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An Intelligent Method for Indian Counterfeit Paper Currency Detection

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Abstract

The production of counterfeit paper currencies has become cheaper because of the advancement in the printing technologies. The circulation of counterfeit currencies down the economy of a country. By leveraging this, there is a mandate to develop an intelligent technique for the detection and classification of counterfeit currencies. The intelligent techniques play a major role in the field of Human Computer Interaction (HCI) too. This paper deals with the detection of counterfeit Indian currencies. The proposed method feature extraction is based on the characteristics of Indian paper currencies. The first order and second order statistical features are extracted initially from the input. The effective feature vectors are given to the SVM classifier unit for classification. The proposed method produced classification accuracy of 95.8%. The experimental results are compared with state-of-the methods and produced reliable results.

Keywords: Counterfeit currency, Indian paper currency, SVM, Intelligent system, Currency detection.

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Introduction

Counterfeit currency or fake currency is the major threatening factor in all the economic countries. In many cases, counterfeit currencies are more similar to the original currency notes. The usage of fake currencies leads to countries inflation and to decrease the confidence in the country currencies. In addition, the government victimizes the individual persons who innocently hold the counterfeit currencies. Individuals who generate the fake currencies earn much profits (Sarkar A et al., 2013).

Fake currencies are generated by different methods. The simplest method is to scan the original currency notes and to take printouts in the high-quality papers. Many culprits do not follow this method. It is mostly captured by the intelligent system. Usually security features are embedded in the currency notes to check the real country currency notes. The security items are such as, latent images, security threads, optically enriched ink and watermarks. Some manufactures of fake currencies also embed these types of security features. The security features will increase the cost for currency manufactures. This type of fake currency is hard to identify by intelligent systems.

Dedicated government printing presses print original Indian currencies. The raw materials, which are used in the printing, are purchased from authenticated places. Mostly the raw materials and printing machines are not transferred from one printing place to another printing place because this act will leave a trace. So, the production of counterfeit currency notes is not an easy task. However, more counterfeit currency notes are in the circulation of a country.

Automatic identification of fake currency systems finds the applications in Auto seller machines, Automated teller machines and the organizations, which handle money. The automated intelligent system is important to transfer healthy currency notes. Many methods are proposed in the area of counterfeit currency detection. Various methods are recorded for paper currency based intelligent systems rather than coins. The automated methods are mostly used with image processing techniques. The proposed method deals with Indian paper currencies.

Many researchers were tried to find out the counterfeit currencies of various countries (Takeda F et al., 2000 & 2003). Some of the researchers proposed the intelligent method to find counterfeit Indian Currencies. The features of the currency are taken for identifying the fake currency notes. Usually the features of color and size are taken. The paper currency is under circulation for many days then the color will change. So, the extraction for features is the main task of any intelligent systems.

The Indian currencies are having the security features as security thread, serial number, latent image, micro lettering, watermark, optical variable ink, identification mark. The general image processing methods of fake currency detection consists of the following stages: pre-processing, binarization, filtering, segmentation, feature extraction and intelligent technique for detection.

Euisun et al., (2006) investigated an approach for bank note classification using wavelet transform. Korean currencies of 1000, 5000 and 10000 are used in this approach (Euisun et al., 2006). Wavelet transform is used to extract the potential features. Euclidean minimum distance classifier is used to classify the currency notes. The usage of wavelet transform is much attracted to this approach. The input images are analysed in various scales and different directions. The important features are extracted from frequency transformed currency images. The currency paper reliability is studied in (Ahmadi et al., 2003). Self-Organizing Map (SOM) and Principle Component Analysis (PCA) is used to check reliability of the currency notes. Mizra et al., (2012) used three different features from banknote classification. Watermark, security thread and identification mark are considered in this paper. Edge detection and edge-based segmentation method is used to extract the features. Sharma et al., (2012) proposed a method for Indian paper currency recognition in which Local Binary Patterns (LBP) are used. Good performance is obtained from the experimental results with low noise.

