Currency And Counterfeit Currency Detection Using Machine Learning Algorithms

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Abstract— **This project aimed to develop a solution which can assist visually impaired individuals in identifying currency denominations and detecting counterfeit currency. To achieve this, we used Teachable Machine for currency denomination detection and MATLAB for counterfeit currency detection. The resulting model was then integrated into an Android application, making it easily accessible to users. The project involved collecting and recording audio files for different currency denominations, which were then used for training the Teachable Machine model. The MATLAB model used edge detection and feature extraction techniques to detect counterfeit currency. The Android application provided an easy-to-use interface for users to detect the denomination of currency and identify its originality. By integrating these two models, we were able to achieve a solution that can be used by visually impaired individuals to easily identify currency and avoid counterfeit currency. In summary, this project presents a practical solution to address the challenges faced by visually impaired individuals in handling currency and detecting counterfeit currency.**

Keywords— Computer vision, Counterfeit Currency, MATLAB, Teachable Machine, Android Studio, Image processing, Feature Extraction.

I. INTRODUCTION

Counterfeit currency is a significant threat to the economy, and in India, it has been a major concern for the Reserve Bank of India (RBI). In response, the RBI has stepped up its efforts to detect and prevent the circulation of fake notes. According to the RBI's annual report for 2021-22, there has been a substantial increase in the detection of counterfeit 500 and 2,000 rupee notes by the banking system. The number of fake notes detected more than doubled for 500 rupee notes and increased by 54.6% for 2,000 rupee notes compared to the previous year. The National Crime Control Bureau (NCCB) has also reported that law enforcement agencies across India have seized fake currency worth over 245 crore rupees since 2016.

To address this problem, the RBI has introduced new currency notes of Rs 500 and Rs 2,000 with several advanced security features, such as the colour-shift windowed security thread, intaglio printing, and latent image, to make it difficult for wrongdoers to imitate them. Figure 1 provides a visual representation of the identification marks present on 2,000 rupee notes, while Table 2 outlines the distinctive features of the same notes. These resources serve as a guide for individuals to identify genuine currency and distinguish it from counterfeit notes. This paper presents a solution that addresses the issue of counterfeit currency detection and currency denomination identification, with a specific focus on providing an accessible solution for visually impaired individuals. The proposed solution is user-friendly, dependable, and readily available to the general public. The paper is structured as follows: Section II provides an overview of the existing literature related to the study, Section III presents the proposed solution, Section IV explains the dataset generation process, Section V outlines the methodology used, Section VI presents the results obtained, and finally, Section VII concludes the study.

TABLE I.   DENOMINATION-WISE COUNTERFEIT NOTES DETECTED IN THE BANKING SYSTEM (SOURCE RBI)

Denominations	2019-20	2020-21	2021-22
₹ 10.00	844	304	354
₹ 20.00	510	267	311
₹ 50.00	47,454	24,802	17,696
₹ 100.00	1,68,739	1,10,736	92,237
₹ 200.00	31,969	24,245	27,074
500 [MG Series]	11	9	14
500 (New) Series	30,054	39,453	79,669
₹ 2000.00	27,020	8,798	13,604
Total	2,96,694	2,08,625	2,30,971
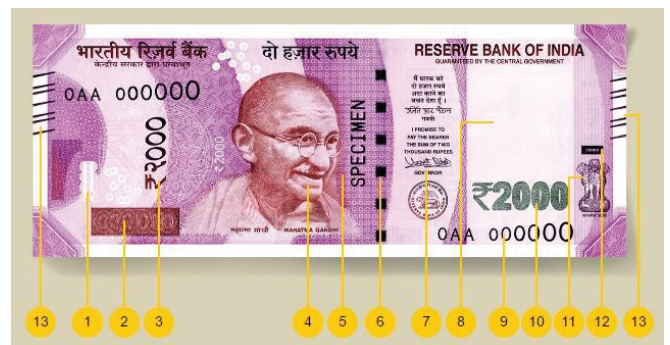
Fig. 1.   Rs 2000 Note with identification marks

