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COUNTERFIET PAPER BANKNOTE IDENTIFICATION BASED ON COLOR AND TEXTURE

BY

Shaurav Lamsal

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Information and Communication Engineering

Department of Electronics and Computer Engineering

Institute of Engineering, Pulchowk Campus

Tribhuvan University

Lalitpur, Nepal

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Department of Electronics and Computer Engineering

Institute of Engineering, Pulchowk Campus

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DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING

The undersigned certify that they have read and recommended to the Department of Electronics and Computer Engineering for acceptance, a thesis entitled **"Counterfeit Paper Banknote Identification Based on Color and Texture"**, submitted by **Shaurav Lamsal** in partial fulfilment of the requirement for the award of the degree of "**Master of Science in Information and Communication Engineering**".

Supervisor: Dr. Aman Shakya
Electronics and Computer Department
Institute of Engineering
Pulchowk Campus

External Examiner: Er. Mahesh Singh Kathayet
Head, Computer Directorate
Police Headquarter, Nepal Police

Committee Chairperson: Dr. Dibakar Raj Panta
Head
Electronics and Computer Department
Institute of Engineering
Pulchowk Campus

November 5, 2015
Date

DEPARTMENTAL ACCEPTANCE

The thesis entitled **"Counterfeit Paper Banknote Identification Based on Color and Texture**", submitted by **Shaurav Lamsal** in partial fulfilment of the requirement for the award of the degree of "**Master of Science in Information and Communication Engineering**" has been accepted as a bonafide record of work independently carried out by him in the department.

Dr. Dibakar Raj Panta
Head of the Department
Department of Electronics and Computer Engineering
Pulchowk Campus, Tribhuvan University, Nepal

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ABSTRACT

Currency identification is the application of systematic methods to determine authenticity of questioned currency. However, identification analysis is a difficult task requiring specially trained examiners; the most important challenge is automating the analysis process reducing human labor and time. Color and texture feature are used for the classification of an image. This thesis present the techniques used for the extraction of feature, identification and classification of counterfeit and genuine bank note. It presented simple method of identification of counterfeit paper banknotes, which automatically using image processing techniques. Color and texture feature of a currency is used for identification. Color descriptor skew, mean and standard deviation is calculated from samples which are checked against the parameter that are previously defined. Texture parameter entropy and correlation are calculated from different set of database image. Matching score below the threshold, input currency image is classified as fake note. Otherwise the currency is genuine. Image processing approach is very useful for classification of different types of currency.

Keywords: Color, Texture, Template matching, Image processing, Counterfeit currency detection

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LIST OF ABBREVIATIONS

CIE	International Commission on Illumination
CMYK	Cyan, Magenta, Yellow, Key (black)
DPI	Dot per inch
GF	Gabor Filter
HSV	Hue, Saturation, Value
RGB	Red, Green, Blue
RMS	Root mean square
ROI	Region of Interest
OVI	Optically variable ink

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Chapter 1: INTRODUCTION

1.1 Background

There are many currencies all over the world, with each of them looking totally different. For instance the size of the paper is different, the same as the color and pattern. The staffs who work for the money exchanging have to distinguish different types of currencies and that is not an easy job. They have to remember the symbol of each currency. This may cause some problems (e.g. wrong recognition), so they need an efficient and exact system to help their work.

Currency counterfeiting is as old as the start of coinage around the world. The paper currencies are the center of target to counterfeiters. Counterfeit detection is mainly executed based on the Chemical or Physical properties of paper currencies. The counterfeiters nowadays can evade the chemical property & physical feature based counterfeit paper currency detection system due to technological advancement [1]. Beside that right now all country in the world has their own currency with different characteristics, size and totally different between each other's [2].

The counterfeiting of currency notes is one of factor which affects the economy of any country. Hence each country tries to deter such counterfeiting of one's currency notes using many methods, among which the security features in currency notes is one of the prominent and the most effective method [3]. The security features are embedded in each currency note is various ways. Some of such features are easily identifiable, some need tools to identify and some need special attention to detect. It is essential that anyone working if field of handling currency notes should have appropriate and adequate knowledge about such features so that one can differentiate the counterfeit note from genuine. Speed and accuracy of processing are two important factors in such systems. Of course, the accuracy may be more important than the speed [4].

A banknote carries security features mainly on its paper, design and printing process. Examination or verification of currency notes is mostly conducted by checking the following aspects: i) physical dimensions, ii) paper quality, iii) design, and (iv) printing technique. Physical dimension of currency note depends on its cut size of length, width, grammage and thickness of paper. The paper on which currency note is printed carries important level of security. Watermarks and security thread are other important parts of security on currency note paper [5].

Security features of genuine paper banknote are described below:

- **See through Register**

  The small floral design printed both on the front (hollow) and back (filled up) of the note in the middle of the vertical band next to the Watermark has an accurate back to back registration. The design will appear as floral design when seen against the light. It is marked as NRN.

- **Fluorescence**

  Number panels of the notes are printed in fluorescent ink. The notes also have optical fibres. Both can be seen when the notes are exposed to ultra-violet lamp.

- **Security Thread**

  The Rs.500 and Rs.100 notes have a security thread with similar visible features and inscription "NRB" (in English). When held against the light, the security thread on Rs.1000, Rs.500 and Rs.100 can be seen as one continuous line. The Rs.5, Rs.10, Rs.20 and Rs.50 notes contain a readable, fully embedded windowed security thread with the inscription "NRB" (in English). The security thread appears to the left of the watermark.

- **Intaglio Printing**

  The portrait of Sagarmatha, Rastra Bank seal, guarantee and promise clause, Number panel, NRB Governor's signature are printed in intaglio i.e. in raised prints, which can be felt by touch, in Rs.20, Rs.50, Rs.100, Rs.500 and Rs.1000 notes.

- **Micro lettering**

  This feature appears between the vertical band and Sagarmatha portrait. It always contains the word "NRB" in Rs. 500. The notes of Rs.20 and above also contain the denominational value of the notes in micro letters. This feature can be seen well under a magnifying glass.

- **Identification Mark**

Each note has a unique mark of it. A special feature in intaglio has been introduced on the left of the watermark window on Rs 100, Rs 500 and Rs 1000 note. This feature is in black circle shapes for with one circle, two circle, three circles in denominations in Rs.100, Rs.500, and Rs.1000 respectively and helps the visually impaired to identify the denomination.

- **Watermark**

When the note is held against the light, the picture of Laligurash and an electrolyte mark showing the number 500 appear in the white space.

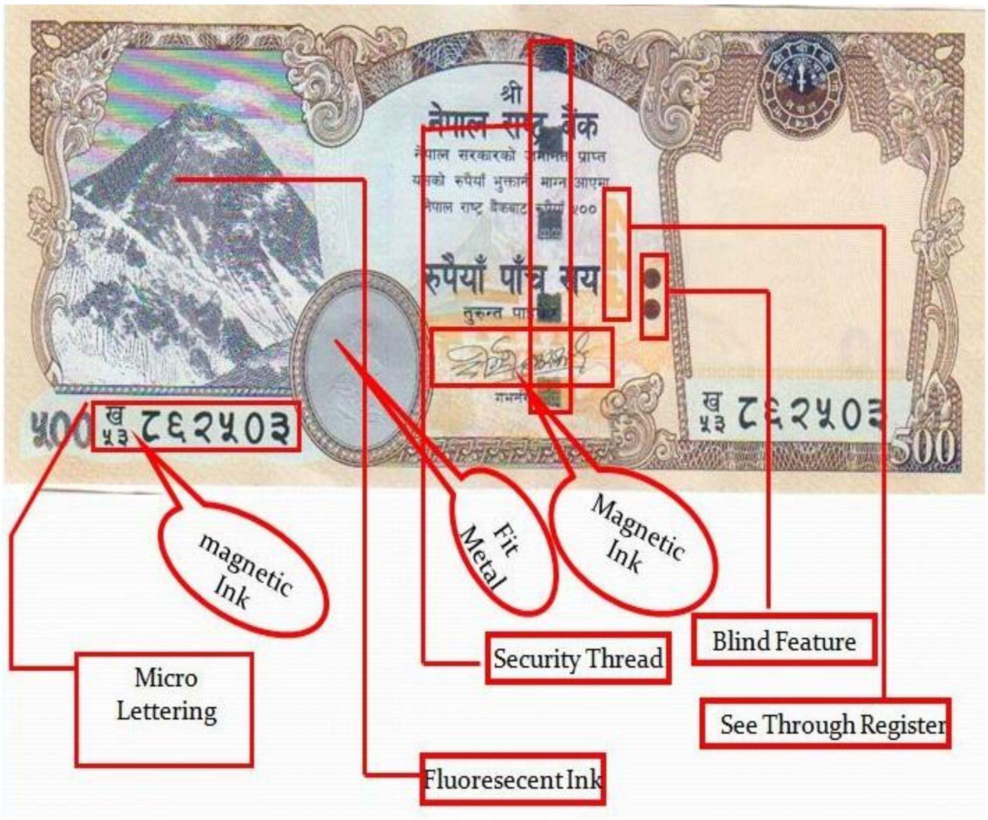


Figure 1.1 Different Security Feature of a Banknote

There are different methods used in detecting counterfeit currency which is described below.

A. Fake Note Detector Machine

Fake Note Detector machine is used mainly in banks, self check out machines, retail stores. It examines the currency that has been inserted and by using various tests, it determines whether currency is counterfeit or not. Common people have facility to find the fake currency using machines available only in banks.

When you place a banknote in this machine, it will scan the ultraviolet properties of the banknote and the magnetic ink present on the banknote. Machine will stop and alert the user when a counterfeit banknote is detected [6].

Features:

- 3-point counterfeit detection: magnetic ink, metal thread and ultraviolet.
- Automatic banknote verification.
- Easy to use.

Limitations:

- Not portable everywhere.
- Detection can be done at certain places like bank and some retail stores

B. Counterfeit Detector Pen

A counterfeit banknote detection pen is a device used to apply an iodine-based ink to banknotes in an attempt to determine their authenticity. Typically, genuine banknotes are printed on paper based on cotton fibers, and do not contain the starches that react with iodine. While detecting a note, pen contains an **iodine solution** that reacts with the starch in wood-based paper to create a black stain. When the solution is applied to the fiber-based paper used in real notes, no discoloration occurs [6].

Features:

- Detect notes printed on normal copier paper instead of the fine papers used by genuine authority.
- Effective against notes printed on standard printer or photocopier paper.

- If the note is real, the ink turns yellow.
- If the note is counterfeit, it will turn a dark blue or black.

Limitations:

- Not applicable for starch free papers.
- Effectiveness is much lower.

C. Counterfeit Money Detector

Counterfeit Money Detector is a mobile based application which allows user to see little marks and other security measures to probe a banknote's authenticity under an Ultraviolet light [6].

Features:

- Provides Watermark detection.
- Provides UV lamp on mobile screen to detect security measures

Limitations:

- User himself has to see marks on banknotes and identify whether it is genuine.
- Knowledge about counterfeit notes is required.

Some of the ill-effects that counterfeit money has on society include a reduction in the value of real money; and increase in prices due to more money getting circulated in the economy- an unauthorized artificial increase in the money supply; a decrease in the acceptability of paper money; and losses, when traders are not reimbursed for counterfeit money detected by banks, even if it is confiscated [7].

Different levels of Counterfeit note production are described below:

- **First Level**

Paper note printed from simple color photocopy machine which can be easily distinguished as fake. They are fade in color with no security features like UV features, micro lettering etc.

- **Second Level**

High level of color photocopy or scan technology is used to produced fake note. Such type of note seems as genuine note at a glance but they also don't have security features that present in genuine note.

- **Third Level**

In this level high level of technology like scanner, offset press and digital printing technology is used. It is dine as like a professional. The color combination of such note seems to be same as that of genuine. They don't have security features like watermark, silver thread, micro letter as of genuine note. Also the paper used on such kind of system is smooth. Paper used on publishing fake note uses smooth high quality photocopy paper.

- **Fourth Level**

In this kind of level, very high level of technology and printing techniques and color technology are used. Original paper which is used by Bank for printing the genuine banknote is used. It includes the watermark and security thread but internal security features are not present. They are somewhat different than genuine banknote.

Techniques used to identify counterfeit note in the context of Nepal

- Genuine banknotes are printed in special kind of paper. By touching fake and real note experience people can find difference quickly. Counterfeit note paper is smooth and weak. Counterfeit note are not as bright as genuine one.
- Watermark and security thread are kept in genuine note in a time of paper production then only printing process takes place. So words in security thread can be easily read and indentify but in counterfeit note words below security thread are covered and cannot be read.
- Watermark present in genuine note is clear in vision but it seems unclear in counterfeit note.
- Sound produced by genuine note is hard and different than that of counterfeit note
- When ultraviolet light is strike on genuine note some security features radiate green light but counterfeit note radiates nothing.

- Security features like see through register is printed straight in forward and backward at the same time in genuine note and when held in light clearly NRB is visible in straight line. While in counterfeit note see through register letter NRB be seen disjoint.
- Ultravoilet light when strike on a Mount Everest template of genuine banknote RS 500 can be observed in Devnagari and in English but it cannot be seen in counterfeit note.
- Magnifying glass is used to see the micro text present in genuine note. Nepal Rastra Bank micro text can be seen clearly in genuine note. Counterfeit note don't have such micro text present in counterfeit note.

In recent years, along with the accelerative developments of world economics incorporation course, start Euro area and the increase if Asia economics, frontier trade and personal intercourse of various countries are frequently increasingly. Travelling people always take many countries are probably interweaved together therefore raises the chances of fraud in carrying fake currency. It is a challenge for conventional paper currency recognition systems and machines is on recognizing counterfeit currencies. It is not enough for practical business. The reason is that in most of bank, especially those internationalized banks, there are large quantities of cash belonging too many different countries need to be process, and it is possible that all of them are real cashes. The method of feature extraction of currency notes is same as extraction of optical character from any document which includes various neural network based algorithms.

