

# Development of Smart Money Classifier & Location Tracker Application Based on Convolutional Neural Network (CNN) for The Visually Impaired

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**Abstract**— The number of visually impaired individuals in Indonesia continues to grow each year, caused by both congenital factors and age-related conditions. This situation positions Indonesia as the country with the second-highest number of blind people globally after Ethiopia. To address this, the present research introduces an Android-based mobile application named Smart Money Classifier & Location Tracker, specifically designed to assist visually impaired individuals in independently recognizing Indonesian banknote denominations and tracking their real-time location. The system integrates Convolutional Neural Network (CNN) technology for banknote image classification using a smartphone camera, enhanced with text-to-speech to announce recognition results. Moreover, a GPS-based tracking feature enables family members to monitor the user's position through a dedicated interface that records chronological location history. Testing involved worn and folded banknotes under varied lighting and distances. Results indicate recognition accuracy of 85–99% under optimal conditions. For location tracking, the system estimated positions with average accuracy of 5–15 meters in open areas and 15–25 meters in semi-enclosed spaces, with a data transmission delay of 2–4 seconds. By combining these features, the application improves independence, safety, and convenience for visually impaired individuals, supporting them in everyday life.

**Keywords**— *Android Application, CNN, GPS, Location Tracking, Money Recognition, Visually Impaired*

## I. INTRODUCTION

The number of visually impaired individuals in Indonesia continues to increase annually, both due to congenital factors and age-related causes. Indonesia is currently ranked as the country with the second-highest number of blind people in the world after Ethiopia [1]. According to the Ministry of Health of the Republic of Indonesia, approximately 1.5% of the population suffers from visual impairments, categorized into total blindness and low vision [2], [3]. Visually impaired individuals often face challenges in identifying banknotes. Traditionally, they rely on tactile recognition by folding or memorizing the texture of banknotes. However, this approach is prone to errors due to memory limitations, worn conditions of money, or even exploitation by irresponsible individuals [4].

Money plays a vital role as a medium of exchange, replacing the barter system that required mutual agreement between parties. In modern society, Indonesian Rupiah banknotes are widely used for daily transactions [5]. Nevertheless, visually impaired individuals are at risk of making mistakes during financial transactions, such as misidentifying denominations, receiving incorrect amounts, or falling victim to fraud [6]. Although some banknotes are equipped with tactile marks, their use is often ineffective, making financial independence difficult for visually impaired users. Moreover, mobility in public spaces poses another significant challenge, as individuals are at risk of losing direction. Therefore, a reliable

money recognition and location tracking system is required to improve both financial and personal safety.

Several studies have been conducted to address the problem of money recognition for visually impaired people. Hidayat et al. [8] developed an Android-based application that utilizes a Convolutional Neural Network (CNN) to classify banknotes. Although the system achieved an accuracy of 83%, its performance was limited under real-world conditions such as low light and folded money. Azhar et al. [9] combined CNN and the You Only Look Once (YOLO) algorithm for real-time recognition, achieving a mean average precision (mAP) of 97.5% on validation data and 88% in varied conditions. However, their system only focused on money recognition without considering mobility support. Zakaria et al. [10] implemented a template matching method to detect denominations with voice output, but accuracy significantly decreased under poor lighting conditions. Bahar et al. [11] proposed an Optical Character Recognition (OCR)-based model, yet it was limited by a small dataset and lack of testing on degraded banknotes. Furthermore, Bahar et al. [12] also applied Regular Expression for denomination detection, but the system was only tested on a narrow set of conditions and user groups [13].

From these studies, it is evident that previous works mainly focused on money recognition but overlooked integration with real-time location tracking, which is crucial for mobility and safety. To fill this gap, this research proposes the development of a Smart Money Classifier & Location Tracker application.

The system integrates CNN-based money recognition with text-to-speech output and Global Positioning System (GPS) for real-time location tracking, providing family members with access to the user's position through Firebase synchronization. This integrated approach aims to enhance the independence, accessibility, and safety of visually impaired individuals in daily life.

