

Machine Learning Methods Analysis for Indian Currency Counterfeiting

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Abstract—Imitation of currency made with the intention of misleading people is referred to as counterfeit money. One of the risks that harms a country's economy and so slows global growth is counterfeit money. Producing counterfeit money or creating false features for currency is illegal activity, which needs to be properly analysed. Demonetization resulted in an unexpected inflow of fake currency into banks, which in turn lead an increase in doubtful activities. The review focused on the methodology used to detect counterfeit currency, as well as the success rate of each method. Numerous fake currency detection strategies offered by different researchers are presented in the study. This paper discusses the challenge of determining whether or not a particular sample of cash is fake or real. There are various conventional strategies and methods to detect illegal currency based on the basic features like colors, width, and serial numbers specified on the currency. As per the comparative survey analysis KNN and regression methods will give good accuracy for identifying the fake currency.

Index Terms— Fake currency, Machine learning, Demonetization, Feature Extraction, Classification models, K-NN, SVM, Image Processing, VGG 16.

I. INTRODUCTION

Counterfeiting is the systematic fabrication of real money. The rise of counterfeit cash is posing a serious risk to the global economy, affecting each country severely. In the past, visual examination had been used to identify and authenticate money, particularly currency notes. Without the use of technology, it is hard for humans to identify genuine currency from fake money. Fig 1 shows the Security features of Indian Currency. The Indian government has taken an incredible step by demonetizing 500- and 1000-rupee notes. In India, only the Reserve Bank of India (RBI) has the exclusive power to print banknotes. The RBI offers banknotes in all denominations, from Rs. 2 to Rs. 2000, as it is the country's highest currency regulator. The RBI has released a number of security features [1],[3] so that the general public may recognize fake currency, but detecting a fake note just only on appearance is difficult task. In order to achieve it there are many technologies in image processing is used. By using CNN with image processing, we can achieve the highest accuracy. Counterfeiting is an offence under the Indian Penal Code (IPC), according to the National Crime Records Bureau (NCRB), India (NCRB Compendium 2015–16). The amount of counterfeiting is increasing day by day due to technology advancement [12]. Machine

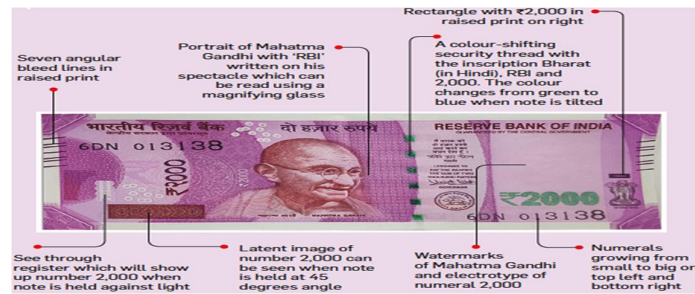


Figure 1: Security features of Indian Currency
Source: <https://rbi.org.in> (Website of Reserve Bank of India)

learning classification models provided a tremendous success in image classification tasks.

Security Features imposed by RBI [14] includes:

- 1.The Security Thread: It can be seen to the left of Mahatma Gandhi Portrait
2. Watermark: It contains Mahatma Gandhi watermark with a light and shade effect and multi direction lines in watermark window
3. Micro letting: This feature will be in between vertical line and Gandhi Portrait.
4. Latent Image: It shows the related value of denominator in numeric terms. It is visible only when the note is held horizontally at level of an eye
- 5.Identification Mark: This feature will be in different shape for different currency note and it is mainly helping the blind people to recognize the note value
- 6.Intaglio Printing; It contains Ashoka Emblem
- 7.See through the Register: With this feature number will be shown when the note is held against light.

II. CURRENCY RECOGNITION TECHNIQUES

There are many techniques had been discovered in the view of identifying the truthfulness of currency. In this study we are focusing on the Image processing and Machine learning Classification Technologies.

A. Machine Learning

Machine learning is a related field of artificial intelligence which involves the development of algorithms and the related models which help the computers to improve their performance in tasks through experience and thereby increasing the performance of the algorithm. It is based on the type of the data which is fed into the learning algorithm [15]. There are several types of ML algorithms, which are related to supervised learning, unsupervised learning, and reinforcement learning.

Supervised learning involves training the model on labelled data, and also it works with the dataset partitioned into training and testing data. It involves the Regression Models and the Classification Models and choosing the type depend on the type of labelled data and the prediction. If there is data which should be fed with the undefined labels the algorithm will not accept it. Regression Models will be implemented when the output value is numeric one and the Classification Models will be implemented when the target value has binary option and the data is classified. A some of the examples for supervised learning includes Logistic Regression, Linear Regression, K-Nearest Neighbour [2], Multiple Regression, Support Vector Machine(SVM), Naive Bayes, Decision trees etc.

