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A Survey on Counterfeit Paper Currency Recognition and Detection

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ABSTRACT
This surveys paper reports various articles dealing with counterfeit paper currency recognition and detection systems. This paper attempts to represent the survey on fake money detection because almost every country in the world is facing the problem of forged money, but in India, the problem is exasperating as the country is hit hard by this evil practices. Counterfeit notes of Rs.100, 500 and 1000 are being spread all over the world that's why it is important to detect such fake notes which are flooded in system. So in this paper we are going to represent survey on methods for fake note detection. Automatic methods for bank note recognition are required in many applications such as automatic selling-goods and vending machines. In the past, only the printing house was able to make counterfeit paper currency, but today it is possible for any person to print counterfeit banknotes simply by using a computer and a laser printer at home. Therefore, the issue of efficiently distinguishing counterfeit banknotes from genuine ones via automatic machines has become more and more important.

Keywords- Counterfeit Detection, Image Processing, Neural Network (NN), Support Vector Machine Embedded System, Pattern Recognition, Microcontroller.

I. INTRODUCTION

It is an important task to classify the paper currencies at banks or large shops quickly and correctly. So far, many different approaches have been proposed to solve the problem of paper currency recognition and verification. Automatic fake note inspection system is a best comparator to human vision inspection. Including computer technology, image processing and pattern recognition, Embedded System, NN, SVM, all these systems can provide reliable, objective and smooth performance on fake note detection. In this paper, we see different methods which promote compactness, high speed transaction, and low cost of paper currency recognition of neural technologies.

Recently, the problem of fake paper currency recognition is dealing very effectively by using neural networks. In comparison with conventional manual method based on discriminative inequalities, neural methods have shown its effectiveness. Over the past few years, as a result of the great technological advances in color printing, duplicating, and scanning, fake money are spread in system largely and Problems have become more and more serious.

II. SURVEY

We are going to evaluate the different Currency Recognition and Verification methods used for currency detection with their advantages and accuracy compare to others. This classification details about the name of publication, author, technique used, problem overcomes with advantages and other methods. It also shows the future scope for existing methods.

Fukumi, M., Omatu, S., Takeda, F, Kosaka, T. invented a pattern recognition system [1] which is not sensitive to the rotation of the input pattern by various degrees. In his paper, rotation invariant neural pattern he designed recognition system with application to coin recognition. This system consists of many slabs and a trainable multilayered network. In 1992, Fukumi M, Omatu S., Takeda F., Kosaka T. proposed research a more effective method to his previous system [2].

For coin recognition, Fukumi M., Omatu S. presented a new method with 100% recognition accuracy and network with small in size [3]. He was designed a Neural network for coin recognition by a genetic algorithm in 1993. Here, GA only specifies the network which cannot be trained so the network while back-propagation algorithm (BPA) is used to train the network. This method is very effective to the variably rotated coin recognition problem. Recognition system of US dollars using a neural network (NN) with random masks is proposed by F. Takeda and S. Omatu with NN and random mask [4] who solved the problem

of same slab values (sum of input pixels) which may be obtained for the different inputs.

Paper currency recognition method [5] by Fumiaki Takeda, Sigeru Omatu, Saizo Onami, Takashi Kadono, and Kengo Terada used structure reduction i.e. small size NN for neuro-recognition method with masks and GA for commercialization of NN. With the use of this new technique, they confirmed that effective masks could be generated. This paper overcome the demerit by the number of the Gaussian components selected artificially which is proposed by Fan-Hui Kong, Ji-Quan Ma, Jia Feng liu [5]. Method is more flexible and important to classify the paper currency at banks quickly and correctly. Using proper number of Gaussian components for GMM classifier, the reliability of system is increased effectively. Zarandy, A., Werblin,, F., Roska T., Chua L.O. proposed a new type of algorithm for bank note recognition. In his paper, Novel types of analogic cellular nonlinear/neural networks (CNN) algorithms for recognizing bank-notes [6]. This is used to avoid the counterfeiting on color copiers with less time and power.

