Counterfeit currency detection techniques

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Abstract - **The currency which is imitated with illegal sanction of state and government is counterfeit currency. Every country incorporates a number of security features for its currency security. Currency counterfeiting is always been a challenging term for financial system of any country. The problem of counterfeiting majorly affects the economical as well as financial growth of a country. In view of the problem various studies about counterfeit detection has been conducted using various techniques and variety of tools. This paper focuses on the researches and studies that have been conducted by various researchers. The paper highlighted the methodologies used and the particular characteristics features considered for counterfeit money detection.**

Keywords— counterfeit, currency, rupee, Indian currency, security features, counterfeit detection techniques, image processing, machine learning.

I. ORGANIZATION OF PAPER

The paper is organized into six sections including organization of paper. Section II gives the introduction of counterfeited currency. In section III general security features of currency is described. The next section deals with Indian currency security features specially for denomination values of 50, 100, 500, 2000 rupee notes. Further sections deals with studies conducted and techniques proposed by various researchers. At last the paper is concluded along with the future studies that can be performed to authenticate the Indian currency.

II. INTRODUCTION

Currency counterfeiting is an ever since a continuous race between the certifier like bank and counterfeiters. All currency contain some security features for its security and also to prevent counterfeiting of currency[3]. Generally, every currency includes intaglio printing, watermark, denomination marks, mark for blinds etc. Other than these features there is a unique feature of every currency which is provided for best security e.g. Indian currency has anti photocopying feature, European Euro has perforation, US dollar has 3D security ribbon and bell in ink and many more[4-7][21]. Many researches and studies have been performed in terms of providing best technique for currency counterfeit detection and authentication. The techniques proposed were composed of different areas of machine learning and image processing. To detect counterfeit currency first line inspection or second line inspection is required. In first line inspection a forged currency can be determined through naked eye e.g. intaglio printing, microtext, varied density watermark etc. on the other side, in second line inspection extra device for authenticity of currency is required e.g. fibre optics light transmission through a paper currency, colour and feature analysis etc.

III. CURRENCY SECURITY FEATURES

See Through Register: It is a small sized denominational value or a design printed on both sides of the note with back to back registration.

Intaglio Printing: Also known as Raised printing provides distinctive looks to the currency and also protects from counterfeiting. The printing process comprises of image printing which is distinctive by rich colors and prudent composition.

Latent Image: It is also consisted of denominational value but normally it seems to be a particular design and when tilted at a particular angle (normally 45 degree) at eye level the denominational value is viewed [2].

Microprinting: Little tiny design or letter printed in the base of any currency note. The micro printing can be visible with the help of magnifying instrument. The tiny letters carved in bank notes are also known as Microlettering.

Security Threads: Security threads are a thin erected strip of plastic or metal foil engraved with some text carved on it [4].

Security Inks: The type of security ink is opted differently by different countries. These inks perform security functions meant to target different types of users and authentication for example eyesight and touch authentication, machine assisted authentication and detection, authentication by color shift property.

Denomination color, size, mark and value: To distinguish one denomination from other different colors, size, marks like circle, rectangle etc. and value in particular language is carved over the currency [8] [10]. Denomination mark also helps the blinds in identifying a particular value currency through finger touch.

Watermark: To protect the currency from counterfeiting one of the authenticated and well-grounded features is watermark. Watermarks can be multi-tonal, digital, electrotype, pixel, vision etc. Watermark images can be built by fabricating variation in paper thickness[11][16][18].

Hologram: Holograms looks like three dimensional photograph having shiny metallic, glass or plastic design in which images are levitating inside. Since these are hard to reproduce and counterfeited hence many countries prefer to incorporate the feature in their currency.

Ultra violet and Infra-red test: UV fluorescent material and infra-red sensing features are erected in banknotes of different countries. The feature is not necessarily presented in every country's currency. UV and Infra-red counterfeit are used to detect special type of ink, numeral and image etc. These features are visible under specific wavelength of ultra violet and infra-red.

Serial Numbers: For record keeping as well as for security purposes each banknote has unique serial number. The pattern of serial number is consisted of alphabets and numerals, printed at the obverse and reverse side of banknotes. Some serial numbers are also written vertically along the banknote length or horizontally. The serial numbers are also written with special inks and could be in zooming, conical designs.

Paper Material: Usually most of the banknotes are made of cotton or cellulose natural material. This cotton is mixed with other textile fibres, linen etc to provide extra strength against the counterfeiting. The banknote is imbued with agents like alcohol, gelatin, polyvinyl for robustness against normal printing and writing papers.

There are several other security features opted by different countries for the security of their currency. These features can be Infra-red glowing, motion thread, holographic portrait and many more.

