IMAGE PROCESSING BASED FEATURE EXTRACTION

OF

INDIAN CURRENCY NOTES

Thesis report submitted towards the partial fulfillment of

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In

VLSI Design & CAD

Submitted by

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, **"Image Processing Based Feature Extraction of Indian Currency Notes"** in partial fulfillment of the requirement for the Award of Degree of M.Tech (VLSI Design & CAD) at Electronics and Communication Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Mr. Parminder Singh Reel, Assistant Professor, ECED.**

The matter embodied in this thesis has not been submitted in any other University/Institute for the award of any degree.

Date: 30/6/2010

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It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

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ABSTRACT

Counterfeit notes are a problem of almost every country but India has been hit really hard and has become a very acute problem. Fake Indian currency of 100, 500 and 1000 rupees seems to have flooded the whole system and there is no proper way to deal with them for a common person.There is a need to design a system that is helpful in recognition of paper currency notes with fast speed and in less time. The recognition system is composed of two parts. The first is preprocessing, including detecting edges, compressing data dimensionalities, and extracting features. The second one is recognition, in which the core is a neural network classifier. Number recognition is a challenging problem researchers had been research into this area for a long time. In our study there are many fields concern with numbers, for example, checks in banks or recognizing numbers in car plates, the subject of digit recognition appears. A system for recognizing isolated digits may be as an approach for dealing with such application. In other words, to let the computer understand the numbers and views them according to the computer process. Scientists and engineers with interests in image processing and pattern recognition have developed various approaches to deal with handwriting number recognition problems such as, minimum distance, decision tree and statistics. In this thesis, I have proposed a new technique for extracting serial numbers of Indian paper currency which can be used for recognition or database purpose. I have used the MATLAB image processing toolbox to develop a software for this purpose. Image Processing involves changing the nature of an image in order to improve its pictorial information for human interpretation, for autonomous machine perception. The Image Processing Toolbox software is a collection of functions that extend the capability of the MATLAB numeric computing environment. The toolbox supports a wide range of image processing operations on the given image. Previous related work in this field is also presented as a state of art literature survey. This technique can be used further in recognizing the currency notes with the help of neural network methods.

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ABBERIVATIONS

ASCII	American Standard Code For Information Interchange
BMP	Bitmap File Format
DICOM	Digital Imaging And Communications In Medicine
FFT	Fast Fourier Transform
HSV	Hue Saturation Value
IEEE	Institute Of Electrical And Electronics Engineers
JPEG	Joint Photographic Experts Group
LVQ	Learning Vector Quantization
MRI	Magnetic Resonance Image
PCA	Principle Component Analysis
PNG	Portable Network Graphics
PCX	Personal Computer Exchange
RGB	Red Green Blue
RBI	Reserve Bank Of India
TIFF	Tagged Image File Format

CHAPTER

1 INTRODUCTION

1.1 INTRODUCTION

Feature extraction of images is challenging work in digital image processing. The feature extraction of Indian currency notes involves the extraction of features of serial numbers of currency notes. What is feature extraction in image processing? The meaning of the feature extraction phase is most conveniently defined referring to the purpose it serves. Feature extraction is that of extracting from the raw data the information which is most relevant for classification purposes, in the sense of minimizing the within-class pattern variability while enhancing the between-class pattern variability. During the feature extraction process the dimensionality of data is reduced. This is almost always necessary, due to the technical limits in memory and computation time. A good feature extraction scheme should maintain and enhance those features of the input data which make distinct pattern classes separate from each other. At the same time, the system should be immune to variations produced both by the humans using it and the technical devices used in the data acquisition stage.

In recent years, along with the accelerative developments of world economics incorporation course, the start of Euro area, and the increase of Asia economics, frontier trade and personal intercourse of various countries are frequent increasingly. Travelling people always take many countries of paper currency. Probabilities that the paper currencies of various countries are probably interweaved together therefore rises increasingly. It is a challenge for conventional paper currency recognition systems. However, the focus of most of the conventional currency recognition systems and machines is on recognizing counterfeit currencies. It is not enough for practical

businesses. The reason is that in most of banks, especially those internationalized banks, there are large quantities of cash belonging to many different countries need to be process, and it is possible that all of them are real cashes.

The situation that cashes belonging to different countries mixes together is possible to occur. It cannot be processed with conventional currency recognition systems. For example there is a currency recognition system, which can correctly recognize and classify the 20 kinds of currency with different par values or coming from different countries because this system knows these currencies so much. Therefore this system is responsible to recognize these 20 kinds of currency specially. However, some pieces of currency not belonging to those 20 kinds, which is unknown for the system, are mixed together with those 20 kinds of currency to input this system accidentally. All of these unknown currencies should be rejected in ideal situation. But because there is not any relative information of these unknown data in the system, it is possible to lead to that these currencies are misrecognized as a certain kind in those 20 kinds of currency. In practice this situation is not permitted to take place. Hence it is necessary to develop the currency recognition systems and bank machines that can not only realize correct recognitions and classifications for known paper currencies, but also complete effective rejections for unknown paper currencies.

The recognition of the serial numbers of the Indian paper currency such as 100, 500 or 1000 banknotes can detect using various methods. The serial numbers are currency issuance numbers, which are used as the identifiers (IDs) of the banknotes. Each sheet has its own serial numbers and the same numbers can not be used more than once. Correctly and fast recognizing these numbers is very important due mainly to at least the three reasons. Firstly, there is a need for proper statistics by the national treasuries and the banks. After the banknotes are produced by some appointed printing factories, they need to be storied into the national treasuries then be sent to different banks for being formally distributed in the markets. Before the national treasuries can accept the banknotes, they need to know the serial numbers of so it's of the banknotes so that the national treasuries can know the total number of each of the different kinds of banknotes. Secondly, there is a need for reprinting of the destroyed banknotes. When the national treasuries or banks find some banknotes that have been destroyed and can not be used, they need to inform the printing factories to reprint those banknotes with the same serial numbers. Thirdly,

there is a need for the diagnosis of the crimes by the public police. It would be very helpful for the public police to find clues of the criminals if the stolen banknotes can be fast and correctly recognized.[1].

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. Optical character recognition has been a topic of interest since possibly the late 1940's when Jacob Rabinow started his work in the field. The earliest OCR machines were primitive mechanical devices with fairly high failure rates.

Today there are many OCR devices in use based on different algorithms. All of the popular algorithms sport high accuracy and most high speed, but still many suffer from a fairly simple flaw: when they do make mistakes (and they all do), the mistakes are often very unnatural to the human point of view. That is, mistaking a "5" for an "S" is not too surprising because most people are willing to agree that these two characters are similar, but mistaking a "5" for an "M" is unexpected. Algorithms make such mistakes because they generally operate on a different set of features than humans for computational reasons. Humans observe strokes and the relations between them, while algorithms measure anything from Transformation Ring Projections [2] of a character to the Fourier Transform of the Horizontal-Vertical Projections of a character. These methods do work and are often computationally efficient, but they make the computer see letters through a decidedly non-human set of eyes.

The problem for handling these banknotes in India is very bad for some difficulties in Law. The legal way to handle is to lodge a police complain and mention the source of the currency and then further investigations are done. The fake currency is then sent to RBI or destroyed. RBI itself has installed currency verification and processing systems in its various offices, each having a processing capacity of 50,000 to 60,000 pieces per hour. Most people do not want to deal with this problem in a legal way because our law enforcement (police) and legal system (courts) are not so easy to deal with. Unlike most developed countries where a common person feels free to report even a smallest problem to the police, in India it is quite different as most people avoid contacting police because those investigations can be painfully inconvenient and especially because many people in law enforcement are not exactly honest. The legal system is even more troublesome, even a small court case in India can easily drag for months and year. Therefore more and more

people have just started to live as is. It is not possible check each and every currency note you receive in a bundle. Most people just pass it along to others, if someone objects you just give different note. In fact most people in India do not even know how to the things to check that differentiates a fake note from a real one. Trying to pass on a currency note, knowing that is a fake, is a punishable offence under sections 120-B, 420 and 489-A, B, C & D of the Indian Penal Code. Possession of counterfeit notes too is punishable with punishment as harsh as life imprisonment. Some features about how to detect a fake Indian rupee note are given below:

1. **Optical Variable Ink:** The colour of the numeral 500 appears green when the banknote is held flat but would change to blue when the banknote is held at an angle. The font size is also reduced.
2. **Latent Image:** When the note is head horizontally, the vertical band on the right shows an image of the number 500.
3. **Security Thread:** The note also has a three millimeter wide security thread with the inscriptions: one thousand, the word 'Bharat' in Hindi and RBI.
4. **Micro lettering:** The 'RBI' and the numeral, "500" - which can be viewed with the help of a magnifying glass - are between the Mahatma Gandhi portrait and the vertical band.
5. **Watermark:** When the note is held against the light, the picture of Gandhi and an electrolyte mark showing the number 500 appear in the white space.

FIGURE 1.1:RBI Security Features[3]

The best way to identify a note is the silver bromide thread that runs vertically through a currency note. Fake currency notes tend to have silver-coloured band painted in place of the silver thread. A real note has a prominent thread with raised 'RBI' markings made on it in English and Hindi. Also, in a real note, the colour of the thread shifts from green to blue when viewed from different angles.

The image processing approach is discussed with Matlab to detect the features of Indian currency. Image processing includes any form of information processing in which the input is an image. Many image processing techniques derive from the application of signal processing techniques to the domain of images a two-dimensional signal such as photographs and videos. The name image processing is most appropriate when both inputs and outputs are images. The extraction of arbitrary information from images is the domain of image analysis, which includes pattern recognition when the patterns to be identified are in images. In computer vision one seeks to extract more abstract information, such as the 3D description of a scene from video footage of it. The tools and concepts of image processing are also relevant to image synthesis from more abstract models, which is a major branch of computer graphics.

MATLAB is an interactive technical computing environment based on an interpreted language whose variables are matrices. MATLAB's language has proven to be easy for everyone to understand; thus its use become productive in MATLAB far more quickly than with other languages.

The Image Processing Toolbox software is a collection of functions that extend the capability of the MATLAB numeric computing environment. The toolbox supports a wide range of image processing Spatial image transformation, Morphological operations, Neighborhood and block operations, Linear filtering and filter design, Transforms, Image analysis and enhancement, Image registration, Deblurring and Region of interest operations. The image formats are supported by Matlab are BMP, HDF, JPEG, PCX, TIFF, XWB etc. Most images find on the Internet are JPEG-images which is the name for one of the most widely used compression standards for images. If we have stored an image you can usually see from the suffix what format it is stored in.

Our approach to feature extraction of Indian currency can be broadly divided into the following parts:

1. Pre-Processing of currency image.
2. Binarisation.
3. Morphological filtering.
4. Segmentation.
5. Feature Extraction.

This thesis is organized as follows:

CHAPTER I: INTRODUCTION. This chapter introduces about feature extraction in image processing, security features of Indian currency.

CHAPTER 2: LITERATURE SURVEY. This chapter shows previous related work done with this thesis.

CHAPTER 3: DIGITAL IMAGE PROCESSING. This chapter explains digital image processing, its aspects and applications.

CHAPTER 4: MATLAB IMAGE PROCESSING TOOLBOX. This chapter focuses on the how the image processing toolbox is used in MATLAB. This chapter discusses the image analysis, basic commands, various image formats supported by MATLAB.

CHAPTER 5: NEURAL NETWORKS. This chapter discusses the basics of neural networks, biological model and its applications.

CHAPTER 6: GRAPHICAL USER INTERFACE. This chapter discusses about graphical user interface and its various elements.

CHAPTER 7: PROPOSED APPROACH. This chapter discusses proposed approach for this work.

CHAPTER 8: EXPERIMENTAL RESULTS. This chapter includes the results of this thesis. Finally we have the conclusion and its future scope.

CHAPTER 2 LITERATURE SURVEY

2.1 LITERATURE SURVEY

A Hierarchical Approach to Feature Extraction and Grouping

Gian Luca Foresti and Carlo Regazzoni presented this paper in June,2000 at IEEE International conference.[4]

This paper presents the problem of extracting and grouping image features from complex scenes is solved by a hierarchical approach based on two main processes: voting and clustering. Voting is performed for assigning a score to both global and local features. The score represents the evidential support provided by input data for the presence of a feature. Clustering aims at individuating a minimal set of significant local features by grouping together simpler correlated observations. It is based on a spatial relation between simple observations on a fixed level, i.e., the definition of a distance in an appropriate space. As the multilevel structure of the system implies that input data for an intermediate level are outputs of the lower level, voting can be seen as a functional representation of the "part-of" relation between features at different abstraction levels. The proposed approach has been tested on both synthetic and real images and compared with other existing feature grouping methods. This paper is focused on the detection of real objects characterized by regular boundaries as 3-D man-made objects in structured environments.

Feature Extraction for Bank Note Classification Using Wavelet Transform

Euisun Choi, Jongseok Lee and Joonhyun Yoon presented this paper in March, 2006 at IEEE International conference. [5]

In this paper, we investigate an approach to feature extraction for bank note classification by exploiting the potential of wavelet transform. In the proposed method, high spatial frequency coefficients taken from the wavelet domain are examined to extract features. We first perform edge detection on bill images to facilitate the wavelet feature extraction. The construction of feature vectors is then conducted by thresholding and counting of wavelet coefficients. The proposed feature extraction method can be applied to classifying any kind of bank note. However, in this paper we examine Korean won bills of 1000, 5000 and 10000 won types. Experimental results with a set of 10,800 bill images show that the proposed feature extraction method provides a correct classification rate of 99% even by using the Euclidean minimum distance matching as classifier. The textured regions of different bill images can be easily discriminated by decomposing the texture into several frequency subbands. In particular, the use of a wavelet transform is an attractive possibility due to its flexible frequency splitting at different scales and orientations. In the proposed method, high spatial frequency subbands are explored to extract features from transformed images.

An Efficient Feature Extraction Algorithm for the Recogntion of Handwritten Arabic Digits

Ahmad T. Al-Taani author of this paper at International Journal of Computational Intelligence in 2006.[6]

In this paper, an efficient structural approach for recognizing on-line handwritten digits is proposed. After reading the digit from the user, the slope is estimated and normalized for adjacent nodes. Based on the changing of signs of the slope values, the primitives are identified and extracted. The names of these primitives are represented by strings, and then a finite state machine, which contains the grammars of the digits, is traced to identify the digit. Finally, if there is any ambiguity, it will be resolved. Experiments showed that this technique is flexible and can achieve high

recognition accuracy for the shapes of the digits represented in this work. Automatic recognition of handwritten digits is difficult due to several reasons, including different writing styles of different persons, different writing devices, and the context of the digit. This leads to digits of different sizes and skews,and strokes that vary in width and shape.

Invariant Features Extraction for Banknote Classification

Peng Wang and Peng Liu author of this paper. This paper published in Proceedings of the 11th Joint Conference on Information Sciences in 2008. [7]

An invariant feature extraction method is proposed for banknote classification. The movement of banknote is complex in the channel of financial instruments. The scale is various. The rotation and translation are also to occur. The method of feature extraction is insensitive to the variety of scale, rotation and translation. It decreases the data variety and improves the reliability of banknote classification. Furthermore, the computation complexity is low in order to meet to the requirement of real-time banknote image processing and classification. The invariant feature extraction method has performed very well when they are applied in banknote sorters. This paper shows an effective method to classify banknote. First, a rotation, translation and scale invariant feature extraction method is proposed. This feature extraction method is suit for the low quality images which are acquired at high speed banknote channel. Furthermore, the computation is sample in order to finish the banknote image processing and classification in real-time. Then, a 3-layer BP neural networks is used predict the face and value of a banknote. The feature extraction method has performed very well when they are applied in banknote sorters.

Thinning Arabic Characters for Feature Extraction

Dr. John Cowell and Dr. Fiaz Hussain presented this paper in 2001 at IEEE International conference. [8]

A successful approach to the recognition of Latin characters is to extract features from that character such as the number of strokes, stroke intersections and holes, and to use ad-hoc tests to differentiate between characters which have similar features. The first stage in this process is to produce thinned pixel thick representations of the

characters to simplifying feature extraction. This approach works well with printed Latin characters which are of high quality. With poor quality characters, however, the thinning process itself is not, straightforward and can introduce errors which can manifested in the later stages of the recognition process. The recognition of poor quality Arabic characters is a particular problem since the characters are calligraphic with printed characters having widely varying stroke thicknesses to simulate the drawing of the character with a calligraphy pen or brush. This paper describes the problems encountered when thinning large poor quality Arabic characters prior to the extraction of their features and submission to a syntactic recognition system.

The techniques used are often sensitive to variations in the orientation of the characters, do not deal with poor quality characters with ragged edges and are not readily transferable to other character sets such as Arabic and Urdu. The calligraphic nature of these character sets means that the approach used for Latin characters is not directly transferable. A recognition system which can deal with a variety of poor quality characters from the Arabic, Latin and other character sets must use an alternative approach.

A License Plate-Recognition Algorithm for Intelligent Transportation System Applications

Christos Nikolaos and Vassili Loumos presented this paper in 2006 at IEEE Transactions On Intelligent Transportation Systems.[9]

In this paper, a new algorithm for vehicle license plate identification is proposed, on the basis of a novel adaptive image segmentation technique (sliding concentric windows) and connected component analysis in conjunction with a character recognition neural network. The algorithm was tested with 1334 natural-scene gray-level vehicle images of different backgrounds and ambient illumination. The camera focused in the plate, while the angle of view and the distance from the vehicle varied according to the experimental setup. The license plates properly segmented were 1287 over 1334 input images (96.5%). The optical character recognition system is a two-layer probabilistic neural network (PNN) with topology 108-180-36, whose performance for entire plate recognition reached 89.1%. The PNN is trained to identify alphanumeric characters from car license plates based on data obtained from

algorithmic image processing. Combining the above two rates, the overall rate of success for the license plate- recognition algorithm is 86.0%. A review in the related literature presented in this paper reveals that better performance (90% up to 95%) has been reported, when limitations in distance, angle of view, illumination conditions are set, and background complexity is low.

