate of approximately 87% in identifying Philippine peso denominations. However, the Money Detector goes beyond just accuracy; it prioritizes user experience through a diverse range of accessible feedback modalities. This caters to individual user preferences and ensures effective communication for all. A Braille display offers tactile identification through raised dots corresponding to each denomination. Speakers announce the denomination and utilize UV light verification for added security, while haptic feedback provides vibration cues for quick denomination recognition. Usability testing yielded overwhelmingly positive results, with participants reporting high levels of satisfaction (average rating of 4.73) and ease of use. They indicated that the Money Detector effectively assisted them in accurately identifying Philippine currency, promoting financial independence and fostering confidence in everyday financial transactions. This project underscores the potential of the Money Detector as a valuable tool for visually impaired individuals. By empowering them to manage their finances independently, navigate daily transactions with greater confidence and security, and participate more fully in the financial landscape, the Money Detector contributes to a more inclusive and empowered society.

Key Words: Visually Impaired; Money Detection; Raspberry Pi; Image Processing

1. INTRODUCTION

Financial independence is vital, yet identifying currency presents a challenge for visually impaired individuals. Traditional methods like sighted assistance or physical differentiation are limiting and insecure.

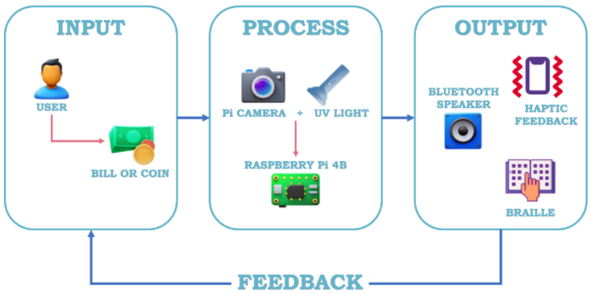

Fig. 1. Conceptual Model of the Study

Technological advancements offer solutions. This study contributes by developing a Money Detector for Visually Impaired using Raspberry Pi, as illustrated in Fig. 1. This user-friendly system aims to address this critical gap by achieving three key objectives:

1. Design and implement a robust vision system enabling accurate denomination reading of Philippine currency. This ensures the Money Detector can reliably identify Philippine peso denominations.
2. Integrate features such as Braille, auditory announcements using speakers, and haptic feedback with corresponding denominations. This prioritizes user experience by providing a variety of accessible feedback modalities catering to individual preferences. Braille output, audio announcements, and haptic feedback empower users to receive information in their preferred format.
3. Evaluate and validate the usability and efficacy of the developed currency recognition system. Rigorous testing ensures the Money Detector effectively assists visually impaired individuals in accurately handling and identifying Philippine currency within real-world financial transactions.

By incorporating these functionalities, the Money Detector goes beyond just accurate denomination identification. It fosters financial independence and confidence in everyday financial interactions for visually impaired individuals.

2. METHODOLOGY

The Money Detector development employed an agile methodology, specifically an iterative approach that prioritizes flexibility and continuous improvement. This methodology aligns well with the project's nature due to several key benefits:

- Rapid Prototyping and Feedback: Agile allows for the creation of functional prototypes early in the development cycle. These prototypes can be used to gather user feedback and iterate on the design, ensuring the Money Detector addresses user needs effectively.
- Adaptability to Change: As requirements or user needs evolve, the agile approach allows for adjustments to be made throughout the development process. This adaptability is crucial for assistive technology projects, where user-centered design principles are paramount.
- Improved Project Management: Agile methodologies break down development into smaller, manageable tasks (often called sprints). This facilitates efficient project management, allowing for progress tracking and potential roadblocks to be identified and addressed quickly.
- Enhanced Collaboration: Agile practices promote close collaboration between developers, researchers, and potentially, end-users. This fosters a more cohesive development process and ensures everyone involved is aligned with project goals.

2.1 Hardware and Software Components

This section details the hardware and software components used to develop the Money Detector for visually impaired individuals.

