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A MOBILE ASSISTIVE APPLICATION OF PHILIPPINE CURRENCY RECOGNITION FOR THE VISUALLY IMPAIRED USING CONVOLUTIONAL NEURAL NETWORK

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Abstract

This thesis addressed the challenge faced by visually impaired individuals in distinguishing between different denominations of Philippine currency. Current assistive technologies are limited, hindering the independence of visually impaired individuals. The proposed solution employed state-of-the-art machine learning, specifically image classification and object detection models. The research design integrated qualitative, quantitative, and experimental approaches, with visually impaired students at Western Mindanao State University as respondents. The machine learning models achieved over 90% accuracy, with a notable 99% for paper and validator models and 90% for coins, despite challenges with newer coin versions. The study emphasized the significant impact of integrating Convolutional Neural Networks (CNN) and user-centric design principles in currency recognition applications, showcasing advancements in assistive technology and addressing the specific needs of the visually impaired. The conclusion underscored broader implications, extending beyond currency recognition to shape future innovations in mobile assistive applications, advocating for inclusivity and empowerment. Recommendations included the continual refinement of the CNN model, ongoing user testing and feedback, and further exploration of optical character recognition, contributing to both academic discourse on assistive technology and the pursuit of a more inclusive and empowered future for individuals with visual impairments.

Keywords: Visually Impaired, Philippine Currency Recognition, Convolutional Neural Network (CNN), Assistive Technology, Inclusivity and Empowerment.

CHAPTER I

INTRODUCTION

Background of the Study

In today's world, smartphones and mobile gadgets have become everywhere. Thanks to these technological advancements, it has become feasible to build applications capable of aiding people with poor eyesight in navigating their surroundings more efficiently. This technology is especially beneficial in the realm of currency identification, where the capability to differentiate between various denominations of currency is necessary.

Utilizing machine learning for bill recognition can significantly enhance the well-being of individuals with visual impairments. Notably, systems based on machine learning can offer a solution that is both accessible and practical by leveraging image or photo recognition technology to determine the value of a currency from a given image. Diverse machine learning models have been developed, together with Convolutional Neural Networks (CNN) and Support Vector Machines (SVM). These models undergo training using comprehensive datasets of bill images, enabling them to remember and recognize the distinctive characteristics of each denomination [15].

A notable example is the system of Alvin Alon, Rhowel Dellosa, et al. (2020) named EyeBill-PH, a system specifically designed to recognize Philippine paper bills. This system utilized a machine learning approach, incorporating a Raspberry Pi 4 as its microcontroller and a Pi camera as a device that captures images. Integrating such technology showcases the potential for practical and efficient solutions in assisting visually impaired individuals with currency recognition [18].

This research addresses the challenges visually impaired individuals face in recognizing Philippine currency. According to Resources for Blind Inc. (RBI), the Philippines is among the countries with the highest number of blind individuals, reaching approximately 500,000 people. Since there is a large number of visually impaired individuals, the increasing importance of mobile assistive technology stresses its role in meeting the specific needs of people in the Philippines with poor eyesight [22].

Farhat Ullah, Muhammad Imad, et al. (2020) conducted a comparable study titled 'Pakistani Currency Recognition.' This study aimed to aid blind individuals in Pakistan using a combination of Convolutional Neural Network (CNN) and Support Vector Machine (SVM). The system is designed to identify various Pakistani banknotes for the benefit of the blind or visually impaired. Lastly, the training and testing of the system involved seven different Pakistani banknotes [13].

In this study, the researcher aimed to create a mobile assistive application capable of recognizing and identifying various denominations of Philippine currency through image processing, specifically using the Convolutional Neural Network (CNN).

Statement of the Problem

This study addressed the challenge visually impaired individuals faced in determining various denominations of Philippine currency. Distinguishing between bills and coins proved to be complex, time-consuming, and challenging for visually impaired individuals. Moreover, this difficulty could result in errors during financial transactions, potentially exposing individuals to theft or fraud. Currently, assistive technologies designed to aid people with poor eyesight in currency recognition in the Philippines are limited. Although a few other assistive devices exist, they are still limited in availability and may not be accessible to everyone who needs them. Consequently, individuals with poor eyesight may continue to rely on others for currency identification, impeding their autonomy and independence.

Purpose of the Study

The primary purpose of this study was to design, develop, and evaluate a mobile assistive application that utilized state-of-the-art Convolutional Neural Network (CNN) technology to recognize Philippine currency denominations. The aim was to enhance the accessibility and independence of people with poor eyesight during their daily financial transactions in the Philippines.

General Objectives

The main goal of this study is to design and create a mobile assistive application for money recognition of Philippine currency for individuals with poor eyesight using state-of-the-art machine learning and computer vision techniques such as Convolutional Neural Networks.

Specific Objectives

1. Designing a system tailored for visually impaired individuals to recognize Philippine currency.

2. Utilized the Convolutional Neural Network (CNN) algorithm in machine learning models to recognize Philippine currency.
3. Developed a mobile assistive application that integrates machine learning models for recognizing Philippine currency in real-time.
4. Evaluated the accuracy of the developed application in recognizing various denominations of Philippine currency and compared it with the precision of at least one existing currency recognition system.
5. Evaluated the performance of the developed mobile assistive application by testing its accuracy, speed, and user satisfaction through a survey.

Scope and Limitations

Scope:

- The application will be specifically built and designed for sight-impaired individuals who need assistance in recognizing Philippine currency.
- The application will provide an audio feedback feature or auditory signals that will notify the detected Philippine currency denomination.
- The application will prioritize user-friendliness and accessibility, ensuring it is easily usable by individuals who are blind or visually impaired.
- The application is crafted to recognize and identify common denominations of Philippine currency, covering recently published bills and coins.
- The application is designed to operate without requiring an internet connection, enabling its use anytime and anywhere.

