IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁘ Peer-reviewed & Refereed journal ⁘ Vol. 13, Issue 3, March 2024

DOI: 10.17148/IJARCCE.2024.13339

Fake Currency Detection using Deep Learning

Mr. K Bhushanm[1], M.Asritha[2], P.Rafiya Sultana[3], P.Anil Kumar[4], S.Mahesh Babu[5]

Assistant Professor, Computer Science and Engineering, VVIT, Guntur, India[1]

Undergraduate, Computer Science and Engineering, VVIT, Guntur, India[2-5]

Abstract: The widespread circulation of counterfeit currency poses a significant threat to global financial stability and integrity, necessitating effective detection measures. In response to this challenge, this project aims to develop a robust and efficient system for automated counterfeit currency detection, utilizing deep learning methodologies. This research presents a comparative analysis focusing specifically on Indian 500 rupee notes, employing machine learning techniques such as Simple Neural Network (NN) and Deep Learning Convolutional Neural Network (CNN). Diverse datasets comprising images of Indian 500 rupee notes sourced from various outlets are utilized for this study. Performance metrics including accuracy, precision, recall, and F1-score are systematically computed for each technique to evaluate detection effectiveness. Results demonstrate the superiority of the CNN-based approach over the NN method, showcasing higher accuracy and robustness in identifying counterfeit Indian 500 rupee notes. This research significantly contributes to the advancement of automated counterfeit detection systems, particularly within the context of Indian currency. By enhancing detection capabilities and strengthening fraud prevention mechanisms, this work aims to bolster financial security measures on a global scale.

Keywords: Indian fake currency detection, simple neural network, convolutional neural network, image classification, counterfeit detection, financial security.

I. INTRODUCTION

Counterfeiting of currency in India has become a significant issue, leading to various measures to combat it. Despite efforts by the Reserve Bank of India (RBI) to incorporate security features into currency notes, detecting counterfeit currency remains challenging. The proliferation of fake currency has been associated with criminal activities like terrorism and money laundering. To address this problem, the Indian government demonetized 500 and 1000 rupee notes, but subsequent reports revealed a surge in fake currency transactions.

The RBI has the sole authority to issue currency notes in India and has introduced multiple security features to aid detection. However, visual inspection alone is insufficient, and many people are unaware of these features. Deep learning models, particularly Simple Neural Networks (NN) and Convolutional Neural Networks (CNN), have shown promise in image classification tasks. A proposed solution involves using a Deep CNN model to classify currency notes as fake or real based on images captured by a camera. This model eliminates the need for manual feature extraction and can be trained on a dataset to effectively detect counterfeit currency. future, there is room for the development of these kind of systems.

In today's digital age, computers and mobile phones play an integral role in our lives, offering various services including application creation. The proliferation of technology has led to the development of solutions like fake currency detection systems, aimed at addressing the challenge of distinguishing between counterfeit and genuine currencies. Digital image processing is utilized in such projects, employing computer algorithms to analyze digital images. This technological advancement is crucial in combating corruption, which hampers the growth of the nation. Traditional methods of detecting fake currency include watermarking, optically variable ink, security threads, latent images, and counterfeit detection pens. To enhance detection capabilities, a proposed solution involves an application system that utilizes digital image processing techniques to identify counterfeit notes. By leveraging Simple Neural Network classifiers, the system aims to provide a simple, accurate, and user-friendly solution for fake currency detection.

II. LITERATURE REVIEW

[1] Vivek Sharan and Amandeep Kaur's 2019 paper introduces a method for detecting counterfeit Indian currency notes using image processing techniques. It focuses on analyzing three key features: the latent image, the Reserve Bank of India (RBI) logo, and the denomination numeral alongside the Rupee symbol and color elements. This approach enables the differentiation between genuine and counterfeit notes, aiding in their detection.

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[2] The 2017 paper "Fake Currency Detection Using Image Processing" by S. Atchaya et al. presents the Performance Matrix for Fake Currency Detection, utilizing MATLAB image processing. This technique leverages neural networks and model-based reasoning. The paper investigates various methods including water marking, optically variable ink, and fluorescence for counterfeit currency identification.

[3] Laavanya et al. introduced a novel method for counterfeit currency detection utilizing a deep convolutional neural network. This framework scrutinizes currency images to identify fake currency notes. The convolutional neural network, pre-trained with two thousand, five hundred, two hundred, and fifty Indian currency note datasets, learns the distinctive feature map of the currencies. Once trained, the network swiftly detects counterfeit currency in real-time.