In 1994, Fumiaki Takeda and Sigeru Omatu invented a new method of recognition and detection by genetic algorithm (GA) to a neuro-paper currency recognition using optimizes masks [7]. They have proved that the GA is effective for systematizing the neuro-paper currency recognition with optimized masks. Also they solved the problem occurred in his paper [5] i.e. every time they cannot get excellent mask for input images. Fumiaki Takeda and Sigeru Omatu [8] were proposed the recognition ability and the transaction speed to classify the Japanese and U.S. paper currency to reduce the input scale of the NN. This one is a low cast currency recognition method. Fumiaki Takeda and Sigeru Omatu suggested a new technique to improve recognition ability and the transaction speed to classify the Japanese and U.S. paper currency. This technique is used to reduce the input scale of the NN without preventing the growth of recognition [9] with high speed transaction and low cost of paper currency recognition machines.

Neural network-based recognition and verification techniques is [10] proposed by Angelo Frosini, Marco Gori and Paolo Priami. The experimental results are very interesting, particularly when considering that the recognition and verification steps are based on low-cost sensors for paper currencies of different countries.

Hybrid neural network method [11] used by M. Tanaka, F. Takeda, K. Ohkouchi and y. Michiyuki have the classification success as less than 90% and learning is very easy. In this paper, unknown patterns can be distinguished from the known patterns. Using NN recognition method with symmetrical masks optimized by GA. Takeda F., Nishikage T., and Matsumoto Y. [12] is a characteristic extraction method for paper currency. This method used a unique mask which has a symmetrical masked area against an axis which divides a long side of the currency equally.

Multiple kinds of paper currency recognition [13] proposed by Fumiaki Takeda and Toshihiro Nishikage is enhanced neuro-recognition system for increasing the more number of recognition patterns using axis-symmetrical mask and two image sensors. Siewert I., Murray T. Dias introduced the new system for Australian currency recognition [14] which is used to increase the overall quality and longevity of the huge number of notes.

Neuro–classification by using principal Components Analysis (PCA) algorithm is used for paper currency by Ali Ahmadi, Sigeru Omatu, Michifumi, and Yoshioka [15]. This method is used to increasing the reliability of paper currency recognition machines which shows that reliability is increased up to 95% when the number of PCA components as well as number of Learning Vector Quantization (LVQ) codebooks are taken properly. Also classification rate of system is 100% for sample testing data. For training the system 3,570 sample of data from 40 different classes is used. Table 1 show the result of classification before and after application of PCA.

TABLE-1:
The Results of Classification Before & After PCA [15]

		recognition rate %	reliability %
No of codebook 120	Original data (180 components)	100	50.1
	Principal component (30)	100	82.6
No of codebook 400	Original data (180 components)	100	61.3
	Principal component (30)	100	95.4

E. H. Zhang, BoJjiang J. H. Duan, Z. Z. Bian presented a method named Paper currency recognition by neural networks [16]. The system is simple, speedy, represents characters of original image and robust to different kinds of RENMINGBI (RMB). In this paper, the problem of how to extract high qualified monetary characteristic vectors from currency image is solved. This method is conformed the results by experiments

and computer simulation. System has the recognition rate of 100%. New advance method as compared to the method proposed in 2002 was neuro–classification using PCA algorithm, is used for paper currency by Ali Ahmadi, Sigeru Omatu, Michifumi, and Yoshioka [18]. This method is used to increase the reliability of paper currency recognition machines up to 100% compare to old method having reliability of 95%. In this method, PCA is applied the remove nonlinear dependencies among variables and extract the main principal features of data. The method can be easily generalized for other kinds of paper currency and considered as a multi-currency classifier with wide variety of data. Table 2 shows test result.

Ali Ahmadi, Sigeru Omatu, Toshihisa Kosaka [19] evaluated and improved the reliability in paper currency neuro-classifiers with reliability increased up to 100%. In this method, local PCA is used for feature extraction. For reliability evaluation method, they used more adequate than what they have applied in their previous work [18].