The major technique of this system is image analysis and image processing, which are part of cognitive and computer science. Image processing is a signal processing after pre-processing. The output can be either an image or a set of characteristics or parameters related to the image. Actually the image is treated as 2-dimensional signal and applies some standard signal processing techniques with image-processing techniques involved. Image analysis is a means that the meaningful information from an image is extracted mainly from digital images by means of digital image processing techniques. Image analysis tasks can be as simple as reading bar coded tags or as sophisticated as identifying a person from their face.

Table 1.1 Technical Specifications for Rs. 500 Denomination Nepalese Paper Banknote

Denomination	Rs. 500 bank-note
Size	160.00 mm x 70.00 mm
Paper	100% cotton mould-made banknote paper
Gsm	85 – 90 gsm
Mean Double fold	5000 (mdf)
Watermark	national flower rhododendron
Security Thread	4.00 mm wide demetallised window thread with text "NRB…NRB" and inverted.
color	brown.
Lithographic Security Features	Rainbow printing Anti-copier line structure Anti-scanner line structure See-through (front to back perfect register) Visible fluorescence Microtext panel
Intaglio Security Features	• Nepalese text on front side of banknote as per Rs. 500 denomination banknote currently in circulation • Embossed intaglio image of Indra with metallic ink. • Microtext line • Latent image showing "५०० 500" • Blind Recognition Feature with a sign of " ⊘⊘ " in the right hand corner with tactile feature.
Letterpress	• Black magnetic fluorescent serial numbers • Black magnetic fluorescent Governor's Signature • Phosphorescent block on the upper part of the Mount Everest • Black magnetic fluorescent series number on front and back
Varnish Coating	Single varnish coating should be durable protecting against soiling.
Screen Printing	iridescent coating

1.2 Problem Definition

The task of image processing is to identify and separate the important objects in an image from the scene background. Clearly, there are two approaches for this problem, among them first one is to define what is exactly meant with important objects and the second is how the correct object masks should look like. However there are some physical problems.

- Poor quality of image data, especially of color for conventional camera systems.
- A fast detection procedure that determines the true object out of many potential object positions as required for real world applications
- The algorithm designed should avoid resource-intensive techniques to determine result.

1.3 Objectives

- To extract the feature of denomination Nepalese paper banknote based on image processing approach.
- To identify counterfeit paper banknote based on color and texture features.

1.4 Scope and limitations

- Color and textures features are only considered for analysis purpose which is totally software based analysis.
- Ultraviolet features and other hardware features analysis is out of scope of the research of the thesis.

1.5 Applications

Low cost software based approach can be implemented in banking sectors. Users with no technical knowledge can use the system to identify counterfeit notes. Prior knowledge of security features that are inherent in notes is not required. This research is trying to eliminate the hardware intensive detection procedure, which is currently in used. Bank, Hotel, Airlines can use this system efficiently. It tries to assist people to identify counterfeit notes without having basic idea behind detect counterfeit notes.

1.6 Organization of Report

The thesis is developed into six chapters, each of which focuses on one different aspect of the project. The thesis states the various algorithms and a technique used in research, evaluates the performance and provides possible future work.

Chapter2 introduces the relevant research and techniques that had been done previously and briefly discusses the limitations of their research. **Chapter3** presents the Image processing techniques and related theory used in this thesis work. **Chapter4** illustrates the overall process of this thesis discussed in this chapter. **Chapter5** focuses on the simulation results and its analysis. **Chapter 6** focuses on Challenging task, Limitation and future enhancement and Conclusion of the thesis.

Chapter 2: LITERATURE REVIEW

This chapter introduces several related works about paper currency feature extraction done by other people. These people proposed many aspects of technique by using different techniques.

The software detects fake currency by extracting existing features of banknotes such as micro-printing, optically variable ink (OVI), water-mark, iridescent ink, security thread, Contour Analysis, Face Recognition, Canny Edge & Hough transformation algorithm. This paper also focuses on the pros and cons of implementation details that may degrade the performance of image processing based paper currency authentication systems [1]. The process of identification is done by comparing the original images of money that will be tested with reference of original currency paper image that has been extracted and capture its characteristics and with the help of canny operator to make edge detection where the previously existing image has to be pre-processing, including extraction characteristics [2] [3].

The Markov chain concept has been employed to model the texture of paper currencies as a random process. The method proposed in this paper can be used for recognizing paper currencies from different countries. The features employed in this paper are independent of the way that a paper currency is placed in front of the sensor. To improve the accuracy of the proposed method in recognizing dirty banknotes, it is necessary to pass the paper currency through a filter in order to reduce the effect of dirt by improving the lightness of the image. Also, to reduce the effect of dirt on the image a linear transform function could be very helpful. The performance results of applying the proposed methods on banknote denominations of 23 different countries indicate that the technique has 95% accuracy [4].

An image analysis based pattern classification method is proposed to authentic the printing process used in printing different texts on currency notes. Features suitable for doing this are selected and then studied to detect fraudulent samples based on the printing method. This classification is done by using Support Vector Machines and Neural Nets. The discriminatory power of the selected features in authenticating the printing process is tested using the Linear Discriminate Analysis. Experimental results show that the proposed framework provides a highly accurate framework for authenticating the printing process in bank notes [5].

This paper is focusing on an advanced mobile based application that is used to identify fake money. The application is an online application. Thus, it requires continuous Internet connection for its execution. For using this application, user need to take a photograph of the required note holding it against sufficient light. Then the software examines the note and gives the appropriate result to the user about the authenticity of the note. This application has mainly Watermark Detection, Security Thread Detection, checking currency series number, identification mark and sees through register mechanism which actually detects the trueness of the currency.[6].

It has reviewed different fake currency detection systems. Commonly Used Methods to Detect Fake Currency are See through Register, Water marking, Fluorescence, Security Thread, Intaglio Printing, Latent image, Micro lettering, Identification Mark, Optically Variable Ink. Digital Image Processing method, MATLAB techniques, Counterfeit Detection Pen, Ultraviolet counterfeit detection scanner have been used for fake currency detection [7].

This paper presents the novel method for detection of the counterfeit Indian Paper Currency. The proposed approach works with all the types of denominations of Indian paper currency. The system relies on a specific feature of the Indian Bank Notes and relied feature is not possible to replicate for the counterfeit makers or producers. And there is no chance that they would be capable to imitate this feature even within a pretty long time. The recognition system is composed of two parts. The captured image is first preprocessed by reducing data size and extracting its features by using image processing toolbox in MATLAB. The feature extraction is finished by considering HSV (Hue Saturation Value). The second step is recognition, in which the core is neural network classifier [8].

Watermark containing the portrait of Bangabandhu Sheikh Muzibur Rahman (Father of the Nation) is chosen to perform face detection and recognition using Principal Component Analysis [1]. Principal components of currency features are extracted and weight vector is computed for the same. The weight vector similarities are then computed using Mahalanobis distance measure. For prediction the image having least distance measure with a class is determined [9].

Challenge in content based color image retrieval system lies in assigning synthetic descriptor to the image features which are economic in terms of memory required and time taken to compare query image features with features of image from database. Texture is a very important feature of an image. Lots of mathematical model have been presented earlier, which describes the textural feature of the images, but most of them are textural features of gray scale images. If the same method tried to extend for color images the time and space parameter surpass the practical boundaries [11].

Chapter 3: RELATED THEORY

3.1 Histogram Analysis

Intensity transformation functions based on information extracted from image intensity histograms play a central role in image processing, in areas such as enhancement, compression, segmentation, and description. The focus of this section is on obtaining, plotting, and using histograms for image enhancement.

Generating and Plotting Image Histograms

The histogram of a digital image with L total possible intensity levels in the range [0, G] is defined as the discrete function

$$h(r_k) = n_k \qquad (3.1)$$

Where r_k the kth intensity level is in the interval [0, G] and n is the number of pixels in the image whose intensity level is r_k. The value of G is 255 for given images. Sometimes it is necessary to work with normalized histograms, obtained simply by dividing all elements of n_k by the total number of pixels in the image, which we denote by n.

$$p(r_k) = \frac{n_k}{n} \qquad (3.2)$$

Where, for integer images, k= 0, 1, 2…L-1. From basic probability, we recognize $p(r_k)$ as an estimate of the probability of occurrence of intensity level r [10].

3.2 Gaussian Filter

Gaussian filtering is used to blur images and remove noise and detail. In one dimension, the Gaussian function is:

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{x^2 / 2\sigma^2} \qquad (3.3)$$

Where ‘σ’ is the standard deviation. Distribution assumed to have a mean zero.

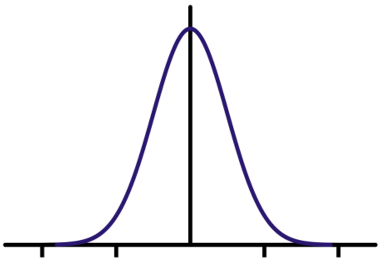


Figure 3.1 Gaussian Curve for Image smoothing

When working with images we need to use the two dimensional Gaussian function. This is simply the product of two 1D Gaussian functions (one for each direction) and is given by:

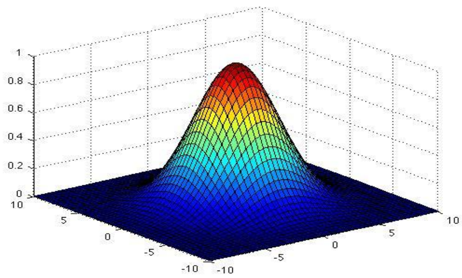


Figure 3.2 Gaussian Curve in 2D

$$G(x) = \frac{1}{2\pi\sigma^2} e^{x^2+y^2 / 2\sigma^2} \quad \text{..} \quad (3.4)$$

3.3 Skewness

Skewness refers to asymmetry of the distribution. A distribution with an asymmetric tail extending out to the right is referred to as “positively skewed” or “skewed to the right,” while a distribution with an asymmetric tail extending out to the left is referred to as “negatively skewed” or “skewed to the left.” Skewness can range from minus infinity to positive infinity.

$$sk = \frac{\mu - \text{mode}}{\sigma} \quad \text{.......... (3.8)}$$

Population modes are not well estimated from sample modes, but one can estimate the difference between the mean and the mode as being three times the difference between the mean and the median, leading to the following estimate of skewness:

$$sk_{est} = \frac{3(M - \text{median})}{s} \quad \text{.......... (3.9)}$$

Many statisticians use this measure but with the ‘3’ eliminated, that is,

$$sk = \frac{(M - \text{median})}{s} \quad \text{.......... (3.10)}$$

This statistic ranges from -1 to +1. Absolute values above 0.2 indicate great skewness.

Skewness has also been defined with respect to the third moment about the mean:

$$\gamma_1 = \frac{\sum (Y - \mu)^3}{n\sigma^3} \quad \text{.......... (3.11)}$$

This is simply expected value of the distribution of cubed z scores. Skewness measured in this way is sometimes referred to as “Fisher’s skewness.” When the deviations from the mean are greater in one direction than in the other direction, this statistic will deviate from zero in the direction of the larger deviations.

3.4 Entropy

Information gained upon learning event of probability p occurred = $\log_2 1/p$bits. A useful and common way to model this uncertainty is to assume that the data is coming randomly according to some probability distribution. The simplest model is to assume that each the symbols s1,.....,sM have associated probabilities of occurrence p1,...,pM, and we see a string of symbols drawn independently according to these probabilities. Since the pi are probabilities, we have $0 \leq pi \leq 1$ for all i. Also, we assume the only possible symbols in use are the s1,...,sM, and so p1 +⋯+pM = 1. How much information does a source provide? Consider just one symbol from the source. The probability that we observe the symbol si is pi, so that if we do indeed observe si then we get log2 1 pi bits of information. Therefore, the average number of bits of information is get based on observing one symbol is:

$$p1 \log_2 \frac{1}{p1} + \cdots \; p_m \; \log_2 1/pm = \sum_{i=1}^{m} pi \log_2 1/pi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

This is an important quantity called the entropy of the source and is denoted by H. Note that the entropy H should not be confused with the frequency response of a system H(ω). These two areas developed somewhat independently and the use of H(·) for frequency response is very common and the use of H for entropy in information theory is universal.

Given a source that outputs symbols s1,...,sM with probabilities p1,...,pM, respectively, the entropy of the source, denoted H, is defined as

$$H = \sum_{i=1}^{m} pi \log_2 1/pi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.13)$$

The importance of the entropy of a source lies in its operational significance concerning coding the source. Since H represents the average number of bits of information per symbol from the source.

3.5 Correlation

The matching process moves the template image to all possible positions in a larger source image and computes a numerical index that indicates how well the template matches the image in that position. Match is done on a pixel-by-pixel basis

- ***Correlation*** is a measure of the degree to which two variables agree, not necessary in actual value but in general behavior.
- The two variables are the corresponding pixel values in two images, template and source.

$$cor = \frac{\sum_{i=0}^{N-1}(x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=0}^{N-1}(x_i - \bar{x})^2 \cdot \sum_{i=0}^{N-1}(y_i - \bar{y})^2}} \quad (3.14)$$

x_i Is the template gray level image

$\bar{x}$ Is the average grey level in the template image

y_i Is the source image section

$\bar{y}$ Is the average grey level in the source image

N is the number of pixels in the section image

(N= template image size = columns * rows)

The value *cor* is between –1 and +1, with larger values representing a stronger relationship between the two images.