## II. METHOD

The research employs a Research and Development (R&D) methodology, which aims to produce a specific product and evaluate its effectiveness. In this study, the product developed is the Smart Money Classifier & Location Tracker application designed to assist visually impaired users in recognizing Indonesian banknotes using Convolutional Neural Network (CNN) technology, while simultaneously providing real-time location tracking. The research process was carried out systematically through several stages to ensure that the application development was well-structured and met the intended objectives.

### A. Application System Design

Application system design is the process of developing a structure that ensures the system meets user requirements and operates efficiently. At this stage, both hardware and software components are designed and integrated to support the overall functionality [14]. The goal is to ensure that the Smart Money Classifier & Location Tracker application can operate optimally and effectively, addressing the needs of visually impaired users as well as their families.

### B. Tools and Materials

Application system design is the process of structuring the system to ensure that it meets user requirements and functions efficiently. In this research, both hardware and software were carefully selected and integrated to support the development of the Smart Money Classifier & Location Tracker application. The hardware setup consisted of a laptop (Lenovo, AMD Ryzen 3, Windows 11, 8 GB RAM) for application development and database operations, as well as two Android smartphones (Redmi Note 12 for visually impaired users and Samsung Galaxy A05s for family members) that served as the main devices for running and testing the application.

On the software side, several tools and platforms were employed. Android Studio was used as the primary development environment, while Kotlin served as the programming language due to its compatibility with Android. Google Maps API was integrated for real-time location tracking, and Firebase was implemented as the cloud database to enable real-time synchronization between users and family members [15]. These hardware and software components formed the foundation of the system design, ensuring that the application could function optimally in assisting visually impaired users with money recognition and location tracking.

### C. Application Architecture

The application architecture describes the structure and relationships among system components to ensure that the application functions effectively, efficiently, and in line with its intended goals. In the Smart Money Classifier & Location

Tracker application, the architecture is designed around two main components: the CNN-based money recognition feature and the real-time location tracking feature using the Global Positioning System (GPS), as shown in Fig. 1.

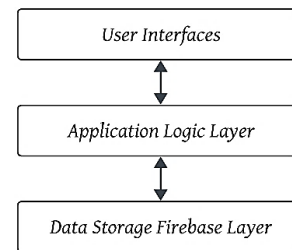


Figure 1. Application Architecture

The application consists of three main layers: (a) User Interface Layer, which provides accessible displays and voice guidance for visually impaired users and family members; (b) Application Logic Layer, which handles core functions such as banknote image processing using CNN and location data processing via GPS and Google Maps API; and (c) Data Storage and Synchronization Layer, which uses Firebase to store recognition results and user location in real time. This layered architecture ensures that money recognition can be performed locally on the smartphone, while location data is simultaneously transmitted to the cloud for family monitoring, thus supporting user mobility and safety.

### D. CNN Model Flowchart

The CNN model flowchart illustrates the process of recognizing banknote images within the application. CNN is employed due to its ability to extract key visual features and achieve high classification accuracy, as shown in Fig. 2.

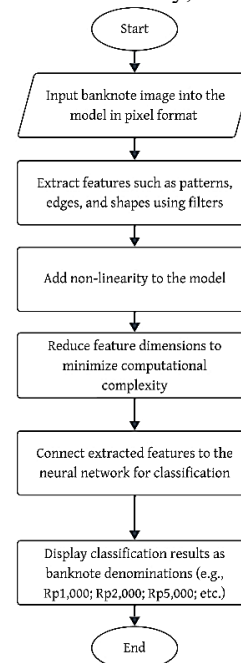


Figure 2. Application Architecture

The process begins with the input layer, where images are captured directly from the smartphone camera and converted

into digital pixel data. These pixels are then passed through convolutional layers, which extract essential features such as edges, lines, and textures of banknotes. The extracted features undergo non-linear transformation using the ReLU activation function, followed by dimensionality reduction in the pooling layer to improve computational efficiency. The results are then processed in the fully connected layer, which maps the extracted features to specific classes of Rupiah denominations. Finally, the output layer provides the classification result (e.g., Rp1,000, Rp2,000, Rp5,000, Rp10,000, Rp20,000, Rp50,000, Rp100,000), which is displayed in the application and read aloud via text-to-speech. This integration allows fast and accurate money recognition in real-time, enhancing user independence.