Limitation:

- The application may struggle to recognize poorly conditioned, damaged, or excessively dirty currency.
- The application lacks the capability to identify counterfeit Philippine currency, posing a potential risk to users.
- Foreign currency may go unrecognized by the application, limiting its scope to Philippine currency.
- The accuracy of currency identification may be affected by environmental factors such as illumination, backdrop, and the orientation of the banknote.
- The application's compatibility with mobile devices or operating systems is not universally guaranteed, potentially excluding some users.
- The accuracy of currency recognition may heavily rely on the quality of the captured images. Poor lighting conditions, low-resolution cameras, or blurred images may impact the application's performance.
- The speed of currency recognition may vary based on the processing power of the user's mobile device. Older or low-performance devices may experience delays in identification.
- The application exhibits occasional low accuracy, particularly in predicting newer versions of Philippine coins.

Significance of the Study

The results of this study benefited the following:

1. **Visually Impaired Individuals**

The primary beneficiaries are visually impaired individuals in the Philippines who face challenges in recognizing and differentiating Philippine currency denominations. This mobile assistive application will empower these individuals to handle financial transactions independently, thereby enhancing their quality of life and social inclusion.

2. **Families and Caregivers**

Families and caregivers of visually impaired individuals will also benefit from the results of this study. This application can reduce some of the burden associated with assisting visually impaired family members with financial matters, promoting a sense of autonomy for both parties.

3. **Educational Institutions**

Institutions providing education and training for visually impaired individuals may find value in this study. This research could serve as a case study or educational resource, illustrating the practical application of machine learning and computer vision.

4. **Government and Nonprofit Organizations**

Government agencies and nonprofit organizations focused on disability rights, accessibility, and assistive technology may benefit from the findings of this study. Furthermore, this research can inform the government and nonprofit organizations related to improving the lives of visually impaired individuals to leverage technology specifically assistive technology, machine learning, and computer vision.

5. **Developers**

This thesis has the potential to be a valuable resource for developers who are interested in assistive technology, machine learning, and mobile application development. Developers in these fields can use this study as a reference and source of information.

6. Future Researchers and Developers

Ultimately, this study can be a valuable resource and source of inspiration for researchers in various related fields. Moreover, this research not only addresses important societal issues but also provides a platform for further exploration, innovation, and collaboration among researchers interested in assistive technology and accessibility for the visually impaired.

CHAPTER II

REVIEW OF RELATED LITERATURE

Related Literature

TensorFlow

The authors of an informative article, namely Erik Nijkamp, Bo Pang, and Ying Nian Wu in their work entitled "Deep Learning with TensorFlow: A Review," have expounded on the widespread nature of a powerful framework for deep learning techniques known as TensorFlow. The bold development was first conceptualized by scholars at Google and has since become widely adopted to enhance various applications related to machine intelligence. This technology stands as a foundation in the landscape of machine learning libraries. Renowned for its versatility and scalability, TensorFlow has become the preferred choice among developers and researchers working in deep learning. This platform is designed to assist with the creation and deployment of intricate neural network models, which is essential for the success of deep learning applications in diverse fields. The framework offers a comprehensive suite of tools and resources, empowering users to construct, train, and optimize diverse neural network architectures. TensorFlow provides a robust foundation for tackling intricate machine learning challenges, from fundamental models like the multilayer perceptron to advanced convolutional neural networks. Its capacity to streamline the implementation process, coupled with features like graph construction functions and the visualization tool Tensor Board, makes TensorFlow an indispensable ally for researchers, engineers, and data scientists seeking to push the boundaries of artificial intelligence [1].

Machine Learning

In a study "What Is Machine Learning?" by Issam El Naqa and Martin Murphy, machine learning serves as a dynamic branch of computational algorithms, meticulously crafted to mimic human intelligence by assimilating knowledge from its environment. This paradigm has become indispensable in the contemporary era of big data, demonstrating its effectiveness across diverse domains, including pattern recognition, computer vision, finance, entertainment, and biomedical applications [2].

The authors Man Ting Kwong, Glen Wright Colopy, Anika M. Weber, Ari Ercole, and Jeroen H. M. Bergmann, assert that machine learning (ML) holds significant promise in addressing the challenges of weaning patients from mechanical ventilation (MV) in the intensive care unit (ICU). Recognizing the complexities of this clinical issue, the authors emphasize the potential of ML to positively impact patient outcomes and reduce the duration of MV, thereby mitigating medical complications, associated costs, and adverse events. Their systematic literature review reveals a limited but promising number of studies utilizing ML in critical care, focusing on predicting outcomes such as successful spontaneous breathing trials, extubation, and arterial blood gases. The authors advocate for further research to explore ML's efficacy in addressing the unique challenges posed by "difficult-to-wean" patients. They underscore the need for robust databases to support the development of ML techniques tailored to the specific requirements of this critical clinical context [3].

Convolutional Neural Network Deep Learning Algorithm

Saad Albawi, Tareq Abed Mohammed, and Saad Al-Zawi explained the key findings regarding Convolutional Neural Networks (CNNs) in their study "Understanding of a convolutional neural network.". The term "Deep Learning" denotes Artificial Neural Networks (ANN) with multiple layers, showcasing their efficacy as powerful tools in handling extensive datasets. CNNs, a prominent type of deep neural network, have gained significant popularity for their outstanding performance, particularly excelling in pattern recognition tasks. The authors emphasize the integral components of CNNs, including convolutional, non-linearity, pooling, and fully connected layers. Notably, CNNs prove to be exceptional in machine learning, particularly in applications dealing with image data such as the ImageNet dataset, computer vision, and natural language processing (NLP). The paper provides valuable insights into the operation of CNN elements and parameters influencing efficiency, contributing significantly to the understanding of Convolutional Neural Networks in the context of deep learning [4].