[4] Upadhyaya et al. conducted a comprehensive review of various counterfeit currency detection techniques proposed by researchers.

[5] In his 2019 paper titled "Indian Paper Currency Detection," Aakash S. Patil introduces an innovative approach designed to improve the recognition accuracy and transaction speed for classifying Indian currency. This technique harnesses the capabilities of the OpenCV library, renowned for its suite of computer vision functions optimized for real-time applications. These functions encompass note identification, segmentation, and recognition tasks.

[6] Megha Jadhav, Yogesh Kumar Sharma, and G. M. Bhandari proposed a system employing deep learning techniques, particularly convolutional neural networks, for the automatic detection of forged banknotes and identification of currency denominations from images captured under diverse lighting conditions. Their system demonstrated remarkable accuracy in both currency identification and forged banknote detection.

[7] The authors utilized a Convolutional Neural Network (CNN) for image processing, designed to handle 80 × 80 pixel images. Their unique CNN model was trained on a dataset comprising 40,000 photos, evenly split between Rs. 500 and Rs. 2,000 denominations, as well as counterfeit and genuine notes. By analyzing features like Mahatma Gandhi's watermark and angular bleed lines, images were classified into false and true categories, achieving a testing accuracy of 85.6%.

[8] G. Hariharan and D. Elangovan propose a method aimed at recognizing and eliminating proxy notes through the integration of image processing techniques and deep learning. The process encompasses image acquisition, pre-processing, segmentation, and deep learning utilizing a CNN algorithm. To enhance image quality and extract pertinent characteristics, the method leverages anisotropic diffusion filters, adaptive coherence mean improvement, and adaptive region growing segmentation.

[9] Yadav et al. conducted a study to determine the authenticity of currency notes by employing a variety of machine learning algorithms. The aim was to compare and identify the most suitable algorithm for this purpose. These machine learning algorithms classify currency notes based on features extracted from images. The dataset used for the study was sourced from the UCI Machine Learning Repository.

[10] In their work, P. Ashok Babu et al. introduced a system employing image processing techniques to discern between genuine and counterfeit currency. The system utilizes MATLAB software for currency recognition, aiming to identify whether an image of currency is authentic or counterfeit. The objective is to analyze the distinctive features of current genuine currency and leverage digital image processing to extract these features. The approach was tested with each denomination of Indian currency, yielding highly accurate results.

[11] In their 2020 paper titled "Fake Currency Detection using Basic Python Programming and Web Framework," Prof. Chetan More, Monu Kumar, Rupesh Chandra, and Raushan Singh presented a system that utilizes the Flask web framework. Flask, known as a micro web framework in Python, forms the backbone of this system, which is written entirely in the Python programming language.

[12] In their 2018 paper titled "Identification of Fake Notes and Denomination Recognition," Archana MR, Kalpitha C P, Prajwal S K, and Pratiksha N proposed a system to reduce human effort by automating the identification of counterfeit notes and denomination recognition. This system is divided into two main components: currency recognition and conversion system. They developed a software interface capable of handling various types of monetary standards.

[13] Y. Neeraja et al. propose a method for fake currency detection using the k-nearest neighbors (k-NN) technique. In this approach, k-NN technology is employed for feature extraction, serving as a robust and versatile classifier. k-NN is commonly utilized as a benchmark for more intricate classifiers, including support vector machines (SVM).

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[14] In their work, K. B. Zende et al. [4] present a system for automatic detection of counterfeit Indian currency based on MATLAB. The process involves several steps, including feature extraction, image segmentation, edge detection, bit plane slicing, and comparison of images. Notably, the paper focuses on extracting various security features such as watermark detection, security thread detection, checking currency series number, identification mark, and see-through register. Additionally, they propose a graphical user interface (GUI) platform for verifying the authenticity of currency notes.

[15] A Deep Convolutional Neural Network (CNN) was utilized for counterfeit money detection, leveraging a synthetic dataset. Through feature extraction, the model enables users to identify suspicious notes via a mobile app. Notably, the VGG-16 variant may consume up to 550 MB of system memory. Transfer learning was employed to fine-tune the pre-trained network's bias parameter using forward and backward passes of back-propagation on fresh data, enhancing model performance. The dataset initially comprised 100 images each of Rs. 2000 and Rs. 500 genuine currency notes, all captured with the notes held up to light to reveal key security features.

III. PROPOSED METHODOLOGY

The proposed methodology involves the implementation of two approaches: one using a Simple Neural Network (SNN) and the other using a Convolutional Neural Network (CNN) for Indian fake currency detection.