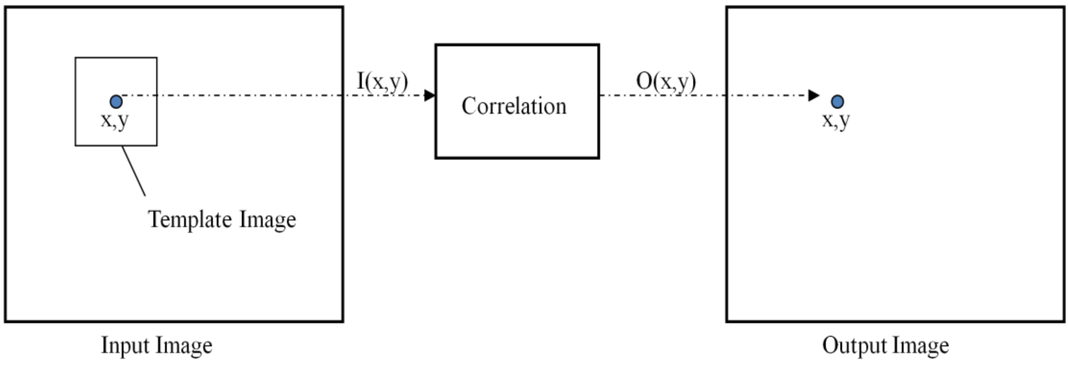


Figure 3.3 Correlation of a Template with an image

3.6 Color and Texture

Challenge in content based color image retrieval system lies in assigning synthetic descriptor to the image features which are economic in terms of memory required and time taken to compare query image features with features of image from database. Texture is a very important feature of an image. Lots of mathematical model have been presented earlier, which describes the textural feature of the images, but most of them are textural features of gray scale images. If the same method tried to extend for color images the time and space parameter surpass the practical boundaries. The solution to this is to convert the color images to gray scales and then extract the textures, but the importance of color features in similarity measurement by a human observer cannot be over looked. So, either a new mathematical model is required to represent the color texture features or during comparison, combine the texture property and color property extracted separately. The work presented here extracts the color feature by quantizing it in color and pixel space, then finding the color dominance locally and globally. The texture feature are extracted using co-occurrence matrix method first, with a liberal value threshold the image names with similar texture are retrieve from the texture database and then as a second level of filtering, color feature is combined with texture feature and similar image are displayed.

The feature extraction system consists of two stages; region extraction and feature extraction. The goal of region extraction is to automatically identify the prominent regions in the images. The basic idea is that the feature sets onto the image. In the application of content-based query for image databases, prominent color and texture regions are extracted and indexed for fast querying [11], [12].

Chapter 4: METHODOLOGY

4.1 Research Methodology

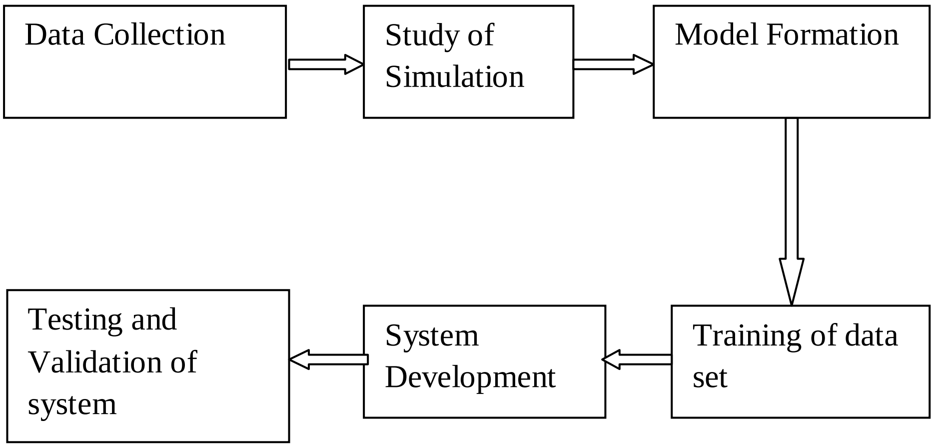


Figure 4.1 Block Diagram of Research Methodology

There are different steps in research, which are described as follows.

- **Data Collection**

  Real and fake note samples are acquired from bank. Samples are scanned at 400 dpi for experimental purpose. Those samples of real and fake notes are stored in database.

- **Study of Simulation**

  Different simulation techniques are prevailing in research field. Opencv, Python, Matlab are some Simulating tools. Among those tools matlab is mostly used because it contains large sets of tool box. Image processing tool box is used in this research study.

- **Model formation**

  Matlab simulator is chosen for model formation and as simulator. Top to bottom program is coded. A working model is formed which takes input and provides an output.

- **Training of data set**

  Fake samples dataset and real samples dataset are tested in model that previously developed. For training purposes typical samples from datasets are taken and tested.

- **System Development**

  System development is performed by analyzing the value that is obtained while testing a datasets. Simulating parameters are changed according to final system development.

- **Testing and validation of system**

  System development is followed by testing and validation. Database that is previously formed are tested in final system. Based on testing and validation system accuracy and performance are calculated.

4.2 Block Diagram

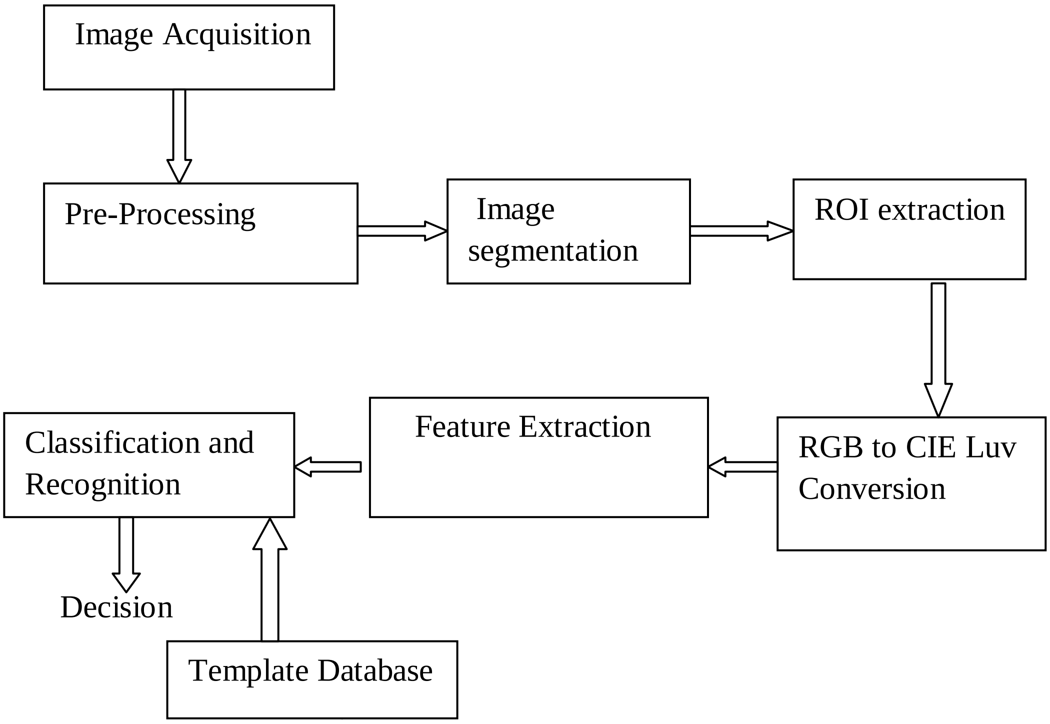


Figure 4.2 Basic Block Diagram of Proposed Work

This thesis report is composed of three phases. The first phase deals with image processing, the second phase deals with feature extraction and the third phase deals with classification of the detected image.

Automatic recognition of fake currency has been a challenging research area. A robust method that is more economically efficient and practically flexible for automatic fake currency inspections are required. Due to great technological advancement counterfeiting problems have become more and more serious. Therefore the issue of efficiently distinguishing counterfeit banknotes from genuine ones via automatic machines has become more and more important. The fake currency detection system is developed to detect the fake currency by applying different techniques and methods on currency note. The fake currency detection system should be able to recognize the note quickly and correctly.

Step 1: Image Acquisition

The image database considered in this chapter is composed of digital images taken by digital scanner. The image we get from camera or scanner is formatted by JPEG or BMP. JPEG (Joint Photographic Experts Group) is a standard for destructive or loss compromising for digital images.

In this thesis, two input images were used the first image is original image of the paper currency and in this case is Rs 500 a Nepalese currency which is often to be counterfeited. The first image is used as a reference currency note, and the second is the test image and is also the currency that to be verified by the system. The main focus is to verify and check its color and texture. It is known to determine the authenticity of a paper currency several ways can be used, such as by looking at the presence or absence of a security thread, the presence of water marks, color difference and the texture difference. With the human eye view, we can distinguish authentic bills with counterfeit banknotes in a way be seen, touched and keep seeing it.

Step 2: Pre-Processing

The aim of pre-processing in currency image inspection is to suppress the unwanted information from the image data and enhance the desired image features important for further processing. Pre-processing is an important step in the sense that, with an effective process, much of the subsequent analysis is simplified. Due to non-uniform lighting, the contrast between currency and background is often very low. In addition, the image is often corrupted with noise and undesired features. Therefore, an image enhancement method capable of removing non-uniform background illumination effects and noises is required. Smoothing filtering is one of the most commonly used techniques for noise removal. Gaussian filter is an efficient filter for smoothing of an image since it don't give ringing effect which is quiet useful in further analysis process.

Step 3: Image Segmentation

Image segmentation sub divides the image into its constituent regions or objects. The level to which sub division is carried depends on the problem being solved. Segmentation algorithm for monochrome images generally are based on one of the two basic properties of image intensity values- Discontinuity and Similarity. In the first category, the approach is to partition an image based on abrupt changes in intensity such as edges in an image. The approach in the second category is based on partitioning an image into regions that are similar according to a set of predefined criteria. Currency note segmentation is done by applying scan line algorithm on the image after edge detection. The line that contains the number of pixels greater than the set threshold is highlighted (marked). As a final point, there is a distinct area produced by the intersection of both the scans. It is in the form of a rectangle which surrounds the currency note present in the image. This forms the localized part of the image. These features present in the currency notes have not changed over a long period of time and continues to be like this only for a foreseeable future. CIE Luv model is one of several color systems used by people to select colors from a color wheel or palette. This color model is considerably closer than the RGB model in the way how humans experience and describe color sensations.

Step 4: Region of Interest Extraction

Image acquisition and image pre-processing techniques are employed; either the entire note or distinct Regions of Interest (ROI) are acquired and compared independently. After segmentation of an image analysis of required region of interest is a crucial part of processing. Among different image segment part, Mount Everest template has been selected as a region of interest.

Step 6: RGB to CIE Luv Conversion

A color can be described as a mixture of three other colors or "Tristimuli". Typically RGB for CRT based systems (TV, computer) or XYZ (fundamental measurements). However, it is frequently useful to separate the color definition into "luminance" and "chromaticity". It is a linear color space, but the conversions are reversible. Coloring information is centred on the color of the white point of the system, subscript n, (D65 in most TV systems).

Step 7: Feature extraction of image

Feature extraction is the special form of dimensionality reduction. It is the method of capturing the visual content of images for indexing and retrieval. When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant then the input data is transformed into a reduced representation set of features. If the attributes extracted are carefully chosen, it is expected that the attributes set extracted the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input. Feature extraction involves simplifying the amount of resources required to describe the large set of data.

Color features mean, standard deviation, variance and skew are calculated from the input template image which is the ROI. Similarly texture features entropy, correlation of an image is calculated which are further used in classification of image. For correlation input segmented image which is in RGB form, is compared with the database images and result of maximum correlation is display based on which further analysis is obtained.

Step 8: Classification of Image

Mean, standard deviation and skew which are the color feature of an input template image also entropy and correlation which are the texture feature are compared with the value of database image. It is like a key point matching since the key features of an input template image is matched with the key points of desired image. Key points from the detected image will be matched with the trained database image's keypoints, Based on the matching score of the input image keypoints and that from database template. Image thus input is classified as a fake or genuine. Extracted features of test currency image are compared with the extracted features of original currency image, if it matches then the currency is original otherwise fake.

Template matching

- Technique used in classifying objects.
- Template matching techniques compare portions of images against one another.
- Sample image may be used to recognize similar objects in source image.

Templates are most often used to identify printed characters, numbers, and other small, simple objects. Currency identification is the measurement of similarity or dissimilarity based on comparisons between suspect note and sample note. When a note in question does not meet the required threshold, it is not authentic.