**E. Application Flowchart**

The application flowchart demonstrates the workflow for two types of accounts: the visually impaired user and the parent/guardian, as shown in Fig. 3.

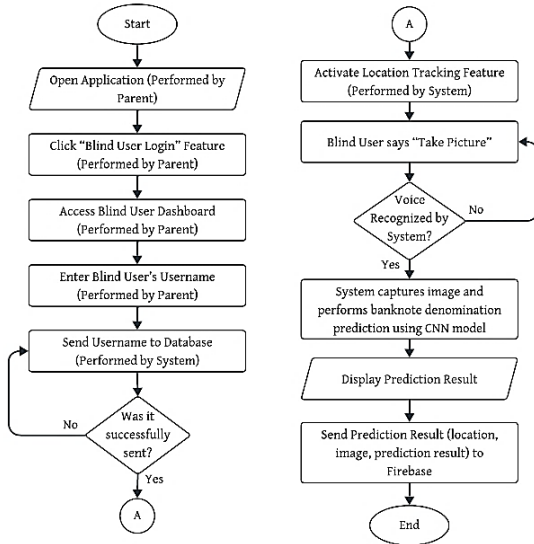


Figure 3. Application Flowchart for Visually Impaired User

For the visually impaired account, the process begins with login, followed by automatic activation of location tracking. The system then waits for a voice command (“Take Picture”) to capture an image of a banknote, which is processed by the CNN model. The recognized denomination is displayed and read aloud, after which the process loops back to allow repeated recognition as needed, as shown in Fig. 4.

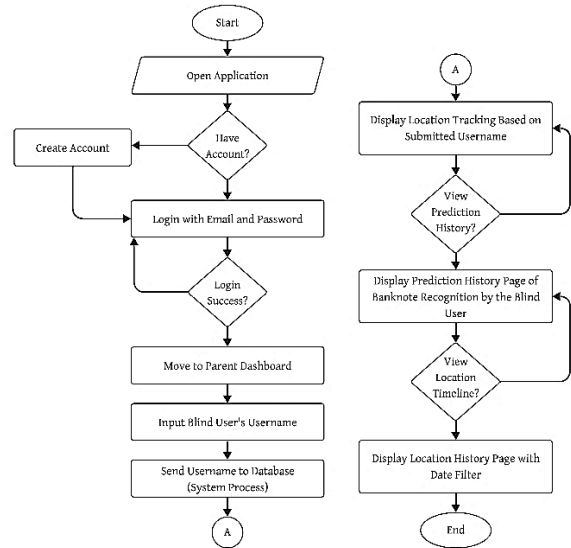


Figure 4. Application Flowchart for Parent Account

For the parent account, the process begins with login or registration, followed by entering the username of the visually impaired user. The system retrieves and displays real-time location tracking. Parents can also access prediction history and location timelines filtered by date, enabling them to monitor the user’s financial interactions and movements.

**F. Application Functionality**

The functionality of the application is designed to ensure effective interaction between visually impaired users and their parents/guardians.

For visually impaired users, key features include sending a username to the system, transmitting real-time location, and performing money recognition through image capture and CNN classification. These features are optimized for accessibility through simple interactions and voice commands, as shown in Table I

TABLE I.  
MAIN FEATURES OF THE SMART MONEY CLASSIFIER & LOCATION TRACKER

No	Feature	Description
1	Send Username	The blind user sends their identity (username) to the system.
2	Send Real-Time Location	The application automatically transmits the user’s location to the server in real time.
3	Banknote Nominal Prediction	Captures an image of a banknote and predicts its denomination using the CNN model.