Rotation-Invariant Neural Pattern Recognition System with Application to Coin Recognition

Minoru Fukumi, Sigeru Omata and Fumiaki Takeda presented this paper in March, 1992 at IEEE International conference.[10]

This paper presents a neural pattern recognition system which is insensitive to rotation of input pattern by various degrees. The system consists of a fixed invariance network with many slabs and a trainable multilayered network. To illustrate the effectiveness of the system, we apply it to a rotation-invariant coin recognition problem to distinguish between a 500 yen coin and a 500 won coin. The rotation-invariant neural pattern recognition system presented in this paper shows good performance for coin recognition With regard to real implementation, the system would require the ability to discriminate more coins, as human can easily do. Much work on transform-invariant pattern recognition remains to be done, including the classification of coins of all nations.

A Paper Currency Recognition Method by a Small Size Neural Network with Optimized Masks by GA

Fumiaki Takeda, Sigeru Omatu, Saizo Onami,Takashi Kadono and Kengo Terada presented this paper in 1994 at IEEE International conference.[11]

This paper presents a structure reduction method for NNs. We adopt slab values which are sums of input pixels as characteristics of the inputs. But there is the possibility of generating the same slab values even when the inputs are different. To avoid this problem, we adopt a mask which covers some parts of input. This enables us to reflect the difference of input pattern to slab values with masks. Still more, it adopt the genetic algorithm (GA) to optimize the masks. We can generate various effective

masks automatically. Finally, this paper show that the proposed method by neuro-recognition with masks can be applied effectively to paper currency recognition machine using the GA.

High Speed Paper Currency Recognition by Neural Networks

Fumiaki Takeda and Sigeru Omatu wrote this paper in January, 1995 at IEEE Computer Society. In this paper a new technique is proposed to improve the recognition ability and the transaction speed to classify the Japanese and U.S. paper currency. [12]

This paper compare two types of data sets, time series data and Fourier power spectra, are used in this study. In both cases, they are directly used as inputs to the neural network. Still more we also refer a new evaluation method of recognition ability. Meanwhile; a technique is proposed to reduce the input scale of the neural network without preventing the growth of recognition**.** This paper applied the NN to paper currency recognition and showed the effectiveness compared with a conventional manual method. Furthermore, it has proposed a structure reduction method of the NN using random masks and showed its effectiveness for time series data and its Fourier power spectra.

A Neuro-Paper Currency Recognition Method Using Optimized Masks by Genetic Algorithm

Fumiaki Takeda and Sigeru Omatu wrote this paper in January, 1995 at IEEE Compute Society. Recently, much research of applications to Neural Networks (NNs) by Genetic Algorithm **(**GA) has been reported. [13]

This paper adopts the GA to a neuro-paper currency recognition method using the masks which it has proposed. Namely, this regards the position of the masked part as a gene. It samples the parental masks and operates "crossover", "selection", and "mutation" to some genes. By repeating a series of the GA operations, it can optimize the masks for the paper currency recognition in a short period. It compares the ability of the NN using the masks optimized by the GA with the one of the NN using the

masks determined by the random numbers. Then it shows that the GA is effective for systematizing the neuro-paper currency recognition with masks.

In this paper, we have adopted the GA to the neuro-paper currency recognition method with masks and have shown .By use of this new technique, it showed that the excellent masks could be obtained by the present method compared with the random search procedure. Still more, it can systematize the mask optimization using the GA.

A Neural Network-Based Model for Paper Currency Recognition and Verification

Angelo Frosini, Marco Gori and Paolo Priami presented this paper in November,1996 at IEEE International conference. This paper describes the neural-based recognition and verification techniques used in a banknote machine, recently implemented for accepting paper currency of different countries.[14]

The perception mechanism is based on low-cost optoelectronic devices which produce a signal associated with the light refracted by the banknotes. The classification and verification steps are carried out by a society of multilayer perceptions whose operation is properly scheduled by an external controlling algorithm, which guarantees real-time implementation on a standard microcontroller-based platform. The verification relies mainly on the property of autoassociators to generate closed separation surfaces in the pattern space. The experimental results are very interesting, particularly when considering that the recognition and verification steps are based on low-cost sensors.

Multiple kinds of Paper Currency Recognition using Neural Network and application for Euro Currency

Fumiaki Takeda and Toshihiro Nishikag, presented this paper in 2000 at IEEE International conference**.** This paper concentrates on report an enhanced neuro-recognition system to increase the more number of recognition patterns using axis-symmetrical mask and two image sensors. One sensor's purpose is discrimination for a known image and another one is exclusion for an unknown image. [15]

Concretely, it implements the proposed method to an experimental system, which has two sensors. And they are arranged on the up side and down side of the aisle, respectively. Finally, we apply this proposed method to Euro currency. It is to be effective in the industrial use such as increasing of the number of pattems with maintaining the non-liner recognition ability In this paper, it has proposed multiple kinds of the paper currency recognition system using axis symmetrical mask and two image sensors. Especially, its effectiveness for some plural kinds of currency has been shown, experimentally. Furthermore, it has applied the proposed method to the Euro currency using its dummy. After this, it is important that the proposed method is implemented to the banking machines for the delivery of the Euro currency. It is also much important requirement to evaluate true Euro currency in the commercial market for the industrial use of the proposed method.

Implementing a Reliable Neuro Classifier for Paper Currency Using PCA Algorithm

Ali Ahmadi,Sigeru Omatu and Michifumi Yoshika presented this paper in August, 2002 at IEEE International conference. This paper presents a PCA based method for increasing the reliability of paper currency recognition machines. [16]

The system is intended for classifying any .kind of currency but in this work we examine only different kinds of US dollar (totally IO bill types**).** The data is acquired through some advanced sensors and after pre-processing come as an array of pixels. The PCA algorithm is used to extract the main features of data and reducing the data size. An LVQ network model is applied as the main classifier of system. By defining a specific criteria for rating the reliability, it evaluate the reliability of system for 1,200 lest data**.** The result shows that reliability is increased up to 95% when the number of PCA components as well as numb of LVQ codebooks are taken properly.

This paper presented a local PCA approach for feature extraction of data in classification of paper currency. The aim is to model the complexity of data and correlation between variables by using a simple linear model. The method first exploits a SOM model to cluster the data space into disjoints regions. Then a standard PCA model is applied in each region.

A Methodology to Evaluate and Improve Reliability in Paper Currency Neuro-Classifiers

Ali Ahmadi,Sigeru Omatu and Toshihisa Kosaka presented this paper in June,2003 at IEEE International conference. This paper gives the advance method based on the PCA Algorithm.[17]

In this paper the reliability of the paper currency classifiers is studied and a new method is proposed for improving the reliability based on the local principal components analysis **(**PCA**).** At first the data space is partitioned into regions by using a self-organizing map (SOM) model and then the PCA is performed in each region. A learning vector quantization (LVQ) network is employed as the main classifier of the system. The reliability of classification is evaluated by using an algorithm which employs a function of winning class probability and second maximal probability. By using a set of test data, it estimates the overall reliability of the system.

The main limitation of PCA is its global linearity, that is, it only defmes a linear projection of data and does not model nonlinear relationship among variables, some developments of non-linear principal component analysis (NLPCA) have been presented to address this limitation.

Research on Paper Currency Recognition by Neural Networks

Er-hu Zhang, Bo Jiang,Jing -Hong Duan,Zheng Zhong Bian presented this paper in November,2003 at IEEE International conference. It is a key process to select original characteristic information from currency image with noises and uneven gray[18].

This article, aiming at the specialties of RENMINGBI (RMB) currency image, puts forward a method using linear transform of image gray to diminish the influence of the background image noises in order to give prominence to edge information of the image. Then the edge characteristic information image is obtained by edge detecting using simple statistics. Finally by dividing the edge characteristic information image in the width direction into different areas, getting the number of the edge characteristic pixels of different areas as input vectors to neural networks, carrying out sorting

recognition by three layer BP NN**,** paper currency is recognized. It is completely feasible to use BP NN to classify RMB. The proposed method of extracting input vectors has advantages of simplicity, high calculating speed, obvious characters of original image, roburest to different kinds of RMB.

New Recognition Algorithm for Various Kinds of Euro Banknotes

Jae Kang and Hwan Kim presented this paper in 2003 at IEEE International conference. Counters for the various kinds of banknotes require high-speed distinctive point extraction and recognition. [19]

This paper proposed a new point extraction and recognition algorithm for banknotes. For distinctive point extraction we use a coordinate data extraction method from specific parts of banknote representing the same colour. To recognize banknotes, the author trained 5 NN. One is for inserting direction and the others are for the face value. The algorithm is designed to minimize recognition time. The simulated results show the high recognition rate and a low training period. The proposed method can be applied to high speed banknote counting machines. By applying the continuous same colured area recognition algorithm to the face value of the banknote, it can extract distinctive data to classify the kind of banknotes, as the area is located in the different positions on each kind of banknotes.

Paper Currency Recognition Using Gaussian Mixture Models based on Structural Risk Minimization

This paper presented by Fan-Hui Kong, Ji-Quan Ma, Jia-Feng Liu in August,2006 at IEEE Conference. [20]

This paper presents paper currency recognition using GMM based on Structural Risk Minimization (SRM). By selecting the proper number of the components with SRM, the system can overcome the demerit by the number of the Gaussian components selected artificially. A total number of 8 bill types including 5, 10(new and old model),20, 50(new and old model), 100(new and old model) are considered as classification categories experiments show that GMM which employs SRM is a more flexible alternative and lead to improved results for Chinese paper currency

recognition. Gaussian Mixture Model (GMM) is a popular tool for density estimation. The parameters of the GMM are estimated based on Maximum Likelihood principle (MLP) in almost all recognition system. However, the number of mixtures used in the model is important for determining the model's effectiveness; the general problem of mixture modeling is difficult when the number of components is unknown.

A Digit Recognition System for Paper Currency Identification Based on Virtual Instruments

This paper presented by Ji Quan,Dongping Quan,mengjie Zhang in 2006 At IEEE Conference.[1]

This paper describes an approach to digit recognition for the serial numbers on the Chinese currency banknotes. The approach consists of a number of components including image preprocessing, image binarisation, morphological filtering, segmentation, feature extraction and digit recognition. The approach was examined and tested on 5000 banknotes with 4000 digits and the approach achieved s single digit recognition rate of more than 99.60%, a serial number recognition rate of 99.50% , and a recognition time of 157ms. The results show that this approach is effective and efficient and can clearly meet the system requirements.

The results show that this approach is effective and efficient and can clearly satisfy the system requirements. The experiments also suggest that the current system is still quite sensitive to the noise of the image, but it could be improved by increasing the number of template digits in the training set, which will be further investigated in the future.

Bangladeshi Banknote Recognition by Neural Network with Axis Symmetrical Masks

This paper presented by Nadim Jahangir and Ahsan Raja Chowdhury in 2007 At IEEE Conference. Automated banknote recognition system can be a very good utility in banking systems and other field of commerce. It can also aid visually impaired people. Although in Bangladesh, bill money recognition machines are not common but it is used in other countries. [21]

In this paper, for the first time, it has proposed a Neural Network based recognition scheme for Bangladeshi banknotes. The scheme can efficiently be implemented in cheap hardware which may be very useful in many places. The recognition system takes scanned images of banknotes which are scanned by low cost optoelectronic sensors and then fed into a Multilayer Perceptron, trained by Backpropagation algorithm, for recognition. Axis Symmetric Masks are used in preprocessing stage which reduces the network size and gurantees correct recognition even if the note is flipped. Experimental results are presented which show that this scheme can recognize currently available 8 notes (1, 2, 5, 10, 20, 50, 100 & 500 Taka) successfully with an average accuracy of 98.57%.

Feature Extraction for Paper Currency Recognition

H.Hassanpour, A.Yaseri and G.Ardeshiri present this paper at IEEE computer society in 2007.This paper proposed a feature extraction method for paper currency detection.[22]

This paper proposes a new technique for paper currency recognition. In this technique, three characteristics of paper currencies including size, colour and texture are used in the recognition. By using image histogram, plenitude of different colures in a paper currency is computed and compared with the one in the reference paper currency. The Markov chain concept has been employed to model texture of the paper currencies as a random process. The method proposed in this paper can be used for recognizing paper currencies from different countries. In this method, using only one intact example of paper currency from each denomination is enough for training the system.

This method was tested this method on more than 100 denominations from different countries, and the system was able to recognize 95% of data, correctly In this method the system can be trained for a new denomination banknote by just introducing one intact example of the banknote to it. In addition the system may recognize the banknote on each side or any direction.

Design and Implementation of a Machine Vision Based but Low Cost Stand Alone System for Real Time Counterfeit Bangladeshi Bank Notes Detection

Dr. Kenji Yoshida, Mohammed Kamruzzaman, Faruq Ahmed Jewel, Raihan Ferdous Sajal presented this paper at IEEE computer society in December, 2007. This paper presents the design of a machine vision based system for real time detection of the counterfeit Bangladeshi bank notes. The proposed system works with the denominations of five hundred and one hundred taka. This system relies on a specific feature of the both five hundred and one hundred taka. [23]

The relied feature is not possible to replicate for the counterfeit makers or producers. There is no foreseeable likelihood that they would be capable to imitate this feature even within a pretty long time. The relied feature is the repeatedly printed "BANGLADESHBANK" on some portions of the notes using microprint technique. The proposed stand alone system captures the portions of the notes with a proprietary scanner called the Grid Scanner. The captured image is then processed by a microcontroller PIC-16F648A or ATMega88 (AVR). The microcontroller then determines the validity of the note based on an OCR technique by looking for the characters 'B', 'A' and 'N' in the scanned image. The success-rate of the counterfeit detection with properly captured image is 100% and the average processing time is 250 milliseconds with above mentioned microcontroller.

CHAPTER 3 DIGITAL IMAGE PROCESSING

3.1 INTRODUCTION

Image processing - a moving horizon! Walking towards a horizon is open ended. The horizon never gets any closer to you, but continually recedes from you. Thus it has been with the growth of image processing, as a technical discipline. Constant progress is being made - but the potential is far from exhausted. In the early years of image processing the concern was of basic phenomena, for example, making models for image data compression, image restoration and image enhancement. Currently there is a great interest in moving beyond physical phenomena and into the realms that are wrapped with psychology, perception and cognition. The research in this branch of image processing is often called as 'Image Understanding'.

The field of a digital-image processing has experienced dramatic growth and increasingly widespread applicability in recent years. Fortunately, advances in computer technology have kept pace with the rapid growth in volume of image data in these and other applications. Digital-image processing has become economical in many fields of research and in industrial and military applications. While each application has requirements unique from the others, all are concerned with faster, cheaper, more accurate, and more extensive computation. The trend is toward real-time and interactive operations, where the user of the system obtains preliminary results within a short enough time that the next decision can be made by the human processor without loss of concentration on the task at hand. An example of this is the obtaining of two-dimensional (2-D) computer-aided tomography (CAT) images. The ability to place earth

oriented sensors into orbit, because of its large economic potential has received considerable research emphasis, and many operational systems have been evolved. Land remote sensing has been evolving since 1960s and its various applications in urban land utilization, forestry and food commodity production forecasting has been producing remarkable results. An off shoot of remote sensing by satellites has been the use of this data for military purposes.

The processing of two-dimensional data, or images, using a digital computer or other special digital hardware typically involves several steps. First, the image to be processed must be put in a format appropriate for digital computing. This image acquisition step can be accomplished in a number of ways, depending on the application. Then the processing must be performed in order to extract the information of interest from the image(s). Finally, the imagery must be reformatted for human or machine viewing, storage, or hardcopy documentation.

3.2 Definition of Digital Image

An image is a 2D array of values representing light intensity. For the purposes of image processing, the term image refers to a digital image. An image is a function of the light intensity.

$$F(x,y)$$

Where f is the brightness of the point (x, y), and x and y represent the spatial coordinates of a picture element, or pixel. By convention, the spatial reference of the pixel with the coordinates (0, 0) is located at the top, left corner of the image. Notice in Figure 3.1 that the value of x increases moving from left to right, and the value of y increases from top to bottom.

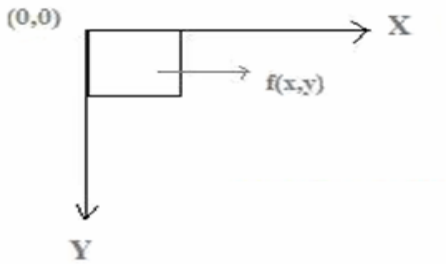


FIGURE 3.1: 2-D Image Representation

3.3 Defining Image Processing

The traditional view of image processing tends to embrace one or more of picture processing, pattern recognition, image interpretation and even graphics. 'Graphics' deals with the generation of images from non-pictorial information and covers diverse applications. In the order of increasing complexity, production of plots of functions, composition of displays for the computer games and scenes used in flight simulators are some of the examples of displays. Picture processing deals with problems in which both input and output are pictures. Over exposed, under exposed or blurred pictures can be improved with contrast enhancement techniques.

'Pattern Recognition' deals with methods for producing either a description of the input picture or -an assignment of the picture to a particular class. In a sense, it is the inverse problem of computer graphics. It starts with a picture and transforms it into an abstract description, a set of numbers, a string of symbols, etc. Further processing of these forms results in assigning the original picture to one of several classes. An automatic mail sorter that examines the postal code written on an envelope and identifies the digits is a typical example of the application. However, the term 'Image Processing' should be used as a catch all for all these activities and in a much broader context with the implicit understanding that the fundamental underlying activity is that of 'Information Processing'. Increasingly, in The future, much information is going to be represented, and subsequently processed, as digital images, be they X-ray scans, satellite images, video films or whatever. This is no more than a reflection of the fact that our information processing channel with the highest band width, by a long way, is the visual one. It is this primacy of images in information representations that renders a digression into the possible social impact of information processing.

3.4 Aspects of Image Processing

It is convenient to subdivide different image processing algorithms into broad subclasses. There are different for different tasks and problems. The aspects of image processing are image enhancement, image restoration and image segmentation.

- **Image Enhancement:** It is among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to

bring out detail that is obscured, or simply to highlight certain features of interest in an image. A familiar example of enhancement is when we increase the contrast of an image because "it looks better." It is important to keep in mind that enhancement is a very subjective area of image processing.

