International Journal of Engineering Research Excellence and Applied Science (IJEREAS)

Volume-II (Issue 4) – December 2024 ISSN: 3048-5355

Advanced Approaches to Counterfeit Currency Detection Using Classification Models

Ms. Rashi Jain Assistant
Professor, Department of
Computer Applications
JECRC University
Jaipur, India
Rashi.jain@jecrcu.edu.in

Abstract **- Counterfeit currency poses a significant threat to national economies and impacts global economic growth. The production of forged currency or falsification of security features is considered a crime under criminal law, classified as an economic crime. In recent years, numerous researchers have proposed various methods to detect and prevent counterfeit currency. These solutions encompass hardware-based techniques, image processing, and machine learning methods. However, advancements in printing and scanning technologies, along with the trade of counterfeit materials, continue to exacerbate the issue.**

This study reviews several counterfeit currency detection techniques proposed by researchers, focusing on methodologies that leverage specific characteristic features and evaluating their success rates. Furthermore, the study examines statistical classification techniques widely used for currency authentication. A comparative analysis of Logistic Regression and Linear Discriminant Analysis (LDA) was conducted to identify the more effective model for currency verification. Results indicate that Logistic Regression outperforms LDA, achieving an impressive accuracy rate of 99%. This study provides valuable insights for selecting the most suitable technique for counterfeit detection, emphasizing the importance of accuracy in currency authentication.

Keywords— fake currency, classification model, statitical techniques, machine learning, Logistic regression, logit regression, Linear Discriminant Analysis, LDA, feature extraction, detection techniques, counterfeiting, economical crime, currency features, image processing, INR, indian rupees, bank notes

I. OUTLINE OF PAPER

The paper is structured into five sections, including the organization of the content. Section I introduces the topic of fake currency and explores various methodologies for addressing counterfeit currency issues. Section II delves into the concept of counterfeit currency, providing foundational insights. Section III outlines and explains different methods used for detecting and identifying counterfeit notes. The subsequent section reviews prior studies in this field, highlighting the techniques they proposed. Finally, the paper concludes by discussing future prospects and potential advancements for developing optimal solutions to combat counterfeit currency.

Introduction

Counterfeiting refers to the deliberate replication of genuine currency with the intent to deceive recipients into accepting it as authentic. The proliferation of counterfeit currency has emerged as a significant global threat, profoundly impacting nations worldwide [2]. According to the National Crime Records Bureau (NCRB) of India, counterfeiting is categorized under the Indian Penal Code (IPC) as an economic crime. Such crimes accounted for 5.1% of the total IPC offenses, as reported in the NCRB Compendium 2015-16 [1]. A study [3] highlights that producing currency through unlawful means constitutes counterfeiting, a practice as ancient as currency itself, often referred to as the world's second-oldest profession. The rise in counterfeit currency can be attributed to advancements in technology and other contributing factors [4]. One harmful consequence of counterfeit money is its adverse effect on the value of legitimate currency, leading to a reduction in its worth [5]. The increasing rate of counterfeiting is largely fueled by the rapid acquisition of advanced technology, driven by its affordability, accessibility, and efficiency [6]. For years, a race has persisted between counterfeiters and financial institutions. To address this pressing issue, researchers have proposed a range of solutions leveraging machine learning and image processing techniques.

II. Currency Detection techniques

Numerous currency detection techniques have been proposed by researchers in the fields of machine learning and image processing.

Machine Learning Techniques:

Machine learning approaches can be categorized into supervised, unsupervised, or a combination of both, depending on the nature of the dataset and the desired outcome. **Supervised learning** involves predicting the output variable using input data and is so named because it relies on training datasets and testing datasets. This category primarily includes techniques such as regression and classification. Regression methods are used when the output variable is continuous (e.g., real values), while classification methods are employed when the output variable falls into specific categories. Common supervised learning techniques include linear regression, multiple regression, logistic regression, linear discriminant analysis, support vector machines, decision trees, neural networks, Naïve Bayes, and k-nearest neighbors [12].In contrast, **unsupervised learning** deals with input data that lacks corresponding output variables. It aims to uncover hidden structures or patterns within the dataset. Unsupervised learning problems are commonly divided into clustering and association. Clustering techniques are used to group data points based on similar characteristics, while association techniques identify rules that define significant patterns in the data. Examples of unsupervised learning techniques include Apriori, k- means clustering, mixture models, hierarchical clustering, anomaly

International Journal of Engineering Research Excellence and Applied Science (IJEREAS)

Volume-II (Issue 4) – December 2024 ISSN: 3048-5355

detection, autoencoders, deep belief networks, Hebbian learning, generative adversarial networks, principal component analysis (PCA), independent component analysis (ICA), non-negative matrix factorization, singular value decomposition, expectation-maximization, and methods of moments [20].