TABLE-2:
Test Results [18]

RMB	Recognition Ratio of Training Set	Recognition Ratio of Test Set
New Printing style of 100	100%	95%
New Printing style of 50	100%	99%
New Printing style of 50	100%	99%
New Printing style of 10	100%	98%

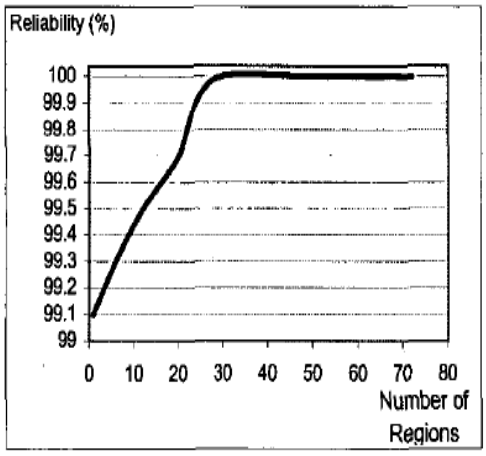

Fig-1: The relation between the system reliability and number of regions in local PCA. [19]

Anti-money laundering based on support vector machine SVM [20] developed by Jun tang, Jian yin used statistical learning theory (SLT). It is presented an unusual customer behavior detection method using SVM. This algorithm has a good performance in detecting unknown money laundering method is simple, rapid and it can be used in real world system. Wanmei soon and Heng-Qing ye [21] introduce a binary integer programming model. In this method binary integer programming model can be updated quickly to detect new arbitrage opportunities, if there is quick exchange in currency i.e. when exchange rates (given as a pair consisting of a bid price and ask price) changes in real-time. This method is efficient and easy to implement. Coin recognition using neural pattern analysis [22] is proposed by R. Bremananth, B. Balaji, M. Sankari and A. Chitra in 2005. They developed a new system for coin recognition USING statistical color threshold method. Using that system authors extracted numerals rather than the use of other images presented in the front and rear side of the coin. Using neural pattern analysis, 92.43% success rate on their test data is achieved. Also algorithm produced an overall accuracy of 92.43% with 102 features extracted from the image. The edge detection and localization process provided an accuracy of 85%.

New model [23] based on structural risk minimization using Gaussian mixture models are invented by Fan-Hui Kong, Ji-Quan Ma, and Jia-Feng Liu. Used intensity estimation based on maximum likelihood principle (MLP) in almost all recognition steps. This method is a more flexible alternative and lead to improved results for Chinese paper currency recognition. Recognition system based on virtual instruments for paper currency identification is introduced by Ji Qian, Dongping Qian, Mengjie Zhang in 2006 [24]. This method is used for serial number recognition of Chinese banknotes. Approach achieved single digit recognition rate more than 99.60%, a serial number recognition rate of 99.50% with recognition time of 157ms. System is effective and efficient. As shown above the recognition rates for all the 10 digits are more than 99.60%, suggesting that this system is very effective. For a more adaptive, intelligent and flexible solution for anti-money laundering, the intelligent agent technology is searched [25] by Shijia Gao, Dongming Xu, Huaiqing Wang, and Yingfeng Wang with scalability, Adaptivity, intelligence. Using image recognition, Gaussian mixture model and structural risk minimization, this paper presents paper currency recognition using GMM.

Machine vision based but low cost stand alone system for real time counterfeit Bangladeshi bank notes detection by Dr. Kenji Yoshida,

Mohammed Kamruzzaman, Faruq Aahmed Jewel, Raihan Ferdous Sajal is proposed in 2007 [26]. System has the detection rate of 100% and the average processing time is 250 milliseconds with microcontroller PIC- 16f648a or atmega88 (AVR). The system exhibits 100% success when the scanner is absolutely or nearly vertical. A new technique of feature extraction for paper currency recognition is invented by H. Hassanpour, A. Yaseri G., and Ardeshiri [27]. They used three characteristics of paper currencies including size, color and texture for the recognition. Also system is able to recognize 95% of data correctly. For Bangladesh paper currency recognition, Jahangir N., Chowdhury A.R. presented a NN with Back propagation algorithm and axis symmetrical masks [26]. Proposed system has average accuracy of 98.57% and IS implemented with cheap hardware. Using localized Gabor wavelet grids for pattern recognition [28], Vinay Kumar. B. and Sai Sharan D. R. introduced new method with an MLP classifier. This method is effectively used for recognition of various types of patterns with recognition rate of 100%.