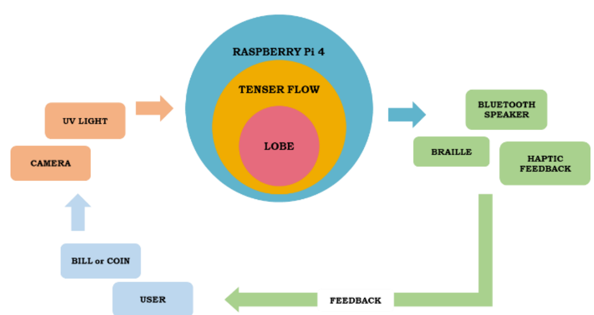

Fig. 2. System Block Diagram

In Fig. 2, there's a block diagram showing how a system works. The core of this system is a Raspberry Pi 4B, which acts like a mini-computer. It's connected to hardware like a camera, UV light, speaker, braille, and haptic feedback. The camera processes images of paper bills, while the UV light will check security features such as security fibers, security threads, and watermarks, which are relevant for certain security features on banknotes. The speaker makes sounds, the braille might display information in a tactile way, and haptic feedback gives touch-based responses. These parts work together to make the system do its job.

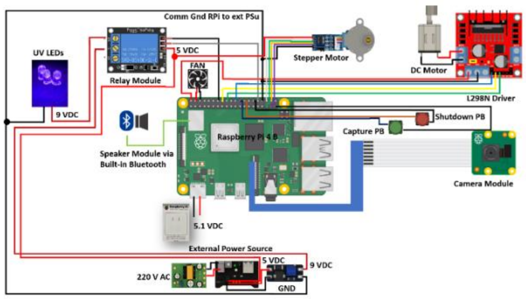

Fig. 3. System Hardware Architecture

Fig. 3 depicts the hardware architecture of the proposed "Money Detector for Visually Impaired Using Raspberry Pi." This system leverages a Raspberry Pi 4 Model B as the central processing unit, coordinating various components to deliver advanced functionality for banknote identification and user feedback.

- Raspberry Pi 4 Model B: This single-board computer acts as the brain of the system, handling image processing, control logic, and communication with other components.
- Raspberry Pi Camera Module 2: This module captures high-resolution images of Philippine currency denominations for denomination identification and potential counterfeit detection.
- LED UV Lights (controlled by Relay 5V): These lights emit ultraviolet radiation, useful for illuminating security features on banknotes invisible under normal light, aiding in counterfeit detection.
- User Feedback System:
    - Mini-Bluetooth Speaker: Provides audio announcements of denomination identification results.
- Haptic Feedback System: For future functionalities, the system incorporates:
    - 4-Phase Stepper Motor (driven by ULN2003 Driver): This motor has the potential to be used for currency sorting or positioning mechanisms in future iterations.
    - DC Motor: This motor could be used to implement vibration or other haptic feedback mechanisms for user interaction.
- AC-17220VAC 10A Fused Power Switch with Male Power Socket: This switch ensures safe and controlled AC power connection to the system.
- MB102 Power Supply Module: This module regulates power from the AC source, providing stable voltage for the Raspberry Pi and other components.
- MT3608 2A Max DC-DC Step Up Booster Power Module: This module can potentially boost the voltage from the power supply to meet specific component requirements, if necessary.
- Raspberry Pi 15.3W USB-C Power Supply: This dedicated power supply provides the primary power source for the Raspberry Pi.

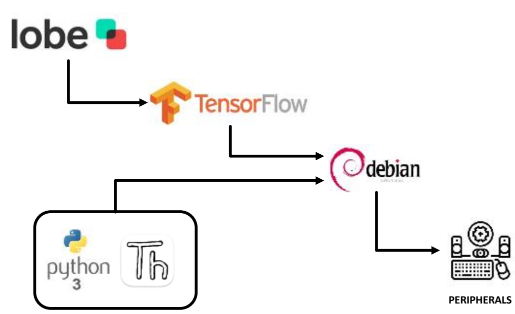

Fig. 4. System Software Architecture

Fig. 4 illustrates the layered software architecture of the Money Detector for Visually Impaired, promoting efficient interaction between hardware components and software functionalities.

- Raspbian GNU/Linux: This operating system forms the base layer, providing core functionality and managing hardware peripherals like the camera, speaker, and UV light.