IV. INDIAN BANKNOTE SECURITY FEATURES

After demonetization in the year 2016 the higher denomination new notes i.e. 500 and 2000 with some extra security features were introduced by Indian government. India produces its currency with denomination value 2, 5, 10, 20, 50, 100, 500, 1000 (till 2016), 2000 (from 2016). Demonetization caused the 1000 rupee notes plucked out from the circulation and making highest denomination currency as 2000. One of the objective of demonetization and releasing of new currency notes of 500 and 2000 is to control the counterfeiting. As proposed by RBI, 50 and 200 rupee new notes will be soon released and of different features and looks. Moreover, old 50 notes will remain the legal tender whereas it is not the same case for old 500 rupee notes, as per RBI's declaration.

The security features are incorporated in each of the denomination value. All Indian banknotes are known to be as the Mahatma Gandhi series. The MG series 2005 introduced the concept of bleed lines different for different currency value. These bleed lines is also one of the identification mark for blinds to detect the denomination value. Along with bleed lines zooming number panel is also one of the feature of this series. The size of the numbers in number panel grew in ascending order. The new 500 rupee notes have inset ‚L' and ‚E' whereas for 2000 rupee note it is ‚R'. The material used for the banknotes is a slush of cotton, balsam blended with

textile fibre and having special dyes. To give more strength to the banknote paper it is infused with gelatin. All the banknotes consist of see through register, raised printing or intaglio printing, color shift security thread and denominational value, identification mark, electrotype watermark, latent image of denominational value, micro lettering and special security ink for number panel which can be tested under Ultra violet test [21]. One of the special features of Indian currency is Anti-photocopying feature Omron, This feature prevents from imitation of all security features of a banknote. Every counterfeited note is inefficient to imitate all the security features of the banknote.

The table illustrates the features of Indian banknotes with denomination values 50, 100, 500 and 2000. The features of banknote 500 and 2000 are shown for new notes whereas for 50 and 100, older banknotes were considered. From table one can easily depict the differentiating features of each denomination value. The table also helps in gathering a fair idea about different features of different denomination value.

TABLE I. DENOMINATION WISE INDIAN CURRENCY FEATURES.

Features/ Denomination (Rs.)	50	100	500	2000
See through register with denominational numeral	√	√	√	√
Mahatma Gandhi portrait and electrotype watermark	√	√	√	√
Zooming Number Panel	x	√	√	√
Fluorescence security ink in Number panel	√	√	√	√
Security thread inscription with Bharat and RBI	√	√	√	√
Security thread with color shift	Fluorescence yellow under ultra violet	Green to blue, fluorescence yellow on reverse side under ultraviolet	Green to blue	Green to blue
Intaglio printing/Raised printing	Portrait of Mahatma Gandhi Reserve bank seal Guarantee and promise clause	Portrait of Mahatma Gandhi Reserve bank seal Guarantee and promise clause	Circle at right on obverse side and 5 bleed lines in 3 blocks on both left and	Horizontal rectangle at right on obverse side and 7 angular bleed lines on both

			right side, identification mark	left and right side, identification mark
	Ashoka Pillar emblem on left, RBI Governor's signatures, identification mark	Ashoka Pillar emblem on left, RBI Governor's signatures, 4 bleed lines in 2 blocks on both left and right side, identification mark		
Denominational Numeral with color shift	√	√	√	√
Denominational value written in Devnagari	x	x	√	√
Introduced in year	Mahatma Gandhi Series November 1975	Mahatma Gandhi Series November 2005	Mahatma Gandhi Series November 2016	Mahatma Gandhi Series November 2016
Size of banknote	147 × 73 mm	157 × 73 mm	150× 63 mm	166×66 mm
Color	Pink-Violet	Blue-green	Stone grey	Magenta
Latent Image of denominational value	√	√	√	√
Micro lettering	√	√	√	√
Identification mark	Square	Triangle	Circle	Rectangle
Year of printing	Reverse side	Reverse side	Obverse side	Obverse side

V. Counterfeit Currency Techniques

Cases of counterfeit currency are caused by cash transaction. In India, for detection of fake notes RBI has also passed a mandate for keeping a Note sorting machine at all currency chest branches of banks. Various studies have been proposed in terms of detection of counterfeit currency. Some techniques are related to the areas of Image processing and some are related to machine learning techniques. The literature survey studies some of the techniques proposed by various authors in both the mentioned areas, based on particular country's' currency and their different denomination values.

The table depicts the related studies performed in the areas of image processing and machine learning from 2009 to 2017. The table also shows the clear description of characteristics or features over which the techniques were proposed.