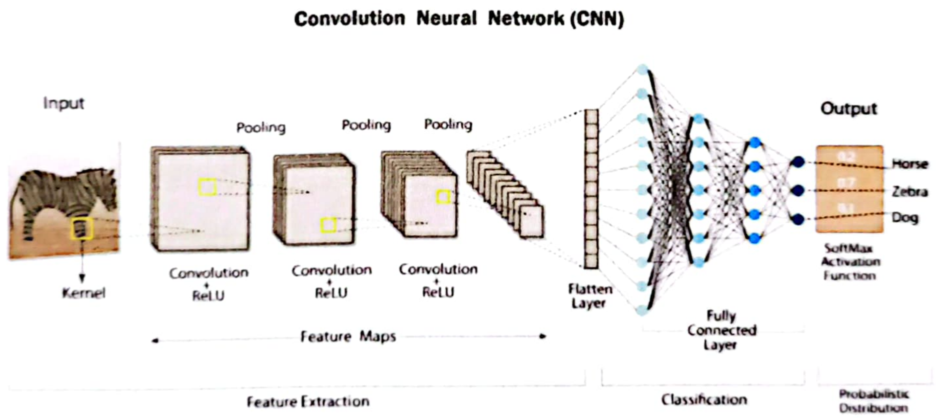


Figure 1 CNN Layer [21]

Anamika Dhillon and Gyanendra Verma delve into the efficacy of deep learning, specifically Convolutional Neural Networks, in image classification. Their review spans classical models like LeNet to advanced architectures such as AlexNet, GoogleNet, ResNet, SENet, and more. Emphasizing applications in wild animal, small arm, and human detection [5].

Object Detection

In the study titled "Object Detection", Yali Amit, Pedro Felzenszwalb, and Ross Girshick stated that the primary objective of object detection is to identify all occurrences of objects within an image belonging to predefined classes, such as people, cars, or faces. Despite a relatively small number of objects typically being present, the challenge lies in the vast number of potential locations and scales at which these objects can appear, necessitating a systematic exploration [6].

SSD MobileNetv2 FPN-lite

Based on research by Martinus Grady Naftali, Jason Sebastian Sulistyawan, and Kelvin Julian titled "Comparison of Object Detection Algorithms for Street-level Objects", SSD MobileNetv2 FPN-lite emerges as a standout performer in the evaluation of street-level object detection algorithms they have conducted. Notably, this model demonstrates remarkable efficiency with an impressively fast inference time of only 3.20ms, making it an ideal candidate for real-time processing applications. The rapid inference time of SSD MobileNetv2 FPN-lite positions it as a compelling choice for scenarios where low latency is crucial, such as in self-driving car systems. This efficiency and commendable overall performance contribute to its suitability for real-world deployment, where a balance between accuracy and speed is essential [7].

Image Classification

Image classification is an intricate process influenced by numerous factors. The study by D. Lu and Q. Weng, "A Survey of Image Classification Methods and Techniques for Improving Classification Performance, " thoroughly explores contemporary practices, challenges, and prospects in image classification. The primary focus is summarizing advanced classification approaches and techniques to enhance accuracy. The paper underscores the pivotal role of a well-designed image-processing procedure as a prerequisite for successfully classifying remotely sensed data into thematic maps. Effectively utilizing multiple features in remotely sensed data and selecting an appropriate classification method is crucial for improving accuracy [8].

Accessibility

According to a study, "Mobile assistive technologies for the visually impaired." by Lilit Hakobyan, Jo Lumsden, Dympna O'Sullivan, and Hannah Bartlett, there are approximately 285 million individuals globally with visual impairment, and the UK alone has 370,000 registered as blind or partially sighted. Ongoing advancements in information technology (IT) are expanding the possibilities of IT-based mobile assistive technologies, aiming to improve the independence, safety, and overall quality of life for those with visual impairments. The study highlights the necessity for successful collaboration between clinical expertise, computer science, and end-users to fully realize the potential advantages of these technologies [9].

The research focuses on enhancing the accessibility of mobile phones and handheld devices through haptic (touch) and audio-sensory channels. It reviews research and innovation in the field, emphasizing the importance of interdisciplinary collaboration to optimize the advantages of these technologies. The overarching goal is to leverage technological advancements to enhance accessibility and address the unique challenges faced by individuals with visual impairments.

Related Studies

Foreign Studies

Muhammad Sarfraz (2015) presented a study titled "An Intelligent Paper Currency Recognition System." This research introduced a system designed to recognize Saudi Arabia's paper currency, employing image processing and other neural network techniques. It is important to note that this system is specifically tailored for the paper currency of Saudi Arabia and does not extend to other currencies [10].

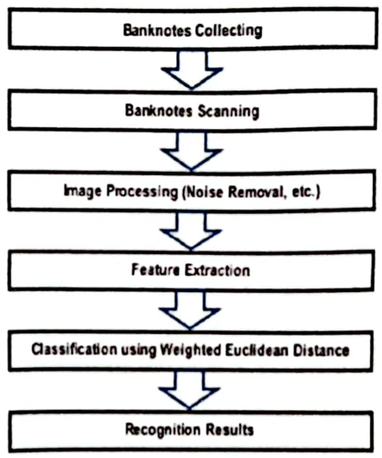


Figure 2 Design flow diagram of currency recognition system. [11]

In the work titled "Using Hidden Markov Models for Paper Currency Recognition" by Hamid Hassanpour and Payam Farahabadi (2009), the authors presented a novel technique for identifying banknotes from various countries. Their approach is based on the Hidden Markov Model, employing a 64-level grayscale to reduce computational load. Through experiments, the algorithm demonstrated a notable 98% precision in identifying paper currency denominations from 100 other countries [12].

In the paper titled "Currency Detection and Recognition Based on Deep Learning" by Qian Zhang, Wei Yan, et al. (2018), the authors employed a Single Shot Multibox Detector (SSD) model within the framework of deep learning for their assignment. Additionally, the project incorporated the Convolutional Neural Network (CNN) model to extract characteristics from backnotes. The trained model achieved an average accuracy of 96.6% in recognizing paper currency [13].

In the study titled "Pakistani Currency Recognition to Assist Blind Person Based on Convolutional Neural Network" by Muhammad Imad, Farhat Ullah, et al. (2020), the authors shed light on the daily challenges faced by visually impaired individuals, emphasizing the difficulty in recognizing their country's currency. The research introduces a system designed to address this issue by utilizing a convolutional neural network and support vector machine to recognize Pakistani currency for people who are blind. The system's training and testing phase involved seven distinct paper denominations, achieving a notable accuracy of 96.85% in recognizing all seven denominations" [14].

