Currency Recognition using Machine Learning

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Abstract - *This paper proposes the technique of currency recognition using image processing. This technique works based on three factors: color, size and texture which are used in the recognition. The technique proposed in this paper can be used to detect the currencies of many countries. For the sake of implementation only Indian paper currencies are considered. With this system it is easier to check currency anywhere and at any time, and the technique is implemented using the CNN (Convolution Neural Network). We tested this method on every denomination of India and the system was able to detect with 95% accuracy. A classification model is generated using all factors mentioned to increase the accuracy of the technique. Paper currency features play an important role in this recognition.*

***Key Words*: Currency recognition, CNN, tflite, flutter_tts, dart, teachable machine.**

1.INTRODUCTION

Nowadays, every country is facing the currency recognition problem due to the fake denominations in the market or illiteracy of the people in the given country, so automatic currency recognition system is important. Accuracy and speed are the two important factors in such a system. Also, accuracy is more important than speed. A currency recogniser recognises the currency and identifies denomination by analysing the prominent attributes. Researchers proposed so many methods. Some of them use physical properties (width, length) and few uses internal properties (texture, colour). In the software field every problem has a solution. Using such software solutions, we can save our time as well as energy. In the early 90's there was one method which identified currency notes using image processing. However, their algorithm does not take aspects of authentication of the notes into account. For such a system it was necessary to have an input of the image after that it was performing some tasks over to it**.**

Great advancement of the technologies in the banking sector has resulted in the introduction of self-servicing for making transactions simple and friendly to the customers. also, we are known with the currency counting machines where this currency recognition technique is used. New techniques related to the recognition are also introduced by these banks like cash deposit by the user itself through the machines without visiting the respective bank. Here currency recogniser is required to check currency and handle it according to the denominations.

In this paper we proposed a system which works based on CNN (Convolution Neural Network) technique. Different modules are used to detect the currency according to the structural view of that currency notes. Classification model is built for the validation of proposed methods.

The formatting of the paper is organized as follows. Section II of the paper gives the related works done in this area. Section III provides a brief description about the currency features. Section IV of the paper gives a detailed explanation of the method. Section V discusses the experiment and results obtained. Section VI and VII presents the inference and conclusion of the study.

2. RELATED WORK

Authors in [1] proposed a method that uses currency features such as centre numeral, latent image, RBI seal, shape, and micro letter for currency recognition. Training data set preparing for getting training models is included. PCA analysis is explained for paper currency recognition.

In [2] authors proposed a method that uses features such as colour, texture, size for paper currency recognition. Dirty banknotes recognition method is included.

Author of [3] proposed a system for paper currency recognition using the MATLAB tool. PCA analysis along with Euclidean Distance explained. LBP technique for matching purpose is explained.

In [4] the authors proposed a technique which detects the country first and then detects the denomination of the country. For identifying the country and the denomination different regions of the currency note included.

Authors of [5] have given a brief idea about the features of the Indian currency. Morphology Filtering process along with some different analysis and segmentation explained. Paper currency detection recognition technique using neural networks is carried out.

[6] is a book regarding the CNN that includes different layer processing through the mathematical demonstration. Each is explained through some graphical way. When the image is captured, it is converted into the matrix format before detection and then matched with a trained model so the whole processing in between the matrix formation and recognition is demonstrated using mathematical calculations. Effects of the different convolutional kernels in horizontal and vertical edges.

In [7] Author explained all aspects of the CNN.

In [8] the author proposed a technique for currency recognition using a neural network. Classification using weighted Euclidean Distance along with the different steps required for data collection and processing included.

In [9], [10] authors proposed a technique of Currency Recognition. [11] is the teachable machine used for data training and getting accuracy.

3. METHODOLOGY

The project paper is based on the image processing technique. The purpose of this project is to recognize currency notes according to their denomination. Tflite model and teachable machine are the important aspects of the projects as these tools provide the classified model for the project. Also, we have used CNN classification algorithm used in the classification process. The process followed by the capturing of currency and then recognition output in the format of voice. The model created work not only as a recognizer but also as a calculator as it adds all the denomination of currency it recognizes, so we don't have to add them manually. flutter_tts is used to get voice format by converting text to voice.