Image Processing Techniques:

Image processing is another widely used domain for currency detection and identification. It involves applying operations on images to enhance quality or extract meaningful features. The image processing workflow typically includes image acquisition, enhancement, segmentation, feature extraction, and analysis. Among these, **edge detection** and **feature extraction** are critical steps.

Edge detection, a form of segmentation, is used to isolate objects of interest within an image. Techniques for edge detection include Roberts, Sobel, Prewitt, Kirsch, Robinson, Marr-Hildreth, Laplacian of Gaussian (LoG), and Canny edge detection methods [9].

Feature extraction, a vital aspect of pattern recognition, follows preprocessing. It consists of two phases: feature selection and classification. This step is essential for constructing patterns and extracting relevant information. Feature extraction methods are broadly classified into three categories:

A) Statistical methods

B) Global transformation and series expansion methods

C) Geometrical and topological methods

These categories encompass various techniques such as zoning, characteristic loci, Fourier transform, rapid transform, moments, Karhunen-Loeve expansion, strokes, and chain codes, among others [11]. Together, these approaches facilitate effective feature extraction and pattern recognition in currency detection systems.

III. LITERATURE REVIEW

Currency counterfeiting poses a significant threat to any nation's economy and impacts its demographics considerably. Fake currency can be identified using various methods, including ultraviolet light detection and light polarization. A currency is confirmed to be counterfeit if both detection methods yield positive results [2]. Reference [3] explores a methodology for detecting counterfeit currency using a counterfeit detection pen and MATLAB. The pen facilitates the identification of currency features such as watermarks, optically variable ink, security threads, and latent images. Additionally, [4] reviews various techniques for detecting counterfeit currency based on security features. Although these studies offer insights into effective solutions, they underscore the need for a 100% accurate and reliable counterfeit detection technique [6]. To assist individuals in verifying the authenticity of currency, an Android application has been developed for detection purposes [7]. Furthermore, [8] discusses currency detection by extracting specific features, such as the security thread, using neural networks and pattern recognition. Table I highlights other implemented methods for currency detection, along with their respective accuracy rates.

TABLE I. TECHNIQUES FOR DETECTION OF COUNTERFEIT CURRENCY.

Authors	Year	Technique	Accuracy /success rate	Applied on
Abba Almu and Aminu Bui Muhammad	2017	Application implemented using MS Access and Visual Basic	77%	Algorithm based on features comparison of Nigerian currency Naira 100, 200, 500, 1000
Jayant Kumar Nayak et. al.	2015	Chan-Vese segmentation, ROI, backpropagation algorithm	98% Average accuracy for both types of notes (average soiled and very soiled)	ROI segmented images of Indian currency denomination values 5, 10, 20, 50, 100, 500
Snigdha Kamal et. al.	2015	SURF Descriptor and SVM Classifier	97%	Feature extraction and recognition based on Central Numeral, Ashoka emblem, Identification mark and color band of Indian rupee 500