Sargano A et al., (2013) investigated a new approach for recognizing Pakistani paper currencies. This approach is applied only for fresh currencies not applicable for folded and wrinkled currencies. The robust features are extracted from bank notes. The features are given into a back propagation neural network for classification. Less features are extracted from the input. So, the proposed method consumes less time for real time applications. 175 pakistani banknotes are used in this experiment. The experimental result shows 100 % recognition accuracy for non-noisy images. Support Vector Machine (SVM), Hidden Markov Model (HMM) and Artificial Neural Network (ANN) are used to classify in the intelligent system proposed by Rashid et al., (2013). Low cost embedded system is proposed to perform the real time classification task. SVM classifier performs well when compared to the HMM and ANN. This technique is experimented in smartphones.

Bangladeshi currency recognition is investigated by Debnath et al., (2009). Initially the input image is converted into RGB to gray scale image and it is compressed. The compressed image is given into a neural network. Negative Correlation Learning based neural network is used to classify the currency notes. Different types of Bangladeshi currencies are used in the experimental investigation. Accuracy of 100% is offered for non-noisy currencies.

Hasanuzzaman et al., (2011), carry out United States (US) currency recognition. This experiment is proposed to visually challenge people to recognize US dollars. Speed Up Robust Features (SURF) are used. Fixed size patches are created for each image. Each patch is checked with the database images. This experiment is conducted for 140 images which includes 20 images from each category of US dollars. Experimental results show that 100% recognition accuracy in the proposed method. Linear Discriminant Analysis (LDA) and Successive Projections Algorithms (SPA) are used to find Brazilian counterfeit bank notes (Vanessada Silva Oliveira et al., 2018). The number of variables for SPA is varied with respect to the currencies of R$ 20, R$ 50 and R$ 100. This model is completely effective for its non-destructive methodology and fastness.

Ji Woo Lee et al., (2017) reviewed banknote recognition methods by various sensors. Counterfeit banknote recognition, serial number recognition, fitness classification and banknote recognition are discussed in the review paper. Worldwide currency notes denomination, physical condition, serial number and authenticity are considered in this research paper. The challenges of bank note recognition, future directions of counterfeit currencies are also narrated in this paper.

In order to detect counterfeit currencies many image processing methods are available in the state-of-the-art literatures. Different methods used many features for the detection of counterfeit currencies. Security threads, brightness information, fluorescence information, printing and serial number are utilized in most of the methods. Luminance histogram and YIQ color space are used in (Bhavani, R et al., 2014) for brightness information. X Ray fluorescence and UV patterns are used as fluorescence characteristics (Roy, A et al., 2015, Rusanov, V et al., 2009). Tie point detection is used as serial number characteristics (Huber-Mörk, R et al., 2007). Infrared features are also utilized for the methods of counterfeit currency detection (Mahajan, S et al., 2014).

Recently, graph based fraud detection has been studied in the literature. The fraud detection is mostly connected with different types of social networks such as websites, banking sectors, insurance networks, e-commerce etc., (West, J., et al., 2016, Bhattacharjee S.D et al., 2017, Pourhabibi T et al., 2020). The graph based anomaly detection is vastly leveraged in these networks. Deep learning based fake Indian currency detection is encountered recently (Zhang, Q et al., 2019). Faster RCNN is used to recognize the counterfeit currencies (Bhavsar, K et al., 2020)

The following countries counterfeit currencies are detected by various methods: United States (USD), Euro (EUR), India (INR), Switzerland (CHF), Nepal (NPR). Kuwait (KWD), Malaysia (MYR), China (CNY), United Kingdom (GBP), South Korea (KRW). By analysing all the methods, many studies are done for Indian currencies (Ji Woo Lee et al., 2017). Secondly Euro and US currencies are analysed by many researchers. The fake currency detection is applied after the process of banknote recognition step. The denomination of the input is the paramount data to the intelligent system. Each country's currencies are different from one another. So, the intelligent system is ensured with the type of input.