- **Image Restoration**: It is an area that also deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a "good" enhancement result.
- **Image Segmentation**: Segmentation procedures partition an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that required objects to be identified individually. On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. In general, the more accurate the segmentation, the more likely recognition is to succeed.

3.5 Applications

There are two compelling reasons why image processing will play an increasingly important role in future defense systems. These are the need for autonomous operation and the need to make greater use of the outputs from a diverse range of sophisticated sensors. Many of the techniques of digital image processing, or digital picture processing as it was often called, were developed in the 1960s at the Jet Propulsion Laboratory, MIT, Bell Labs, University of Maryland, and a few other places, with application to satellite imagery, wire photo standards conversion, medical imaging, videophone, character recognition, and photo enhancement. But the cost of processing was fairly high with the computing equipment of that era. In the 1970s, digital image processing proliferated, when cheaper computers and dedicated hardware became available. Images could then be processed in real time, for some dedicated problems such as television standards conversion. As general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and compute-intensive operations. With the fast computers and signal processors available in the 2000s, digital

image processing has become the most common form of image processing, and is generally used because it is not only the most versatile method, but also the cheapest. Some of its applications are:

- **Remote Sensing:** Remotely sensed imagery has now been available from the Landsat series of satellites for over 10 years in US. During this period, the data use has expanded from investigations performed by a group of sponsored investigators to attempted routine use by private companies, agribusiness, and resource planners in that country. The data is becoming a powerful tool in meeting the needs of the world in resource exploitation and management. New analysis methods are being developed to take advantage of the new types of data. It also provided other instruments such as radar altimeter and a microwave scatterometer. All these instruments are widely used in the military. Recent intelligence reports of the Iran-Iraq War and how the satellites were used for the reconnaissance of each other's territory is a case which brings to light the vulnerability of today's Armies to the remote sensing technology.
- **The Autonomous Vehicle:** One of the most important applications of image processing currently under progress by the US strategic computing programme, managed by the Department of Defense's Advanced Research Projects Agency (DARPA) is 'The Autonomous Vehicle'. The proposed vehicle will contain a small modular computer control system. Vision modules will be included that provide basic scene processing and object recognition capabilities. With vision modules as input devices, symbolic processor modules will then be able to directly process fragments of pictorial, graphic and three dimensional scenic images when further supported by rule based image understanding in a compact but powerful symbol processor and interfaced with specialized motor controlled systems, these vision modules will enable the computer controlled autonomous vehicle to 'See', to move about and to interact intelligently with its environment.
- **Medical Science:** It is used for inspection of images obtained from x-rays.MRI Or CAT scans. Analysis of cell images and chromosome karotypes.
- **Radar Science:** The dominant application of imaging in the microwave band is radar. The unique feature of imaging radar is its ability to collect data over virtually any region at any time, regardless of weather or ambient lighting conditions. Some radar waves can penetrate clouds, and under certain conditions

can also see through vegetation, ice, and extremely dry sand. In many cases, radar is the only way to explore inaccessible regions of the Earth's surface. Imaging radar works like a flash camera in that it provides its own illumination (microwave pulses) to illuminate an area on the ground and take a snapshot image. Instead of a camera lens, radar uses an antenna and digital computer processing to record its images. In a radar image, one can see only the microwave energy that was reflected back toward the radar antenna.

CHAPTER 4

MATLAB IMAGE PROCESSING TOOLBOX

4.1 INTRODUCTION

Image Processing Toolbox provides a comprehensive set of reference-standard algorithms and graphical tools for image processing, analysis, visualization, and algorithm development. It can restore noisy or degraded images, enhance images for improved intelligibility, extract features, analyze shapes and textures, and register two images. Most toolbox functions are written in the open MATLAB language, giving us the ability to inspect the algorithms, modify the source code, and create our own custom functions. Image Processing Toolbox supports engineers and scientists in areas such as biometrics, remote sensing, surveillance, gene expression, microscopy, semiconductor testing, image sensor design, colour science, and materials science. It also facilitates the learning and teaching of image processing techniques.

4.2 Key Features

- Image enhancement, including filtering, filters design, deblurring, and contrast enhancement.
- Image analysis, including feature detection, morphology, segmentation, and measurement.
- Spatial transformations and image registration.
- Image transforms, including FFT, DCT, Radon, and fan-beam projection.
- Support for multidimensional image processing.
- Support for ICC version 4 colour management system.

- Modular interactive tools, including ROI selections, histograms, and distance measurements.
- Interactive image and video display.
- DICOM import and export.

4.3 Importing and Exporting Images

Image Processing Toolbox supports images generated by a wide range of devices, including digital cameras, frame grabbers, satellite and airborne sensors, medical imaging devices, microscopes, telescopes, and other scientific instruments. It can visualize, analyze, and process these images in many data types, including single- and double-precision floating-point and signed or unsigned 8-, 16-, and 32-bit integers. There are several ways to import or export images into and out of the MATLAB environment for processing. It can use Image Acquisition Toolbox (available separately) to acquire live images from Web cameras, frame grabbers, DCAM-compatible cameras, and other devices. Using Database Toolbox (also available separately), it can access images stored in ODBC/JDBC-compliant databases. MATLAB supports standard data and image formats, including JPEG, TIFF, PNG, HDF, HDF-EOS, FITS, Microsoft Excel, ASCII, and binary files. It also supports multiband image formats, such as LANDSAT. Low-level I/O functions enables to develop custom routines for working with any data format. Image Processing Toolbox supports a number of specialized image file formats. For medical images, it supports the DICOM file format, including associated metadata, as well as the Analyze 7.5 and Interfile formats. The toolbox can also read geospatial images in the NITF format and high dynamic range images in the HDR format.

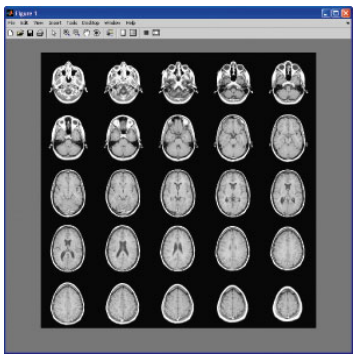


FIGURE 4.1: A Display of MRI Slices from a Series of DICOM files[24]

4.4 Pre and Post-Processing Images

Image Processing Toolbox provides reference-standard algorithms for pre- and post-processing tasks that solve frequent system problems, such as interfering noise, low dynamic range, out-of-focus optics, and the difference in colour representation between input and output devices.

4.4.1 Enhancing Images

Image enhancement techniques in Image Processing Toolbox enable to increase the signal-to-noise ratio and accentuate image features by modifying the colours or intensities of an image. It can:

- Perform histogram equalization
- Perform decorrelation stretching
- Remap the dynamic range
- Adjust the gamma value
- Perform linear, median, or adaptive filtering

The toolbox includes specialized filtering routines and a generalized multidimensional filtering function that handles integer image types, multiple boundary padding options, and convolution and correlation. Predefined filters and functions for designing and implementing its own linear filters are also provided.

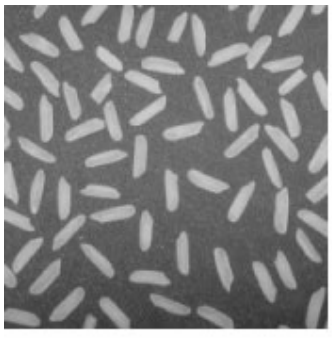


FIGURE 4.2: Original Image of a Rice Grain with Non uniformity Background Intensity[24].

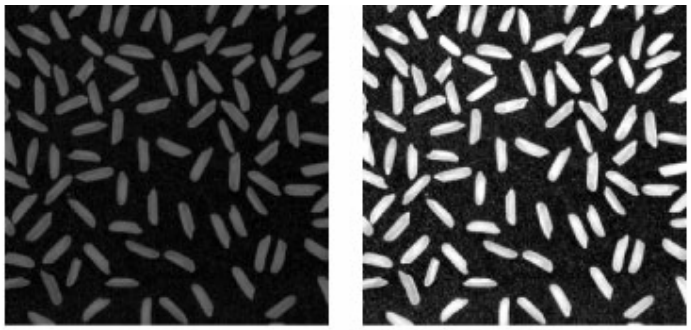


FIGURE 4.3(a) Result of Subtraction of Non uniformity from Original [24]
(b) Result of Automatic Thresholding. [24]

4.4.2 Deblurring Images

Image Processing Toolbox supports several fundamental deblurring algorithms, including blind, Lucy-Richardson, Wiener, and regularized filter deconvolution, as well as conversions between point spread and optical transfer functions. These functions help correct blurring caused by out-of-focus optics, movement by the camera or the subject during image capture, atmospheric conditions, short exposure time, and other factors. All deblurring functions work with multidimensional images.

4.4.3 Managing Device-Independent Colour

Image Processing Toolbox enables us to accurately represent colour independently from input and output devices. This is useful when analyzing the characteristics of a device, quantitatively measuring colour accuracy, or developing algorithms for several different devices. With specialized functions in the toolbox, it can convert images between device-independent colour spaces, such as RGB, XYZ, more flexibility and control, the toolbox supports profile-based colour space conversions using a colour management system based on ICC version 4. For example, it can import n-dimensional ICC colour profiles, create new or modify existing ICC colour profiles for specific input and output devices, specify the rendering intent, and find all compliant profiles on your machine.

4.4.4 Image Transforms

Transforms such as FFT and DCT play a critical role in many image processing tasks, including image enhancement, analysis, restoration, and compression. Image Processing Toolbox provides several image transforms, including DCT, Radon, and fan-beam projection. It can reconstruct images from parallel-beam and fan-beam projection data

(common in tomography applications). Image transforms are also available in MATLAB and in Wavelet Toolbox (available separately).

4.4.5 Image Conversions

Imaging applications often require conversion between data classes and image types. Image Processing Toolbox provides a variety of utilities for conversion between data classes, including single- and double-precision floating-point and signed or unsigned 8-, 16-, and 32-bit integers. The toolbox includes algorithms for conversion between image types, including binary, gray scale, indexed colour, and true colour. Specifically for colour images, the toolbox supports a variety of colour spaces such as YIQ, HSV, and YCrCb, Bayer pattern encoded, and high dynamic range images.

4.5 Analyzing Images

Image Processing Toolbox provides a comprehensive suite of reference-standard algorithms and graphical tools for image analysis tasks such as statistical analysis, feature extraction, and property measurement. Statistical functions let the analyze the general characteristics of an image by:

- Computing the mean or standard deviation
- Determining the intensity values along a line segment
- Displaying an image histogram
- Plotting a profile of intensity values

4.5.1 Edge-detection algorithms

It identifies object boundaries in an image. These algorithms include the Sobel, Prewitt, Roberts, Canny, and Laplacian of Gaussian methods. The powerful Canny method can detect true weak edges without being "fooled" by noise

4.5.2 Image segmentation algorithms

It determine region boundaries in an image. It can explore many different approaches to image segmentation, including automatic thresholding, edge-based methods, and

morphology-based methods such as the watershed transform, often used to segment touching objects.

4.5.3 Morphological operators

It enables to detect edges, enhance contrast, remove noise, segment an image into regions, thin regions, or perform skeletonization on regions. Morphological functions in Image Processing Toolbox include:

- Erosion and dilation
- Opening and closing
- Labeling connected components
- Watershed segmentation
- Reconstruction
- Distance transform

Image Processing Toolbox also contains advanced image analysis functions that helps to:

- Measure the properties of a specified image region, such as the area, center of mass, and bounding box
- Detect lines and extract lines segments from an image using the Hough transform
- Measure properties, such as surface roughness or colour variation, using texture analysis functions

4.6 Displaying and Exploring Images

Image Processing Toolbox provides a suite of tools for interactive image display and exploration. It can load an image from a file or from the MATLAB workspace, view image information, adjust the contrast, closely examine a region of pixels, and zoom and pan around the image. It can interactively place and manipulate ROIs, including points, lines, rectangles, polygons, ellipses, and freehand shapes. It can also interactively crop, create histograms and contours, and measure distances. The toolbox includes tools for displaying video and sequences in either a time-lapsed video viewer or image montage. Volume visualization tools in MATLAB let you create isosurface displays of multidimensional image data sets.

4.7 Spatial Transformations and Image Registration

Spatial transformations alter the spatial relationships between pixels in an image by mapping locations in an input image to new locations in an output image. Image Processing Toolbox supports common transformational operations, such as resizing, rotating, and interactive cropping of images, as well as geometric transformations with arbitrary-dimensional arrays. Image registration is important in remote sensing, medical imaging, and other applications where images must be aligned to enable quantitative analysis. Using Image Processing Toolbox, it can interactively select points in a pair of images and align the two images by performing a spatial transformation, such as linear conformal, affine, projective, polynomial, piecewise linear, or local weighted mean. You can also perform image registration using normalized 2-D cross-correlation.

4.8. Use of Image Processing in MATLAB

The question is how to handle images in Matlab? When working with images in Matlab, there are many things to keep in mind such as loading an image, using the right format, saving the data as different data types, how to display an image, conversion between different image formats, etc. These are some of the commands designed for these operations. Most of these commands require having the Image processing tool box installed with Matlab. To find out if it is installed, type `ver` at the Matlab prompt. This gives a list of what tool boxes that are installed on the system. The first section of this is quite heavy. The only way to understand how the presented commands work is to carefully work with the examples. A digital image is composed of pixels which can be thought of as small dots on the screen. A digital image is an instruction of how to colour each pixel. We will see in detail later on how this is done in practice. A typical size of an image is 512-by-512 pixels. It is convenient to let the dimensions of the image to be a power of 2. For example, 2^9=512. In the general case it can be say that an image is of size *m*-by-*n* if it is composed of *m* pixels in the vertical direction and *n* pixels in the horizontal direction.

Let us say that we have an image on the format 512-by-1024 pixels. This means that the data for the image must contain information about 524288 pixels, which requires a lot of

memory! Hence, compressing images is essential for efficient image processing. Fourier analysis and Wavelet analysis can help us to compress an image significantly.

4.9 Image Formats Supported By MATLAB

The following image formats are supported by Matlab:

- BMP
- HDF
- JPEG
- PCX
- TIFF

Most images find on the Internet are JPEG-images which is the name for one of the most widely used compression standards for images. If it has stored an image it can usually see from the suffix what format it is stored in. For example, an image named myimage.jpg is stored in the JPEG format and it will see later on that it can load an image of this format into Matlab.

4.10 Working formats in MATLAB

If an image is stored as a JPEG-image on the disc it will first read it into Matlab. However, in order to start working with an image, for example perform a wavelet transform on the image, it must convert it into a different format. This section explains four common formats.

4.10.1 Intensity image (gray scale image)

This is the equivalent to a "gray scale image" and this is the image in will mostly work.It represents an image as a matrix where every element has a value corresponding to how bright/dark the pixel at the corresponding position should be colured. There are two ways to represent the number that represents the brightness of the pixel: The double class (or data type). This assigns a floating number ("a number with decimals") between 0 and 1 to each pixel. The value 0 corresponds to black and the value 1 corresponds to white. The other class is called uint8 which assigns an integer between 0 and 255 to represent the

brightness of a pixel. The value 0 corresponds to black and 255 to white. The class uint8 only requires roughly 1/8 of the storage compared to the class double. On the other hand, many mathematical functions can only be applied to the double class.

4.10.2 Binary Image

This image format also stores an image as a matrix but can only colour a pixel black or white (and nothing in between). It assigns a 0 for black and a 1 for white.

4.10.3 Indexed Image

This is a practical way of representing colour images. An indexed image stores an image as two matrices. The first matrix has the same size as the image and one number for each pixel. The second matrix is called the colour map and its size may be different from the image. The numbers in the first matrix is an instruction of what number to use in the colour map matrix.

4.10.4 RGB Image

This is another format for colour images. It represents an image with three matrices of sizes matching the image format. Each matrix corresponds to one of the colours red, green or blue and gives an instruction of how much of each of these colours a certain pixel should use.

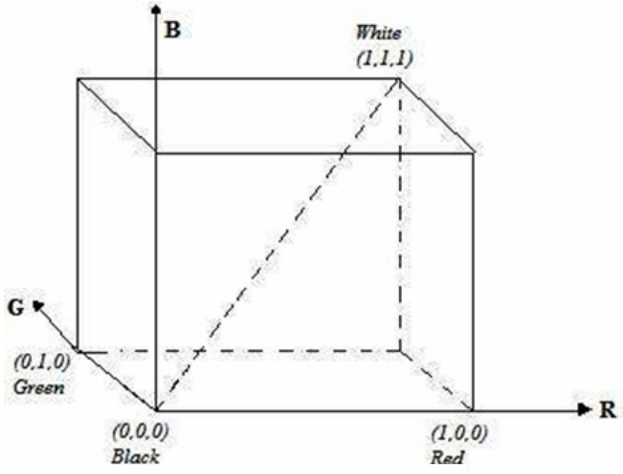


FIGURE 4.4: The Colour Cube for a RGB Colour Model. [25]

4.10.5 Multiframe image

In some applications we want to study a sequence of images. This is very common in biological and medical imaging where we might study a sequence of slices of a cell. For these cases, the multiframe format is a convenient way of working with a sequence of image

4.11 How to convert between different formats

The following table shows how to convert between the different formats given above. All these commands require the Image processing tool box.

4.11.1 Image Format Conversion

(Within the parenthesis just type the name of the image that to be convert.)

Operation:	**Matlab command:**
Convert between intensity/indexed/RGB format to binary format.	`dither()`
Convert between intensity format to indexed format.	`gray2ind()`
Convert between indexed format to intensity format.	`ind2gray()`
Convert between indexed format to RGB format.	`ind2rgb()`
Convert a regular matrix to intensity format by scaling.	`mat2gray()`
Convert between RGB format to intensity format.	`rgb2gray()`
Convert between RGB format to indexed format.	`rgb2ind()`

4.11.2 How To Convert Between Double And Uint8 ?

When it store an image, it should store it as a uint8 image since this requires far less memory than double. When it is processing an image (that is performing mathematical operations on an image) it should convert it into a double. Converting back and forth between these classes is easy.

```
I=im2double(I);
```

converts an image named `I` from uint8 to double.

```
I=im2uint8(I);
```

converts an image named `I` from double to uint8.