Lamsal S, Shakya A	2015	Image classification based on colour and texture using Skew, mean, standard deviation, entropy and correlation value	95%	Color descriptor and texture parameter of Nepal currency 500
Ballado et. al.	2015	Canny Edge detection and proposed to inbuild OVD patch	100%	GUI based program for Philippine currency Peso 500, 1000
Vishnu R & Omman B	2014	Pattern matching on similarity of feature extracted, dominant color and shape detection method.	97%	6 security features considered; Color, shape, Centre, Ashoka emblem, RBI seal, Signature i.e. 50, 100, 500, 1000 of Indian currency
Singh et. al.	2014	Visual Bag of Words, feature detection and extraction using SIFT, SURF and ORB-FREAK	96%	Currency recognition application specially designed for visually impaired for Indian denomination value 10, 20, 50, 100, 500, and 1000. Excluded color, text and size of denomination.
Ankush Roy et.al.	2014	SVM and ANN	100%	Based on security thread, Ink, printing technique and artwork of Indian currency
Abbas Yaseri and Sayed Mahmoud Anisheh	2013	Wiener filter Fourier Mellin transform SVM Classifier	98%	Different quantization levels and segmentation of the paper currency dataset of 150 banknotes of 101 different denominations from 23 countries
Subra Mukherjee et.al.	2012	defining window size of an image,segmentation on the basis of Identification mark, fourier descriptor for feature extraction	97%	Unique identification mark on different denominations of Indian currency i.e. Rupee 20,50,100,500,1000
F. M. Hasanuzzaman et. al.	2012	Component based recognition using SURF	100%	Reference region of 14 ground truth images of seven categories bill; US Dollar 1, 2, 5, 10, 20, 50, 100
Kalyan Kumar Debnath et.al.	2010	Negatively correlated Ensemble Neural Network	100%	Gray scale image of 7 different types of Bangladeshi taka 2,5,10,20,50,100, 500 and 1000
F. Grijalva et. al.	2010	Eigen faces based on Principal Component Analysis	99%	Currency recognition application specially designed for visually impaired for all denomination value of US Dollar

Hamid Hassanpour et.al.	2009	Hidden Markov Model	98%	Size, color histogram and texture based features of Iranian Rial

TABLE II. SIMULATION OF LOGISTIC REGRESSION.

Simulation	Training (model fit %)	Testing (model validation %)
1	98.8	99
2	99.4	98.6
3	99.4	98.3
4	98.7	99.2
5	98.6	99.3
6	99.4	99.3
7	99.3	98.3
8	98.9	99.8
9	98.7	99.3
10	99.1	99.3
11	98.8	99.1
12	99.4	98.8
13	99.3	98.6
14	98.7	99.3
15	99.0	99.5
16	99.3	99.3
17	99.2	98.9
18	98.8	99.8
19	98.7	99.4
20	99.0	99.3
Average Accuracy	99.0	99.3

International Journal of Engineering Research Excellence and Applied Science (IJEREAS)

Volume-II (Issue 4) – December 2024 ISSN: 3048-5355

IV. Comparative Study of Statistical Classification Approaches

Numerous past studies have shown that image processing and pattern recognition techniques are central to currency authentication. Researchers have applied methods such as Canny edge detection, Sobel operator, and SIFT, along with machine learning techniques like Fourier descriptors, Artificial Neural Networks (ANN), neural networks based on Region of Interest (ROI) and HSV, and Support Vector Machines (SVM) using SURF descriptors. On closer inspection, these approaches can be categorized into three key areas: image processing, machine learning, and statistical techniques. While the statistical techniques rely more on mathematical models, the application of machine learning and image processing methods highlights the potential of statistical approaches, such as regression analysis and Linear Discriminant Analysis (LDA), for currency authentication. These statistical techniques are particularly suited for classification problems where the target variable is categorical.

To evaluate the performance of these statistical techniques, the average accuracy of models was computed and compared. The dataset used for this analysis was obtained from the UCI Machine Learning Repository, with the dataset's owner being Volker Lohweg and the donor being Helene Darksen. The dataset contains 1,372 instances, with a distribution of 55% genuine currency and 45% counterfeit currency. The independent attributes in the dataset are variance, skewness, kurtosis, and entropy, all derived using wavelet transforms on Euro banknotes. The target variable, "class," identifies whether a banknote is genuine (0) or fake (1). For the analysis, the dataset was divided into training and testing sets using Bernoulli's function for random partitioning, with different ratios (70:30 and 60:40) applied. The dataset was simulated 20 times for each technique, with random distributions of the training and testing sets in each simulation. IBM SPSS 20 software was used for the simulations. The table below presents the average accuracy of the classification models, along with the results from each simulation for both statistical techniques.

TABLE III. Simulation of Linear Discriminant Analysis.