For parent accounts, functionalities include login / registration, linking with the visually impaired user’s username, tracking real-time location, viewing money recognition history, and accessing location timelines by date filters. These features provide parents with direct oversight of user activities and enhance safety monitoring, as shown in Table II

TABLE II.  
MAIN FEATURES FOR USERS

No	Feature	Description
1	Login	Parents access the system using their registered email and password.
2	Register	Create a new account by filling in the required information requested by the system.
3	Send Username	Send the blind user's username to connect location and history data.
4	Real-Time Location Tracking	Display the current location of the blind user in real time.
5	View Prediction History	Display a list of banknote denomination predictions along with images and the location where the prediction was made.
6	View Location Timeline	Display the location history based on a specific date filter.

### G. User Interface Design

The application's user interface (UI) is planned with an emphasis on usability, accessibility, and user comfort, particularly for visually impaired users and their parents. The design prioritizes intuitive navigation, simple interaction (including voice guidance), and clear layouts for effective use.

#### 1) Splash Screen

The splash screen serves as the opening page displaying the application's logo and name while the system loads.

#### 2) Login Page

Allows users to access the system using registered email and password.

#### 3) Registration Page

Enables parents or guardians to create new accounts and connect them with visually impaired users through a username.

#### 4) Dashboard for Visually Impaired User

Displays main features for banknote recognition and real-time location tracking.

#### 5) Dashboard for Parent

Provides features for monitoring the visually impaired user, including location tracking and access to prediction history.

#### 6) Prediction History Page

Shows past banknote recognition results along with captured images and location data.

#### 7) Location Timeline Page

Displays the visually impaired user's movement history with date-based filtering

### H. Testing Parameters

To ensure that the application runs properly and meets the intended objectives, several key testing parameters were evaluated. The tests covered aspects of functionality, prediction accuracy, and location tracking precision, as shown in Table III.

TABLE III.  
TESTING PARAMETERS

No	Testing Parameters	Description	Testing Method	Success Criteria
1.	Application Functionality	Testing whether all application features work	Feature validation results	All functions run according to scenarios

No	Testing Parameters	Description	Testing Method	Success Criteria
		according to user requirements		without errors
2.	Accuracy of Money Prediction with CNN	Testing classification results of banknote denominations from images	Confusion Matrix, accuracy calculation (%)	Minimum 85% accuracy in money classification
3.	Money Detection Distance	Testing optimal distance between camera and banknotes	Recording success rates to obtain the most accurate distance	Minimum 80% accuracy within optimal range
4.	ocation Tracking Accuracy	Testing the precision of real-time location displayed in the application	Comparison between actual location and GPS-based application output	Maximum deviation of $\pm 10$ meters from actual location

Based on these parameters, comprehensive testing was carried out to ensure that every component of the application performed reliably. Functionality testing verified that all features operated without errors, while prediction accuracy served as the main indicator of CNN performance in classifying banknotes. Furthermore, location tracking accuracy was evaluated to guarantee that the system provided precise real-time positioning of visually impaired users. The results from these evaluations formed the basis for analyzing and refining the system to ensure its optimal usability.

## III. RESULTS AND DISCUSSION

This section presents an overall discussion of the software design and the results of system performance testing, along with their analysis. The purpose of these tests was to ensure that the developed system functioned as intended and aligned with the initial design objectives. The research was conducted at the AH Building of Politeknik Negeri Malang, located at Jl. Soekarno Hatta No. 9, Malang, East Java. The study began in February, right after the proposal seminar revision, and was carried out over approximately five months. The first four months were dedicated to system design, development, and implementation, covering activities such as requirements analysis, interface design, coding, and functional testing. The final month was focused on refining the system based on trial results and user feedback, as well as completing the thesis documentation. This timeline provided a structured framework for ensuring the accuracy, reliability, and usability of the Smart Money Classifier & Location Tracker application.

### A. Implementation Results

This section presents an overall discussion of the software design and the results of system performance testing, along with their analysis. The purpose of these tests was to ensure that the developed system functioned as intended and aligned with the initial design objectives. The research was conducted

at the AH Building of Politeknik Negeri Malang, located at Jl. Soekarno Hatta No. 9, Malang, East Java. The study began in February, right after the proposal seminar revision, and was carried out over approximately five months. The first four months were dedicated to system design, development, and implementation, covering activities such as requirements analysis, interface design, coding, and functional testing. The final month was focused on refining the system based on trial results and user feedback, as well as completing the thesis documentation. This timeline provided a structured framework for ensuring the accuracy, reliability, and usability of the Smart Money Classifier & Location Tracker application.

