

A STUDY AND ANALYSIS OF FAKE INDIAN CURRENCY IDENTIFICATION SYSTEM

THESIS

SUBMITTED TO
BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
LUCKNOW

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Under the supervision of

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2021



Dedicated to My Papa...



CANDIDATE'S DECLARATION

I, **Snehlata**, solemnly declare that the research work embodied in this thesis entitled “**A STUDY AND ANALYSIS OF FAKE INDIAN CURRENCY IDENTIFICATION SYSTEM**” carried out by me under the guidance and supervision of **Prof. Vipin Saxena, Department of Computer Science, Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow, India** is an original work and does not contain part of any work submitted for the award of any degree either in this University or any other University around the globe. It is further undertaken that the thesis is essentially free from all kinds of plagiarism.

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CERTIFICATE

This is to certify that the thesis titled “A STUDY AND ANALYSIS OF FAKE INDIAN CURRENCY IDENTIFICATION SYSTEM” submitted by Ms. SNEHLATA is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to Babasaheb Bhimrao Ambedkar University Lucknow satisfies all the requirements as stipulated in the *Doctor of Philosophy (Ph.D.) regulations -1999 as amended in 2013* and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

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LIST OF ABBREVIATIONS

GOI	Government of India
RBI	Reserve Bank of India
FICN	Fake Indian Currency Note
FCORD	Fake Indian Currency Notes Coordination Centre
FDS	Fraud Detection System
IPC	Indian Panel Code
NCRB	National Crime Records Bureau
BMP	Bitmap
HDF	Hierarchical Data Format
GIF	Graphics Interchange Format
JPEG/JPG	Joint Photographic Experts Group
PCX	PiCture eXchange
TIFF	Tagged Image File Format
PNG	Portable Graphics Format
MATLAB	MATrix LABoratory
RGB	Red, Green, Blue
HSV	Hue-Saturation-Value
PC	Personel Computer
PCA	Principle Component Analysis
GLCM	Gray Level Co-occurrence Matrix
UML	Unified Modeling Language
OMG	Object Management Group
OMT	Object-Modeling Technique
OCL	Object Constrained Language
INR	Indian Rupee
Rs (₹)	Rupee
RMB	Renminbi
USD	United State Dollar
KRW	Korean Won
AUD	Australian Dollar

SAR	Saudi Arabian Riyal
EUR	Euro
US	United State
UK	United Kingdom
GA	Genetic Algorithm
LVQ	Linear Vector Quantization
OCR	Optical Character Recognition
OVI	Optically Variable Ink
PIC	Peripheral Interface Controllers
HMM	Hidden Markov Model
NN	Neural Network
FNN	Feed-Forward Neural Network
SVM	Support Vector Machine
ANN	Artificial Neural Network
CNN	Convolutional Neural Network
SURF	Speeded Up Robust Feature
LBP	Local Binary Pattern
DTC	Decision Tree Classifier
BC	Bayesian Classifier
k-NN	k- Nearest Neighbor
NB	Naïve Bayes
LR	Logistic Regression
LDA	Linear Discriminant Analysis
SIFT	Scale-Invariant Feature Transform
LBG	Linde-Buzo-Gray
KPE	Kekre's Proportionate Error
SPCR	Saudi Paper Currency Recognition
pXRF	Portable X-ray Fluorescence
WEKA	Waikato Environment for Knowledge Analysis
ROI	Region of Interest
2D DWT	Two-Dimension Discrete Wavelet Transform
ATM	Automated Teller Machine
MSE	Mean Square Error

UV	Ultra-Violet
LED	Light-Emitting Diode
IA	Image Acquisition
ED	Edge Detection
IS	Image Segmentation
IE	Image Extraction
COMP	Comparison
E	Energy
Ent	Entropy
Con	Contrast
Hom	Homogeneity
Corr	Correlation

LIST OF PUBLICATIONS

A. INTERNATIONAL JOURNALS

- [1] **Snehlata and Vipin Saxena**, “Identification of Fake Currency: A Case Study of Indian Scenario”, *International Journal of Advanced Research in Computer Science (IJARCS)*, (ISSN: 0976-5697), 8(3), 1-6, (2017).
- [2] **Snehlata and Vipin Saxena**, “An Efficient Technique for Detection of Fake Currency”, *International Journal of Recent Technology and Engineering (IJRTE)*, (ISSN: 2277-3878), 8(3), 1-8, (2019). (SCOPUS)
- [3] **Snehlata and Vipin Saxena**, “A Novel Approach for Identification of Fake Indian Currency Using Genetic Algorithm”, *International Journal of Future Generation Communication and Network (IJFGCN)*, (ISSN: 2233-7857), 14(1), 644-651, (2021). (ESCI)
- [4] **Snehlata and Vipin Saxena**, “A Neural Network Approach for Currency Identification” *Walailak Journal of Science and Technology (WJST)*, (ISSN: 1686-3933), Communicated for Publication, (2021). (SCOPUS)
- [5] **Snehlata and Vipin Saxena**, “A Reliable Technique for Currency Recognition Using Neural Network”, *IET Image Processing*, (ISSN: 1751-9667), Communicated for Publication, (2021). (SCIE)
- [6] **Snehlata, R. Dileep Kumar and Vipin Saxena**, “Evaluating People’s Awareness of New Indian Currency Security Features”, *Walailak Journal of Science and Technology (WJST)*, (ISSN: 1686-3933), Communicated for Publication, (2021). (SCOPUS)

B. LIST OF CONFERENCES

B.1 INTERNATIONAL CONFERENCE

- [7] **Snehlata and Vipin Saxena**, “Texture Feature Technique for Security of Indian Currency”, *3rd International Conferences on Recent Innovations in Computing (ICRIC-2020)*, Published in **LECTURE NOTES IN ELECTRICAL ENGINEERING (LNEE)**, Springer, Singapore, 701, 695-706, ISBN NO (978-981-15-8296-7) held on 05th June 2020, organized by Department of Computer Science & Information Technology, Central University of Jammu, J & K., India.

B.2 CONFERENCES ATTENDED

- [8] **Snehlata and Vipin Saxena**, “Modeling and Evaluation to Identify the Fake Currency”, *International Conferences on Science Technology for Sustainable Future*, Presented in **1st North Indian Science Congress (NISC-2018)**, from 10th January 2018 to 11th January 2018, **Babasaheb Bhimrao Ambedkar University, Lucknow**.
- [9] **Snehlata and Vipin Saxena**, “TRACECON”- **National Conference on “Trends in Cyber Investigation & Forensics”**, Attended from 27th April 2020 to 30th April 2020, organized by **Reloading Cyber Warriors, Cyber Security Training & Consultancy (keycbr)**.
- [10] **Snehlata and Vipin Saxena**, “A Novel Method for Currency Identification using Machine Learning Algorithms” Presented in *International Conference on Future Engineering (ICFE-2020)*, held at **Ayodhya**, from 26th June 2020 to 27th June 2020.

- [11] **Snehlata** and Vipin Saxena, “Genetic Algorithm for Solving Currency Identification Problem”, Presented in 2nd *International Conference on Interdisciplinary Research and Physical Sciences*, held at **Greater Noida**, from 16th August 2020 to 17th August 2020.

C. WORKSHOPS ATTENDED

- [1] One Week Workshop on “Emerging Research Trends in Computer Science (ERTCS-2017)” from 20th March 2017 to 24th March 2017, organized by the Department of Computer Science, Babasaheb BhimRao Ambedkar University, Lucknow.
- [2] Two Days Workshop on “Effective Image Processing Tools for Novice: Learn Image Processing for Contemporary Applications” from 01st December 2017 to 02nd December 2017, organized by the Department of Information Technology, Indian Institute of Information Technology, Allahabad.
- [3] Two Weeks Training Course on “Cyber Security” from 1st February 2018 to 15th February 2018, organized by the Department of Information Technology, Babasaheb Bhimrao Ambedkar University, Lucknow.
- [4] One Week workshop on “Image and Video Analytics” from 29th March 2018 to 02nd April 2018, organized by the Department of Computer Science and Engineering, Motilal Nehru National Institute of Technology Allahabad.
- [5] Two Weeks Faculty Development Program on “Ensuring Excellence in Teaching/Learning/Research in Higher Educational Institutions using ICT (ID)” from 22nd December 2018 to 06th January 2019, organized by

Department of Information Technology, Babasaheb Bhimrao Ambedkar University, Lucknow.

- [6] Five Days Workshop on “Effective Image Processing and Machine Learning Tools for Contemporary Applications” from 03rd June 2019 to 07th June 2019, organized by the Department of Information Technology, Indian Institute of Information Technology, Allahabad.
- [7] One Day “Author Workshop Program” on 07th August 2019, jointly organized by Springer Nature and Indian Institute of Information Technology, Allahabad.
- [8] AICTE (ATAL) sponsored the Five Days National Workshop on “Artificial Intelligence - Machine Learning with Python- 2019” from 16th September 2019 to 20th September 2019, organized by the Department of Computer Science, Babasaheb Bhimrao Ambedkar University, Lucknow.
- [9] One Week Online Short Term Training Program (STTP) on “Trends in Cyber Investigation & Forensics” from 27th April 2020 to 30th April 2020, organized by Reloading Cyber Warriors, Cyber Security Training & Consultancy (keycbr).
- [10] One Day Online Webinar on “Smart Contracts on Block Chain”, on 25th May 2020, organized by the Department of Computer Science, Anurag University Hyderabad.
- [11] Online Quiz on “Research Metrics in Scientific Publications” conducted on 27th May 2020, with a score of 100%, organized by the Department of Electronics and Communication Engineering, MLR Institute of Technology, Hyderabad.

- [12] National Level Two Days Online Faculty Development Program on “Art of Writing & Publishing Research Paper and Application of Statistical Tools” from 27th May 2020 to 28th May 2020, organized by Department of Commerce, Aurora’s Degree & PG College, Hyderabad.
- [13] Two Days Online Webinar on “Fundamental of MATLAB & Simulation”, from 28th May 2020 to 29th May 2020, organized by the Department of Electrical and Electronics Engineering, School of Engineering, Shri Satya University of Technology & Medical Sciences, Sehore, M.P.
- [14] One Day Online Webinar on “5G Technology & its Applications”, on 28th May 2020, organized by the Department of Electronics and Communication Engineering, Sri Vasavi Institute of Engineering & Technology, Andhra Pradesh.
- [15] One Day Online Webinar on “Fuzzy Logic and its Application”, on 29th May 2020, organized by the Department of Science & Humanities, SRM TRP Engineering College, Trichy.
- [16] One Day Online Webinar on “Nuances of Scientific Publishing”, on 29th May 2020, organized by the Department of Science & Engineering, Anurag University, Hyderabad.
- [17] Five Days Online Workshop on “Emerging IT Technologies”, from 29th May 2020 to 02nd June 2020, organized by the Department of Computer Science and Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj.

- [18] Two Days Hands-on Training on “Solving Multiobjective Problems Using Deterministic & Stochastic Algorithms (V2.0)”, from 30th May 2020 to 31st May 2020, conducted by Coimbatore Institute of Technology- Teaching Learning Centre (CIT-TLC) through Online Modes.
- [19] National Level One Week Online Faculty Development Program on “Design Thinking”, from 01st June 2020 to 05th June 2020, organized by MITS School of Business, Madanapalle Institute of Technology & Science, Andhra Pradesh.
- [20] Five Days Online Short Term Training Program (STTP) on “Sensor, IoT & Machine Learning”, from 01st June 2020 to 05th June 2020, organized by K.J. Somaiya College of Engineering, Vidyavihar, Mumbai.
- [21] One Day Online Webinar on “Developing a Machine Learning Models from Start to Finish”, on 06th June 2020, organized by the Department of Computer Science & Engineering, Anurag University, Hyderabad.
- [22] One Week International Online Faculty Development Programme on “Recent Advances in Computer Science and Allied Domains (RACSAD-2020)” from 08th June 2020 to 12th June 2020, organized by the Department of Computer Science, School of Engineering & Technology, Sharda University, India.
- [23] One Week International Online Faculty Development Programme on “Moodle Learning Management System” from 15th June 2020 to 19th June 2020, organized by Don Bosco College Central Library and IQAC, Itanagar, Arunachal Pradesh, India.

- [24] Three Days National Webinar Lecture Series on “Academic Writing and Research Ethics” from 27th June 2020 to 29th June 2020, organized by Don Bosco College Central Library and IQAC, Itanagar, Arunachal Pradesh, India.
- [25] One Week Online Workshop on “Image Processing Using MATLAB” from 06th July 2020 to 11th July 2020, organized by the Department of Computer Science and Engineering and Department of Information Technology, St. Xavier’s Catholic College of Engineering, Nagercoil.
- [26] One Day Online Webinar on “Internet of Things - Industrial Perspective” on 11th July 2020, organized by BVICAM, New Delhi.
- [27] Two Week Online Faculty Development Programme on “Emerging Technologies for Education and Research in CS and IT” from 13th July 2020 to 25th July 2020 and obtained A+ Grade, organized by BVICAM, New Delhi.
- [28] One Day Online Webinar on “BlockChain – Technological Perspective” on 18th July 2020, organized by BVICAM, New Delhi.
- [29] One Day Online Webinar on “Simplifying IPR and Patent Filing” on 24th July 2020, organized by BVICAM, New Delhi.
- [30] Three Days Online Short Term Training Program (STTP) on “MATLAB and MATHEMATICA for Scientific Research” from 27th July 2020 to 29th July 2020, organized by Department of Mathematics, Arul Anandar College Karumathur, Madurai.
- [31] One Week Online Short Course on “Safety Aware Peaceful Life in COVID-19 (SAPLC-2020): A Computer Science Perspective” from 28th July 2020 to 2nd

August 2020, organized by Department of Computer Science & Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj.

- [32] One Week Faculty Development Programme on “Research Methodology and Technology Led Paradigm Shift in Teaching and Learning Process” from 04th August 2020 to 12th August 2020, organized by Internal Quality Assurance Cell, Research and Consultancy Cell, P.G.D.A.V. College in collaboration with Buniyaad Education Society, Delhi.
- [33] One Day Online Webinar on “Unleashing Data Science and AI”, on 08th August 2020, organized by BVICAM, New Delhi.
- [34] One Day Online Webinar on “Hadoop Distributed File System”, on 18th August 2020, organized by Department of Bachelor of Computer Application, P. C. Jabin Science College, Hubballi.
- [35] National Level One Day Online Webinar on “LaTex and its Application” on 19th August 2020, organized by Department of Bachelor of Computer Science, SBRR Mahajana First Grade College(Autonomous), Mysuru, Karnataka.
- [36] One Day Online Webinar on “Use LMS, Virtual Teaching and OBE Software for Engineering Colleges”, on 20th August 2020, organized by vmedulife Software Services.
- [37] One Week International, Faculty Development Program on “Emerging Trends & Technologies in Data Science”, from 24th August 2020 to 29th August 2020, organized by Department of Computer Science and Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh.

- [38] National Level One Week Online HANDS-ON, Faculty Development Program on “Artificial Intelligence Using Python”, from 14th September 2020 to 19th September 2020, organized by Department of Computer Science, ST. Mary’s Integrated Campus, Hyderabad.
- [39] AICTE (ATAL) sponsored the Five Days Online Faculty Development Programme on “Emotional Intelligence”, from 13th September 2020 to 17th September 2020, organized by the Department of Management Studies, Indian Institute of Information Technology, Allahabad, India.

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SUMMARY

In the present work, the major contribution is to read the value and extract various features from the currency to increase the accuracy for identifying the fake currency using image-processing tools. This process will help to improve fraud detection and provides faster ways to determine the currency value. In the present work, an image of Indian currency is captured and fed to the system where it goes through several algorithms to read the value from the currency and extract the features like security thread, bill dimensions, serial number, etc. The proposed research has several goals of interest like increasing the speed of identification of fake currency as well as accuracy. One of the important things in research is the research gap that represents the gap of research with respect to the current scenario. In currency identification, there are lots of research papers available in India or other country but after demonetization in India, there is less amount research paper on the newly arrived currency. In another country, there are so many research papers that arrived after the demonetization but in India due to fewer amount of sources available so there is no research paper available. In this way, one can say that after demonetization, research papers on new currency are very less hence, the present research work is an attempt in this direction. The entire thesis work has been organized in eight chapters and is briefly discussed below:

CHAPTER I

INTRODUCTION

This chapter provides an introduction to the currency and its importance worldwide. The evolution of currency and its denominations in detail respect of foreign and India. It also highlights the important security feature of Indian currency. Lots of researchers have done work in the field of identification of currency. Demonetization

is play the important role in the field of currency. The old note will be replaced by the feature of a new note. Many countries have changed the currencies generally after ten years. Recently, the Indian Prime Minister has changed the currency of note of Rs 10, Rs 20, Rs 50, Rs 100, Rs 200, Rs 500, and Rs 1000 and issued a new direction for new currencies. As per RBI guidelines currency in the Indian scenario has to be changed after an interval of every 10 years therefore different designs of the notes along with new series have appeared in the Indian Business market and the old series has been eliminated by RBI. This chapter also contains the introduction of computational methods and tools for currency identification.

CHAPTER II

REVIEW OF LITERATURE

This present chapter deals with the previous work available on the currency in respect of foreign and Indian fake currency identification. Indian currency is also divided into old and new currency identification. From the literature, it is revealed that many researchers have done work on the identification of fake currency. Several reputed journals, e-books, Wikipedia, etc. are consulted for understanding the new research problems and more than 180 references are given in the thesis. During the initial stage of the present work, a lot of research papers have been consulted and more than five years' papers have been discussed in the present chapter. Exhaustive kinds of literature have been discussed related to all the problems sort out in the present work.

CHAPTER III

IDENTIFICATION OF FAKE CURRENCY THROUGH SECURITY THREAD

In this chapter, an object-oriented model is designed to represent the dynamic aspects for identification of fake currency and successfully implemented on newly launched a note of Rs 2000 by an Indian Government. A MATLAB code is generated

and through a code, we got class descriptions for real and fake Images of the currency. Results are produced in the form of tables and graphs. The contents of this chapter have been published in the **International Journal of Advanced Research in Computer Science (IJARCS) (ISSN: 0976-5697), 8(3), 1-6, (2017).**

CHAPTER IV

DESIGN AND IMPLEMENTATION OF METHOD FOR FAKE CURRENCY IDENTIFICATION

In this chapter, PCA is an excellent approach for the detection of fake currency in the Indian scenario as well as worldwide. Many researchers have implemented this approach on notes of various kinds but not for the Indian currency. In the present work, an efficient model is proposed through which results are presented in the form of a graph. The converged result has been obtained by computing mean, covariance, eigenvalues, eigenvectors and new data set has been generated for the identification of fake currency. The contents of this chapter have been published in the **International Journal of Recent Technology and Engineering (IJRTE), (ISSN: 2277-3878), 8(3), 1-8, (2019) (Scopus).**

CHAPTER V

TEXTURE FEATURE ANALYSIS FOR IDENTIFICATION OF FAKE CURRENCY

In this chapter, a well-known method, Feature extraction is the most important technique in paper currency recognition. According to the reviewer, texture feature plays an important role in paper currency detection. Texture feature is generally a statistical-based approach and in the present work, a new model is proposed for paper currency detection. The presented model is computing the texture properties like Gray Level Co-occurrence Matrix (GLCM) of Rs 500 for real and fake currency. The

Principle Component Analysis (PCA) is used for the reduction of a higher dimension of an image. The proposed work provides a better result with the collaboration of PCA and GLCM. The texture properties have been used and GLCM measured the variation in intensity at a pixel of interest of the currency. The computed results have been presented in the form of tables and graphs. The contents of this chapter have been published in the **Recent Innovations in Computing, ICRIC 2020, Lecture Notes in Electrical Engineering (LNEE), ISBN NO (978-981-15-8296-7), 701, 695-706, Springer, Singapore, (2020).**

CHAPTER VI

GENETIC ALGORITHM APPROACH FOR FAKE CURRENCY IDENTIFICATION

From time to time there is the arrival of new currency in the form of different currency along worldwide. In India demonetization was recently applied in 2016 and later there was the arrival of new notes of Rs. 50, Rs 100, Rs. 500, Rs. 2000. Although it minimizes the use of fake currency, hackers and intruders generate the fake currency via the use of a high-quality scanner and printer. In this chapter, an application of the Genetic Algorithm is applied for fake currency identification based on feature extraction. The steps of the Genetic algorithm are used for the solution of currency identification problems will the current problem. The contents of this chapter have been published in the **International Journal of Future Generation Communication and Network (IJFGCN), (ISSN: 2233-7857), 14(1), 644-651, (2021). (ESCI)**

CHAPTER VII

NEURAL NETWORK APPROACH FOR CURRENCY IDENTIFICATION

In this chapter, a novel method for currency identification is based on the feature extraction method using Machine Learning Algorithm. The proposed system can

identify the legitimacy of currency by checking specific security features such as watermarks, latent images, security threads, etc. Identification of counterfeit currencies is done using Machine Learning Techniques. The methodology involves extracting and encoding these security features. Security features are extracted from the input image, feature detection and classification are performed using different Machine Learning Algorithms. The ultimate aim of this approach to calculate the accuracy of the distinct method of Machine Learning. In the end, this method improves the accuracy of currency identification. The contents of this chapter have been communicated for publication in International Journals.

CHAPTER VIII

CONCLUSIONS AND FUTURE PERSPECTIVES

This chapter is emphasized on the security strength for the new arrival notes of currency in the Indian scenario. Although the digital transfer of money is very easy it may lack security features as nowadays as internet frauds are increasing. The work shall also be emphasized on this approach. The outcome of the work shall be helpful for software industries for implementation of the proposed research models in the Indian Market. From future perspectives, this work can be extended for newer Indian currency with the other important security features of currency.



CHAPTER I

Introduction

CHAPTER I

INTRODUCTION

1.1 CURRENCY AT A GLANCE

From ancient times, currency has played a very crucial role in human civilization. With the change of time, its presentation view has been evolved. Generally, the term currency is a medium of exchange or standard parameter or a value, which provides the facility of goods and services. Earlier, the medium of exchange was developed based on valuable things such as animals, precious heavy metal in way of ingots and later coins then credits, paper money and currently digital currency. The concept of money as a commodity was removed by Fiat money and promises the value stated on it.

1.2 WORLD CURRENCY

The term world currency is also known as the global currency, which is used in the transaction at the International market. The world currency is also used in the foreign exchange and the International market and it has no limitation. Since the mid-20th century, the dollar and euro have been present in the world as a primary world currency, which is shown in figures 1.1 and 1.2, respectively. According to the survey, between 40% and 60% of the worldwide, foreign exchanges are dealt in the dollar.



Figure 1.1 Dollar Currency [190]



Figure 1.2 Euro Currency [191]

1.3 INDIAN CURRENCIES

Money is any object or record that is typically time-honoured for the payment of items and services and the repayment of money owed in a particular socio-economic context or country. The currency of India is the Indian Rupee (INR). The word "rupee" originates from the Sanskrit word rup or rupa meaning silver. Sher Shah Suri (1486-1545) introduced the very first rupee, which has a ratio of 40 copper pieces (Paisa) per rupee. The name is derived from the Sanskrit word raupyakam, which means silver. In the 18th century, private banks such as - the Bank of Bengal, the Bank of Bombay and the Bank of Madras began the process of issuing paper currency. The Indian government was provided with a monopoly on printing currency after the paper currency act of 1861. The Government of India (GOI) has introduced paper currency in the form of Rs 10 in 1864, Rs 5 in 1872, Rs 10,000 in 1899, Rs 50 in 1905, Rs 500 in 1907, Rs 1,000 in 1909, and Rs 1 and Rs 2^{1/2} in 1917 that represented in table 1.1.

Table 1.1 History of Paper Currency

Year →	1864	1872	1899	1900	1905	1907	1909	1917
Currency →	Rs 10	Rs 5	Rs 10,000	Rs 100	Rs 50	Rs 500	Rs 1000	Rs 1 and 2 ^{1/2}

The GOI has printed currency until RBI was established in 1935, assuming that accountability. By 1938, only Rs 10, Rs 100, Rs 1,000 and Rs 10,000 were issued. RBI issued notes Rs 5, Rs 10, Rs 20, Rs 50, Rs 100, Rs 500 and Rs 2000, also known as banknotes. With the demonetization printing of Rs 5 note was stopped. After the freedom, the ruling government of that time planned to remove the picture of George VI from the banknotes. The government has continued Rs 1 and also RBI also continued all different denominations including Rs 5,000 and Rs 10,000. Rs 20 and Rs 50 banknotes were introduced in the year 1970. Currencies that were more than Rs 100 stopped in the year 1978. By 1987, Rs 500 notes were introduced trailed by Rs 1,000. Meanwhile, Rs 1 and Rs 2 notes were stopped in the year 1995. The central government had approved the design of the currency which was recommended by RBI's central board. In India, currency notes are printed by three important presses which are- Currency Note Press in Nashik, the Bank Note Press in Dewas, the Bharatiya Reserve Bank Note Mudran (P) Ltd. at Salboni and Mysore and the Watermark Paper Manufacturing Mill in Hoshangabad. RBI issues Mahatma Gandhi series banknotes on which the picture of Mahatma Gandhi was printed on the front side of the note. In 1996, all lion capital series banknotes were replaced by the Mahatma Gandhi series and introduced notes of Rs 10 and Rs 500. In the year 2009, Rs 5 note printing was started. The denomination was written in 17 languages on each banknote. On which Hindi and English denominations were written on the front side and remaining on the backside which shows the diversity of India. The Indian currency denoted by a word such as 'Rs' or 'INR', is an abbreviation of the Rupee. In the year 2010, the design of Rupee was finalized by the Reserve bank of India (RBI). In the year 2012, the new ₹' symbols of the rupee were fused into Mahatma Gandhi series banknotes in sections of ₹10, ₹20, ₹50, ₹100, ₹500 and ₹1,000.






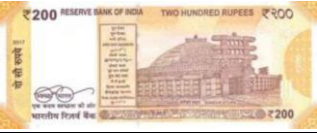



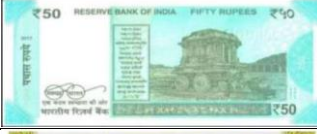

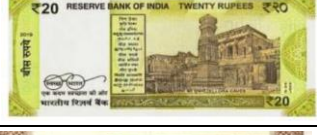


DENOMINATION	AVERAGE SIZE	OBSERVE FACE	REVERSE FACE
₹ 2,000	66mm x 166mm		
₹ 500	66mm x 150mm		
₹ 200	66mm x 146mm		
₹ 100	66mm x 142mm		
₹ 50	66mm x 135mm		
₹ 20	63mm x 129mm		
₹ 10	63mm x 123mm		

Figure 1.3 New Currency Arrived in India

1.4 INDIAN CURRENCY DEMONETIZATION

Demonetization is the process of withdrawing a particular note from the market. If RBI introduces any change in the banknotes then demonetization plays a very important role [192]. The old note will be replaced by the feature of a new note. Demonetization is necessary for every country because this is a direct or indirect way to remove black money from the market. However, this is the best approach by the government to remove black money from the market. Earlier, demonetization was occurred several times, the first time in January 1946, the second time in January 1978 and recently it is

done in November 2016. In 1946 demonetization, Rs 1000 and Rs 10,000 notes were removed [188]. In 1978 demonetization, Rs 1000, Rs 5000 and Rs 10,000 were removed to eliminate the counterfeit note from the market. On 8 November 2016, the Indian Prime Minister Narendra Modi had announced to stop the circulation of Rs 500 and Rs 1000 notes of the Mahatma Gandhi series and also launched new Rs 500 and Rs 2000 note of the Mahatma Gandhi series as shown in figure 1.3 on pre page.

Demonetization has three most important objectives:

- ☞ To fight against black money;
- ☞ To find counterfeit notes;
- ☞ To promote Cashless transactions or Digital transactions.

Black money means money that has no record in the banking system or no tax paid to the state. According to RBI, approximately 99% of the money is invalid or black money. Out of Rs 15.41 lakh, an invalid note has come back from Rs 15.31 lakh note and another related reference is [131].

Another main objective of demonetization is to find counterfeit notes. In 2016, when demonetization occurred in India, then 6.32 lakh fake notes were detected. As per RBI records, the number of fake notes reached 18.87 lakh till the year 2020 as shown in figure 1.4.



Figure 1.4 Statistics of Fake Note in India [193]

After demonetization, the highest number of fake currency recovered in the category of Rs 100 that is 1.7 lakh in 2019-20, 2.2 lakhs in 2018-19 and 2.4 lakh in 2017-18. Compared to the previous year, the amount of fake currency increased denomination of Rs 10, Rs 50, Rs 200 and Rs 500 respectively 144.6%, 28.7%, 151.2% and 37.5% as per RBI records.

Another objective of demonetization is a cashless or digital transaction. According to RBI data, the currency in circulation is increased after the demonetization as shown in figure 1.5. It has increased from 16.4 lakh to 24.2 lakh in the year 2016 and from 9 lakh to 11.60 lakh in the year 2020.

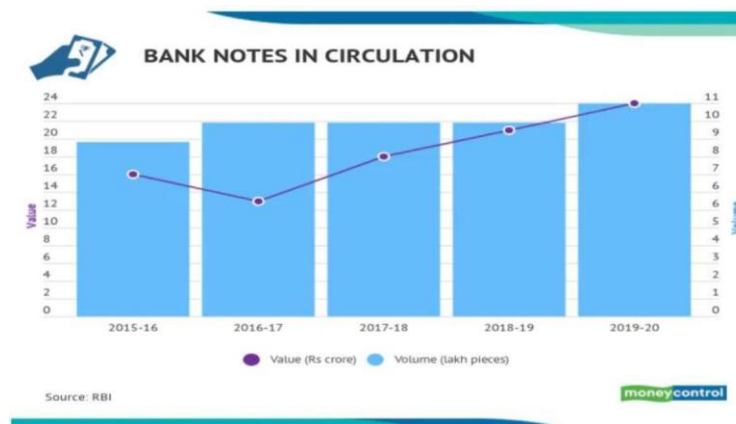


Figure 1.5 Indian Currency in Circulation [193]

1.5 FAKE CURRENCIES IN INDIA

Technology is rapidly growing for the conversion of physical currency into digital currency due to the availability of fake currency in the business market. In some of the countries, it has been implemented but in some countries around the world is suffering due to the availability of fake currency. Currency replication is the most important threat in the business market. Currency replication is also known as counterfeit currency or fake currency, which is presently questioning due to sophisticated techniques such

as printing and scanning. Due to counterfeit notes, India is facing many problems and challenges in the business market. Many researchers have been encouraged to develop robust and effective currency detection machines. In November 2016, Prime Minister of India Mr. Narendra Modi announced that existing rupee notes of 500 and 1000 cease to be valid currency and that step is taken to rein black money and forged currency in the country. The Prime minister also launched new rupee 500 and 2000 notes and discontinued the existing rupee of 500 and 1000 notes [145]. In the year 2017-18, according to an annual report published by the Reserve Bank of India (RBI), fake currency note detection has been dropped 31.4% as compared to the previous year due to the high- security feature of note-making forged difficult. In the Indian economy; Fake Indian Currency Note (FICN) is a term used by officials and media to refer to forged currency notes. In 2012, in response to a parliamentary inquiry, the Finance Minister, P. Chidambaram stated that there was no confirmed estimate of forged currency in India. However, there are several states and central agencies that work together and the Minister of Home Affairs has included the Fake Indian Currency Notes Coordination Centre (FCORD) to check the problem.

1.6 SECURITY FEATURES OF INDIAN CURRENCIES

The most recent plan of the banknotes is as opposed to the old Mahatma Gandhi Series as far as shading, size and theme. The theme of the new arrangement notes is India's legacy destinations. There are different security highlights consolidated into the banknotes to ensure them against duplicating as demonstrated in below figure 1.6. Consequently, the validness of an authentic currency note is predicated based on these security highlights.



Figure 1.6 A Sample Note of Rs 500 (a) Obverse (b) Reverse [194]

For Indian Banknotes, there are some important security features of Indian currency in a sample note of Rs 500 as follows in two parts:

☞ Obverse

1. See-through register
2. Latent Image
3. Denominational numeral in Devanagari
4. Watermark
5. Micro Letter
6. Security thread
7. Guarantee Clause
8. Mahatma Gandhi Portrait and Electrotype Watermark

9. Number Panel
10. Denominational Number
11. Ashok Pillar emblem
12. Some features for visually impaired
 - ☞ Bleed lines;
 - ☞ Circle with 500 raised (Rectangle for 2000).

☞ **Reverse**

13. Year print on the left side of the note
14. Logo of Swachh Bharat
15. Language Panel
16. Motif of Red Fort
17. Denominational numeral ५०० in Devnagari

1.7 ROLE OF IMAGE PROCESSING IN INDIAN CURRENCY IDENTIFICATION

A digital image consists of pixels that on the screen can be considered as tiny dots. A digital image is a colouring instruction for each pixel [91] [168]. Normally, an m-by-n image is made up of m pixels in the vertical direction and n pixels in the horizontal direction. Suppose an image on format 512 by 512 pixels. That means the data for the image contains information about 262144 pixels, which require a lot of memory. Hence, image compression is the most important technique of image processing. There are different formats supported of an image like BMP, HDF, JPEG, PCX, TIFF, and XWB. If an image is stored in a JPEG format, firstly read the image into MATLAB. Then it used the different formats as follows:

Gray Scale Image: An Image is always represented in the form of a matrix with a value for each component that represents the corresponding value to bright and dark that is

colored. There is the two way to a representation of the brightness of the pixels: One is a double class that assigns the floating number (“a number with decimals”) between 0 and 1 to each pixel. Then the value 0 is black and the value 1 is white. Another class that assigns the value between 0 and 255 is called uint8.

Binary Image: An image is stored as a matrix by this image format, but can only color (and nothing in between) a pixel black or white. It assigns 1 for white and 0 for black. The image is generally stored in matrix form but this image format pixel represents in black or white. It represents 0 for black and 1 for white.