Unsupervised learning involves training a model on unlabelled data and it is mainly classified into clustering and association rules. It is somewhat similar to train the model without the instructor. When the problem involves grouping of data based on the similar shared characteristics, we can use the clustering rules. Some of the examples includes Apriori, k-means, clustering, mixture models, hierarchical clustering, anomaly detection, autoencoders, deep belief net, generative adversarial networks, principal component analysis.

The most frequently used algorithm includes k-Nearest Neighbour, Support Vector Machine and Gradient Boosting.

- K-Nearest Neighbours: It uses the entire data for training and it doesn't have separate training phase for the implementation. It is mainly used for the classification. It is also known as non-parametric learning algorithm. It stores the data and classifies among it based on the similarity [13]. It classifies the given data point by looking at the closest neighbor and it measure the distance between them by using Euclidian, Manhattan etc. It is very easy to implement and flexible to handle multiple features from the dataset.

To calculate the distance between the nearest point by using Euclidian distance is:

$$dist(A, B) = \sqrt{\frac{\sum_{i=1}^m (x_i - y_i)^2}{m}}$$

where x_i is the first classified object

y_i is the nearest predicted object

While calculating the distance there maybe errors due to the noise by the device which captures the image, feature extraction may not be as efficient.

The accuracy is entirely depending on the currency dataset.

- Support Vector Classifier (SVC): It is a supervised machine learning; it is mainly used for the classification and regression problems. This algorithm classifies the data in the dataset into 2 classes based on the image extraction. Data classification can also be done based on the pattern recognition. Kernel function is used to convert linearly separable data from the nonlinear one. The accuracy is entirely depending on the combination of training set and the testing set. The algorithm works well for non linear
- Gradient Boosting Classifier: This algorithm can be used on the dataset having the combination of multiple decision trees. In this algorithm the number of training data are less and the testing time is also less.

For implementing any ML algorithms on the dataset, we need to normalize the data points so that the selected model is not depend on the particular value. To do this we need to set range for each feature between 0 and 1. The equation for normalization is

$$X_{norm} = \frac{X_{current} - X_{min}}{X_{max} - X_{min}}$$

To do it we need to import MinMaxScaler library from the Sklearn pre-processors directory.

B. Image Processing

It mainly related to the classification of image features. It involves image acquisition, pre-processing of images, Edge detection, Feature Extraction. [4,5,6]. The image acquisition will be done by camera by using suitable lighting techniques. In pre-processing of images where the images will be converted into required binary pixels based on the configuration of RGB pixel values, the first two values correspond to the height and width of the images. Here we will normalize the pixel values. The two major steps will be carried out after pre-processing they are edge detection and feature extraction [8]. Edge detection will come in the segmentation concept where we will consider the borders and edges mapping. In the feature extraction the required features like strip data, number series, image related to identification, denomination and many other features will be extracted along with number panel details [16] and it is a part of correct pattern recognition which will be then matched with the template stored in the model related to training and testing data. The feature extraction again divided into related feature selection and classification. In feature selection stage only, the important feature related to chosen model will be considered example if we have selected k-NN for detecting the currency truthfulness it will select only classification data. Fig 2 shows the Image pre- processing steps.

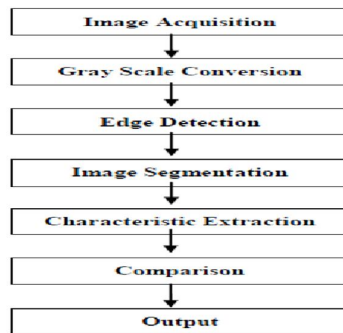


Figure 2: Image pre-processing steps

The process in turn involves three model evaluation. The data will be collected from the dataset

- (a) **Currency Classification Model:** From the front light image of the note, this model can determine the denomination, the type of note that is real or fake, the proper face orientation and its alignment.

- (b) **Water Mark Identification Model:** This model determines if the Mahatma Gandhi watermark is present on the note when the image of the currency is shadowed.
- (c) **Ultraviolet Strip Detection Model:** This model detects from an ultraviolet image of the note whether or not the note contains a fluorescent strip and, if it does, whether the strip is continuous or dashed.