4.2 Proposed Method: Counterfeit Banknote Identification

Input: Test image and currency Database

Output: Identification of Banknotes

Procedure:

Step 1: Image acquisition

Step 2: Image Segmentation

Step 3: Feature extraction from ROI of an image

Step 4: Classify the input image for identification

Step 5: Output

4.3 Software Required

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

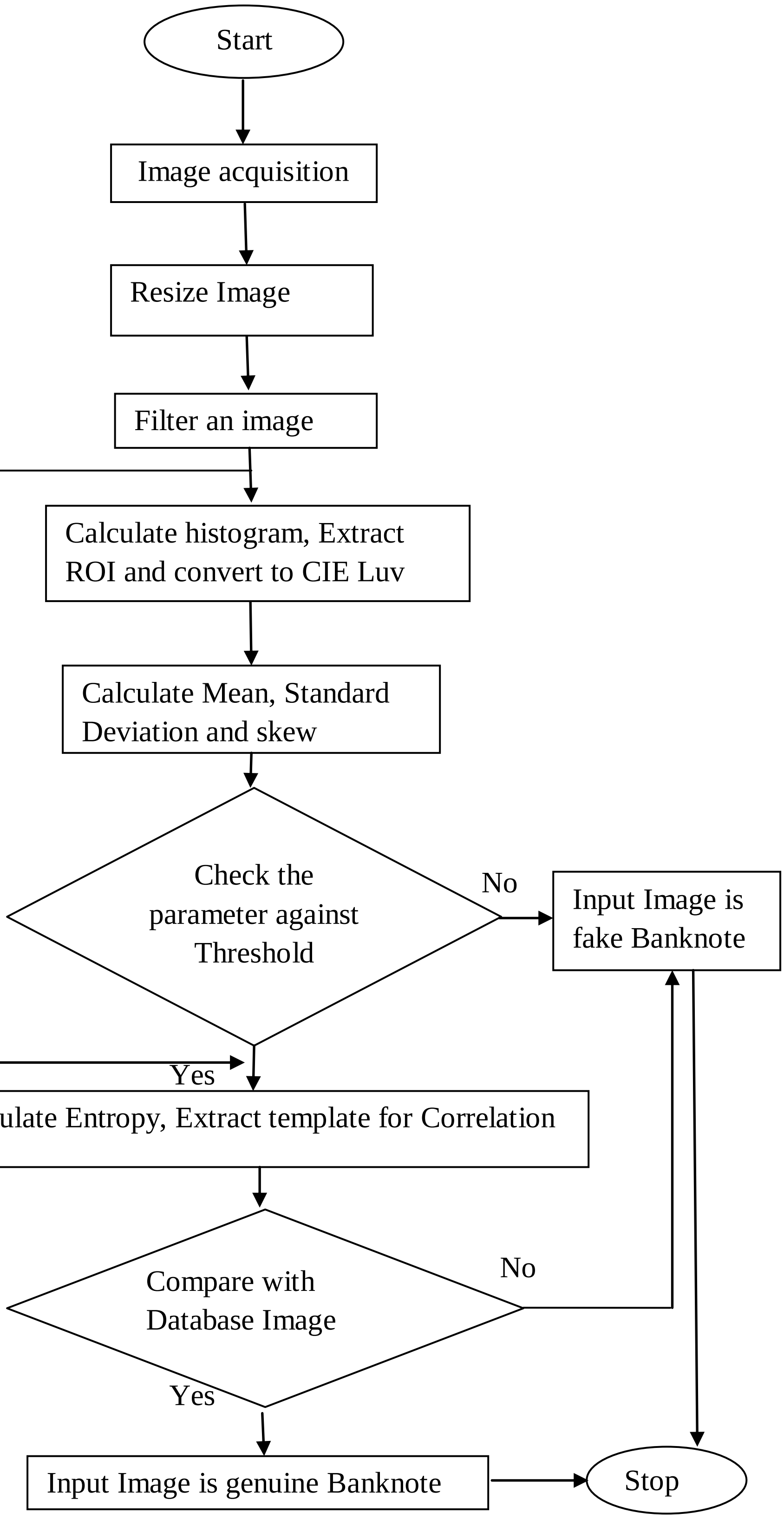


Figure 4.2 Flowchart of Proposed Method

4.4 Experimental Design

Magnified scan digitized images of genuine and fake currency notes (Nepalese rupees of denomination 500) are collected. For considering study, 200 genuine samples and another 40 samples of fake currency note images are considered. Resolution is 400 dpi and Images used are of jpeg types. Bank notes used here are with no marks and writing in ROI. Banknotes of real and fake samples are scanned. ROI used for calculation are free of marks and handwriting. Effects of such marking are discussed in the report.

There are different printing techniques used in real notes. Technologies used for printing fake notes are different than that of real notes. However, the printing technique that is hard to replicate because some of its inherent characteristics. There are numerous printing processes like offset, dry offset, intaglio, letterpress, serigraphy, screen printing, inkjet, bubble-jet, digital printing, etc. that can be used for printing currency notes. Out of these many possibilities, only a few processes are normally used in practice.

Database of fake notes consist of different quality. Such samples are not generated from same source. Color to print those samples are different, it indicate that sources are different. Database of real samples are originated from same source. So printing techniques and paper quality used to print those notes are similar and don’t change randomly. Those different in printing techniques and paper quality can be used to detect counterfeit notes.

Chapter 5: SIMULATION RESULTS AND ANALYSIS

5.1 Histogram Analysis

Figure 5.1, the first figure is Fake input sample taken and corresponding below figure is showing its RGB color histogram of a template of above sample image. A color histogram is a representation of the distribution of colors in an image. The color histogram can be built for any kind of color space, although the term is more often used for three-dimensional spaces like RGB or HSV. For monochromatic images, the term intensity histogram may be used instead. For multi-spectral images, where each pixel is represented by an arbitrary number of measurements, the color histogram is N-dimensional with N being the number of measurements taken. Each measurement has its own wavelength range of the light spectrum, some of which may be outside the visible spectrum. If the set of possible color values is sufficiently small, each of those colors may be placed on a range by itself; then the histogram is merely the count of pixels that have each possible color. Most often, the space is divided into an appropriate number of ranges, often arranged as a regular grid, each containing many similar color values.

Color histograms are flexible constructs that can be built from images in various color spaces, whether RGB**,** chromaticity or any other color space of any dimension. A histogram of an image is produced first by discretization of the colors in the image into a number of bins, and counting the number of image pixels in each bin. For example, a Red–Blue chromaticity histogram can be formed by first normalizing color pixel values by dividing RGB values by R+G+B, then quantizing the normalized R and B coordinates into N bins.