RGB Image: This is another colour image format. It is an image with three size matrices that match the image format. Each matrix matches one of the colours red, green, or blue and shows how many of these colours a certain pixel should use.

Image processing is the procedure portrayal and information analysis and control of numerical information outwardly contained in an advanced image to upgrade its visual structure. From side to side image processing blurred pictures can be upgraded, clinical images explain, and satellite photos normalized. Image processing programming can likewise interpret numeric data into visual images that can be altered, upgraded, sifted, and enlivened.

In this method, the image information is digitized and distinctive mathematical activities are ordinarily applied to the information with a digitalized PC, to make an improved picture that is increasingly helpful or satisfying to a human passerby, or to play out some of translation and recognition undertakings normally performed. Likewise, it is named image processing [59].

1.8 COMPUTATIONAL METHODS

1.8.1 GENETIC ALGORITHM

Some of the research work is based on the concept of Genetic algorithms, and hence there is a need to describe the concept of Genetic algorithms in brief. In the year, 1968, Charles Darwin developed a theory based on the biological evaluation that states the natural existence of the strongest species. This was based on the natural selection of small inherited variation for increasing the individual ability to compile, survive, and reproduce. Based on this theory, the concept of the genetic algorithm was developed by Goldberg. Genetic Algorithms are the heuristic search and optimization techniques that mimic the process of natural evolution. Some basic steps for the genetic algorithm to optimize the solution of any problem:

1.8.1.1 Selection

The primary objective of the selection operator is to emphasize the good solutions and eliminate the bad solutions in a population while keeping the population size constant. Selects the best, discards the rest .”

There are the different techniques to implement selection in Genetic Algorithm:

- ☞ Tournament selection
- ☞ Roulette wheel selection
- ☞ Proportionate selection
- ☞ Rank selection
- ☞ Steady-state selection, etc.

1.8.1.2 Crossover

The most popular crossover selects any two solutions strings randomly from the matting pool and some portion of the strings is exchanged between the strings. The selection point is selected randomly. A probability of crossover is also introduced to give freedom to an individual solution string to determine whether the solution would go for crossover or not. The process of crossover is shown below in figure 1.7.

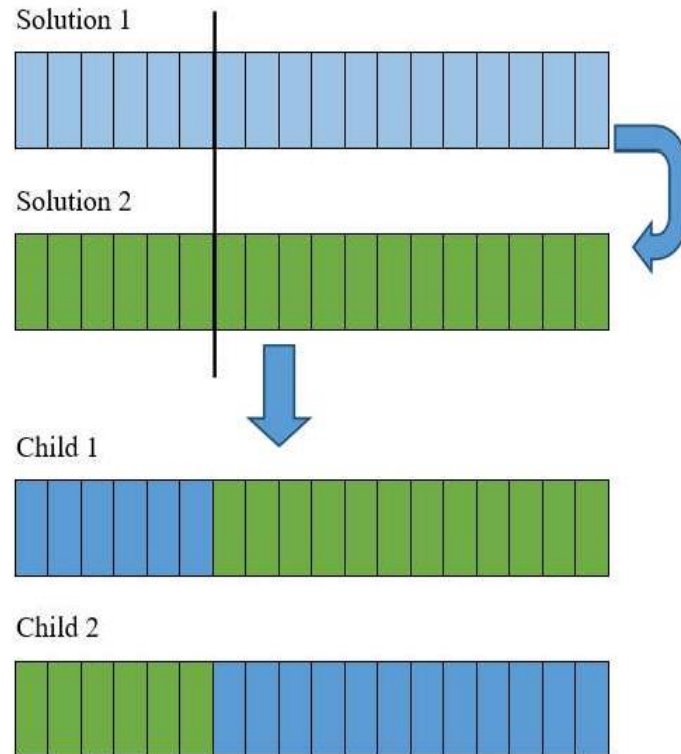


Figure 1.7 Process of Crossover

1.8.1.3 Mutation

The mutation is the occasional introduction of new features into the solution strings of the population pool to maintain diversity in the population. Though crossover has the main responsibility to search for the optimal solution, the mutation is also used for this purpose as represented in figure 1.8.

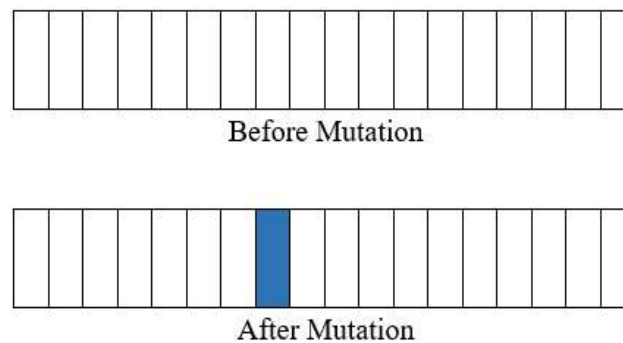


Figure 1.8 Process of Mutation

1.8.2 PRINCIPLE COMPONENT ANALYSIS

Principle Component Analysis (PCA) is a method of identification of data patterns in which data are expressed to highlight similarities and differences. Once the pattern is found in the data, it can be compressed i.e. reduced the number of dimensions without losing much information. So we detect and visualize the small data in a very easy way. The effective results have got with the help of a machine learning algorithm. In figure 1.9 represented the steps of currency detection with the help of the PCA method.

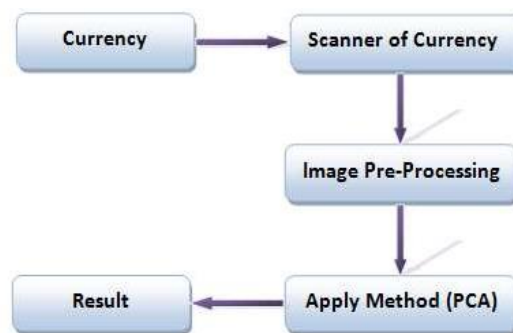


Figure 1.9 Representation of PCA Technique

1.8.3 TEXTURE FEATURE EXTRACTION

Feature extraction is the most important technique in paper currency recognition. Texture feature is generally a statistical-based approach and in the present work, a new model is proposed for paper currency detection. The presented model is computing the texture properties like Gray Level Co-occurrence Matrix (GLCM) of Rs 500 for real and fake currency. The process of feature extraction is shown in figure 1.10.

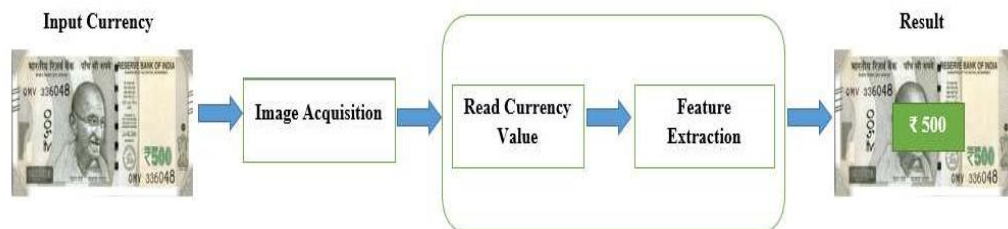


Figure 1.10 Process of Feature Extraction

1.8.4 NEURAL NETWORK TECHNIQUE

One of the techniques is Neural Network which is part of a machine learning algorithm. The proposed Neural Network method has trained according to the color and texture features of a currency. These properties have shown the uniqueness of currency. The input of the model is properties of currency on which basis model divides the dataset into training, testing and validation. The neural network approach gives better results in comparison to a previous technique used in currency recognition research.

1.9 COMPUTATIONAL TOOLS

1.9.1 UNIFIED MODELING LANGUAGE (UML)

The concept of object-oriented technology is also used in the present work. Let us describe the concept of modeling which stands for designing the structure before its development. Modeling solves several critical aspects related to developing structure. It helps to understand the complexity, assists in detecting and omitting the errors, and to understands the different requirements needed in developing the architecture. Along with all these features, the allocation of resources can also be utilized through the design process. Using a model, one can assure that the functionality and all the end-user requirements are easily possible to meet out as well as this design will support scalability, robustness, security, extendibility, and other characteristics. The role of modeling becomes more and more important as the size of the domain increase because large software projects are most vulnerable to failure since they are more complex than small projects. Modeling also plays an important role in the reduction of the cost factor. To perform the modeling of the architecture a well-known modeling language Unified Modeling Language (UML) is used which is a standard language based on the features of visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system. It is considered to be a blueprint in software development and speeds

up the software development process. It captures the object-oriented software information and the business rules information. Business rules describe the interfaces between systems and components. UML fulfills the requirement needed for a general understandable communication mode which should be language and platform-independent. UML assists in better communication among different components of the architecture development processes. It is a graphical language that clarifies and refines the ideas that spoken language may not be adequate to cover. The graphical notations used in UML sound more and remains everlasting impact compared to that of spoken or written problem specification. Such notations help the persons with even basic knowledge of programming to participate in the development process like gathering requirements through communication among the individuals in a very easy manner using just a few easily learned notations of the UML. By using modeling, one can visualize all design-related issues and check them against the user requirement before starting to code that design. Unified Modeling Language (UML) describes the artifacts of a software system and it focuses on conceptual and physical representations. The present work is based upon the Unified Modeling Language (UML) for the various software and hardware issues related to a fake currency identification system. Therefore, it is necessary to give a brief overview of UML.

History of UML

Earlier the development of the software was done directly without the use of any modeling language for its design. This causes lots of problems related to delay of project completion time, wastage of cost factor due to lack of proper and easy communication among the individuals in the development process. This problem came to end as the software professionals started moving towards using the standard modeling language to get assistance in designing and developing the software systems.

In 1994, James Rumbaugh left the Journal Electric and joined the Rational software corporation. His joining results to be a turning point for the Rational as now this cooperation evolved two most popular object-oriented approaches Rumbaugh's OMT dedicated towards object-oriented analysis and Grady Booch's methods as object-oriented design. As the tie passed, both Rumbaugh and Booch's had merged their approaches and started their work on a unified method.

In the year 1995, one more scientist named Dr. Ivar Jacobson had joined the Rational. His joining is considered to be a new life towards the UML approach and the three methodologists were collectively referred to as three Amigos. They had combined their design methods into one set of notations and performed their efforts towards the standardization to object modeling.

In 1996, an effort of the greedy Booch James Rumbaugh and Ivar Jacobson resulted in the formation of an international consortium that starts the UML specification. Now the development of non-proprietary unified modeling language came to existence with the help of these three Amigos, during OOPSLA 96.

In 1997, the first version of Unified Modeling Language i.e. UML 1.0 was released and UML 1.1 was released after integrating it with some other standardization efforts and it is adopted by the Object Management Group (OMG).

Slowly-slowly as time has passed, UML has launched its different version after several minor revisions in the original form of UML and these came to be known as UML 1.3, 1.4, and 1.5. These versions have fixed all the bugs with the first version of UML, followed by UML 2.0 major revision, a current OMG standard. The first part of UML 2.0, the superstructure was adopted by OMG in October 2004, later on, the other part notably the infrastructure, the object constrained language (OCL), and diagram interchange was rectified in November 2005. The UML version 2.1.1 was adopted in

August 2007 and is available in the form of XML 2.1. Currently, UML version 2.1.2 is also available with OMG. Later on, 2.2 and 2.3 were also launched and finally, UML 2.4.1 version also arrived and was considered to be formally released in the year 2011. Object Management Group (OMG) has provided a new modeling language to the software industries named Unified Modeling Language (UML) which assists in designing, developing, and deployment of quality computer applications. Major companies and individuals have influenced the unified modeling language.

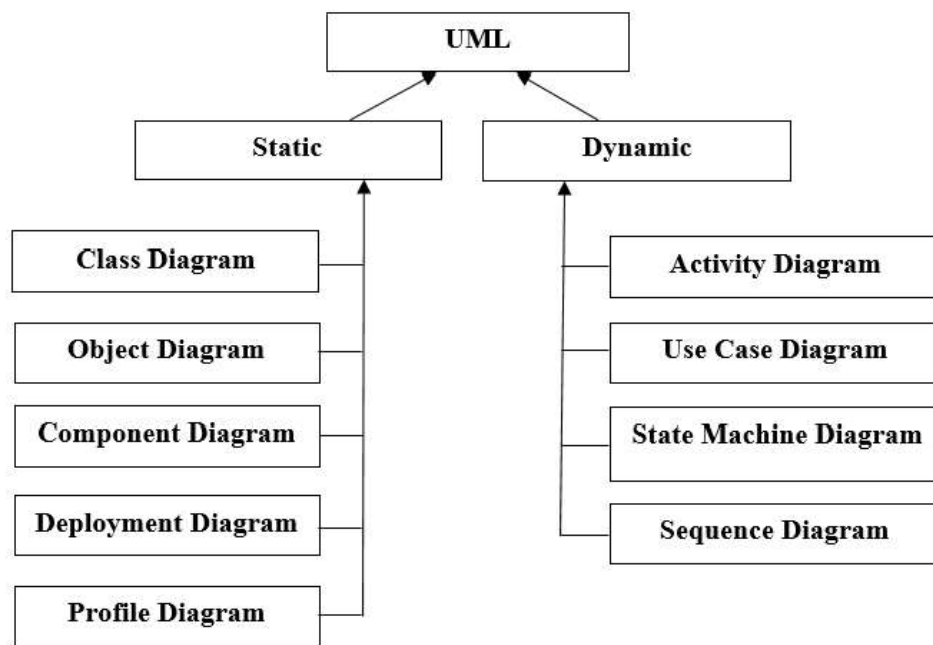


Figure 1.11 UML Classification

1.9.1.1 Structure Diagrams of UML

A Structure diagram is one of the types of UML diagrams as shown above in the UML classification figure 1.11. Structure diagrams are used to represent the static part of software modeling. Such diagrams mainly emphasize the things used to model the system and are being modeled along with relationships and dependencies among elements. Some of the important structure diagrams, which we used in the research, are describe below:

1.9.1.1.1 Class Diagram

It is used to describe the static structure of a system and is considered a backbone of UML. With the help of the class diagram, one can represent the different types of classes in the problem domain along with the existing relationship among them. The class diagram contains the description of the attributes i.e. properties and the operations i.e. methods going to be performed in the problem domain. In general, a class diagram represents a graphical view of the system, which is going to be developed. In other words, a class diagram represents an abstraction of entities' common characteristics. The general syntax of the UML class diagram is shown in figure 1.12. The attributes are represented in the figure and play a specific role in process execution. The general syntax of the UML process class is shown below in figure 1.13.

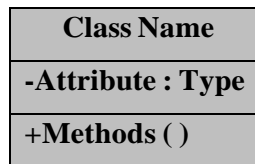


Figure 1.12 A General Syntax of UML Class Model

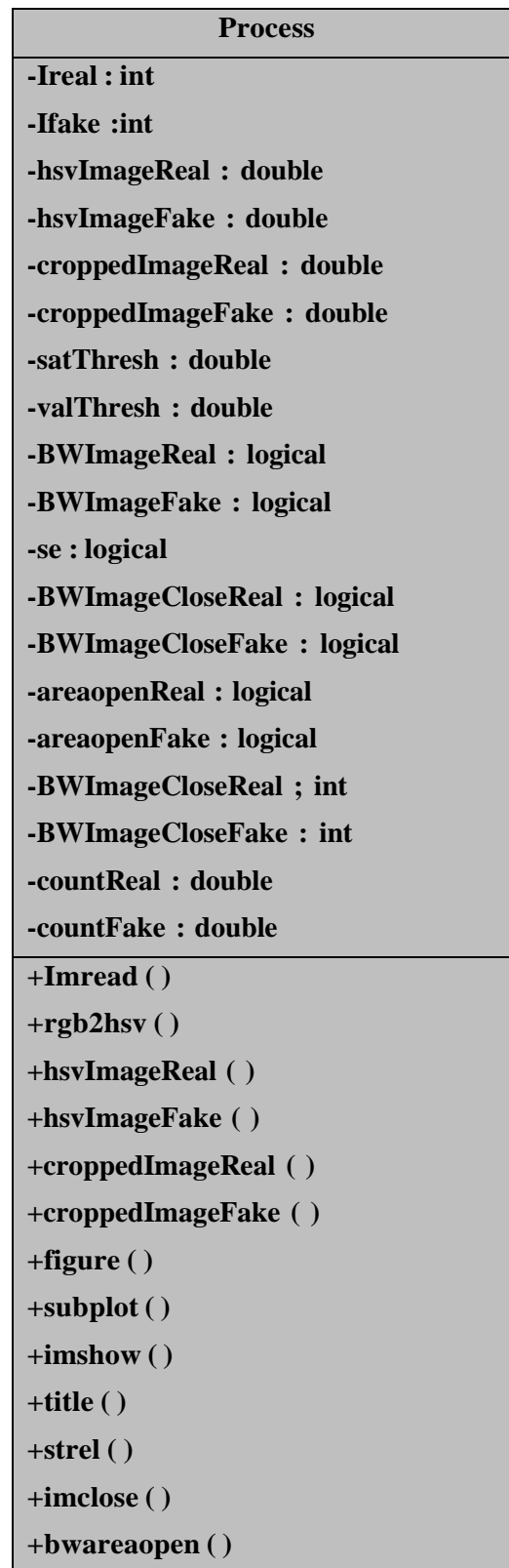


Figure 1.13 A General Syntax of UML Process Class

1.9.1.2 Behavior Diagram of UML

Behavior diagrams are used to show the functionality of the system. They modeled the dynamic behavior of the software systems. One can easily detect process flows among various objects and components in the system using the behavior diagram. The behavioral diagram used in modeling the system is in the form of an activity diagram.

1.9.1.2.1 Activity Diagram

These diagrams play a very important role in modeling the dynamic nature of a system by representing the flow of control from activity to activity. Activity can be defined as the occurrence of an operation on some class, which results in changes of the currently existing state of the system. The activity diagram is shown below in figure 1.14. The above activity diagram shows the formulation of the appropriate population by implementing the genetic algorithm concepts. An initially created population formed by the set of chromosomes and gens, as shown above, is taken for checking of its fitness value. The fitness value of chromosomes of the selected population is compared among themselves with the process of evaluation, selection, crossover, mutation. If the fitness value is valid then the selected best chromosomes are allowed to take part in the formation of the next population generation otherwise they are ignored.

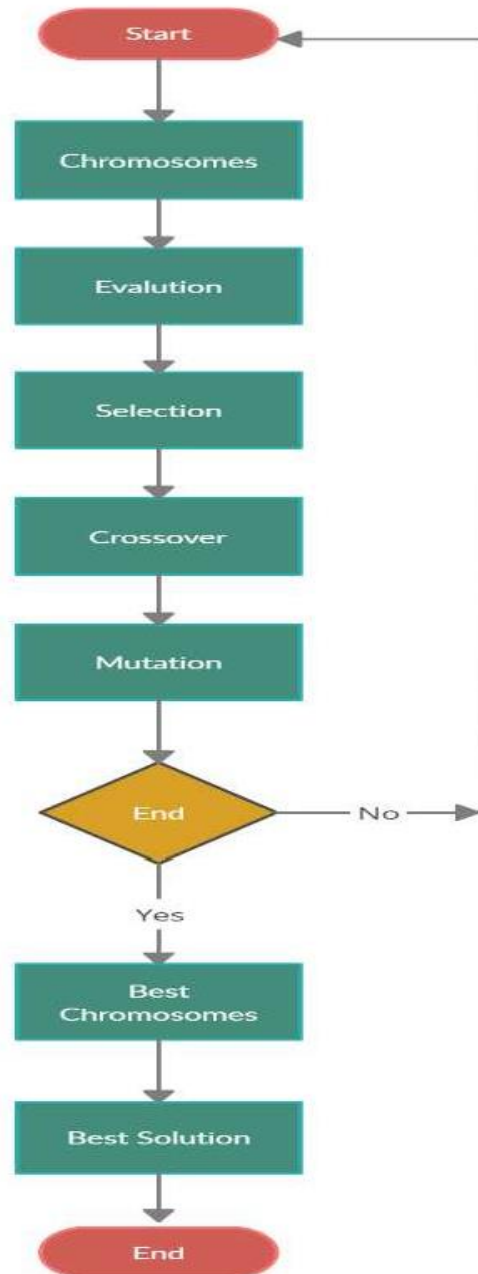


Figure 1.14 Representation of Activity Diagram of Concept of Genetic Algorithm

1.9.2 MATLAB

In the present work, MATrix LABoratory (MATLAB) tool is used for the representation of results which is a software of Library that is used for designing for finding these kinds of features in the availability of currency. There is so many

securities feature of Indian currency that is based on generally color, size, and some Identification marks. Color is the most important feature of currency recognition. MATLAB is a very significant tool designed with a mathematical background and capable of doing numerical computations, display data graphically, and solving many other technical and scientific issues [168]. While working with a MATLAB image, there are many different things to remember, for example loading an image in the right format, saving the data as various conversions between various image formats, and so on. MATLAB is generally a computational tool for research, development, and analysis. This tool has supported all types of image formats like BMP, HDF, JPEG, PCX, TIFF, XWB, PNG, etc. In present time characteristics, extraction of Image is very challenging work in the field of Digital Image Processing.

CHAPTER II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

This chapter aims to analyze the currency detection techniques, approaches, ideas, and standards from the field of fake currency identification. It provides a high-level overview of the relevant state of the art in this area, the achievements in search, limitations, and problems. Fake Currency identification has been the focus of the research community for the last decade. There has been a large amount of work done for currency detection, the work for a new currency has just begun. From the literature, it is revealed that many researchers have done work on the identification of fake currency. Let us explain some of the important references. To make it simple and easy to understand we have divided the related work into two sections:

2.1 FOREIGN CURRENCY IDENTIFICATION

In the year 1995, Takeda and Omatu [152] have provided a framework that improves the accuracy and speed of the U.S. and Japanese currency recognition. Authors have used two datasets such as series data and Fourier power spectra as an input of Neural Network. This design is generally using the subset of the main data which is obtained by the random masks. Here discussed the result between main data and subset data and also a comparison between the subset data to Fourier power spectra and time series. In the year 1996, Frosini et al. [52] have designed a model that recognizes and verifies the different countries' currency using a neural network approach. This system gives a very appropriate result using the low-cost sensor.

In the year 1998, Leelasantitham et al. [88] have proposed a method for Thai currency detection based on the watermark feature. The watermark feature has been identified

by correlation mapping to the border of the testimonial image. Then entered the position value of the watermark to the neural network for verification. This practical approach applies to the different types of value of a currency. After classification, the model is trained and gives 99% accuracy.

In the year 2000, Takeda [151] has designed the system for Euro currency recognition. They used the axis-symmetrical mask and two image sensors. First, the proposed system tested on a duplicate copy of currency then it applied to daily life currency. In the year 2003, Ahmadi et al. [5] have studied the reliability of US (dollar) paper currency. They used the Principle component analysis (PCA) for feature extraction and with the help of the model has mapped the data and variables. Aoba et al. [16] have also proposed the NN model for the US bill. They told that the NN model is based on three layers. The infrared image takes as an input in the NN model then visible all features of the bill. On that basis, calculated the acceptance and rejection rate of bills. Takeda et al. [153] have described the importance of the NN model in the field of banking application. This approach is based on the Thai bill. They said that take the bill as an image and get slab value in the form of pixel mask value. Then it merges with the non-masked value of the bill. At the last slab, the value provides input in the NN model and trains it. For the verification of the model, it applies to the DSP unit. Zhang et al. [180] have proposed the neural network (NN) model for RENMINBI (RMB) china currency identification. They explained this model gives the best result if use variation in the value of a currency. As input in the NN model has used the different characteristics of a currency. The result of the experiment was satisfactory.

In the year 2004, He et al. [65] have provided a framework for Scotland currency validation based on optimization technique Genetic Algorithm (GA). Ahmadi et al. [6] have explained a method that is based on PCA which increases the reliability of the

recognition system and the proposed system recognizes the six different types of bills of US dollars. Firstly, the image is captured by the Line sensor, then, the image is extracted with the main feature and decreased the dimension of the image using the PCA technique. It is used Linear Vector Quantization (LVQ) network and outcomes show that the dependability has been incremented up to 95% when the PCA component and LVQ vectors are taken correctly to recognize the currencies for Australian blind people.

In the year 2006, Hinwood et al. [68] have introduced a device for blind people to identify the Australian currency. In the year 2007, Hassanpour et al. [64] have explained a novel technique for banknote recognition, which is based on currency characteristics such as color, size and texture. With the help of a histogram, input currency has been compared to the reference currency. The authors introduced the model design of paper currencies based on the Markov chain concept. The proposed methodology can be used to identify the paper currency of different countries. With an example of paper currency for the training system, but they tested over 100 denominations from a different country. The proposed system recognizes 95% correct data.

Yoshida et al. [178] have presented the design of a machine vision-based paradigm which gives the real-time address of fake Bangladesh banknotes. The proposed system works based on a distinct feature of five hundred and one hundred taka. It is not possible for fake note manufacturers to make fake notes based on this feature and there is no possibility that they will follow this feature for a long time. According to the author, a special feature "BANGLADESHBANK" is printed on some parts of the note. In the proposed system, the authors first capture portions of the note through the Grid scanner, then this captured image has processed by the microcontroller PIC-16F648A. Then the microcontroller looks for the characters i.e. δ , α , and

dasianNpsila in the scanned image and checks the validity of the note through the OCR technique. The success rate of spurious detection with properly captured images is 100% and the average processing time is 250 ml seconds with the microcontroller mentioned above.

In the year 2009, Hassanpour et al. [63] have proposed an efficient technique for different countries' currency recognition with the help of Hidden Markov Models (HMM). This approach has given the high accuracy of paper currency detection. In the year 2010, Roy et al. [130] have provided the framework for authenticating the printing process in the currency with the help of the pattern recognition method.

In the year 2011, Bhattacharyya et al. [29] have done a relative analysis of data mining for credit card fraud. The authors proposed two advanced data mining techniques for better card fraud detection; with logistic regression. This study is based on a real-life credit card case study. Qian et al. [116] have proposed a new technique of locating currency. The new technique is based on electromagnetic. Electromagnetic detection has led to a basic analysis of pulse eddy current technology, approach instrument design, for experimental result analysis and characteristic volume extraction. The advantage of the technology is based on pulse eddy current technology.

In the year 2012, Further, Fan et al. [50] have described the database end up outdated quickly and find out that different estimations of a similar substance exist in a database related to the currency. García-Lamont et al. [55] have Authors have introduced a method to identify the Mexican bills through the texture feature such as color and texture. The authors have also suggested using this model for other countries' currency recognition.

Hasanuzzaman et al. [62] have described that due to a rapid increase of blind employees and uses in the bank, a novel camera-based computer vision technology has been used to identify the banknotes for visually impaired people. The system helps in capturing the image of blind users. The proposed algorithm has been evaluating the dataset based on positive and negative images of U.S. banknotes. The recognition rate of the algorithm is true for 100% and false for 0%. This proposed system has some properties such as high accuracy, low false rate, less time. Rajaei et al. [120] have introduced a system that recognizes the Iranian and United Arab Emirates currency based on texture feature analysis. Authors have used texture features such as color, texture, size. First, input the image of the currency and then convert it into a matrix form. Based on matrix has got statistical moment values of texture in currency. Xin-Yan and Lin [169] have proposed money number recognition of China's currency based on its properties of number.

In the year 2013, Bruna et al. [31] have described the hardware and software-based low-cost system for detection of fake Euro currency provided by Italy's central bank. Feng et al. [51] designed the Renminbi Banknote (RMB) a serial number identification system. RMB is China's paper currency and the authors introduced a system that only extracts RMB Characters while scanning the China currency. They discussed two methods for locating the region containing the RMB serial number are skew correction and orientation detection. The detected text field is binomial by the throttling technique. An inverse averaging method is then introduced to extract the RMB character from the final result. Yan and Chamber [175] have proposed the prototype for digital Forensic currency. Texture feature has been used in the system which is input in the feed-forward network (FNN). It provides the comparison results between real and fake New Zealand currency. Yaseri and Anisheh [177] have proposed a system that also identified the

Euro currency with the help of image processing steps such as pre-processing and segmentation. After applying the image processing steps, the received value is called a feature vector. Then feature vector is input in SVM for currency identification. Yan and Lin [174] have described the Feedforward Neural Network for the identification of fake currency. Feedforward Neural Network has been taken with all the common features of banknotes then it compares with a suspect note.

In the year 2014, Ghazvini et al. [57] have provided a case study of the banknotes dataset using machine learning algorithms. The comparative results have been given between Support Vector Machines (SVM), Naive Bayes, and Artificial Neural Network (ANN). Ahmed et al. [7] have proposed a software system that detects the counterfeit Bangladeshi currency along with its features like micro-printing, optically variable ink, watermark, iridescent ink, security thread, and ultraviolet lines using OCR (Optical Character Recognition), Contour Analysis, Face Recognition, Speeded Up Robust Features (SURF) and Canny Edge and Hough transformation algorithm of Open CV.

In the year 2015, Ballado et al. [22] have developed an efficient system for Philippine paper currency recognition. This system is based on image processing and canny edge technique. Chambers et al. [34] have discussed currency security and forensics. In a currency security survey, the most common thread is a counterfeit note. Hijazi et al. [67] have proposed Convolution Neural Network (CNN) for image and pattern recognition. Lamsal and Shakya [86] have proposed a method for currency detection with the help of Image Processing. The Authors used the Color and Texture features of currency for Identification and recognition purpose. The Color parameter is calculated by the mean and standard deviation of sample images and the Texture parameter is calculated for a different set of databases. Then, a matching process is done between a sample and tested images. Mann et al. [90] have Authors have studied the comparison

of the security feature of different countries. The countries are India (rupee), Australia (dollar), US (dollar), China (renminbi), Italy (euro), and UK (pound). In the end, concluded the Indian currency has a maximum number of security features. One of the best security features is the anti-photocopying or "Omron" that makes the Indian currency unique. So it creates a disadvantage to counterfeiting. Sarfraz [135] has presented the Saudi Arabian paper currency recognition system. This approach is very efficient in terms of accuracy. Yan et al. [176] have generally designed a framework for automatic currency recognition based on color feature and texture feature. They suggested a Feed-Forward Neural Network (FNN) and find the similarity between samples and suspected banknotes.

In the year 2016, Abdallah et al. [3] have discussed a review paper on the Fraud Detection System (FDS) that represented the time test of detecting cheat in digital transmission systems. Authors have also told that along with the detection of fraud, fraud prevention is also important. Hlaing et al. [69] have used four approached, first input the image, second preprocessing, third is texture feature such as GLCM and the last one is recognition, which is k- Nearest Neighbor (k-NN) classifier. The identification system has given a satisfactory result for a large database of currency. Jyothi et al. [77] have proposed the Neural Network based system which identifies the different countries' currency. The proposed detection technique is based on the colour, text and shape feature of currency, which applied the Neural Network model.

Shoeb et al. [142] have created a system to identify the fake currency that separates it from the real note. This approach, includes image processing, histogram, color moments, and texture feature. The results have shown in the form of a histogram, statistical analysis that distinguish real and fake Egyptian note. Uddin et al. [158] have designed a machine to identify the Bangladeshi currency taka, which identifies it based

on the security parameters of the currency with the help of Image processing and Support Vector Machine (SVM). The author has also described the pros and cons of a machine for improving the security of taka.

In year 2017, Abburu et al. [2] have Authors have designed a currency identification system. Image processing techniques have been used to identify the features of currency such as color, size, and texture. Authors have used 20 countries' currencies. Almu and Muhammad [11] have proposed the Nigerian Naira currencies recognition system. This system used Image processing techniques and in the end, after the system developed then also have taken the feedback of the users. Doush and AL-Btoush [47] have prepared the Jordanian currency dataset and applied the SIFT algorithm on it using a mobile phone. Then has developed an automatic mobile currency detection system. In the end, it has provided the difference between color SIFT and Gray SIFT algorithms. Elmurngi and Gherbi [49] have given the comparison result between the different supervised algorithm includes Naive Bayes (NB), Support Vector Machine (SVM), k-Nearest Neighbors (k-NN), and Decision Tree. The best result is SVM machine learning that gives better accuracy of currency detection. Lee et al. [87] have presented the report concerning the four research fields such as banknote recognition, fake banknote recognition, serial number recognition, and fitness classification and in the area of banknotes recognition, it has told the advantages and drawbacks of various sensors in ATM. Omatu [103] has described the features of Singapore Dollars. Based on these features have identified counterfeit currency using spectral sub-band. Pham et al. [109] have proposed the genetic algorithm-based system which identifies the different countries' currencies. This system has captured the different regions of currencies by Visible-Light Line Sensor. Then applied the GA algorithm to optimize

the similarity mapping of a different class of currencies. Experimental results of the proposed system have given better accuracy using different currencies.

In the year 2018, Akter et al. [9] have proposed a low-cost system for Bangladeshi currency identification with the help of supervised methods. The model based on colour, texture and edge features gives better results in comparison to previous methods. With the help of Euclidean distance have calculated the distance between the features of an input image and template image of currency in the proposed algorithm. Ansari and Mahraj [14] have proposed a robust method for the Pakistani currency recognition system. This method is Otsu's thresholding, which identifies the identification mark of currency. The effect of this method has been shown in different values of a currency and received better results. Aulia et al. [19] have proposed the Saudi Paper Currency Recognition (SPCR) system. The SPCR system analyzed the different patterns of various denominations such as 1, 2, 5 and 10, and present the comparison results between the Geometric and Grayscale templates. Dhar et al. [44] have proposed a fusion technique that identifies the Bangladesh currency. This fusion technique has included the SURF, LBP, and SVM methods. First, extract the feature of currency based on the SURF and LBP method then trained them with an SVM classifier. The result of the proposed system is 92.6%. Jara et al. [76] have explained a new approach for counterfeit currency detection. A new approach is that a portable X-ray fluorescence (pXRF) recognizes attributes of the fake currency that is generated by a counterfeiter. In this experiment, a genuine note correlation value is 1 but the fake note has no correlation value. Thus, this approach is very efficient for the currency detection field. Kogilawanee and Ramanan [80] have discussed a new approach in the direction of Sri Lanka currency recognition. The recognition steps have included feature extraction such as color, texture, and dots, of currency. Soe et al. [147] have

described a method of Myanmar currency detection. This method includes the recognition and counting phase for currency. Thus, this approach has provided a better recognition system as well as a counting machine. Tessfaw et al. [154] have proposed an image processing-based approach with the help of SVM for Ethiopian currency detection. The Features extracted from the Ethiopian currency using the local binary technique then applied classification algorithm on it. Finally, the accuracy of the proposed technique is 98% that is a high-performance rate. Zhang and Yan [181] have provided a framework using neural networks with the help of the multi-approach method to detect New Zealand currency. Authors have proposed a deep learning and convolution neural network for gaining better results in the area of foreign currency detection.