C. VGG16 Model (Visual Geometry Group)

The VGG related to the concept that it has 16 layers of Deep Neural Network (VGGnet). This model is proposed by Karen Simonyan and Andrew Zisserman by 2014. This model is built to overcome some of the limitations of image processing which was mainly towards the feature selection difficulty. Because of huge number of parameters, i.e., it has 138 million parameters which is very difficult to handle. This model works fine for artificial dataset. Here Deep CNN works as a feature extractor. This model will work good for up to 550 MB of device memory [10]. Fig 3 shows the VGG16 architecture

This model works in two steps

(a) Fine Grained Image Classification: Here we use the classification strategies which are similar in both visually and semantical manner. It is very challenging task to achieve unless the dataset is fully trained.

(b) Transfer Learning: Here the CNN model will contain huge trained dataset and weights and bias related to the parameter will be tuned as per the network requirement by using back propagation techniques. As per the studies the accuracy of vgg16 for 2000 rupees is 100% but for 500 it is 60%. Importance need to be given for the security features called see through the register and this transfer learning process is suitable only for the phone with high end requirement and the dataset needs to be highly balanced.

It has 2 convolution layers initially followed by max pooling and it continues and again related 3 convolution layers followed by pooling and at last dense. layer and the data output will keep on reduce as it moves down i.e. $224 \times 224 \times 64$ and after pooling for next phase $112 \times 112 \times 128$ for layer 3 and 4 and it will continue.

To implement VGG 16 in the application we need to import keras.os and the corresponding sequential model because we are using the sequential image data. The Flatten is the process of converting all the resultant matched data into numerical one which will be used in the dense layer.

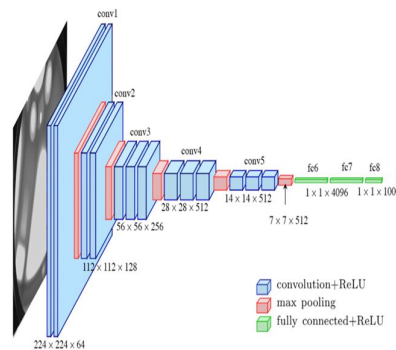


Figure 3:VGG 16 architecture

C. Counterfeit Detector Pen

Here the ink present in the pen contain the tincture of Iodine will turn black or dark blue [11], if the note is fake. Or else it will turn to yellow. The limitation includes the pen will not work if the note is starch or toed or if it contains any manuscript. Figure 4 shows the counterfeit pen.



Figure 4: counterfeit pen

III. RELATED STUDY

Many researchers have worked for the detection of currency-recognition techniques in various ways. Counterfeiting is a risk to nation economy and it affects the demography [17]. Various fake currency detection techniques related have been proposed in machine learning and image processing. It includes K-Nearest Neighbour, SVM and Gradient boosting algorithm etc. In order to detect the originality of the currency an android application [8] has also been developed. The highlights of Techniques for detection of counterfeiting involve the developments in every year with the advancement in technology.

In 2015 a researcher Jayant Kumar Nayak used technique of back propagation algorithm to check the fake currency, and came up with 90% of accuracy and it is applied on Indian currency value 5,10,20,50,100,500. In 2015 an author named Snighada Karmal used SURF Descriptor and SVM Classifier and achieved 95% of accuracy and feature extraction was based on Identification Mark and optical ink. Not considered all the security features. In 2014 author Vishnu R and Omman B used concept of pattern Recognition and by choosing color and shape detection model with respect to k-NN achieved an accuracy of 97% and it was limited to 50,100,500,1000 Rupees currency. In 2014 Alekhya D, Surya Prabha ,G.D & Durga Rao G V had discussed in their study related to the reproducing any currency with an illegal means will be considered as counterfeiting.

By using Visual Bag of words, SIFT, SURF technologies Singh et.al did research on currency recognition application which was specially designed for visually impaired Indian citizen with denomination values 10,20,50,500,1000, but excluded color, text and size of the denomination. In the year 2013 Abbas Yaseri and Sayed Mahmoud Anisheh did research on currency by considering different quantization levels and segmentation related to 150 banknotes and achieved an accuracy of 98%. By implementing the window size of an image and segmentation based on Fourier descriptor author named Subra Mukherjee achieved 90% of accuracy in detecting currency counterfeiting. In 2017 an author by name T Agasti G Buranand P.Wade and P.Chitra has mentioned in their study by name “Fake Currency detection using Image processing” and they concluded the importance of feature selection and gave importance to the Ultra Violet models. Ankush Roy had proposed study on detection of fake currency based on the security thread, Ink, Printing technique and artwork of Indian Currency by using SVM and ANN algorithms, achieved an accuracy rate of 94% limitation was related to the printing of ink and Ultraviolet radiations’ Almu and Aminu Bui Muhammad in 2017 did research on currency by implementing Visual Basic and MS Access along with image comparison and achieved an accuracy of 77%, the model was not able to detect he huge data.