4.12 How to read files?

When it encounter an image we want to work with, it is usually in form of a file (for example, if it download an image from the web, it is usually stored as a JPEG-file). Once we are done processing an image, it may want to write it back to a JPEG-file so that it can, for example, post the processed image on the web. This is done using the imread and imwrite commands. Make sure to use semi-colon(;) after these commands, otherwise it will get lots of number scrolling on the screen. These commands require the Image processing tool box.

Operation:	**Matlab command:**
Read an image.	`imread()`
Write an image to a file.	`imwrite( , )`

4.13 Loading And Saving Variables In MATLAB

This section explains how to load and save variables in Matlab. Once it has read a file, it probably convert it into an intensity image (a matrix) and work with this matrix. Once we are done we may want to save the matrix representing the image in order to continue to work with this matrix at another time. This is easily done using the commands save and load. Note that save and load are commonly used Matlab commands, and works independently of what tool boxes that are installed.

Operation:	**Matlab command:**
Save the variable `X` .	`save X`
Load the variable `X` .	`load X`

4.14 How To Display An Image In MATLAB

Here are a couple of basic Matlab commands (do not require any tool box) for displaying an image.

Operation:	**Matlab command:**
Display an image represented as the matrix `X`.	`Imagesc(X)`
Adjust the brightness. s is a parameter such that -1<s<0 gives a darker image, 0<s<1 gives a brighter image.	`brighten(s)`
Change the colors to gray.	`colormap(gray)`

Sometimes image may not be displayed in gray scale even though it might have converted it into a gray scale

CHAPTER 5 NEURAL NETWORKS

5.1 INTRODUCTION

An Artificial Neural Network (ANN) is information processing that is originated from the biological nervous systems, such as the brain, process information. The key element of this system is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurones. This is true of ANNs as well. . By configuring virtual neural networks that function like the human brain, computers can perform tasks at greater speeds and with increased flexibility of application. These networks are capable of offering invaluable insights into the vast information that are common today.[29]

5.2 Historical Background

Neural network simulations appear to be a recent development. However, this field was established before the advent of computers, and has survived at least one major setback and several eras. Many important advances have been boosted by the use of inexpensive computer emulations. Following an initial period of enthusiasm, the field survived a period of frustration and disrepute. During this period when funding and professional

support was minimal, important advances were made by relatively few reserchers. These pioneers were able to develop convincing technology which surpassed the limitations identified by Minsky and Papert. Minsky and Papert, published a book (in 1969) in which they summed up a general feeling of frustration (against neural networks) among researchers, and was thus accepted by most without further analysis. Currently, the neural network field enjoys a resurgence of interest and a corresponding increase in funding. The first artificial neuron was produced in 1943 by the neurophysiologist Warren McCulloch and the logician Walter Pits. But the technology available at that time did not allow them to do too much.

Progress during the late 1950s and early 1980s was important to the re-emergence on interest in the neural network field. Several factors influenced this movement. For example, comprehensive books and conferences provided a forum for people in diverse fields with specialized technical languages, and the response to conferences and publications was quite positive. The news media picked up on the increased activity and tutorials helped disseminate the technology [29].Academic programs appeared and courses were introduced at most major Universities (in US and Europe). Several new commercial with applications in industry and financial institutions are emerging. Significant progress has been made in the field of neural networks-enough to attract a great deal of attention and fund further research. Advancement beyond current commercial applications appears to be possible, and research is advancing the field on many fronts. Neural networks based chips are emerging and applications to complex problems developing. Clearly, today is a period of transition for neural network technology.

5.3 Why use neural networks?

Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. This expert can then be used to provide projections given new situations of interest and answer "what if" questions. Other advantages include:

1. Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.
2. Self-Organization: An ANN can create its own organization or representation of the information it receives during learning time.
3. Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
4. Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage.

5.4 Neural networks versus conventional computers

Neural networks take a different approach to problem solving than that of conventional computers. Conventional computers use an algorithmic approach i.e. the computer follows a set of instructions in order to solve a problem. Unless the specific steps that the computer needs to follow are known the computer cannot solve the problem. That restricts the problem solving capability of conventional computers to problems that already understand and know how to solve. But computers would be so much more useful if they could do things that we do not exactly know how to do. Neural networks process information in a similar way the human brain does. The network is composed of a large number of highly interconnected processing elements (neurones) working in parallel to solve a specific problem. Neural networks learn by example. They cannot be programmed to perform a specific task. The examples must be selected carefully otherwise useful time is wasted or even worse the network might be functioning incorrectly.

The disadvantage is that because the network finds out how to solve the problem by itself, its operation can be unpredictable. On the other hand, conventional computers use a cognitive approach to problem solving; the way the problem is to solved must be known and stated in small unambiguous instructions. These instructions are then converted to a high level language program and then into machine code that the computer can understand. These machines are totally predictable; if anything goes wrong is due to software or hardware fault. Neural networks and conventional algorithmic computers are not in competition but complement each other. There are tasks are more suited to an

algorithmic approach like arithmetic operations and tasks that are more suited to neural networks. Even more, a large number of tasks, require systems that use a combination of the two approaches (normally a conventional computer is used to supervise the neural network) in order to perform at maximum efficiency.

The potential uses of neural network technology are a widely diversified market with many possibilities. The understanding of biological networks and learning increases, artificial neural networks will continue to advance. The potential of such a system is virtually limitless. These systems are not confined to being controlled by algorithms, as are typical computers. As a result, these systems are not limited in their numerous possibilities of applications. The highly intricate nature of nonlinear mathematics and the increased complexity of ever-growing numbers of interconnected processing elements, will make the evolution of artificial networks difficult but extremely functional.

5.5 Human and Artificial Neurons

Much is still unknown about how the brain trains itself to process information, so theories abound. In the human brain, a typical neuron collects signals from others through a host of fine structures called dendrites. The neuron sends out spikes of electrical activity through a long, thin stand known as an axon, which splits into thousands of branches. At the end of each branch, a structure called a synapse converts the activity from the axon into electrical effects that inhibit or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurons. When a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes.

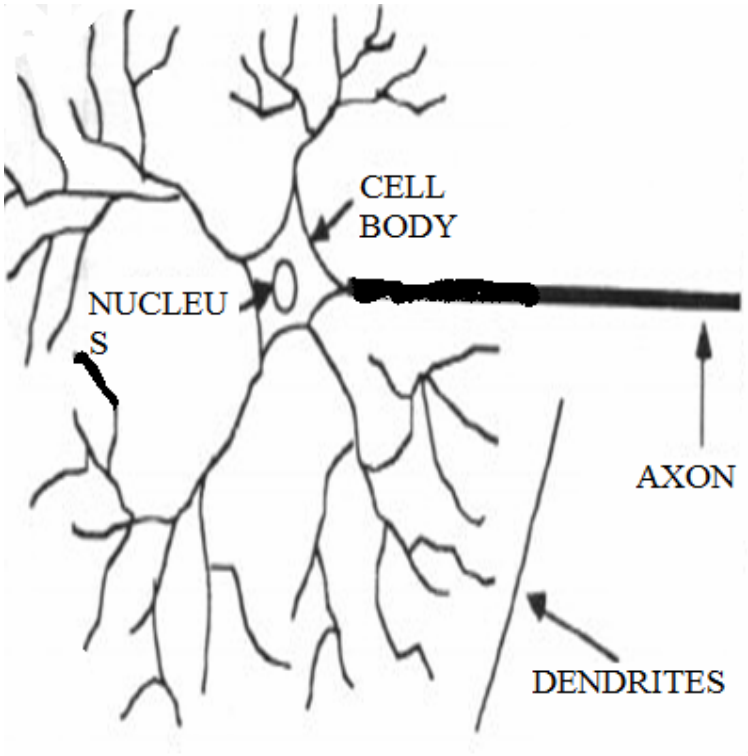


FIGURE 5.1: Components of a neuron[29]

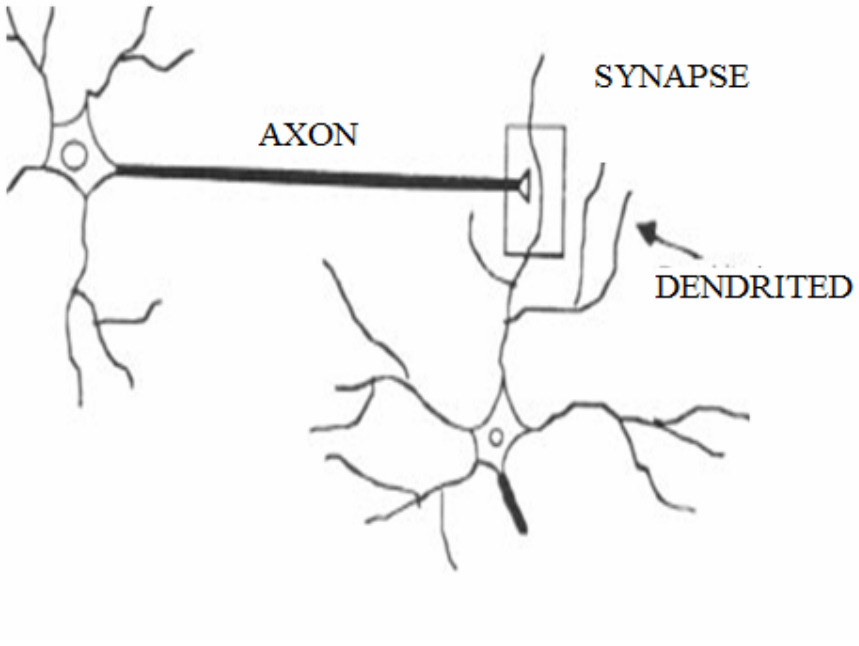


FIGURE 5.2: The synapse [29]

This is not to say that localization does not exist in the brain. Neurons in the superior temporal of the cerebral cortex, for example, respond selectively to faces. But there is no "grandmother cell", i.e., no cell that responds specifically to the face of someone's grandmother. Instead, each neuron has a different response pattern to a set of faces. Ensembles of neurons encode the response to identify a particular face. And an overlapping ensemble may identify another face. A very real difficulty of correlating artificial neural networks with biological ones lies in the way weights are modified in the former and synaptic strengths are modified in the latter. Weights are altered mathematically in a computer network, based on differences in values. Synaptic strengths, on the other hand, are modified in response to synaptic activity.

The back propagation model, in particular, is held to be biologically unrealistic insofar as it would require a supervisor and a violation of the unidirectional flow of information seen in axons. Some researchers have postulated parallel, backward-directed axons to return error information, but the modification of synaptic strength by these axons is still very hypothetical. These neural networks by first trying to deduce the essential features of neurons and their interconnections. We then typically program a computer to simulate these features. However because our knowledge of neurons is incomplete and our computing power is limited, our models are necessarily gross idealizations of real networks of neurons.

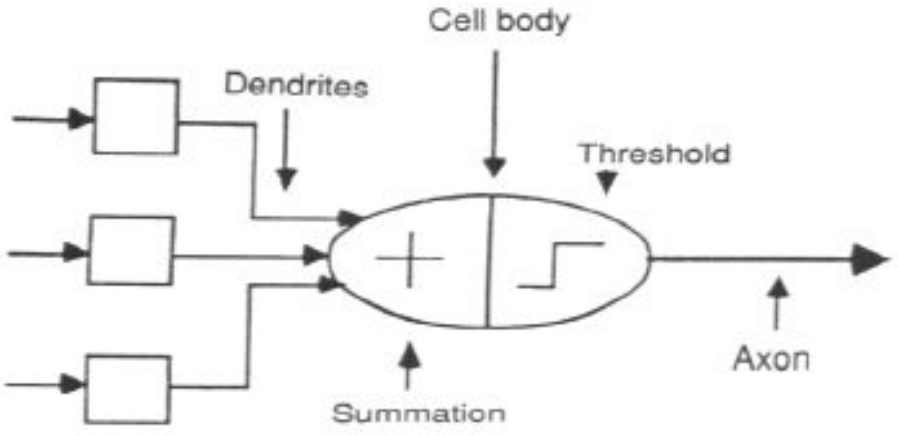


FIGURE 5.3: The neuron model[33]

5.6 Architecture of neural networks

5.6.1 Feed-forward networks

Feed-forward ANNs allow signals to travel one way only; from input to output. There is no feedback (loops) i.e. the output of any layer does not affect that same layer. Feed-forward ANNs tend to be straight forward networks that associate inputs with outputs. They are extensively used in pattern recognition. This type of organisation is also referred to as bottom-up or top-down.

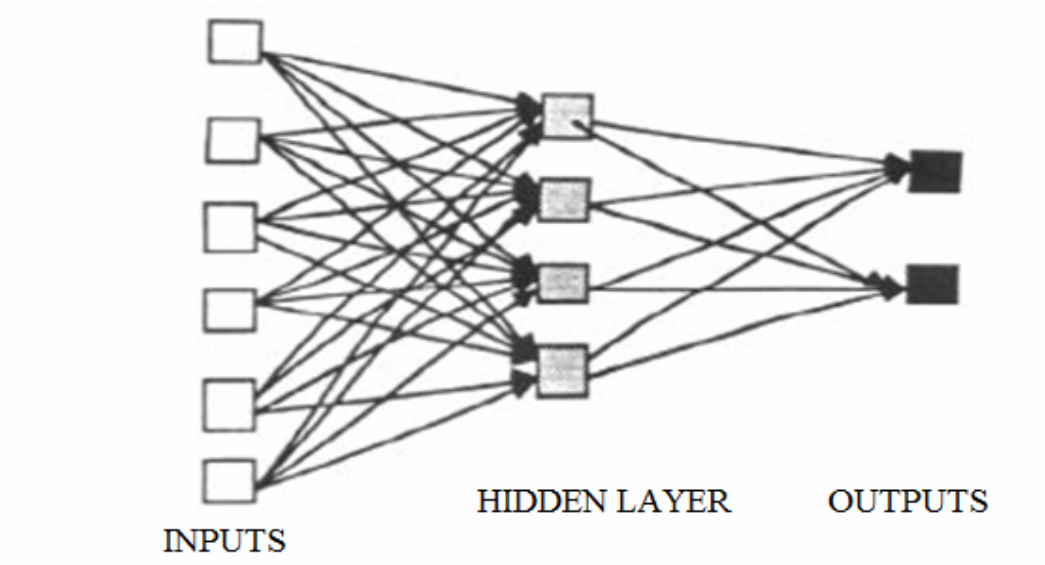


FIGURE 5.4:FEED FORWARD NETWORK[33]

5.6.2 Feedback networks

Feedback networks can have signals travelling in both directions by introducing loops in the network. Feedback networks are very powerful and can get extremely complicated. Feedback networks are dynamic; their 'state' is changing continuously until they reach an equilibrium point. They remain at the equilibrium point until the input changes and a new equilibrium needs to be found. Feedback architectures are also referred to as interactive or

recurrent, although the latter term is often used to denote feedback connections in single-layer organizations.

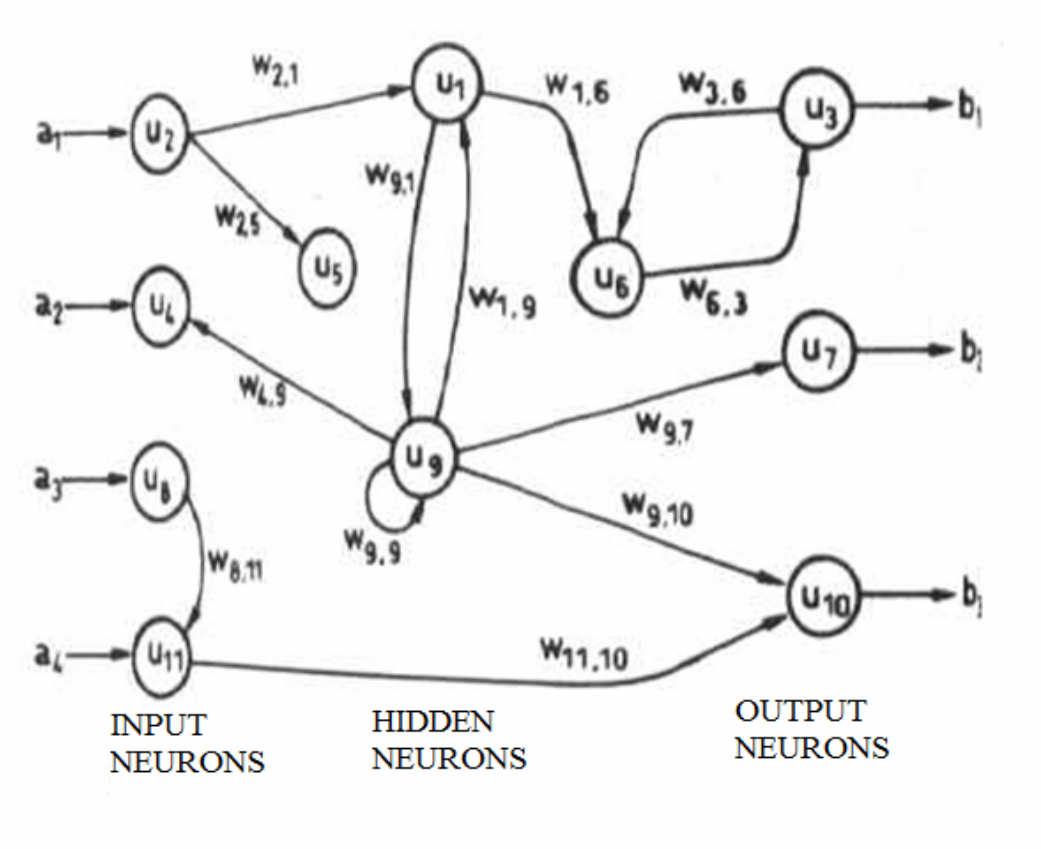


FIGURE 5.5:FEEDBACK NETWORK[29]

5.6.3. Network layers

The commonest type of artificial neural network consists of three groups, or layers, of units: a layer of "**input**" units is connected to a layer of "**hidden**" units, which is connected to a layer of **"output"** units.

1.The activity of the input units represents the raw information that is fed into the network.

2.The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units.