In the year 2019, Alnowaini et al. [12] have proposed a new automated system that detects the Yemeni currency. This system is based on image processing and Machine learning technique which includes the image acquisition, pre-processing, feature extraction, classification and recognition steps. On that basis, authors have given comparative results between genuine and suspected currency. Hardani et al. [61] have extracted the feature of Indonesia currency with the help of the GLCM technique and have been verified by the k-NN algorithm. The results have been shown with high accuracy to recognize the currency. Pham et al. [110] have proposed Convolutional Neural Network (CNN) based architecture for different countries' currency. The authors used a dataset of different notes like Indian note (INR), Korean won (KRW) and the United States dollar (USD). Experimental results of the proposed system have given better accuracy using different currencies. Sufri et al. [148] have proposed the neural network approach for Malaysian Ringgit currency detection. Swami et al. [150] have proposed a method for fake currency detection with different approaches. Based on

Image processing and MATLAB application, fake and real currency were identified. The proposed system is for blind people so that they can recognize the currency without any help and do their work. It is an effective approach to blind people. Authors have extracted the color feature of note then applied k-Nearest Neighbors (k-NN), Decision Tree Classifier (DTC), Support Vector Machine (SVM) and Bayesian Classifier (BC) for each denomination class of notes. Vijayakumar et al. [164] have developed a smartphone wallet system, which detects currency security and fake currency. The authors have described that this is a sensor that provides the information on the amount spent from the wallet and the data is saved on the cloud. If the wallet is stolen then you get the complete information. Xu et al. [170] have created a system to identify the serial number pattern for the security of the note. Though, divided this pattern into two parts, the first is text localization and the second is text recognition. So this analysis is very helpful for fake currency detection. Zarin and Uddin [179] have proposed the fusion method for Bangladeshi currency identification. This fusion method includes OCR Face Recognition and Hough transformation which provide comparative results.

In the year 2020, Athapaththu et al. [18] have Author has created a device that detects the new Sri Lankan currency, which is used for blind people. The proposed system is based on image processing and machine learning algorithms that identified various postures of currency such as worn-torn notes, changes in light, scaling and rotation, and fake notes. Doshi has proposed [46] proposed an efficient Image processing technique that has to extract various features from the U.S. currency. The features of currency are dimensions, colour written letters, security thread, texture, Federal Reserve indicator, serial number, and various other details that help to increase the accuracy of fake currency detection. The proposed framework has used machine learning and deep neural network to extract more features more and improve accuracy.

In the year 2021, Pachón et al. [105] have Authors have demonstrated that the first convolution neural network has been done in currency recognition. But it is not clear what is better than custom and transfer learning techniques in respect of processing speed and time. Therefore, the authors presented the comparison between custom and transfer approaches on Colombian banknotes. Alexnet- type custom model give results 100% accuracy

2.2 INDIAN CURRENCY IDENTIFICATION

2.2.1 Old Currency Identification

In the year 2011, Dayakshini and Sathisha [41] have designed a low-cost system with the use of a microcontroller to recognize Indian currency which has used the serial number of currency. The result has provided on comparison of the previous system that is high accuracy and less time. Verma et al. [163] have proposed the Indian currency identification system which is based on pattern recognition. Authors have used limited features of the note.

In the year 2012, Mirza and Nanda [93] have proposed a system in the field of Indian currency recognition which is a mile of stone in the field of fake currency identification. Authors have used special security features such as a watermark and latent image of currency.

In the year 2013, Jain and Vijay [75] have proposed image processing to extract paper currency recognition, and neural network matching technologies to extract the region of interest and move to extract the paper currency value group. First, the authors take the image by a scanner and adjust their size and pixel level. Comparison of the value of the currency through pattern recognition and neural network matching techniques. Santhanam et al. [134] have studied methods of detection to detect fake currency. These

detection methods are based on a polarization concept, image processing technique and holographic technique. They discussed methods based on the physical properties of currency rather than chemical properties to detect fake currency. They also elaborated mathematical models, experimental validation, and laboratory visualization-based simulations on how to detect fake currency. Ravi and Ravi [127] have Authors have introduced an Indian currency recognition system which based on texture feature using the PCA method. Authors said that extract the feature of note as a feature vector then it used for the recognition process.

In the Year 2014, Alekhya et al. [10] have studied the use of image processing and other parameters to detect fake notes. Fake notes have been detected by using some features of note, and it has been implemented on MATLAB. Bhasharkar et al. [28] have discussed a currency recognition technique based on image processing. Image processing approaches are performed based on basic steps such as image acquisition, pre-processing and final recognition of the pose. The image processing approach is discussed with MATLAB to identify the characteristic of the currency note. Finally, the results are displayed for real or fake currency. Danti and Nayak [39] have introduced a Neural Network (NN) model for the Indian currency identification system with the help of a grid that gives a better result. Grid technique is used for Feature Extraction. Ismail and Makon [71-72] have designed the software for the counterfeit note of India. This software has to identify the currency using the attribute classification of the currency. The authors also elaborated all processing with the image by machine. The machine has a fitted camera for a scan of the currency and software has prepared for image segments through attribute detection methods. They have also designed software with MATLAB tools. Kumar and Bhatia [84] have described the detailed feature extraction in image processing. The authors have explained the feature and feature extraction method for

character recognition. R and Omman [118] have studied the Indian currency recognition system and proposed a method to detect counterfeit currency using an image processing approach with the help of the security feature of currency. The authors also elaborated the principal component analysis used to reduce constructed size and a parallel classification to forecast trial samples. In the end, the result has been shown by the author to validate the proposed model with the tested random sample using the WEKA tool. But it is not the method of feature extraction. The authors also studied the results of the central digits invalidity of 100% with the group of currencies. Singh et al. [144] have developed a system of currency identification through mobile phones for visually impaired users. The approach has been applied to other currencies to check its speed and accuracy which is 96.7% on 2584 images. Thakur and Kaur [155] have introduced a Fuzzy based new approach for currency detection. This system has given a better result than previous methods. Thakur and Kaur [156] have presented various currency recognition techniques and discuss various currency recognition systems. The technique has developed using various methods and algorithms. For currency detection, the author used various kind technique and algorithms. Also provided the comparison result. Thus, also has expanded the capacity that depends exclusively on the currency note characteristics and feature extraction of the country. Venugopal et al. [162] have designed a machine that deposited the Indian banknotes in an account, shown the amount, and also find the counterfeit note. Yadav et al. [172] have designed a system to detect fake currency using the MATLAB algorithm and extract the feature with the help of image processing. Yadav et al. [171] have designed a system for automatic processing and have verified Indian currency using image processing. The authors explained two features of Indian currency that are based on fake notes which include identification marks and currency numbers. They also used the Sobel operator and the extraction of attributes on the input image of currency and then comparing it with the

attribute of the real or original currency. Image-processing played the important role in currency detection. They elaborated on several steps: including image pre-processing, edge detection, image segmentation, character extraction, and comparison.

In the year 2015, Bhurke et al. [30] have created an algorithm that more easily detects the currency and has also told that a good algorithm should be simple and high accuracy with less time. The design of this proposed algorithm is easy and capable of detecting more and more currency. The authors used five currencies to work for this project and the chosen banknotes are the Indian Rupee (INR), Australian Dollar (AUD), Euro (EUR), Saudi Arabian Riyal (SAR), and US Dollar (USD). Walke and Chandwadkar [166] have designed a machine that uses SVM to identify fake currency and gives coins instead of real currency. First, the image of a currency is taken and then apply the pre-processing steps. If a currency is real then the machine gives the equivalent value of the currency in the form of a coin. Kamal et al. [78] have developed a system that recognizes counterfeit notes in India as mutilated notes. Kumar and Dudyala [81] have checked the Indian paper currency using decision tree rules and machine learning methods. Nayak et al. [100] have proposed the technique based on image processing and Neural Networks in the direction of Indian currency detection. Rahmadhony et al. [119] have given a new approach such as sensor and backpropagation to the recognition of the Indian currency. R and B [117] have identified the Indian currency with the help of the SIFT method. Vora et al. [165] have described a framework to detect the banknote focusing on the Region of Extraction (ROI) methods and after pre-processing have to use a two-dimension discrete wavelet transform (2D DWT) technique. The latter used to develop a currency recognition system. The OCR technique yielded better results. Prasanthi and Setty [114] have proposed a model using image processing and MATLAB technique that recognize the real and fake Indian banknotes.

In the year 2016, Atchaya et al. [17] have presented an algorithm for currency security thread recognition using Image processing and MATLAB. C and G [32] have presented an algorithm for an Automated Teller Machine (ATM) which can help with currency number recognition. Due to the algorithm, a currency note number is entered on the server so that the customer can recover his money at any time and it has also been reported that the proposed Algorithm, ATM becomes more reliable and convenient for users. Darade and Gidveer [40] have studied the use of image processing and other parameters to detect fake notes. Fake notes have been detected by using some features of note, and it has been implemented on MATLAB. According to Murthy et al. [97] said that a lot of the software of currency identification is available, but if you look in terms of accuracy and speed, it is very less. Therefore, the authors have created a system that recognizes fake currency with high accuracy and speed. Nila et al. [102] have proposed a survey for a fake currency detection system. In that report, many machines have developed with the help of the Image processing tool in MATLAB. This machine detects the fake Indian currency. Pilia and Arora [111] have described a feature of currency, i.e. a security thread on which basis design the system for recognizes fake currency. The Authors have described fake currency as a very complex problem for every country. So they designed a system that identifies the fake currency of India and also other countries. Therefore, gave a small contribution in this area and developed a system that gives high accuracy. Rathee et al. [124] have a deep study of the physical and chemical properties of note to identify counterfeit note based on which a system has designed that can detect counterfeit note. Based on three important attributes of note, such as security thread, intaglio printing (RBI logo), and identification mark, the basis on detecting the genuine and counterfeit note has been used. The proposed design has been measured based on speed and means square error (MSE). Rathee [125] has

provided the Indian currency detection approach based on Image processing and MATLAB. Sahu and Verma [132] have described a survey report on Indian currency identification regarding different methods. Methods are such as pre-processing and feature extraction give better results. Sawant and More [136] have proposed a simulated currency detection system using image processing and other distance calculation method. They applied image processing steps on security features like latent image, color, identification mark of the Indian note.

In the year 2017, Patel et al. [106] have proposed the currency identification system using NN Tool. The accuracy of the proposed system is 95.6%. The dataset which is input in the NN Tool model has a different denomination of Indian currency. Sharma and Narang [138] have discussed all the methods used by different countries for currency identification. This approach is very effective for research purpose because here get all information regarding previous methods.

In the year 2018, Mittal and Mittal [95] have proposed a new Neural Network-based approach to detect the bogus Indian currency. The dataset of currency has been prepared of different denomination of currency. In this approach is trained real note features then it compared with a suspected note. Experimental results accuracy is 96.6%. Upadhyaya et al. [159] have described the comparison results of different techniques of currency identification. Authors told that there is so many research paper in an area of currency detection but here provide a better comparative method that gives better accuracy. The two methods as Logistic Regression (LR) and Linear Discriminant Analysis (LDA) give the high accuracy for currency detection. Tigani and Saadane [157] also proposed the statically predictive model to estimate the financial market stability based on historical data.

In the year 2019, Dhapare et al. [43] have conducted a comparative study of the methods used by the researchers in the field of detecting Indian currency from the last decade. S and Sasikumar [130] have proposed Fake currency notes are increasing day by day, in order to overcome this, design a very helpful and efficient system to detect the fake currency. Detecting the fake currency note is done by counting the number of interruptions in the thread line. For predicting the note is real or fake based on a number of interruptions. If the number of interruptions is zero, if it is a real note otherwise it is fake and also we calculate the entropy of the currency notes for the efficient detection of a fake currency note. MATLAB software is used to detect fake currency notes.

In the year 2020, Akshatha et al. [8] have designed a framework for bogus currency detection using the Open CV tool and Python language. The framework has been designed not for only Indian currencies but also other countries' currencies. It is a low-cost application used by mobile phones. Bahrani [21] has proposed a deep learning approach for fake currency identification. The real-time system is based on a web application or mobile application which is more helpful for blind people. It worked on all different types of denomination of Indian currency. Neelambika et al. [101] have explained that image processing technique is very important for currency recognition systems. This system is very important for paper currency recognition. This is used in place of electronic banking, currency recognition, currency monitoring, etc. This system is very useful for blind people. Therefore, the authors have proposed a system that can detect currency with high accuracy and less time. The image processing technique has extracted the hide and visible features of a currency. Authors also elaborated the advantage and disadvantage of the proposed system for currency authentication system.

2.2.2 New Currency Identification

In the year 2017, A et al. [1], Deshpande and Shrivastava [42] have elaborated the Rs 2000 new currency security features which are mentioned in RBI guidelines. Through this approach, it is easy to understand Rs 2000 security attributes by common people. Agasti et al. [4] have used image processing steps to identify the newly Rs 500 counterfeit note of India. Feature Extraction is the most important part of an image that bases a comparison between real and fake currency. Gaikwad and Bhosle [53] have developed an automatic counterfeit currency detection system that is based on New Indian Currency. After demonetization, it is a very big deal to recognize the counterfeit currency so the author developed the system that recognizes the new currency based on security features of a currency. Ponishjino et al. [112] have introduced the HSV method to detect the recently launched Rs 500 and Rs 2000 fake notes.

In the year 2018, Wanjara et al. [167] have proposed the bogus currency detection system with the help of MATLAB. This proposed system is work on the newly launched Rs 500 and Rs 2000 currency. P and B [104] have proposed a low-cost model that gives 98.8% accuracy for currency detection. This model has used the GLCM technique and neural network approaches. Rangari et al. [123] and Pujar [115] have presented the currency recognition system with the help of image processing and MATLAB tool. The authors said that this system is based on a newly introduced currency Rs 500 and Rs 2000. Rajan et al. [121] have presented an effective algorithm that used the ORB feature extraction technique for Rs 2000 newly launched currency. The authors have compared the ORB technique to the SIFT algorithm. Finally, the ORB technique has given a faster result for currency recognition. Singh et al. [143] have developed a tool based on image processing and Machine learning for newly launched currency. The proposed system has extracted security features such as security thread

and latent image, of currency. Using a clustering algorithm the features of currency are classified then trained from the SVM model. Through the SVM model matched the pattern of the desirable feature.

In the year 2019, Jadhav et al. [74] have created a system whereby fake currency detection can be done with the help of machine learning and image processing. The authors have experimented on newly launched Rs 500 Indian and Saudi currency. Rathore and Sagar [126] have presented a report on fake currency detection based on the features of a newly launched currency. The authors described all security features of note that are inbuilt according to RBI guidelines. Sambana et al. [133] have suggested a lot of methods based on Artificial Intelligent for old and new Indian currency detection. Veling et al. [161] have proposed a system for fake currency identification with the help of MATLAB. The scanned image is input into the algorithm of image processing with different lights such as UV, normal LED, Red LED, Green LED and Blue LED and the aspect ratio has been calculated to wavelength. The graph of Real and Fake currency is presented in the context of Entropy and Wavelength.

In the year 2020, Babu et al. [20] have analyzed the different deep and machine learning algorithms on the new Indian currency. The authors gave the comparative results between real and fake currency. Chowdhury et al. [36] and Naresh et al. [99] have proposed such a module to identify the original note according to its feature by using image processing and Neural Network. The image of the note is first analysed by pre-processing steps and then by identifying the original note from the NN model. To identify the Indian note, its recognition is divided into two parts: the first is to use color and texture properties to create a feature vector and classify the design samples using the base of those properties. Second, Indian notes are input into the NN model for classification. Chavan et al. [35] have explained the purpose of the coin distributed

machine in this proposed system. Authors said that currency algorithm is used when a security thread is passed under the UV rays then has found that the currency is genuine or not. After real currency is detected, the coin distribution is done instead. D'cruz et al. [38] have given way to identify fake notes based on deep learning. An artificial data set is created by a different mode for training the model. According to the different security features of note, training the model and then detect the real and fake currency. The authors also made this model for this smartphone, which can identify fake notes by taking currency images from the camera and help people. Gopane and Kotecha [58] have proposed a reliable method of Indian currency detection. This methodology has identified the security features of the new Indian currency and shown desirable accuracy. Guttikonda and Lakshmi [59] have told that the proposed presentation is dependent on image processing, which has proved very helpful in the area of note detection. The note detection system is very costly that is available in the bank. At the same time, the author has created such a suppression process that will separate the currency according to their security features. This system is less expensive so that anyone can detect fake notes. J and V [73] have provided the method for currency recognition and bogus currency detection for blind people. The author said that this method applied to the new launch of Indian currency after demonetization. This experiment has used the Neural Network algorithm for currency recognition and fake detection. Kumar and Chauhan [82] have studied on new currency recognition system with the help of image processing, k-mean and SVM algorithm. Kumar and Chauhan [83] have provided a computer vision-based Indian currency detection system. According to the author, using OpenCV effective algorithm gives accurate and unique results. This experiment has been applied to the new Rs 200 note. M and Kannammal [89] have presented a survey report on currency detection. The survey gives a

comparative study for the feature of currency. This survey has a comparative study among security features of different currencies and the methods that have been mentioned which are used in fake currency detection. Here, the image processing and feature extraction methods have been applied to Rs 2000. Mishra et al. [94] have told that research work is being developed for the analysis of currency every day. Researchers have detecting fake currency by using new technology like MATLAB and image processing. The authors have created a device that is dependent on the currency's attribute base and can easily detect fake currency. Sirwani et al. [146] have presented an application to recognize the old note. After demonetization, notes go from one person to another while using new currency, the notes become old and dirty. Even inside ATMs, it is difficult to identify such notes. A system has been created to identify the old messy Indian note. This system works on paper currencies which are Rs 50, Rs 200, and Rs 500. In the real world, people can validate money because the human eye is limited and it is difficult to distinguish fake and real currency from unattended. Shetty et al. [140] have implemented a technique that gives the identification results of fake currency. This system is also based on Image processing techniques. The results are represented of input and suspected image in terms of aspect ratio, color, and texture feature. Washisht and Kumar [160] have explained the comparative study between the different methods of currency detection and also explained the pros and cons of methods. Authors have discussed the latest technology such as deep learning and neural network arrived in the research area for currency detection which gives the best results. In the year 2021, Andrushia et al. [13] have proposed the real-time approach of fake currency identification in terms of new notes. The authors explained the system which has used different technologies such as Image processing and SVM algorithms that give reliable results. The feature vector extracted from the notes in respect of color and

texture feature gives the comparative results between real and fake currency. Other related references are [15], [37], [54], [70], [128], [129], [149] and [182-185] which were accessed in the present work.

CHAPTER III

Identification of Fake Currency Through Security Thread

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CHAPTER III

IDENTIFICATION OF FAKE CURRENCY THROUGH SECURITY THREAD

This chapter deals with the fake currency identification approach over the newly arrived Indian currency. The security thread is one of the security features of a currency. In every country, many people generate fake currency which is similar to the original currency. It may be in the form of notes and coins. In the business market, it is very difficult to identify fake currency and it is also true that original currency in the form of notes and coins are available in the bank custody. Many researchers have applied different methods to identify fake notes and coins. The present work deals in this direction for the identification of newly launched Rs 500 and Rs 2000 notes in the Indian market. An object-oriented model is proposed for designing systematic steps for the identification process and implemented in MATLAB. Results are produced in the form of tables and graphs. From the literature, it is observed that in the year 1938, the Reserve Bank of India (RBI) has issued currency notes of Rs 2, Rs 5, Rs 10, Rs 100, Rs 1000 rupees notes. Later on, RBI has issued denomination of Rs 1, Rs 20, Rs 50, and Rs 500 rupees notes. As per RBI guidelines, currency in the Indian scenario has to be changed after an interval of every 10 years therefore different designs of the notes along with new series have appeared in the Indian Business market and the old series has been eliminated by RBI. During past years, it is observed from the business market worldwide that a tremendous amount of fake currency in the form of notes and coins are available in the business market and also in the bank.

3.1 BACKGROUND

Many researchers have introduced new techniques and some of the techniques for identification are watermarking, latent image, micro lettering, see-through register optically variable link, security threads, intaglio printing, fluorescence, identification mark, legal provisions against counterfeit. Automatic tools are also available for fake currency identification. Fake currencies are available online for the use of banking services but the accuracy may differ from one approach to another approach. Hence, there is a need to develop a robust system for reliable identification with minimum processing speed and accuracy of the currency. For this purpose, digital image processing is adopted by many researchers in which authors extract different attribute after image acquisition and considers as an object the attributes may be watermarking, latent image, micro lettering, see-through register, optically variable link, security threads, intaglio printing, fluorescence, identification mark, legal provisions against counterfeit. For recognition of the attributes, the author generally used MATLAB as a computational tool for the development and implementation of design steps for the analysis purpose and it supports image acquisition as bmp, jpeg, tiff, gif, png, jpg, etc. After Image acquisition characteristics of the attributes are extracted for digital image processing which contains visible as well as invisible features taken from the currency notes. Authors applied different methods of extraction of the image but it should be an excellent and feasible extraction of the image for consideration of input reliable data. The data is further classified into the number of pattern distinct classes having attributed like distinct method HSV image, Edge detection, Segmentation, etc. These features are well described in the literature. Lots of researchers have done work in the field of identification of currency. Many countries have changed the currencies generally after ten years. In the year 2016, the Indian Prime Minister has changed the currency of note of Rs 500 and Rs 1000 and issued a new direction for new currencies.

3.2 MATERIALS AND METHODS

In the Indian scenario, the Reserve Bank of India (RBI) has issued the guidelines related to currency under the Act 1935. Before, these silver coins were used during 1540-45. Based on the 1934 Act, in the year 1917 Government of India (GOI) introduced a note of Rs 1, thereafter a Rs 5 in 1938 and Rs 2 in 1943. These notes were having fewer security features hence improving the security features like watermarking, micro lettering, etc. and another technique has been discussed. After that GOI has introduced Rs 10, Rs 20, and Rs 50, Rs 100, Rs 500, and 1000 from time to time which contains the features watermarking, Window Security Thread, Latent Image, and Intaglio, etc. as per rules of RBI the series were absolute after series of notes after 10 year. In 2011 new series of Rs 1, Rs 2, Rs 5, Rs 10 were introduced with new Rupees symbols while before this year series of Mahatama Gandhi watermark was introduced were Rs 10, Rs 20, Rs 50, Rs 100, and Rs 1000. Due to the counterfeit problem faced by RBI and availability of the high-resolution scanners, any person can print the counterfeit note through a computer by a color laser printer. In the banks, there are some machines which are available with the bank persons used to detect counterfeit persons but sometimes fail to detect these kinds of notes. In the present work, these kinds of problems resolve through a small piece of code which is based upon the following aspects as MATLAB and UML.

In the MATLAB technique, we have created different classes of Digital Image Processing steps including Image Acquisition, HSV conversion, and Edge detection, Image Segmentation, Characteristics Extraction, and Comparison of Images. Each class has its attributes and methods represented in the following table 3.1.

Table 3.1 Representation of UML Classes and Attributes

Sr. No.	Name of Class	Attributes	Methods
1.	IA	IAReal IAFake	imread ();
2.	HSV	IAReal IAFake hsvReal hsvFake	rgb2hsv();
3.	ED	cropReal cropFake satThresh vatThresh BIReal BIFake	hsvReal (,;,); hsvFake (,;,); cropReal (,;,); cropFake (,;,); figure; subplot (, ,); imshow (); title(' ');
4.	IS	se closeReal closeFake	strel (' ', ,); imclose (,); figure;
5.	IE	openReal openFake closeReal closeFake	bwareaopen (,); imshow (); title (' '); figure;
6.	COMP	openReal openFake lineReal lineFake	bwlabel (); disp (' :'); num2str ();

IA is the class of Image Acquisition that has its attributes and methods to obtain the image using a camera, scanner, etc. HSV is the class of Hue-Saturation-Value to convert the RGB Image into each different component. ED is the class of Edge Detection that resizes the image and extracts the region of interest using its Attributes and Methods. IS is the class of Image Segmentation that divides the image into its constituent region or objects. IE is the Image Extraction that extracts the characteristics of the Image. COMP is the class of comparison that compares the image based on characteristics.

3.3 CONTRIBUTION OF WORK

In the present work, a UML activity diagram has been designed which is used to represent the run time behavior of the software. This diagram consists of groups performed by the actor. The UML activity diagram for the detection of fake currency is shown below in figure 3.1.

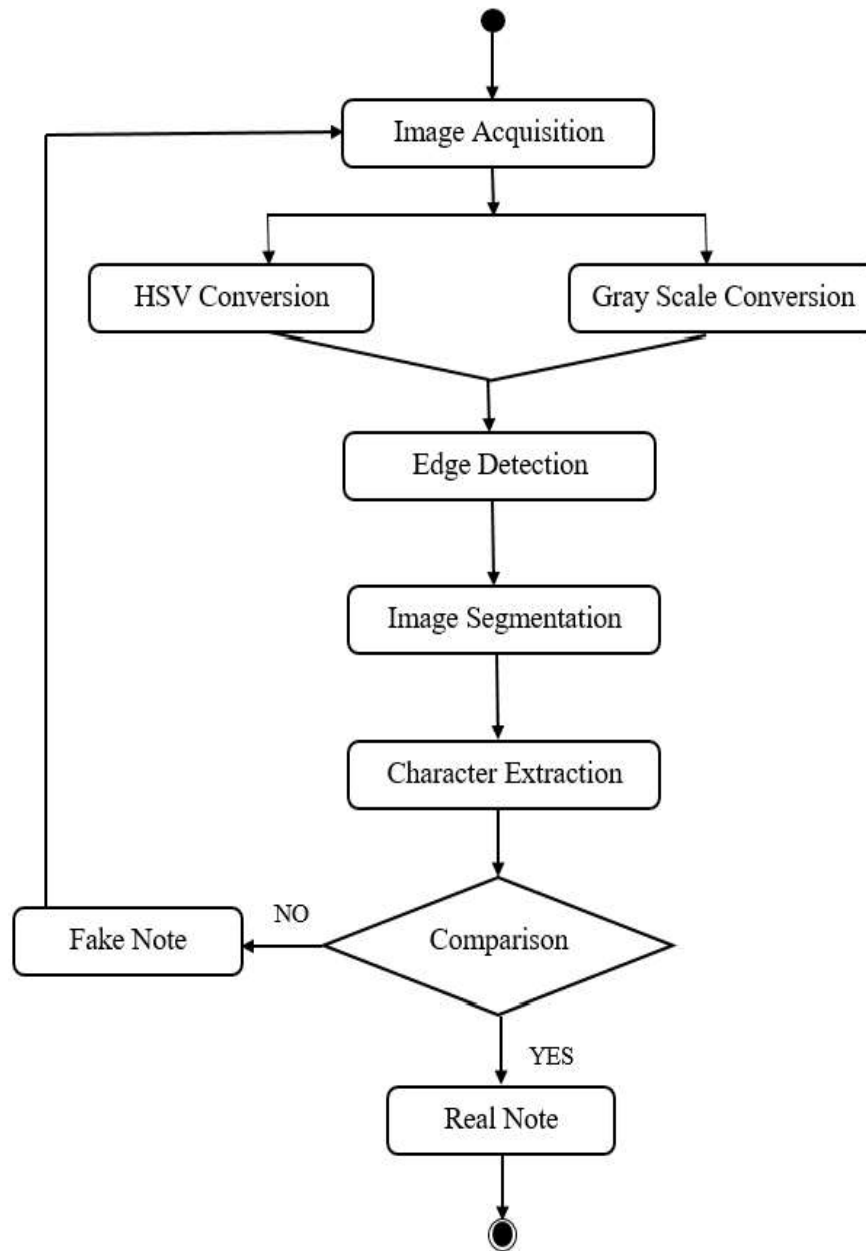


Figure 3.1 UML Activity Diagram for Fake Currency Detection

The steps along with the description are described below in brief:-

STEP 1 → Activity Name : Image Acquisition

Description : Obtain the Image of Real and Fake currency through Camera or Scanner.

STEP 2 → Activity Name : HSV Conversion

Description : The acquired RGB images are converted into HSV on the kind information to be extracted.

STEP 3 → Activity Name : Edge Detection

Description : The edge detection technique is used to detect the boundary of Image using cropping techniques.

STEP 4 → Activity Name : Image Segmentation

Description : In this process the Image is divided into different segments.

STEP 5 → Activity Name : Character Extraction

Description : After segmentation the distinguish feature of Image is extracted in this steps.

STEP 6 → Activity Name : Comparison

Description : Compare the characteristics of Image and display the outputs.

3.4 RESULTS AND DISCUSSION

The above UML diagram has been implemented through code written in MATLAB. The different parameters have been selected for getting the optimized result. A Rs 2000 rupees real and fake notes are first scanned by a scanner and the outlook of notes are represented in figures 3.2 (a) and (b), respectively.



Figure 3.2 (a) Image of Real Currency of Rs 2000



Figure 3.2 (b) Image of Fake Currency of Rs 2000

The Government of India (GOI) has launched a currency of Rs 2000 note in November 2016. Since the value of a note is very high, therefore there is a lot of chances by intruders to generate the fake currency and during the subsequent months' police department of India has also recovered the big chunks of Rs 2000 from various places. Later on, these two acquired images have been in RGB color and converted into the Hue-saturation-value (HSV) format. By this process, the complete image has been

separately looked at each Red, Green, Blue component and these two images are represented in figures 3.3 (a) and (b), respectively.



Figure 3.3 (a) Conversion of Real Currency from RGB to HSV Image

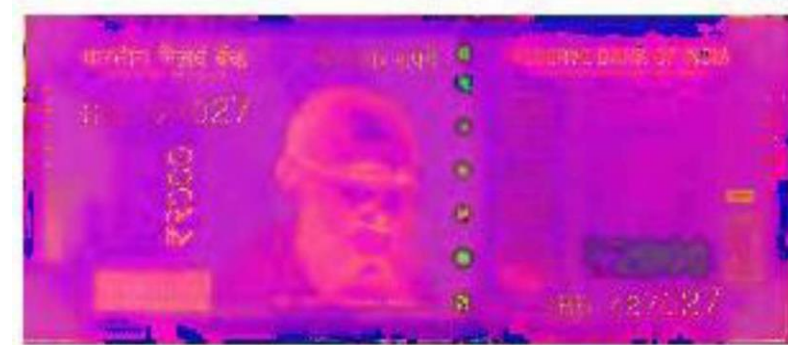


Figure 3.3 (b) Conversion of Fake Currency from RGB to HSV Image

Since the image contains the number of segmented parts therefore one can apply security threads as a Region of Interest (ROI) to these parts. In the present case, a strip is considered as a security thread for checking whether the rupee 2000 note is real or fake. These security threads in the forms of strips are shown below in the following figures 3.4 (a) and (b), here real and fake strip, respectively.



Figure 3.4 (a) Crop Image of Real Strip



Figure 3.4 (b) Crop Image of Fake Strip

Further, we compared the number of black pixels of real and fake currency and got strips which contain some black pixel as one and three in real and fake currencies respectively which have been represented in the following figures 3.5 (a) and (b), respectively.



Figure 3.5 (a) Number of Black Pixels in Real Currency



Figure 3.5 (b) Number of Black Pixels in Fake Currency

The variation between the real and fake note is also represented through a histogram as represented in figures 3.6 (a) and (b) for the real and fake note. It is represented the relative frequency of the various gray levels of real and fake currency.