TABLE II.   FEATURES OF 2000 RS NOTE

1	See through register with denominational numeral 2000	8	Mahatma Gandhi portrait and electrotype (2000) Watermark, Ashoka Pillar emblem on the right
2	Latent image with denominational numeral 2000	9	Number panel with numerals growing from small to big on the top left side and bottom right side.
3	Denominational numeral 2000 in Devnagri	10	Denominational numeral with Rupee Symbol, ₹ 2000 in colour changing ink (green to blue) on bottom right.
4	Portrait of Mahatma Gandhi in the Centre	11	Ashoka Pillar emblem on the right
5	Micro letters 'RBI' and '2000'	12	Intaglio or raised printing of Mahatma Gandhi portrait (4), Ashoka pillar emblem (11), horizontal rectangle identification mark with 72000 on the right, seven angular bleed lines both on the left and right sides
6	Coloured shift windowed security threat with inscriptions 'Bharat', RBI and 2000. Colour of the thread changes from green to blue when the note is tilted.	13	Year of printing of the note on the left
7	Guarantee Clause, Governor's signature with Promise Clause and RBI emblem towards right of Mahatma Gandhi's portrait		

II. LITERATURE SURVEY

Two recent studies [5] and [6] have focused on detecting counterfeit currency using deep learning techniques. In [5] a dataset of 40,000 images was created by generating 10,000 images for each of the four categories. The dataset was split into a ratio of 80:20 for training and testing respectively. The model was implemented with 5 convolution layers, a flatten layer and 4 fully-connected layers. The training data was further divided into 30,000 images for training and 2,000 images for cross-validation. The model was trained and tested on the dataset resulting in a high accuracy rate.

In [6] the input image was first pre-processed by converting RGB to grayscale format, normalising pixel intensity values, and tuning hyper-parameters. Two CNN architectures were proposed for classifying currency notes of Rs. 500 and Rs. 2000 each. Both architectures consisted of different types of layers including convolution, pooling, flatten and fully connected layers. The model achieved high classification accuracy for both denominations.

The three papers [8][9][10] all use image processing techniques for the recognition of Indian currency notes. They start by acquiring an image of the currency note, which is then converted to grayscale.

In [7] author explains the different methods used to detect the originality of currency notes, including the traditional method, digital image processing method, and an Android-based currency detection method. The section also describes the software used in the proposed implementation, such as MATLAB, Teachable-Machine, and Android Studio, as well as the different steps involved in currency detection using digital image processing, such as image acquisition, pre-processing, image segmentation, feature extraction, and comparison.

III. PROPOSED SOLUTION

Three softwares were used in proposed solution.

1. *Teachable Machine:* It is a AI web-based, machine learning tool. It leverages cutting-edge technologies such as deep learning and neural networks to empower users with the ability to teach their own models to classify, recognise and detect objects, sounds or actions, based on their own input data.
2. *Android Studio:* It is a highly sophisticated integrated development environment (IDE) designed for the creation of Android applications. It is equipped with advanced tools and technologies that enable developers to create, test, and deploy high-quality and visually appealing mobile applications for the Android platform.
3. *MATLAB:* It is a programming language and environment used for numerical computing, data analysis, and visualisation. It is widely used in various fields such as engineering, science, and finance.
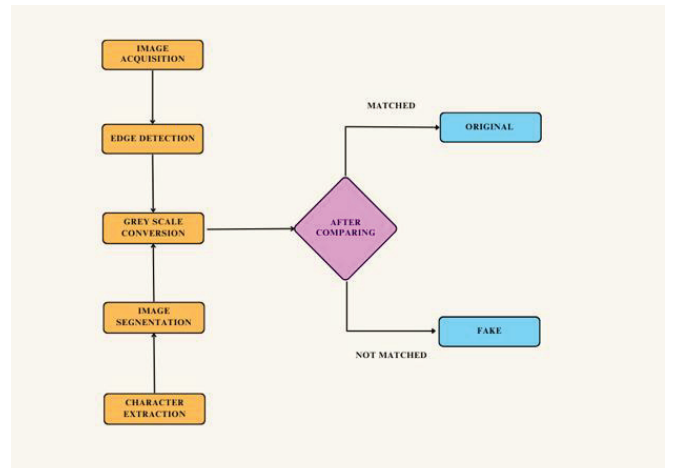