Alternative to regular method, new NN [29] is used to solve the problem of paper currency verification with SVM to distinguish counterfeit banknotes from genuine ones. Using this method, they achieved very good performance. The proposed classifier has very good generalization ability and needed low computing power when using a linear kernel. A new method of RBF NN model for anti-money laundering is used by Lin-Tao LV, Na Ji, and Jiu-long Zhang in 2008 for money laundering [30]. Model based on APC-iii clustering algorithm and recursive least square algorithm is used for anti-money laundering (AML). The proposed method is compared against SVM and outlier detection methods, which show that the proposed method has the highest detection rate and the lowest false positive rate. Model is feasible and effective in money laundering detection with high correction rate which results in reducing false positive rate and enhancing detection rate remarkably. For extracting high-qualified monetary characteristic from currency images by recognizing the infrared images, Chengxiang liu, Shuangchen Ruan and Guiming Huang Yaobo Jian and Li Zhang introduced new identification system [31]. Using this method we can get very good experiment results and the recognition rate is 100% in the application. This method for recognition is good in the speed of recognition. The recognition rate is up to 100%. This method is effective and can be used in the field of identifying the paper currency. Sajal R.F., Kamruzzaman M., Jewel F.A. searched z machine vision automatic system for real time recognition and sorting of Bangladeshi bank notes [32]. Author invented machine vision algorithm with an automatic banknotes sorting system.

With SVM for paper currency verification Chin-Chen Chang Tai-Xing Yu and Hsuan-Yen [33], proposed new recognition system including discrete wavelet transformation (DWT) which is also be applied so as to reduce the input scale of SVM. SVM classifier is achieved very good performance with very good generalization ability and needs low computing power when using a linear kernel. With speed up to 8 to 9 bank notes per second and the rate of success is 100%. Zhongnian li, Xin Zhou, Yonghong Chen [35] showed that real money and false money can be distinguished by three detection facilities including fluorescence detection of forgery, infrared detection of forgery, and magnetic detection of forgery during every working process of the sorter with accuracy of 100%. System is highly automated and intelligent and also successfully realize is another feature of the sorter. Method includes picture processing, integrated fusion technology of artificial neural network (ANN) and dual CPU. System based on ANN helped to analyze and process the picture character with improved recognition accuracy rate and provided a detecting mode and an algorithm to identify denomination, orientation and RMB new degree. Research on money laundering by Xingqi Wang, Guang Dong [36] is introduced with detection based on improved minimum spanning tree clustering and its application with effectiveness. But existing methods have some drawbacks of having high complexity and low efficiency. Also most of existing methods faiedl to run without parameters tuned suitably but new algorithm is simple and effective and can detect suspicious money laundering transactions effectively and efficiently.

Using SVM li Wenhong Tian Wenjuan, Cao Xiyan and Gao Zhen proposed new method for serial number identification of RMB in 2010 [37]. In this paper, they studied the Multi-class Optimize Algorithm and analyzed Sequential Minimal Optimization Algorithm (SMOD) and its precondition for serial number recognition. Method showed the advantages of SVM in solving limited samples, non-linear and high dimension pattern recognition problems. Compared to NN and fuzzy theory algorithm, its computing load is fairly low with high training rate and high identification rate. For automatic paper-money inspection, Keon-Ho Lee, Ttae-Hyoung Park invented image segmentation of UV patterns [38]. The proposed method is suitable for separating the UV pattern and showed very high accuracy and low complexity. Liu Li, Ye Yu-Tang, Xie Yu, Pu Liang introduced a advance method for serial number extraction based on statistics and fuzzy membership. It proposed a recognition system based on CIS and DSP

[39]. The result showed that the recognition system runs stably and accurately. The collected image shows clearly. The system runs with highly exact rate on number recognition. Paper shows that recognition system is based on radial basis function. System has the correct recognize rate up to 98%. It achieves good results in paper currency sorting. Based on local binary pattern (LBP), Junfang Guo, Yanyun Zhao, Anni Cai introduced a reliable method for paper currency. In his paper a reliable method is presented for paper currency. Recognition based on LBP [40]. System has good accuracy and high processing speed and this improved method has a high recognition rate as well as robustness for noise and illumination change. Also have advantage of simplicity, low computation complexity. The average time of recognition achieved 15ms per sheet.