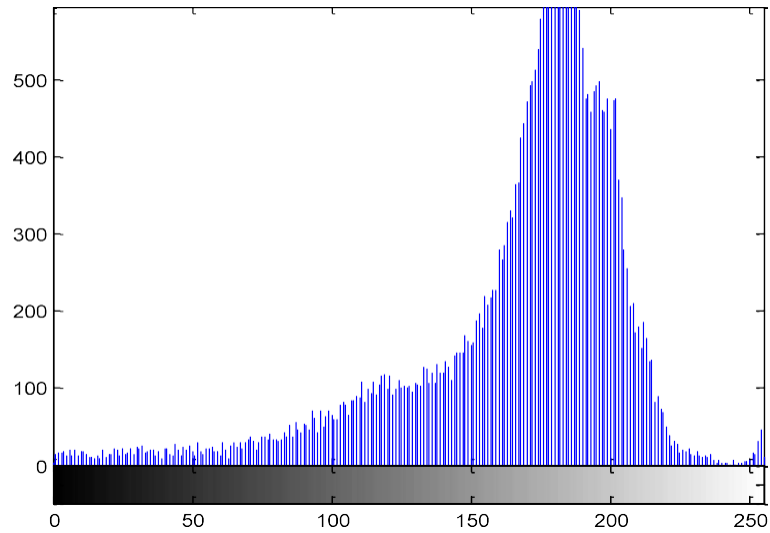


Figure 3.6 (a) Histogram of Real Currency of Rs 2000

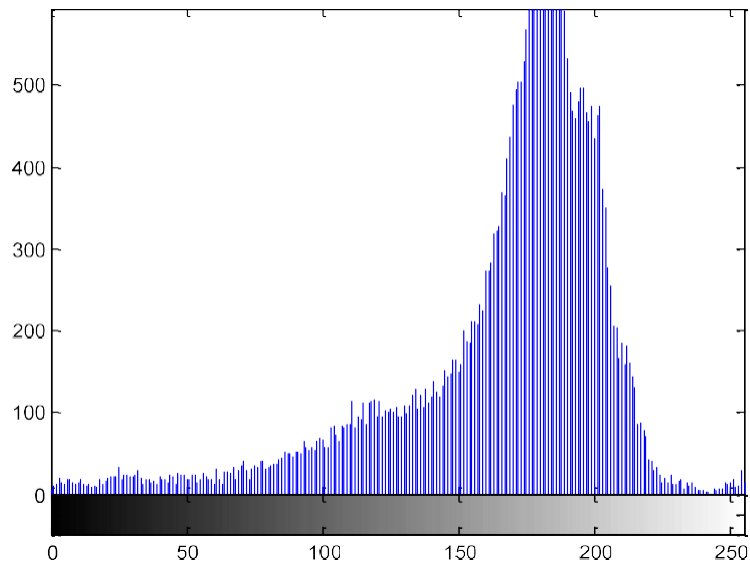


Figure 3.6 (b) Histogram of Fake Currency of Rs 2000

3.5 MAJOR FINDINGS

From the above work, it is concluded that UML is an important modeling language used to represent static and dynamic aspects of the research problem. Some of the findings of the presented work in this chapter are briefly summarized below:

- ☛ The proposed approach of fake currency identification is based on an Image processing algorithm;
- ☛ In the present work, a UML activity model is designed to represent the dynamic aspects for the identification of fake currency and successfully implemented on newly launched a note of Rs 2000 by an Indian Government;
- ☛ A MATLAB code is generated and through a code, we got class descriptions for real and fake Images of the currency. This is because of a selection of optimized classes and attributes;
- ☛ The above aspects can be extended for other kinds of currencies of different countries.

CHAPTER IV

Design and Implementation of Method for Fake Currency Identification

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CHAPTER IV

DESIGN AND IMPLEMENTATION OF METHOD FOR FAKE CURRENCY IDENTIFICATION

During the past years, some of the researchers are using matching techniques for the identification of the fake currency either by using the Mathematical formulation or by using the readymade simulation tools. A lot of methods namely edge detection, segmentation, feature extraction, pattern matching have been used for finding and identification of fake currency. In this chapter is described, Principal Component Analysis (PCA) is used to detect the feature of currency through modeling and a proposed algorithm is elaborated to recognize the fake currency in the form of note Rs 2000 of Indian currency. Graphs are also designed to justify the present approach along with the comparison of results.

4.1 BACKGROUND

Technology is rapidly growing for the conversion of physical currency into digital currency due to the availability of fake currency in the business market. In some of the countries, it has been implemented but in some countries around the world is suffering due to the availability of fake currency. Currency replication is the most important threat in the business market. Currency replication is also known as counterfeit currency which is presently questioning due to sophisticated techniques such as printing and scanning. Due to the counterfeit note, India is facing many problems and challenges in the business market. Many researchers have been encouraged to develop robust and effective currency detection machines.

In November 2016, Prime Minister of India Mr. Narendra Modi announced that existing rupee notes of 500 and 1000 cease to be valid currency and that step is taken to rein

black money and forged currency in the country [85]. The Prime minister also launched new rupee 500 and 2000 notes and discontinued the existing rupee of 500 and 1000 notes. In the year 2017-18, according to an annual report published by the Reserve Bank of India (RBI), fake currency note detection has been dropped 31.4% as compared to the previous year due to the high- security feature of note-making forged difficult. In the Indian economy; Fake Indian Currency Note (FICN) is a term used by officials and media to refer to forged currency notes.

In 2012, in response to a parliamentary inquiry, the Finance Minister, P. Chidambaram stated that there was no confirmed estimate of forged currency in India. However, there are several states and central agencies that work together and the Minister of Home Affairs has included the Fake Indian Currency Notes Coordination Centre (FCORD) to check the problem.

4.2 MATERIALS AND METHODS

4.2.1 Security features of Indian Currency

The fake currency detection system varies depending on specific features of banknotes of the country [7]. For Indian banknotes, features are considered. For testing purposes Rs 2000 note, there are some important security features of Indian currency: - Watermark, Security thread, Latent Image, Intaglio Florescence Micro lettering, Identification Mark, Optically Variable Ink.

4.2.2 Legal Provisions against Counterfeiting

Printing and circulation of forged notes are offenses under section 489A to 489 E of the Indian Penal Code (IPC) and are punishable by fine or imprisonment or both in the courts of law. The currency has great significance in everyday life. Therefore, many researchers have become interested in the recognition of currencies and have proposed various approaches. According to the literature, image processing is the most efficient method in the currency recognition area. A banknote has safety features mainly in the

design and printing of paper. The identification and examination of currency notes are mostly carried out by the following aspects:

- ☛ Physical dimension
- ☛ Paper quality
- ☛ Design

4.2.3 Printing Technique

The physical dimension of the note depends on its cutting size, length, width, thickness, and grammage. The paper on which currency note is printed has a high level of security. Watermark and Security thread are the most important components of currency note paper security.

4.2.4 Storage of Image of Currency

A rupee 2000 real note first scanned by scanner and outlook of notes are represented in figures 3.2 (a) and (b), thereafter, the scanned image is the input in MATLAB.

4.2.5 The Reasons for Selecting the Features

Micro-printing is widely used for a robust feature of Indian banknotes. The advantage of micro-printing is that it cannot be visible without a magnifying glass or appropriate focus of the camera, this feature is very tough to replicate in fake notes by the normal printing process and require a very high cost and the other reason is Optically Variable Ink (OVI), which is very costlier ink and is impossible to forge through a printer or ordinary printing machines. In real notes, the printing quality of the watermark is very good, perfect, and unmutilated. That is the reason why it is very hard to knock off counterfeits. The stitching technique of the security threads and the pattern around the security thread are identifiable. A new dimension in stopping counterfeit notes is created by the presence of ultraviolet lines in the banknotes. Therefore, these features

are used to perform forgery detection. Table 4.1 represents the existence of these features in various Indian banknotes based on the experiment and is shown below:

Table 4.1 Features in the Indian Currencies

Features	Availability Among Notes
Watermark	Rs 20, Rs 50, Rs 100, Rs 500, Rs 1000, Rs 2000
Security Thread	All Notes
Latent Image	Rs 20, Rs 50, Rs 100, Rs 500, Rs 1000, Rs 2000
Intaglio Printing	Rs 20, Rs 50, Rs 100, Rs 500, Rs 1000, Rs 2000
Fluorescence	Rs 20, Rs 50, Rs 100, Rs 500, Rs 1000, Rs 2000
Micro Lettering	Rs 5, Rs 10, Rs 20
Identification Mark	Rs 20, Rs 50, Rs 100, Rs 500, Rs 1000
Optically Variable Ink	Rs 500, Rs 1000, Rs 2000

4.2.6 PCA Technique

Principle Component Analysis (PCA) is a method of identification of data patterns in which data are expressed to highlight similarities and differences. Once the pattern is found in the data, it can be compressed i.e. reduced the number of dimensions without losing much information. PCA transforms the ‘p’ which is the original correlated variable into ‘p’ uncorrelated components (also called orthogonal components or principle components). These components are the original variables of the linear function.

The transformation is given by

$$Z = X A \tag{4.1}$$

where,

X denotes n*p matrix of n observations on p variables;

Z denotes n*p of n values for each of p components;

A denotes $p \times p$ of coefficient defining the linear transformation.

PCA is a measurement quantity reduction technique in which an image is represented in higher dimensions. The processing of an image in higher dimensions requires more time for the processor. A weight vector is obtained, after the projection of a higher to a lower dimension. A weight vector represents original data (higher dimension) in terms of Eigenvectors (lower dimension). The phase contains the following stages:

- 1) Information is extracted from the Image and data is acquired;
- 2) The covariance matrix is constructed from the acquired data;
- 3) To find Eigenvalues and Eigenvectors;
- 4) Short Eigenvectors and find principle Eigenvectors;
- 5) Data is mapped and stored.

4.3 EXPERIMENTAL RESULTS AND DISCUSSION

An easy approach to extracting data contained in a currency image is to capture the variation in an image collection, regardless of any judgment of feature, and use this data to encode and compare with fake currency images. In figure 4.1, the proposed approach to detecting the false currency is shown below. The eigenvectors can be considered as a collection of the feature that characterizes together and the difference between real and fake currency images. Each image location contributes to each eigenvector more or less. This approach to recognition involves the following initialization operations:

A. Get Input Image

This process acquires the real and fake image of currency using `imread ()` function.

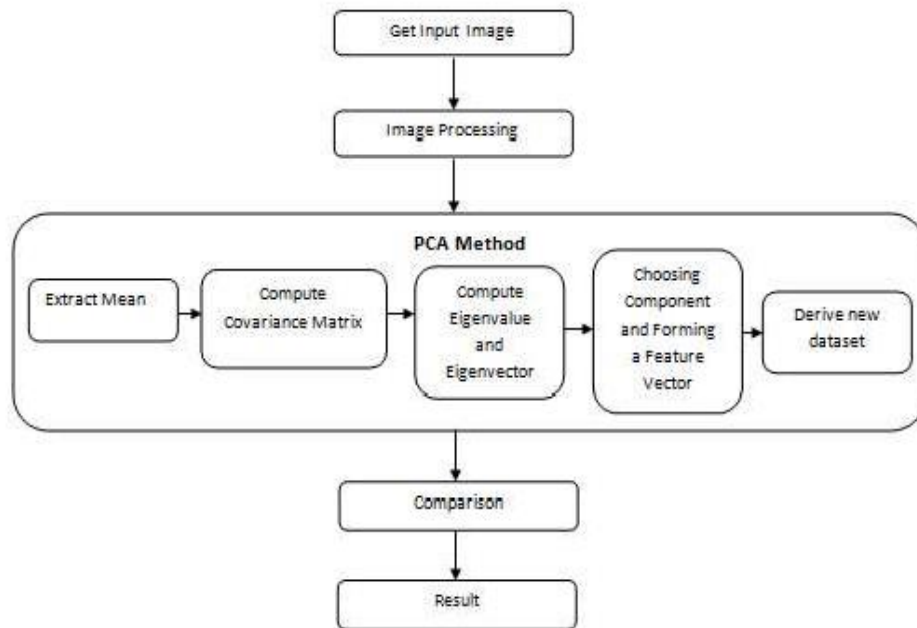


Figure 4.1 Proposed Approach for Detection of Fake Currency

B. Image pre-processing

The acquired image is in RGB color. The RGB image has been converted to HSV (Hue-Saturation-Value) and Gray. After getting an RGB image then it converts into a binary image.

1. PCA Method

a) Extract the mean

To make PCA work properly, the First step is to normalize the data which is done by subtracting the respective means from the given number in the column. Therefore for given two dimensions X and Y, all X will change to x- and Y will change to y- then:

$$Mean(\bar{X}) = \frac{1}{n} \sum_{i=1}^n X_i \tag{4.2}$$

b) Compute the Covariance Matrix

As the dataset taken is 3-dimensional, this results in a covariance matrix of 3*3. A numerical measure of the degree of correlation is denoted by P_{xy} between two variable

was introduced by the great statistician Karl Pearson (1857-1936) and it is called the coefficient of correlation and given by:

$$P_{xy} = \frac{\text{cov}(x, y)}{\sqrt{\text{var}(x) \text{var}(y)}} = \frac{\sum (Xi - \bar{X})(Yi - \bar{Y})}{\sqrt{\sum_{i=1}^n (Xi - \bar{X})^2 \sum_{i=1}^n (Yi - \bar{Y})^2}} \quad (4.3)$$

As covariance is always measured between two dimensions. If there is a dataset with more than two dimensions, it is possible to calculate more than one covariance measurement. For example, calculate cov(1,2), cov(2,3) and cov(3,1) form three dimensional data sets. For the n-dimensional data set, different covariance values can be used in the following formula:

$$C_2^n = \frac{n!}{(n-2)! * 2!} \quad (4.4)$$

Suppose, three-dimensional data set, then to make covariance has three rows and three columns with dimensions <x, y & z> is given below as:

$$\sigma = \begin{bmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{xz} \\ \sigma_{yx} & \sigma_{yy} & \sigma_{yz} \\ \sigma_{zx} & \sigma_{yz} & \sigma_{zz} \end{bmatrix} \quad (4.5)$$

c) Calculate the Eigenvalues and Eigenvectors

Calculation of Eigenvalues and Eigenvectors is possible only if it is a square matrix, λ is an Eigenvalue for a matrix A if it is a solution of the characteristic equation [186]:

$$\det(\lambda I - A) = 0 \quad (4.6)$$

Here, I is an identity matrix with the same dimension as A and the determinant of the matrix is denoted by \det For each Eigenvalue λ there will be a corresponding Eigenvector v , can be find by solving the equation given below [186]:

$$(\lambda I - A)v = 0 \quad (4.7)$$

d) Selecting Component and Forming a Feature Vector

Firstly, order the Eigenvalues from largest to smallest to arrange the components in order. Here given with dataset of n variables. For the corresponding n Eigenvalues and Eigenvectors, the Eigenvector corresponding to the highest Eigenvalue will be the principle component of the dataset and it will be our call to choose the number of Eigenvalues to proceed with our analysis. For reducing dimensions, choose only say p Eigenvalues and ignore the rest. For forming feature matrix which is a matrix of vectors i.e. Eigenvectors (in this case). Only those Eigenvectors want to proceed with. Since three dimensions in the current example, it can either choose the one that corresponds to the higher value of Eigen or simply take both and given by [186]:

$$FeatureVector = (eig_1, eig_2) \quad (4.8)$$

e) Derive the new dataset

It will be the final step that forms the principle components. For that purpose, take the transpose of the feature vector and left-multiply with the transpose of scaled data [186].

The resulting equation will be given by:

$$NewData = FeatureVector^T * ScaledData^T \quad (4.9)$$

where,

NewData is the Matrix consisting of the principle components,

FeatureVector is the Matrix formed using the Eigenvectors then choose to keep and

ScaledData is the scaled version of the original dataset.

According to the theory of Eigenvalues and Eigenvectors, Eigenvectors provide information about the pattern that exists in the data. In the above-discussed example, if plot the Eigenvectors on the scatter data plot and find that the principle Eigenvector fits the data. The other Eigenvector will not carry much information as it perpendicular to the principle vector. Therefore it will not lose much while reducing the dimension.

f) Comparison

In this step, the comparison between real and fake currency through histogram and from figures 4.2 and 4.3 is represented the relative frequency of the different gray levels of real and fake currency.

g) Experimental Result

The proposed technique is implemented using MATLAB to get the evidence of a difference between real and fake images. After finding the Eigenvalue and Eigenvector then it plots in figures 4.4 and 4.5. The entire matrix Eigenvectors of a matrix are perpendicular to each other. Therefore in PCA, there is a transformation of the original data set using these perpendicular Eigenvectors instead of the normal x- and y-axes.

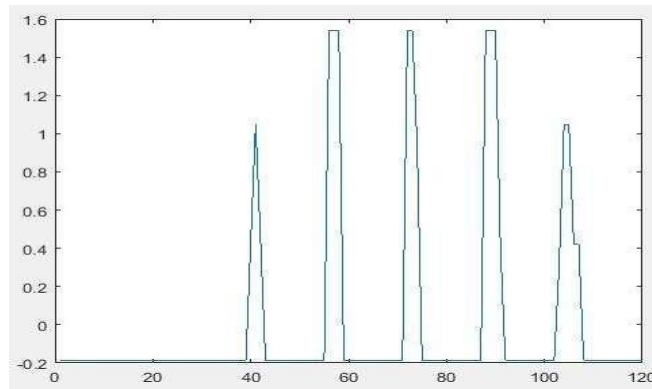


Figure 4.2 Histogram of Real Currency of Rs 2000

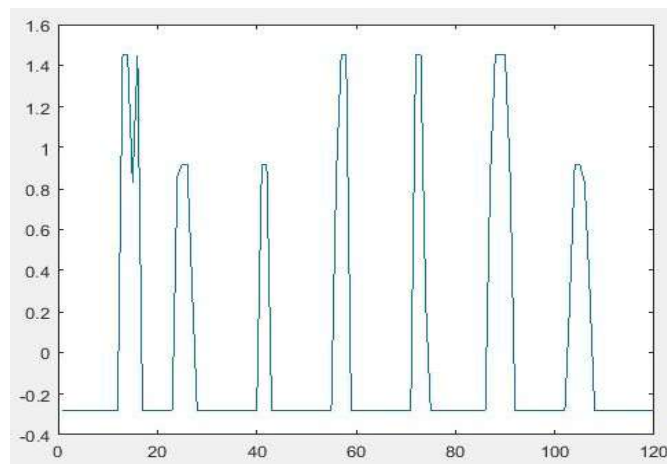


Figure 4.3 Histogram of Fake Currency of Rs 2000

Then classified data points are obtained as a combination of contributions from x and y . The difference will be observed when ignoring many Eigenvectors.

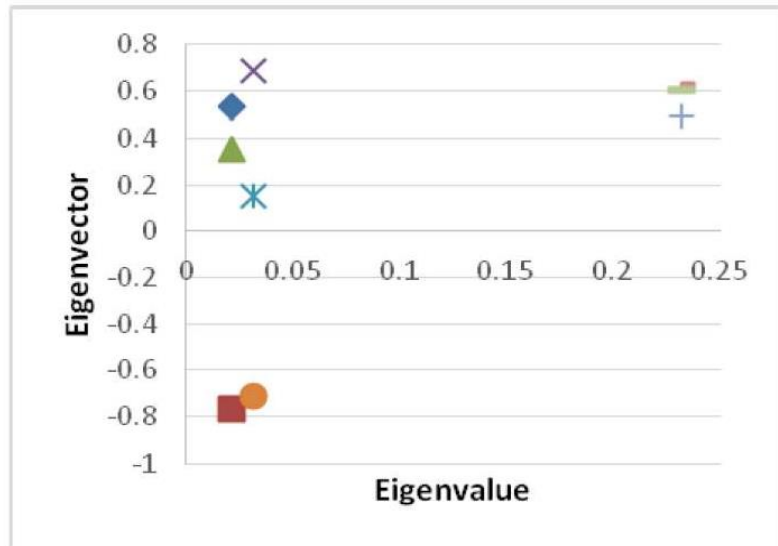


Figure 4.4 Representation of Real Currency of Rs 2000

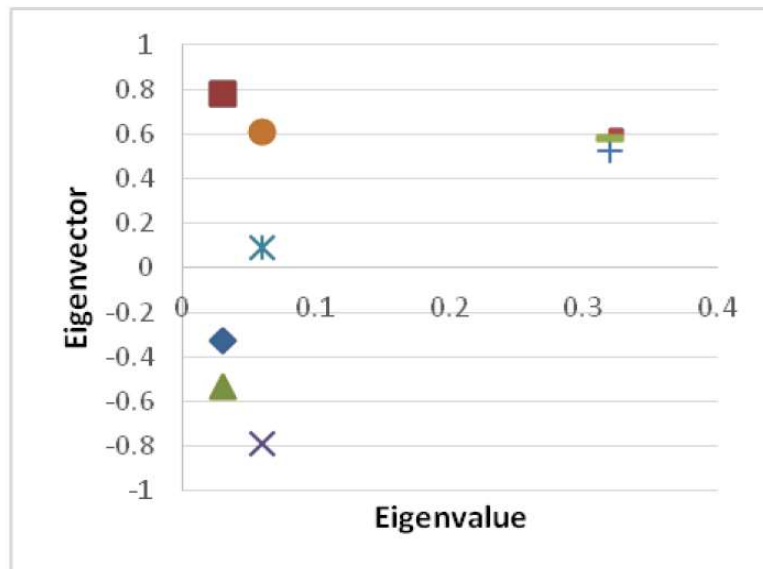


Figure 4.5 Representation of Fake Currency of Rs 2000

4.4 MAJOR FINDINGS

From the work presented in this chapter, the following conclusion have been arrived at:

- ☛ PCA is an excellent approach for the detection of fake currency in the Indian scenario as well as worldwide;
- ☛ Many researchers have implemented this approach on notes of various kinds but not for the Indian currency;
- ☛ In the present work, an efficient model is proposed through which results are presented in the form of a graph;
- ☛ The converged result has been obtained by computing mean, covariance, eigenvalues, eigenvectors and new data set has been generated for the identification of fake currency.

CHAPTER V

Texture Feature Analysis for Identification of Fake Currency

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CHAPTER V

TEXTURE FEATURE ANALYSIS FOR IDENTIFICATION OF FAKE CURRENCY

In recent years, the security of currency has gain importance in the field of research. With the advent of digital technology, color printer and color scanner are the cheapest way for a counterfeiter to produce fake currency. Feature extraction is the most important technique in paper currency recognition. According to the reviewer, texture feature plays an important role in paper currency detection. Texture feature is generally a statistical-based approach and in the present work, a new model is proposed for paper currency detection. The presented model is computing the texture properties like Gray Level Co-occurrence Matrix (GLCM) of Rs 500 for real and fake currency. The Principle Component Analysis (PCA) is used for the reduction of the higher dimension of an image. The proposed work provides better results with the collaboration of PCA and GLCM. The texture properties have been used and GLCM measured the variation in intensity at a pixel of interest of the currency. The computed results have been presented in the form of tables and graphs.

In the digital era of technology, it is very difficult to identify fake paper currency. Illegal replication of original currency is known as counterfeiting. The Government of India (GOI) has used the term fake currency in place of counterfeit. This is a very challenging issue to identify fake currency. Reserve Bank of India (RBI) is the only body that takes sole responsibility to print paper currency in India. Extracting security features from Indian currency is most important for the accuracy and robustness of the automated system. Features extraction in the form of color, shape, texture, or context are the most important techniques of image processing and pattern recognition. Although many

techniques are available in the literature to find out the pattern of paper currency, feature extraction is the most common technique in the form of color features, transform features, shape features, texture features, edge, and boundary features. From the literature of the currency identification, it is observed that there is no work on the newly developed paper currency by RBI but some little information in the literature are available for the Mexican banknotes, Euro, US Dollar related to the countries namely Australia, Cyprus, Sri Lankan, and Bangladesh. Further, it is found from the literature that the banknotes of each country are modeled by extracting the very important feature that depends on the nationality of currency. Therefore, the contribution of the systematic approach is to recognize the currency by texture feature analysis. In the following figure 5.1, the traditional way to image analysis in image processing is represented. In the year 2010, Kekre et al. [79] have explained a method for image retrieval using texture feature extraction from GLCM, Linde-Buzo-Gray (LBG) and Kekre's Proportionate Error (KPE) algorithms. In the year 2013, Mohanaiah et al. [96] have described the GLCM approach for image texture feature extraction. In the work, it is presented an application of GLCM to extract the second-order statistical texture feature analysis for estimation of the image using Xilinx FPGA. The computed results present the texture feature analyses with high accuracy in less computation time and it is efficiently used for real-time pattern recognition application. In the year 2012, Hamza and Al-Assadi [60] also described a new method of image improvement on optimal texture features extracted from GLCM using a genetic algorithm that finds ideal texture features separated from GLCM dependent on the fitness function.

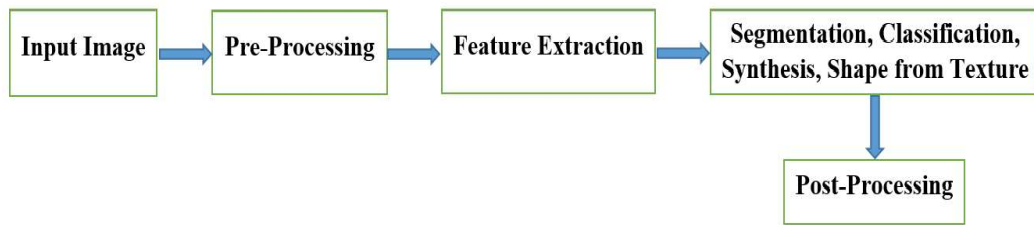


Figure 5.1 Representation of Texture Feature Analysis

5.1 AN OVERVIEW OF FEATURE EXTRACTION

This section briefly elaborates on digital Image processing, pattern recognition, and feature extraction. Feature extraction is the most essential chunk of pattern recognition that deals with dimensionality reduction. To deal with enormous information that contains redundant data, the feature extraction method is used to effectively reduce the data size without losing important and relevant information. In general, feature contains information about color, shape, surface, or context [139]. The kind of literature has suggested a lot of techniques for feature extraction from images, some are listed below in figure 5.2.

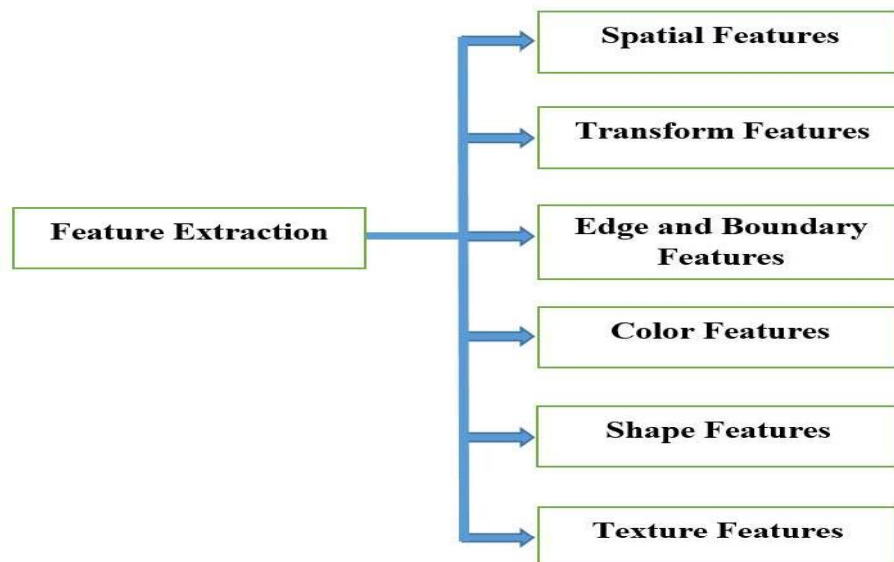


Figure 5.2 Various Types of Feature Extraction

5.2 CONCEPT OF GLCM

GLCM is a technique for the extraction of texture features and according to Guiying Li [187], GLCM is defined as the texture of continual arrangement of information having the structure of regular intervals. Texture study means size, shape, density, arrangement, surface characteristics, and appearance of an object and also of its elementary part. As texture contains vital information regarding any object, so that texture feature extraction leads to the key function in the Image processing field.

In the year 2020, Sharma et al. [137] proposed a novel method of object recognition using the point feature technique for color images. The SURF algorithm is used to find the object detection for unique feature matches of color images. This approach of detection has robustly find objects between colored cluttered images. In the year 2019, Patel et al. [107] proposed a method that suggests to uses K- means and EK means clustering methods on various tumor images. The characteristics are observed based on geometrical features. Images were trained by advanced machine learning algorithms like Artificial Neural Network (ANN) and Support Vector Machine (SVM) where it divides the tumor into the malignant type and due to segmentation it gives tumorous part. That system used characteristic extraction by further segmenting GLCM characteristics into Haralick features. Neville et al. [187] demonstrated various texture feature extraction methods and characterized them as model-based and transform information, statistical, structural methods. Among all listed methods, the Statistical based feature extraction method is prominent for texture feature extraction that incorporates first-order statistics, second-order statistics, and higher-order statistics. In the present scenario, the co-occurrence matrix and texture feature are most popularly used in the area of image identification which was suggested by Haralick in early 1973

that is based on second-order statistical features. Suggestions regarding texture feature contain the following two steps:

- ☛ Firstly, the computation of the co-occurrence matrix;
- ☛ Based on the computation of the co-occurrence matrix, texture features are calculated.

This idea is quite useful in Image analysis for currency identification. After optimizing the fourteen texture features, the idea of Haralick in 1973, Andrea Baraldi, and Flavio Parmiggiani in 1995 proposed a new approach of the five statistical parameters energy, entropy, contrast, homogeneity, and correlation [187]. The explanation is as follows:

m, n : coefficient of co-occurrence Matrix;

$X(m, n)$: element in the co-occurrence Matrix at the co-ordinates m, n ;

K : Dimension of co-occurrence Matrix.

The five statistical parameters are explained below in brief:

5.2.1 Energy

The performance can be measured in terms of Energy (E) which can be measured as the extent of pixel pair repetitions. It measures the uniformity of an image. When pixels are very similar, the energy value will be large. The energy is defined as:

$$E = \sqrt{\sum_{m=0}^{K-1} \sum_{n=0}^{K-1} X^2(m, n)} \quad (5.1)$$

5.2.2 Entropy

Entropy (Ent) is the proportion of arbitrariness that is utilized to describe the surface of the information picture. Its worth will be maximum when all the components of the co-occurrence matrix are equivalent. It is defined below:

$$Ent = \sum_{m=0}^{K-1} \sum_{n=0}^{K-1} X(m,n)(-ln(X(m,n))) \quad (5.2)$$

5.2.3 Contrast

The Contrast (Con) is characterized in equation (5.3), which is a proportion of power of a pixel and its neighbor over the picture. In the visual impression of a genuine world, differentiation is deflected by the distinction in color and brightness of the object and different objects within a similar field of view.

$$Con = \sum_{m=0}^{K-1} \sum_{n=0}^{K-1} (m-n)^2 X(m,n) \quad (5.3)$$

5.2.4 Homogeneity

Homogeneity returns a value that measures the closeness of the distribution of elements in GLCM to the GLCM diagonal. The value of energy is 1 for a diagonal GLCM and having the range as [0 1].

$$Hom = \sum_{m,n} \frac{X(m,n)}{1+|m-n|} \quad (5.4)$$

5.2.5 Correlation

Correlation returns a measure of how correlated a pixel into its neighbor over the whole image. Its range is [-1 1] and defined below:

$$Corr = \sum_{m,n} \frac{(m - \mu_m)(n - \mu_n)X(m,n)}{\sigma_m \sigma_n} \quad (5.5)$$

5.3 PRINCIPLE COMPONENT ANALYSIS

According to the data hypothesis, extract the important feature of currency image for identification and compare one currency to another currency feature to a database. A basic way to deal with extricating the data contained in an image of a currency is to by

one way or another catch the variety in a collection of currency image, autonomous of results of features and utilize this data to computed and analyze the single currency image [141]. In the Present work, it is defined that Principle Component Analysis (PCA) is a method of recognition based on the feature of texture that features are expressed in the term of resemblance and dissimilarity. Once the pattern is matched in data then it can be compressed.

The transformation function is given below:

$$M = YW \quad (5.6)$$

where,

Y denotes $a * b$ matrix of a observations on b variables;

M denotes $a * b$ of a values for each of b the components;

W denotes $b * b$ of coefficient defining the linear transformation.

5.4 EXPERIMENTAL RESULTS AND DISCUSSION

There are two phases, which are training and testing and explained below briefly:

5.4.1 Training Phase

It contains the following stages:

- ☛ Generate the currency database;
- ☛ Features are extracted from the currency;
- ☛ Calculate Mean;
- ☛ Subtract mean from each currency image, known as mean aligned currency;
- ☛ Calculate covariance of the mean aligned currency;
- ☛ Calculate Eigenvalues and Eigenvectors;
- ☛ Identify Eigenvectors and find principle Eigenvectors;
- ☛ Find the direction of Data.
- ☛

5.4.2 Testing Phase

It contains the following stages:

- ☛ For testing, a test currency image, make it a column vector;
- ☛ Subtract mean of currency to this test currency;
- ☛ Calculate the distance.

Let us first describe the characteristics of Rs 500 Indian paper currency which is depicted below in figure 5.3.



Figure 5.3 Representation of Rs 500 Indian Paper Currency

The presented currency has the following silent features listed below:

- ☛ See-through register
- ☛ Latent image
- ☛ Denomination numerical in Devanagari
- ☛ Mahatma Gandhi's portrait in the center facing to the right
- ☛ Windowed security thread
- ☛ Guarantee clause

- ☛ Portrait and electrotype watermark
- ☛ Number panel with numerals growing from small to big on the top left side and bottom right side
- ☛ Denomination in numerals with rupee symbol in color-changing ink (green to blue) on the bottom right
- ☛ Asoka pillar emblem on the right
- ☛ Circle with Rs 500 in raised print on the right
- ☛ Five bleed lines on left and right in raised print
- ☛ Year of printing of the note on left
- ☛ Swachh Bharat logo with the slogan
- ☛ Language panel towards the center
- ☛ Red Fort with Indian flag
- ☛ Denomination numeral in Devanagari on right

The image database used in this study served as the main feature extraction of the texture using GLCM. The GLCM method incorporates the averaging of a coefficient matrix having the direction of 0° , 45° , 90° , and 135° [61]. The above-mentioned six features of GLCM used in this research are Energy, Entropy, Contrast, Homogeneity, and Correlation. The values of these features are depicted as the training and test database from our keenly observed image data set. Table 5.1 shows the value of the characteristics of GLCM used as input to database training.

Table 5.1 Characteristics of GLCM Database Training

Energy	Entropy	Contrast	Homogeneity	Correlation
0.20645	1.35718	0.83730	0.811055	0.749905

5.4.3 Classification and Identification System Testing

The determination of value k's are 1, 3, and 5 which are carried out with the help of the PCA classification process for a fixed amount of training data. The right value of k is depending upon the level of closeness and accuracy of the identification process. Hence as a result of the identification process to determine the value of the k, the testing process is observed with a certain accuracy as depicted in table 5.2.

Table 5.2 Accuracy of the Identification Result

Banknote	k-values	Accuracy (%)
	k=1	100
Rs 500	k=3	90
	k=5	80

The proposed technique is implemented using MATLAB to get real currency from the database. Based on the k-value is obtained and shown in different accuracy to currency detection, graph plot between k-value and accuracy in figure 5.4.