Simulation	Training	Testing
1	98.1	98.7
2	98.2	97.9
3	98.4	97.4
4	98.4	98.0
5	98.2	98.4
6	98.2	98.3
7	98.5	98.8
8	98.1	98.6
9	98.4	97.8
10	98.1	98.5
11	98.1	97.9
12	98.	97.3
13	98.3	98.2
14	98.0	98.0
15	98.7	97.7
16	98.2	98.0
17	98.5	97.9
18	98.1	98.5
19	98.5	97.9
20	98.9	97.2
Average Accuracy	98.3	98.5

From Table II and Table III, it is observed that the training and testing models are highly consistent, indicating reliable results for both techniques. The model validation shows that the estimated percentages for the training and testing models are comparable. When comparing the two techniques in terms of classification accuracy, it is evident that the Logistic Regression model outperforms the Linear Discriminant Analysis model, achieving an average accuracy of 99% for the training model and 99.3% for the testing or validation model.

V. Conclusion and Future scope

The detection of counterfeit currency remains a persistent challenge for the research community, prompting ongoing efforts to identify the most effective solutions. Extensive studies have been conducted on various techniques tailored to specific currency denominations, with a primary focus on image processing, pattern recognition, and machine learning. Many models and detection methods have been simulated across multiple runs to improve accuracy and cover all possible permutations. However, a significant gap exists in incorporating statistical techniques, such as Regression Analysis and Linear Discriminant Analysis (LDA), which could enhance models' ability to predict whether a currency is genuine or counterfeit. This paper provides an overview of different detection methodologies and their associated accuracy rates. It also compares the performance of logistic regression and LDA as prediction and classification techniques. The simulation results indicate that logistic regression achieves an impressive 99% accuracy, suggesting that statistical methods could be leveraged to design more effective and accurate counterfeit currency detection models.

References

[1] NCRB compedium Report (2015-2016), crime report, http://ncrb.gov.in/StatPublications/CII/CII2015/FILES/CrimeInIndia2015.pdf

[2] Santhanam, K., Sekaran, S., Vaikundam, S., & Kumarasamy, A. M. (2013, September). Counterfeit currency detection technique using image processing, polarization principle and holographic technique. In Computational Intelligence, Modelling and Simulation (CIMSim), 2013 Fifth International Conference on (pp. 231-235). IEEE.

[3] Alekhya, D., Surya Prabha, G. D., & Durga Rao, G. V. (2014). Fake currency detection using image processing and other standard methods. IJRCCT, 3(1), 128-131.

[4] Thakur, M., & Kaur, A. (2014). Various fake currency detection techniques. International Journal for Technological Research in Engineering, 1(11), 1309-1313.

[5] Jadhav S., Khanai R, Authentication And Counterfeit Detection Of Currency Using Image Processing. In International Conference on Recent Innovations in Engineering and Management (ICRIEM-16), 2016, pp. 709-715.

[6] Ahmed, Z., Yasmin, S., Islam, M. N., & Ahmed, R. U. (2014, December). Image processing based Feature extraction of Bangladeshi banknotes. In Software, Knowledge, Information Management and Applications (SKIMA), 2014 8th International Conference on (pp. 1-8). IEEE.

[7] Sneha R, Deepika P K , Nagaveni S, Swetha Shree D , Asha K S. "Automatic counterfeit currency detection using Image Processing." International Research Journal of Engineering and Technology (IRJET) Vol. 4, Issue 5, 2017

[8] Pilania, Eshita, and Bhavika Arora. "Recognition of Fake Currency Based on Security Thread Feature of Currency.", International Journal Of Engineering And Computer Science, Volume 5 Issues, pp. 17136-17140, 2016.

[9] Muthukrishnan, R., & Radha, M. (2011). Edge detection techniques for image segmentation. International Journal of Computer Science & Information Technology, 3(6), 259.

[10] Atchaya, S., K. Harini, G. Kaviarasi, and B. Swathi. "Fake Currency Detection Using Image Processing.", International Journal of Trend in Research and Development, special issue, pp72-73, 2016.

[11] Kumar, G., & Bhatia, P. K. (2014, February). A detailed review of feature extraction in image processing systems. In Advanced Computing & Communication Technologies (ACCT), 2014 Fourth International Conference on (pp. 5-12). IEEE.