3. The behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and output units.

This simple type of network is interesting because the hidden units are free to construct their own representations of the input. The weights between the input and hidden units determine when each hidden unit is active, and so by modifying these weights, a hidden unit can choose what it represents. The single-layer organisation, in which all units are connected to one another, constitutes the most general case and is of more potential computational power than hierarchically structured multi-layer organisations. In multi-layer networks, units are often numbered by layer, instead of following a global numbering.

5.7 Back propagation Model

Backpropagation model -- a model which can solve many more difficult problems. Backpropagation has proven to be so powerful that it currently accounts for 80% of all neural network applications. In Backprop, a third neurode layer is added (the hidden layer) and the discrete thresholding function is replaced with a continuous (sigmoid) one. But the most important modification for Backprop is the generalized delta rule, which allows for adjustment of weights leading to the hidden layer neurodes in addition to the usual adjustments to the weights leading to the output layer neurodes.

5.8 Applications

Given this description of neural networks and how they work, what real world applications are they suited for? Neural networks have broad applicability to real world business problems. In fact, they have already been successfully applied in many industries. Since neural networks are best at identifying patterns or trends in data, they are well suited for prediction or forecasting needs including: [32]

1. Sales forecasting

2. Industrial process control

3. Customer research

4. Data validation

5. Risk management

6. Target marketing

But to give some more specific examples; ANN are also used in the following specific paradigms: recognition of speakers in communications; diagnosis of hepatitis; recovery of telecommunications from faulty software; interpretation of multimeaning Chinese words; undersea mine detection; texture analysis; three-dimensional object recognition; hand-written word recognition; and facial recognition.

5.7.1 Neural networks in Medicine

Artificial Neural Networks (ANN) is currently a 'hot' research area in medicine and it is believed that they will receive extensive application to biomedical systems in the next few years. At the moment, the research is mostly on modeling parts of the human body and recognizing diseases from various scans (e.g. cardiograms, CAT scans, ultrasonic scans, etc.).

Neural networks are ideal in recognizing diseases using scans since there is no need to provide a specific algorithm on how to identify the disease. Neural networks learn by example so the details of how to recognize the disease are not needed. What is needed is a set of examples that are representative of all the variations of the disease. The quantity of examples is not as important as the 'quantity'. The examples need to be selected very carefully if the system is to perform reliably and efficiently.

5.7.2 Neural Networks in Business

Business is a diverted field with several general areas of specialization such as accounting or financial analysis. Almost any neural network application would fit into one business area or financial analysis. There is some potential for using neural networks for business purposes, including resource allocation and scheduling. There is also a strong potential for using neural networks for database mining that is, searching for patterns implicit within the explicitly stored information in databases. Most of the funded work in this area is classified as proprietary. Thus, it is not possible to report on the full extent of the work

going on. Most work is applying neural networks, such as the Hopfield-Tank network for optimization and scheduling.

There is a marketing application which has been integrated with a neural network system. The Airline Marketing Tactician (a trademark abbreviated as AMT) is a computer system made of various intelligent technologies including expert systems. A feedforward neural network is integrated with the AMT and was trained using back-propagation to assist the marketing control of airline seat allocations. The adaptive neural approach was amenable to rule expression. Additionally, the application's environment changed rapidly and constantly, which required a continuously adaptive solution. The system is used to monitor and recommend booking advice for each departure. Such information has a direct impact on the profitability of an airline and can provide a technological advantage for users of the system.

While it is significant that neural networks have been applied to this problem, it is also important to see that this intelligent technology can be integrated with expert systems and other approaches to make a functional system. Neural networks were used to discover the influence of undefined interactions by the various variables. While these interactions were not defined, they were used by the neural system to develop useful conclusions. It is also noteworthy to see that neural networks can influence the bottom line.

CHAPTER 6 GRAPHICAL USER INTERFACE

6.1 INTRODUCTION

As the volume and complexity of data and results continues to grow with the increasing complexity of data sources and algorithms, the need for intuitive representations of that data and results becomes increasingly critical. The graphical representation of the results is often not only the most effective means of conveying the points of the study or work which has provided the data, but is in most cases an expectation of the audience of the work. Even as computing hardware continues to increase in capability, MATLAB continues to be one of the best applications available for providing both the computational capabilities of generating data and displaying it in a variety of graphical representations.

MATLAB is not just a computation and plotting package, it is a versatile and flexible tool which allows users with even the most elementary programming capabilities to produce sophisticated graphics and graphical user interfaces. This chapter introduces the basic elements of the MATLAB GUIs. The chapter does not contain a complete description of components or GUI features, but it does provide the basics required to create functional GUIs for the programs.

6.2 How a Graphical User Interface Works

A graphical user interface provides the user with a familiar environment in which to work. This environment contains pushbuttons, toggle buttons, lists, menus, text boxes,

and so forth, all of which are already familiar to the user, so that he or she can concentrate on using the application rather than on the mechanics involved in doing things. However, GUIs are harder for the programmer because a GUI-based program must be prepared for mouse clicks (or possibly keyboard input) for any GUI element at any time. Such inputs are known as events, and a program that responds to events is said to be event driven. The three principal elements required to create a MATLAB Graphical User Interface are:-

1. **Components**. Each item on a MATLAB GUI (pushbuttons, labels, edit boxes, etc.) is a graphical component. The types of components include graphical controls (pushbuttons, edit boxes, lists, sliders, etc.), static elements (frames and text strings), menus, and axes. Graphical controls and static elements are created by the function ***uicontrol***, and menus are created by the functions ***uimenu*** and ***uicontextmenu***. Axes, which are used to display graphical data, are created by the function ***axes***.

2. **Figures.** The components of a GUI must be arranged within a figure, which is a window on the computer screen. In the past, figures have been created automatically whenever we have plotted data. However, empty figures can be created with the function ***figure*** and can be used to hold any combination of components.

3. **Callbacks**. Finally, there must be some way to perform an action if a user clicks a mouse on a button or types information on a keyboard. A mouse click or a key press is an event, and the MATLAB program must respond to each event if the program is to perform its function. For example, if a user clicks on a button, that event must cause the MATLAB code that implements the function of the button to be executed. The code executed in response to an event is known as a call back. There must be a callback to implement the function of each graphical component on the GUI.

6.3 Creating and Displaying a Graphical User Interface

MATLAB GUIs are created using a tool called guide, the GUI Development Environment. This tool allows a programmer to layout the GUI, selecting and aligning the GUI components to be placed in it. Once the components are in place, the programmer can edit their properties: name, colour, size, font, text to display, and so forth. When guide saves the GUI, it creates working program including skeleton functions that the programmer can modify to implement the behavior of the GUI. When guide is executed, it creates the Layout Editor, shown in Figure 6.1. The large white area with grid lines is the *layout area,* where a programmer can layout the GUI. The Layout Editor window has a palate of GUI components along the left side of the layout area. A user can create any number of GUI components by first clicking on the desired component, and then dragging its outline in the layout area. The top of the window has a toolbar with a series of useful tools that allow the user to distribute and align GUI components, modify the properties of GUI components, add menus to GUIs, and so on. The basic steps required to create a MATLAB GUI are:

1. Decide what elements are required for the GUI and what the function of each element
2. will be. Make a rough layout of the components by hand on a piece of paper.
3. Use a MATLAB tool called guide (GUI Development Environment) to layout the components on a figure. The size of the figure and the alignment and spacing of components on the figure can be adjusted using the tools built into guide.
4. Use a MATLAB tool called the Property Inspector (built into guide) to give each component a name (a "tag") and to set the characteristics of each component, such as its
5. colour, the text it displays, and so on.
6. Save the figure to a file. When the figure is saved, two files will be created on disk with the same name but different extents. The fig file contains the actual GUI that you have created, and the M-file contains the code to load the figure and skeleton call backs for each GUI element.

Write code to implement the behavior associated with each call-back function.

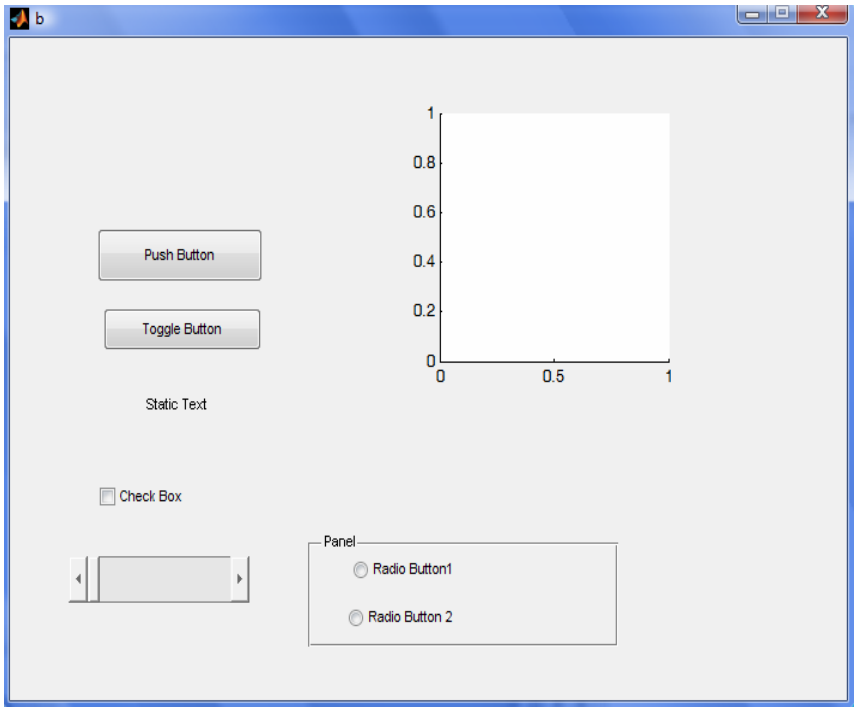


Figure 6.1 A Figure Window showing examples of MATLAB GUI elements.

6.4 Graphical User Interface Components

This section summarizes the basic characteristics of common graphical user interface components. It describes how to create and use each component, as well as the types of events each component can generate. The components discussed in this section are:-

- Text Fields
- Edit Boxes
- Frames
- Pushbuttons
- Toggle Buttons
- Checkboxes
- Radio Buttons
- Popup Menus
- List Boxes
- Slide

6.4.1 Text Fields

A text-field is a graphical object that displays a text string. It can specify how the text is aligned in the display area by setting the horizontal alignment property. By default, text fields are horizontally centered. A text field is created by creating a ***uicontrol*** whose style property is 'edit'. A text field may be added to a GUI by using the text tool in the Layout Editor. Text fields do not create callbacks, but the value displayed in the text field can be updated in a callback function by changing the text field's String property.

6.4.2 Edit Boxes

The editable text style is used in situations that require the user to enter strings of characters or numbers. The strings, in turn, are used by the application for which the interface has been built. The editable text item can be initialized with a string or string matrix that the user can delete, edit, or leave alone. Clicking anywhere within this object will change the mouse from a pointer to a text insertion indicator. Once the text insertion indicator is available, characters can be inserted by typing the desired keys or deleted by using the delete or backspace key. Portions or all of the text can be highlighted by click and dragging within the *uicontrol* item, to allow for quick string replacement or deletion. It is a good idea, whenever possible, to initialize the editable text *uicontrol* with the default value of the string so that the user does not always need to type in the most likely string.

6.4.3 Frames

A frame is a graphical object that displays a rectangle on the GUI.The use of frames to draw boxes around groups of logically related objects. A frame is created by creating a uicontrol whose style property is 'frame'. A frame maybe added to a GUI by using the frame tool in the Layout Editor. Frames do not generate callbacks. The frame makes the GUI more aesthetically pleasing by providing a solid that helps blend a set of uicontrols into one complete and cohesive interface. If the colors remain in their default values or are appropriately chosen, the edges of other uicontrol objects like static text, check boxes, and radio buttons will no longer be distinctly visible.

6.4.4 Pushbuttons

A pushbutton is a component that a user can click on to trigger a specific action. The pushbutton generates a callback when the user clicks the mouse on it. A pushbutton is created by creating a uicontrol whose style property is 'pushbutton'. A pushbutton may be added to a GUI by using the pushbutton tool in the Layout Editor. Push buttons have a 3-dimensional look that makes it appear as if they are being pressed when the user clicks on the object. In addition, they are very similar in appearance on all computing platforms.

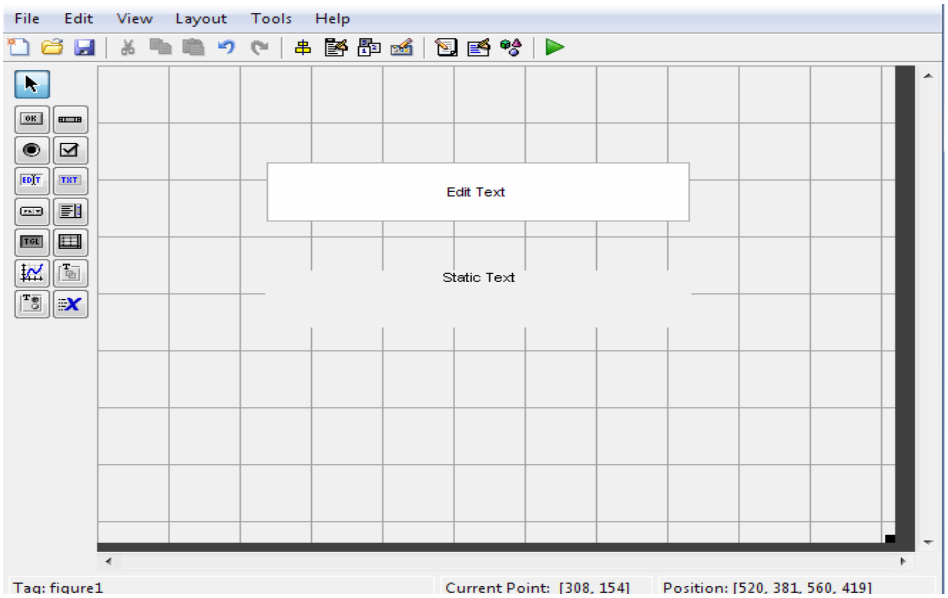


Figure 6.2 Layout of a simple GUI with an edit box and a text field.

6.4.5 Toggle Buttons

A toggle button is a type of button that has two states: on (depressed) and off (not depressed). A toggle button switches between these two states whenever the mouse clicks on it, and it generates a callback each time. The 'Value' property of the toggle button is set to max (usually 1) when the button is on, and min (usually 0) when the button is off. A toggle button is created by creating a uicontrol whose style property is toggle button. A toggle button may be added to a GUI by using the toggle button tool in the Layout Editor. This function locates the toggle button using the handles structure and recovers its state from the Value property. Then, the function locates the text field and displays the state in the text field.

6.4.6 Checkboxes and Radio Buttons

Checkboxes and radio buttons are essentially identical to toggle buttons except that they have different shapes. Like toggle buttons, checkboxes and radio buttons have two states: on and off. They switch between these two states whenever the mouse clicks on them, generating a callback each time. The 'Value' property of the checkbox or radio button is set to max (usually 1) when they are on, and min (usually 0) when they are off. Both checkboxes and radio buttons are illustrated in Figure 6.1.A checkbox is created by creating a uicontrol whose style property is 'checkbox', and a radio button is created by creating a uicontrol whose style property is 'radiobutton'. A checkbox may be added to a GUI by using the checkbox tool in the Layout Editor, and a radio button may be added to a GUI by using the radio button tool in the Layout Editor. Checkboxes are traditionally used to display on/off options, and groups of radio buttons are traditionally used to select among mutually exclusive options.

6.4.7 Popup Menus

Popup menus are graphical objects that allow a user to select one of a mutually exclusive list of options. The list of options that the user can select among is specified by a cell array of strings, and the 'Value' property indicates which of the strings is currently selected. A popup menu may be added to a GUI by using the popup menu tool in the Layout Editor.

6.4.8 List Boxes

List boxes are graphical objects that display many lines of text and allow a user to select one or more of those lines. If there are more lines of text than can fit in the list box, a scroll bar will be created to allow the user to scroll up and down within the list box. The lines of text that the user can select among are specified by a cell array of strings, and the' Value' property indicates which of the strings are currently selected. A list box is created by creating a uicontrol whose style property is 'listbox'. A list box may be added to a GUI by using the listbox tool in the Layout Editor.

6.4.9 Sliders

Sliders are graphical objects that allow a user to select values from a continuous range between a specified minimum value and a specified maximum value by moving a bar with a mouse. The 'Value' property of the slider is set to a value between min and max depending on the position of the slider. A slider is created by creating a uicontrol whose style property is 'slider'. A slider may be added to a GUI by using the slider tool in the Layout Editor.

CHAPTER 7 PROPOSED APPROACH

7.1 INTODUCTION

There is no well-developed theory for feature extraction; mostly features are very application oriented and often found by heuristic methods and interactive data analysis. It is not possible to give an overview of such interactive feature extraction methods; in any specific problem such as, e.g., character or speech recognition, there is an accumulated knowledge of the most feasible ways to extract the relevant information. Speed and accuracy of processing are two important factors for feature extraction method. The accuracy may be more important than the speed. Currently, there are a number of techniques for feature extraction which using image processing.