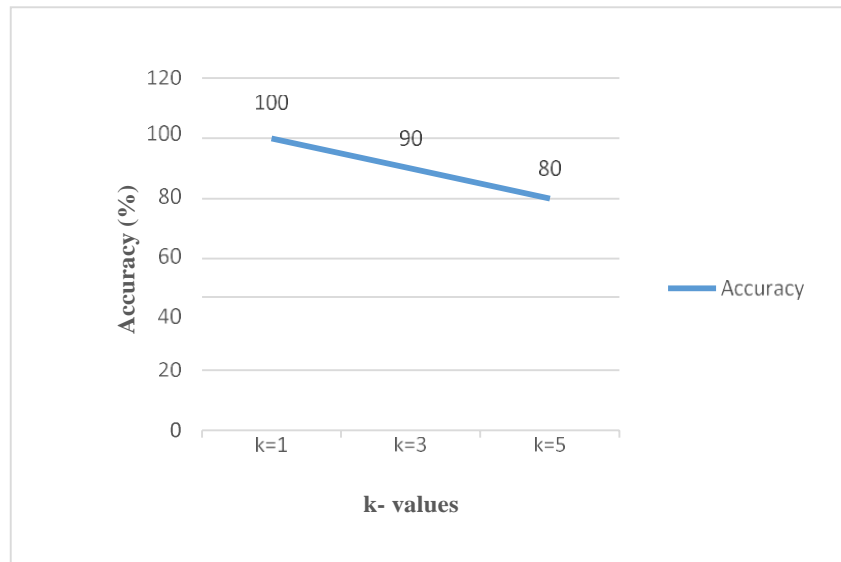


Figure 5.4 The Graph between k-values and Accuracy

5.5 MAJOR FINDINGS

From the above, the major findings are described below briefly:

- ☛ The texture pattern of the genuine Rs 500 currency is exceptionally powerful in the process of information securing which can influence the estimation of surface element extraction utilizing the GLCM technique;
- ☛ The estimation of k in the arrangement input utilizing the PCA technique can decide the exactness of the characterization procedure and ID of the realness of rupee currency;
- ☛ The after-effects of the recognizable proof of the authenticity of the rupee tried right now an accuracy of 100% when the value of $k=1$, the accuracy of 90% when the estimation of $k=3$ and accuracy of 80% when the estimation of $k=5$ with the arrangement of the measure of 20 training data and 10 testing data;
- ☛ The accuracy of the value for $k=1$ is the most elevated of the accuracy value. It is because when an estimation of $k=1$ is the default value research can be inferred that the more noteworthy of the separation technique that has 1 nearest neighbor of that information worth or it very well may be considered that information possess;
- ☛ Right now be reasoned that the more prominent the estimation of k given to the framework during the arrangement and identification procedure will cause the lower level of accuracy produced from the system.

CHAPTER VI

Genetic Algorithm Approach for Fake Currency Identification

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CHAPTER VI

GENETIC ALGORITHM APPROACH FOR FAKE CURRENCY IDENTIFICATION

In any country, there is always the arrival of different kinds of new currency from time to time. In India, the government applied demonetization in the year 2016, and later on, there was the arrival of new notes in the form of 10, 20, 50, 100, 500, and 2000 Indian rupees. Although it minimizes the use of fake currency in any Country hackers and intruders generate the fake currency through a high-quality scanner and printer.

This chapter presents, an application of the Genetic algorithm that is used for the identification of fake currency based on feature extraction. An algorithm has been implemented for the identification of fake currency in the form of notes.

6.1 BACKGROUND

In the year 1968, Charles Darwin developed a theory based on the biological evaluation that states the natural existence of the strongest species. This was based on the natural selection of small inherited variation for increasing the individual ability to compile, survive, and reproduce. Based on this theory, the concept of the genetic algorithm was developed by Goldberg. Since the present work is based on the application of a genetic algorithm for the identification of fake Indian currency notes, therefore, it is necessary to describe some of the important references related to the work.

Hermawanto [66] explained the concept of a genetic algorithm for solving the mathematical equality problem by taking the four variables. In the year 1999, Gen and Cheng [56] proposed the concept of the genetic algorithm to achieve crossover by a solution of irregular cut point and created the off-screen by a blend of one parent to one side cut point which section of the other parent of the correct slice point and applied it

to the designing point. Bashansky and Yaari [27] proposed a famous approach of a black box which is used for selecting the optimized chromosomes which is a very advantageous approach and simple to implement the genetic algorithm. One of the important papers introduces in the year 2012 was Dharmistha and Vishwakarma [45] developed an accuracy process model and further optimized the weights assigned on the internal layers' architecture of the Artificial Neural Network (ANN). Nanhao and O'Connor [98] described the genetic algorithm which is also used in the field of wireless sensor networks with which a method for finding the 100 possible solutions for a given task. In the year 2015, Bashir [23] explained the bit by bit mathematical calculation of hereditary calculation for addressing the Eggcrate work. The outcomes demonstrated that the Eggcrate work has a known worldwide least at [0, 0] with an ideal capacity estimation of zero. Bashir and Mahdi [26] explained Queen Problem which is a well-known optimization technique used for the genetic algorithm. Further, the application of generation is described by the solution of fitness function by selecting the coordinated and fitness function [24-25]. The other important references related to genetic algorithms are [33], [48], [108], [113], [122], and [173]. From the review of the literature, it is observed that there is little use of the genetic algorithm for solving the problem related to identifying spatial, transform, edge and boundary, color, shape, texture features of any kind of Image.

In the present chapter, the concept of a genetic algorithm is used for finding the generation of new chromosomes process till the matching of the result. Sufficient iterations have been performed by the use of the Python programming language. Results are depicted on the Indian currency of note of Rs 500 represented in figure 5.3.

6.2 METHODOLOGY AND IMPLEMENTATION

For Implementation of the concept of genetic algorithm, the following steps are used:

1. *Input the image of the note of Rs 500 and compute the number of chromosomes generation, crossover rate, mutation rate values;*
2. *Divide the chromosomes into the number of blocks of the same size;*
3. *Initialize the number of chromosomes by taking the four variables;*
4. *Repeat the following sub-activities for identification of fake currency;*
 - 4.1 *Compute the fitness value of the chromosomes of the objective function;*
 - 4.2 *Compute the highest fitness function chromosomes and the selection of the chromosomes;*
 - 4.3 *Compute the chromosomes along with probability values;*
 - 4.4 *Mutate rate parameter by reproducing the genes at a random position;*
5. *Repeat step 4 till the finding of the best chromosomes.*

The genetic algorithm assesses the objective function to be upgraded at some arbitrarily chosen purpose of the definition area. By the utilization of this strategy, another arrangement of focuses (another population) is produced. Steadily, the focuses on the population approach neighborhood towards maxima and minima of the function. The above technique has been implemented in the Indian currency of note of Rs 500 and steps are shown in figure 1.14.

6.2.1 Genetic Algorithm

The genetic algorithm evaluates the target function to be optimized at some randomly selected point of the domain definition. By the use of this method, a new set of points (a new population) is generated. Gradually, the points in the population approach towards local maxima and minima of the function.

The above technique has been implemented in the Indian Currency of note of Rs 500 and steps are discussed in brief:

Step 1

Input the scanned Image of Rs 500, then apply image pre-processing and extract the feature of the most vulnerable parts of currency. For this purpose, MATLAB is used to get the feature vector as shown in figure 6.1.

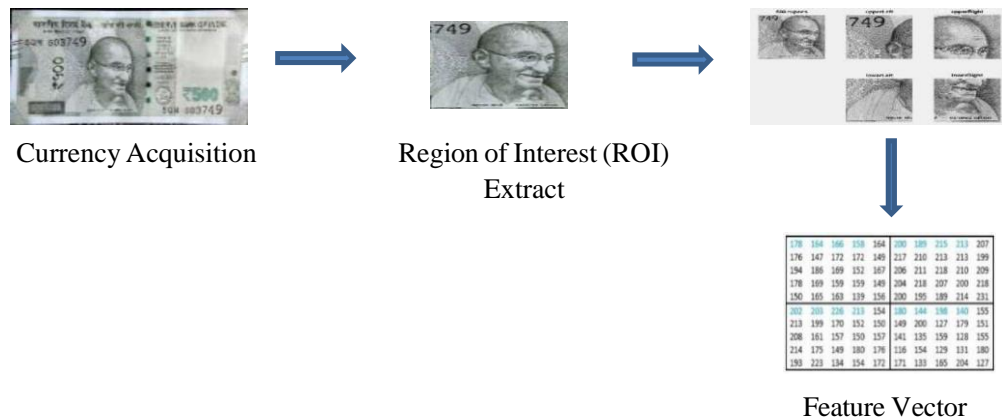


Figure 6.1 Feature Extraction of Rs 500

Step 2

Image is analyzed and divided into some blocks each with the same size and give a label to each block and save the pixels of each block in temporary storage to retrieve these pixels when constructing the original image matrix. The construction of the

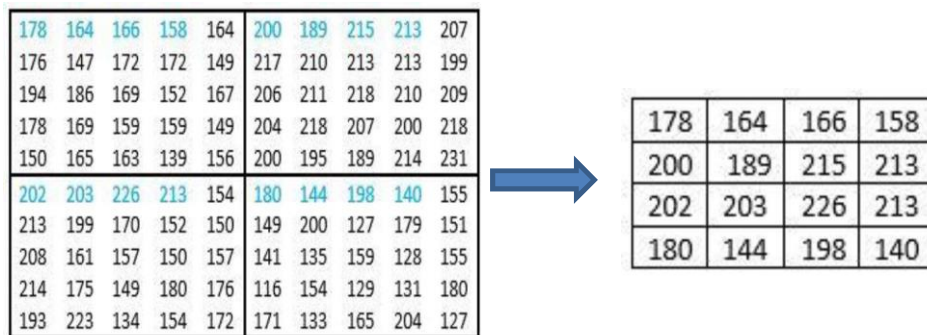


Figure 6.2 Construction of the Original Chromosomes Matrix

original image matrix. The construction of the original matrix is represented in figure 6.2.

Step 3

Consider the initial population consisting of some chromosomes taken as Ch [] and each chromosome consists of some genes of a block in the blocks matrix that results from the first stage:

$$\text{Ch [1]} = [\text{a; b; c; d}] = [178; 164; 166; 158]$$

$$\text{Ch [2]} = [\text{a; b; c; d}] = [200; 189; 215; 213]$$

$$\text{Ch [3]} = [\text{a; b; c; d}] = [202; 203; 226; 213]$$

$$\text{Ch [4]} = [\text{a; b; c; d}] = [180; 144; 198; 140]$$

Step 4

Repeat the following sub-activities for the identification of fake currency:

Steps 4.1

Compute the fitness evaluation the fitness evaluation $F_{\text{eval}} []$ using objective function of each chromosome by taking fitness function as:

$$f(x) = ((a + 2b + 3c + 4d) - 50) \quad (6.1)$$

$$F_{\text{eval}} [1] = \text{Abs} ((178 + 2*164 + 3*166 + 4*158) - 50) = 1586$$

$$F_{\text{eval}} [2] = \text{Abs} ((200 + 2*189 + 3*215 + 4*213) - 50) = 2025$$

$$F_{\text{eval}} [3] = \text{Abs} ((202 + 2*203 + 3*226 + 4*213) - 50) = 2088$$

$$F_{\text{eval}} [4] = \text{Abs} ((180 + 2*144 + 3*198 + 4*140) - 50) = 1572$$

Step 4.2

For finding the next generation, let us compute the highest probability of the fittest chromosome. To calculate the fitness probability, first, compute the fitness taken as fitness [] of each chromosome. To avoid partition by zero issues, the assessment of F_{eval} is added by 1 and represented below:

$$\text{Fitness [1]} = 1 / (1 + F_{\text{eval}} [1]) = 0.00063011972$$

$$\text{Fitness [2]} = 1 / (1 + F_{\text{eval [2]}}) = 0.00049358342$$

$$\text{Fitness [3]} = 1 / (1 + F_{\text{eval [3]}}) = 0.00047869794$$

$$\text{Fitness [4]} = 1 / (1 + F_{\text{eval [4]}}) = 0.00063572791$$

$$\begin{aligned} \text{Total} &= 0.00063011972 + 0.00049358342 + 0.00047869794 + 0.00063572791 \\ &= 0.00223812899 \end{aligned}$$

Step 4.3

The probability for each chromosome is to be computed by:

$$P [i] = \text{Fitness [i]} / \text{Total} \quad (6.2)$$

$$P [1] = 0.00063011972 / 0.00223812899 = 0.28153860784$$

$$P [2] = 0.00049358342 / 0.00223812899 = 0.22053394697$$

$$P [3] = 0.00047869794 / 0.00223812899 = 0.21388308812$$

$$P [4] = 0.00063572791 / 0.00223812899 = \mathbf{0.28404435707}$$

Therefore, chromosome 4 has the most elevated wellness esteem, this is the most noteworthy likelihood that to be picked for the cutting edge chromosome. For the computation of cumulative probability considered as Cum [], consider Roulette Wheel for the selection process as shown below:

$$\text{Cum [1]} = 0.2815$$

$$\text{Cum [2]} = 0.2815 + 0.2205 = 0.502$$

$$\text{Cum [3]} = 0.2815 + 0.2205 + 0.2138 = 0.7158$$

$$\text{Cum [4]} = 0.2815 + 0.2205 + 0.2138 + 0.2840 = 0.9998$$

Using Roulette-Wheel, to calculate the cumulative probability of selection process and generate the random number taken as Rand [] between 0-1 as given below:

$$\text{Rand [1]} = 0.201$$

$$\text{Rand [2]} = 0.284$$

$$\text{Rand [3]} = 0.099$$

$$\text{Rand [4]} = 0.822$$

If random number Rand [1] is smaller than Ch [1] then select Ch [1] as a chromosome in the new population for the next generation represented as New_Ch [].

$$\text{New_Ch [1]} = \text{Ch [1]}$$

$$\text{New_Ch [2]} = \text{Ch [2]}$$

$$\text{New_Ch [3]} = \text{Ch [1]}$$

$$\text{New_Ch [4]} = \text{Ch [4]}$$

Chromosomes Ch [] in the population are now represented below:

$$\text{Ch [1]} = [178; 164; 166; 158]$$

$$\text{Ch [2]} = [200; 189; 215; 213]$$

$$\text{Ch [3]} = [178; 164; 166; 158]$$

$$\text{Ch [4]} = [180; 144; 198; 140]$$

For interchanging the sub chromosome, used a one cut point to select a random point in the parent chromosome. Parent chromosome which will mate is randomly chosen and the quantity of mate Chromosome is controlled utilizing crossover rate taken as pc [] boundary.

Chromosome k will be chosen as a parent if $\text{Rand}[k] < pc$. Assume one set that the crossover rate is 25% then chromosome number k will be chosen for crossover if a randomly created an incentive for chromosome k underneath 0.25. Consider an irregular number taken as Rand []:

$$\text{Rand [1]} = 0.191$$

$$\text{Rand [2]} = 0.259$$

Rand [3] = 0.760

Rand [4] = 0.006

For the random number above, parents are Ch [1] and Ch [4], will be selected for crossover:

Ch [1] > < Ch [4]

Ch [4] > < Ch [1]

After chromosome determination, the following cycle is deciding the situation of the crossover point. This is finished by producing a random number between 1 to (length of Chromosome - 1). For this situation, created random numbers ought to be somewhere in the range of 1 and 3. After that one gets the crossover point, the parent's chromosome will be cut at the crossover point and its qualities will be exchanged. For instance, one produced 3 irregular number and get:

C [1] = 1

C [2] = 1

C [3] = 2

Then for the first crossover and second crossover, parent's gens will be cut at gen number 1, Example

Ch [1] = Ch [1] > < Ch [4]

= [178; 164; 166; 158] > < [180; 144; 198; 140]

= [178; 144; 166; 140]

Ch [4] = Ch [4] > < Ch [1]

= [178; 144; 166; 140]

After the crossover process compute new chromosomes:

Ch [1] = [178; 144; 166; 140]

Ch [2] = [200; 189; 215; 213]

Ch [3] = [178; 164; 166; 158]

Ch [4] = [178; 144; 166; 140]

Step 4.4

After the change of chromosome dictated by the mutation rate boundary and mutation measure is finished by supplanting the gen at an arbitrary situation with another worth. For this cycle, first, process the complete length of gen (Tot_gen) in the population as follow:

$$\begin{aligned} \text{Tot_gen} &= \text{Number_of_gen_in_Chromosome} * \text{Number of population} \\ &= 4*4 \\ &= 16 \end{aligned}$$

Therefore, in mutation measure, an arbitrary number is created between 1 to Tot_gen. To mark the position of gen in a chromosome, whenever a created arbitrary number is more modest than change rate (pm). Assume, characterize pm 10% it is normal that 10% (0.1) of total_gen in the population that will be changed:

$$\begin{aligned} \text{Number of mutations} &= 0.1*16 \\ &= 1.6 \\ &= 2 \end{aligned}$$

Assume the age of irregular numbers yield as 8 and 14 then the chromosomes are Chromosome number 2 gen number 4 and Chromosome number 4 gen number 2.

Suppose generated random numbers are:

Ch [1] = [178; 144; 166; 140]

Ch [2] = [200; 189; 215; **213**]

$$\text{Ch [3]} = [178; 164; 166; 158]$$

$$\text{Ch [4]} = [178; \mathbf{144}; 166; 140]$$

For completing the change cycle, think about one emphasis or one generation of the genetic calculation. One would now be able to assess the target work after one generation as:

$$\text{Ch [1]} = [178; 144; 166; 140]$$

$$\begin{aligned} \text{F_eval [1]} &= \text{Abs} ((178 + 2 * 144 + 3 * 166 + 4 * 140) - 50) \\ &= \text{Abs} ((178 + 288 + 498 + 560) - 50) \\ &= 1474 \end{aligned}$$

$$\text{Ch [2]} = [200; 189; 215; \mathbf{213}]$$

$$\begin{aligned} \text{F_eval [2]} &= \text{Abs} ((200 + 2 * 189 + 3 * 215 + 4 * 213) - 50) \\ &= \text{Abs} ((200 + 378 + 645 + 852) - 50) \\ &= 2025 \end{aligned}$$

$$\text{Ch [3]} = [178; 164; 166; 158]$$

$$\begin{aligned} \text{F_eval [3]} &= \text{Abs} ((178 + 2 * 164 + 3 * 166 + 4 * 158) - 50) \\ &= \text{Abs} ((178 + 328 + 498 + 632) - 50) \\ &= 1586 \end{aligned}$$

$$\text{Ch [4]} = [178; \mathbf{144}; 166; 140]$$

$$\begin{aligned} \text{F_eval [4]} &= \text{Abs} ((178 + 2 * 144 + 3 * 166 + 4 * 140) - 50) \\ &= \text{Abs} ((178 + 288 + 498 + 560) - 50) \\ &= 1474 \end{aligned}$$

From the advancement of the new Chromosome, one can see that the objective function is diminishing, this implies that we have better chromosomes or arrangements contrasted and the past Chromosome age. New chromosome for the following emphasis are given beneath:

Ch [1] = [178; 144; 166; 140]

Ch [2] = [200; 189; 215; 213]

Ch [3] = [178; 164; 166; 158]

Ch [4] = [178; 144; 166; 140]

These new chromosomes will go through a similar cycle as the past generation of Chromosomes, for example, evolution, selection, crossover, and mutation, and eventually, it creates another generation of Chromosomes for the following emphasis. This cycle will be rehashed until a foreordained number of generations.

Steps 5

The above-said process is repeated until the finding of the best chromosomes.

6.3 EXPERIMENTAL STUDY

To execute the Simple Genetic Algorithm (SGA) code written in Python programming language, the fundamental three stages of the SGA, for example, select, crossover, and mutation are manually determined. This method is called as generation and another population creates at each progressive generation. Toward the finish of the run, rehashing the cycle until the best arrangement is resolved. After getting the best chromosome of acquiring, the currency image is compared to a chromosome of the reference currency image. To reduce the computation time, the proposed algorithm uses the currency. This chapter is representing the calculation behind the genetic algorithm for paper currency detection.

6.4 MAJOR FINDINGS

- ☛ The texture pattern of the genuine Rs 500 currency is exceptionally powerful in the process of information securing can influence the estimation of surface element extraction utilizing the Feature vector;

- ☛ The estimation of chromosomes in the arrangement input utilizing the genetic algorithm (GA) technique can decide the exactness of the characterization procedure and ID of the realness of rupee currency;
- ☛ The GA does find near-optimal results quickly after searching a small portion of the search space;
- ☛ This algorithm is easy to produce and simple to understand and enhancements easily introduced that show the effective algorithm much flexibility;
- ☛ Results show that the genetic algorithm can find an optimal solution for currency identification problems.

CHAPTER VII

Neural Network Approach for Currency Identification

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CHAPTER VII

NEURAL NETWORK APPROACH FOR CURRENCY IDENTIFICATION

Currency is the backbone of the Indian economy. Currency counterfeiting is a serious crime that affects a country's finances. India is facing more serious problems due to the increase in fake currencies in the market. In recent years, currency identification is an important area of research. The Government of India (GOI) declared the demonetization of all Rs 500 and Rs 1,000 bills on November 8, 2016. There was also an introduction of Rs 500 and Rs 2,000 new currencies in exchange for demonetized currencies. After demonetization, there are many fake currencies came into the limelight. As a solution, various fake currency detection methods are available worldwide, but most of them are hardware-based and are not cost-effective. In the advent of technology, Image processing plays an important role in currency identification. The proposed system will be useful to detect counterfeit currencies in banking systems. Feature extraction is the most important technique for pattern recognition based on texture analysis. The proposed system can identify the legitimacy of currency by checking specific security features such as watermarks, latent images, security threads, etc. Identification of counterfeit currencies is done using machine learning techniques. The methodology involves extracting and encoding these security features. Security features are extracted from the input image, feature detection and classification are performed using different machine learning algorithms. This approach presents a novel method for currency identification based on the feature extraction method using a machine learning algorithm. The ultimate aim of this approach is to calculate the accuracy of the distinct method of machine learning. In the end, this

method improves the accuracy of currency identification.

7.1 BACKGROUND

In the past time, people only seen the value of money, not check the realness of money with the help of technology. Thus, many cases have arrived for fake currency in India. Counterfeiting is generally a duplicate form of real currency which provides truth to other people for the faith that received note is real. Fake currency is a widespread threat to the whole country that impacts each other. According to the National Crime Records Bureau (NCRB), in India counterfeiting crime is one of the parts of the IPC related to Economic crimes. Economic crime has 5.1% of IPC crimes [189]. Currency recognition has much technology applied by the researchers.

UV recognition technology already arrived in India but due to the development phase of counterfeiting, this technology is not better. In the area of currency recognition, image processing plays an important role. Image processing has included image acquisition, segmentation feature extraction and so on. Currency recognition is done based on size, colour, texture, scaling, rotation and other factors. Today, currency recognition has many techniques used for getting better results. One of the techniques is Neural Network which is part of a machine learning algorithm. The proposed Neural Network method has trained according to the colour and texture features of a currency. These properties have shown the uniqueness of currency. The input of the model is properties of currency on which basis model divides the dataset into training, testing and validation. The neural network approach gives better results in comparison to a previous technique used in currency recognition research. Some researchers developed a system using a different algorithm or technique. But using colour and texture feature-based neural network model gives the best accuracy.

The Indian rupee is the official currency of the Republic of India. In the previous years, the identification of counterfeit currency takes place with the help of hardware-based of mechanical devices that are available in the bank, often, that device is not accessible by common people. India is facing more serious problems due to the increase the fake currency in the market. Now, most of the method focuses on having access to the public to identify the counterfeit currency.

7.2 PROPOSED METHODOLOGY

A. Load dataset

In the first step load the dataset in our proposed algorithm.

B. Pre-processing

After loading the dataset, we have to apply a pre-processing step before the classification as mention in figure 7.1.

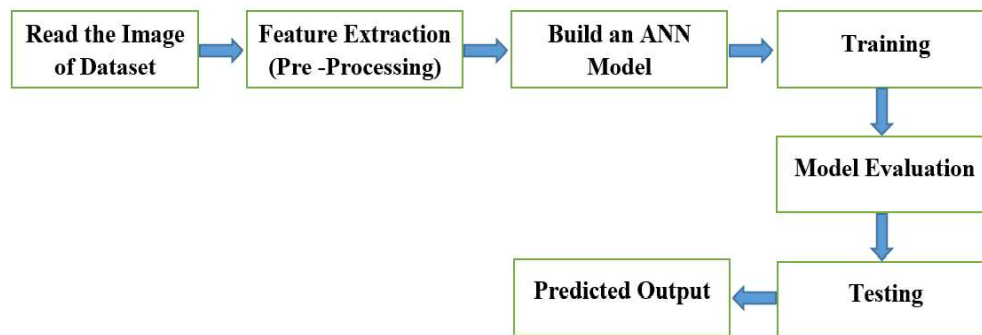


Figure 7.1 Process for Currency Identification

a) Feature Extraction

The step involves the task of extracting those attributes which is most important to classify the dataset correctly. For datasets having two or more classes, feature extraction is choosing the most effective feature which can separate the classes accurately. Class

separability depends not only on the class distribution but also on the classifier to be used.

☛ Texture Feature

Texture features have used GLCM properties, in which select few properties such as contrast, correlation, energy, and homogeneity.

☛ Colour Feature

After that, each of the databases was used in the extraction of colour features: red, green and blue intensity average values called dmr, dmg and dmb as shown in figure 7.2.

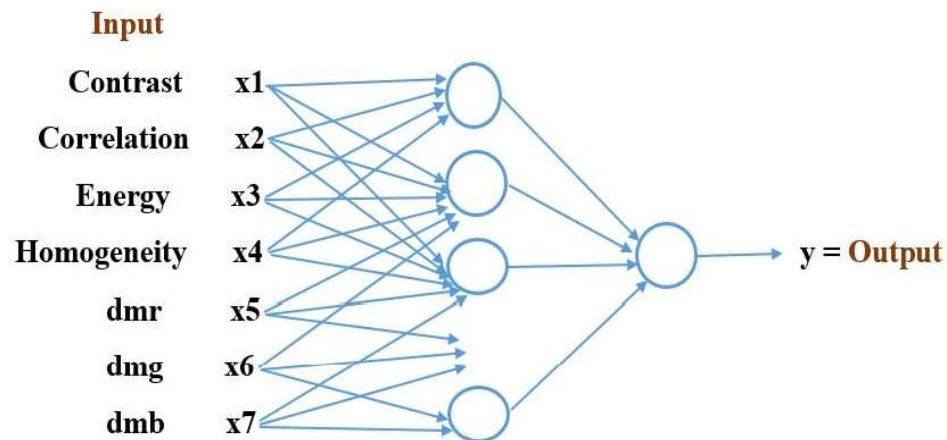


Figure 7.2 Features for Currency Datasets

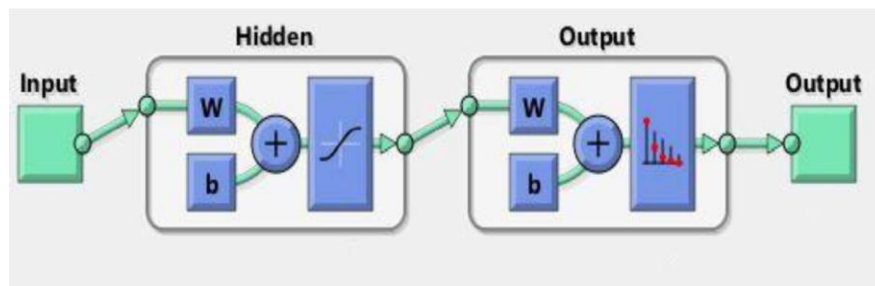


Figure 7.3 ANN Model

C. After pre-processing the datasets are divided into three parts. One of which is used as a training dataset, the second is validation and the other as a testing dataset.

☛ **Training**

These are presented to the network during training, and the network is adjusted according to its error (70%).

☛ **Validation**

These are used to measure network generalization, and to halt training when generalization stops improving (15%).

☛ **Testing**

These do not affect training and so provide an independent measure of network performance during and after training (15%).

D. Confusion Matrix

A classification algorithm represented by the confusion matrix is generally a presentation way of performance. In the confusion matrix, each column and row represented as predicted class and actual class. With the help of this presentation of classifier has to find out the non- categorization of data. The confusion matrix provides a deep view of classification rather than accuracy. If a number of the sample different from each other, then the classification matrix gives very confusing results. There are some entries in the confusion matrix are mentioned below:

☛ Positive

- i. True positive (tp)
- ii. False positive (fp)

☛ Negative

- I. True negative (tn)
- II. False negative (fn)

As discussed above, accuracy is not the correct performance parameter. So with the help of a pair of different parameters of the confusion matrix gives satisfactory results. They are as follow:

☛ Accuracy

Accuracy is calculated as the total number of correct predictions (tp+tn) divided by the total number of the dataset (tp+fp+fn+tn).

$$Accuracy = \frac{tp + tn}{tp + fp + fn + tn} \quad (7.1)$$

☛ Precision

Precision is defined as the ratio of correctly classified data in positive class (tp) to the total number of data classified as to be in positive class (tp+fp).

$$Precision = \frac{tp}{tp + fp} \quad (7.2)$$

☛ Recall

Recall or Sensitivity is defined as the ratio of tp to the total number of data classified under positive class.

$$Recall = \frac{tp}{tp + fn} \quad (7.3)$$

☛ F-measure

F-measure is defined as a combined representation of Precision and Recall and is defined as follows;

$$F - measure = 2 * \frac{Precision * Recall}{Precision + Recall} \quad (7.4)$$

The complete artificial neural network model is shown in figure 7.3.

7.3 EXPERIMENTAL RESULTS AND DISCUSSION

Datasets

This chapter used two datasets for currency recognition and validation. In the first dataset, we have ready based on Region of Interest (ROI) of denomination of currency. These datasets have a total of 60 images, each denomination category has 10 images of banknotes. Figure 7.4 has demonstrated sample images of each category.

In second, the banknote dataset is collected from using public API from IEEE [92]. It consists of 6 categories of banknotes of data: 10, 50, 100, 200, 500 and 2000 which is represented in table 7.1. Each category has 72 images of banknotes. Each category of banknotes covers all the conditions of partial occlusion, cluttered background, rotation, scaling change and illumination change as well as wrinkling.

Table 7.1 Banknotes Categories

Category ID	Image Category
1	₹ 10
2	₹ 50
3	₹ 100
4	₹ 200
5	₹ 500
6	₹ 2,000

Experiment Results 1:

The sample images for dataset 1 are shown below in figure 7.4. The Artificial Neural Network (ANN) confusion matrix has included training, validation, testing and combined performance of dataset but figure 7.5 shows the overall performance of image sizes such as 64x64, 128x128 and 256x256. Table 7.2 represented the accuracy of each size image in the dataset. Accuracy has shown in the form of true and false recognition rates of the currency. Figure 7.6 shows the error histogram of the ANN model for 20

bins. It has shown the all the error included all level is maximum equal to '0' and the model has shown satisfy that classification.