The main goal of study conducted by Jadhav, Sharma and Bhandari in 2019 to distinguish between fake currency and real one. Jadhav, Sharma and Bhandari, 2019. To input the image of the note, we can use camera and by using Deep Learning methodology feature extraction will be done. In order to distinguish between the real and fake notes they used image comparison methods. They used MATLAB tool for automatic recognition of fake and real notes. In the year 2019, by using CNN, SSD and MLP techniques Zhang, Yan and Kankanhalli, did research on the fake currency detection using deep learning technologies. By using the augmentation of original dataset and adding an additional feature to it and they created a novel dataset and proper trained it with all the parameters. They used CNN, PCA and FBN methodologies for the implementation and used 300 images and the system was not able to handle more data.

By utilizing the methods of image processing and Deep learning Chowdar y.Jana and Parekh built an integrated method for recognizing the fake currency. They employed CNN,KNN techniques on the selected features. They also used G-LCM for proper color identification and feature extraction of all the denomination classes such as 10 rupees,20 rupees,50 rupees,100 rupees,200 rupees and 2000 rupees. The accuracy obtained by KNN was 91%, CNN 100%. Lavanya M and Vijaya Raghavan in the year 2019, incorporated the security threads concept of notes. They took 100 images per currency, in that 50 were captured from original dataset and 50 were augmented one, by employing Navi Bayes and Logistic Regression achieved an accuracy of 81.5%.

TABLE I. CONFUSION MATRIX

		Predicted/Classified	
		Negative	Positive
Actual	Negative	True Negative (TN _{tr})	False Positive (FP _{gt})
	Positive	False Negative (FN _{tr})	True Positive (TP _{gt})

IV. PERFORMANCE STATISTICS OF MACHINE LEARNING ALGORITHMS BASED ON ANALYSIS

Confusion matrix (CM) is used to assess all evaluation parameters that are used to measure the accuracy of a classification method. As shown in table 1.

Where True Positive =Genuine notes are classified as Real Note, False Positive= Genuine Notes are classifying as fake notes. The related percentage of fake currency that are wrongly labelled as genuine notes is determined using the False Positive Rate (FPR). The related percentage of fake currency that are wrongly labelled as fake notes is determined using the False Negative Rate (FNR).

Accuracy indicates the ability of being true.

$$A_c = \frac{TP_{gg} + TN_{ff}}{TP_{gg} + TN_{ff} + FP_{gf} + FN_{fg}}$$

Precision represents the probability of an item's relevance. Recall represents the proportion of a relevant items chosen to all relevant items available. It can be calculated by using formula Precision (Pr) and Recall (Re) are:

$$P_r = \frac{TP_{gg}}{FP_{gf} + TP_{gg}}$$

$$R_e = \frac{TP_{gg}}{FN_{fg} + TP_{gg}}$$

The dataset includes total 1372 samples, out of which 610 are real note samples and 762 of which are counterfeit note samples [18]. The data above show that KNN performs with the greatest consistency. When comparing the other two algorithms, we can note that GBC had an accuracy of 99.4% which is relatively close to the performance of k-NN, while SVM had an accuracy of 97% for 80% training data and 20% of testing data. In addition to that, it is clear that the precision values will also coincide while calculating True currency and false currency.

In addition, it can be shown from the confusion matrices that KNN just made two inaccurate predictions, compared to GBC's six and SVC's incorrect predictions of 26 samples. When we are building model related to false positive and false negative conditions, we should be very careful and avoid choosing SVM as it gives 26 wrong predictions for the collected data. Performance metrics and performance statistics are shown in table 2 and table 3 respectively.

TABLE II. PERFORMANCE MATRICES

Algorithm	Accuracy	Precision
K-NN	99.9%	99.9%
SVC	97%	99.7%
GBC	99.4%	99%

TABLE III. PERFORMANCE STATISTICS

KNN		SVC		GBC	
760	2	736	26	759	3
0	610	0	610	3	607

V. CONCLUSION

Finding the best technique to identify the currency is real or not is challenging task as the community will be using the technology is getting advanced for the researchers. Even though many algorithmic implementations have been done in machine learning, the process is completely depending on the feature extraction. As per analysis is concerned K-NN will give the best result in implementation used with image chosen image processing techniques. This paper gives a brief review of approaches and studies performed by researchers and their respective accuracy rates.

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