Figure 3 Pakistani Currency [15]

In the article "Fast-moving Coin Recognition using Deep Learning" by Yufeng Xiang and Wei Qi Yan (2021), the authors presented a solution for the swift recognition of coins employing deep learning techniques. They determined that the Long Short-Term Memory (LSTM) within the Recurrent Neural Network (RNN) proved to be the most effective model for recognizing rapidly moving objects. Ultimately, the study achieved high accuracy using the proposed method" [16].

The significance of assistive technology in enhancing the life rate of people with visual problems is increasingly recognized. Frontiers (2022) suggests that assistive technology is crucial in advancing the achievement of Sustainable Development Goals (SDGs), facilitating healthy, productive, independent, and dignified lives for children with disabilities. Various assistive technologies, such as mobile assistive applications, screen readers, electronic magnifiers, and braille displays, have been developed to address these needs [17].

Most smartphones and the growing accessibility of affordable mobile devices have propelled mobile applications to prominence as assistive technologies for visually impaired individuals. Research indicates that these applications offer diverse forms of assistance, such as navigation support, object recognition, and currency identification. In summary, mobile applications are crucial in supporting visually impaired individuals worldwide.

Local Studies

In the study "Coin Identification and Conversion System using Image Processing" conducted by John Moises Rigon, Danielle Dumalian, et al. (2022), the researchers employed two technologies, namely YOLOv3 and Convolutional Neural Network (CNN), for the recognition of four distinct coin currencies in the Philippines. Challenges arose in recognizing coins during the testing phase due to varying directions and complex patterns. The research indicated that maintaining a 6-cm length between the camera and the coin proved optimal for efficient coin detection, in which, in the end, the system demonstrated a precision ranging from 96.30% to 98.15% at various degree angles [18].

In the study titled "Coin Detection and Classification Model Using Canny Edge Algorithm" by Carlo Tumoling, Anna Liza Ramos, et al. (2019), the researchers developed a system capable of recognizing coins in the Philippine banknotes using the Canny Edge Algorithm. Their findings indicated that the Canny Edge Algorithm outperformed other methods, achieving the highest accuracy score of 99.74%, in contrast to Laplacian of Gaussian getting an accuracy of 97.25% and Rober's Edge detection, reaching a precision of 93% [19].

To advance the growth of assistive applications specifically tailored to the individuals with a low eyesight in the Philippines, more research is needed. Moreover, an existing study named the EyeBill-PH system has been explored; this system utilized a Raspberry Pi 4 paired with a Pi Camera. It enables the recognition of Philippine banknotes. A gap exists even with the previous study in mobile assistive applications for currency recognition. Lastly, a mobile assistive application capable of recognizing various denominations of Philippine currency is still in need [20].

Synthesis

Visually impaired individuals rely upon someone for assistance in identifying denominations of Philippine currency. While the help of others can sometimes be unavailable, they tend to stop their financial transactions as there is no other way for them to identify the currency on their own. The researcher of this study wanted to solve this problem by developing a mobile assistive application that can recognize Philippine currency accurately using state-of-the-art machine learning.

Table 2 Comparison Table

ATTRIBUTES	EyeBill-PH	Cash Reader	iBill Banknote	Denomination Detector	Noteify	This Study's System
Coin	✗	✗	✗	✗	✗	✔
Money counter feature	✗	✗	✗	✗	✗	✔
Free	✔	✗	✗	✔	✔	✔
No need internet	✔	✗	✗	✔	✔	✔
Android Application	✗	✔	✗	✔	✔	✔
Computer generated audio output	✔	✔	✔	✔	✔	✔
Paper Bill	✔	✔	✔	✔	✔	✔

Table 2 shows a comparative analysis of different money recognition systems for assisting the visually impaired. These systems include "EyeBill-PH", "Cash Reader", "iBill Banknote", "Denomination Detector", "Noteify", and a new system developed as part of this thesis. Among the different attributes, the capacity to recognize coins is exclusive to this application. Surprisingly, none of the systems offer a feature to count money. When considering the cost aspect, "EyeBill-PH", "Denomination Detector", "Noteify" and this thesis's system stand out as free options, whereas "Cash Reader" and "iBill Banknote" are paid applications. Regarding internet dependency, while "Cash Reader" and "iBill Banknote" require connectivity, the other systems can function offline. Most of the systems are tailored for the Android platform, except for "EyeBill-PH" where the platform uses Arduino, and "iBill Banknote" where the platform is a physical tool. Aiding the visually impaired, all systems incorporate computer-generated audio outputs and can recognize paper bills.

This study's application can recognize both coins and paper bills while also being a free application that does not require internet connectivity. Each system has its advantages, but this study's application addresses multiple needs essential to the visually impaired community in the Philippines.

CHAPTER III

METHODOLOGY

Research Design

This study employed a mixed-methods procedure, integrating qualitative, quantitative, and experimental research methods. Qualitative research involved interviews with visually impaired individuals to acquire meaningful insights into their needs and selections for the software. Quantitative research utilized usability testing to evaluate the effectiveness and precision of the application's recognition capabilities. Finally, the study incorporated an experimental research design, providing a systematic method to assess the efficacy of the mobile assistive application for recognizing Philippine currency. Participants assigned to the experimental group underwent training to familiarize themselves with using the application for currency recognition.

Respondents

The survey focused on visually impaired individuals who use mobile devices, with participants specifically invited from Western Mindanao State University in Zamboanga City, Philippines. This targeted approach, suggested by panelists, ensured a diverse and relevant perspective on the necessity for system development.

Research Locale

The study was conducted at the Western Mindanao State University located in Zamboanga City, Philippines. The choice of this locale was based on the accessibility of participants and resources and per the panelists' recommendations. The university serves as an ideal setting for the study, allowing for a focused examination of the application's effectiveness in a real-world environment due to a diverse population of potential users.