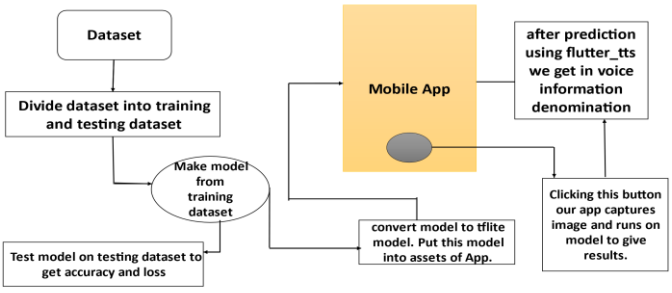


Fig -1: Name of the figure

3.1 Components of Model

1. Tflite

TensorFlow Lite or in short tflite is a set of tools which helps to run ML models on various devices. It supports various languages and has high performance. It helps in common machine learning tasks like images or audio-based classification, helps in NLP with text classification, pose estimation and object detection.

Flat Buffers are the formats which are used to represent TensorFlow lite model in a special efficient way. This leads to small code footprints and high efficiency as it has fast inference. A TensorFlow Lite model has metadata which is human readable model description and machine-readable data, in our case for classification of images.

First it is necessary to divide the dataset into training and testing dataset format, then a classified model is generated using CNN classification method and then that created model is converted into the tflite model and added into the assets of application.

2. Flutter, camera, flutter text to speech module

Flutter is Open-Source Framework by Google for building apps which are fast, productive, and flexible. Using Flutter, we can build mobile apps using widgets. Also, many pros of Flutter include Hot Reload and Hot Restart which we don't have while building mobile apps with Java or Kotlin using Android Studio. In Flutter application, if you must insert plugin or dependencies, you have to mention it in puspec.yaml.

In building this application we used many modules or plugins which include camera module, tflite module, flutter_tts module, etc.

Camera module is Flutter plugin in Android allowing access to web cameras. It is used to display live camera preview in a widget, video recording and many more functions. Camera module dependencies need to be mentioned in pubspec.yaml in flutter. We use this module in an asynchronous manner where some functions are run in the background.

Flutter Text to Speech or flutter_tts module is used in Flutter apps to convert texts to speech. This camera module is used to capture the image of currency and pass it to the classification model for the further process. After recognition completion the denomination amount is displayed in the format of text, and which is converted into the voice using this flutter_tts module.

3. TensorFlow

TensorFlow is an open-source library which helps us to develop and train ML models. Various operations involved in the Convolutional Neural Network Model like Convolution Operation, ReLU layer, Pooling, Flattening can be easily done using TensorFlow. Different lite versions of TensorFlow are used to build this technique.

3.2 Image Classification using CNN

1. Notes features

Currency recognition is a field which is studied by many researchers over the last couple of years. Currency can be recognised in a variety of ways depending on features you use for classification as well as machine learning model.

Every currency on this planet has certain features on which we can easily classify them. In case of Indian currencies, they have some security features which are crucial for recognition of the denomination. Certain features like the dominant colour of denomination are one of important features for classification. So, we can infer that a model using grayscale image for currency recognition will surely be left out of one of the important features of classification and can hamper accuracy.

Most striking feature while recognizing notes is identification marks of Indian currency. For every denomination there are specific geometric symbols which correspond to them.

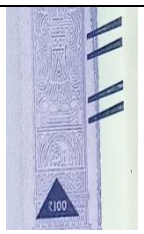
Denomination	Identification Mark
10	 **Fig. 2:** RS 10 mark
20	 **Fig. 3:** RS 20 mark
50	 **Fig. 4:** RS 50 mark
100	 **Fig. 5:** RS 100 mark
200	 **Fig. 6**: RS 200 mark
500	 **Fig. 7**: RS 500 mark
2000	 **Fig. 8**: RS 2000 mark

Table 1: Denomination with Identification Mark

As per Reserve Bank of India, in Indian currency notes there are 8 security features present. These features are Watermark, Latent Image, Intaglio, Fluorescence, Security thread, Micro Lettering, Identification mark, Optically Variable Ink.

Some importance features in notes which our Neural Network model can consider while classification:

1. Intaglio Painting

The portrait of Mahatma Gandhi, Ashoka Pillar Emblem on the left, the Reserve Bank seal, guarantee and promise clause, RBI Governor's signature are printed in intaglio i.e., in raised prints, which can be felt by touch.

These images can be used by neural networks for classification.

2. Overall majority Colour

As mentioned earlier, every note has a certain majority colour depending on denomination. After the Demonetisation of 2016, the Government of India issued some new currencies with new colours. Also, currencies of denominations like Rs. 50, Rs. 100, etc were introduced with newer look and colour. This feature is very important especially when images used for classification use RGB colours.