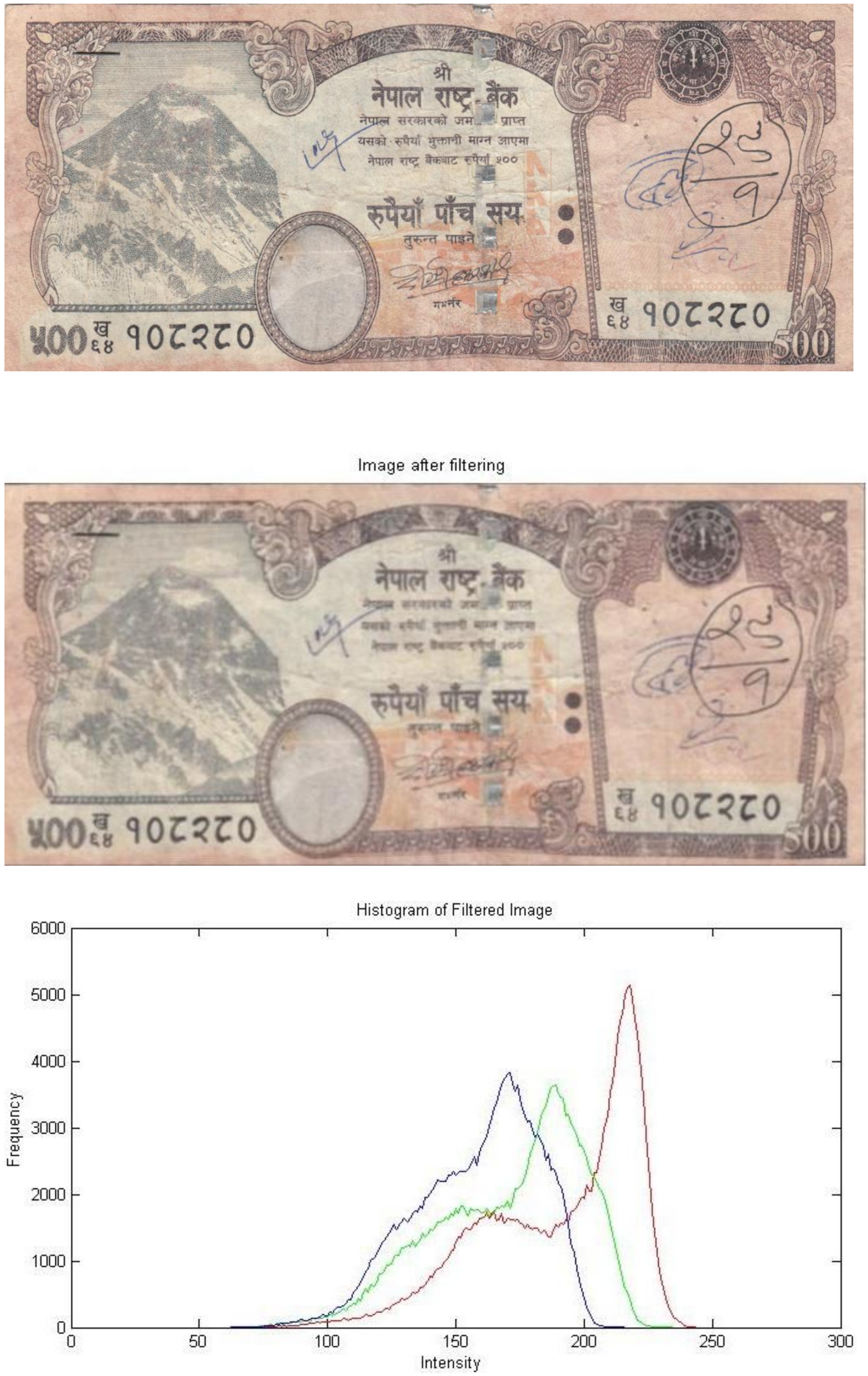


Figure 5.1 Fake Sample and filtered image with its Histogram plot

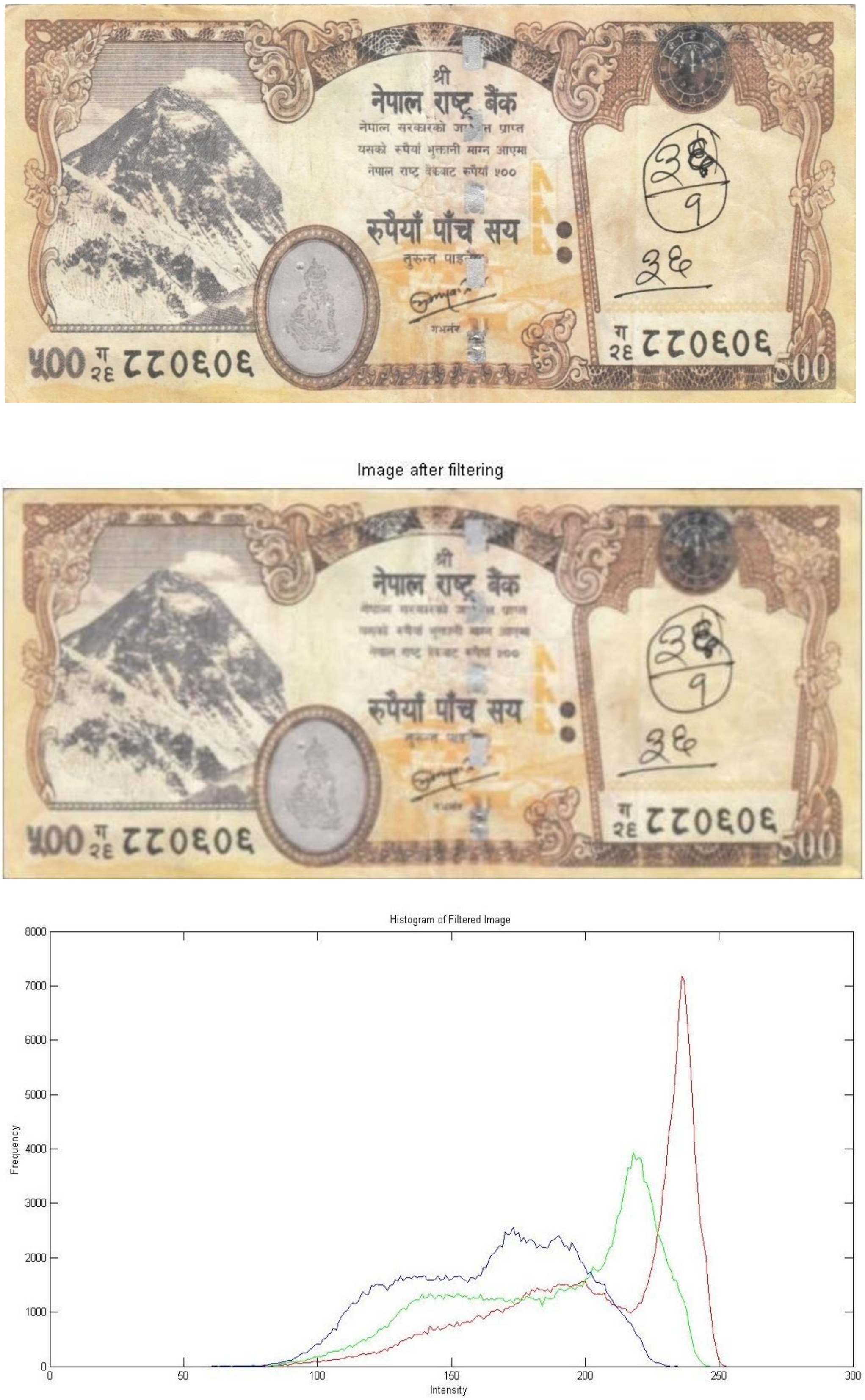


Figure 5.2 Fake Sample and filtered image with its Histogram plot

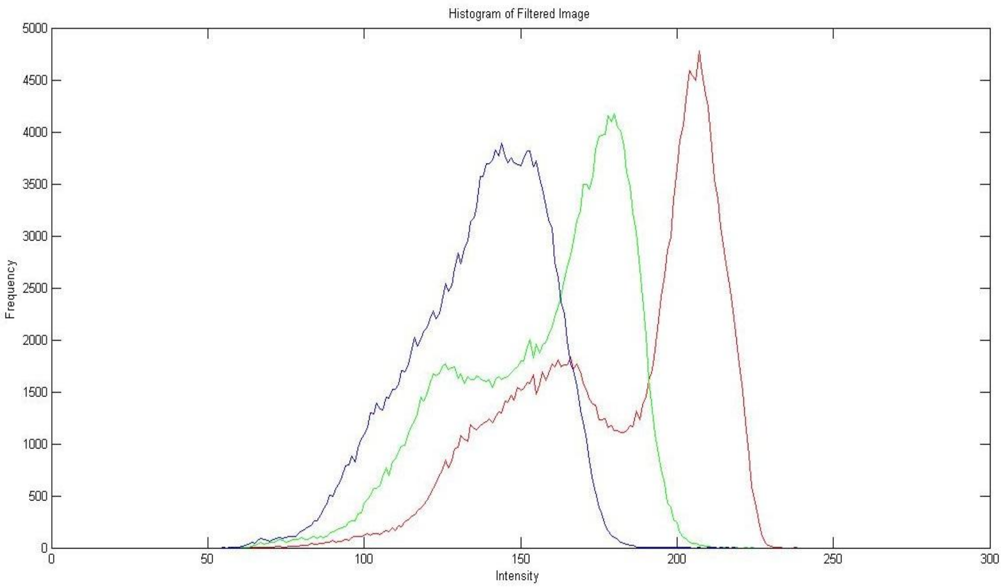


Figure 5.3 Genuine Sample and filtered image with its Histogram plot

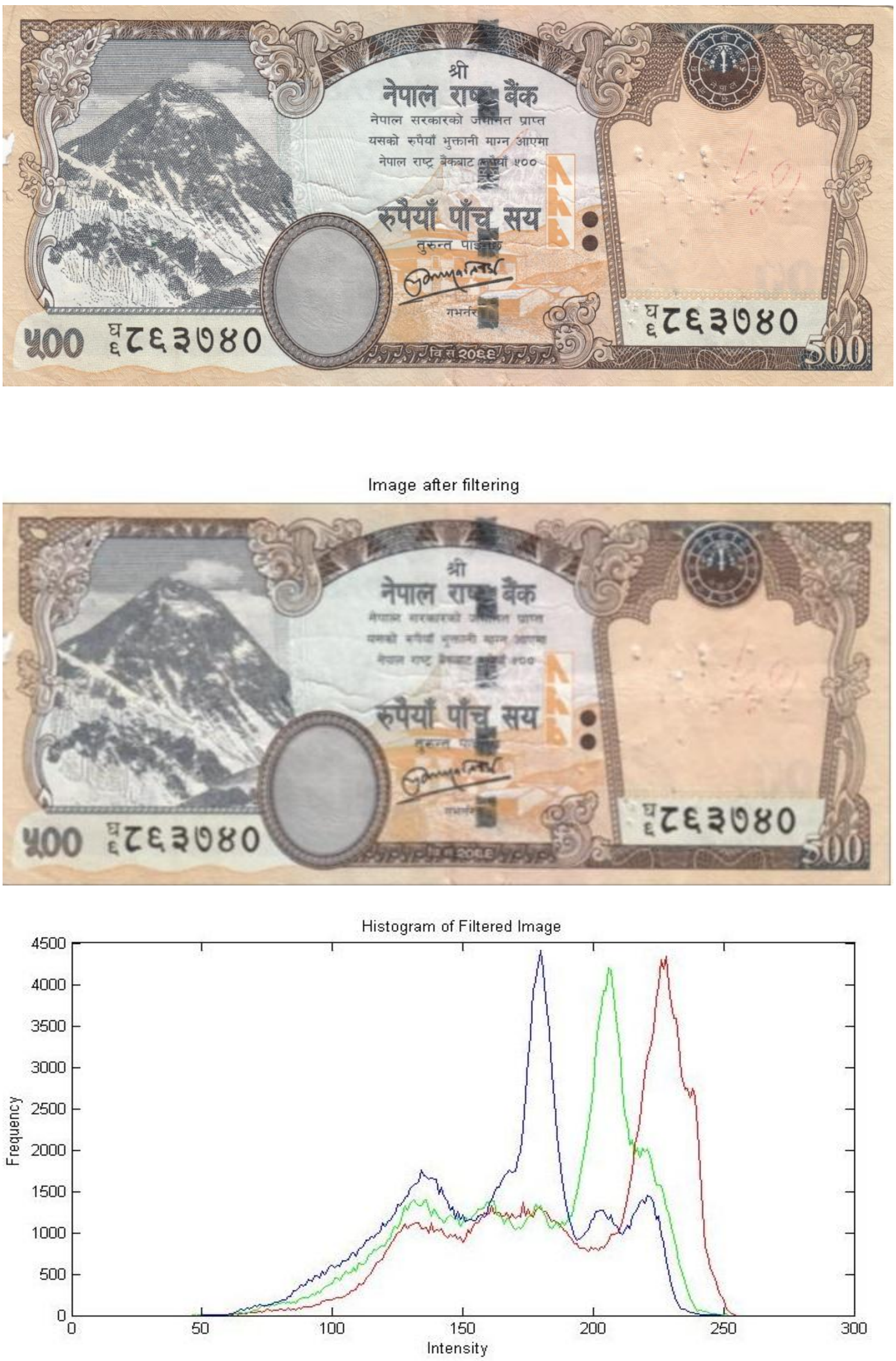


Figure 5.4 Genuine Sample and filtered image with its Histogram plot

X-axis represented the intensity value whereas is Y-axis represented the frequency of intensity occurring on image. Here, the histogram analysis shows that the image print quality and also depends on intensity of light as there is a different intensity level at different time. From above histogram showing in figure 5.1, it is clear that it can go for further processing. Similarly figure 5.3 and 5.4 shows genuine sample and its corresponding histogram.

5.2 Color Features Analysis

5.2.1 Skew Calculation

Skew of a template image which is converted to CIE Luv is calculated. Skew is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point.

(a) (b)

Figure 5.5 Fake sample template and it’s CIE Luv color space

(a) (b)

Figure 5.6 Real sample template and it’s CIE Luv color space

The skew for a normal distribution is zero, and any symmetric data should have a skew near zero. Negative values for the skew indicate data that are skewed left and positive values for the skew indicate data that are skewed right. By skewed left, it means that the left tail is long relative to the right tail. Skew of Luv color space is calculated because it tells about the presence of luminance and chromaticity. Value represents the amount lightness present in an image.

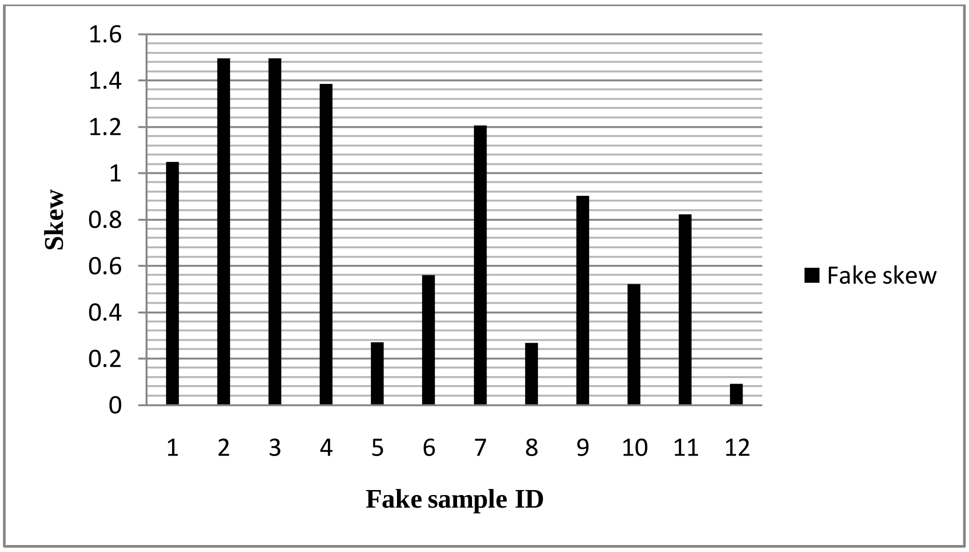


Figure 5.7 Graph of Skew of different fake samples

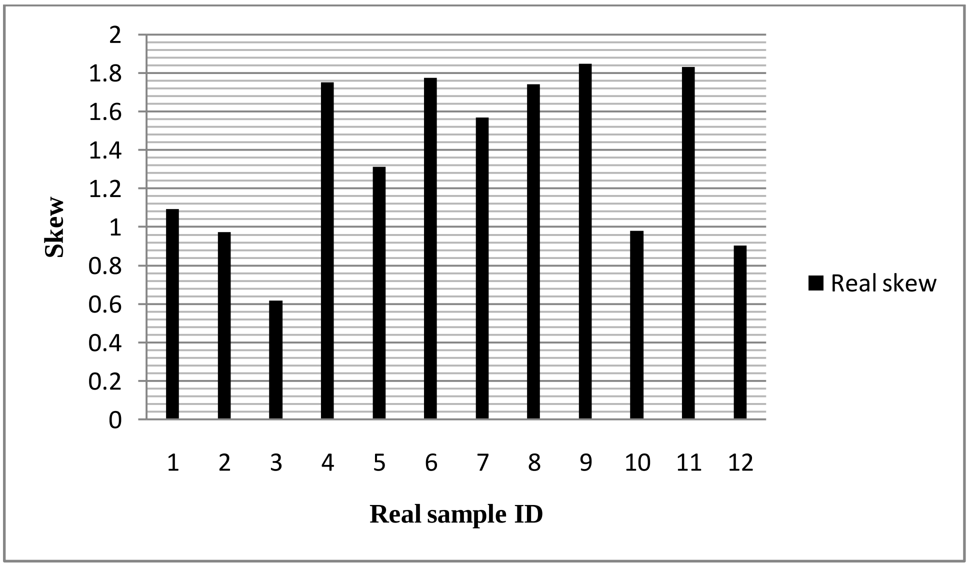


Figure 5.8 Graph of Skew of different fake samples

Skew of real notes on average are higher than that of fake note. It is useful for further analysis of an image. Skew can play an important role in classification of currency. Threshold value is defined for classification of an image using skew. Figure 5.5 and figure 5.6 show the conversion of RGB images to Luv color space. Figure 5.7 and figure 5.8 show the graph of skew value calculated of fake and real samples respectively.

5.2.2 Mean and Standard Deviation Calculation

Mean and Standard Deviation of a template image is calculated. As the image is converted to CIE Luv plane and Mean and Standard Deviation of Luv plane is calculated. Fake banknotes may sometime appear same as genuine notes in color but by computing the average color from the image, we may be able to decide whether they are actually printed by using the same technique. RMS contrast of a template image extracted from a banknote. The RMS contrast does not depend on the spatial frequency content or the spatial distribution of intensity in the image. It is defined as the standard deviation of the pixel. Overall contrast of fake currency banknotes are less than that of real banknotes. It is because of the printing technique used in real notes. Color combinations are also in a predefined way. Paper used to print the real notes is used of cotton. Fake notes used the high quality paper and combination of color is not considered.