Population and Sampling

Population

The population included visually challenged Western Mindanao State University students who require aid in identifying Philippine currency. Individuals who are fully blind and those with limited vision or other visual impairments are included.

Sampling

This purposive sampling approach was chosen to ensure that the study focused on a specific subgroup that directly aligns with the research objectives, which revolve around the development and evaluation of a mobile assistive application for currency recognition.

Data Gathering Instruments, Techniques, and Procedures

Data Gathering Procedure

As part of the researcher's ethical considerations, all participants received detailed information about the purpose and objectives of the study. Additionally, the researchers ensured confidentiality and anonymity, guaranteeing that participants would not be subjected to harm or risks during the study. After obtaining informed consent from the participants, the researchers delivered and interpreted the data collection instrument to the respondents, evaluating the developed application in terms of its accuracy, speed, and user satisfaction and feedback.

Data Gathering Techniques

The researcher collected data using surveys administered to visually impaired individuals at Western Mindanao State University. The survey served as a valuable tool for gathering insights regarding the mobile application's accuracy, speed, and user satisfaction and feedback.

Table 3 shows the survey questionnaire's Likert scale of 1 to 5. with 1 being the lowest, interpreted as "Strongly Disagree," and five being the highest, interpreted as "Strongly Agree."

Table 3 Likert Scale Rating

Rating	Interpretation
1. 1	Strongly Disagree
2. 2	Disagree
3. 3	Neutral
4. 4	Agree
5. 5	Strongly Agree

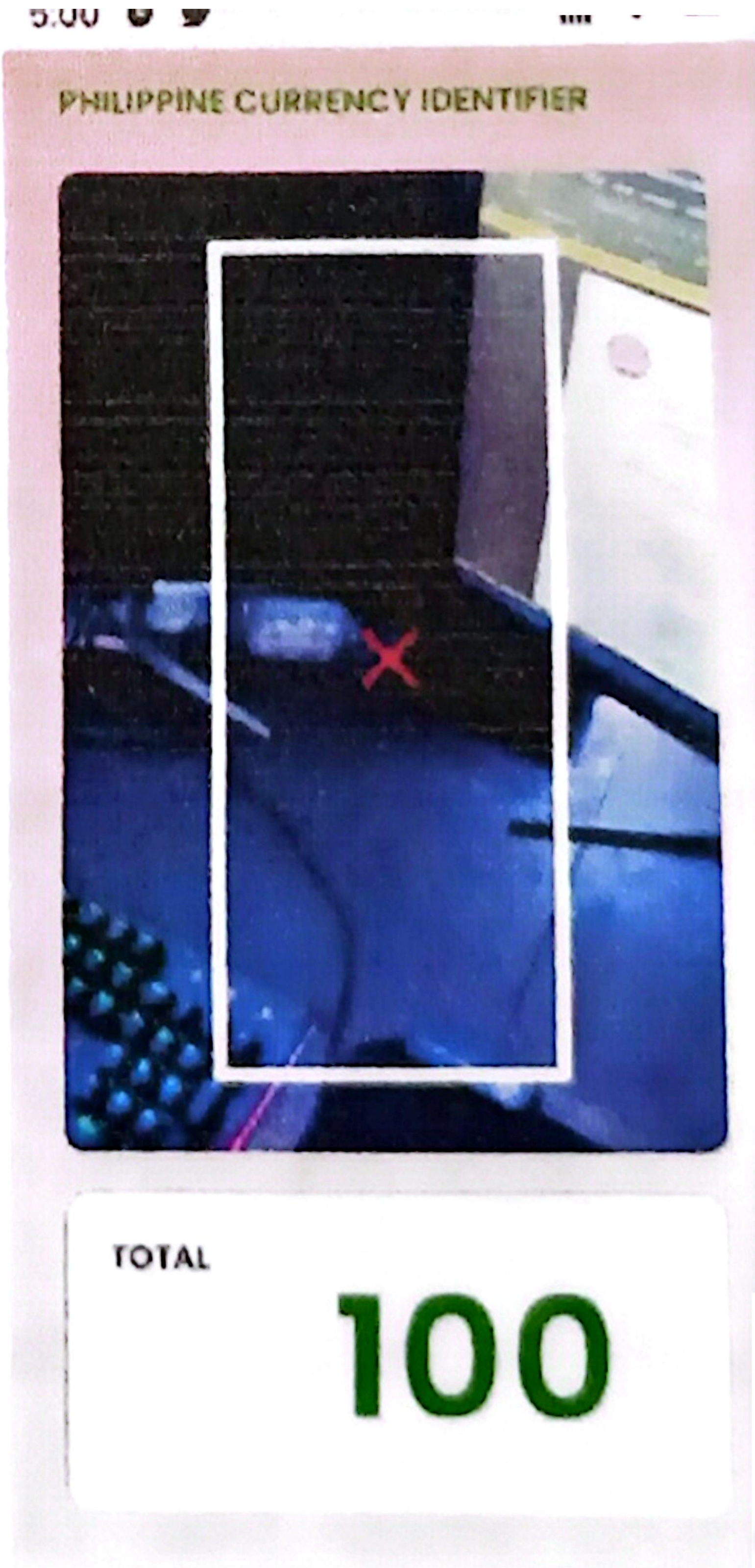
Statistical Tools

Descriptive statistics were employed to itemize and represent the data for this study. The researcher utilized Microsoft Excel and Word as graphing tools to define the findings visually. For instance, the mean, median, and standard deviation of the mobile application's accuracy scale for identifying Philippine currency were computed to determine the central tendency of responses. These statistical measures, presented through graphs and charts created in Microsoft Excel, offer a comprehensive understanding of the data trends.

Analytical Tools

The figure below shows the application's flow from the end-users' perspective. It describes the flow of the application.


5:00
PHILIPPINE CURRENCY IDENTIFIER
DETECTED
100
TOTAL
100


5:00
PHILIPPINE CURRENCY IDENTIFIER
TOTAL
100

The researcher integrated a minimalist design to provide a simple, clean, and smooth user experience. One consideration is the selection of a color palette designed to optimize contrast and readability, specifically for users with visual impairments, as shown in Figures 12 and 13. When a currency is detected, the text is displayed in bright yellow with a dark background to emphasize the detected value, as shown in Figure 12. Additionally, it shows a lightweight green color, indicating a positive output. In contrast, figure 13 uses light red to display negative feedback. Moreover, in both figures, the total section box's text spaces were widened to avoid confusion for the user.