Figure 7.4 Sample Images of Own Banknote for Dataset 1

Table 7.2 Recognition Results of Banknotes Based on Size

Size of Currency	No. of Images	False Recognition rate	True Recognition rate
64x64	60	5%	95%
128x128	60	10%	90%
256x256	60	13.3%	86.7%

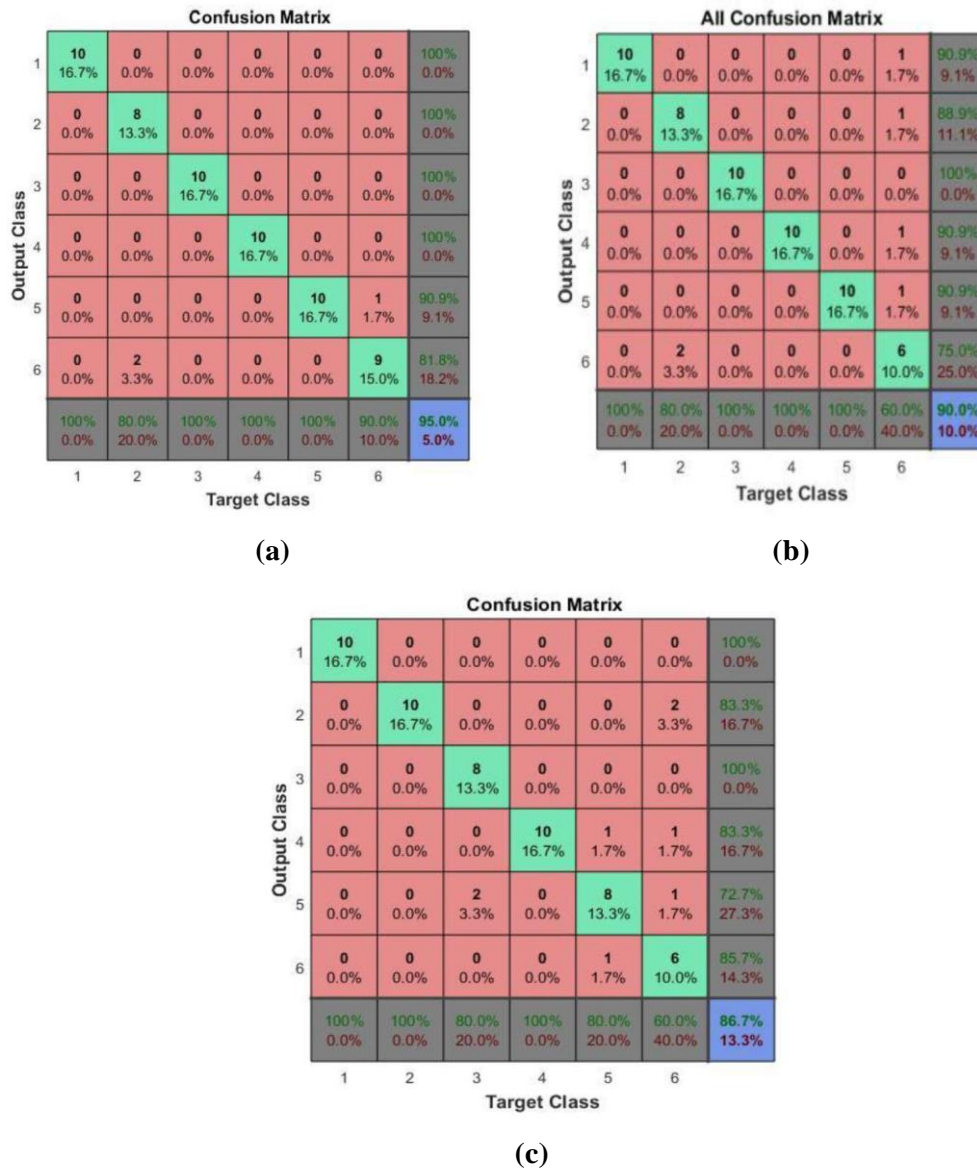


Figure 7.5 ANN Confusion Matrix (a) 64x64 (b) 128x128 (c) 256x256

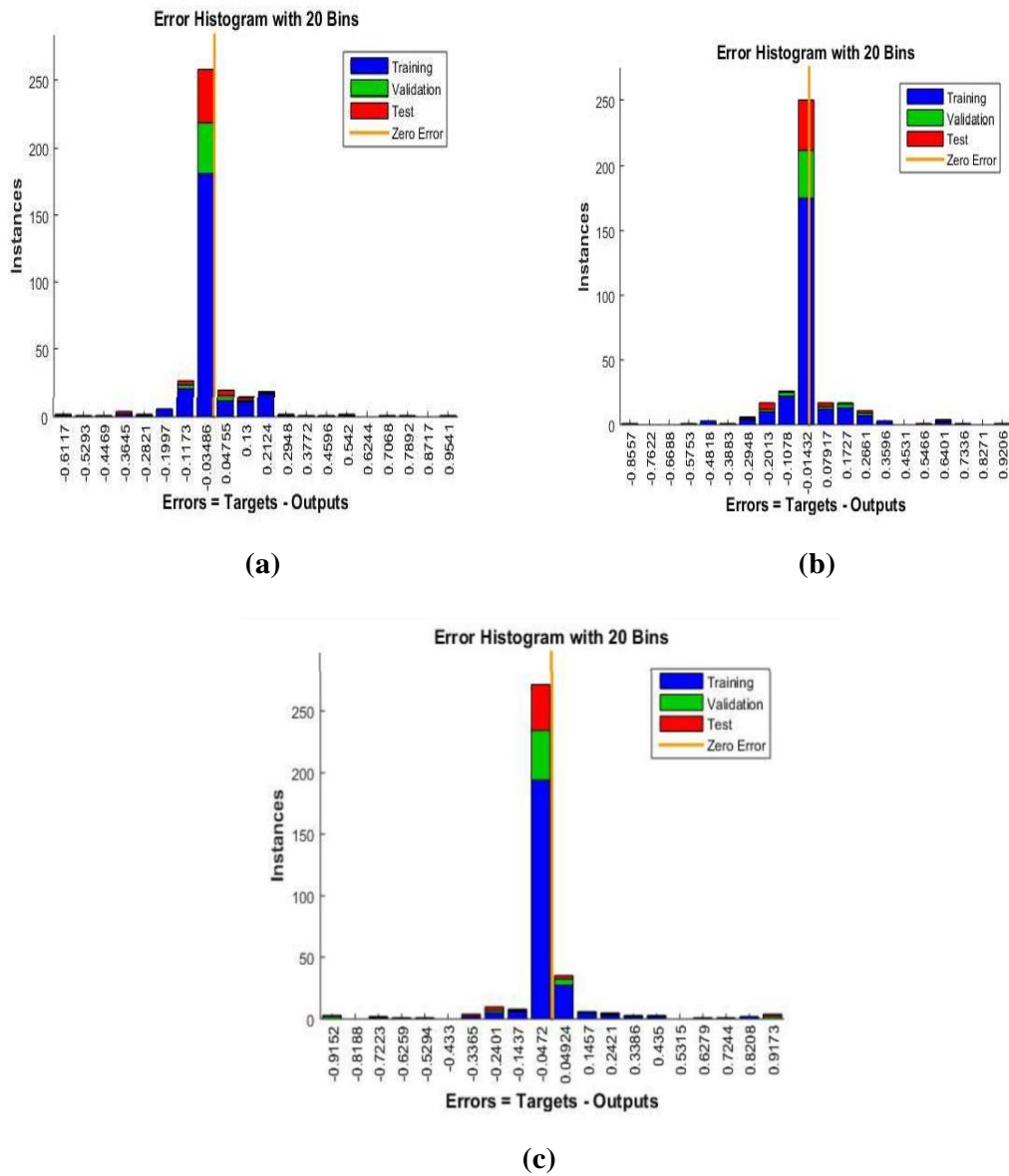


Figure 7.6 ANN Training Error Histograms (a) 64x64 (b) 128x128 (c) 256x256

Experiment Results 2:

In this dataset, all categories of notes have been taken in a different conditions such as seizer, mesh up the background, rotation, scaling, and changes in the condition of light as well as crinkled. The sample images are shown below in figure 7.7.



Figure 7.7 Sample Images from Each Category of Dataset 2 [92]

In our testing database, the proposed algorithm has given 100% true and 0% false recognition rates of each category of the denomination. Table 7.3 shows the results of each denomination. The proposed algorithm has extracted the colour and texture feature of banknote and given better recognition results. Thus, our algorithm has given a better result for the very large or complex dataset which makes it more effective than other algorithms. Table 7.4 shows the recognition rate of the online dataset with their relevant size. Figures 7.8 and 7.9 represented the confusion matrix and error histogram of each size of currency, respectively.

Table 7.3 Recognition Results for Six Categories of Banknotes

Currency	No. of Images	False Recognition rate	True Recognition rate
₹ 10	72	0	100%
₹ 50	72	0	100%
₹ 100	72	0	100%
₹ 200	72	0	100%
₹ 500	72	0	100%
₹ 2,000	72	0	100%

Table 7.4 Recognition Results of Banknotes Based on Size

Currency	No. of Images	False Recognition rate	True Recognition rate
64x64	432	22.20%	77.80%
128x128	432	19%	81%
256x256	432	19.70%	80.30%

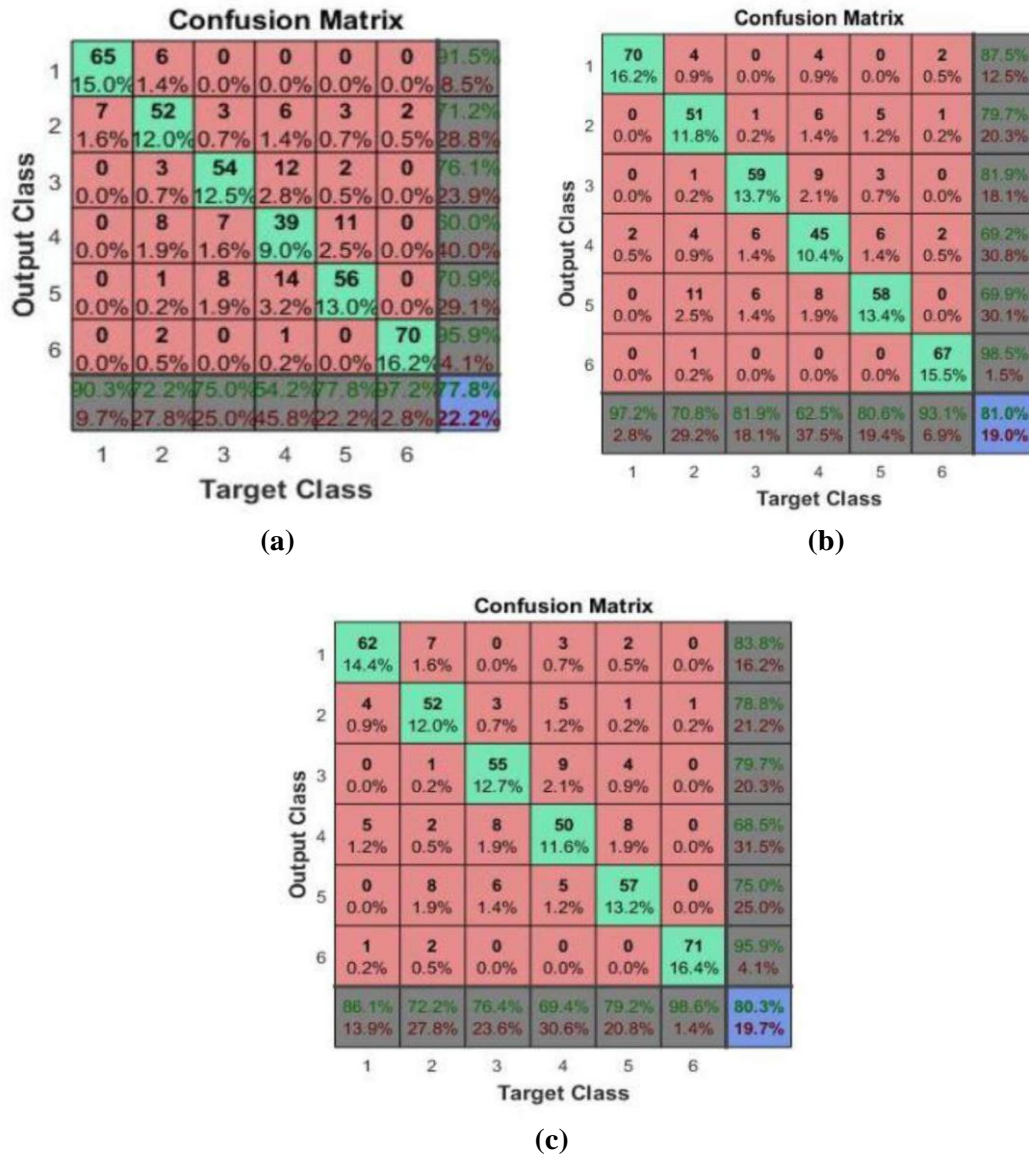


Figure 7.8 ANN Confusion Matrix (a) 64x64 (b) 128x128 (c) 256x256

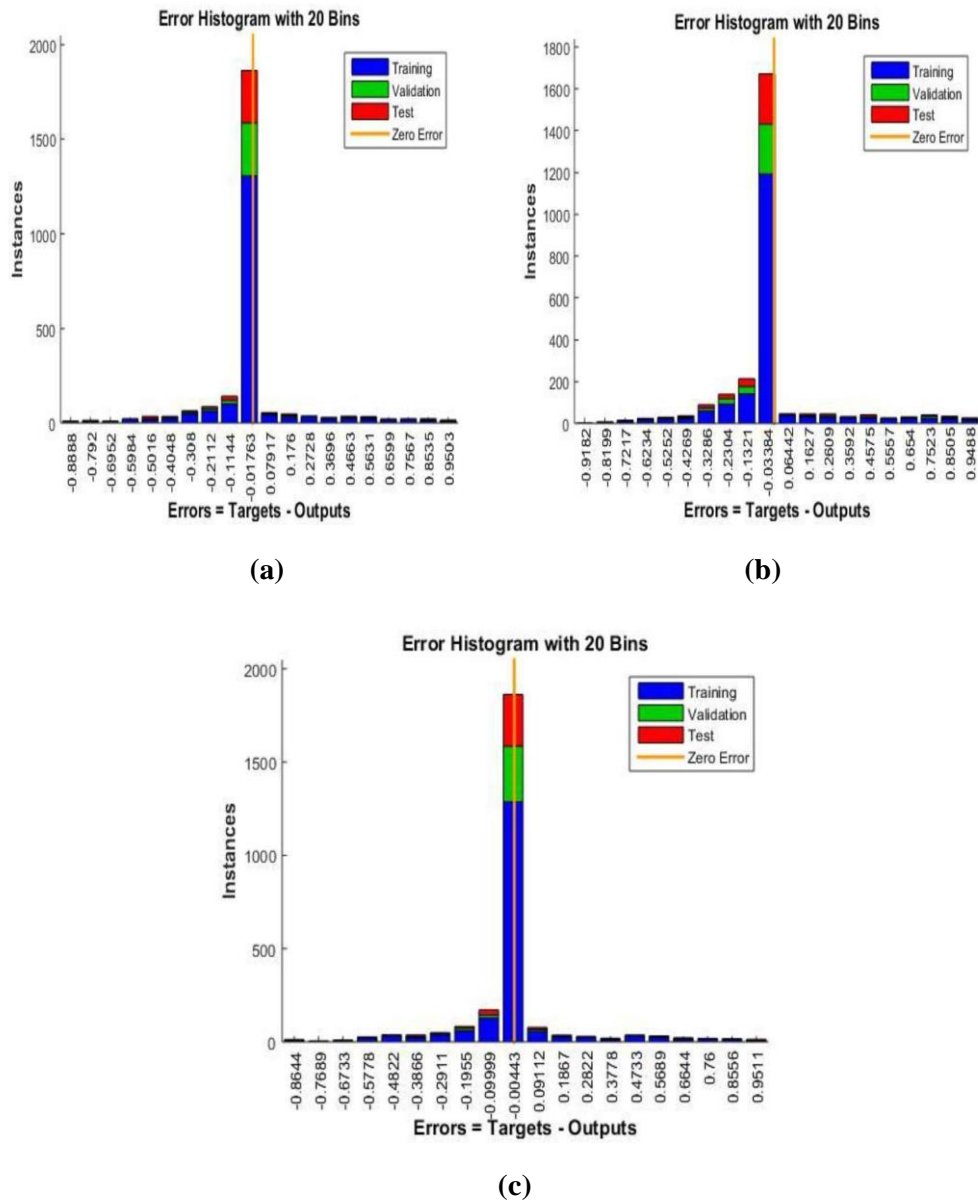


Figure 7.9 ANN Training Error Histograms (a) 64x64 (b) 128x128 (c) 256x256

7.4 MAJOR FINDINGS

In this chapter, we have worked on two datasets for currency identification:

- ☛ Our proposed framework was based on the colour and texture feature of currency then trained the Neural Network model and got the recognition rate of the currency.
- ☛ In the end, we analyzed all categories of notes have taken in different conditions such as seizer, mesh up the background, rotation, scaling, and changes in the condition of light as well as crinkled.
- ☛ Our proposed algorithm recognizes the currency with different sizes apply to both datasets and got effective results.
- ☛ In our study, first, we apply the proposed algorithm on our own created dataset and second apply to the online available dataset. Both results differ from each other with different conditions.

CHAPTER VIII

Conclusions and Future Perspectives

CHAPTER VIII

CONCLUSIONS AND FUTURE PERSPECTIVES

The Identification of fake notes in the Indian business market is a big challenge as there is no technique available in the shop of businessmen. The common person cannot identify the currency whether it is fake or real.

In the present work, some of the methods have been implemented for the Identification of fake currency so that the crime of fake currency may be minimized. From the presented work, some of the major findings are summarized below:

- ☛ The entire work is based on the new arrival of Indian currency.
- ☛ The proposed approach of fake currency identification is based on an Image processing algorithm;
- ☛ UML is used for designing of the activity model which is found that UML is an excellent modeling language for the identification of fake currency and successfully implemented on newly launched a note of Rs 2000 by an Indian Government;
- ☛ In different problems, MATLAB code is generated and through a code, we got class descriptions for real and fake Images of the currency. This is because of a selection of optimized classes and attributes;
- ☛ PCA is an excellent approach for the detection of fake currency in the Indian scenario as well as worldwide;
- ☛ The model proposed in a second Chapter is found to be efficient and obtained the optimized results;
- ☛ The converged results have been obtained by computing mean, covariance, eigenvalues, eigenvectors and new data set has been generated for the identification of fake currency;

- ☛ The texture pattern of the genuine Rs 500 currency is exceptionally powerful in the process of information securing which can influence the estimation of surface element extraction utilizing the GLCM technique;
- ☛ The estimation of k in the arrangement input utilizing the PCA technique can decide the exactness of the characterization procedure and ID of the realness of rupee currency;
- ☛ Also results show that the genetic algorithm can find an optimal solution for currency identification problems;
- ☛ In the last chapter, we analysed all categories of notes have taken in different conditions such as seizer, mesh up background, rotation, scaling, and changes in the condition of light as well as crinkled.
- ☛ The outcome of the work shall be helpful for software industries for implementation of the proposed research models in the Indian Market.

From the presented work it is also observed that the work can be extended in many direction and some of the prominent directions are given below:

- ☛ This research work supports the new Indian currency. Hence the work can be extended for all currencies and coins in different environmental conditions.
- ☛ One of the important directions is to use the proposed model. The present work can be applied to the currency of the other countries. Further, an application can be developed for the Indian currency. So that common person having a smart phone can be identified the note even this will help to the common businessman for minimization of fraud related to the fake currency.
- ☛ The presented work can be extended for consideration of the various security features, which can only be seen in the presence of Ultraviolet Light. These methods allow decreasing the fake currency threat in financial transactions.

- ☛ The work can be extended for the large database of currency to getting better results with the help of different algorithms.

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APPENDIX

**Reprints of Published
Research Papers**



Identification of Fake Currency: A Case Study of Indian Scenario

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Abstract: In every country, many people generate the fake currency which is similar to the original currency. It may be of the form of notes and coins. In the business market, it is very difficult to identify the fake currency and it is also true that original currency in the form of notes and coins are available in the bank custody. Many researchers have applied different methods to identify the fake notes and coins. The present work is in this direction for identification of newly launched 500 and 2000 notes in the Indian market. An object-oriented model is proposed for designing of systematic steps for identification purpose. This is further implemented in the MATLAB. Results are produced in the form of tables and graphs.

Keywords: Currency; HSV Image; UML; MATLAB; Gray Scale Image; Security Features.

I. INTRODUCTION

From the literature it is observed that in the year 1938, Reserve Bank of India (RBI) has issued currency notes of 2, 5, 10, 100, 1000 rupees notes. Later on, RBI has issued denomination of 1, 20, 50 and 500 rupees notes having value in it. As per RBI guidelines currency in Indian scenario has to be changed after interval of every 10 year therefore different designs of the notes along with new series have appeared in Indian Business market and the old series have eliminated by RBI. During past years, it is observed from the business market worldwide that tremendous amount of fake currency in the form of notes and coins are available in the business market also in the bank.

Many researchers have introduced new techniques and some of the techniques for identification are watermarking, latent image, micro lettering, see through register optically variable link, security threads, intaglio printing, fluorescence, identification mark, legal provisions against counterfeit. Automatic tools are also available for fake currency identification. Fake currencies which are available online for the use of banking service but the accuracy may differ from one approach to another approach. Hence, there is need to develop a robust system for the reliable identification with minimum processing speed and accurate of the currency. For this purpose digital image processing is adopted by many researchers in which authors extracts different attribute after image acquisition and considers as an object the attributes may be watermarking, latent image, micro lettering, see through register, optically variable link, security threads, intaglio printing, fluorescence, identification mark, legal provisions against counterfeit. For recognition of the attributes, author generally used MATLAB as computational tool for development and implementation of design steps for the analysis purpose and it supports image acquisition as bmp, jpeg, tiff, gif, png, jpg etc. After Image acquisition characteristics of the attributes are extracted for digital image processing which contains visible as well as invisible features taken from the currency notes. Authors applied different methods of extraction of the image but it should be an excellent and feasible extraction of the image for consideration of input reliable data. The data is further classified into the number of pattern distinct classes having attributed like distinct method HSV image, Edge detection, Segmentation etc. These features

are well described in the literature. Lets us describe some of the important features related to these aspects. Lots of researchers have done work in the field of identification of currency. Many countries have changed the currencies generally after a period of ten years. Recently, Indian Prime Minister has changed currency of note of Rs 500 and Rs 1000 and issued new direction for new currencies.

II. RELATED WORK

From the literature, it is revealed that many researchers have done work on the identification of fake currency. Let us explain some of the important references. In the year 2008, Yoshida et al. [1] have studied the Bangladesh currency and designed a machine based system for Identification of Bangladeshi bank notes. The proposed system is based on basically denominations of five hundred and one hundred taka. In proposed system, authors first captured the image of note through scanner then processed in microcontroller PIC-16F648A. After microcontrolling they determine the validity of note based on some characters i.e. dasiaBpsila, dasiaApsila and dasiaNpsila on the OCR technique of scanned Image. The success rate of proposed system of counterfeit detection with properly scanned image is 100% and average processing image is 250 milliseconds. Hassanpour et al. [3] have proposed a new technique of paper currency recognition which is based on three characteristics of paper currencies including size, color and texture. By using Image histogram, the different color in paper currency is compared to reference paper currency. They presented model texture of the paper currencies based on Markov chain concept. The proposed method can be used for recognizing the paper currency from different countries. With one example of paper currency for training system but they tested more than 100 denomination from the different country. The proposed system recognizes 95% correct data.

Qian et al. [4] have proposed the new technology of detection of currency. The new technology is based on electromagnetic. Electromagnetic detection introduced the basic principle of pulse eddy current technology, the inspection equipment design, to experimental results analysis and the characteristic quantity extraction. The advantage of technology is based on pulse eddy current technology. Bhattachary et al. [5] have discussed the comparative study of data mining for credit card fraud. They proposed two advanced data mining approaches for better card fraud detection; with logistic

regression. This study is based on real life data of transaction from an international credit card operation. Santhanam *et al*. [6] have studied the detection methods to detect the fake currency. These detection methods are based on polarization concept, Image processing technique and Holographic technique. They discussed the methods generally based on physical properties of currency rather than chemical properties to detect the counterfeit currency. They also elaborated the mathematical model, experimental verification and lab view based simulation in the way of fake currency detection. Yan and Lin [7] have designed a money number recognition system and discussed the position of money number when is based on gray value accumulation and through the least square method they detected the edge line of money number using the geometrical rotation gray adjacent interpolation method to correct the number which is based on character structure characteristic to realized the character recognition. The presented system has high accuracy of recognition of money number.

Feng *et al*. [8] have designed the Renminbi Bank Note (RMB) serial number recognition system. RMB is the paper currency of china and authors presented new system that extracts the RMB characters directly from scanned RMB images. They discussed the two techniques to detect the region which contains RMB serial number that are skew correction and orientation identification. The detected text region is binarized by thresholding technique. After a contrast average method is introduced to extract the RMB character from the finalized result. Jain and Vijay [9] have proposed an image processing to extract paper currency recognition and neural networks matching techniques to extract the region of interest and elaborated the step to extract the paper currency denomination. Firstly authors take image by scanner and adjust their size and pixel level. Through the pattern recognition and neural networks matcher technique is used to match the value of paper currency. Bhasharkar *et al*. [10] have discussed the currency recognition technique based on Image processing. The image processing approach based on basic steps like Image acquisition, pre-processing and finally recognition of the currency are demonstrated. The image processing approach is discussed with MATLAB to identify the feature of currency note. Finally, the results are demonstrated for genuine or fake currency.

Yan and Chambers [11] have designed a prototype for automated currency detection based on generally color feature and texture feature. They also proposed the feed Forward Neural Network (FNN) and measured the similarity between sample and suspect banknote. Yadav *et al*. [12] have designed a system for fake currency detection using MATLAB algorithm and feature extraction with HSV color space and other applications of Image processing. Yadav *et al*. [13] have designed a system for automated recognize and verify the Indian currency using Image processing. Authors described the two characteristics of Indian currency that is based on counterfeit note which included Identification mark and currency serial number. They also used Sobel operator and characteristics extraction which have been performed on the Image of currency and then it is compared with the characteristics of the genuine or original currency. The currency has verified by Image processing technique. They also elaborated the number of steps including Image processing, edge detection, image segmentation, characteristic extraction and comparison.

Thakur and Kaur [14] have presented the different fake currency detection techniques and reviewed different fake currency detection systems. The system has developed using different methods and algorithms. Authors describe the different methods and algorithm used for fake currency

detection system and compared them and also elaborated the ability which depends on the currency note characteristics of particular country and extraction of feature. Ismail and Makone [15] have studied the fake currency of India and presented software for Identification of fake currency with the help of feature extraction classification based on Image processing. Authors also elaborated all processing with the Image by machine. The machine has fitted camera to scan the image of currency note and software processed the image segments with the help of character recognition methods. They also designed software with MATLAB tool. Alekhya *et al*. [16] have studied the fake currency detection using Image processing and other standard methods and elaborated the some other methods to detect fake currency through security features of currency and using MATLAB.

Bhurke *et al*. [17] have designed an algorithm for currency recognition. The proposed algorithm based on image processing approach has discussed with MATLAB to detect the feature of paper currency. They discussed basic requirement for an algorithm which have simplicity, less complexity, high speed and efficiency and proposed an algorithm design an easy but efficient algorithm that useful for maximum number of currencies. Authors used five currencies to work on for this project and selected currencies are Indian Rupees (INR), Australian Dollar (AUD), Euro (EUR), Saudi Arabia Riyal (SAR) and US Dollar (USD). R and Omman [18] have studied the Indian currency recognition system and proposed a method to recognize the fake currency using Image processing approach and also identified by extracting feature like Central Numeral, Shape, RBI seal, Latent Image and Micro Letter. Authors also elaborated the principle component analysis which has used to reduce the dimensions and a similarity based classifier constructed to predict test sample. Results have also validated by constructing models using classifier implemented using WEKA and testing with unseen samples not considered in feature extraction. Authors also studied the central numeral results in an accuracy of 100% with all family of currencies. Ahmad *et al*. [19] have designed a machine based system for identification of Bangladeshi currency in the form of taka and presented a core software system to build a robust system for detection of fake currency through extraction of important features like security thread, ultraviolet lines, watermark contour Analysis, face Recognition etc. Authors also elaborated the advantages and disadvantages of the proposed system for improving currency authentication system.

Vora *et al*. [20] have designed an algorithm for currency detection based on feature extraction methods and used two dimension discrete wavelet transform (2D DWT) which has used to develop a currency recognition system after the pre processed of system with example of serial number feature method by implementing the OCR technique to found better results. Walke and Chanwadkar [21] have designed a machine that recognizes the fake currency using SVM with Note to coin Exchanger and presented a machine to provide coin for genuine note Firstly an image is taken then used Image processing technique to process it if note has genuine then machine provides the coin to its equivalent value. Rathee *et al*. [22] have studied the physical and chemical properties of fake currency and presented a core software system to build a robust system for detection of fake currency using physical properties. In Image processing algorithm, they adopted the extraction of important feature such as security thread, intaglio printing (RBI LOGO) and identification mark which have been adopted as security feature of Indian currency and elaborated the difference between real and fake currency based on above three security features. Authors also measured the performance of proposed system based on accuracy and mean square error.

Abdallah et al. [23] have presented the survey paper on Fraud Detection System (FDS) and described the issue and challenges during Fraud detection on electronic commerce system. They discussed the fraud detection system has important as well as fraud prevention system. C and G [24] have proposed an algorithm to currency note number recognition using Image processing for an Automated Teller Machine (ATM) and elaborated the algorithm that has automatically noting and saving the currency note number to server at the time of withdrawal, so that customer has benefitted in recovering their currency back and also described that their proposed algorithm makes the ATM more reliable and user friendly. Paliana and Arora [29] have designed a system that recognized the fake currency based on security thread feature of currency. Authors described the counterfeit notes are a very big problem of every country so they presented a system that verified the Indian currency & other countries using Image Processing technique with fast speed and less time. Other related references are [2], [25], [26], [27] and [28].

III. MATERIALS AND METHODS

In Indian scenario, Reserve Bank of India (RBI) has issued the guidelines related to currency under Act 1935. Before this silver coins were used during 1540-45. On the basis of 1934 Act, in the year 1917 Government of India (GOI) introduced a note of Rs 1, there after a Rs 5 in 1938 and Rs 2 in 1943. These notes were having a less security features hence for improving the security features like watermarking, micro lettering etc. and other technique has discussed.

After that GOI has introduced Rs 10, Rs 20, and Rs 50, Rs 100, Rs 500 and 1000 from time to time which contains the features watermarking, Window Security Thread, Latent Image and Intaglio, etc. as per rules of RBI the series were absolute after series of notes after 10 year. In 2011 new series of Rs 1, Rs 2, Rs 5, Rs 10 were introduced with new Rupees symbols while before this year series of Mahatama Gandhi watermark were introduced were Rs 10, Rs 20, Rs 50, Rs 100 and Rs 1000.

Due to counterfeit problem faced by RBI and availability of the high resolution scanners, any person can print the counterfeit note through computer by a color laser printer. In the banks, there are some machines which are available with the bank persons used to detect counterfeit persons but sometimes fail to detect these kinds of notes. In the present work, these kinds of problems resolve through a small piece of code which is based upon the following aspects:-

A. MATLAB

A Matrix Laboratory (MATLAB) is software of Library is used for designing for finding these kinds of features in the available of currency. There are so many security feature of Indian currency that are based on generally color, size and some Identification mark. The color is most important feature of currency recognition.

MATLAB is generally computational tool for research, development and analysis. This tool is supported all type of image formats like BMP, HDF, JPEG, PCX, TIFF, XWB, PNG etc. In present time characteristics extraction of Image is very challenging work in the field of Digital Image Processing.

In MATLAB technique, we have created different classes of Digital Image Processing steps including Image Acquisition, HSV conversion, and Edge detection, Image Segmentation, Characteristics Extraction and Comparison of Images. Each class has its own attributes and methods represented in the following Table I.

Table I. Representation of UML Classes and Attributes

Sr. No.	Name of Class	Attributes	Methods
1.	IA	IAReal IAFake	imread ();
2.	HSV	IAReal IAFake hsvReal hsvFake	rgb2hsv();
3.	ED	cropReal cropFake satThresh vatThresh BIReal BIFake	hsvReal (:,:,:); hsvFake (:,:,:); cropReal (:,:,:); cropFake (:,:,:); figure; subplot (, ,); imshow (); title(' ');
4.	IS	se closeReal closeFake	strel (' ', ,); imclose (); figure;
5.	IE	openReal openFake closeReal closeFake	bwareaopen (.); imshow (); title (' '); figure;
6.	COMP	openReal openFake lineReal lineFake	bwlabel (); disp (' '); num2str ();

IA is the class of Image Acquisition that has its own attributes and methods to obtain the image using camera, scanner etc. HSV is the class of Hue-Saturation-Value to convert the RGB Image into each different component. ED is the class of Edge Detection that resizes the image and extracts the region of interest using its own Attributes and Methods. IS is the class of Image Segmentation that divides the image into its constituent region or objects. IE is the Image Extraction that extract the characteristics of Image. COMP is the class of comparison that compares the image on the base of characteristics.

B. UML

Unified Modeling Language (UML) is a standard language which is used for software design based on the object-oriented technique. It is a tool for producing the pictorial designs which are classified as static or dynamic design.

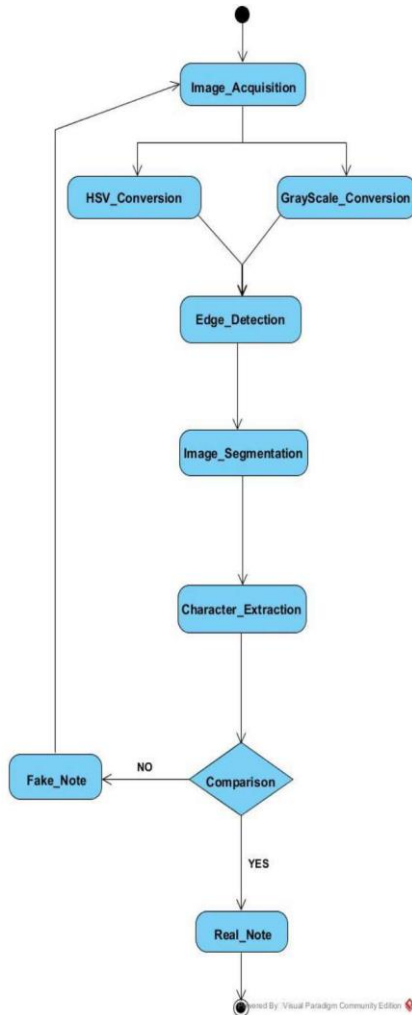


Figure 1. UML Activity Diagram for fake Currency Detection

In the present work, we have designed UML activity diagram which is used to represent run time behavior of software. This diagram consists of grouped together which perform by the Actor for the present work a UML activity diagram for the detection for fake currency in the Figure 1. It consists of the following activities:-

- STEP 1:-** Activity Name : Image Acquisition
Description : Obtain the Image of Real and Fake currency through Camera or Scanner.
- STEP 2:-** Activity Name : HSV Conversion
Description : The acquire RGB images are converted into HSV on the based on what information extracted.
- STEP 3:-** Activity Name : Edge Detection
Description : The edge detection technique is used to detect the boundary of Image using cropping.
- STEP 4:-** Activity Name : Image Segmentation
Description : In this process the Image is divided into different segment.

- STEP 5:-** Activity Name : Character Extraction
Description : After segmentation the distinguish feature of Image is extracted in this steps.
- STEP 6:-** Activity Name : Comparison
Description : Compare the characteristics of Image and display the outputs.

IV. RESULTS AND DISCUSSION

The above UML diagram has been implemented through code written in MATLAB. The different parameters have been selected for getting the optimized result. A 2000 rupee real and fake notes are first scanned by a scanner and outlook of notes are represented in Figure 2(a) and (b).



(a)



(b)

(b)

Figure 2. Images of (a) Real currency and (b) Fake currency

The Government of India (GOI) has launched this new currency of an Rs 2000 note in November, 2016. Since the value of note is very high, therefore there is lot of chances by intruders to generate the fake currency and during the subsequent months police department of India has also recovered the big chunks of Rs 2000 from the various places.

Later on these two acquired images have been in RGB color and converted into the Hue-saturation-value (HSV) format. By this process the complete image has been separately looked each Red, Green, Blue component and these two images are represented below.