- Python 3.0: This widely used programming language serves as the primary tool for controlling hardware components and coordinating their functionalities within the Money Detector system.
- TensorFlow and Lobe:
  - These tools can be employed for machine learning tasks on the Raspberry Pi.
  - Lobe offers a user-friendly platform to train a model for denomination recognition of Philippine currency.
  - TensorFlow provides a powerful open-source library for building and deploying the trained model.
- Python Scripts: These scripts act as connectors, seamlessly integrating the different layers by orchestrating interactions between hardware and software elements. They leverage the capabilities of Python to control hardware and call upon machine learning models for denomination identification.

2.2 Image Acquisition and Preprocessing

This section describes the process of capturing and pre-processing images of Philippine currency denominations for accurate identification.

Image Acquisition Setup:

To ensure consistent image quality, the Money Detector is enclosed, eliminating external light interference (light bleeding inwards) (Feng & Liu, 2013). This allows for controlled lighting conditions within the device.

A uniform background is essential to isolate the currency from its surroundings. The bills/coins were placed on a non-reflective, frosted white surface. This surface diffuses the UV LED light, minimizing the circular UV light pattern that might otherwise appear in the captured image (Yang, Lu, & Jin, 2020).

The Raspberry Pi Camera Module 2 was positioned approximately 20 cm above the currency, ensuring the entire bill/coin is captured within the frame.

Image Capture Process:

- User Interaction: A button is pressed to initiate the image capture process.
- UV Light Activation: A UV LED light is activated momentarily to capture features visible only under ultraviolet light, such as security fibers, security threads, and watermarks, which are relevant for certain security features on banknotes.
- Image Acquisition: Upon button press, the Raspberry Pi Camera captures an image of the placed currency.

Pre-processing Techniques:

Lobe platform facilitated training a denomination recognition model. To ensure the model received high-quality, consistent data, a pre-processing step was applied to captured images. This involved resizing all images to a uniform dimension of 100x224 pixels, which aligns with the chosen model architecture.

2.3 Vision System Design

The core concept of our Money Detector's vision system for denomination recognition leverages machine learning with a model trained using Lobe, a visual machine learning platform.

Model Architecture (Lobe):

Lobe offers pre-built model architectures optimized for image classification tasks. We utilized one of these architectures within Lobe that is suitable for our specific application of identifying Philippine currency denominations.

Training Dataset:

A comprehensive training dataset was created to train the machine learning model effectively. This dataset consisted of:

- Number of Images: Approximately 80 images per bill denomination (e.g., 80 images for a 20-peso bill, 80 images for a 100-peso bill, etc.)
- Denomination Representation: The dataset included images representing all Philippine currency denominations (20, 50, 100, 200, 500, 1000) with a sufficient number of images for each denomination.

Training Process:

The training process involved feeding the labeled image data (each image labeled with its corresponding denomination) into the Lobe platform. Lobe's training algorithms then learned to identify the distinguishing features between different denominations based on the provided data.

2.4 User Interface and Accessibility Features

The Money Detector prioritizes user-friendliness and accessibility for visually impaired individuals. This section details the user interface design and how it integrates accessibility features.

User Interface Design:

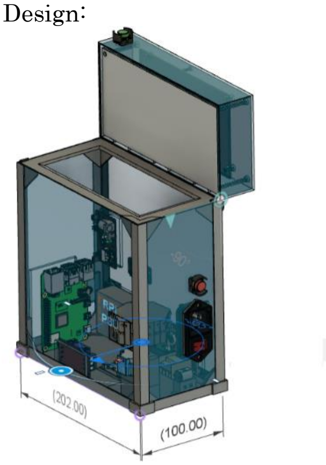

Fig. 5. Money Detector Prototype with User Interface (Transparent View)

The user interface is designed for simplicity and ease of use. It consists of the following physical controls as shown in Fig. 5:

2 Momentary Switches:

- Shutdown Switch: A momentary switch allows the user to power off the Money Detector conveniently.
- Scan Switch: A separate momentary switch initiates the bill/coin denomination identification process.