1) *Data Collection and Preprocessing:* Gather a dataset of genuine and counterfeit Indian currency images. Preprocess the images by resizing and normalizing them.
2) *Model Architecture:* Define the architecture of both SNN and CNN models. SNN comprises input, fully connected, and output layers. CNN includes convolutional, pooling, and fully connected layers.
3) *Training:* Train both models using the prepared dataset. Specify training parameters such as optimizer, batch size, and epochs.
4) *Evaluation:* Evaluate the trained models using performance metrics like accuracy, precision, recall, and F1-score on a separate test dataset.
5) *Comparison:* Compare the performance of SNN and CNN models to determine the most effective approach for counterfeit currency detection.
6) *Implementation:* Develop an interactive application for users to input currency images and classify them using the trained models.
7) *Validation:* Validate the application's performance by testing it with various currency images and assessing its accuracy in detecting counterfeit notes.

By following this proposed methodology, a robust and efficient system for automated counterfeit currency detection can be developed, aiding in financial security enhancement.

IV. IMPLEMENTATION

A.Fake currency detection using SIMPLE NN:

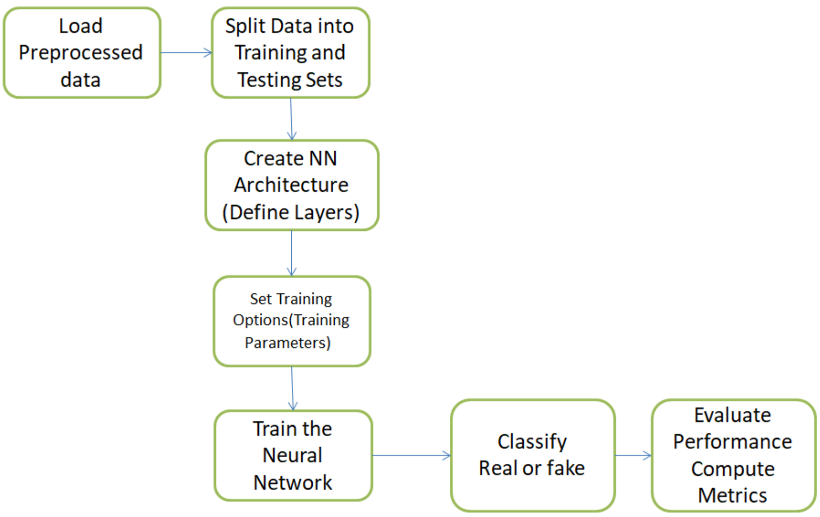

Fig .1 Simple NN architecture

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1) *Load Image Data & Preprocess Data:* This step involves loading the image dataset containing both genuine and counterfeit currency images. Data preprocessing techniques such as resizing, normalization, or augmentation may be applied to enhance the quality and consistency of the images.

2) *Split Data into Training and Testing Sets:* The dataset is divided into two subsets: a training set used to train the neural network and a testing set used to evaluate its performance.

3) *Create NN Architecture (Define Layers):* The architecture of the neural network is defined, specifying the arrangement and configuration of different layers such as input layer, fully connected layers, activation functions (e.g., ReLU), softmax layer for classification, and the output layer for determining the class label.

4) *Set Training Options (Training Parameters):* Training options are set, including parameters like the choice of optimization algorithm (e.g., Adam), mini-batch size (number of samples used in each iteration), number of epochs (number of times the entire dataset is passed through the network during training), and validation data (subset of training data used for validation during training).

5) *Train the Neural Network:* The neural network is trained using the training data, specified layers, and training options. During training, the network learns to differentiate between genuine and counterfeit currency images by adjusting its parameters to minimize the error between predicted and actual labels.

6) *Load and Display Input Image (Optional):* Optionally, an input image can be loaded and displayed to demonstrate how the trained neural network classifies it as genuine or counterfeit currency.

7) *Classify Input Image:* The trained neural network is used to classify the input image as either genuine or counterfeit currency based on the learned features and parameters.

8) *Display Classification Result (Optional):* Optionally, the classification result (i.e., whether the input image is predicted as genuine or counterfeit) can be displayed for visualization or further analysis.

9) *Classify Test Images:* The trained neural network is applied to classify a separate set of test images to assess its performance on unseen data.

10) *Evaluate Model Performance:* The performance of the model is evaluated using metrics such as accuracy (proportion of correctly classified images), precision, recall, and F1 score (harmonic mean of precision and recall).