3. Latent Image

A latent image showing denominational value in numeral is at the vertical band on the right side of Mahatma

Gandhi's portrait. When the currency note is held horizontally at eye level only then this latent image is visible.

4. ID mark

Identification mark is a geometrical symbol corresponding to the denomination of currency. This feature is not available for Rs. 10 notes. This feature is in different shapes for various denominations and helps the visually impaired to identify the denomination.

5. Centre Numeral

We can see that on Indian currency, denomination is printed in figures and words. Numerical representation of denomination is present at the centre of notes.

3.3 Proposed methodology for Currency recognition using CNN

Step 1: Collecting Dataset and cleaning it.

Collecting samples for the dataset is the big task in the project building, as the dataset is the responsible thing for the coming output of the classification model. Before passing it through the classification model the dataset should be cleaned as it contains some images which will affect the model during image recognition.

For this model nearly 600 images were collected. Then these images were cleaned to get a better classification model. Sometimes background-coloured images affect model generated, so discarding them is best option. So, image cleaning is important.

Step 2: Making CNN model for dataset collected for image classification.

Every image is a 2D matrix of pixels of different values with RGB colours. Images consist of pixels in a grid. Every image processing is involved with 3 basic steps - 1) Importing images using appropriate image importing tools 2) Image pre-processing/ analysing and manipulating images. 3) Analysed output.

Here in the project, we used TensorFlow for Image Classification. Images used are $224 \times 224px$. CNN concept is that not all pixels are needed to identify features of an image or classify them.

Steps involved in in image classification are dataset, Convolution, ReLU layer, Pooling, Flattening, Neural Connections, converting generated model to tflite model an Exporting model to Flutter application.

Convolution: Convolution basically is a combined integration of two functions, and it shows you how one function modifies or affects other functions.

$$(f * g)(t) = \int_{-\infty}^{\infty} f(\tau)g(t-\tau)d\tau \quad (1)$$

(1)is an example of convolution.

There is input image

$$x \in R^{H \times W \times D} \quad (2)$$

(2)(where D = 3 where it represents RGB image format layers and $H \times W$ is pixel matrix size) and a feature detector matrix . Here we apply convolution on each red, green, and blue layer separately , so we can represent each image as $R^{H \times W}$. Suppose the dimension of the image is $n \times n$ and the feature matrix is $f \times f$.

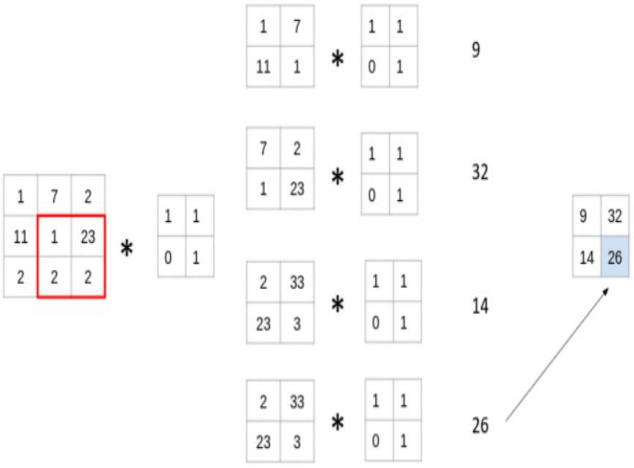


Fig. 9: Convolution of image matrix

In the given diagram, we can see the use of convolution. These feature matrices or convolution kernels are used to detect various things like edges, horizontal and vertical ones, or other features. After convolution, i.e., multiplying each value of matrix with each value of kernel, we get a matrix of

$$(n - f + 1) \times (n - f + 1) \quad (3)$$

(3)which is a Feature Map. We can create multiple feature maps for targeting each feature on notes and for each feature we must create separate filters.