Voice-Guided Interaction

The researcher included voice-guided interactions in the developed mobile assistive application, which significantly enhanced accessibility for visually impaired users. This voice-guided interaction utilizes Google Text-to-Speech technology, offering a real-time auditory cue for understanding and interacting with the application.

Non-Visual Feedback

The researcher integrated non-visual feedback mechanisms such as auditory cues, vibration feedback, and sound effects, thereby offering alternative sensory feedback to enhance the user experience. For instance, the application provides instructive guidance to users within auditory cues. In the case of vibration feedback, the system employs vibrations to alert users when a currency is successfully detected. Lastly, regarding sound effects, the application included a distinctive continuous ticking sound, signaling the active use of the camera and indicating that the system is currently scanning an object based on its camera's point of view.

Gesture Functionality

The researcher incorporated gesture functionality to enhance user-friendliness and accessibility. For instance, when a currency is detected, users receive clear instructions through auditory cues and are prompted to act by swiping right to add the detected currency or swiping left to skip it.

User-Centric Design Philosophy

The researcher also applied a user-centric design philosophy that fulfills the needs and preferences of visually impaired individuals before developing the mobile assistive application.

2. Integration of Image Processing Algorithm and Machine Learning Models

The second objective was integrating an image processing algorithm, specifically Convolutional Neural Network (CNN), into machine learning models.

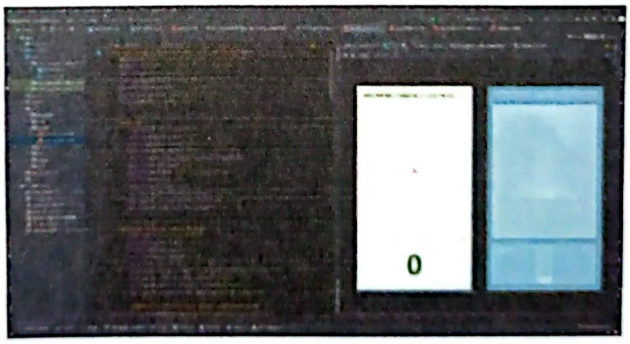
The researchers used two different types of machine learning models, namely, image classification and object detection models. For the image classification model, an online tool called Teachable Machine with Google was used to train the three image classification models. For the object detection model, the TensorFlow library was used. Both platforms integrated pre-trained models that utilize an algorithm called Convolutional Neural Network.

```python
if isImageClassification:
    ImageClassifierWriter = image_classifier.MetadataWriter
    # Task Library expects label files that are in the same format as the one below.
    _SAVE_TO_PATH = "allMoneyMetadata.tflite"
    _INPUT_NORM_MEAN = 127.5
    _INPUT_NORM_STD = 127.5

    # Create the metadata writer.
    writer = ImageClassifierWriter.create_for_inference(
        writer_utils.load_file(model_final_path), [_INPUT_NORM_MEAN], [_INPUT_NORM_STD],
        [label_final_path])

    # Verify the metadata generated by metadata writer.
    print(writer.get_metadata_json())

    # Populate the metadata into the model.
    writer_utils.save_file(writer.populate(), _SAVE_TO_PATH)
```

Figure 14 TFLITE Metadata Adder

These models were then saved in TFlite format, a suitable format for mobile and embedded devices. To provide additional information for each model, such as its input and output and other valuable data, the researchers added metadata using the tflite-support library, including its labels as shown in Figure 14.

3. Development of Mobile Assistive Application



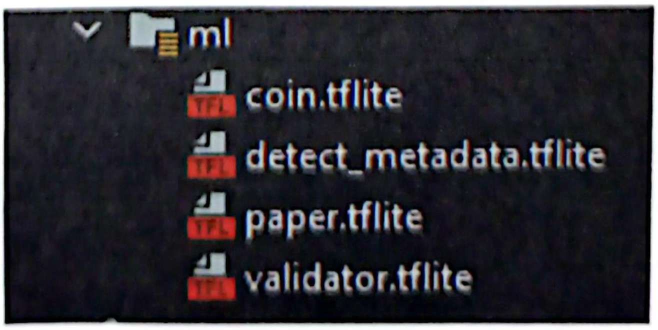


Figure 15 Android Studio and Figure 16 Machine Learning Models

The developer created a mobile assistive application using the Android Studio IDE, as shown in Figure 15. The application was developed using Kotlin as the programming language. The machine learning models, which were trained using the Convolutional Neural Network (CNN) algorithm, were seamlessly incorporated into the application through this Integrated Development Environment (IDE). This integration is shown in Figure 16, where the developer right-clicked the highlighted folder named 'app,' then navigated to the 'TensorFlow Lite Model' option and imported the actual file of the machine learning models.

Additionally, the developer included dependencies in various Gradle files to ensure the application's effective utilization and correct integration of the models.

4. Performance Evaluation Through Surveys

The researcher conducted data gathering for performance evaluation through a survey with the participation of the visually impaired respondents. The survey is divided into three categories: accuracy, speed, and user satisfaction. The collected data were then transcribed and analyzed to extract meaningful conclusions about the accuracy, speed, and overall user satisfaction.

5. Comparison with Existing Systems Through Surveys

The researcher guided the respondents on using the developed mobile assistive application for this study and a similar currency recognition application called "Cash Reader". The objective is focused on the comparison for the category of accuracy. Through the research questionnaire, participants provided feedback, particularly regarding their perception of the developed mobile assistive application's accuracy compared to other currency recognition systems. The collected data were analyzed, and meaningful insights were extracted.

Machine Learning Models

1. Object Detection Model

The object detection model was an initial validator checker, acting as the first layer in the application's currency recognition system. This crucial model, designed to determine the presence of currency in the live mobile camera feed, operates with a dual-label system, distinguishing between 'money' representing paper bills and 'coin' indicating metallic currency.