Fig. 2. Flowchart of MATLAB Implantation

The model design and implementation flowchart for authenticity checking are presented in Figure 2. The figure provides comprehensive view of the working model and outlines the different methods that can be used to identify a currency and check its authenticity, with the help of MATLAB based feature extraction and machine learning models. Fig.3 shows the flowchart of the Teachable Machine Android application, which involves the use of floating model and quantized model. The floating model is used for training the image recognition model, which is then converted into a quantized model for efficient deployment on mobile devices. The Android application then utilises this quantized model to recognise and classify images in real-time, enabling users to easily detect and distinguish between different types of currency notes. This flowchart highlights the various steps involved in the process, including data collection, model training, conversion to quantized model, and integration with the Android application.
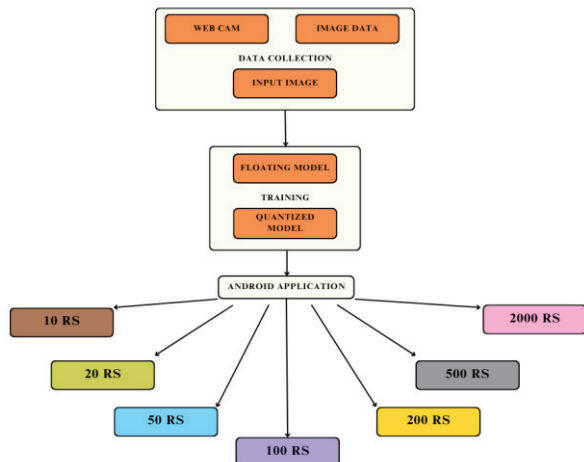
Fig. 3.   Flowchart of Teachable Machine Android Application

IV.   DATASET GENERATION

1. The size of all the currency images in the dataset which are captured in landscape mode is 5344×3006.

2. Whereas the size of all the currency images in the dataset which are captured in portrait mode is 3006×5344.

TABLE III.

Dataset	Source	Users	Items	Type
Indian Currency Notes	Mendeley Data, Kaggle	2.5 Million, 8 Million	17,000	Image Dataset

Image Cropping - Every image was cropped to reduce the background. A total of 17,000 images were generated in the data augmentation process. Every image generated 90 copies of itself on applying the above mentioned techniques in Fig.4, 5& 6. 2,000 images of each category were generated in this process. The techniques used for data augmentation are Zooming, Rotating, Flipping.
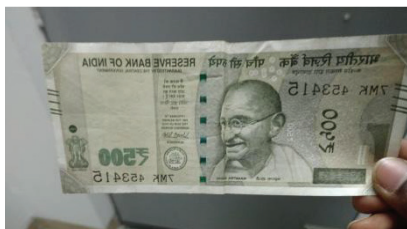

Fig. 4.   Rotated Image

Fig. 5.   Original Image

Fig. 6.   Figure 1 After Data Augmentation

V.   METHODOLOGY

A. Image Processing Method-

The proposed system is designed to check whether a currency note is genuine or fake. To start the process, the system needs an image of the currency note, which can be captured using a digital camera or scanner. This image is then converted from a colour image to a grayscale image, which makes it easier to analyse [8][9][10]. The system then identifies the regions of the currency note that are important for analysis, such as the denomination and security features. These regions are then cropped and segmented so that the system can extract relevant features, such as the intensity of the ink used on the note. If these features meet certain criteria, the note is considered to be genuine. If not, it is flagged as a potential counterfeit. This process helps prevent counterfeit currency from entering circulation and protects the integrity of the currency system[7].

1) Image acquisition-

Image acquisition is the process of capturing an image through a digital camera or scanner. It involves taking a picture or scanning a document to create a digital copy. The resulting image is then ready to be processed using various digital image processing techniques.

2) Image pre-processing-

It is like preparing an image before we start analysing it. In image pre-processing, we may adjust the brightness and contrast, remove any noise or unwanted parts of the image, or even enhance certain parts of the image to make it clearer. By doing all of this, we can make sure that the image is ready for the next step in the analysis process.

3) Image segmentation-

It is the process of dividing an image into multiple segments or regions based on its characteristics such as colour, texture, or intensity. It is like breaking down a puzzle into smaller pieces, where each piece contains a specific part of the image. This makes it easier to analyse and process the image in a meaningful way.

4) Feature extraction-

In this step, specific characteristics or features are identified and extracted from the segmented image regions. These features can include colour, shape, texture, or intensity.

5) Comparison-

Once the features are extracted, they are compared with the features of known genuine notes. If the features match, then the note is considered genuine. If they do not match, then the note is flagged as a potential fake.

B. Android Based Currency Detection-

The system is designed to detect currency notes using real-time images captured through an Android application. The system has three main stages: data collection, model training, and application development [7].