Based on BP NN, improved genetic algorithm (GA) is used for currency recognition by [41]. Model reduced training time for back propagation neural networks and gain higher recognition speed and better recognition effect. Compared with pure BP algorithm, the cycles times of GA-BP algorithm is smaller and the convergence speed is faster while the convergence error is same. RENMINGBI (RMB) number identification with genetic evolution NN was used by li Jing luanshuang Mei-Shan Jin Wuwei [42]. This method effectively improved the accuracy and speed of number identification of paper currency. Number recognition is found by Ke-Yong Shao, Yang Gao, Na Wang, Hong-Yan Zhang, Fei li, Wen-Cheng li in his paper [43] based on intersection change. System adaptability is very high. And as classification features is less, computing is low. System has quick identification and accurate feature, and the accuracy reached to 97.5%. Felipe Grijalva, J.C. Rodríguez, Julio larco and Luis Orozco developed a new Smartphone recognition system of the U.S. banknotes' denomination for visually impaired people [44]. System has maximum accuracy rate of 99.838% under ideal conditions and has ability to show an accuracy of 99.158% under indoor conditions.

Microcontroller based system to automatically identify the serial numbers of the Indian currency was invented by Dayakshini, Sathisha K. In his paper, bank automation system for Indian currency [45]. The system is accurate, fast and reliable and low cost in comparison with currently available systems. Embedded system for Indian paper currency recognition was built by Ms. Trupti Pathrabe, Mrs. Swapnili Karmore in 2011 [46]. System realized on a specific feature of the Indian bank notes. The success-rate of the counterfeit detection with properly captured image is 100%. Neural network classifier achieved very good performance. Furthermore, the proposed classifier has very good generalization ability and needs low computing power. Kuldeep Verma, Bhupesh Kumar Singh, Anupam Agarwal proposed Indian currency recognition based on texture analysis [47]. Because of recognition by some extrinsic feature, error was their due the pollution and depreciation suffered by the currency during the transactions. Therefore, this paper developed an Indian currency recognition system based on the intrinsic feature of the currency.

The existing system worked with all the types of denomination of Indian paper currency are compared to the system invented by Sanjana, Manoj Diwakar [48]. In his work, the success-rate of the counterfeit detection with properly captured image is 100% [46]. Network classifier has achieved very good performance. Furthermore the proposed classifier has very good generalization ability and needs low computing power. Hence, it is found suitable for implementing an automatic verifier for paper currency. With a CDD camera Sanjana, Manoj Diwakar, Anand Sharma presented new method for automated recognition of Indian currency notes in machine vision [48]. With CDD camera image is scanned and software processed the image segments with the help of SVM and character recognition methods. ANN is used to train the data and to classify the segments using its datasets. This technique is very adaptive to implement in real time world. Existing method for detecting fake notes is time taking as this involves filing a case to the police, sending the document for verification and then waiting for results to so new method using machine vision is introduced. Banknote recognition for the blind is suggested by Faiz m. Hasanuzzaman, Xiaodong yang, and Yingli Tian [49] using effective component-based with 100% true recognition rate and 0%false recognition rate. Method with high accuracy, high true recognition rate, low false recognition rate and robustness can handle a variety of currency designs with high efficiency, ease to use.

Previous devices available in the Malaysian currencies recognition are very expensive as compared to this low cost and compact device to assist blind people to distinguish Malaysian bank notes. Aisah Mohamed, M. Ikram Ishak, Norlida Buniyamin proposed this device for vision impaired with providing various beeping sound patterns to indicate the respective Malaysian bank note value [50]. For Persian Banknote Recognition, Ahangaryan F.P., Mohammad Pour, T. Kianisarkaleh A. proposed a method [52] using Wavelet and NN with reorganization more than 99% of all data sets with excellent classification rate. Robust and effective component based banknote recognition by SURF features was presented by F. Hasanuzzaman, X. Yang, and Y. Tian in 2011 [53] with effectiveness in

collecting more class-specific information and is robust in dealing with partial occlusion and viewpoint changes. Also have more accuracy, 100% recognition rate and robust nature.

III. CONCLUSION

This paper has provided a survey of fake note recognition and detection methodologies reported in last decade. These available techniques are classified according to the methods used year wise. The core ideas of these methodologies along with their drawbacks/critics are discussed. However, because of different algorithms, advantages and recognition rate, it is not prudent to explicitly declare the best available methods. There has been no prior survey on the currency identification methodologies and the comprehensive survey presented in this paper will be useful in developing and analyzing new approaches and algorithms with good performance. The last few years have shown some encouraging trends in forged paper currency recognition and detection research.

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