In this paper, Indian counterfeit currencies are detected by intelligent techniques. Indian currencies are called as Rupees which are mentioned throughout the paper. The higher value paper currencies of Rupees 100, Rupees 500 and Rupees 2000 are used in this experiment. The rest of the paper is formulated as follows: Section 2 describes in detail about proposed methodology, section 3 shows the experimental results with comparative analysis and the last section concludes the research paper with future directions.

Proposed Methodology

The proposed method for Indian counterfeit currency detection consists of database collection, pre-processing stage, feature extraction, classification and detection stages. The overview of the proposed methodology is given in figure 1.

Pre-processing

Pre-processing step is the important step to improve the performance of the classification task. This step is a paramount step because it removes the noises, which are presented in the input. The currencies are circulated, so they are torn, worn and noisy. Added noises are removed by the pre-processing step and to improve the quality of the input. Gaussian filter, median filter and wiener filter are generally used as processing filters. In this proposed method, wiener filter is used as a pre-processing filter. It conserves the details of the edges and is useful to clean the banknotes.

Feature Extraction

Feature Extraction plays a paramount role in an intelligent system. The success of any system relies on the effective feature extraction phase. The proposed method also has a proper feature extraction step. If the scale of the input image is so high, then it is mandated to reduce the dimension and scale of the input. So, the inputs are transferred into reduced representation in the form of feature vectors.

The optimal set of features which are representing the whole input image efficiently. It also requires less processing time with more discriminative power. Such features are carefully extracted through the feature extraction phase. The features, which are used in the proposed method, are to efficiently detect the counterfeit Indian currencies. Such features are only adopted in this approach. It consists of structural, statistical and textural features. Aspect ratio, color are the structural features. Aspect Ratio of Indian currencies are given in table 1.

The pre-processed RGB image is converted into YIQ color space. In this, color space Y denotes luminance information and where as I and Q denotes the information about chrominance. The relationship between RGB and YIQ color space is given in (Russ J.C., 2006). Y Component provides better information compared to the other components of the YIQ color space. The luminance histogram is also found with respect to the pixels. Each histogram comprises 256 bins. The paper currency image which is represented by 256 bin histograms may reduce the discrimination power.

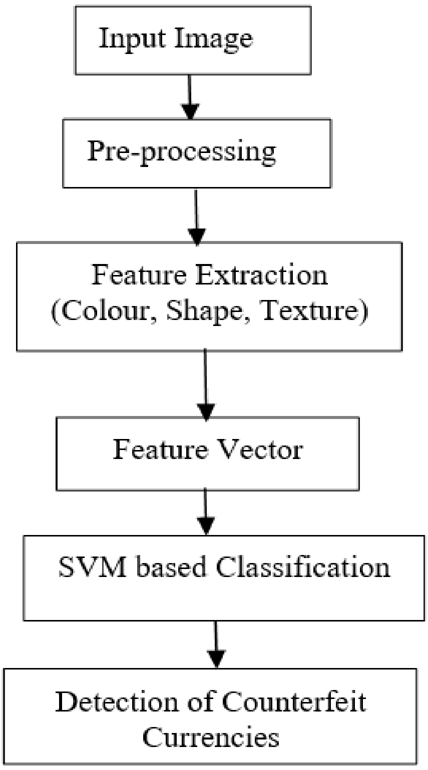

Figure1: Overview of proposed Counterfeit currency Detection

If the light is passed through the paper currency, some part of light is reflected and some part of the light is refracted by the paper currency. Equation 1 shows the refraction process.

$$l = l_1(1 - \gamma)e^{-ad} \quad (1)$$

Where l is the intensity of refracted light, l_1 is the intensity of incident light, γ is the reflection coefficient, a is the absorption of currency and d is the thickness of medium (Sun, B et al 2008). The value of an image pixel is related with the basic characteristics of a currency image. It includes reflection, refraction and absorption. So, the statistical features of an image are also considered to represent the input image.