To collect data, images of currency notes are captured from different denominations, either through direct camera capture on a mobile device or by showing the currency to a webcam. These images need to include different sides of the currency notes and be classified into different denominations. Teachable machines/images are used for data collection. The more images collected, the more accurate and

efficient the system becomes. In the model training stage, the machine learns all the images in each class using the "Teach Model" option. The optimal epochs, batch size, and learning rate are set, which helps in the efficient learning of the images. After model training, the machine exports the learned data as tensorflow.js, TensorFlow, and TensorFlow Lite files (Floating/Quantized type as in Figure 7), which are then used to develop an Android application in Android Studio. Finally, the exported files, which are in TensorFlow Lite format, are integrated into the application software in Android Studio, resulting in the development of an efficient currency detection application. With the help of this system, users can easily detect counterfeit currency notes, ensuring the safety of financial transactions.
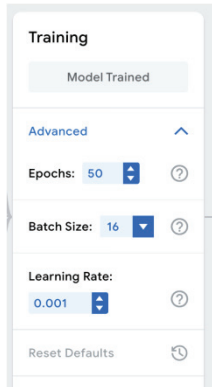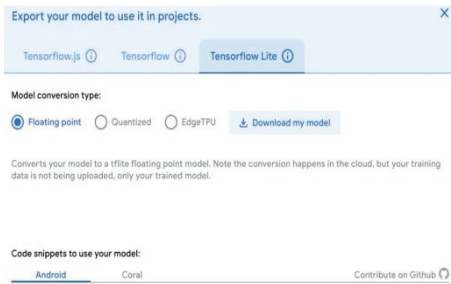

Fig. 7.   Import Files

Fig. 8.   Model Training

C. Android Application Development-

The focus of this project is to develop an Android application that can accurately detect various denominations of currency. To achieve this goal, we have chosen to use the Android Studio development environment. Additionally, we have leveraged an online voice recorder to record audio files that correspond to the sound of different currencies. These audio files have been incorporated into our application to provide an additional means of currency identification.
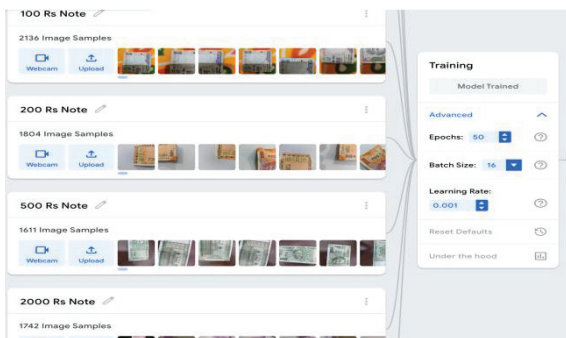

Fig. 9.   Data Collection & Model Training

In Figure 9, we can see the data collection process for various currency denominations, including 10, 20, 50, 100, 200, 500, & 2000. Once the data is collected, then we used Teachable Machine to train the model for currency detection. The model was trained on the collected images of the currency denominations and was taught to recognise the different features of each denomination, such as the colour, size, and unique features of the currency notes. After the model is trained, then we built an Android Studio application to detect the currency type using the concept of image recognition. When a user takes a picture of a currency note using the app, the image is analysed by the trained model, which recognises the features of the note and predicts the denomination. The model then produces an audio output expressing the currency type, which can be heard by the user. Overall, this approach combines image recognition and audio output to enable effective currency detection. This method provides a simple and user-friendly way for people, especially those who are visually impaired, to identify different currency denominations.
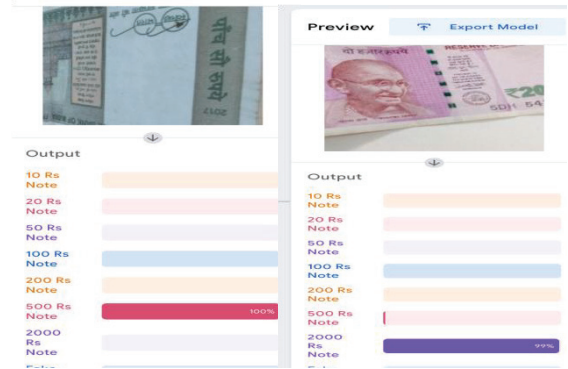
VI.   RESULT & ANALYSIS

Fig. 10. Teachable Machine Output of 500 Rs & 2000 Note

Figure 10 shows the intermediate output of the Teachable Machine for currency type detection. The model achieves a 100% accuracy rate for the detection of a 500 Rs note, while a 99% accuracy rate is achieved for the detection of a 2000 Rs note. This demonstrates the effectiveness of the model in accurately identifying currency types in real-time.
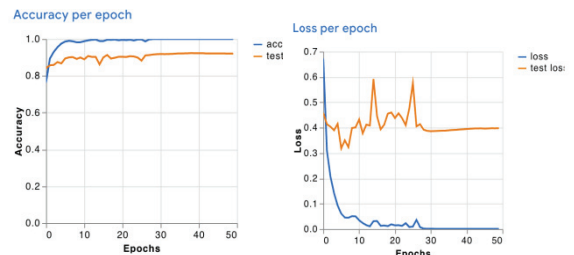