**1) Training Data Collection**

The CNN model was trained using a total of 1,754 images, covering seven denominations of Indonesian Rupiah banknotes: Rp1,000, Rp2,000, Rp5,000, Rp10,000, Rp20,000, Rp50,000, and Rp100,000. Each denomination contained a different number of samples, as shown in Table IV

TABLE IV  
TOTAL TRAINING SAMPLES

No.	Class	Denomination	Total Image
1.	1	Rp. 1.000	236
2.	2	Rp. 2.000	340
3.	3	Rp. 5.000	484
4.	4	Rp. 10.000	568
5.	5	Rp. 20.000	624
6.	6	Rp. 50.000	654
7.	7	Rp. 100.000	619
Total			3.525

**2) Image Classification Training**

The image training process was carried out to extract distinctive features from each denomination. Through this training, the CNN model learned to recognize visual patterns that differentiate each class, enabling accurate classification of banknote denominations, as shown in Table V




TABLE V.  
BANKNOTE DENOMINATIONS

Banknote Denomination	Image
Rp1.000	
Rp 2.000	
Rp5.000	
Rp10.000	
Rp20.000	
Rp50.000	
Rp100.000	

**B. Application Testing**

To ensure cross-device compatibility, the application was tested on various smartphone brands and Android versions. This test aimed to verify successful installation, smooth operation, and minimize potential system errors before evaluating functionality in detail, as shown in Table VI

TABLE VI  
TOTAL TRAINING SAMPLES

No.	User Name	Merk Smartphone	Android Version	Installation Result		Image
				Yes	No	
1.	Hafidh					
2.	Nisa	REDMI NOTE 12	15		V	
3.	Sabila	OPPO A55	8.0		V	

Functionality testing was first conducted to ensure the system worked according to its design objectives. As shown in Table 6, all features such as login, money recognition, and location tracking operated successfully without errors, indicating that the system was able to fulfill its functional requirements, as shown in Fig. 4 and Table VII.



Figure 4. Testing with Similar Light Intensity (Lux)

TABLE VII  
RESULT OF TESTING WITH SIMILAR LIGHT INTENSITY (LUX)

No	Light (Lux)	Confidence Level (%)	Status
1.	170 lx	96,14%	Success
2.	160 lx	95,56%	Success
3.	154 lx	69,67%	Success
4.	149 lx	84,04%	Success
5.	136 lx	98,78%	Success
6.	129 lx	92,04%	Success
7.	124 lx	93,42%	Success
8.	119 lx	96,14%	Success
9.	113 lx	95,56%	Success
10.	116 lx	88,78%	Success
11.	98 lx	96,30%	Success

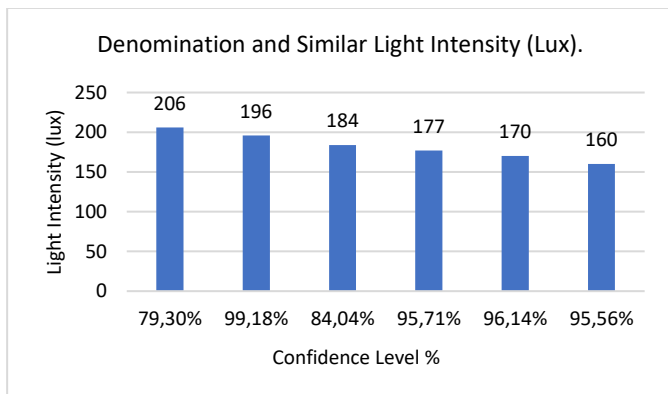


Figure 5. Graph of Denomination and Similar Light (Lux) Testing

Testing of the CNN model was then carried out under different environmental conditions. Lighting factor was examined to measure the model’s robustness when recognizing banknotes in similar illumination. Table 7 and Figure 5 show that recognition accuracy remained above the minimum threshold of 85%, demonstrating the system’s capability to handle variations in brightness, as shown in Fig. 5.