[12] Visani, C., & Jadeja, N. A Study on Different Machine Learning Techniques for Spam Review Detection.

[13] Alshayeji, Mohammad H., Mohammad Al-Rousan, and Dunya T. Hassoun. "Detection method for counterfeit currency based on bit-plane slicing technique." International Journal of Multimedia and Ubiquitous Engineering Vol.10, Issue11,pp. 225-242, 2015

[14] Mukherjee S. "Artificial neural network to recognize an Indian currency note using unique identification mark." Journal of Applied and Fundamental Sciences Vol 1, Issue 2, pp. 213-220, 2015

[15] Roy, Ankush, Biswajit Halder, Utpal Garain, and David S. Doermann. "Machine-assisted authentication of paper currency: an experiment on Indian banknotes." International Journal on Document Analysis and Recognition (IJDAR) Vol 18, Issue 3, pp. 271-285, 2015

[16] Asadizanjani, N., Dunn, N., Gattigowda, S., Tehranipoor, M., & Forte, D. (2016). A database for counterfeit electronics and automatic defect detection based on image processing and machine learning. ISTFA, Nov.

[17] Ballado, A. H., JC Dela Cruz, G. O. Avendaño, N. M. Echano, J. E. Ella, M. E. M. Medina, and B. K. C. Paquiz. "Philippine currency paper bill counterfeit detection through image processing using Canny Edge Technology." In Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), International Conference on, pp. 1-4. IEEE, 2015.

[18] Kavya, B. R., and Devendran B. "Indian currency detection and denomination using SIFT." International Journal of Science Enineering and Technology. Vol 4, Issue 6, pp.1909-1911, 2015

[19] Prasanthi, B. Sai, and D. Rajesh Setty. "Indian paper currency authentication system—A quick authentication system." International Journal of Scientific and Engineering Research, Vol 6, Issue 9, pp. 1249-1256, 2015.

[20] Elmurngi, E., & Gherbi, A. (2017). An empirical study on detecting fake reviews using machine learning techniques.

[21] Lamsal S, and Shakya A "Counterfeit paper banknote identification based on color and texture.", Proceedings of the IOE Graduate Conference, pp. 160-168. 2015.

[22] Kamal, Snigdha, Singh S, Chawla, Goel N, and Balasubramanian R. "Feature extraction and identification of Indian currency notes." In Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), 2015 Fifth National Conference on, pp. 1-4. IEEE, 2015.

[23] Almu, A., & Muhammad, A. B. (2017). Image-Based Processing Of Naira Currency Recognition. Annals. Computer Science Series, 15(1).

[24] Ahmed, Z, Yasmin S, Islam N, and Ahmed R U. "Image processing based Feature extraction of Bangladeshi banknotes." In Software, Knowledge, Information Management and Applications (SKIMA), 2014 8th International Conference on, pp. 1-8. IEEE, 2014.

[25] Rahman S, Banik P, Naha S., "LDA based paper currency recognition system using edge histogram descriptor". International conference on Computer and Information Technology (ICCIT), 2014 17th International Conference on, pp. 326-331. IEEE, 2014.

[26] Akbar M, Awaluddin AS, Putra AA, Widyarto S. "Original and Counterfeit Money Detection Based on Edge Detection", International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering 2013.

[27] Nayak, J. K., Majhi, C., Srivastav, A. K., & Dash, A. K. (2015, December). Neural network approach for Indian currency recognition. In India Conference (INDICON), 2015 Annual IEEE (pp. 1-6). IEEE.

[28] Grijalva, F., Rodriguez, J. C., Larco, J., & Orozco, L. (2010, September). Smartphone recognition of the US banknotes' denomination, for visually impaired people. In ANDESCON, 2010 IEEE (pp. 1-6). IEEE.

[29] Santhanam K, Sekaran S, Vaikundam S, Kumarasamy AM. "Counterfeit currency detection technique using image processing, polarization principle and holographic technique", Computational Intelligence, Modelling and Simulation (CIMSim), 2013 Fifth International Conference on, pp. 231-235. IEEE, 2013

[30] Singh, S., Choudhury, S., Vishal, K., & Jawahar, C. V. (2014, August). Currency recognition on mobile phones. In Pattern Recognition (ICPR), 2014 22nd International Conference on(pp. 2661-2666). IEEE.