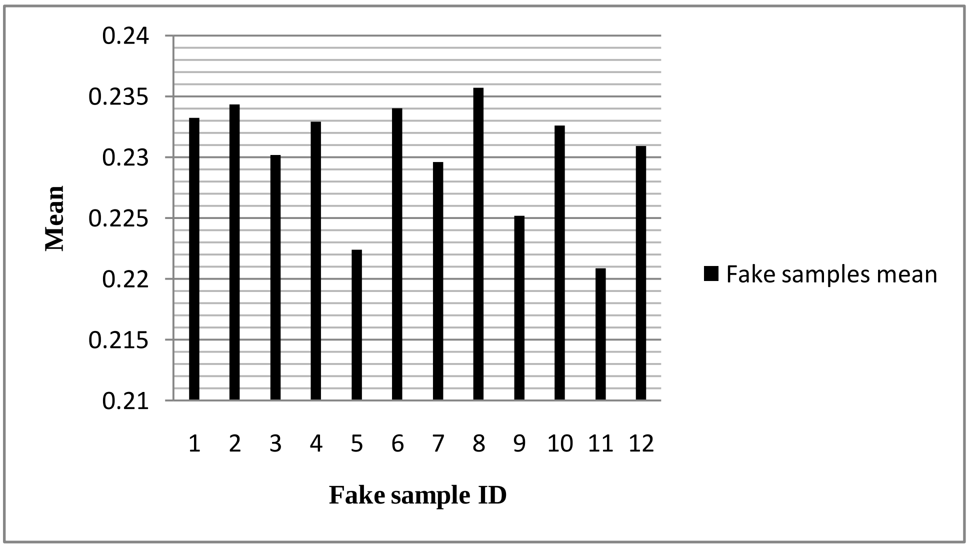


Figure 5.9 Graph of mean of fake note samples

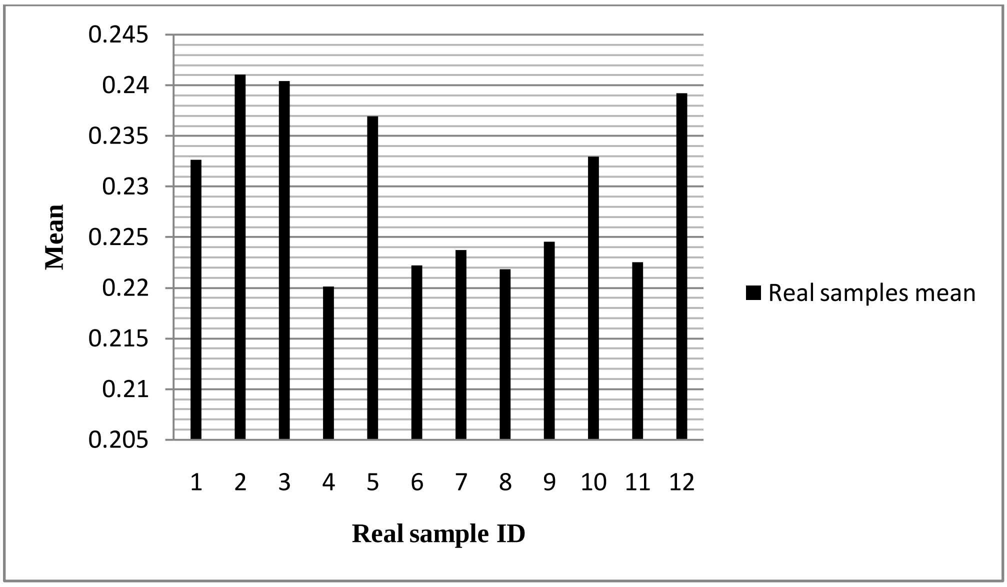


Figure 5.10 Graph of mean of real note samples

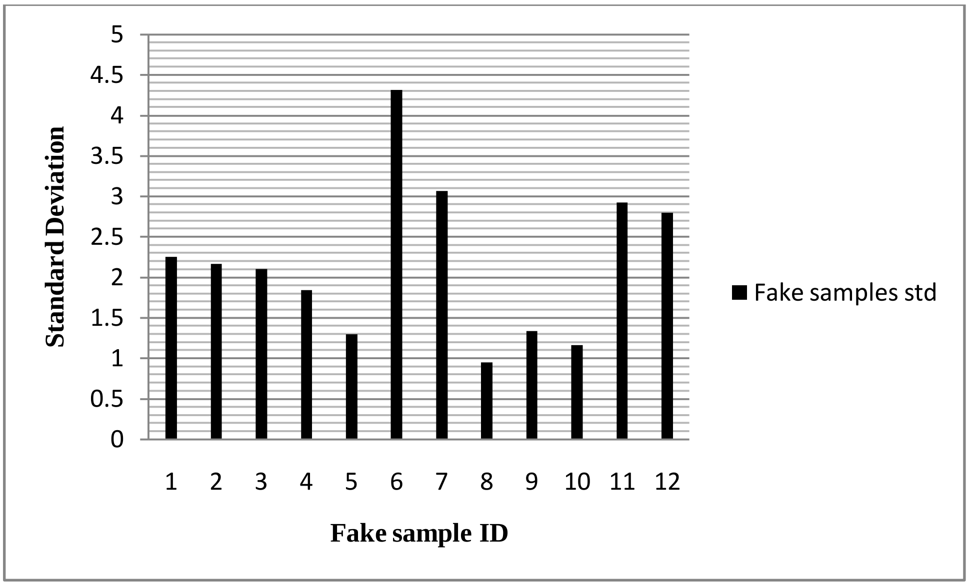


Figure 5.11 Graph of standard deviation of fake note samples

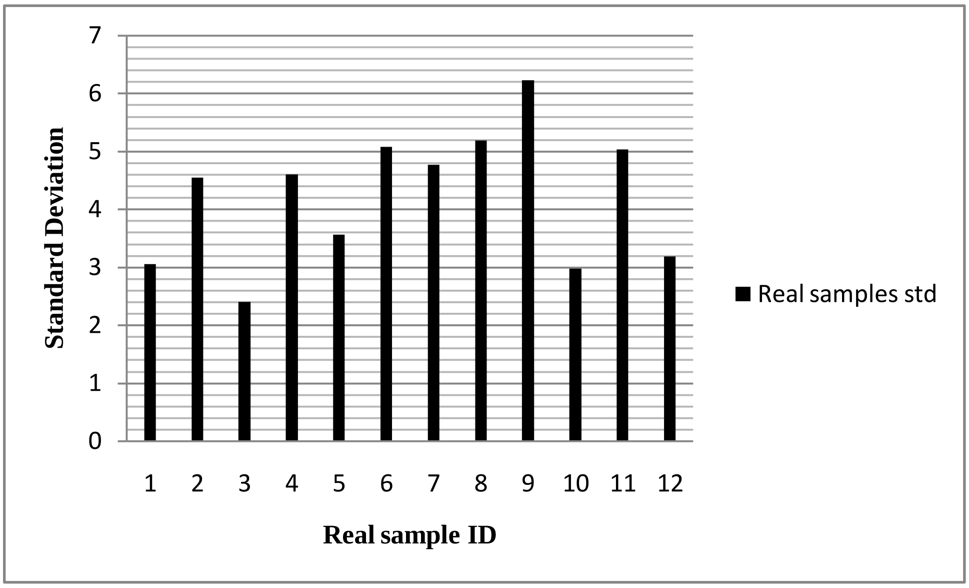


Figure 5.12 Graph of standard deviation of real note samples

Figure 5.9 and figure 5.10 show mean value of fake and real samples respectively. That gives average color information, which is also called mean of image, is almost equal of real and fake notes. Figure 5.11 and figure 5.12 show standard deviation of fake and real samples respectively. Root mean square Contrast which is also called standard deviation is greater in value of real notes than fake notes samples. It is because amount of a particular color used for printing is different for different printing processes. Combinations of color in printing real notes are defined and don't vary from one note to next for particular denomination. Standard deviation of a template is in the range of value xe-04 (where x is value) which is very small quantity since template sample is very small compared to image.

5.3 Texture Features Analysis

Texture is a very useful feature for Currency recognition. Textural features corresponding to human visual perception are very useful for optimum feature selection and texture analyzer design. There are some set of texture features that have been used quite frequently for image retrieval. Mostly used parameter for texture analysis is correlation, homogeneity, entropy and GLCM. Entropy and correlation are used in this thesis for analysis of texture features of an image.

5.3.1 Entropy Calculation

Entropy of a template image of different samples of real and fake are calculateshown in graph. Entropy of different color channel red, green, blue of a template image is presented in graph.

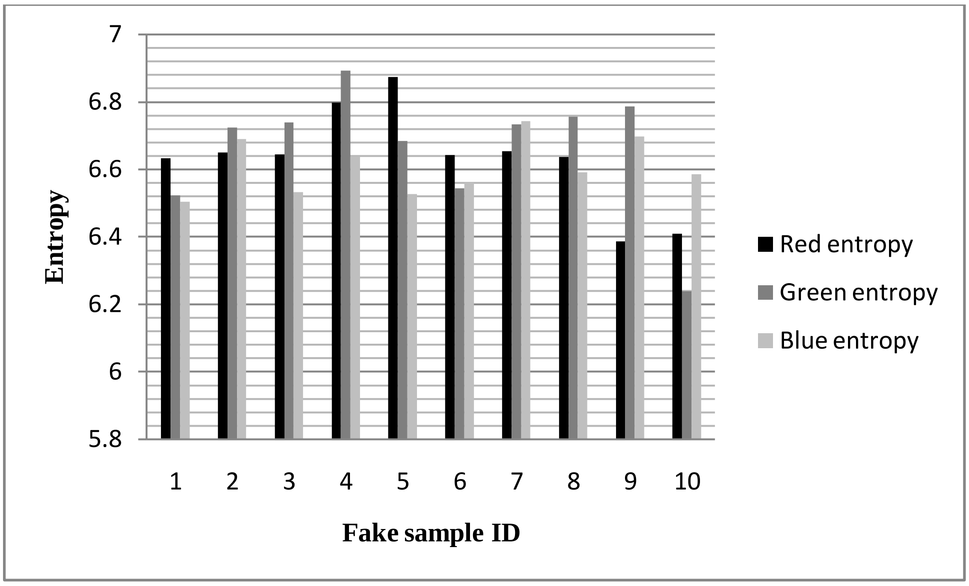


Figure 5.13 Graph of entropy of fake note samples

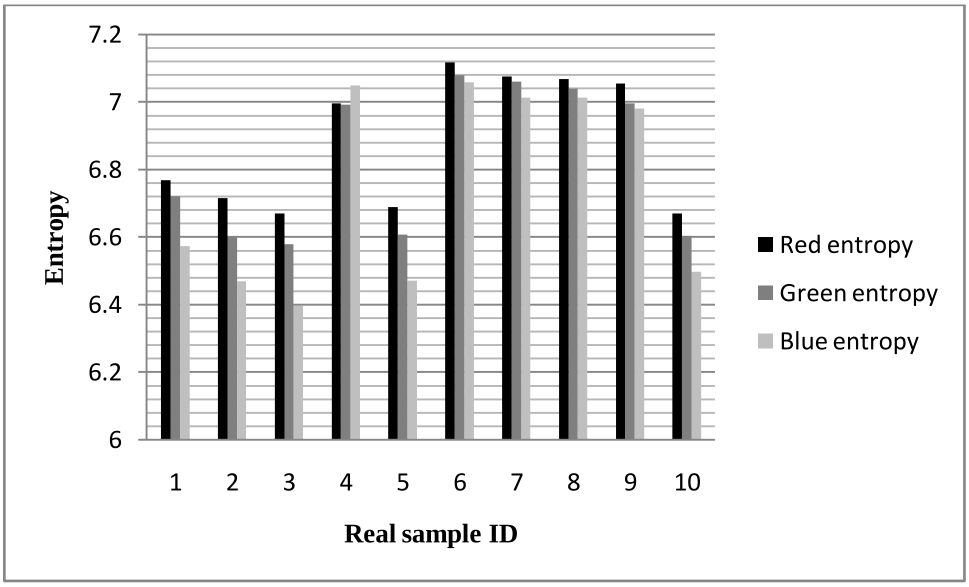


Figure 5.14 Graph of entropy of real note samples

Figure 5.13 and 5.14 show entropy of fake and real note samples respectively. It gives the amount of information contained by red channel is highest, green are in middle and average amount of information carried by blue channel is least in real note. Whereas in fake note amount of information carried by different channel are random which don't follow any significant pattern. In the above run six fake and five real samples are used in an experiment.

Texture is a very important feature of an image. Lots of mathematical model have been presented earlier, which describes the textural feature of the images, but most of them are textural features of gray scale images. But in this analysis color image is used for texture feature extraction. Among different region of interest Mount Everest template on the left top corner of an image is used for texture feature calculation because the intensity variation at that region is good for analysis of textural feature of an image. The data extracted from that region contribute in classification purpose very efficiently.

5.3.2 Correlation Calculation

Correlation matches the input template image with the database image. Three different database images which are typical are taken. Different correlation value of fake note samples and real notes sample are calculated. Correlation value thus calculated is normalized correlation value. Input filter image is used for correlation purpose. Template of filter image is extracted from an image using image segmentation. Segmented image is correlated with the database image. In the experiments three typical real notes samples are used for correlation. Normalized cross correlation result in the brighter part of an image where template image matches to database image.

If the image intensity varies with position, Correlation can fail. For example, the correlation between the template and an exactly matched region can be less than correlation between the template and a bright spot. The range of $c(x, y)$ is dependent on the size of the feature. Correlation is not invariant to changes in image intensity, such as lighting conditions. Normalized cross correlation is used for analysis of an image.

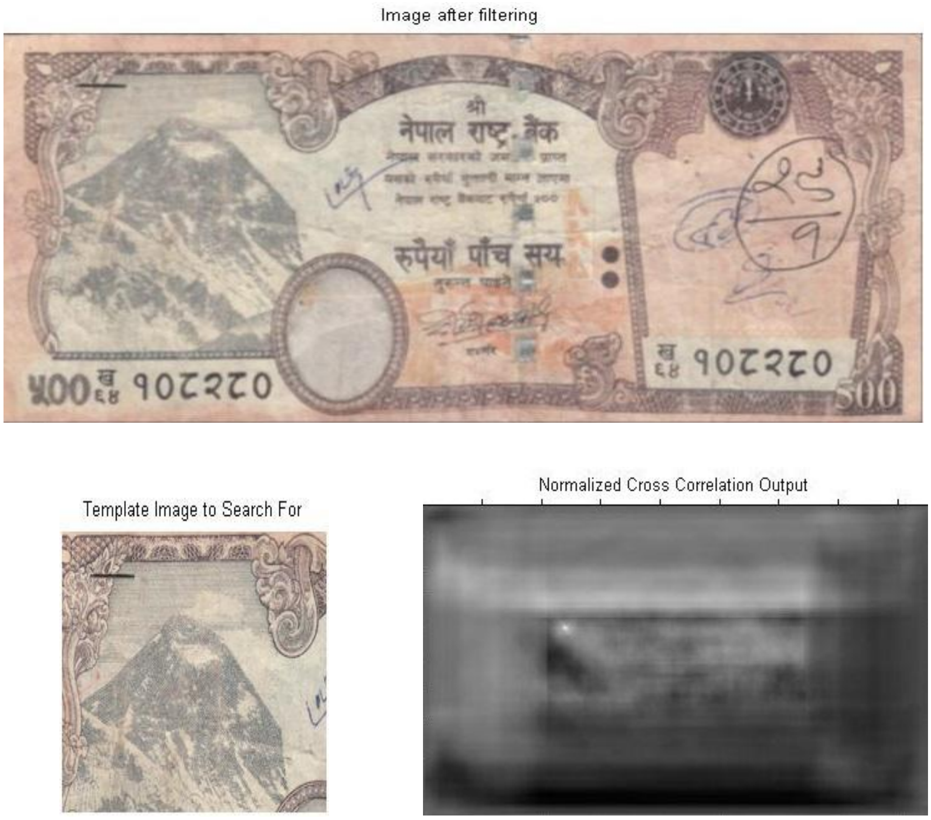
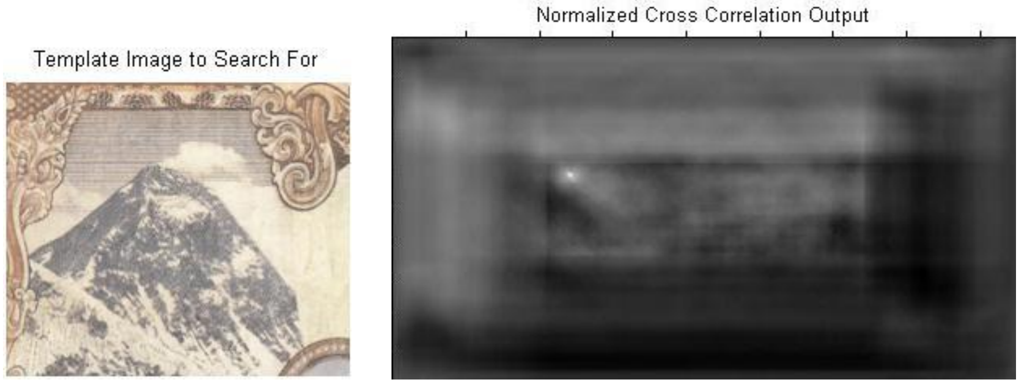


Figure 5.15 Normalized cross correlation of fake sample

(a)



(b) (c)

Figure 5.16 Normalized cross correlation of fake sample

Figure 5.17 Normalized cross correlation of real sample

Figure 5.18 Normalized cross correlation of real sample

Figure 5.15, figure 5.16 shows filter image whose template has been extracted. Normalized cross correlation image that is found by moving a template of fake sample to the database image. The Brightness part of image shows that there occurs maximum correlation. Similarly figure 5.17, figure 5.18 shows filter real note sample, its template and normalized cross correlation. For classification of an image, whether it matches the database image or not, there need numerical value. Numerical value is calculated and that value is analyzed whether it satisfies the predefined value or not.