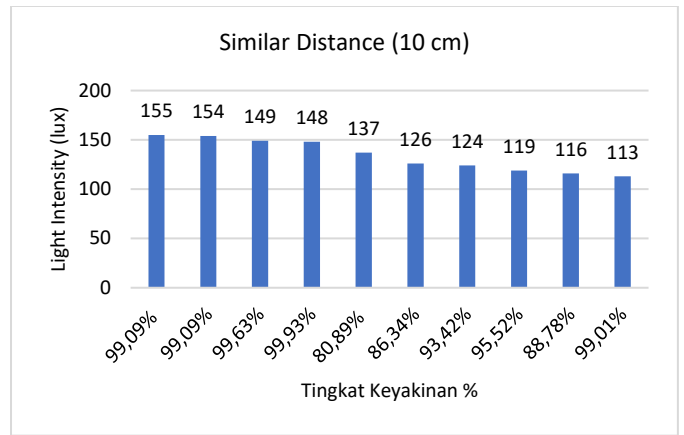


Figure 6. Graph of Similar Distance (10 cm) Testing

Distance was evaluated to determine its influence on recognition accuracy. The results indicate that an optimal distance of 10 cm achieved the highest success rate, with recognition confidence reaching above 99%. When the distance was either increased or decreased from this optimal point, the recognition accuracy gradually declined, ranging between 87% and 99%. This reduction was primarily caused by image distortion, blurring, or loss of clarity due to changes in camera focus and lighting reflection. Nevertheless, even at non-optimal distances, the system maintained accuracy within an acceptable range, demonstrating its robustness and reliability in handling variations in object distance during testing, as shown in Fig. 6.

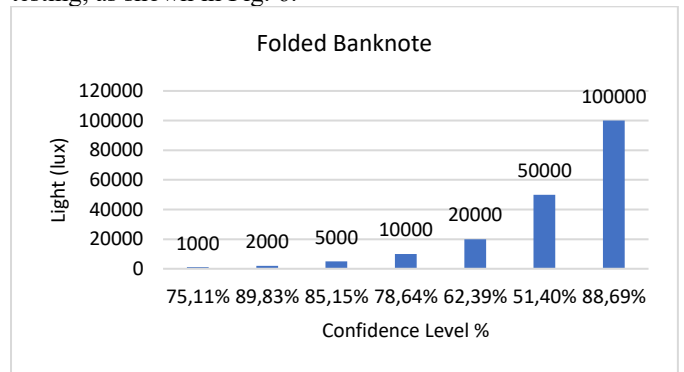


Figure 7. Graph of Folded Banknote Testing

An additional evaluation was carried out to analyze the impact of banknote conditions, particularly when the notes were folded. As illustrated in Figure 7, the system demonstrated consistent classification performance, with confidence levels ranging from approximately 51% to 89%. Despite partial occlusion and distortion caused by folds, the CNN model was still able to recognize key visual features of the banknotes and maintain reliable accuracy. These findings highlight the robustness of the proposed method in handling real-world scenarios, ensuring practicality and usability for visually impaired individuals when dealing with worn or imperfect banknotes, as shown in Fig 7.

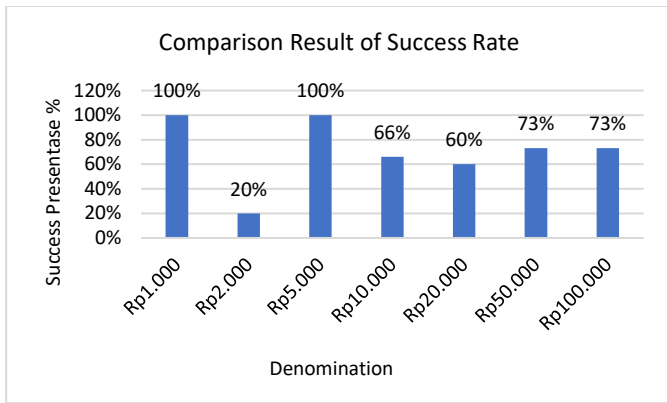


Figure 8. Graph of Success Rate Comparison Result

Comprehensive testing that combined factors of nominal, distance, and lighting. These results confirm that the system consistently achieved accuracy above 85%, meeting the predefined success criteria across different scenarios, as shown in Fig. 8.