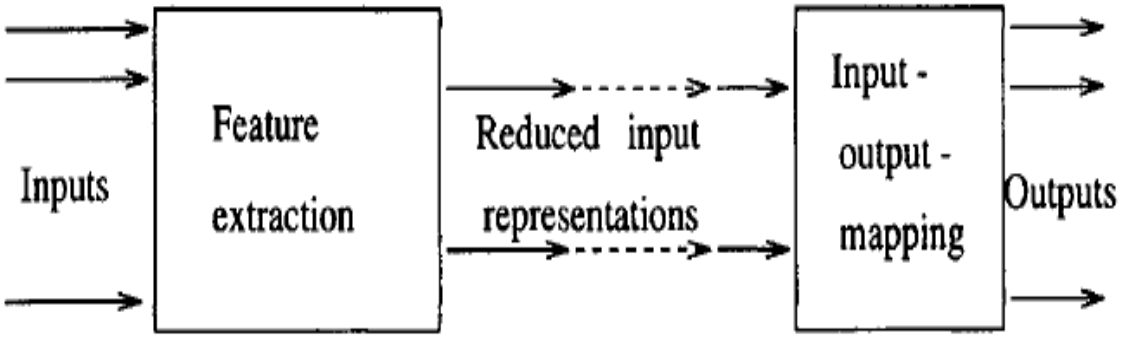


FIGURE 7.1: The Feature Extraction Approach [36]

7.2 BASIC THEORY

7.2.1 Thresholding

In gray level documents, the data extraction procedure often requires binarizing the images, which discards most of the noise and replaces the pixels in the characters and the pixels in the backgrounds with binary 0s and 1s, respectively. The feature extraction and the recognition performance of the characters largely depend on the quality of the data extracted. Thresholding method is used to separate object and background, which is divided image into two modes (Fig. 7.2). The way to resolve both categories is by assigning a thresholding value T. Each point (x,y) which have value *f(x,y)* > T is called point object, and each point (x,y) which have value *f(x,y)* < T is called background object. A threshold image *g(x,y)* is defined as,

$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) > T \\ 0 & \text{if } f(x,y) \leq T. \end{cases} \quad (1)$$

Pixel which have value 1 correspond the object and pixel which have value 0 correspond background. T is a constant. This approach is called global thresholding. Global thresholding algorithms use a single threshold for the entire image.

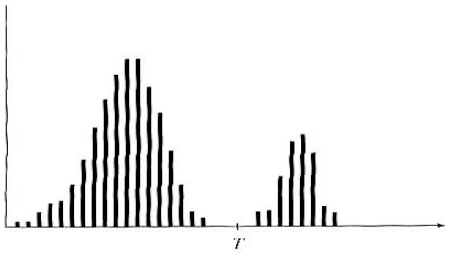


FIGURE 7.2: Histogram intensity [26]

The other approach of thresholding is local thresholding. Locally, adaptive binarization methods compute a designated threshold for each pixel based on a neighborhood of the pixel. Some of the methods calculate a smooth threshold surface over the entire image. If a pixel in the original image has a gray level higher than the threshold surface value at the corresponding location, it is labeled as background, otherwise it is labeled as print. Other locally adaptive methods do not use explicit thresholds, but search for object pixels in a

feature space such as gradient magnitude among others. Real-life documents are sometimes designed deliberately with stylistic, colorful, and complex backgrounds, causing difficulties in character extraction methods. While global thresholding techniques can extract objects from simple, uniform backgrounds at high speed, local thresholding methods can eliminate varying backgrounds at a price of long processing time.

7.2.2. Mathematics Morphology

Mathematics morphology is a method for image analysis that is based on nonlinear neighbourhood operation. The neighbourhood is called structuring element (SE). Mathematical morphology analyses images by using operators developed using set theory. It was originally developed for binary images and was extended to included grey-level data. The word morphology concerns shapes. In mathematical morphology, images are processed according to shape, by treating both as sets of points. In this way, morphological operators define local transformations that change pixel values that are represented as sets. The basic operations are erosion and dilation. Dilation performs a maximum on the SE which produces a growing of the brighter region. Erosion performs a minimum on the SE which produces a growing of the darker Region. Erosion and dilation have very few practical uses. Usually, they are combined into another two operations:

A. Opening is the combination of erosion dilation with the same SE. This operation can erase white holes on the object.

B. Closing is the combination of dilation erosion with the same SE. This operation can remove black holes on white objects.

7.3 SYSTEM DESIGN

The system is designed by applying image Processing toolbox and other related Matlab toolboxes. This system is divided into some section in order to support the future recognition process .The proposed approach is divided into following parts :-

7.3.1. Image Preprocessing

In order to feature extraction of paper currencies effectively, the currency images are collected with appropriate spatial resolutions and brightness resolution, where the spatial resolution describes how many pixels comprise a digital image or how many dots are in each inch of a digital image. Every pixel in a digital image represents the intensity of the original image at the spatial location where it was sampled. The concept of the brightness resolution addresses how accurately the digital pixel's brightness can represent the intensity of the original image. With higher brightness resolution, a digital image appears more natural and more continuous, in which more information is included in it. As the brightness resolution decreases, the image appears coarser and more mechanical. The conversion of paper-based documents to electronic image format is an important process in computer systems for automated document delivery, document preservation, and other applications. The process of document conversion includes scanning, displaying, quality assurance, image processing, and text recognition. After document scanning, a sequence of data preprocessing operations are normally applied to the images of the documents in order to put them in a suitable format ready for feature extraction.

FIGURE 7.3: Original Currency Images.

7.3.2 Binarisation

Binarisation of images is to convert the given image into binary images by using the concept of thresholding and channel subtraction technique. The brief theory of thresholding and channel subtraction is described below:

7.3.2.1 Thresholding

During the thresholding process, individual pixels in an image are marked as “object” pixels if their value is greater than some threshold value (assuming an object to be brighter than the background) and as “background” pixels otherwise. This convention is known as threshold above. Variants include threshold below, which is opposite of threshold above; threshold inside, where a pixel is labeled "object" if its value is between two thresholds; and threshold outside, which is the opposite of threshold inside. The thresholding is of two types:

- Global Thresholding
- Local Thresholding

To extract the serial numbers as features from currency notes, it is necessary to first mask them. As observed, all serial numbers in Indian Currency have a consistent font, size and colour. Since the serial number colour is RED, we initiate the pre-processing for feature extraction, by extracting only the RED Channel information, hence only the serial numbers. To facilitate the next process and decrease the processing time, image is converted to BW (Black and white). Conversion is done by applying toolbox (function im2bw). The function has variable level (threshold) which is needed as thresholding value at conversion from RGB to BW. Determination of thresholding value is using global thresholding by applying function graythresh which able to define the compatible thresholding value.

7.3.2.2 Channel Subtraction

The alternative approach is to subtract an image from a known background before thresholding. This assumes that the background is known precisely, otherwise many more details than just the target feature will appear in the resulting image. Clearly, the subtraction will be unfeasible if there is noise on either image, and especially on both. In this approach, there is no implicit shape description, but if the thresholding process is sufficient, it is simple to estimate basic shape parameters, such as position. The subtraction approach is illustrated

in Figure 7.4(b). Here, we seek to separate or extract the walking subject from the background. We obtain most of the subject with some extra background just behind the subject's head. This is due to the effect of the moving subject on lighting. Also, removing the background removes some of the subject: the horizontal bars in the background have been removed from the subject by the subtraction process. These aspects are highlighted in the thresholded image Figure 7.4(c).

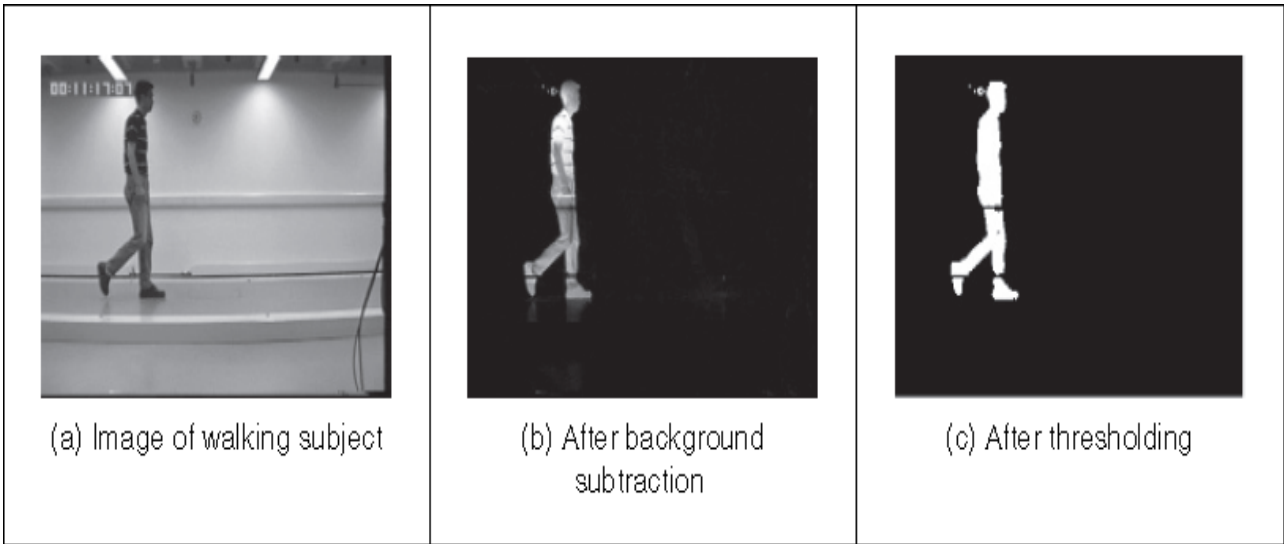


FIGURE 7.4**:** Shape extraction by subtraction and thresholding.[37]

Even though thresholding and subtraction are attractive because of simplicity and hence their speed, the performance of both techniques is sensitive to partial shape data, noise, variation in illumination and occlusion of the target shape by other objects. Accordingly, many approaches to image interpretation use higher level information in shape extraction, namely how the pixels are connected within the shape. In our approach we use the above theory on our currency image we get the following image after channel subtraction and thresholding.

FIGURE 7.5: Converted image (BW) after thresholding

7.3.3 Morphology Filtering

After image binarisation, the digits on the serial numbers of the banknotes often have some discontinuous particles, some further noise and some unexpected edges. To make the recognition task easier, we apply four morphological transformations to the binary images. Morphological transformations extract and alter the structure of particles in an image. We applied four binary processing functions erosion, dilation, opening and closing to remove noise.

7.3.4. Segmentation

Segmentation procedure means partitioning an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that required objects to be identified individually. On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. In general, the more accurate the segmentation, the more likely recognition is to succeed.

Based on the binary images processed by the morphological transformations, it will need to segment the small objects, the digits on the serial numbers, from the large banknote images. To implement this, first used the Sobel operator to the large binary banknote images in order to distinguish the regions of interest (ROIs) from the background, then extract the ROIs in order to obtain the small digits.

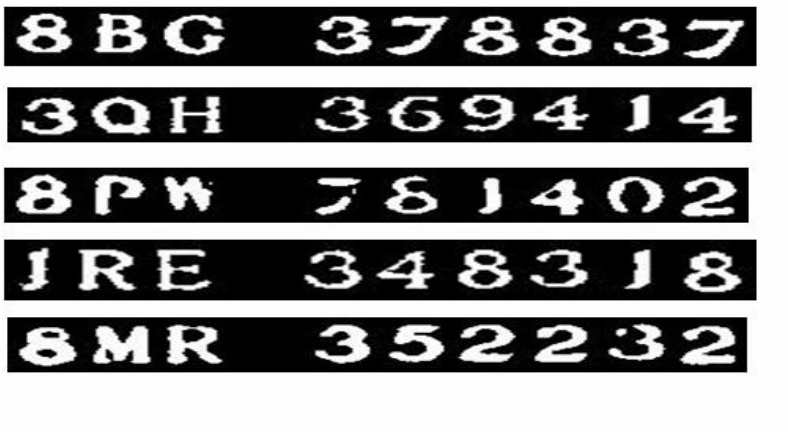


FIGURE 7.6: Extracted Serial Numbers of different Notes

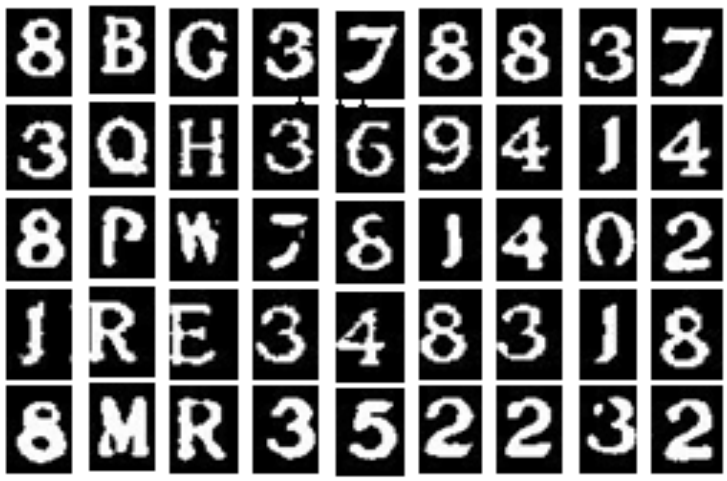


FIGURE 7.7: Segmented Serial Number Digits

7.3.5 Heuristic analysis of characters

The segmentation algorithm described above sometimes detects redundant elements, which do not correspond to proper characters. These elements are not reliably separable by traditional OCR methods, although they vary in size as well as in contrast, brightness or hue. Since the feature extraction methods do not consider these properties, there is a need to use additional heuristic analyses to filter non-character elements. The analysis expects all elements to have similar properties. Elements with considerably different properties are treated as invalid and excluded from the recognition process. The analysis deals with statistics of brightness and contrast of segmented characters. In addition, the heights of

detected segments are same for all characters. The sequence of steps can be assembled as follows:

1. Segment the serial number.
2. Analyse the brightness and contrast of segments and exclude faulty ones.
3. Analyse the hue and saturation of segments and exclude faulty ones.

FIGURE 7.8: Serial Number for heuristic analysis

If we assume that there are not big differences in brightness and contrast of segments, we can exclude the segments, which considerably differ from the mean. Let i^{th} segment of plate be defined by a discrete function $f_i(x,y)$,where w_i and h_i are dimensions of the element. We define the following statistical properties of an element. The global brightness of such segment is defined as a mean of brightness's of individual pixels:

$$p_b^{(i)} = \sum_{X=0}^{Wi} \sum_{Y=0}^{hi} f(x,y)$$

The global contrast of the i^{th} segment is defined as a standard deviation of brightness's of Individual pixels:

$$p_c^{(i)} = \sqrt{\frac{\sum_{x=0}^{w_i} \sum_{y=0}^{h_i} \left(p_b^{(i)} - f(x,y)\right)^2}{w_i \cdot h_i}}$$

The function f (x, y) represents only an intensity of grayscale images, but the additional heuristic analysis of colours can be involved to improve the recognition process. This analysis separates character and non-character elements on colour basis. If the captured snapshot is represented by a HSV colour model, we can directly compute the global hue and saturation of the segments as a mean of hue and saturation of individual pixels:

$$p_h^{(i)} = \sum_{x=0}^{w_i} \sum_{y=0}^{h_i} h(x,y) \; ; \; p_s^{(i)} = \sum_{x=0}^{w_i} \sum_{y=0}^{h_i} s(x,y)$$

Where $h(x, y)$ and $s(x, y)$ is a hue and saturation of the certain pixel in the HSV colour model. If the captured snapshot is represented by a RGB color model, there is need to transform it to the HSV model first. The formulas for individual properties of a character are as follows:

brightness (BRI)	$\frac{p_b^{(i)} - \overline{p}_b}{\overline{p}_b}$	Contrast (CON)	$\frac{p_c^{(i)} - \overline{p}_c}{\overline{p}_c}$
hue (HUE)	$\frac{p_h^{(i)} - \overline{p}_h}{\overline{p}_h}$	Saturation (SAT)	$\frac{p_s^{(i)} - \overline{p}_s}{\overline{p}_s}$

Table 7.1 shows the analysis of individual property of elements using the formulas described above.

Table 7.1: Individual Element Properties

Sr. No.	BRI	CON	HUE	SAT
Char1	-0.0043	-0.187	-0.6232	0.1608
Char2	-0.0372	0.0480	-0.5208	0.3701
Char3	-0.0063	-0.0018	-0.3898	0.0933
Char4	-0.0061	0.1987	0.2436	-0.0569
Char5	0.0018	0.1695	0.2508	-0.1310
Char6	-0.0099	0.0041	0.2561	-0.0127
Char7	0.0080	-0.0590	0.2817	-0.1564
Char8	0.0569	-0.2047	0.3037	-0.3488
Char9	-0.0029	0.0329	0.1978	0.08616

7.3.6 Feature Extraction

Feature extraction or selection is a pivotal procedure considerably for currency recognition, which effects on design and performance of the classifier intensively. If the differences of selected features are so large, it can easily construct a classifier with good recognition performance. It is difficult to get it with the contrary situation. The essential task of feature

extraction and selection is how to find the correspondingly effective features out of many pending features. Feature types are categorized as follows:

- Structural features: It describes geometrical and topological characteristics of a pattern by representing its global and local properties.
- Statistical features: Statistical features are derived from the statistical distribution of pixels and describe the characteristic measurements of the pattern.
- Global transformation: Global transformation technique transforms the pixel representation to a more compact form. This reduces the dimensionality of the feature vector and provides feature invariants to global deformation like translation, dilation and rotation.

The traditional approaches aim to derive local features by measuring specific image properties. The main target has been to estimate curvature: peaks of local curvature are corners, and analyzing an image by its corners is especially suited to images of artificial objects. The second area includes more modern approaches that improve performance by using region or patch-based analysis. By applying the feature extraction we get the following extracted feature of a digit.