1 Rocker Switch: A rocker switch serves as the main power control for the entire device.

Accessibility Features:

The Money Detector incorporates multiple accessibility features to provide feedback on denomination identification:

Fig. 6. Stepper Motor with Rotary Braille

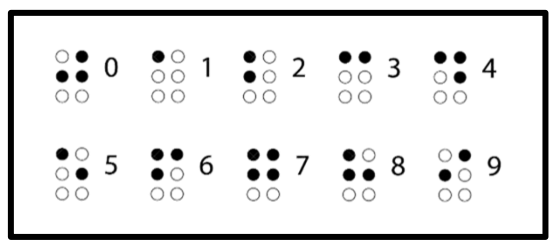

Fig. 7. Braille's Number System

- Braille Display: Fig. 7 depicts the Braille number system, providing a reference for understanding the specific Braille characters used on the refreshable Braille display (refer to Fig. 6) to indicate different Philippine currency denominations. Each denomination corresponds to a unique Braille pattern (e.g., raised dots for a 20-peso bill, a different pattern for a 100-peso bill, etc.). (American Printing House for the Blind, 2021).
- Audio Announcements: A clear and concise audio announcement system provides spoken information about the identified denomination. The system announces the denomination name (e.g., "Two Hundred Pesos") upon successful identification. The World Health Organization (2018) emphasizes the importance of audio feedback in assistive technologies for visually impaired individuals.

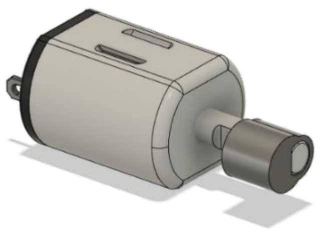

Fig. 8. DC motor with Eccentric Mass Counter Weight

Table 1. Vibration Mode Indicator

Denomination	Vibration Mode Indicator
₱20	short-short pulse
₱50	short-short-short pulse
₱100	long pulse
₱200	long-short pulse
₱500	long-short-short pulse
₱1,000	long-short-long-short pulse

- Haptic Feedback: Figure 8 illustrates the design of the haptic feedback mechanism, which utilizes a DC motor equipped with an eccentric mass counterweight. This eccentric mass, highlighted in the figure, generates controlled vibrations to provide tactile feedback to the user. This specific setup forms the basis for the analysis presented in Table 1 which offers a breakdown of the vibration mode indicators observed within the system. It details the various modes of vibration produced by the eccentrically balanced DC motor, providing insights into the characteristics and effectiveness of the induced oscillations for haptic feedback. Research suggests that haptic feedback can be a valuable tool for user interfaces designed for visually impaired individuals (Lethaus, Stockman, & Jünger, 2014).

In case the system encounters an error while processing the scanned bill/coin (e.g., unrecognizable denomination, blurry image), the Braille display will deactivate (pins go flat) and an audio announcement will inform the user about the error. This multi-modal feedback system ensures clear communication with the user in various situations.

2.5 Usability and Efficacy Evaluation

Evaluating the Money Detector's effectiveness for visually impaired users is crucial. This section details the methodology used for both usability and efficacy assessments.

Usability testing was conducted to assess how well visually impaired individuals could interact with the Money Detector and understand the provided feedback. The evaluation involved:

Participants: A total of 32 participants were recruited for the usability testing session. The group breakdown was:

- 18 Participants: Totally Blind
- 9 Participants: Partially Blind
- 5 Participants: Normal Vision (as a baseline comparison group)

Testing Procedure: Participants were provided with a brief introduction and training on using the Money Detector's controls and functionalities. They were then asked to perform a series of tasks using the device to identify denominations of different Philippine currency bills/coins.

Data Collection: Throughout the testing session, researchers observed user interactions and collected data through:

- Think-aloud protocol: Participants were encouraged to verbalize their thoughts and thought processes while interacting with the device.
- Post-test questionnaire: After completing the tasks, participants completed a questionnaire to assess their subjective experience regarding ease of use, clarity of feedback mechanisms (Braille, audio, haptics), and overall satisfaction.