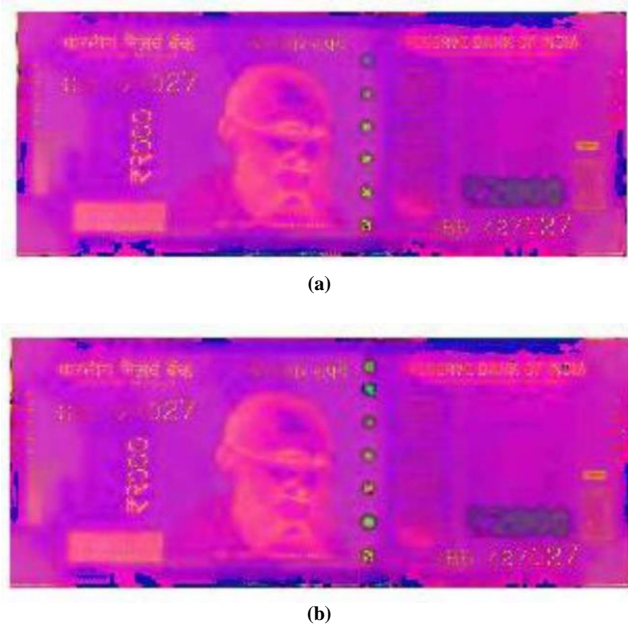


Figure 3. Conversion of RGB into HSV Image (a) Real currency and (b) Fake currency

Since the image contains the number of segmented parts therefore one can apply security threads as a region of Interest (ROI) to these parts. In the present case, a strip is considered as a security thread for checking whether the rupee 2000 note is real or fake. These Security Threads in the forms of strips are shown below in the following Figures 4(a) and (b).

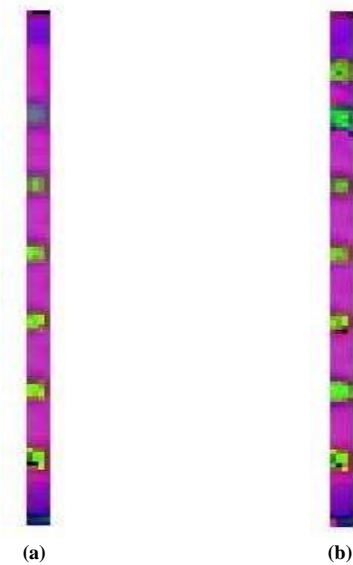


Figure 4. Crop Image of (a) Real strip and (b) Fake strip

From the below, we compared the number of black pixels of real and fake currency. We got strip which contains number of black pixel as one and three in real and fake currencies respectively which have been clearly represented in the following Figures 5(a) and (b).

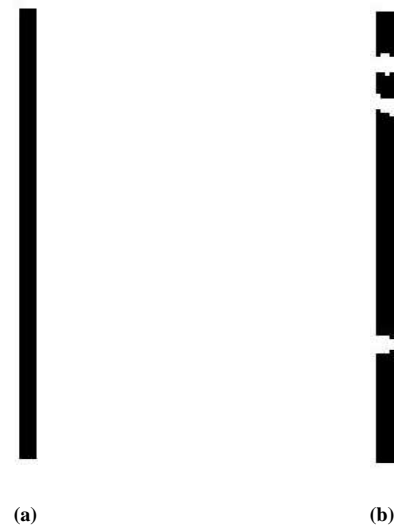


Figure 5. Number of black pixels in (a) Real currency and (b) Fake currency

The variation between the real and fake note is also represented through a histogram and from the Figure 6(a) and (b) it clearly represented the relative frequency of the various gray levels of real and fake currency.

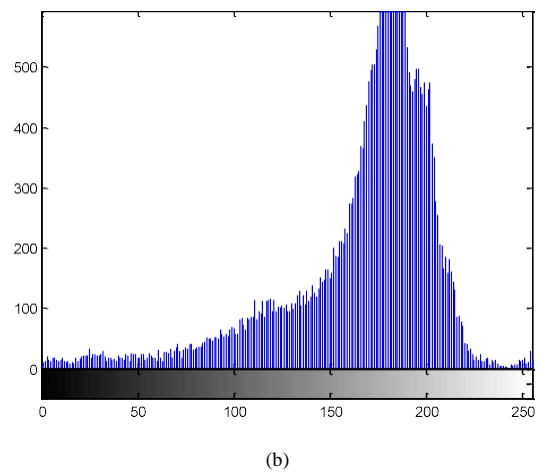
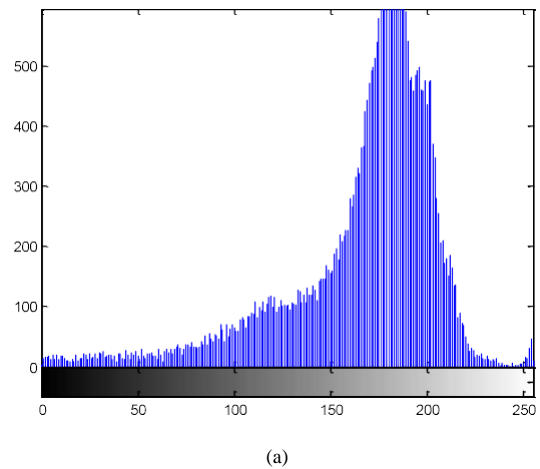


Figure 6. Histogram of (a) Real currency and (b) Fake currency

V. CONCLUSIONS

From the above work it is concluded that UML is an important modeling language used to represent static and dynamic aspects of the research problem. In the present work, a UML activity model is designed to represent the dynamic aspects for identification of fake currency and successfully implemented on newly launched a note of Rs 2000 by an Indian Government. A MATLAB code is generated and through a code, we got class descriptions for real and fake Images of the currency. This is because of selection of optimized class and attributes. The above aspects can be extended for the another kinds of currencies of different countries.

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An Efficient Technique for Detection of Fake Currency

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Abstract: During the past years, some of the researchers are using the matching techniques for identification of the fake currency either by using the Mathematical formulation or by using the readymade simulation tools. A lot of methods namely edge detection, segmentation, feature extraction, pattern matching has been used for finding and identification of the fake currency. In the present work, Principal Component Analysis (PCA) is used to detect the feature of currency through modeling and a proposed algorithm is elaborated to recognize the fake currency in the form of note Rs 2000 of Indian currency. Graphs are also designed to justify the present approach along with the comparison of results.

Keywords: Eigenvalues, Eigenvectors, Fake Currency, Matching Techniques.

I. INTRODUCTION

Technology is rapidly growing for the conversion of the physical currency into the digital currency due to the availability of fake currency in the business market. In some of the countries, it has been implemented but in some countries around the world is suffering due to the availability of the fake currency. Currency replication is the most important threat in the business market. Currency replication is also known as counterfeit currency which is presently questioning due to sophisticated techniques such as printing and scanning. Due to the counterfeit note, India is facing many problems and challenges in the business market. Many researchers have been encouraged to develop robust and effective currency detection machine.

On November 2016, Prime Minister of India Mr. Narendra Modi announced that existing rupee notes of 500 and 1000 cease to be valid currency and that step is taken to rein black money and forged currency in the country. Prime minister also launched new rupee 500 and 2000 notes and discontinued existing rupee of 500 and 1000 notes. In the year 2017-18, according to an annual report published by Reserve Bank of India (RBI), fake currency notes detection has been dropped 31.4% as compared to the previous year due to high-security feature of notes making forged difficult. In Indian economy; Fake Indian Currency Note (FICN) is a term used official and media to refer to forged currency notes.

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In 2012, in response to a parliamentary inquiry, the Finance Minister, P. Chidambaram stated that there was no confirmed estimate of forged currency in India. However, there are several states and central agencies work together and the Minister of Home Affairs have included the Fake Indian Currency Notes Coordination Centre (FCORD) to check the problem.

II. RELATED WORK

Due to an evaluation of new currency after denomination in India, it is necessary to check whether the arrival notes in the form of currency are genuine or not. The newly arrived currency is in Indian rupees of notes of 10, 20, 50, 200, 500 and 2000. Limited literature on the study of fake currency is available. However, some of the important references are described below in brief. Takeda and Omatu [2] proposed a neural-based acknowledgment and check strategies utilized in a banknote machine. The approach has been applied on Euro currency by the use of its dummy and implemented to the banking machine for getting the euro currency from the machine. Effective results have been proposed by the use of the reduced data set of Fourier power spectra. Frosini et.al. [3] described neural network-based currency verification of 23 distinct countries. The produced results are based on the lowest sensors by reducing the computational load with 98% accuracy. Leelasantham et al. [4] have also proposed a strategy for investigating the water stamp on currency note by utilizing relationship mapping and background neural system. In this strategy, the area of water stamp is identified by interrelation mapping technique. Five types of notes like 20, 50, 100, 500 and 1000 of Thai cash note were prepared for 20 tests. The produced results have 100% of accuracy for recognizing the true currency notes.

In the year 2003, Zang et al. [5] have described paper currency which is broadly connected in numerous fields, for example, bank framework and programmed offering merchandise framework. The proposed technique gives high ascertaining speed, evident characters of unique, great vigorous to various types notes of 10, 20, 50, 100 with the desired accuracy. Yoshida et al. [6] have designed a machine vision-based framework for constant recognition of fake Bangladeshi monetary orders. The proposed framework based on five hundred and one hundred takas. The depended include is not conceivable to reproduce for the fake creators or makers. In the method, the framework captures the segments of the notes with a restrictive scanner called Grid Scanner. The captured image is then prepared by a



microcontroller PIC-16F648A or ATmega88 (AVR) and decides the legitimacy of note in the light of an OCR strategy. In the scanned image, searching these characters *dasiaBpsila*, *dasiaApsila* and *dasiaNp*. The achievement rate of the fake location with the legitimately caught image is 100% with handling time is 250 milliseconds. Hassanpour et al. [7] have proposed a new strategy for paper currency identification with three qualities of paper currencies forms which include size, shading, and surface or texture. By the use of image histogram, wealth of various hues in a paper currency is computed and compared with the one in the references paper currency with the help of chain idea utilized to show surface of the paper currencies forms as an arbitrary procedure with a strategy that can be utilized for perceiving paper currencies from distinct countries. In this technique, utilizing a single example of paper currency from every division is sufficient for training framework and tested the techniques on an excess of 100 divisions from various nations, and the framework could perceive 95% of data, accurately.

In the year 2010, Roy et al. [9] have discussed an image analysis based example arrangement strategy that proposed to real the printing procedure used in printing different text on currency notes. Linear Discriminate Analysis (LDA) is proposed for validating the printing procedure. The proposed technique gives a very accurate framework for verifying the printing procedure in monetary orders. Further, Fan et al. [10] have described the database end up outdated quickly and find out that different estimation of a similar substance exists in a database related to the currency. Bhattachary et al.

[11] discussed a comparative analysis with two sophisticated approaches to information mining for better identification of card fraud through logistical regression. The study is based on real-life data of a transaction from international credit card operation. New technology was proposed by Qian et al. [12] for the detection of currency based on electromagnetism which uses the basic principle of eddy current technology, the inspection equipment design, experimental results analysis and the characteristics quantity extraction.

Garcia-Lamont et al. [13] have described the recognition method of Mexican banknotes through artificial vision and is generally based on color and texture concerning with respect to RGB space and Local binary patterns. The proposed method applied to other countries banknotes. Hasanuzzaman et al. [14] have described that due a rapid increase of blind employees and uses in the bank, a novel camera-based computer vision technology has been used to identify the banknotes for visually impaired people. The system helps for capturing the image by the blind users. The proposed algorithm has been evaluating the dataset on the based on positive and negative images of U.S. banknotes. The recognition rate of the algorithm is true for 100% and false for 0%. Bruna et al. [15] have proposed the system that detects the counterfeit of euro banknotes and calculate its performance based on speed and accuracy. Feng et al. [16] have also proposed a new system for identification of Renminbi Banknote (RMB) character from RMB images with two different methods namely skew correction and orientation identification. After applying these two methods the binarization technique was used to compute the performance. Jain and Vijay [17] have described the image processing

technique that extract the region of interest of image and also denomination of paper currency by considering the scanning image and further adjust size and pixel of the scanned image. This technique was used to match the value of a paper currency. Santhanam et al. [18] have proposed two types of methods; one is ultraviolet detection and second is the polarization of light that passed through currency for Identification of Counterfeit Currency and it is based on only physical property. Yan and Lin [19] have described the Feedforward Neural Network for the identification of the fake currency. Feedforward Neural Network has been taken with all the common features of banknotes then it compares with a suspect note. Yan et al. [20] designed a prototype for automated currency detection which is based on generally color feature and texture feature and also proposed the Feed Forward Network (FNN). Also, it measured the similarity between a real and fake banknote.

Ahmad et al. [21] have proposed a software system that detects the counterfeit currency along with its features like micro-printing, optically variable ink, watermark, iridescent ink, security thread and ultraviolet lines using OCR (Optical Character Recognition), Contour Analysis, Face Recognition, Speeded Up Robust Features (SURF) and Canny Edge and Hough transformation algorithm of Open CV. Alekhya et al. [22] have studied fake currency detection using image processing and other standard methods and explained some other methods to detect fake currency through security features of currency using MATLAB. Gates and Matthews [23] have discussed the privacy and ownership of data. The data could be related to personal, finance, online transfer and social media with three laws of the data value and data ownership.

Ismail and Makone [24] have studied the fake currency of India and introduced software for identification of fake currency identification with the help of feature extraction classification based on an image by machine. That machine was equipped with a camera to scan the image of a currency note and the image is processed by the software with the help of character recognition methods and developed software by the use of MATLAB tool. In the year 2014, R and Omman [25] proposed a currency identification system which is based on the principle feature of currency and compared the result using WEKA classifier. WEKA classifier produced the high performance of that algorithm. Singh et al. [26] have developed a system of currency identification through mobile phones for visually impaired users. The approach has been applied to other currencies to check its speed and accuracy which is 96.7% on 2584 images. Thakur and Kaur [27] presented a different fake currency detection techniques and reviewed different fake currency detection system. This approach was based on different methods and algorithms used for the counterfeit currency detection system and compared them. Yadav et al. [28] described the fake currency Identification method with feature extraction using MATLAB. This approach has been designed as a system to verify Indian currency using image processing. It described two characteristics of Indian currency to identify counterfeit notes which are identification mark and



currency serial number. Generally, the image processing technique applied on currency using Sobel Operator. The system has followed the number of steps including image processing, edge detection, image segmentation, characteristic extraction, and comparison.

Ahmad et.al. [29] designed a machine-based system for the identification of Bangladeshi currency in the form of taka and presented a core software system to build a robust system for the detection of counterfeit currency through the extraction of important features like security thread, ultraviolet lines, watermark contour analysis, face recognition etc. with the advantages and disadvantages of the proposed system for improving currency authentication system. Bhurke et. al. [30] designed an algorithm for currency recognition. The proposed algorithm has based on Image processing technique using MATLAB. The basic requirement for an algorithm has simplicity, less complexity, high speed and efficiency and proposed an algorithm design an easy but efficient algorithm that useful for a maximum number of currencies. To work on this project authors used five currencies and selected currencies are Indian Rupee (INR), Australian Dollar (AUD), Euro (EUR), Saudi Riyal (SAR) and US Dollar (USD) and in this regard, Hijazi and Kumar [31] have proposed Convolution Neural Network (CNN) for image and pattern recognition.

Sarfraz [32] also described paper currency recognition which has been studied by many of the researchers and the main object of the work is dealing with 110 images that are a combination of a tiled and non-tiled image for computations of the performance. Most of the methods were used for pattern recognition. Vora et.al. [33] designed an algorithm for fake currency detection based on feature extraction methods and also used two-dimension discrete wavelet transform (2D DWT). Walke and Chanwadkar [34] designed a machine which recognizes counterfeit currency using SVM with to coin exchanger and presented a machine to provide a coin for genuine note. Firstly, an image is taken then used image processing technique to process. If the note is genuine then the machine will provide coin to its equivalent value.

Abdallah et.al. [35] is an excellent source of information on Fraud Detection System (FDS) and described the challenges and issues during fraud detection on electronic commerce and emphasized that fraud detection system is important as same as fraud prevention system. Rashmi, C. and Kumar, H [36] proposed an algorithm to recognize currency note number using image processing for an Automated Teller Machine (ATM) and explained the algorithm that has automatically saved the currency number on the server and it is also easier to currency recovery and also explained their proposed algorithm makes ATM more reliable and user friendly. Pilia and Arora [37] designed a system that recognized the fake currency based on a security thread feature of currency and also described that counterfeit notes are a very big problem for every country hence presented a system that verified the Indian currency & other countries using Image Processing technique with less time and fast speed.

Rathee et.al. [38] studied the physical and chemical properties of counterfeit currency and presented a core software system to build a robust system for the detection of counterfeit currency using physical properties. In the

proposed algorithm authors used the some features: - security thread, intaglio printing (RBI LOGO), identification marks which were adopted as a security feature of Indian currency and also explained the difference between real and fake currency based on the above three security features, the performance of the proposed system was also measured based on accuracy and mean square errors. Agasti et.al. [44] have used the Image processing method for currency recognition which is the most important method for feature extraction. After extracting the valuable features, the intensity has been computed. Sharma and Narang [45] have explained the currency of different currency. Many researchers have been worked on currency recognition system using different methods. Snehlata and Saxena [46] have provided an object-oriented model for currency identification system by the use of MATLAB. Jara et al. [47] have described the falsification of currency banknotes which are a frequent illegal activity and proposed aspects generally identify the false banknote using portable X-ray Fluorescence spectrometer (pXRF). Tigani and Saadane [48] also proposed the statically predictive model to estimate the financial market stability based on historical data.

III. MATERIALS AND METHODS

A. Indian Currency

Money is any object or record that is typically time-honored for the payment of items and services and the repayment of money owed in a particular socio-economic context or country. The currency of India is the Indian Rupee (INR). The word "rupee" originates from the Sanskrit word rup or rupa meaning silver. Sher Shah Suri (1486-1545) introduced the very first rupee, which has a ratio of 40 copper pieces (Paisa) per rupee. The name derived from Sanskrit word raupyakam, which means silver. In the 18th century private banks such as - the Bank of Bengal, the Bank of Bombay and the Bank of Madras began the process of issuing paper currency. The Indian government was provided the monopoly on printing currency after the paper currency act of 1861. India's government (GOI) printed currency until RBI was established in 1935, assuming that accountability. In 1938 only Rs 10, Rs 100, Rs 1000 and Rs 10000 were issued. RBI currently issued notes Rs 5, Rs 10, Rs 20, Rs 50, Rs 100, Rs 500 and Rs 2000, also known as banknotes. The printing of notes in Rs 5 demonetization was also stopped.

B. Security feature of Indian Currency

The Fake currency detection system varies depending on specific features of banknotes of country (21). For Indian Banknotes, features are considered. For testing purpose Rs 2000 note. There are some important security features of Indian currency: - Watermark, Security thread, Latent Image, Intaglio Florescence Micro lettering, Identification Mark, Optically Variable Ink.

C. Legal provisions against counterfeiting

Printing and circulation of forged notes are offences under



section 489A to 489 E of Indian Penal Code (IPC) and are punishable by fine or imprisonment or both in the courts of law. The currency has great significance in everyday life. Therefore, many researchers have become interested in the recognition of currencies and have proposed various approaches. According to literature, image processing is the most efficient method in currency recognition area. A banknote has safety features mainly in the design and printing of paper. The identification and examination of currency notes are mostly carried out by the following aspects:

- (1) Physical dimension
- (2) Paper quality
- (3) Design
- (4) Printing Technique

The physical dimension of the note depends on its cutting size, length, width, thickness and grammage. The paper on which currency note is printed has a high level of security. Watermark and Security thread are the most important components of currency note paper security.

D. Storage of Image of Currency

A rupee 2000 real note first scanned by scanner and outlook of notes are represented in the figures 1 and 2, thereafter, the scanned image is the input in MATLAB.



Fig.1. Image of Real Currency



Fig.2. Image of Fake Currency

E. The Reasons for Selecting the Feature

Micro-printing is widely used for a robust feature of Indian banknotes. The advantage of micro-printing is that they cannot be visible without a magnifying glass or appropriate focus of the camera, this feature is very tough to replicate in fake notes by the normal printing process and actually require a very high cost and the other reason is Optically Variable Ink (OVI), which is very costlier ink and is impossible to forge through printer or ordinary printing machines. In real notes, the printing quality of watermark is very good, perfect and unmutilated. That is the reason why it is very hard to knock off for the counterfeits. The stitching technique of the security threads and the pattern around the security thread are clearly identifiable. A new dimension in stopping counterfeit notes is created by the presence of ultraviolet lines in the banknotes.

Therefore, these features are used to perform forgery detection.

Table I represents the existence of these features in various Indian banknotes based on the experiment and is shown below:

Table-I: Features in the Indian Currencies

Features	Availability Among Note
Watermark	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000
Security Thread	All notes
Latent Image	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000
Intaglio Printing	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000
Fluorescence	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000
Micro Lettering	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000
Identification Mark	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000
Optically Variable Ink	Rs 5, Rs 10, Rs 100, Rs 500, Rs 1000, Rs 2000

F. PCA Technique

Principle Component Analysis (PCA) is a method of identification of data patterns in which data are expressed in order to highlight similarities and differences. Once the pattern is found in the data, it can be compressed i.e. reduced the number of dimensions without losing much information. PCA transforms the ‘p’ which is the original correlated variable into ‘p’ uncorrelated components (also called orthogonal components or principle component). These components are original variables of the linear function.

The transformation is given by

$$Z = X A \tag{1}$$

Where

X denotes n*p matrix of n observations on p variables;
 Z denotes n*p of n values for each of p components;
 A denotes p*p of coefficient defining the linear transformation.

PCA is a measurement quantity reduction technique in which image is represented in higher dimensions. The processing of an image in higher dimensions requires more time of the processor. A weight vector is obtained, after the projection of higher to a lower dimension. A weight vector represents original data (higher dimension) in term of Eigenvectors (lower dimension). The phase contains the following stages:

- 1) Information is extracted from the Image and data is acquired;
- 2) The covariance matrix is constructed from the acquired data;
- 3) To find Eigenvalues & Eigenvectors;
- 4) Short Eigenvectors and find principle Eigenvectors;
- 5) Data is mapped and stored.



G. Image Processing with MATLAB

MATLAB (MATrix LABoratory) is a very significant tool designed with a mathematical background and capable of doing numerical computations, display data graphically and solving many other technical and scientific issues [8]. While working with a MATLAB image, there are many different things to remember, for example loading an image in the right format, saving the data as various conversions between various image formats and so on.

Let's discuss some of the commands for different operations. A digital image consists of pixels that on the screen can be considered as tiny dots. A digital image is a coloring instruction for each pixel [8]. Normally, an m-by-n image is made up of m pixels in the vertical direction and n pixels in the horizontal direction. Suppose an image on format 512 by 512 pixels. That means the data for the image contain information about 262144 pixels, which require a lot of memory. Hence, image compression is the most important technique of image processing. There are different formats supported of an image like BMP, HDF, JPEG, PCX, TIFF and XWB. If an image stored as a JPEG format, firstly read the image into MATLAB. Then it used the different formats as follows:

Gray Scale Image: An Image is always represented in the form of a matrix with a value for each component that represents the corresponding value to bright and dark that is colored. There is the two way to a representation of the brightness of the pixels: One is a double class that assigns the floating number ("a number with decimals") between 0 and 1 to each pixel. Then the value 0 is black and the value 1 is white. Another class that assigns the value between 0 and 255 is called uint8.

Binary Image: An image is stored as a matrix by this image format, but can only color (and nothing in between) a pixel black or white. It assigns 1 for white and 0 for black. The image is generally stored in matrix form but this image format pixel represents in black or white. It represents as 0 for black and 1 for white.

RGB Image: This is another color image format. It is an image with three size matrices that match the image format. Each matrix matches one of the colors red, green or blue and shows how many of these colors a certain pixel should use.

IV. PROPOSED METHOD

An easy approach to extracting data contained in a currency image is to capture the variation in an image collection, regardless of any judgment of feature and use this data to encode and compare with fake currency images. In figure 3, the proposed approach to detecting the false currency as shown below:

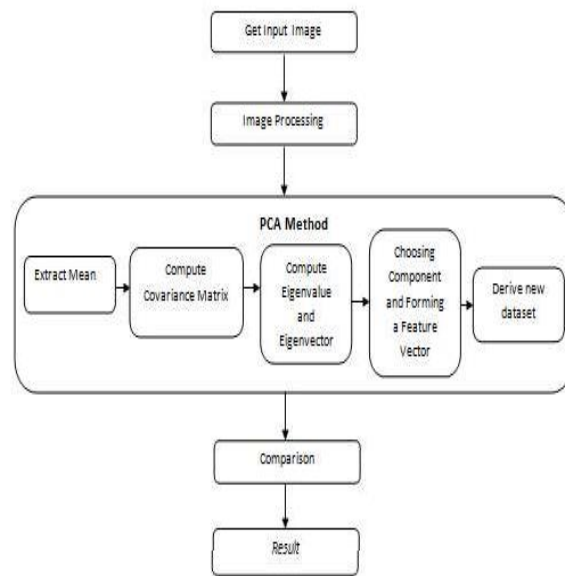


Fig.3. Proposed Approach for Detection of Fake Currency

These eigenvectors can be considered as a collection of the feature that characterizes together and the difference between real and fake currency images. Each image location contributes to each eigenvector more or less. This approach to recognition involves the following initialization operation:

A. Get Input Image:

This process acquires the real and fake image of currency using imread () function.

B. Image Pre-processing:

The acquired image is in RGB color. The RGB image has been converted to HSV (Hue-Saturation-Value) and Gray. After getting an RGB image then it converts into a binary image.

C. PCA Method

a) Extract the mean

To make PCA work properly, the First step is to normalize the data which is done by subtracting the respective means from the given number in the column. Therefore, for given two dimensions P and Q, all P will change to p- and Q will change to q- then:

$$Mean(\bar{P}) = \frac{1}{n} \sum_{i=1}^n P_i \quad (2)$$

b) Compute the Covariance Matrix

As the dataset taken is 3-dimensional, this results in a covariance matrix of 3*3. A numerical measure of the degree of correlation is denoted by S_{pq} between two variables which were introduced by the great statistician Karl Pearson (1857-1936) and that's called coefficient of correlation and given by:

$$S_{pq} = \frac{\text{cov}(p,q)}{\sqrt{\text{var}(p)\text{var}(q)}} = \frac{\sum (P_i - \bar{P})(Q_i - \bar{Q})}{\sqrt{\sum_{i=1}^n (P_i - \bar{P})^2 \sum_{i=1}^n (Q_i - \bar{Q})^2}} \quad (3)$$

The covariance is measured between two dimensions. If there is a dataset with more than two dimensions, it is possible to calculate more than one covariance measurement. For example, calculate cov(1,2), cov(2,3) and cov(3,1) form three dimensional data sets. For the m-dimensional data set, different covariance values can be used by the following formula:

$$C_2^m = \frac{m!}{(m-2)! * 2!} \quad (4)$$

Suppose, three-dimensional data set, then to make covariance has three rows and three columns with dimensions <p, q & r> is given below as:

$$\sigma = \begin{bmatrix} \sigma_{pp} & \sigma_{pq} & \sigma_{pr} \\ \sigma_{qp} & \sigma_{qq} & \sigma_{qr} \\ \sigma_{rp} & \sigma_{rq} & \sigma_{rr} \end{bmatrix} \quad (5)$$

c) Calculate the Eigenvalues and Eigenvectors

Calculation of eigenvalues and eigenvectors is possible only if it is a square matrix, λ is an Eigenvalue for a matrix A if it is a solution of the characteristic equation [43]:

$$\det(\lambda I - A) = 0 \quad (6)$$

Here, I is an identity matrix with the same dimension as A and the determinant of the matrix is denoted ~~det~~. For each Eigenvalue λ , there will be a corresponding Eigenvector v , can be find by solving equation given below [47]:

$$(\lambda I - A)v = 0 \quad (7)$$

d) Selecting Component and Forming a Feature Vector

Firstly, order the eigenvalues from largest to smallest to arrange the components in order with dataset of n variables. For the corresponding n eigenvalues and eigenvectors, the eigenvector corresponds to the highest eigenvalue will be the principle component of the dataset and it will be our call to choose the number of eigenvalues to proceed our analysis. For reducing dimensions, choose only to say p Eigenvalues and ignore the rest [43].

For forming a feature matrix which is a matrix of vectors i.e. eigenvectors (in this case). Actually, only those eigenvectors want to proceed with. Since three dimensions in the current example, it can either choose the one corresponds to the higher value of Eigen or simply take both and given by [43]:

$$FeatureVector = (eig_1, eig_2) \quad (8)$$

e) Derive the new dataset

It will be the final step forms the principle components. For that purpose, take the transpose of the feature vector and

left-multiply with the transpose of scaled data [47]. The resulting equation will be given by:

$$NewData = FeatureVector^T * ScaledData^T \quad (9)$$

Here,

NewData is the Matrix consisting of the principle components,

FeatureVector is the Matrix formed using the eigenvectors then choose to keep and

ScaledData is the scaled version of the original dataset.

According to the theory of eigenvalues and eigenvectors, eigenvectors provide information about the pattern exist in the data. In the above-discussed example, if plot the eigenvectors on the scatter data plot and find that the principle eigenvector actually fits the data. The other Eigenvector will not carry much information as it perpendicular to the principle vector. Therefore, it will not lose much while reducing the dimension.

f) Comparison

In this step, the comparison between real and fake currency through histogram represented in figures 4 and 5 which is clearly represented the relative frequency of the different gray levels of real and fake currency.

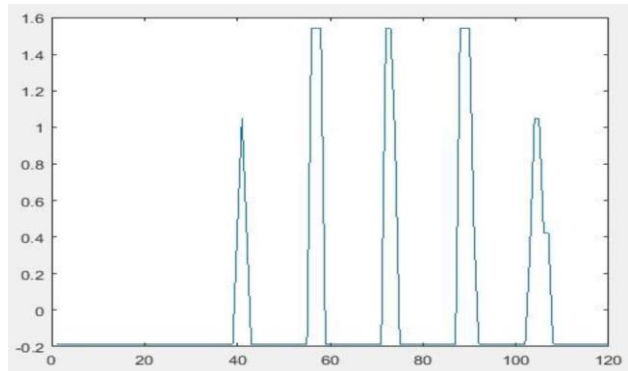


Fig.4. Histogram of Real Currency

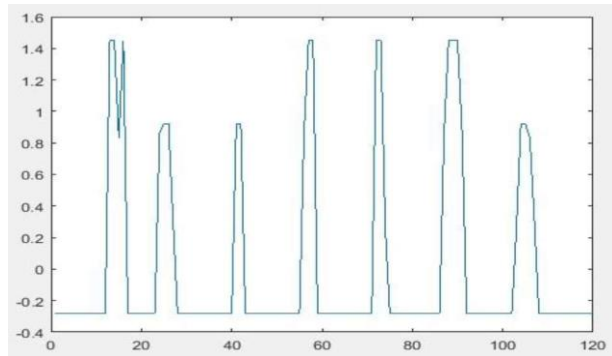


Fig.5. Histogram of Fake Currency

g) Experimental Result

The proposed technique is implemented using MATLAB to get evidence of a difference between real and fake image. After finding the eigenvalue and eigenvector then it plots in figures 6 and 7. All eigenvectors of a matrix are perpendicular to each other. Therefore, in PCA, instead of the normal x- and y-axes, the original data set is transformed using these perpendicular eigenvectors. Then classified data points are obtained by combining x and y contributions. The difference will be observed when ignoring many Eigenvectors.

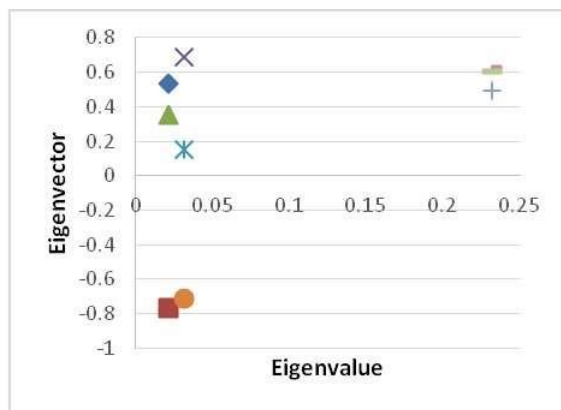
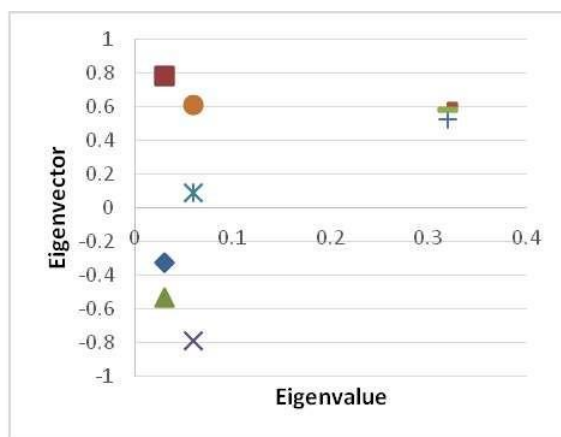


Fig.6. Representation of Real Currency



(b)

Fig.7. Representation of Fake Currency

From the above work, it is concluded that PCA is an excellent approach to detect fake currencies in Indian scenario as well as worldwide. Many researchers have implemented this approach on notes of various kinds but not for Indian Currency. In the works, an efficient model is proposed through which results are presented in the form of the graph. The converged result has been obtained by computing mean, covariance, eigenvalues, eigenvectors and new data set has been generated for Identification of fake currency.

V. CONCLUSION

From the above work, it is concluded that PCA is an excellent approach for the detection of fake currency in the Indian scenario as well as worldwide. Many researchers have implemented this approach on notes of various kinds but not for the Indian currency. In the present work, an efficient model is proposed through which results are presented in the form of the graph. The converged result has been obtained by computing mean, covariance, eigenvalues, eigenvectors and new data set has been generated for identification of fake currency.