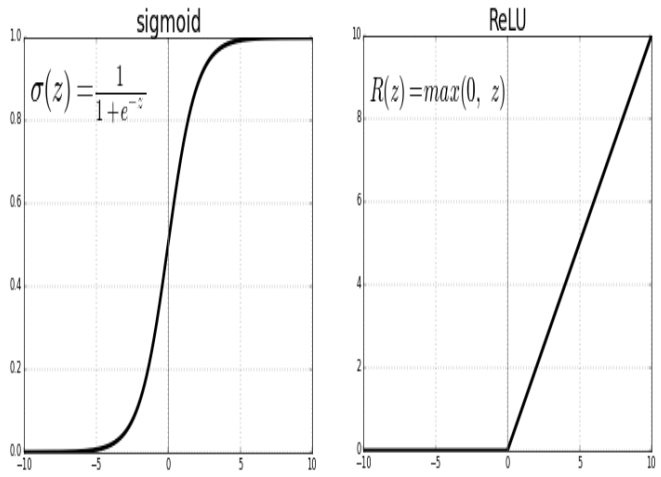


Fig. 10: Variation Graph for Sigmoid and ReLU functions

ReLU layer:- We use Rectifier function because we want to increase nonlinearity in our image or in our CNN. Rectifier acts as that filter. If we apply ReLU , it makes everything below 0 the same value or flattens it.

Pooling:- Pooling is needed especially for orientation correction of currency notes. In the dataset we have images which are rotated or sometimes slim or fat, but we want the neural network to recognise all of them as the same note. We need to make sure that our neural network has a feature called spatial invariance meaning that it doesn't care where features are in cases like rotation or whether features are a little bit different. Various types of pooling exist like mean or max pooling.

Flattening:- Pooled feature map is converted to linear matrix or one long column. Now we run a Neural Network considering this linear matrix as input.

Full Connection: - In this step we run Neural Network and Neural Network using Backpropagation and Gradient Descent builds the whole Neural Network.

Suppose we have neural network of one layer:

$$Z = W_T.X + b \quad (4)$$

in (4) Here W_T are randomised weights matrix ; X is image which is input, and b is randomised bias matrix and Z is output.

We apply sigmoid function or can apply ReLU function on Z .

ReLU function :

$$f(x) = \max(0, x) \quad (5)$$

Sigmoid function :

$$f(x) = 1/(1 + e^{-x}) \quad (6)$$

$$O = \sigma(Z) \quad (7)$$

$$O \in (0,1) \quad (8)$$

If actual output is O' and we are getting O as output.

Let Error be E.

Gradient Descent equation :

$$W' = W - (learning\ rate) \times \frac{\partial E}{\partial w} \quad (9)$$

For CNN we have a filter matrix as our gradient of parameter.

$$Z = X * f \quad (10)$$

$$f' = f - (learning\ rate) * \frac{\partial E}{\partial F} \quad (11)$$

$$= f - (learning\ rate) * \frac{\partial E}{\partial O}.\frac{\partial O}{\partial Z}.\frac{\partial Z}{\partial F} \quad (12)$$

This is how we correct mistakes by backward propagation and correct filter matrix. This is how we make correct filters which can be applied on images, and we get correct recognition of currency notes.

3.4 Teachable Machine

Teachable machine[reference number included here] is an online software which helps to train our dataset and use it with the tflite module in the asset folder of the Application. Through this model 600 images are classified, and each image is checked according to its accuracy of matching with denomination. In it multiple classes are created with each currency value. By uploading $224 \times 224px$ images size and setting accurate epoch value we got near about 95% accuracy through our model.

4. ALGORITHM

1. Data collection
2. Data cleaning
3. Data trained with the epoch size 50 batch size 16 and learning rate 0.001
4. Module exported
5. Two files generated label.txt and model.tflite
6. Files included in asset folder of program
7. Model is loaded into flutter application
8. Apk file is generated after building all components
9. Denomination captured

10. Output in the form of a voice.

4.1 Accuracy Per class

For this model it is necessary to check the accuracy of every denomination to check the currency note correctly. As on the teachable machine we created the model of different classes containing the denominations, and then setting proper epoch value the below accuracy achieved. For this image processing project, we included all the Indian denominations ranging from 10 to 2000.

Accuracy per class

CLASS	ACCURACY	# SAMPLES
0	1.00	34
10	0.75	12
20	0.83	12
50	0.86	14
100	1.00	16
200	1.00	14
500	1.00	12
2000	0.89	9

Fig. 11: Accuracy Per Class

4.2 Accuracy per epoch

Also, the loss factor is considered to achieve better accuracy through epoch. For this the data set is trained for the 500 epoch and then graphical accuracy is achieved for images included in the dataset.