The integration of this model plays a pivotal role in enhancing the application's functionality by efficiently verifying the existence of currency within the camera's field of view. Notably, this model processes input images of size 320 by 320, strategically optimizing its computational efficiency while maintaining high accuracy in detecting and localizing currency objects.

2. Image Classification Model

2.1. Paper Model

The paper model focuses on paper currency, it has 7 classifications: 'twenty,' 'fifty,' 'onehundred,' 'twohundred,' 'fivehundred,' 'onethousand,' and 'onethousandnew.'

2.2. Coin Model

The coin model is tailored for metallic currency, encompasses 8 classifications: 'onecoinnew,' 'onecoinold,' 'fivecoinnew,' 'fivecoinold,' 'tencoinnew,' 'tencoinold,' 'twentycoin,' and 'cointail'—referring to the back of the coin, specifically for classifications 'onecoinnew,' 'onecoinold,' 'fivecoinnew,' and 'tencoinnew.' These coins share a similar pattern and color, and the application prompts users to flip the coin once detected, ensuring enhancing the overall usability of the system.

2.3. Validator Model

The Validator model serves as the second layer validator checker in the developed mobile assistive application, comprising two classifications: 'Valid' and 'Invalid.' This model acts as a further checker on the accuracy of the object detection model. In instances where the object detection model may inaccurately identify objects, this model becomes instrumental in determining whether the detected image genuinely contains Philippine currency ('Valid'), if it contains foreign currency ('Foreign'), or if it is an incorrect detection ('Invalid'). This additional layer of validation enhances the overall robustness of the application.

The development of the three image classification models was meticulously carried out using Teachable Machine with Google, an accessible online tool designed for training image classification models. This platform, harnessing the capabilities of the TensorFlow library, provides a user-friendly environment conducive to the creation and refinement of models tailored to specific tasks. The models exhibit proficiency in processing images of size 224 by 224, strategically balancing computational efficiency with accurate classification.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

This section outlines the conclusions and recommendations drawn from the study. Focusing on the developed mobile assistive application designed for recognizing different denominations of Philippine currency. The application is specifically tailored for visually impaired individuals, featuring the integration of state-of-the-art machine learning, specifically Convolutional Neural Network (CNN).

Conclusion

This thesis, entitled 'A Mobile Assistive Application of Philippine Currency Recognition for the Visually Impaired Using Convolutional Neural Network,' has successfully developed a mobile assistive application. The primary focus is recognizing the Philippine currency, which is achieved through Convolutional Neural Network (CNN) technology. The key findings of this study emphasize the effectiveness of integrating CNN and incorporating user-centric design principles to address the unique challenges faced by individuals with visual impairments in distinguishing and utilizing currency. By concentrating on Philippine currency and tailoring the application to the distinctive needs of the visually impaired, this research showcases how combining technology and a profound understanding of user requirements can significantly enhance the overall user experience.

This journey began with a clear set of objectives aimed at providing technological solutions to enhance the independence and financial inclusivity of the visually impaired community in the Philippines. Through thorough experimentation, research, and analysis, I have demonstrated the feasibility of the developed mobile application, showcasing its potential as a valuable tool in the daily life of a visually impaired individual.

While celebrating the achievements of this thesis, it is essential to acknowledge certain limitations, specifically the low accuracy of the new version of Philippine coins. The current version of the mobile assistive application may benefit from an additional refinement to improve the user experience and address potential challenges in diverse real-world scenarios. This acknowledgment sets the stage for future research endeavors, encouraging them to make continuous improvements tailored to the evolving needs of the visually impaired community.

The application's success establishes a strong groundwork for broader applications in assistive technology, providing opportunities for further investigation and progress. Considering the practical implementation of this cutting-edge technology, its positive impact on visually impaired individuals steadily becomes more pronounced as they gain increased confidence and autonomy in navigating financial transactions. These observations hold meaningful implications within the field of assistive technology by bearing witness to society's ever-increasing demand for inclusivity and empowerment. These research findings extend beyond currency recognition itself, shaping the future towards an era where advanced technological solutions are seamlessly integrated into intuitive, user-friendly applications to ensure a smoother experience while promoting inclusion amongst those with visual impairments.

In conclusion, the created mobile assistive application serves as evidence of technology's potential to bring about positive and meaningful transformation. By embracing all possible outcomes, this research will act as a catalyst for additional advancements toward betterment. My efforts in addressing the obstacles faced by visually impaired individuals while managing currency enhance their daily living experiences and set an exemplary model for upcoming innovations that prioritize accessibility and user experience. As we foster inclusivity through enforcing easy access measures, it propels us into a future where technology evolves into an effective ally, ensuring no individual is deprived or left behind.

Recommendations

Considering the qualitative feedback derived from the survey and the comprehensive findings of this study, several recommendations are proposed to enhance the developed mobile assistive application for Philippine currency recognition for visually impaired users:

1. Continual Refinement of CNN Model:

   Considering concerns raised by respondents and limitations in the application's accuracy, especially in coin detection and distinguishing between different denominations of new currency versions, it is recommended that the Convolutional Neural Network (CNN) model be refined continuously. This includes adding more images to denominations with low accuracy and exploring additional settings for fine-tuning the model.

2. Continues User Testing and Feedback

   To ensure the application effectively evolves in response to the dynamic needs of visually impaired users, it is crucial to establish and maintain continuous user testing and feedback mechanisms. This iterative process is a foundation for refining and enhancing the application based on authentic, real-world user experiences. Further user studies with larger sample sizes are also recommended for more robust statistical analysis. Gathering longitudinal data on user experience over extended periods of use will provide comprehensive insights into the application's long-term effectiveness and user satisfaction.

3. User Experience

   To address user feedback, consider adding voice customization, money-counting capability, and enhanced accessibility options. Prioritize inclusivity in developing these features to enhance the overall user experience.

4. Optical Character Recognition

   Consider delving into integrating advanced technologies, such as optical character recognition, to extract serial numbers and enhance the validation of currency authenticity.