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Texture Feature Technique for Security of Indian Currency

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Abstract. In the recent year, security of currency has gain importance in the field of research. With the advent of digital technology, color printer and color scanner are cheapest way for counterfeiter to produce fake currency. Feature extraction is the most important technique in paper currency recognition. According to reviewer, texture feature plays the important role for paper currency detection. Texture feature is generally a statistical based approach and in the present work, a new model is proposed for paper currency detection. The presented model is computing the texture properties like Gray Level Co-occurrence Matrix (GLCM) of Rs 500 for real and fake currency. The Principle Component Analysis (PCA) is used for reduction of higher dimension of image. The proposed work provides better result with the collaboration of PCA and GLCM. The texture properties have been used and GLCM measured the variation in intensity at pixel of interest of the currency. The computed results have been presented in the form of table and graphs.

Keywords: Currency, Security, Texture Feature, Gray-Level, GLCM.

1 Introduction

In the digital era of technology, it is very difficult to identify the fake paper currency. Illegal replication of original currency is known as counterfeiting. The Government of India (GOI) has used the term fake currency in place of counterfeit. This is very challenging issue to identify the fake currency. Reserve Bank of India (RBI) is the only body that takes sole responsibility to print paper currency in India. Extracting security features from Indian currency is most important for accuracy and robustness of the automated system. Features extraction in the form of colour, shape, texture or context are most important technique of image processing and pattern recognition. Although, many techniques are available in the literature to find out the pattern of paper currency, but feature extraction is the most common technique in the form of colour features, transform features, shape features, texture features, edge and boundary features. From the literature of the currency identification it is observed that there is no work on the newly developed paper currency by RBI but some little information in the literature are available for the Mexican banknotes, Euro, US Dollar related to the countries namely Australia, Cyprus, Sri Lankan and Bangladesh. Further it is found from the literature that the banknotes of each country are modelled by extracting the very important feature that depends on the nationality of currency. Therefore, the contribution of systematic approach is to recognize the currency by texture feature analysis. In the following Fig.1, the traditional way to image analysis in image processing is represented.

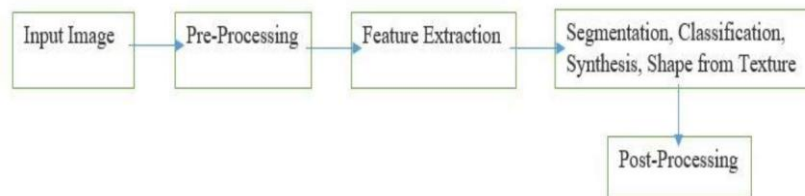


Fig.1. Representation of Texture Feature Analysis

In the present paper, Section 2 describes a state of art of work on the texture feature analysis, Section 3 describes the feature extraction methods, Section 4 is related to the result of implementation and finally Section 5 describes the discussion and concluding remarks of the work.

2 State of Art of Texture Feature Analysis of Paper Currency

In the texture feature analysis, authors have to first identify the texture features on the basis of Pattern and analysis the same by various approaches. In this reference, P. Mohanaiah et al. [15] have described the GLCM approach for image texture feature extraction. In the work, it is presented an application of GLCM to extract the second order statistical texture feature analysis for estimation of the image using Xilinx FPGA. The computed results present the texture feature analyses with high accuracy in less computation time and it is efficiently used for real time pattern recognition application. Ghazi Alnowaini et al. [2] proposed a new automated system that identifies the Yemeni paper currency real or fake based on image processing technology with machine learning algorithms. In this proposed framework has different five steps such as currency acquisition, preprocessing, feature extraction, classification and verification. The system has found to detect the currency real or fake in respect of accuracy and fast processing time. Satishkumar S. Chavan et al. [6] designed an automatic coin dispensing machine to resolve this issue. There have three modules such as detection of a genuine currency note, determining the value of the note and dispensing of equivalent coins. Here the genuine currency analyses through security thread with the help of histogram of currency captured by Ultraviolet (UV) light. The robust system has 92.12% accuracy for detection of denomination of the currency, 100% accuracy for dispensing of equivalent coins and 90.07% accuracy for the genuineness of currency. H. B. Kekre et al. [13] have explained a method for image retrieval using texture feature extraction from GLCM, Linde-Buzo-Gray (LBG) and Kekre's Proportionate Error (KPE) algorithms. Further, Chao Tong et al. [2017] proposed a new algorithm to differentiate the new and old currency based on five level statistical parameters of texture of currency in gray-scale image, gray level-gradient co-occurrence matrices and multi-DAG-SVM classifier. The experimental outcomes demonstrate the algorithm with high speed and greater efficiency at the classification level. Ruaa Mohammed Hamza and Dr. Tawfiq A. Al-Assadi [9] also described a new method of image improvement on optimal texture feature extracted from GLCM using genetic algorithm which finds ideal texture features separated from GLCM dependent on the fitness function. Wei Q. Yan et al. [22] developed a prototype that identify the currency. There are two highlight vectors which comprised of colour features and texture features. A lots of research work is available on currency being grouped through a Feedforward Neural Network (FNN) and also measured difference among sample and counterfeit banknote. Farid Garcia-Lamont et al. [8] addressed the use of the artificial vision to recognition of Mexican currencies which may be grouped by colour and texture features with respect to the RGB space and the local binary patterns. This mechanism displays the characterization outcome for the Mexican

currencies and the planned strategy may be enforced to identify the currencies of different countries by the use of colours to recognize the groups. Snehlata and Saxena [19] have proposed a case study of Indian currency identification system which is based on currently launched Rs 500 and Rs 2000 through object oriented approach. Arya and M. [4] have proposed Fake currency notes are increasing day by day, in order to overcome this, design a very helpful and efficient system to detect the fake currency. For detecting the fake currency note is done by counting the number of interruptions in the thread line. For predicting the note is real or fake on the basis of a number of interruptions. If the number of interruption is zero, if it is real note otherwise it is fake. And also we calculate the entropy of the currency notes for the efficient detection of a fake currency note. MATLAB software is used to detect the fake currency note. A. Ahmadi et al. [1] explained a method that is based on PCA which increases the reliability of recognition system and proposed system recognizes the six different types of bills of US dollars. Firstly, image is captured by Line sensor, then, image is extracted with main feature and decreased the dimension of the image using PCA technique. It is used Linear Vector Quantization (LVQ) network and outcomes show that the dependability has been incremented up to 95% when the PCA component and LVQ vectors are taken correctly to recognize the currencies for Australian blind people. A. Hinwood et al. [11] have proposed a Money Talker that electronically recognize the different colours and texture of Australian currencies. Firstly, currency is captured by the system then light is passed through currency and respective sensors and detect the different ranges of values depending on the colour of the currency. F. Takeda et al. [20] described a method to recognize Thai banknotes with slab values that are stored in digital form as input of Neural Network (NN) for recognition process. M. Aoba et al. [3] presented Euro banknotes recognition system which uses the two types of NN's. A. Frosini et al. [7] explained the neural based recognition technique which are used in banknotes machines. Snehlata and Saxena [18] described the efficient technique for currency detection by the use of PCA for providing the better way to currency identification. Generally, PCA is used for dimension reduction. The eigen-values and eigen-vectors provide the better discrimination of the fake and real currency that provides the better results in the form of graph and table. Priyal has proposed [5] proposed an efficient Image processing technique that has to extract various features from the U.S. currency. The features of currency are dimensions, colour written letters, security thread, texture, federal reserve indicator, serial number, and various other details that help to increase the accuracy of fake currency detection. The proposed framework has used machine learning and deep neural network to extract the more feature more and improve accuracy.

3 An Overview of Feature Extraction

This section briefly elaborates about digital Image processing, pattern recognition and feature extraction. Feature extraction is the most essential chunk of pattern recognition that deals with the dimensionality reduction. To deal with enormous information that contains redundant data, the feature extraction method is used to effectively reduce the data size without losing important and relevant information. In general, feature contains information about colour, shape, surface or context. The kind of literature have suggested a lots of techniques for feature extraction from images, some are listed below in Fig.2.

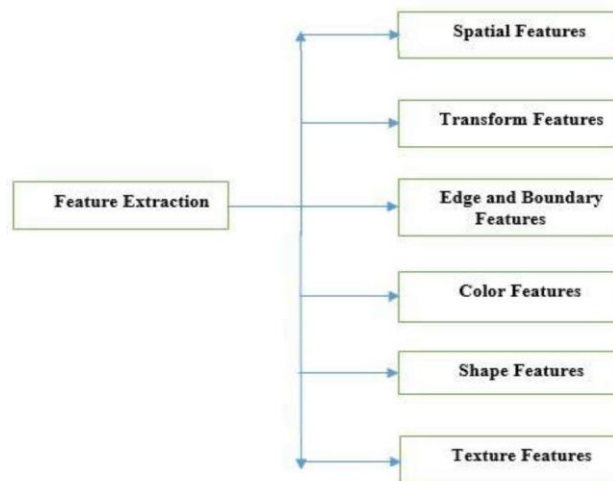


Fig. 2. Various Types of Feature Extraction.

3.1. GLCM

GLCM is a technique for extraction of texture features and according to, Guiying Li [2012], GLCM is defined as the texture of continual arrangement of information having the structure of regular intervals. Texture study means size, shape, density, arrangement, surface characteristics and appearance of an object and also of its elementary part. As texture contains vital information regarding any object, so that texture feature extraction leads to the key function in the Image processing field.

Singh et al. [16] proposed a novel method of object recognition using point feature technique for colour images. The SURF algorithm used to find the object detection for unique feature matches of colour images. This approach of detection has robustly find object between colored cluttered images. Singh et al. [17] proposed a method suggests to uses K- means and EK means clustering methods on various tumor images. The characteristics are observed based on geometrical features. Images were trained by advance machine learning algorithms like Artificial Neural Network(ANN) and Support Vector Machine(SVM) where it divides the tumor into the malignant type and due to segmentation it gives tumorous part. That system used characteristic extraction by further segmenting GLCM characteristics into Haralick features.

Neville et al [2003] demonstrated various texture feature extraction methods and characterized as model-based and transform information, statistical, structural methods. Among all listed methods, Statistical based feature extraction method is prominent for texture feature extraction that incorporates first order statistics, second order statistics and higher order statistics. In the present scenario, the co-occurrence matrix and texture feature are most popularly used in the area of image identification which was suggested by Haralick in early 1973 [12] that is based on second order statistical features. Suggestions regarding texture feature contain the following two steps:

- Firstly, the computation of the co-occurrence matrix;
- Based on computation of co-occurrence matrix, texture features are calculated.

This idea is quite useful in Image analysis for currency identification. After optimizing the fourteen texture features, the idea of Haralick [1973], Andrea Baraldi and Flavio Parmiggiani [1995] proposed a new approach of the five statistical parameters energy, entropy, contrast, homogeneity and correlation. The explanation is as follows:

m, n : coefficient of co-occurrence Matrix;

$X(m, n)$: element in the co-occurrence Matrix at the coordinates m, n ;

K : Dimension of co-occurrence Matrix.

The five statistical parameters are explained below in brief:

(a) Energy

The performance can be measured in terms of energy (E) which can be measured as the extent of pixel pair repetitions. It measures the uniformity of an image. When pixels are very similar, the energy value will be large. The energy is defined as:

$$E = \sqrt{\sum_{m=0}^{K-1} \sum_{n=0}^{K-1} X^2(m, n)} \quad (1)$$

(b) Entropy

The Entropy (Ent) is the proportion of arbitrariness that is utilized to describe the surface of the information picture. Its worth will be maximum when all the components of the co-occurrence matrix are the equivalent. It is defined below:

$$Ent = \sum_{m=0}^{K-1} \sum_{n=0}^{K-1} X(m, n)(-In(X(m, n))) \quad (2)$$

(c) Contrast

The Contrast (Con) is characterized in equation (3), which is a proportion of power of a pixel and its neighbour over the picture. In the visual impression of a genuine world, differentiate is deflected by the distinction in colour and brightness of the object and different objects within a similar field of view.

$$Con = \sum_{m=0}^{K-1} \sum_{n=0}^{K-1} (m - n)^2 X(m, n) \quad (3)$$

(d) Homogeneity

Homogeneity returns a value that measures the closeness of the distribution of elements in GLCM to the GLCM diagonal. The value of energy is 1 for a diagonal GLCM and having the range as [0 1]

$$Hom = \sum_{m,n} \frac{X(m, n)}{1 + |m - n|} \quad (4)$$

(e) Correlation

Correlation returns a measure of how correlated a pixel into its neighbour over the whole image. It's range is [-1 1] and defined below:

$$Corr = \sum_{m,n} \frac{(m - \mu_m)(n - \mu_n)X(m, n)}{\sigma_m \sigma_n} \quad (5)$$

3.2. Principle Component Analysis

According to the data hypothesis, extract the important feature of currency image for identification and compare one currency to another currency feature to a database. A basic way to deal with extricating the data contained in an image of a currency is to by one way or another catch the variety in a collection of currency image, autonomous of results of features and utilize this data to computed and analyse the single currency image [15]. Snehlata and Saxena [18] briefly discussed that Principle Component Analysis (PCA) is a method of recognition based on the feature of texture that features are expressed in the term of resemblance and dissimilarity. Once the pattern is matched in data then it can be compressed.

The transformation function as given below:

$$M = YW \quad (6)$$

Where

Y denotes $a \times b$ matrix of a observations on b variables;

M denotes $a \times b$ of a values for each of b components;

W denotes $b \times b$ of coefficient defining the linear transformation.

There has included two phases: Training and Testing.

The Training phase contains the following stages:

- 1) Generate the currency database;
- 2) Features are extracted from the currency;
- 3) Calculate Mean;
- 4) Subtract mean from each currency image, known as mean aligned currency;
- 5) Calculate covariance of the mean aligned currency;
- 6) Calculate Eigenvalues and Eigenvectors;
- 7) Identify Eigenvectors and find principle Eigenvectors;
- 8) Find the direction of Data.

The Testing phase contains the following stages:

- 1) For testing, a test currency image, make it a column vector;
- 2) Subtract mean of currency to this test currency;
- 3) Calculate the distance.

4 Results and Discussion

Let us first describe the characteristics of Rs 500 Indian paper currency which is depicted below in Fig.3.



Fig.3. Representation of Rs 500 Indian paper currency

The presented currency has the following silent features listed below:

1. See through register
2. Latent image
3. Denomination numerical in Devanagari
4. Mahatma Gandhi's portrait in centre facing to right
5. Windowed security thread
6. Guarantee clause
7. Portrait and electrotype watermark

8. Number panel with numerals growing from small to big on the top left side and bottom right side
9. Denomination in numerals with rupee symbol in colour changing ink (green to blue) on the bottom right
10. Asoka pillar emblem on the right
11. Circle with Rs 500 in raised print on the right
12. Five bleed lines on left and right in raised print
13. Year of printing of the note on left
14. Swachh Bharat logo with the slogan
15. Language panel towards the centre
16. Red Fort with Indian flag
17. Denomination numeral in Devanagari on right

The image database used in this study served as the main feature extraction of the texture using GLCM. The GLCM method incorporates the averaging of coefficient matrix having the direction of 0^0 , 45^0 , 90^0 and 135^0 [10]. The above mentioned six feature of GLCM used in this research like are Energy, Entropy, Contrast, Homogeneity and Correlation. The values of these feature are depicted as the training and test database from our keenly observed image data set. Table 1 shows the value of the characteristics of GLCM used as input to database training.

Table 1. Characteristics of GLCM database training.

Energy	Entropy	Contrast	Homogeneity	Correlation
0.20645	1.35718	0.83730	0.811055	0.749905

4.1. Classification and identification system testing

The determination of value k as in our case 1, 3 and 5 is carried out with the help of PCA classification process for fixed amount of training data. The right value of k is totally depending upon the level of closeness and accuracy of the identification process. Hence as a result for the identification process to determine the value of k testing process are observed with the certain accuracy as depicted in Table 2.

Table 2. Accuracy of the identification result.

Banknote	k-values	Accuracy (%)
Rs 500	k=1	100
	k=3	90
	k=5	80

The proposed technique is implemented using MATLAB to get real currency from the database. Based on k- value obtained different accuracy to currency detection, graph plot between k-value and accuracy in Fig. 4.

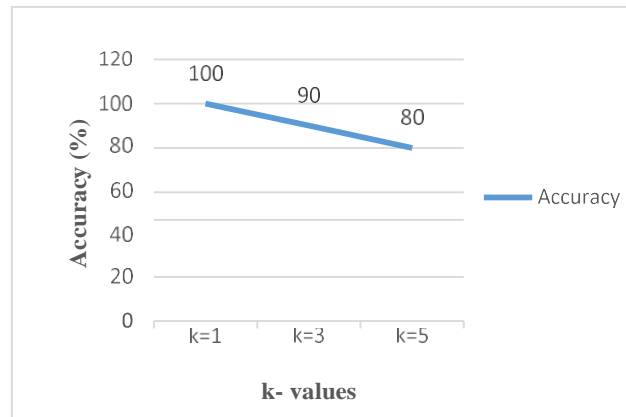


Fig.4. The Graph between k-values and Accuracy.

5 Conclusion

The texture pattern of the genuine Rs 500 currency is exceptionally powerful in the process information securing can influence the estimation of surface element extraction utilizing the GLCM technique. The estimation of k in the arrangement input utilizing the PCA technique can decide the exactness of the characterization procedure and ID of the realness of rupee currency. The after effects of the recognizable proof of the authenticity of the rupee tried right now an accuracy of 100% when the value of k=1, accuracy of 90% when the estimation of k=3 and accuracy of 80% when the estimation of k=5 with the arrangement of the measure of 20 training data and 10 testing data. The accuracy of the value for k=1 is the most elevated of accuracy value. It is on the grounds that when an estimation of k=1 is the default value research can be inferred that the more noteworthy of the separation technique that has 1 nearest neighbour of that information worth or it very well may be considered that information possess. Right now be reasoned that the more prominent the estimation of k given to the framework during the arrangement and identification procedure will cause the lower level of accuracy produced from the system.

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A Novel Approach for Identification of Fake Indian Currency Using Genetic Algorithm

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Abstract

In any country, there is always arrival of different kinds of new currency from time to time. In India, the government applied demonetization in the year 2016, and later on, there was the arrival of new notes in the form of 10, 20, 50, 100, 500, and 2000 Indian rupees. Although it minimizes the use of fake currency in any Country but hackers and intruders generate the fake currency through a high-quality scanner and printer. In the present work, an application of the Genetic algorithm is used for the identification of fake currency based on feature extraction. An algorithm has been implemented for the identification of fake currency in the form of notes.

Keywords: Genetic Algorithm, Currency, Security, Feature Extraction, Pattern Recognition.

1. Introduction

In the year 1968, Charles Darwin developed a theory based on the biological evaluation that states the natural existence of the strongest species. This was based on the natural selection of small inherited variation for increasing the individual ability to compile, survive, and reproduce. Based on this theory, the concept of the genetic algorithm was developed by Goldberg. Since the present work is based on the application of a genetic algorithm for the identification of fake Indian currency notes, therefore, it is necessary to describe some of the important references related to the work.

Hermawanto [1] explained the concept of a genetic algorithm for solving the mathematical equality problem by taking the four variables. In the year 1997, Gen and Cheng [2] proposed the concept of the genetic algorithm to achieve crossover by a solution of irregular cut point and created the off-screen by a blend of one parent to one side cut point which section of the other parent of the correct slice point and applied it to the designing point. Bashkansky and Yaari [3] proposed a famous approach of a black box which is used for selecting the optimized chromosomes which is a very advantageous approach and simple to implement the genetic algorithm. One of the important paper introduces in the year 2012 which was Dharmistha and Vishwakarma [4] developed accuracy process model and further optimized the weights assigned on the internal layers' architecture of the Artificial Neural Network (ANN). Nanhao and O'Connor [5] described the genetic algorithm which is also used in the field of wireless sensor networks with which a method for finding the 100 possible solutions for a given task. In the year 2015, Bashir [6] explained the bit by bit mathematical calculation of hereditary calculation for addressing the Eggcrate work. The outcomes demonstrated that the Eggcrate work has a known worldwide least at [0, 0] with an ideal capacity estimation of zero. Bashir and Mahdi [7] explained Queen Problem which is a well-known optimization technique used for the genetic algorithm. Further, the application of generation is described by the solution of

fitness function by selecting the coordinated and fitness function [8, 9]. The other important references related to genetic algorithms are [10, 11, 12, 13, 14 and 15]. From the review of the literature, it is observed that there is little use of the genetic algorithm for solving the problem related to identifying spatial, transform, edge and boundary, color, shape, texture features of any kind of the Image.

In the present work, the concept of genetic algorithm is used for finding the generation of new chromosomes process till the matching of the result. Sufficient iterations have been performed by the use of Python programming language. Results are depicted on Indian currency of note of Rs 500.

2. Methodology and Implementation

For Implementation of the concept of genetic algorithm, the following steps are used:

1. *Input the image of the note of Rs 500 and compute the number of chromosomes generation, crossover rate, mutation rate values;*
2. *Divide the chromosomes into the number of blocks of the same size;*
3. *Initialize the number of chromosomes by taking the four variables;*
4. *Repeat the following sub-activities for identification of fake currency;*
 - 4.1. *Compute the fitness value of the chromosomes of the objective function;*
 - 4.2. *Compute the highest fitness function chromosomes and the selection of the chromosomes;*
 - 4.3. *Compute the chromosomes along with probability values;*
 - 4.4. *Mutate rate parameter by reproducing the genes at a random position;*
5. *Repeat step 4 till the finding of the best chromosomes.*

The genetic algorithm assesses the objective function to be upgraded at some arbitrarily chosen purpose of the domain definition. By the utilization of this strategy, another arrangement of focuses (another population) is produced. Steadily, the focuses in the population approach towards local maxima and minima of the function. The above technique has been implemented in the Indian currency of note of Rs 500 and steps are discussed below in brief:

Step1

Input the scanned Image of Rs 500, then apply image pre-processing and extract the feature of the most vulnerable parts of currency. For this purpose, MATLAB is used to get the feature vector as shown in figure 1.

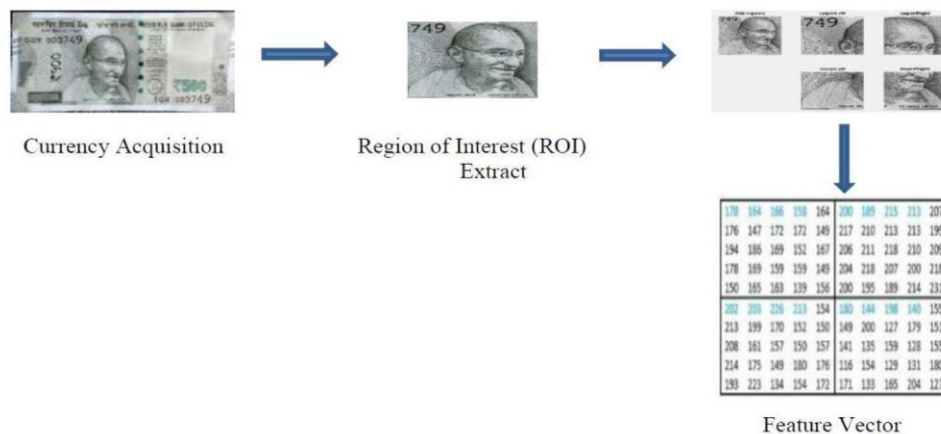


Figure 1. Feature Extraction of Rs 500

Step 2

Image is analyzed and divided into some blocks each with the same size and give a label to each block and save the pixels of each block in temporary storage to retrieve these Pixels as when constructing the original image matrix. The construction of the original matrix is represented in the following figure 2.

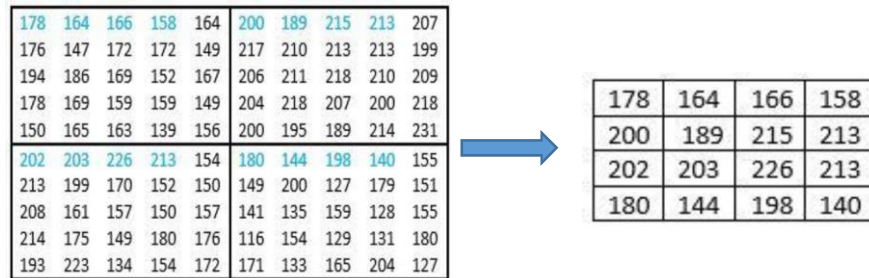


Figure 2. Construction of the Original Chromosomes Matrix

Step 3

Consider the initial population consisting of some chromosomes taken as Ch [] and each chromosome consists of some genes of a block in the blocks matrix that results from the first stage:

- Ch [1] = [a; b; c; d] = [178; 164; 166; 158]
- Ch [2] = [a; b; c; d] = [200; 189; 215; 213]
- Ch [3] = [a; b; c; d] = [202; 203; 226; 213]
- Ch [4] = [a; b; c; d] = [180; 144; 198; 140]

Step 4

Repeat the following sub activities for identification of fake currency:

Step 4.1

Compute the fitness evaluation taken as F_eval [] using objective function of each chromosome by taking fitness function as

$$f(x) = ((a + 2b + 3c + 4d) - 50) \tag{1}$$

- F_eval [1] = Abs ((178 + 2*164 + 3*166 + 4*158) - 50) = 1586
- F_eval [2] = Abs ((200 + 2*189 + 3*215 + 4*213) - 50) = 2025
- F_eval [3] = Abs ((202 + 2*203 + 3*226 + 4*213) - 50) = 2088
- F_eval [4] = Abs ((180 + 2*144 + 3*198 + 4*140) - 50) = 1572

Step 4.2

For finding the next generation, let us compute the highest probability of the fittest chromosome. To calculate the fitness probability, first, compute the fitness taken as fitness [] of each chromosome. To avoid partition by zero issues, the assessment of F_eval is added by 1 and represented below:

- Fitness [1] = 1/ (1+F_eval [1]) = 0.00063011972
- Fitness [2] = 1/ (1+F_eval [2]) = 0.00049358342
- Fitness [3] = 1/ (1+F_eval [3]) = 0.00047869794
- Fitness [4] = 1/ (1+F_eval [4]) = 0.00063572791

Total = 0.00063011972 + 0.00049358342 + 0.00047869794 + 0.00063572791
=0.00223812899

Step 4.3

The probability for each chromosome is to be computed by:

$$P[i] = \text{Fitness}[i] / \text{Total} \quad (2)$$

P [1] = 0.00063011972/0.00223812899 = 0.28153860784
P [2] = 0.00049358342/0.00223812899 = 0.22053394697
P [3] = 0.00047869794/0.00223812899 = 0.21388308812
P [4] = 0.00063572791/0.00223812899 = **0.28404435707**

Therefore, chromosome 4 has the most elevated the wellness esteem, this is the most noteworthy likelihood that to be picked for the cutting edge chromosome. For the computation of cumulative probability considered as Cum [], consider Roulette Wheel for the selection process as shown below:

Cum [1] = 0.2815
Cum [2] = 0.2815 + 0.2205 = 0.502
Cum [3] = 0.2815 + 0.2205 + 0.2138 = 0.7158
Cum [4] = 0.2815 + 0.2205 + 0.2138 + 0.2840 = 0.9998

Using Roulette-Wheel, to calculate the cumulative probability of selection process and generate the random number taken as Rand [] between 0-1 as given below:

Rand [1] = 0.201
Rand [2] = 0.284
Rand [3] = 0.099
Rand [4] = 0.822

If random number Rand [1] is smaller than Ch [1] then select Ch [1] as a chromosome in the new population for the next generation represented as New_Ch [].

New_Ch [1] = Ch [1]
New_Ch [2] = Ch [2]
New_Ch [3] = Ch [1]
New_Ch [4] = Ch [4]

Chromosomes Ch [] in the population are now represented below:

Ch [1] = [178; 164; 166; 158]
Ch [2] = [200; 189; 215; 213]
Ch [3] = [178; 164; 166; 158]
Ch [4] = [180; 144; 198; 140]

For interchanging the sub chromosome, used a one cut point to select a random point in the parent chromosome. Parent chromosome which will mate is randomly chosen and the quantity of mate Chromosome is controlled utilizing crossover rate taken as pc [] boundary. Chromosome k will be chosen as a parent if Rand[k] < pc. Assume one set that the crossover rate is 25% then chromosome number k will be chosen for crossover if a randomly created

an incentive for chromosome k underneath 0.25. Consider an irregular number taken as Rand []:

Rand [1] = 0.191
Rand [2] = 0.259
Rand [3] = 0.760
Rand [4] = 0.006

For the random number above, parents are Ch [1] and Ch [4], will be selected for crossover:

Ch [1] > < Ch [4]
Ch [4] > < Ch [1]

After chromosome determination, the following cycle is deciding the situation of the crossover point. This is finished by producing a random number between 1 to (length of Chromosome - 1). For this situation, created random numbers ought to be somewhere in the range of 1 and 3. After that one get the crossover point, the parent's chromosome will be cut at the crossover point and its qualities will be exchanged. For instance, one produced 3 irregular number and get:

C [1] = 1
C [2] = 1
C [3] = 2

At that point for the main hybrid and second hybrid, parent's gens will be cut at gen number 1, Example

Ch [1] = Ch [1] > < Ch [4]
= [178; 164; 166; 158] > < [180; 144; 198; 140]
= [178; 144; 166; 140]
Ch [4] = Ch [4] > < Ch [1]
= [180; 144; 198; 140] > < [178; 164; 166; 158]
= [178; 144; 166; 140]

After the crossover process, compute the new chromosomes:

Ch [1] = [178; 144; 166; 140]
Ch [2] = [200; 189; 215; 213]
Ch [3] = [178; 164; 166; 158]
Ch [4] = [178; 144; 166; 140]

Step 4.4

After the change of chromosome dictated by the mutation rate boundary and mutation measure is finished by supplanting the gen at arbitrary situation with another worth. For this cycle, first process the complete length of gen (Tot_gen) in the populace as follow:

Tot_gen = Number_of_gen_in_Chromosome * Number of population
= 4*4
= 16

Therefore, in mutation measure, an arbitrary number is created between 1 to Tot_gen. To mark the position of gen in chromosome, whenever created arbitrary number is more modest than change rate (pm). Assume, characterize pm 10% it is normal that 10% (0.1) of total_gen in the populace that will be changed:

$$\begin{aligned}\text{Number of mutations} &= 0.1 * 16 \\ &= 1.6 = 2\end{aligned}$$

Assume the age of irregular numbers yield as 8 and 14 then the chromosomes are Chromosome number 2 gen number 4 and Chromosome number 4 gen number 2.

Suppose generated random numbers are

Ch [1] = [178; 144; 166; 140]

Ch [2] = [200; 189; 215; **213**]

Ch [3] = [178; 164; 166; 158]

Ch [4] = [178; **144**; 166; 140]

For completing the change cycle, think about one emphasis or one generation of the genetic calculation. One would now be able to assess the target work after one generation as:

Ch [1] = [178; 144; 166; 140]

$$\begin{aligned}F_eval [1] &= \text{Abs} ((178 + 2 * 144 + 3 * 166 + 4 * 140) - 50) \\ &= \text{Abs} ((178 + 288 + 498 + 560) - 50) = 1474\end{aligned}$$

Ch [2] = [200; 189; 215; **213**]

$$\begin{aligned}F_eval [2] &= \text{Abs} ((200 + 2 * 189 + 3 * 215 + 4 * 213) - 50) \\ &= \text{Abs} ((200 + 378 + 645 + 852) - 50) = 2025\end{aligned}$$

Ch [3] = [178; 164; 166; 158]

$$\begin{aligned}F_eval [3] &= \text{Abs} ((178 + 2 * 164 + 3 * 166 + 4 * 158) - 50) \\ &= \text{Abs} ((178 + 328 + 498 + 632) - 50) = 1586\end{aligned}$$

Ch [4] = [178; **144**; 166; 140]

$$\begin{aligned}F_eval [4] &= \text{Abs} ((178 + 2 * 144 + 3 * 166 + 4 * 140) - 50) \\ &= \text{Abs} ((178 + 288 + 498 + 560) - 50) = 1474\end{aligned}$$

From the advancement of the new Chromosome, one can see that the objective function is diminishing, this implies that we have better chromosomes or arrangements contrasted and the past Chromosome age. New chromosome for the following emphasis are given beneath:

Ch [1] = [178; 144; 166; 140]

Ch [2] = [200; 189; 215; 213]

Ch [3] = [178; 164; 166; 158]

Ch [4] = [178; 144; 166; 140]

These new chromosomes will go through similar cycle as the past generation of Chromosomes, for example, evolution, selection, crossover and mutation and eventually, it creates another generation of Chromosomes for the following emphasis. This cycle will be rehashed until a foreordained number of generations.

Steps 5:

The above-said process is repeated until the finding of the best chromosomes.

3. Concluding Remarks

To execute the Simple Genetic Algorithm (SGA) code written in Python programming language, the fundamental three stages of the SGA, for example, select, crossover and mutation are manually determined. This method is called as generation and another populace creates at each progressive generation. Toward the finish of the run, rehashing the cycle until the best arrangement is resolved. After getting the best chromosome of acquiring, currency image is compared to a chromosome of reference currency image. To reduce the computation time, the proposed algorithm uses the currency. This paper is representing the calculation behind the genetic algorithm for paper currency detection.

The texture pattern of the genuine Rs 500 currency is exceptionally powerful in the process of information. The estimation of chromosome in the arrangement input utilizing the genetic algorithm technique can decide the exactness of the characterization procedure and identification of the realness of rupee currency. The genetic calculation finds close ideal outcomes rapidly subsequent to looking through a little segment of the hunt space. The calculation is not difficult to create and easy to comprehend and improvements effortlessly presented that show the viability of calculation. The computed results show that the genetic algorithm can find an optimal solution for currency identification problems.

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