11) *Plot Confusion Matrix:* A confusion matrix is plotted to visualize the classifier's performance in terms of true positive, true negative, false positive, and false negative classifications, providing insights into its ability to distinguish between genuine and counterfeit currency images.

B.Fake currency detection using CNN:

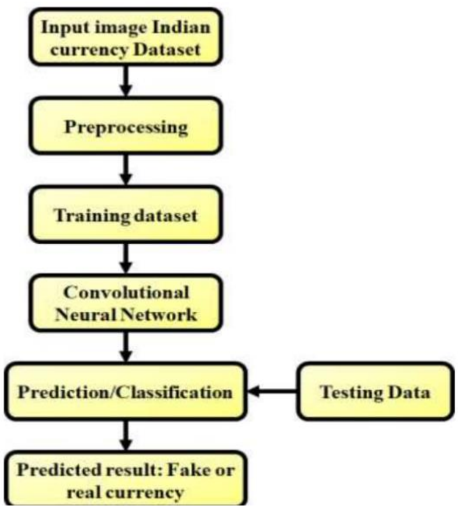

Fig. 2 CNN Architecture

ISSN (O) 2278-1021, ISSN (P) 2319-5940

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1) *Initiating Parameters:* This section initializes parameters by clearing the workspace, resetting the GPU device if available, and specifying the number of classes, which is set to 2 for distinguishing between real and fake currency.

2) *Loading and Preprocessing Data:* The image dataset is loaded from the specified directory (dataDir) using the imageDatastore function. It is then divided into training and testing sets with an 80-20 split ratio using splitEachLabel. Sample images from the training set are displayed to visualize the data.

3) *Defining CNN Architecture:* The CNN architecture is constructed using convolutional, batch normalization, ReLU activation, and max-pooling layers. It concludes with fully connected, softmax, and classification layers.

4) *Specifying Training Options:* Training options such as the optimization algorithm (Adam), maximum epochs, mini-batch size, learning rate schedule, and execution environment are specified using training Options.

5) *Training the CNN Model:* The CNN model is trained using train Network with the training data (imdsTrain), defined layers, and specified options.

6) *Classifying Input Image:* Users are prompted to select an input image via a file dialog (uigetfile). The selected image is then classified using the trained CNN model (classify).

7) *Evaluating Model Performance:* Model evaluation on the test set involves comparing predicted labels (Y_pred) with ground truth labels (Y_test). Metrics including accuracy, confusion matrix, precision, recall, and F1 score are computed and displayed.

8) *Plotting Confusion Matrix:* A confusion matrix and chart are plotted to visualize the model's performance on the test set.

V. RESULTS

The results of the project will be as follows:

CNN

Epoch	Iteration	Time Elapsed (hh:mm:ss)	Mini-batch Accuracy	Mini-batch Loss	Base Learning Rate
1	1	00:00:05	50.00%	0.8672	0.0010
2	50	00:00:46	100.00%	-0.0000e+00	0.0010
3	100	00:01:26	100.00%	4.4703e-08	0.0010
4	150	00:02:07	100.00%	-0.0000e+00	0.0010
5	200	00:02:48	100.00%	-0.0000e+00	0.0010
5	220	00:03:04	100.00%	-0.0000e+00	0.0010

Fig. 3 Epoch details of CNN

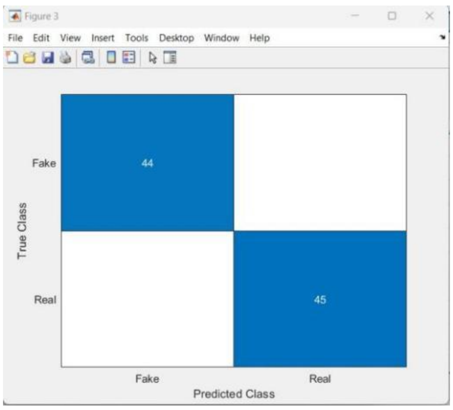

Fig .4 Confusion Matrix of CNN

ISSN (O) 2278-1021, ISSN (P) 2319-5940

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DOI: 10.17148/IJARCCE.2024.13339