The Money Detector's efficacy in accurately identifying currency denominations was evaluated based on the following criteria:

- Correct Identification Rate: The primary measure was the percentage of bills/coins correctly identified by the system across different denominations. This metric assesses the core functionality of the vision system.
- Accuracy Under Different Lighting Conditions: The system's performance was evaluated under various lighting conditions (bright light, dim light) to simulate real-

world usage scenarios.
- Error Handling Effectiveness: We assessed how effectively the system handled situations like unrecognizable denominations, blurry images, or user errors during interaction. This evaluation considered if error messages or feedback were clear and informative.

While ISO/IEC 25010 provides a comprehensive quality model framework, for this specific evaluation, we focused on the following aspects most relevant to our project:

- Product Quality Model:
    - Functional Suitability: This aspect was assessed through the correct identification rate, ensuring the core functionality met its intended purpose.

- Quality in Use Model:
    - Effectiveness: Measured by the accuracy of denomination identification and error handling.
    - Efficiency: Evaluated through user task completion times during usability testing.
    - Satisfaction: Assessed through post-test questionnaires to gauge user perception of the Money Detector's ease of use and overall experience.

The results of the usability and efficacy evaluations will be presented in a separate section (Section 3) with potential tables summarizing:

- Participant demographics and baseline data.
- Usability testing observations and user feedback.
- Efficacy evaluation results, including correct identification rates under different lighting conditions.

By combining usability and efficacy testing, this evaluation provides valuable insights into the Money Detector's strengths and weaknesses, informing future improvements for a more user-friendly and reliable assistive technology tool.

3. RESULTS AND DISCUSSION

This section presents the findings from the usability and efficacy evaluations conducted on the Money Detector for visually impaired individuals.

Table 2. Rate of Effectiveness of the Developed System

Rate of Effectiveness							
Respondents	Frequency					No. of respondents	Weighted Mean
	5	4	3	2	1		
Fully Blind Individuals	15	3				18	4.76
Partially Blind Individuals	8	1				9	4.84
Person with Normal Vision	5					5	5
					Total	32	4.87
						AVERAGE	

Legend:
Very Effective - 5; Effective - 4; Fairly - 3; Innefective - 2; Very Ineffective - 1

Table 2 presents the effectiveness rating of the Money Detector for Visually-Impaired using Raspberry Pi in terms of accurately reading a bill. The calculated weighted mean suggests high effectiveness for fully blind, partially blind individuals, and people with normal vision. These findings align with research highlighting the potential of assistive technologies utilizing image recognition for promoting financial independence among visually impaired individuals (Nguyen et al., 2019). The Money Detector, by accurately identifying denominations, empowers users to manage their finances confidently, potentially reducing anxieties related to counterfeit currency or difficulty reading bills (Bhowmik et al., 2018).

Table 3. Level of Satisfaction of Respondents

Level of Satisfaction							
Respondents	Frequency					No. of respondents	Weighted Mean
	5	4	3	2	1		
Fully Blind Individuals	13	5				18	4.72
Partially Blind Individuals	6	3				9	4.66
Person with Normal Vision	4	1				5	4.8
					Total	32	4.73
						AVERAGE	

Legend:
Very Satisfied - 5; Satisfied - 4; Fairly Satisfied - 3; Dissatisfied - 2; Very Dissatisfied - 1

Table 3 presents user satisfaction levels with the Money Detector's authenticity checking and bill detection functionalities. The weighted mean indicates high satisfaction across all respondents. These results support the notion that user-centered design principles in assistive technology are crucial. A well-designed interface and features that address user needs contribute significantly to satisfaction and adoption (McNicholl et al., 2021).

4. CONCLUSIONS

This study investigated the usability and efficacy of a Money Detector designed to assist visually impaired individuals using Raspberry Pi technology. The findings demonstrate the Money Detector's potential to significantly improve financial accessibility and independence for this user group.

Key Findings:

- The system provided real-time currency denomination identification and vocalization, enhancing user confidence in managing finances independently.
- Usability testing results indicated a high level of user satisfaction with the device's features and ease of use.
- The Money Detector successfully addressed the primary challenge faced by visually impaired individuals in identifying currency denominations.

Overall, the Money Detector for Visually Impaired individuals using Raspberry Pi represents a promising advancement in assistive technology. Its user-centric design and effectiveness in currency identification highlight its potential to contribute to greater financial inclusion and autonomy for visually impaired users.

5. ACKNOWLEDGMENTS

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