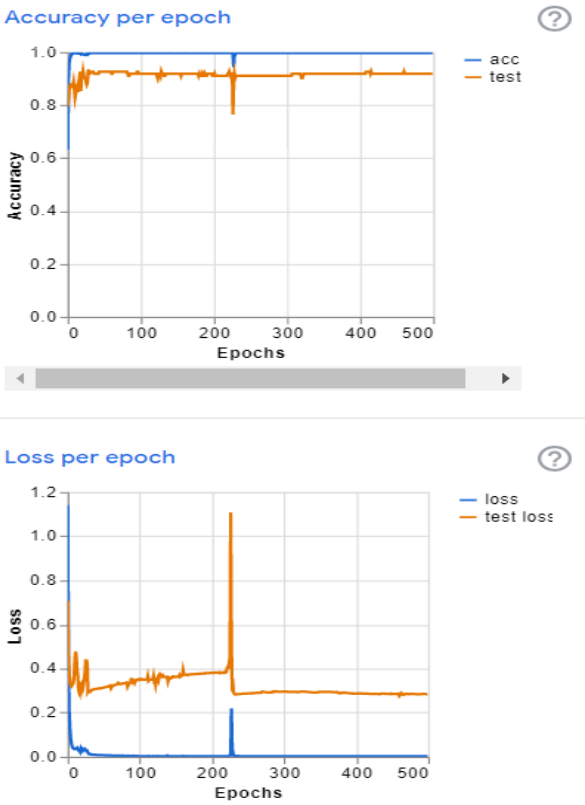


Fig. 12: Loss and accuracy according to epoch value

4.3 Accuracy on Teachable Machine

When we capture any image of a currency note then the model identifies the correct denomination through the trained dataset. As for e.g., the denomination of 200 is captured by the camera module then it is checked with the trained data with the help of tflite and as we can see through the output table the accuracy for the 200-currency note is 100% it means technique works properly. The same happens with the other currency denominations.

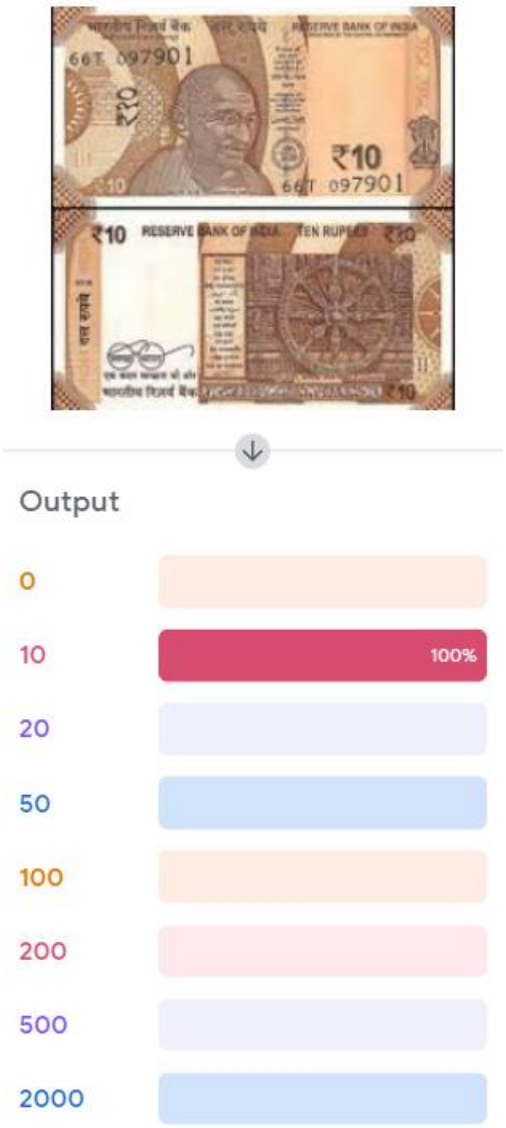


Fig. 13: Accuracy Model

4.4 Flutter App

The interface with the header A-Eye is in a dark mode, and camera button widget in bottom middle area.

Fig. 14: Interface

5. FUTURE SCOPE

Nowadays, technology is growing on a large scale. The proposed system can be extended towards coin detection also for fake currency recognition. Denomination of other countries other than India can be added also comparison between them can be achieved. When an image is loaded from the outside into the training folder then it is not giving 100% accuracy. We can improve this problem by optimizing the system.

6. CONCLUSION

Thus, the different methods proposed in this paper were implemented successfully and verified by performing experiments over the model. CNN is found to be the best feature for performing the technique by using tflite and flutter_tts modules. Accuracy of 95% achieved by performing the classification of models. Also, the detection of the coins is performing well in this method.

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