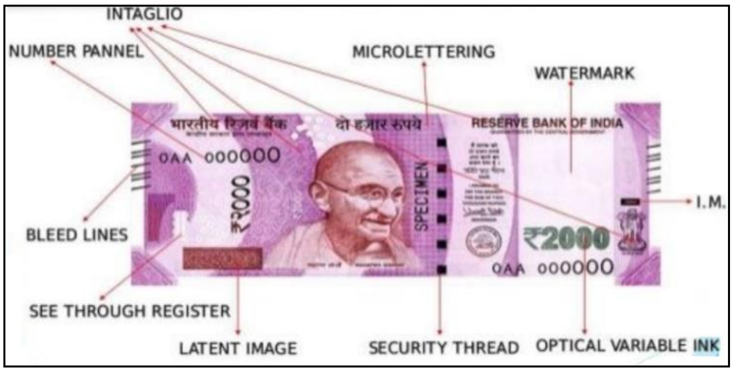

Figure 2. Security Features of original INR 2000

The Indian paper currencies have unique security features which are merged in the currency. It mainly used to differentiate the counterfeit currencies. To enhance this property with the feature extraction step, image derivatives are calculated. Initially the input images are separated into four blocks with respect to the length and width.

Table 1. Aspect Ratio of Indian Paper Currencies

Sl.No	Denomination	Aspect Ratio
1	50	0.496598
2	100	0.464968
3	200	0.452054
4	2000	0.397590

The first derivatives of the input image blocks are represented by $B_i(i,j), B_j(i,j)$. The security features such as letter and flag are existing in the original currencies and which are not there in counterfeit currencies. After finding the first derivative (equation 2) the embedded features appear but for the fake currencies which are not there. Mean, variance, covariance are the statistical features used in the proposed method.

$$\nabla B(i,j) = \begin{cases} B_i(i,j) = \dfrac{\partial B(i,j)}{\partial i} \\ B_j(i,j) = \dfrac{\partial B(i,j)}{\partial j} \end{cases} \tag{2}$$

The average of each block is calculated by the equation (3). It highlights the thickness and embedded colors of the paper currency. Each block minimum value is calculated by the equation (4). It is found from the derivative of the image. This statistical feature represents printing ink of the currency.

$$Average(A) = \frac{1}{mn}\sum_{x=1}^{m}\sum_{y=1}^{n} B(x,y) \quad (3)$$

$$minimum\ value = \frac{1}{n}\sum_{x=1}^{m} minimun\left(B(i,x)\right) \quad (4)$$

Each block maximum value is calculated by the equation (5). It is found from the derivative of the image. This statistical feature represents the texture and thickness of the currency. Variance is the one of the vibrant statistical features. It is calculated between the squared difference of the arithmetic mean and mean of each block of derivative image. Variance reflects the level of roughness in the currency. If the variance value is greater than the input has higher roughness.

$$maximum\ value = \frac{1}{n}\sum_{x=1}^{m} maximum\left(B(x,i)\right) \quad (5)$$

$$Variance = \frac{1}{n}\sum_{x=1}^{m} B_i(x_i - A^2) \quad (6)$$

The amount of changes of the two images is represented by a covariance feature. It is calculated by equation 7.

$$Covariance = \frac{Cov(B_i, B_j)}{\sigma_i \sigma_j} \quad (7)$$

The textural features are one of the important features to describe inputs. Texture roughness features are used in this proposed method through Gray Level Co-Occurrence Matrix (GLCM). It is basically calculated from the changes of horizontal and vertical directions. The second order statistics are used for texture analysis. The co-occurrence matrix is constructed with respect to the distance measured between two pixels and the relative orientation between pixels. GLCM matrix describes how the two pixels with gray levels (G_1, G_2) are configured with respect to the distance and orientation. Energy, correlation, entropy, homogeneity and contrast are calculated under texture feature extraction (Khin Nyein Nyein Hlaing, 2015).