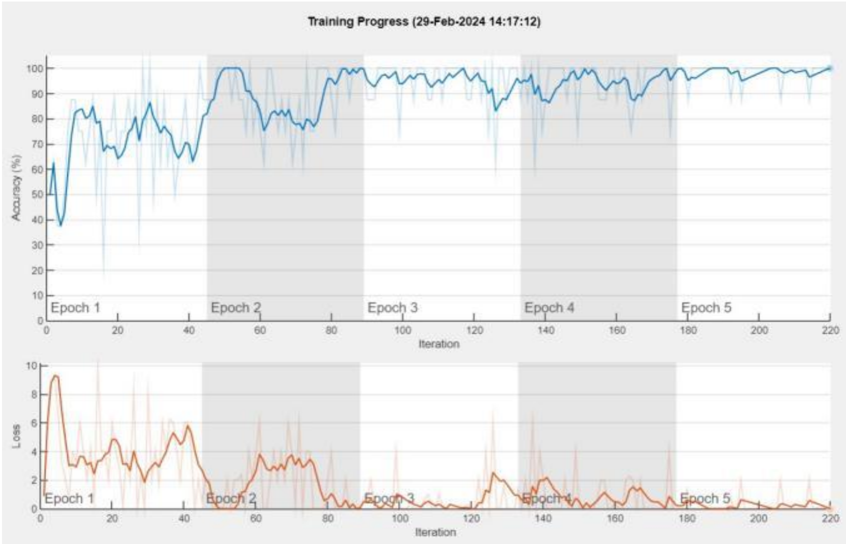

Fig. 5 Training Progress of CNN

SNN

Epoch	Iteration	Time Elapsed (hh:mm:ss)	Mini-batch Accuracy	Validation Accuracy	Mini-batch Loss	Validation Loss	Base Learning Rate
1	1	00:00:06	48.44%	51.69%	7.9889	7.7025	0.0010
1	5	00:00:11	70.31%	65.17%	4.7329	5.5530	0.0010
2	10	00:00:15	79.69%	86.52%	3.2383	2.0015	0.0010
3	15	00:00:20	90.62%	89.89%	1.5378	1.4719	0.0010
4	20	00:00:24	95.31%	96.63%	0.3140	0.2258	0.0010
5	25	00:00:28	98.44%	97.75%	0.0540	0.0467	0.0010

Fig .6 Epoch details of Simple NN

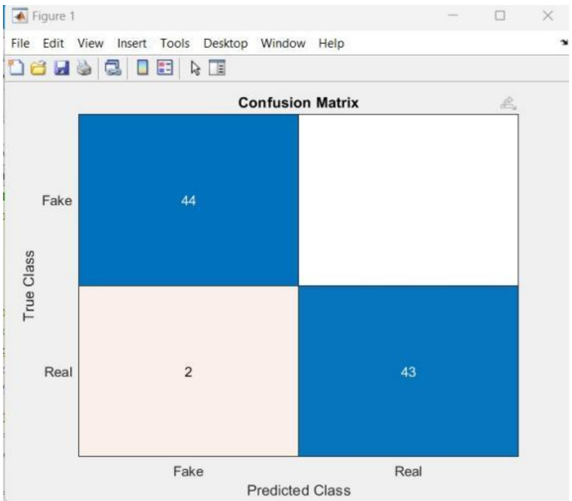

Fig. 7 Confusion Matrix of Simple NN

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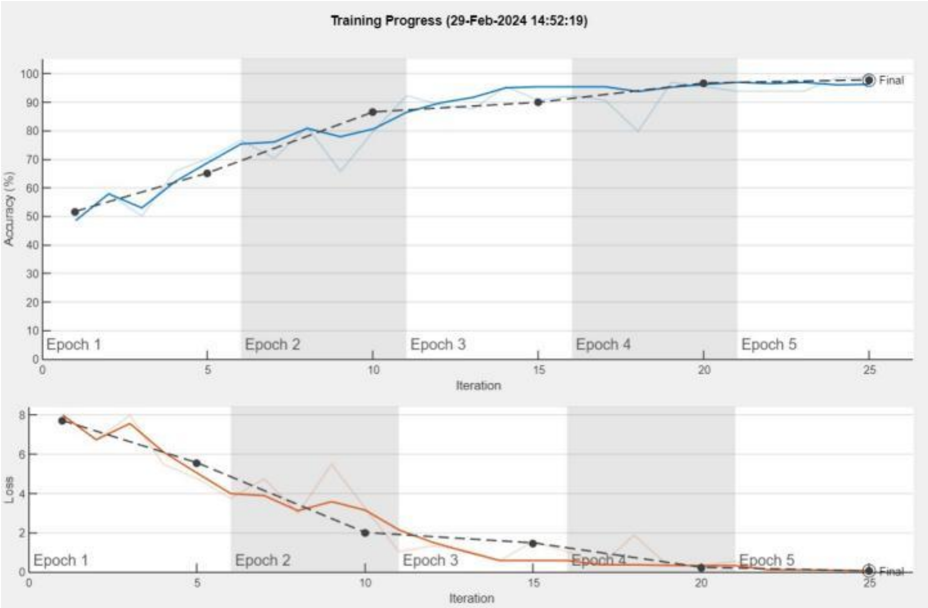