Normalized correlation value of different samples with database images are calculated and plotted in graph. That graph shows the threshold value that should be taken for classification.

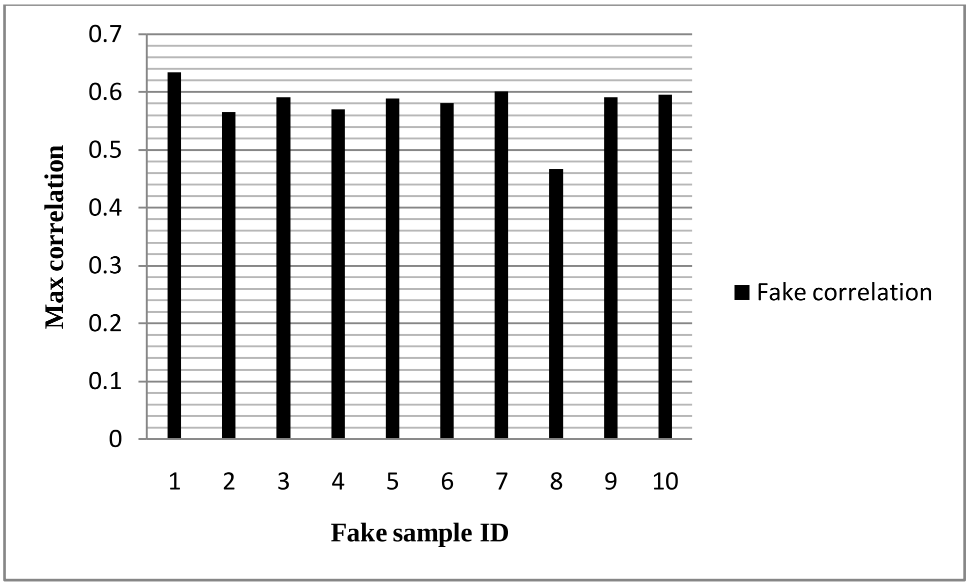


Figure 5.19 Graph of correlation of fake note samples with database sample one

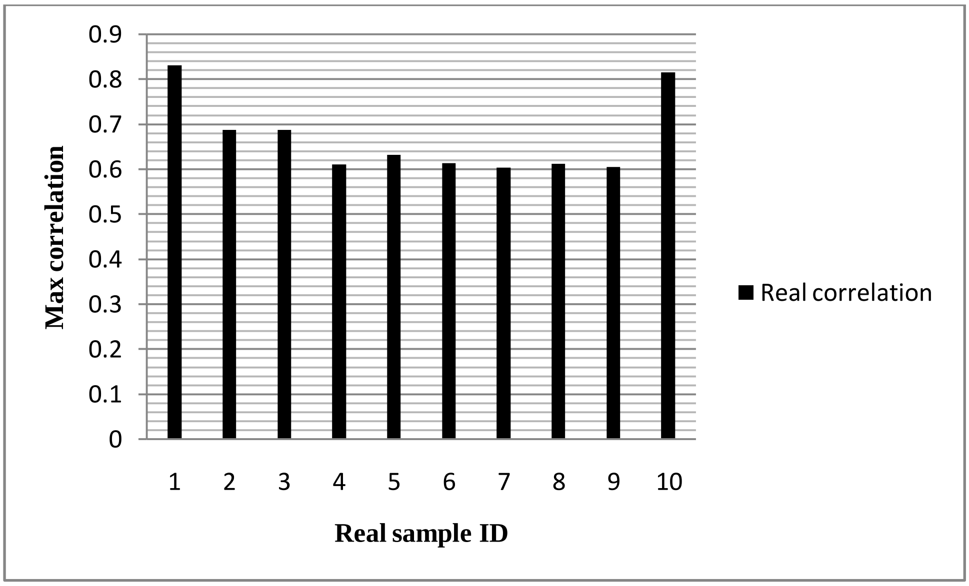


Figure 5.20 Graph of correlation of real note samples with database sample one

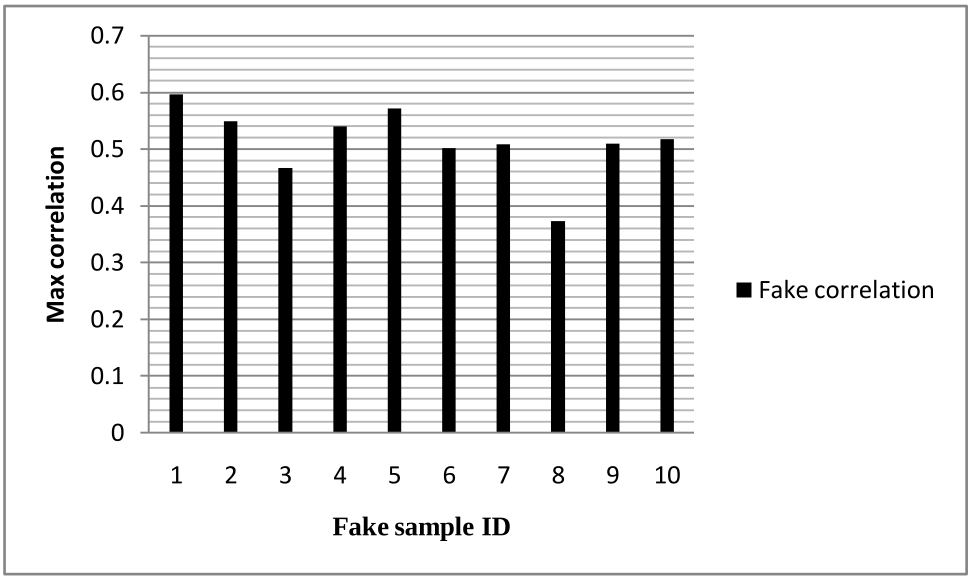


Figure 5.21 Graph of correlation of fake note samples with database sample two

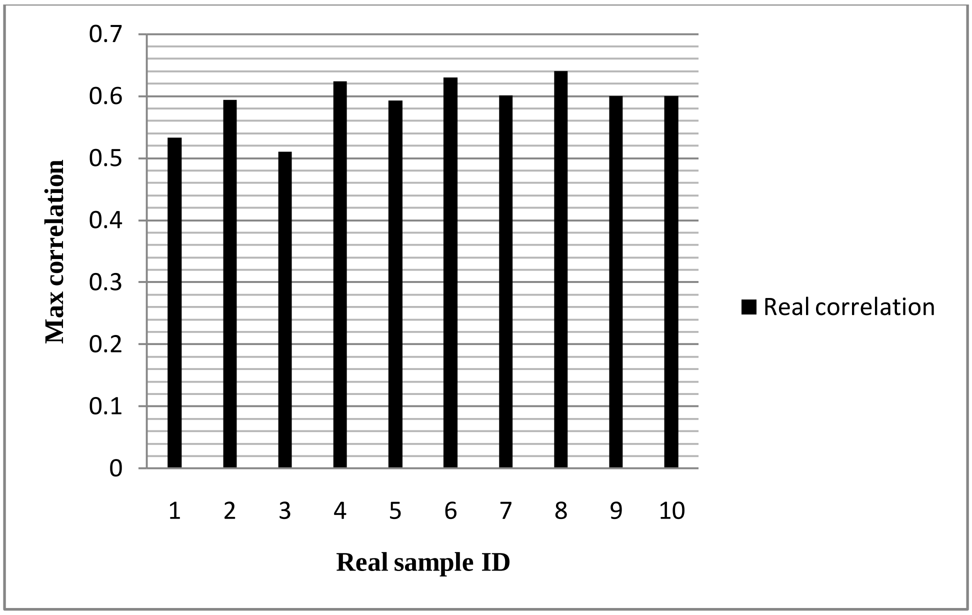


Figure 5.22 Graph of correlation of real note samples with database sample two

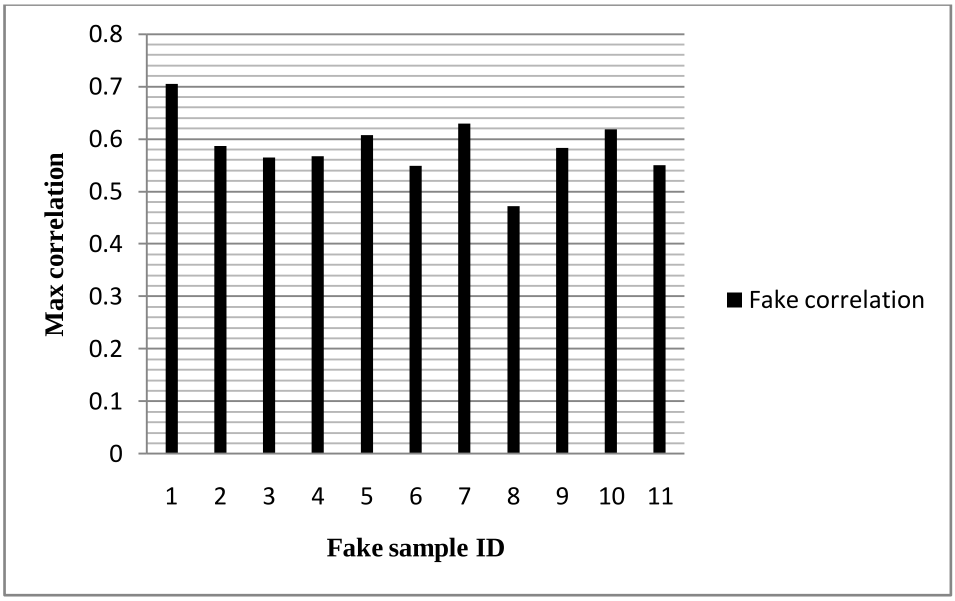


Figure 5.23 Graph of correlation of fake note samples with database sample three

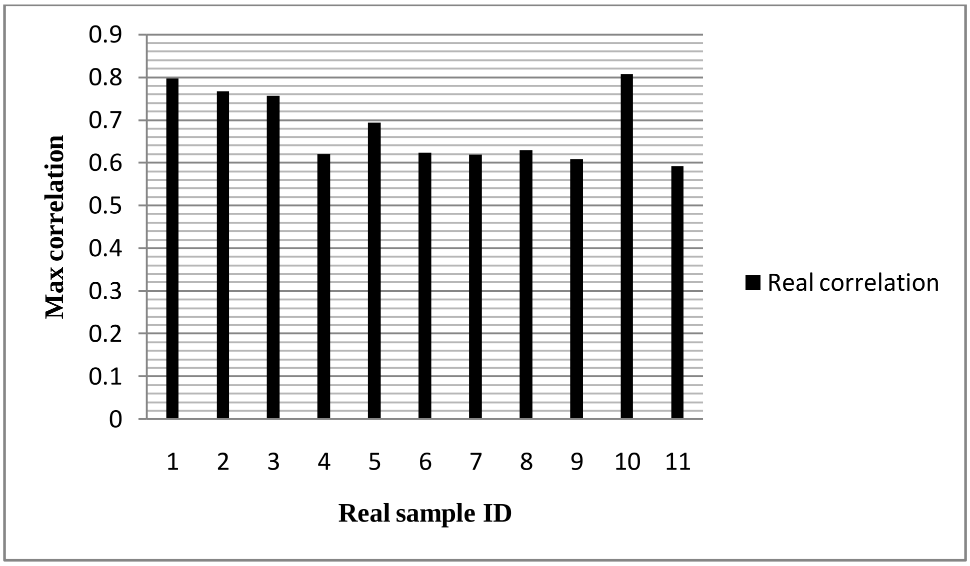


Figure 5.24 Graph of correlation of real note samples with database sample three

Figure 5.19, figure 5.20 and figure 5.21 shows the plot of normalized correlation value of fake samples with the database image sample one, sample two and sample three respectively. Similarly Figure 5.22, figure 5.23 and figure 5.24, shows the plot of normalized cross correlation value of real note samples when correlated with database sample one, sample two, sample three respectively.

5.4 Classification

Table 5.1 Classification Analysis

Banknote type	Total bank note tested	Bank notes correctly recognized	Identification Ability
Rs 500 (fake)	40	38	95%
Rs 500 (real)	70	67	95.71%
Number of features	Color part has 3 descriptors	Texture part has 2 descriptors	
Features used	To describe color skew, mean and standard deviation are used	To describe texture entropy and correlation are used	
Analysis	Skew, Mean, Standard Deviation as color parameter along with combination of entropy and correlation as texture parameter contribute to classification of counterfeit paper banknote.		

Table 5.2 Misclassification Rate Analysis

Banknote type	Total bank note tested	Mean	Skew	Standard Deviation	Entropy	Correlation
Rs 500 (fake)	40	2.50%	2.50%	45%	2.50%	42.50%
Rs 500 (real)	50	0%	0%	14%	0%	0%

Mean, Skew and Entropy are the least effective characteristic showing the lowest level of misclassifications when removed. Standard deviation and correlation contribute substantially to the overall effectiveness as a high misclassification rate is observed when removed.

Process used to print banknotes provides important checkup for authentication of the notes. In many cases counterfeiting have been reported even on the paper identical to one as used for genuine notes leaving a very narrow gap to identify the original from the fake. However, the printing technique that is hard to replicate because some of its inherent characteristics. There are numerous printing processes like offset, dry offset, intaglio, letterpress, serigraphy, screen printing, inkjet, bubble-jet, digital printing, etc. that can be used for printing currency notes. Out of these many possibilities, only a few processes are normally used in practice.