The smoothness of an image is measured by energy. Lesser smoother image is uniformly distributed. Correlation reflects the relationship between two pixels. μ_1, μ_2 are mean and σ_1,σ_2 are the standard deviations of $P(G_1, G_2)$. Randomness of the image is calculated by entropy, which has low values for smooth images. Homogeneity shows high values for less contrast images. Local variations are determined by contrast which score high values for high contrast images. These statistical features are used to analyse the difference between two types of images.

$$Energy = \sum_{G_1,G_2} P(G_1, G_2)^2 \tag{8}$$

$$Correlation = \sum_{G_1,G_2} \frac{(G_1 - \mu_1)(G_2 - \mu_2)P(G_1, G_2)}{\sigma_1 \sigma_2} \tag{9}$$

$$Entropy = \sum_{G_1,G_2} P(G_1, G_2) \log P(G_1, G_2) \tag{10}$$

$$Homogeneity = \sum_{G_1,G_2} \frac{P(G_1, G_2)}{1 + |G_1 - G_2|^2} \tag{11}$$

$$Contrast = \sum_{G_1,G_2} (G_1 - G_2)^2 P(G_1, G_2) \tag{12}$$

All the features are extracted for the input dataset and feature vector is generated. The feature vector is given as input to the SVM classifier which classifies as original currency and counterfeit currency.

SVM based Classification

Counterfeit currency detection has been done through various neural network classifiers. SVM is one of the classifiers which are used effectively for various image processing applications such as segmentation, scene understanding, classification (Andrushia et al., 2015, 2019). In the proposed method, SVM is used for counterfeit currency detection. Table 2 shows the parameters which are used for the SVM based classification. Input dataset is divided into training and testing dataset. 80 % of input data is used for training and 20% of the input is used for testing purposes.

Table 2: Parameter setting for SVM classifier

Parameters	Quantity
Denomination of INR	100, 500, 2000
Number of original paper currencies	100
Number of counterfeit paper currencies	20
Activation function	Sigmoid, Gaussian

Experimental Results

In this section, the performance of the proposed method is experimented and compared with state-of-the-art methods. 120 Indian currencies are used for this experiment. INR 100, INR 500 and INR 2000 are used for the classification of original and counterfeit. 100 number of original currencies and 20 counterfeit currencies are used in the experimental work. This experiment is conducted on the personal computer with MATLAB 2013 software. The input dataset is collected from the internet.

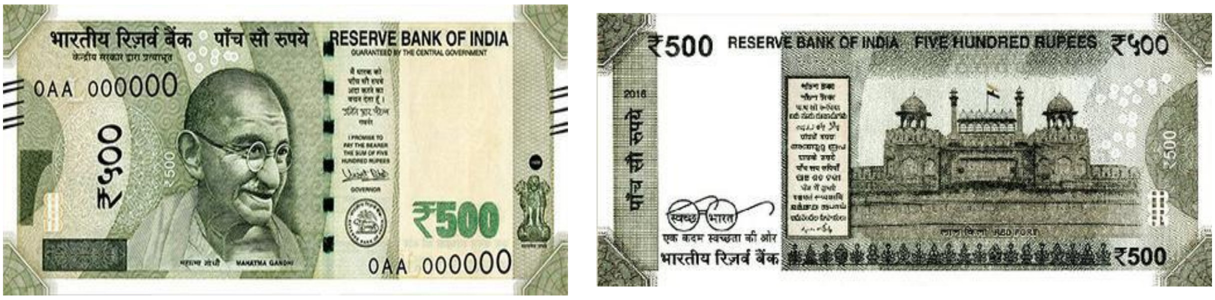

Figure 3: INR 500 paper currency front side and back side

To check the performance of the proposed method, classification accuracy metric is calculated. 120 input images on which 100 original currencies and 20 counterfeit currencies are taken. The input dataset consists of the dirty, worn and torn images. Wrong classification currencies are from the torn and worn category. Classification Accuracy is calculated by the equation (13)

$$Classification\ Accuracy = \frac{Number\ of\ \ correctly\ classificed\ currencies}{Number\ of\ total\ datasets} \tag{13}$$

Figure 4. INR 2000 paper currency front side and back side

Figure 3 and 4 shows the INR 500 and INR 2000 currencies images. Figure 5 shows the pre-processed currency images. Figure 6 reflects a sample counterfeit INR 500 paper currency.