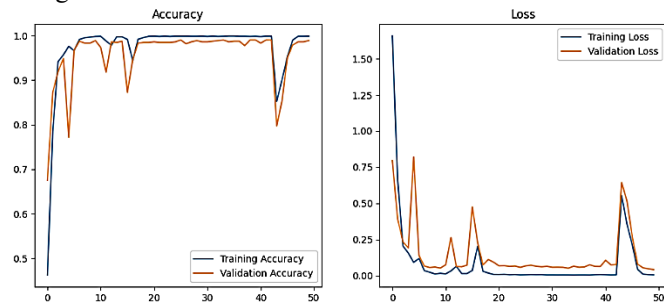


Figure 9. Graph of Accuration Training Process and Loss Epoch

Finally, model performance during training was analyzed. As shown in Figure 9, the accuracy curve increased steadily while the loss decreased across epochs, confirming that the CNN model was well-trained and generalized effectively to unseen data, as shown in Table VIII

TABEL VIII.  
TOTAL TRAINING SAMPLES

Epoch	Accuracy	Loss	Val Accuracy	Val Loss
1	0.2999	27.392	0.6752	0.7955
2	0.7421	0.7706	0.8723	0.3918
3	0.9293	0.2400	0.9191	0.2325
4	0.9595	0.1433	0.9489	0.1911
5	0.9756	0.0866	0.7716	0.8204
6	0.9472	0.1798	0.9674	0.1385
7	0.9875	0.0385	0.9872	0.0658
8	0.9942	0.0238	0.9830	0.0556
9	0.9972	0.0098	0.9830	0.0592
10	0.9974	0.0135	0.9887	0.0515
11	0.9989	0.0068	0.9730	0.0745
12	0.9961	0.0100	0.9177	0.2632
13	0.9643	0.1051	0.9858	0.0634
14	0.9964	0.0198	0.9844	0.0607
15	0.9983	0.0065	0.9872	0.0721
16	0.9905	0.0249	0.8723	0.4737
17	0.9333	0.2229	0.9461	0.2282
18	0.9899	0.0270	0.9830	0.0733

Epoch	Accuracy	Loss	Val Accuracy	Val Loss
19	0.9921	0.0278	0.9844	0.1112
20	0.9981	0.0052	0.9844	0.0919
21	0.9983	0.0074	0.9858	0.0674
22	0.9979	0.0064	0.9844	0.0685
23	0.9996	0.0026	0.9844	0.0633
24	0.9980	0.0067	0.9844	0.0660
25	0.9987	0.0039	0.9858	0.0566
26	0.9995	0.0021	0.9901	0.0669
27	0.9992	0.0037	0.9816	0.0716
28	0.9989	0.0044	0.9858	0.0641
29	0.9980	0.0062	0.9887	0.0606
30	0.9993	0.0021	0.9858	0.0639
31	0.9993	0.0020	0.9858	0.0574
32	0.9987	0.0028	0.9872	0.0579
33	0.9976	0.0041	0.9887	0.0571
34	0.9986	0.0036	0.9901	0.0507
35	0.9993	0.0031	0.9858	0.0647
36	0.9995	0.0021	0.9872	0.0574
37	0.9984	0.0030	0.9872	0.0593
38	0.9989	0.0022	0.9773	0.0747
39	0.9976	0.0039	0.9901	0.0634
40	0.9985	0.0055	0.9901	0.0628
41	0.9981	0.0043	0.9830	0.1057
42	0.9989	0.0042	0.9901	0.0739
43	0.9987	0.0050	0.9901	0.0765
44	0.9457	0.2180	0.7972	0.6438
45	0.8832	0.3845	0.8539	0.5154
46	0.9477	0.2365	0.9504	0.2677
47	0.9878	0.0553	0.9787	0.0789
48	0.9985	0.0086	0.9858	0.0535
49	0.9988	0.0049	0.9858	0.0468
50	0.9995	0.0029	0.9887	0.0410