TABLE II. RELATED STUDIES FOR COUNTERFEIT DETECTION.

Technique	Characteristics	Currency	Authors	Year
Image based segmentation based on template matching	Latent Image, Denomination value, Intaglio printing, identification mark, see through register, satyamev jayate logo, RBI logo and Reserve Bank of India.	India: Rupees 100, 500, 1000	Rajebhosale Sagar S. et.al.	2017
SLIC Algorithm	Template comparison based on RGB values	India: Rupees (new notes) 500, 2000	Sneha R. et.al.	2017
Pattern Recognition and Neural network technique based on ROI and HSV	Security thread	India: Rupees 500	Pilania E., Arora B.	2016
Sobel Operator	Currency barcode and serial No.	India: Rupee 500, 1000	Atchaya S. et.al.	2016
Edge Detection, NI-IMAQ and ROI	Matching of Mean Values and standard deviation value of fake and genuine currency	India: Rupee 100	Antoney A. et. al.	2016
canny edge detection	Bit-planes of the original images (0-7)	Kuwait: Dinar 20	Alshayeji H et.al.	2015
Fourier Descriptor Artificial Neural Network	Identification Mark (I.D mark)	India: Rupees 20, 50, 100, 500 and 1000.	Mukherjee S. et. al.	2015
Bi-clustering SVM and ANN	Ink, Thread, Art-work, Printing technique	India: Rupees 500	Roy A et. al.	2015
Canny edge detection	GUI based Optically Variable Device Patch	Phillipine: Peso 500 and 1000	Ballado et.al.	2015
SIFT technique	See Through register, Identification mark, Security thread, Governer's signature, Microlettering, year of print	India: Rupee, 100, 500, 1000	Kavya B R, Devendran B	2015
Feature extraction and comparing black pixels with white pixels	Identification mark, security thread , watermark ,numeral watermark, floral design and micro-lettering	India: Rupee, 100	Prasanthi B.S , Setty D.R	2015
Color parameter using Skew,	Colour and texture feature	Nepal: Indian Rupee500	Lamsal S, Shakya A	2015

Technique/Method	Features	Currency	Author	Year
mean and Standard deviation value Texture parameter using entropy and correlation				
Multi Class Classifier, Support Vector Machine (SVM) classifiers, SURF descriptor for feature extraction	central numeral, Ashoka Pillar emblem, colour band and identification mark	India: Rupee, 50, 100, 500, 1000	Snigdha Kamal S. et.al.	2015
OCR (Optical Character recognition), Contour Analysis, Face Recognition, Speeded UP Robust Features (SURF) and Canny Edge & Hough transformation algorithm	micro-printing, optically variable ink (OVI), water-mark, iridescent ink, security thread and ultraviolet lines	Bangladesh: Taka 100, 500, 1000	Ahmed Z. et.al.	2014
LDA method on Edge Histogram Descriptor based on inter class and intra class classification	Canny Edge detection and Inter-class and Intra-class distance calculation of noisy images	Bangladesh: Taka 100, 500	Rahman S. et.al.	2014
Canny edge detection	Watermark	Pakistan: Pakistani Rupee 100	Muhammad A. et.al.	2013
Ultra Violet (UV) detection using NI-IMAQ and polarization of light, Spin coating and Ellipsometric analysis and holographic detection	Dye, Cotton material used in currency and Hologram	India: Rupees 100	Santhanam K. et.al.	2013
Sobel operator with gradient magnitude	Identification mark, Security Thread and Watermark	India: Rupees 100, 500 and 1000.	Mirza R., Nanda V.	2012
Principal Component Analysis (PCA), linear vector quantization	Direction of rotation of bill	US: Dollar 1, 5, 10, 20, 50, 100	Yoshioka et. al.	2009
(LVQ) network, hidden Markov models (HMMs)				

VI. CONCLUSION AND FUTURE SCOPE

From past few years technological advancements in terms of printing, scanning etc. technologies imitation of currency has become a serious problem. Hence there is a need for a robust system that can accurately classify the fake notes from genuine ones. This paper is an effort to suggest various techniques proposed by various researchers in terms of considering particular characteristics or feature extraction from denomination values of particular country's currency. Most of the techniques or system design proposed by various researchers is from the application areas of Image processing and machine learning. Periodical up-gradation of currency's features need periodical up-gradation of proposed techniques or proposing new techniques or methodologies. The design of techniques can be extended by considering data mining prediction techniques like map reduce or generating a android based system design which could provide a solution for this complex issue. The need of robust technology is still an essential need hence proposing a technique/methodology/system in this direction will help the country to face the financial and economical challenge caused by counterfeited currency.

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