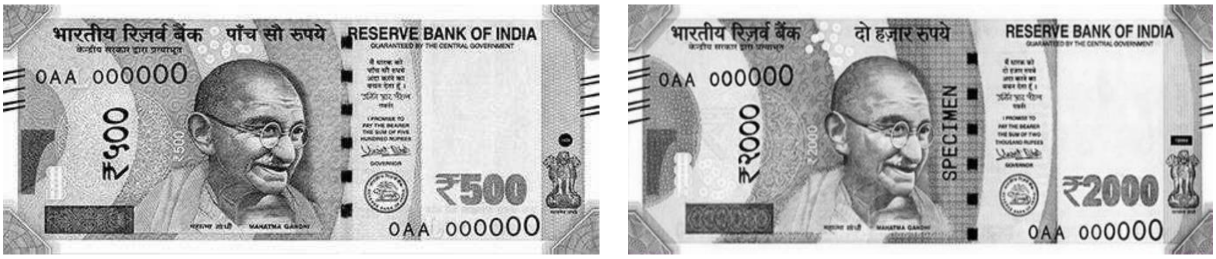

Figure 5. Pre-processed Currency images

Figure 6. Counterfeit INR 500 Currency

Table 3. Classification results of the proposed method

Types of Rupees	Original/ Counterfeit	Number of paper currencies	Number of paper currencies checked correctly
100	Original	30	30
100	Counterfeit	10	9
500	Original	50	48
500	Counterfeit	5	4
2000	Original	20	20
2000	Counterfeit	5	4
	Total	120	115

The classification accuracy of the proposed method is 95.8%. The detailed identification of currencies in each denomination is given in the table 3. The intelligent technique for counterfeit currency detection has achieved high accuracy values. The original currencies are classified correctly compared to the counterfeit currency. Several state-of-the art methods which are related to the counterfeit currency detection are available in (Kang K et al., 2016, Lim H et al., 2017, Khin Nyein 2015). The proposed method (P) is compared with the state-of-the-art-methods of M1 (Sangwook Baek et al., 2016) and M2 (Kang K et al., 2016).

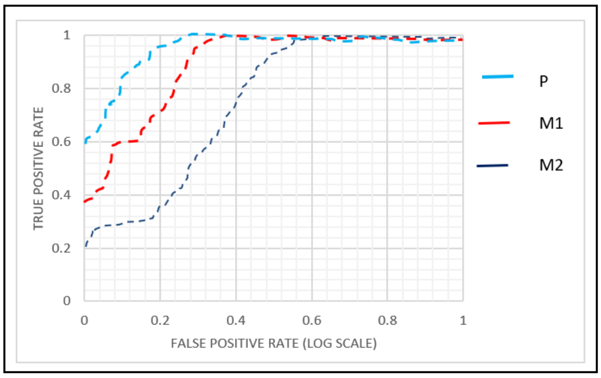

Figure 7. ROC based Performance Comparison.

The performance of the proposed method is compared with the performance metrics of Receiver Operating Characteristic (ROC). Figure 7 shows the ROC of the proposed and state-of-the art methods. The proposed method produced reliable results compared to the other methods.

Conclusion

This paper proposed an intelligent method for identifying counterfeit Indian currencies. It is based on the robust features of Indian paper currencies. The input features are selected from the characteristics of currencies. All the features are extractable from the input image. Paper currencies based first order and second order statistical features used for the identification of counterfeit currencies. Effective feature vectors are given to SVM classifiers to detect the original and fake currencies. INR 100, INR 500 and INR 2000 are used for this experiment. 95.8% classification accuracy is achieved for the proposed method. The experimental results are compared to the state-of-the methods and produced reliable results. The proposed method can be implemented for real world applications by incorporating more number of features in the extraction phase.

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