The training process of the Convolutional Neural Network (CNN) model for banknote classification with seven classes showed strong performance. In the early epochs (1–5), accuracy rapidly increased from 29.99% to 97.56% with a significant reduction in loss, indicating effective learning of basic visual features. From epoch 6–30, the model achieved high stability, with training accuracy close to 99% and validation accuracy above 98%, showing no significant overfitting. Although slight fluctuations appeared in validation loss, overall consistency was maintained. A temporary drop occurred at epochs 44–46, likely due to the absence of early stopping or data variation, but performance quickly recovered. By the final epoch, the model reached 99.95% training accuracy and 98.87% validation accuracy, with a final validation accuracy of 99.18%, confirming its robustness for banknote classification tasks, as shown in Table IX

TABEL 9.  
MODEL TRAINING EPOCH EVALUATION






No	Denomination	Precision (%)	Recall (%)	F1-Score (%)
1.	Rp1.000	80	71	75
2.	Rp2.000	67	69	68
3.	Rp5.000	95	92	93
4.	Rp10.000	92	99	95

No	Denomination	Precision (%)	Recall (%)	F1-Score (%)
5.	Rp20.000	96	97	97
6.	Rp50.000	96	97	96
7.	Rp100.000	95	98	98

Table 9 presents the model performance evaluation using precision, recall, and F1-score across different banknote denominations. The results show lower performance on small denominations such as Rp1,000 (75% F1-score) and Rp2,000 (68%), likely due to their poorer physical condition (worn or folded). In contrast, medium to high denominations (Rp5,000 and above) achieved over 90% precision and recall, with the highest F1-score of 98% on Rp100,000. Overall, the model performs very well on higher-value banknotes with clearer features, though further improvement is needed for small denominations, as shown in Table X

TABLE 10.

APPLICATION TESTING RESULTS WITH UNSUCCESSFUL DETECTION

No	Image	Light (lux)	Distance	Confidence Level	Trial	Status
1.	 Rp2.000	215 lx	5cm	97,26 %	1x	Failed
2.	 Rp2.000	161 lx	5cm	90,69 %	2x	Failed
3.	 Rp2.000	119 lx	5cm	89,93 %	3x	Failed
4.	 Rp100.000	118 lx	5cm	56,46 %	1x	Failed
5.	 Rp100.000	109 lx	5cm	97,40 %	2x	Failed

Based on Table X, the application shows difficulty in detecting Rp2,000 and Rp100,000 banknotes compared to

other denominations. The Rp2,000 note tends to have low contrast and limited distinctive features, while the Rp100,000 note often suffers from color dominance and reflections from holograms or glossy surfaces. These factors reduce the clarity of captured images, making it harder for the CNN model to extract stable features.

Overall, the system provided reliable money classification under diverse conditions and accurate real-time location tracking with GPS, achieving the research objectives and demonstrating strong potential to support blind users in daily activities.

#### IV. CONCLUSION

Based on the research and development of the Smart Money Classifier & Location Tracker application, it can be concluded that the system successfully integrates Convolutional Neural Network (CNN) for banknote recognition and GPS with Firebase for real-time location tracking. The application is able to identify nominal values through the smartphone camera and deliver the results via text-to-speech, while location data can be monitored by family members to ensure user safety. Field testing showed a practical accuracy of 90%, with the optimal detection distance being approximately 5 cm, thus proving the effectiveness of the application in supporting the independence and security of blind users. For future work, it is recommended that the application be extended to other platforms such as iOS to reach a wider range of users. Additionally, the location tracking feature could be enhanced with geo-fencing technology, enabling automatic notifications when the user leaves a predefined safe zone. These improvements would further increase the reliability and usefulness of the application in real-world scenarios.

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