Fig .8 Training Progress of Simple NN

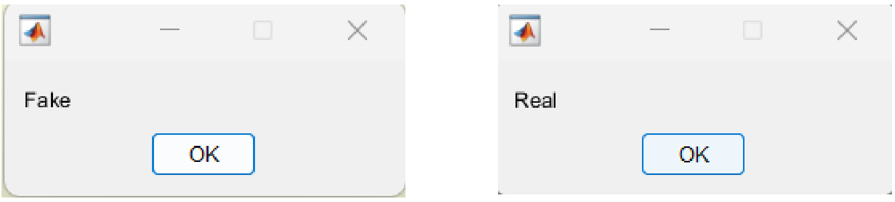

Fig .9 Outputs

Comparision

TABLE I. COMAPRISION BETWEEN BOTH MODELS

	CNN	**SNN**
Accuracy	100%	97.7%
Precision	1	1
Recall	1	0.95
F1 Score	1	0.97

VI. CONCLUSION

In conclusion, the comparative analysis conducted in this study highlights the effectiveness of various techniques for Indian fake currency detection. While Simple Neural Network (NN) methods offer a viable approach, the Deep Learning Convolutional Neural Network (CNN) emerges as the most robust and accurate technique. By leveraging convolutional layers, batch normalization, and pooling layers, the CNN architecture demonstrates superior performance in identifying counterfeit Indian currency with higher accuracy and reliability. These findings underscore the significance of deep learning approaches in bolstering financial security and fraud prevention measures. Moving forward, continued research and development in this domain are crucial for advancing automated counterfeit detection systems and safeguarding against financial crimes.

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VII. LIMITATIONS

The Limitations for the project may be as follows:

A. *Limited Dataset*: Due to the scarcity of diverse datasets, the project focused solely on counterfeit detection of Indian 500 rupee notes. Although the developed code demonstrates effectiveness for this currency, the absence of extensive data impedes its adaptation to distinguish other currency denominations. Despite this constraint, the implemented code architecture and methodologies hold promise for broader currency detection with access to suitable datasets, indicating potential for future expansion and refinement.

B. *Overfitting*: There's a risk of overfitting, especially with complex models like CNNs, where the model learns to memorize the training data rather than generalize patterns. Overfitting can occur if the model is trained on a small dataset or trained for too many epochs, leading to reduced performance on unseen data.

C. *Hardware Requirements*: Deep learning models, especially CNNs, often require significant computational resources for training and inference. This could be a limitation for deployment, particularly in resource-constrained environments where access to high-performance computing is limited.

VIII. FUTURE WORK

The future scope of this project lies in several promising directions. Firstly, there is potential for further optimization of the CNN architecture and hyper-parameters to enhance accuracy in detecting counterfeit Indian currency. Augmenting the dataset with diverse examples and expanding it could improve the model's ability to generalize to real-world scenarios. Integrating the model into real-time detection systems would enable swift identification and prevention of counterfeit transactions. Additionally, investigating the model's robustness against adversarial attacks and deploying it with user-friendly interfaces for seamless integration into financial systems are crucial steps. Continuous monitoring and updates, along with collaboration with stakeholders, would ensure the model's effectiveness against evolving counterfeit techniques. By pursuing these avenues, the project can contribute significantly to the development of advanced counterfeit detection systems, bolstering financial security and fraud prevention measures in India and beyond.

IX. ACKNOWLEDGEMENTS

We extend our heartfelt gratitude to **Sri Hari Sir**, our esteemed Project Coordinator and Associate Professor at VVIT Institute, whose insightful guidance and unwavering support propelled us to delve deeper into the intricacies of our project. His expertise and encouragement have been invaluable throughout this journey.

We also express our sincere appreciation to **Bhushnam Sir**, our dedicated Project Guide and Assistant Professor at VVIT Institute, for his continuous support and mentorship. His profound knowledge and constructive feedback have played a pivotal role in shaping the outcome of our project.

This project would not have been possible without the collective efforts and support of everyone mentioned above We are truly grateful for their contributions and collaboration.

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