Fig. 11. Accuracy & Loss per epoch

In terms of formulas, accuracy is calculated as the ratio of the number of correctly predicted labels to the total number of labels. Mathematically, it can be expressed as:

$$Accuracy = \frac{Number\ of\ Correctly\ Classified\ Images}{Total\ Number\ of\ Images}$$

On the other hand, loss per epoch represents the difference between the predicted output and the actual output for a given input during each epoch of the training process. The goal is to minimise the loss, as it indicates how well the

model is performing on the training data. The loss function used depends on the specific problem and model architecture being used. Mathematically, the loss function can be expressed as:

$$Loss = (1 / n) * \Sigma(y_i - \hat{y}_i)^2$$

where:

- n: total number of training examples
- y_i: the actual output of the i-th training example
- $\hat{y}_i$: the predicted output of the i-th training example.

Confusion Matrix

Class	10 Rs Note	20 Rs Note	50 Rs Note	100 Rs Note	200 Rs Note	500 Rs Note	2000 Rs Note
10 Rs Note	180	3	6	11	10	7	4
20 Rs Note	0	255	1	2	4	0	4
50 Rs Note	20	4	160	48	5	15	4
100 Rs Note	14	3	20	255	10	14	5
200 Rs Note	0	1	1	5	260	4	0
500 Rs Note	7	0	7	12	0	214	2
2000 Rs Note	2	1	0	4	16	6	233
Fake Notes	0	0	0	0	0	0	1

Fig. 12. Confusion Matrix

A confusion matrix is a table used to evaluate the performance of a classification model. It shows the number of correct and incorrect predictions made by the model compared to the actual outcomes (or ground truth) for each class in the data. A confusion matrix typically has four sections, or quadrants:

TABLE IV.   CONFUSION MATRIX

	Actual Positive	Actual Negative
Predicted Positive	True Positive	False Positive
Predicted Negative	False Negative	True Negative

1. True positive (TP): The model correctly predicted the positive class.
2. False positive (FP): The model incorrectly predicted the positive class when the actual class was negative (a Type I error).
3. False negative (FN): The model incorrectly predicted the negative class when the actual class was positive (a Type II error).
4. True negative (TN): The model correctly predicted the negative class.
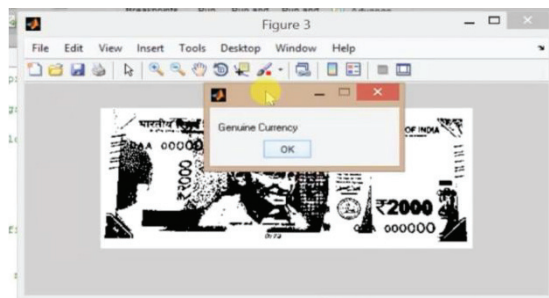

Fig. 13. Counterfeit Currency Detection

Figure 10 displays the results of the experiment conducted to detect the type and originality of currency. The image acquisition step is common for both stages, which are Android-based currency type detection and MATLAB-based currency originality detection. Figures 7 show the output of currency type detection, while Figure 10 displays the results of currency originality detection with edge detection and feature extraction output floating window. If the accuracy level of currency originality detection is below 95%, it suggests that we need to collect more data and feed it to the teachable machine to obtain a more accurate model.

VII.   CONCLUSION

In conclusion, the project successfully achieved the goal of creating a currency detection system that can detect both the denomination and originality of banknotes. The system utilised both MATLAB and Teachable Machine for counterfeit currency detection and currency denomination detection, respectively, and an Android application was created to make it accessible to visually impaired or blind people.

The system showed an overall accuracy of above 95%, indicating that it can be a reliable tool for detecting banknotes. By combining different approaches and technologies, the project demonstrated the potential for creating innovative solutions that can improve the accessibility and independence of people with visual impairments.

The project's success highlights the importance of using technology for social welfare and creating solutions that can benefit the larger community. Future work can include integrating additional features, such as text-to-speech conversion, to further enhance the accessibility of the system. Overall, the project serves as a valuable contribution towards creating an inclusive and accessible society.

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