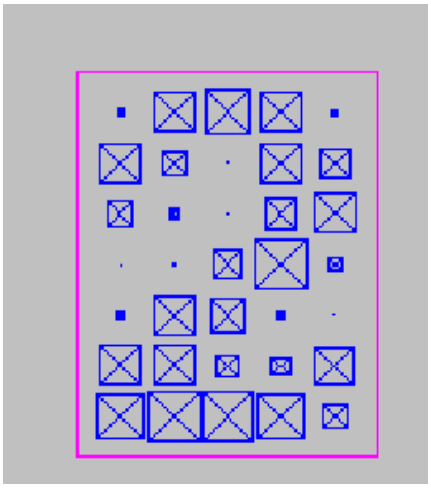


FIGURE 7.9: Extracted Numeric Digit

I have implemented the above discussed theory in my thesis for feature extraction of Indian currency notes. The block diagram for above proposed approach is given below:-

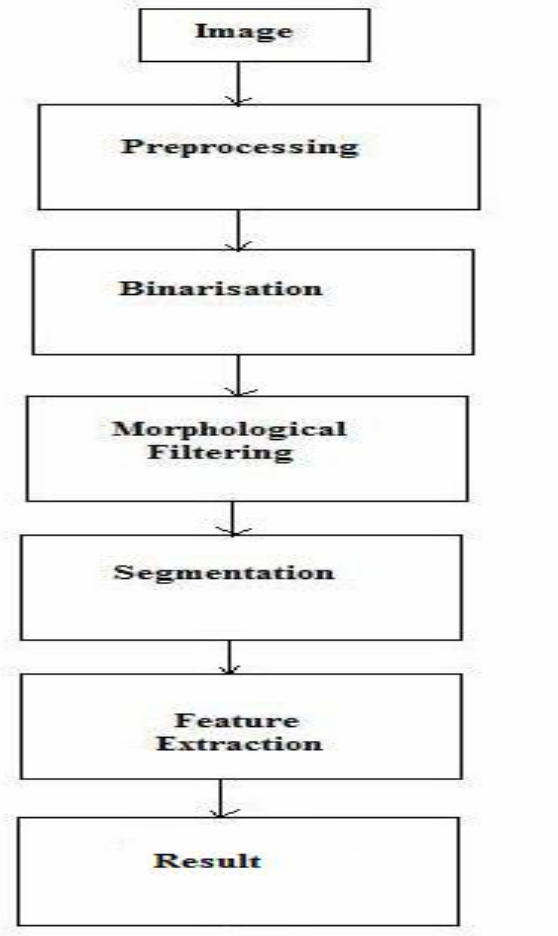
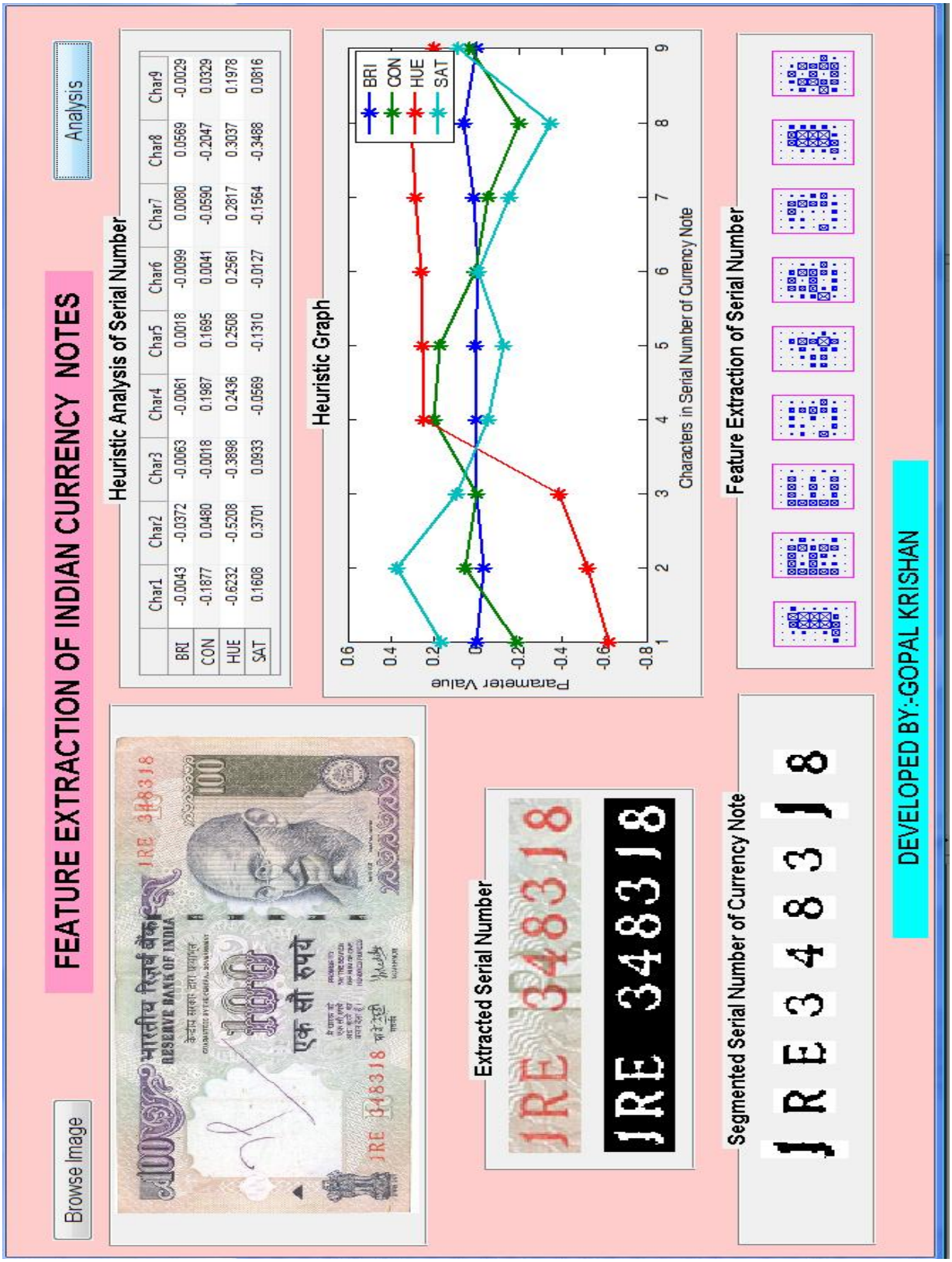


FIGURE 7.10: Feature extraction Approach

Graphical user interface designed for doing the above work is shown in figure 7.11. This GUI is designed in Matlab. It shows the various blocks of feature extraction of currency. Numerous Indian Currency notes of value 100 were analyzed in this work. The experimental results of the work carried out in this thesis are shown in next chapter. The random results display the extracted serial number, segmentation of serial number, Heuristic Analysis of serial number and feature extraction.



	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9
BRI	-0.0043	-0.0372	-0.0063	-0.0061	0.0018	-0.0099	0.0080	0.0569	-0.0029
CON	-0.1877	0.0480	-0.0018	0.1987	0.1695	0.0041	-0.0590	-0.2047	0.0329
HUE	-0.6232	-0.5208	-0.3898	0.2436	0.2508	0.2561	0.2817	0.3037	0.1978
SAT	0.1608	0.3701	0.0933	-0.0569	-0.1310	-0.0127	-0.1564	-0.3488	0.0816

FIGURE 7.11: GUI for Feature Extraction for Indian Currency

CHAPTER 8

EXPERIMENTAL RESULTS

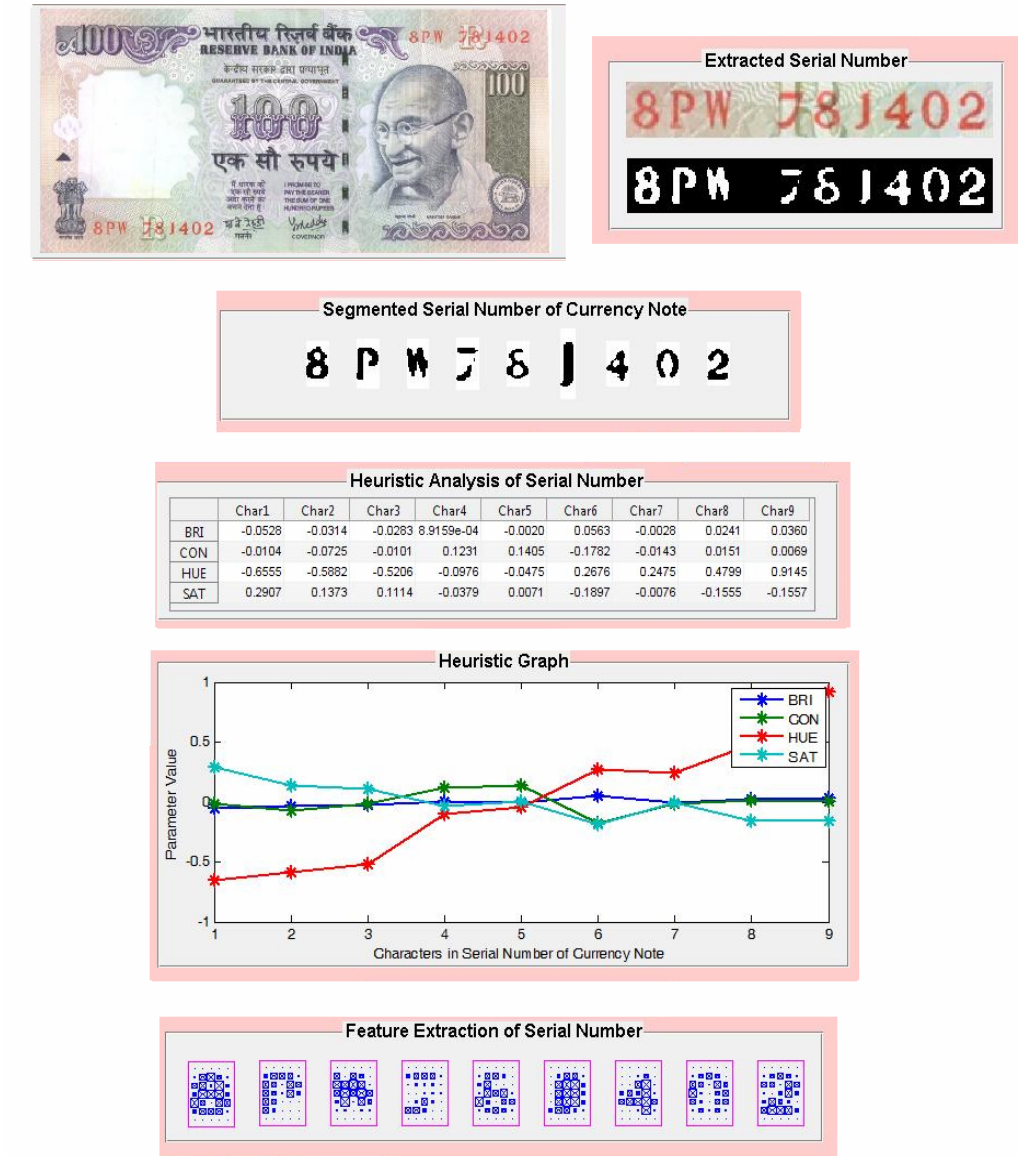
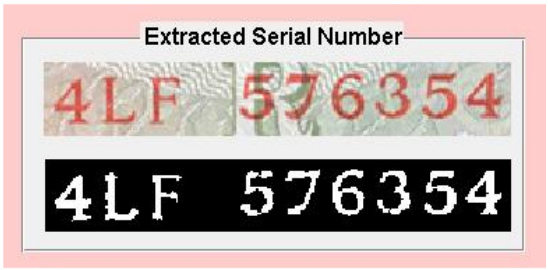
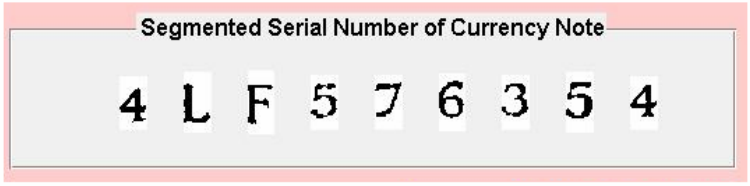


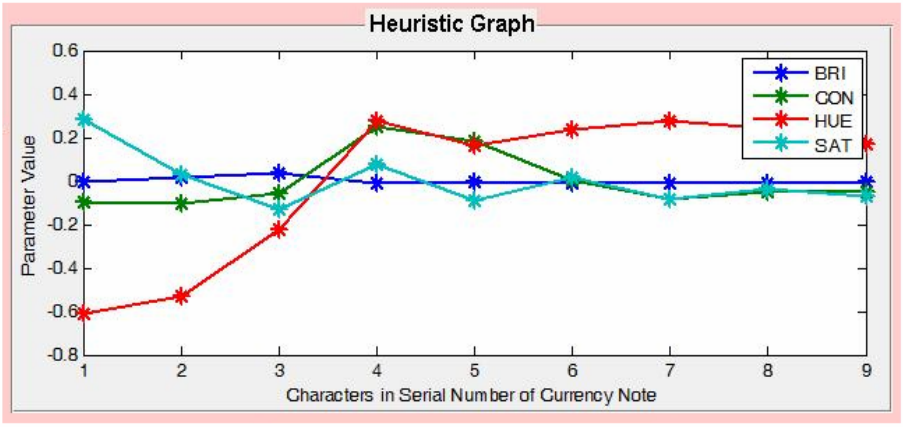
FIGURE8.1 (a): Analysis of 100 rupee currency note using proposed Approach





Heuristic Analysis of Serial Number

	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9
BRI	-0.0035	0.0183	0.0350	-0.0119	-0.0055	-0.0089	-0.0127	-0.0092	-0.0017
CON	-0.0933	-0.1041	-0.0595	0.2510	0.1852	0.0012	-0.0806	-0.0487	-0.0512
HUE	-0.6083	-0.5287	-0.2262	0.2754	0.1617	0.2349	0.2757	0.2456	0.1699
SAT	0.2826	0.0293	-0.1290	0.0746	-0.0868	0.0154	-0.0842	-0.0342	-0.0677



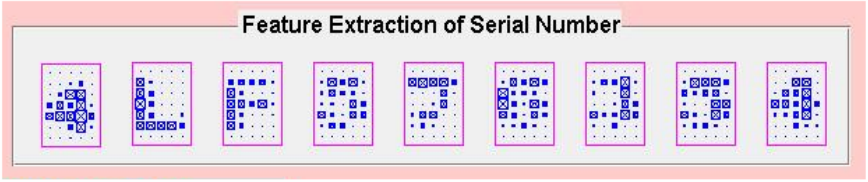
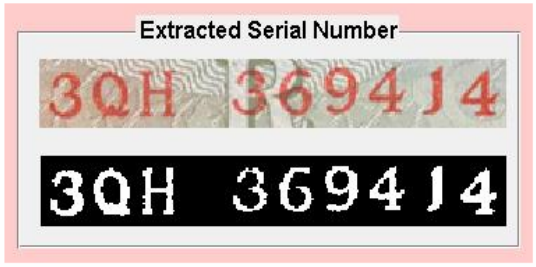
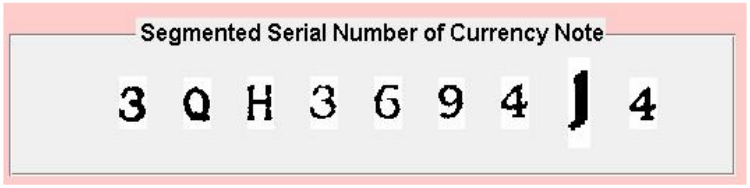
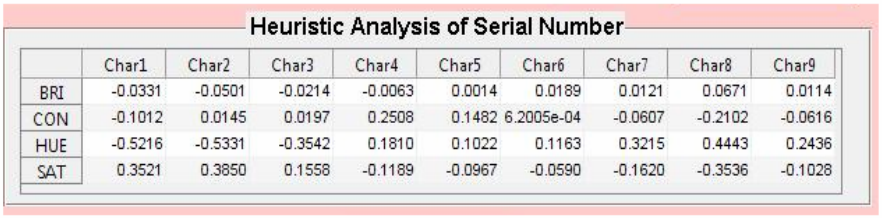


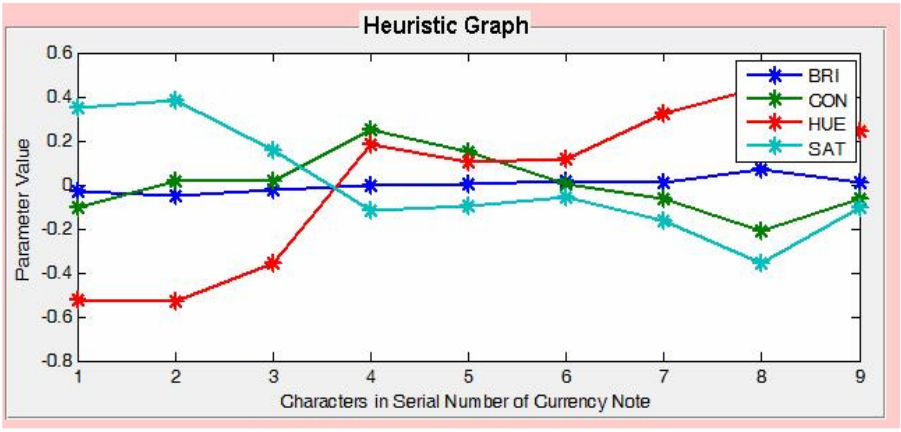
FIGURE 8.1 (b): Analysis of 100 rupee currency note using proposed Approach







	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9
BRI	-0.0331	-0.0501	-0.0214	-0.0063	0.0014	0.0189	0.0121	0.0671	0.0114
CON	-0.1012	0.0145	0.0197	0.2508	0.1482	6.2005e-04	-0.0607	-0.2102	-0.0616
HUE	-0.5216	-0.5331	-0.3542	0.1810	0.1022	0.1163	0.3215	0.4443	0.2436
SAT	0.3521	0.3850	0.1558	-0.1189	-0.0967	-0.0590	-0.1620	-0.3536	-0.1028