Any printing process involves ink pigment. There are many types of inks like CMYK (cyan, magenta, yellow, and black ink) ink, fluorescence ink, optical ink, etc. Final finish of print result applies varnishing and fused. The basic components of printing ink are pigment, solvent and drier. Where ink pigment is responsible for color effect on a substrate, drier is responsible to bind ink pigment to substrate. Solvent is responsible for soluble of ink pigment and drier. Drying mechanism of intaglio and offset printing are quite different. The solvent of offset printing ink is oily based and normally drying under heating effect. Here drying time is less and final effect on substrate is brighter and sharper edge. In intaglio printing, drying mechanisms of ink pigment is mainly achieved through evaporation and penetrations of ink solvent on its substrate. The required drying time of intaglio printing is more than offset printing. Therefore, the final effect of intaglio printing is less bright and less sharp edge as compared to that of offset printing.

Handwriting and other marking decreases the value thus calculated. It has no effect in classification of fake samples. It plays vital role in classification genuine samples. Color parameter value and texture parameter decrease with marking then without.

Chapter 6: EPILOGUE

6.1 Discussion

There are different challenges that are arises throughout the thesis. Identification of region of interest for analysis purpose is difficult task. ROI selection plays vital role because wrong selection increases processing cost with no benefit in identification. Calculation of parameters for classification and how many to use them are also played vital role in analysis and classification. There are numbers of banknotes with different quality. Clean and dirty paper notes are available in the market. So identification algorithm should identify both kinds of notes.

6.2 Conclusions

Software based approach that is able to identify fake currencies from images is presented. An empirical approach for automated digital currency identification is formulated based on image processing technique. A two parts feature values is formulated consisting of color features and texture features. A technique used for the extraction of feature, identification and classification of counterfeit and genuine bank note is presented. It presents automatic identification of counterfeit paper banknotes, which automatically using image processing techniques.

- Color and texture feature of a currency is used for identification.
- Color descriptor skew, mean and standard deviation is calculated from samples which are checked against the parameter that are previously defined.
- Texture parameter entropy and correlation are calculated from different set of database image.
- Matching score below the threshold, input currency image is classified as fake note. Otherwise the currency is genuine.

6.3 Limitations and Future enhancement

This thesis is based on some assumption so there is limitation. Banknotes in the context of Nepal contain different writing and marking by user.

- Marking decreases the overall contrast and correlation of note.
- Classification of counterfeit notes not affected by simple marking in ROI but it affects in real notes. If the marking are more and drastic than classification might not be possible.

- Color like red, and yellow are normally laid in notes while handing notes in cultural rituals. Such color that might present in notes with affects overall classification.

Future research will include refining the characteristics chosen, the Gabor texture and SIFT features can be compared against those of the correlation and entropy used in this thesis. Color parameter like central moment and kurtosis can be used for classification purpose. Neural network based classification can be done. Principal component analysis, Back propagation NN, Support Vector Machine (SVM) can be used in currency authentication. Limitations that are present in this thesis study can be removed by increasing parameter and region of interest.

References

1. Ahmed, Z.; Yasmin, S.; Islam, M.N.; Ahmed, R.U., "Image processing based Feature extraction of Bangladeshi banknotes," *Software, Knowledge, Information Management and Applications (SKIMA), 2014 8th International Conference on , vol., no., pp.1,8, 18-20 Dec. 2014*
2. Muhammad Akbar, Awaluddin, Agung Sedayu, Aditya Andika Putra, SetyawanWidyarto, "Original and Counterfeit Money Detection Based on Edge Detection", *2013 International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering November 7th-8th, 2013, Bandung,Indonesia*.
3. Ankush Roy, Biswajit Halder, Utpal Garain "Machine-assisted authentication of paper currency: an experiment on Indian banknote".
4. H. Hassanpour and E. Hallajian, "Using Hidden Markov Models for Feature Extraction in Paper Currency Recognition".
5. Ankush Roy, Biswajit Halder, Utpal Garain "Authentication of Currency Notes through Printing Technique Verification".
6. Rupali Deshmane, Akash Gattani, Prajyoti kadam, Anand Pardeshi "Design of Counterfeit: Currency Detector", *Sinhgad Institute of Management and Computer Application (SIMCA).*
7. Megha Thakur, Amrit Kaur, "Various Fake Currency Detection Techniques", *International Journal For Technological Research In Engineering Volume 1, Issue 11, July-2014*.
8. Pragati D. Pawar, Shrikant B. Kale, "Recognition of Indian Currency Note Based on HSV Parameters*" International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Impact Factor (2012): 3.358*
9. Vishnu, R.; Omman, B., "Principal component analysis on Indian currency recognition," *Computer and Communication Technology (ICCCT), 2014 International Conference on, vol., no., pp.291, 296, 26-28 Sept. 2014*.
10. Yu, Ning, et al. "Underwater range-gated laser imaging system design with video enhancement processing." *Instrumentation and Measurement, Sensor Network and Automation (IMSNA), 2013 2nd International Symposium on. IEEE, 2013.*

11. Khan, Md SA, M. A. Ansari, and Javed Miya. "Enhancement of Color Image Retrieval Capabilities: Fusion of Color with Texture Optimization." *Communication Systems and Network Technologies (CSNT), 2011 International Conference on. IEEE, 2011*.

12. Mojsilovic, Aleksandra, et al. "Matching and retrieval based on the vocabulary and grammar of color patterns." *Image Processing, IEEE Transactions on 9.1 (2000): 38-54.*

Appendices

a) Standard Deviation of fake and real samples

Samples	1	2	3	4	5	6	7	8	9
Fake samples standard deviation	2.2497	2.1649	2.1044	1.8429	1.299	4.3106	3.0648	0.9516	1.3384
Real samples standard deviation	3.0483	4.545	2.4049	4.5963	3.5621	5.0775	4.7651	5.1904	6.2258

b) Mean of fake and real samples

Fake samples mean	0.2332	0.2343	0.2302	0.2329	0.2224	0.234	0.2296	0.2357	0.2252
Real samples mean	0.2326	0.241	0.2404	0.2201	0.2369	0.2222	0.2237	0.2218	0.2245

c) Skew of fake and real samples

Fake samples skew	1.0489	1.4957	1.4957	1.3846	0.2711	0.56	1.2055	0.268	0.9011
Real samples skew	1.0943	0.9737	0.6174	1.752	1.3118	1.7754	1.5696	1.7403	1.8458

d) Entropy of fake and real samples

Fake samples	1	2	3	4	5	6	7	8	9
Red entropy	6.6318	6.6487	6.6441	6.7965	6.8739	6.6418	6.6533	6.6367	6.3865
Green entropy	6.5229	6.7241	6.7376	6.8923	6.6842	6.5422	6.7332	6.7546	6.7856
Blue entropy	6.5028	6.6892	6.5327	6.6387	6.5268	6.5608	6.7416	6.5907	6.6967

Real samples	1	2	3	4	5	6	7	8	9
Red entropy	6.7674	6.7154	6.6699	6.9961	6.6884	7.117	7.0758	7.067	7.0536
Green entropy	6.7205	6.5986	6.5786	6.9912	6.6062	7.079	7.0589	7.0388	6.995
Blue entropy	6.5718	6.4678	6.3966	7.0483	6.4692	7.0574	7.013	7.012	6.9793

d) Correlation of fake and real samples

Correlation with database sample1	1	2	3	4	5	6	7	8	9
Fake correlation	0.5964	0.5485	0.4662	0.5403	0.571	0.5013	0.5086	0.373	0.509
Real correlation	0.5335	0.5942	0.5102	0.6241	0.5926	0.63	0.6007	0.64	0.6004

e) Correlation of fake and real samples

Correlation with database sample2	1	2	3	4	5	6	7	8	9
Fake correlation	0.6341	0.5652	0.59	0.5693	0.5884	0.5807	0.601	0.4672	0.59
Real correlation	0.831	0.6873	0.6867	0.6094	0.6314	0.6126	0.6022	0.6107	0.6041

f) Correlation of fake and real samples

Correlation with database sample3	1	2	3	4	5	6	7	8	9
Fake correlation	0.7051	0.5868	0.5647	0.5676	0.6071	0.5482	0.6289	0.4723	0.5834
Real correlation	0.7968	0.7662	0.7563	0.6211	0.6939	0.6235	0.619	0.6291	0.6087

g) Matlab Code

```
clear
clc
close all

[imname,impath]=uigetfile({'*.jpg;*.png'});
RGBImage=imread([impath,'/',imname]);
InputImage=imresize(RGBImage,[312 640]);
DatabaseImage= imread('real12.jpg');%database image real 12
rgbImage=imresize(DatabaseImage,[312 640]);

%skew
 r_channel=RGBImage(:,:,1);
 b_channel=RGBImage(:,:,2);
 g_channel=RGBImage(:,:,3);
 %denoise each channel


xyzTransformation = makecform('srgb2xyz');
xyzI = applycform(rgbim,xyzTransformation);
%convert xyz to luv colorspace
warning('off');

luvTransformation = makecform('xyz2uvl');
luvI = applycform(xyzI,luvTransformation);
I3=imcrop(luvI,[319 46 71 209]);%croping number at right bottom corner
figure,imshow(I3)

%figure,imshow(luvI,'initialmagnification','fit');
%seperate l,u,v
L=I3(:,:,1);
U=I3(:,:,2);
V=I3(:,:,3);


%find mean,color variance and color skewness for each channel

 m= mean(L(:));
 display(m)
 s = std(L(:))^2;
 display(s)
 sk= skewness(L(:));
 display(sk)



gaussian=fspecial('gaussian',7,0.8);
RGB_Gaussian=imfilter(InputImage,gaussian);

%figure;
```

```
%imshow(RGBImage)
%title('Input Image')

figure,imshow(RGB_Gaussian);
title('Image after filtering')

redPlane = RGB_Gaussian(:, :, 1);
greenPlane = RGB_Gaussian(:, :, 2);
bluePlane = RGB_Gaussian(:, :, 3);
subplot(2,2,1);imshow(RGB_Gaussian)
title('Filter Image')

RE = entropy(redPlane);
GE = entropy(greenPlane);
BE = entropy(bluePlane);

% Let's get its histograms.
[pixelCountR,grayLevelsR] = imhist(redPlane);
subplot(2, 2, 2);
plot(pixelCountR, 'r');
title('Histogram of red plane')
xlim([0 grayLevelsR(end)]); % Scale x axis manually.

[pixelCountG,grayLevelsG] = imhist(greenPlane);
subplot(2, 2, 3);
plot(pixelCountG, 'g');
title('Histogram of green plane')
xlim([0 grayLevelsG(end)]); % Scale x axis manually.

[pixelCountB,grayLevelsB] = imhist(bluePlane);
subplot(2, 2, 4);
plot(pixelCountB, 'b');
title('Histogram of blue plane')
xlim([0 grayLevelsB(end)]); % Scale x axis manually.

%I2 = imcrop(RGB_Gaussian,[260 48 127 41]);%croping nepal rastra bank
%figure, imshow(I2)
I3=imcrop(RGB_Gaussian,[319 46 71 209]);%croping number at right bottom corner
figure,imshow(I3)


[r,c]=size(RGB_Gaussian);
totmean1=sum(RGB_Gaussian(:))/(r*c);
display(totmean1);

totdiff=(RGB_Gaussian-totmean1).^2;
totsum=sum(totdiff(:));
nele=(r*c)-1;
totvar1=totsum/nele;
display(totvar1);
```

```
totstd1=sqrt(totvar1);
display(totstd1);

[rows,columns,numberOfColorBands] = size(rgbImage);
% Display the original color image.
subplot(2, 2, 1);
imshow(InputImage, []);

axis on;
title('Input Currency Image')
% Enlarge figure to full screen.
set(gcf, 'units','normalized','outerposition',[0, 0, 1, 1]);

% Let's get our template by extracting a small portion of the Input image.
templateWidth = 211;
templateHeight = 183;
smallSubImage = imcrop(InputImage, [30,14, templateWidth, templateHeight]);
subplot(2, 2, 2);
imshow(smallSubImage, []);
axis on;
title('Template Image to Search For')

% Ask user which channel to search for a match.
% channelToCorrelate = menu('Correlate which color channel?', 'Red', 'Green',
'Blue');
% It actually finds the same location no matter what channel you pick,
% for this image anyway, so let's just go with red (channel #1).
channelToCorrelate = 1;
correlationOutput = normxcorr2(smallSubImage(:,:,2), rgbImage(:,:,
channelToCorrelate));
subplot(2, 2, 3);
imshow(correlationOutput, []);
axis on;
title('Normalized Cross Correlation Output')

% Find out where the normalized cross correlation image is brightest.
[maxCorrValue, maxIndex] = max(abs(correlationOutput(:)));
display(maxCorrValue);
[yPeak, xPeak] = ind2sub(size(correlationOutput),maxIndex(1));
% Because cross correlation increases the size of the image,
% we need to shift back to find out where it would be in the original image.
corr_offset = [(xPeak-size(smallSubImage,2)) (yPeak-size(smallSubImage,1))];
if (s>(2.97e-04))&&(maxCorrValue>0.54)
subplot(2, 2, 4); % Re-display image in lower right.
imshow(rgbImage);
axis on; % Show tick marks giving pixels
hold on; % Don't allow rectangle to blow away image.
% Calculate the rectangle for the template box.  Rect = [xLeft, yTop,
widthInColumns, heightInRows]
boxRect = [corr_offset(1) corr_offset(2) templateWidth, templateHeight];
```

```
% Plot the box over the image.

rectangle('position', boxRect, 'edgecolor', 'g', 'linewidth',2);
% Give a caption above the image.
title('The Input Image Genuine')
else
   subplot(2,2,4);
   imshow(InputImage);
   title('The input currency is Fake')
end;
```

h) Database of fake notes samples

I) Database of real notes samples