References

1. Bo Pang, Erik Nijkamp, and Ying Nian Wu. 2019. Deep Learning With TensorFlow: A Review. *Journal of Educational and Behavioral Statistics* 45, 2 (September 2019), 227–248. DOI:https://doi.org/10.3102/1076998619872761
2. Issam El Naqa and Martin J. Murphy. 2015. What Is Machine Learning? *Machine Learning in Radiation Oncology* (2015), 3–11. DOI:https://doi.org/10.1007/978-3-319-18305-3_1
3. Man Ting Kwong, Glen Wright Colopy, Anika M. Weber, Ari Ercole, and Jeroen H. M. Bergmann. 2018. The efficacy and effectiveness of machine learning for weaning in mechanically ventilated patients at the intensive care unit: a systematic review. *Bio-Design and Manufacturing* 2, 1 (December 2018), 31–40. DOI:https://doi.org/10.1007/s42242-018-0030-1
4. Saad Albawi, Tareq Abed Mohammed, and Saad Al-Zawi. 2017. Understanding of a convolutional neural network. *2017 International Conference on Engineering and Technology (ICET)* (August 2017). DOI:https://doi.org/10.1109/icengtechnol.2017.8308186
5. Anamika Dhillon and Gyanendra K. Verma. 2019. Convolutional neural network: a review of models, methodologies and applications to object detection. *Progress in Artificial Intelligence* 9, 2 (December 2019), 85–112. DOI:https://doi.org/10.1007/s13748-019-00203-0
6. Yali Amit, Pedro Felzenszwalb, and Ross Girshick. 2021. Object Detection. *Computer Vision* (2021), 875–883. DOI:https://doi.org/10.1007/978-3-030-63416-2_660

7. Martinus Grady Naftali. 2022. Comparison of Object Detection Algorithms for Street-level Objects. *arXiv.org*. Retrieved from https://arxiv.org/abs/2208.11315

8. D. Lu and Q. Weng. 2007. A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing* 28, 5 (March 2007), 823–870. DOI:https://doi.org/10.1080/01431160600746456

9. Lilit Hakobyan, Jo Lumsden, Dympna O'Sullivan, and Hannah Bartlett. 2013. Mobile assistive technologies for the visually impaired. *Survey of Ophthalmology 513–528*. DOI:https://doi.org/10.1016/j.survophthal.2012.10.004

10. Muhammad Sarfraz. 2015. An Intelligent Paper Currency Recognition System. *Procedia Computer Science* 65, (2015), 538–545. DOI:https://doi.org/10.1016/j.procs.2015.09.128

11. Muhammad Sarfraz. 2015. *Design flow diagram of currency recognition system.* Retrieved from https://doi.org/10.1016/j.procs.2015.09.128

12. Hamid Hassanpour and Payam M. Farahabadi. 2009. Using Hidden Markov Models for paper currency recognition. *Expert Systems with Applications* 36, 6 (August 2009), 10105–10111. DOI:https://doi.org/10.1016/j.eswa.2009.01.057

13. Qian Zhang and Wei Qi Yan. 2018. Currency Detection and Recognition Based on Deep Learning. *2018 15th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS)* (November 2018). DOI:https://doi.org/10.1109/avss.2018.8639124

14. Muhammad Imad. 2020. Pakistani Currency Recognition to Assist Blind Person Based on Convolutional Neural Network. Retrieved from https://al-kindipublisher.com/index.php/jcsts/article/view/529

15. Muhammad Imad, Farhat Ullah, Muhammad Hassan, and Naimullah. 2020. *Dataset*. Retrieved from https://al-kindipublisher.com/index.php/jcsts/article/view/529/488
16. Yufeng Xiang and Wei Qi Yan. 2021. Fast-moving coin recognition using deep learning. *Multimedia Tools and Applications* 80, 16 (March 2021), 24111–24120. DOI:https://doi.org/10.1007/s11042-021-10857-5Guanming Shi, Shiyao Ke, and Adriana Banozic. 2022. The Role of Assistive Technology in Advancing Sustainable Development Goals. *Frontiers in Political Science* 4, (May 2022). DOI:https://doi.org/10.3389/fpos.2022.859272
17. Guanming Shi, Shiyao Ke, and Adriana Banozic. 2022. The Role of Assistive Technology in Advancing Sustainable Development Goals. *Frontiers in Political Science* 4, (May 2022). DOI:https://doi.org/10.3389/fpos.2022.859272
18. Danielle M. Dumaliang, John Moises Q. Rigor, Ramon G. Garcia, Jocelyn F. Villaverde, and Jobenilita R. Cunado. 2021. Coin Identification and Conversion System using Image Processing. *2021 IEEE 13th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)* (November 2021). DOI:https://doi.org/10.1109/hnicem54116.2021.9732002
19. Carlo D. Tumoling and Jhenalyn Z. Marundan. 2019. Coin Detection and Classification Model Using Canny Edge Algorithm. *iiitb*. Retrieved from https://www.academia.edu/39024697/Coin_Detection_and_Classification_Model_Using_Canny_Edge_Algorithm
20. Alvin Sarraga Alon, Rhowel M. Dellosa, Nino U. Pilueta, Honeylet D. Grimaldo, and Estrelita T. Manansala. 2020. EyeBill-PH: A Machine Vision of Assistive Philippine Bill Recognition Device for Visually Impaired. *2020 11th IEEE Control*

and System Graduate Research Colloquium (ICSGRC) (August 2020). DOI:https://doi.org/10.1109/icsgrc49013.2020.9232557

21. Debasish Kalita. 2023. *Convolutional Neural Network (CNN)*. Retrieved from https://www.analyticsvidhya.com/blog/2022/03/basics-of-cnn-in-deep-learning/

22. Jose Robredo Jr. 2018. Philippine country Report to World Blind Union Asia Pacific, General Assembly, Ulaanbaatar, Mongolia – World Blind Union – Asia Pacific. Retrieved November 24, 2023 from https://wbuap.org/archives/1434