[31] Mirza R, Nanda V. "Design and implementation of Indian paper currency authentication system based on feature extraction by edge based segmentation using Sobel operator", International Journal of Engineering Research and Development. Vol 3, Issue 2, pp.:41-46, 2012

[32] Omatu S, Yoshioka M, Kosaka Y. "Reliable banknote classification using neural networks",Advanced Engineering Computing and Applications in Sciences, ADVCOMP'09. Third International Conference on, pp. 35-40, IEEE, 2009

[33] Chhotu Kumar, Anil Kumar Dudyala, "Bank Note Authentication Using Decision Tree rules and Machine Learning Techniques", IEEE International Conference on Advances in Computer Engineering and Applications (ICACEA), March 2015.

[34] Debnath, K. K., Ahmed, S. U., Shahjahan, M., & Murase, K. (2010). A paper currency recognition system using negatively correlated neural network ensemble. Journal of Multimedia, 5(6), 560-567.

[35] Hassanpour, H., & Farahabadi, P. M. (2009). Using Hidden Markov Models for paper currency recognition. Expert Systems with Applications, 36(6), 10105-10111.

[36] Hasanuzzaman, F. M., Yang, X., & Tian, Y. (2012). Robust and effective component-based banknote recognition for the blind. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 42(6), 1021-1030.

[37] Mann Manisha, Shukla S.K.,Gupta Shruti "A comparative study on security features of banknotes of various countries"International Journal of Multidisciplinary Research and Development (83-91) Volume: 2, Issue: 6, June 2015.

[38] Anahita Ghazvini, Jamilu Awwalu, Azuraliza Abu Bakar, "Comparative Analysis of Algorithms in Supervised Classification: A case Study of Bank Notes Dataset", International Journal of Computer Trends and Technology (IJCTT), pg. no. 39-43,volume 17 number 1, ISSN: 2231-2803, Nov 2014

[39] Ballado, A. H., Cruz, J. D., Avendaño, G. O., Echano, N. M., Ella, J. E., Medina, M. E. M., & Paquiz, B. K. C. (2015, December). Philippine currency paper bill counterfeit detection through image processing using Canny Edge Technology. In Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), 2015 International Conference on (pp. 1-4). IEEE.

[40] Yaseri, A., & Anisheh, S. M. (2013). A novel paper currency recognition using Fourier mellin transform, hidden Markov model and support vector machine. International Journal of Computer Applications, 61(7).

[41] Nur Syhuda Mohamad, Burairah Hussin, A.S. Shibghatullah, A.S.H. Basari, "Banknote Authentication using Artificial Neural Network", International Symposium on Research in Innovation and Sustainability, pg. no. 1865-1868, ISSN 1013-5316, 15-16 October.

[42] Kamal, S., Chawla, S. S., Goel, N., & Raman, B. (2015, December). Feature extraction and identification of Indian currency notes. In Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), 2015 Fifth National Conference on (pp. 1-4). IEEE.

[43] Masato Aoba, Testsuo Kikuchi, Yoshiyasu Takefuji, "Euro Banknote Recognition System using three-layered Perceptron and RBF Networks", IPSJ Transactions on Mathematical Modeling and its applications, pg. no. 99-109, Volume 44 No. SIG 7(TOM 8), May 2003.

[44] B.Sai Prasanthi, D.Rajesh Setty, "Indian Paper currency authentication system- A quick authentication system", International Journal of Scientifica & Engineering Research, pg. no. 1249-1256, Volume 6, Issue 9, ISSN: 2229-5518, September 2015.

[45] Vishnu, R., & Omman, B. (2014, December). Principal features for Indian currency recognition. In India Conference (INDICON), 2014 Annual IEEE (pp. 1-8). IEEE.

[46] M. F. Santos, P. Cortez1, J. Pereira & H. Quintela data mining techniques, "Corporate bankruptcy prediction using data mining techniques", Data Mining VII: Data, Text and Web Mining and their Business Applications, WIT Transactions on Information and Communication Technologies, Vol 37, ISSN 1743-3517, Pg 349-357, 2006.