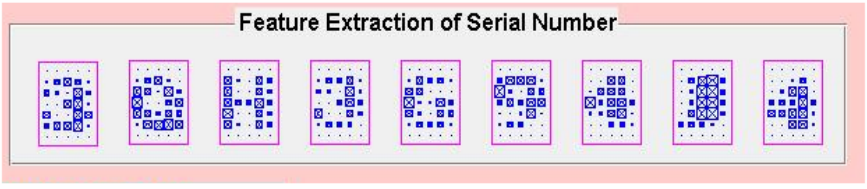


FIGURE 8.1 (c): Analysis of 100 rupee currency note using proposed Approach

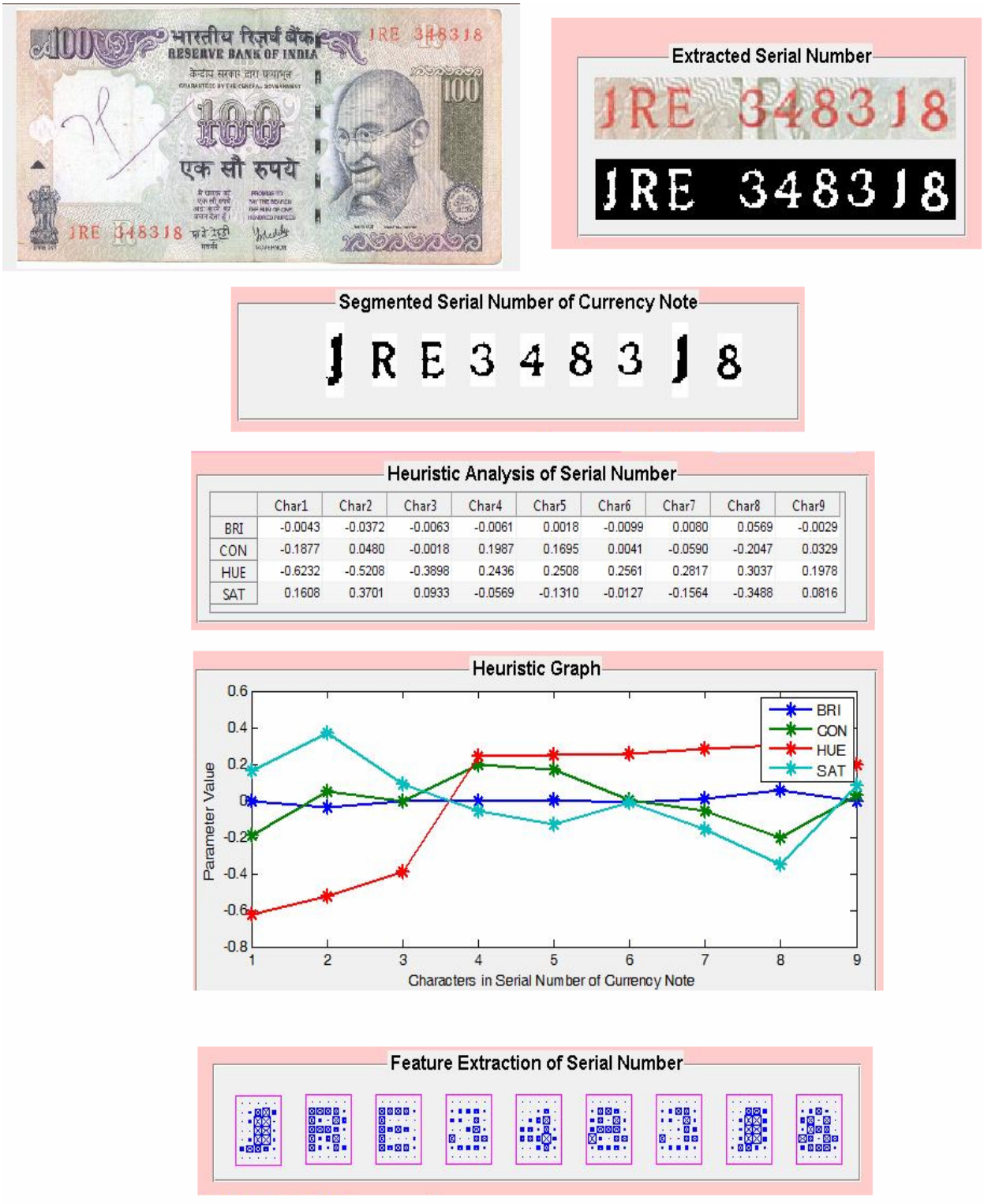


FIGURE 8.1 (d): Analysis of 100 rupee currency note using proposed Approach

Extracted Serial Number

9DK 774412

9DK 774412

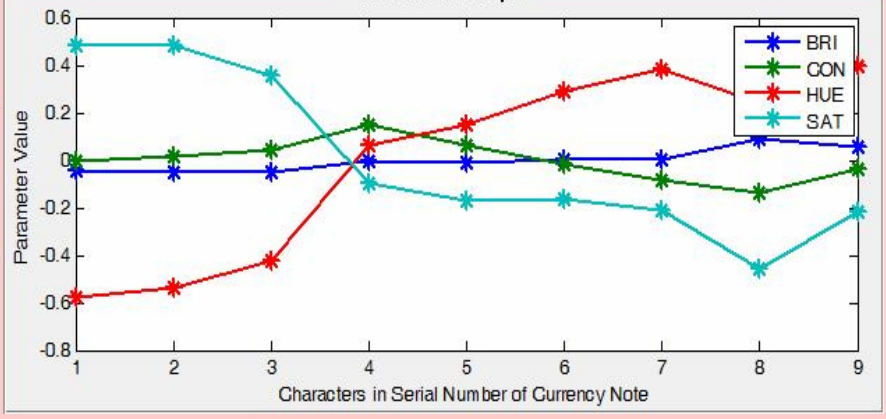
Segmented Serial Number of Currency Note

9 D K 7 7 4 4 J 2

Heuristic Analysis of Serial Number

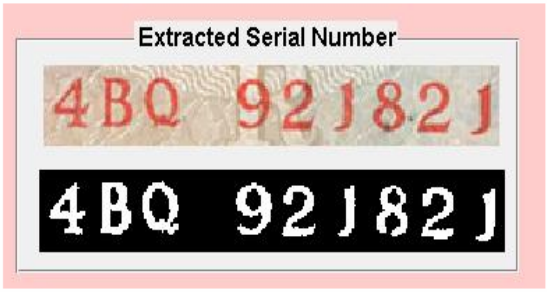
	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9
BRI	-0.0404	-0.0504	-0.0485	-0.0053	-0.0084	0.0031	0.0052	0.0885	0.0562
CON	-0.0047	0.0162	0.0453	0.1520	0.0621	-0.0143	-0.0805	-0.1365	-0.0396
HUE	-0.5746	-0.5341	-0.4225	0.0628	0.1525	0.2914	0.3866	0.2419	0.3960
SAT	0.4814	0.4829	0.3551	-0.0978	-0.1723	-0.1653	-0.2099	-0.4592	-0.2148

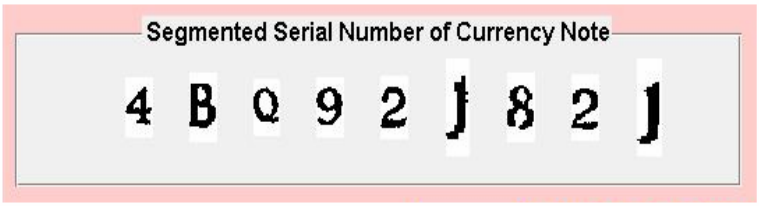
Heuristic Graph



Feature Extraction of Serial Number

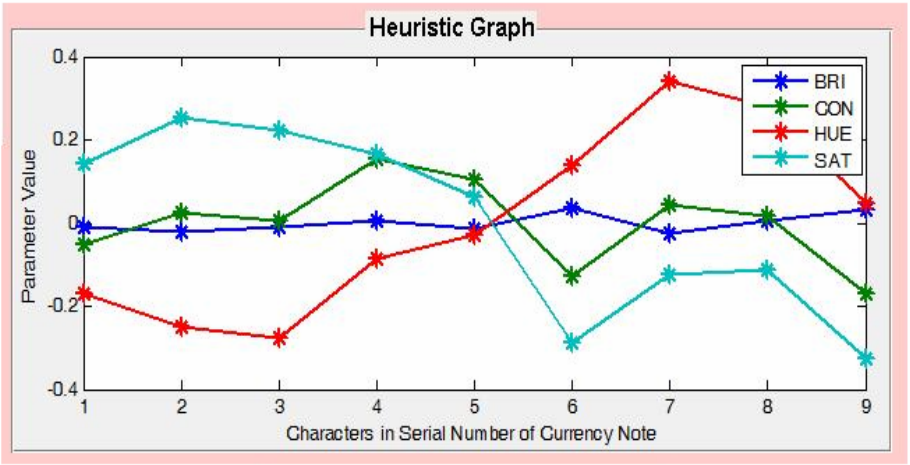
FIGURE 8.1 (e): Analysis of 100 rupee currency note using proposed Approach





Heuristic Analysis of Serial Number

	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9
BRI	-0.0092	-0.0195	-0.0108	0.0055	-0.0142	0.0350	-0.0262	0.0067	0.0329
CON	-0.0525	0.0234	0.0052	0.1537	0.1038	-0.1290	0.0457	0.0187	-0.1690
HUE	-0.1683	-0.2513	-0.2763	-0.0865	-0.0267	0.1386	0.3408	0.2808	0.0488
SAT	0.1435	0.2523	0.2231	0.1662	0.0630	-0.2869	-0.1241	-0.1112	-0.3259



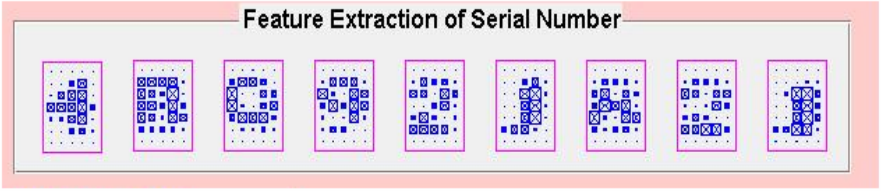


FIGURE 8.1 (f): Analysis of 100 rupee currency note using proposed Approach

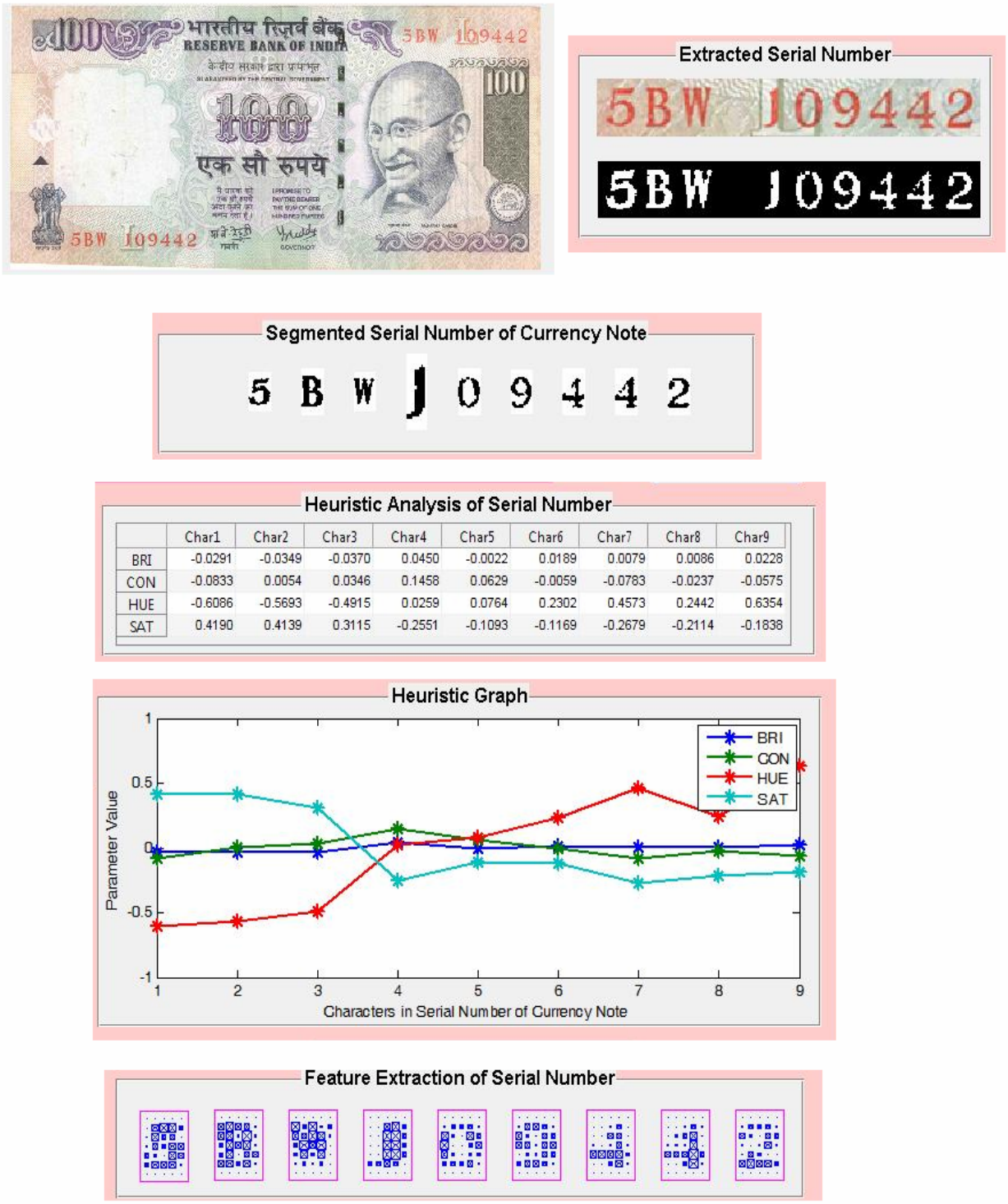
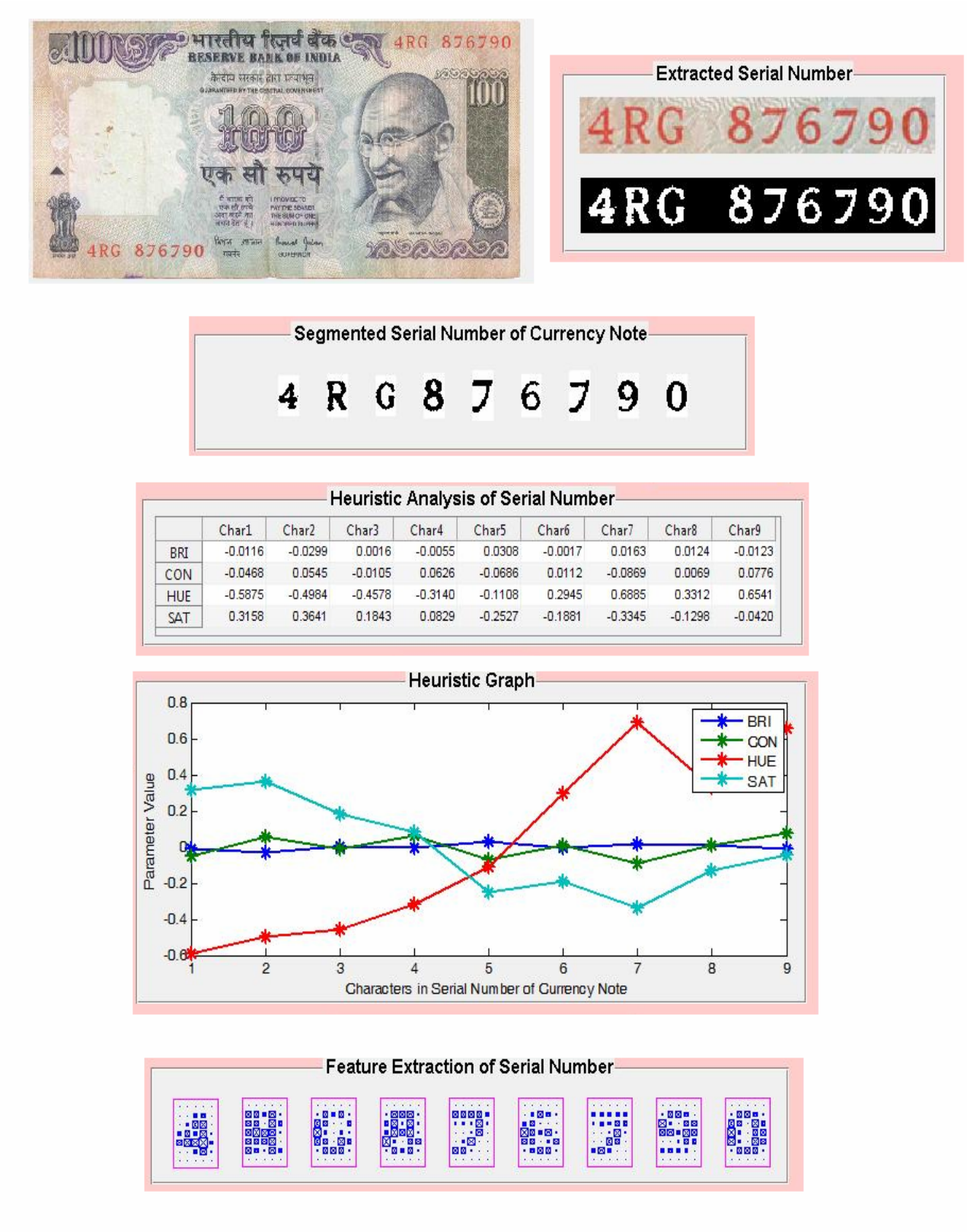


FIGURE 8.1 (g): Analysis of 100 rupee currency note using proposed Approach



	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9
BRI	-0.0116	-0.0299	0.0016	-0.0055	0.0308	-0.0017	0.0163	0.0124	-0.0123
CON	-0.0468	0.0545	-0.0105	0.0626	-0.0686	0.0112	-0.0869	0.0069	0.0776
HUE	-0.5875	-0.4984	-0.4578	-0.3140	-0.1108	0.2945	0.6885	0.3312	0.6541
SAT	0.3158	0.3641	0.1843	0.0829	-0.2527	-0.1881	-0.3345	-0.1298	-0.0420

FIGURE 8.1 (h): Analysis of 100 rupee currency note using proposed Approach

CONCLUSION

This thesis is an effort to suggest an approach for the feature extraction of Indian Currency Notes. Approaches suggested from the beginning of scanning a document to converting it to binary image, thresholding, morphological filtering and word segmentation has been successfully stated. One of the challenges faced in the character segmentation part is that two characters are sometimes joined together. There are even cases where a single character breaks apart. Solutions to these challenges are likely to be presented in future.

Also intensive Heuristic analysis of serial number characters across the note, suggests a particular trend in terms of values of hue and saturation, contrast and brightness. It can be concluded that while contrast and brightness are dependent on the extrinsic factors of sensor, hue and saturation are more likely dependent on the consistent pattern design of note.

In our current approach, the whole character itself was used as a feature. Selection of feature extraction method is single most important factor in achieving high recognition performance.

In future, an inclusion of consistent pattern design of the note can help extraction using Neural Network methods with them trained on feature vectors obtained from above system.

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1. Published paper at National Conference on Recent Emergences and Scope of Electronics Architecture held at Haryana Engineering College, Jagadhari on 19-20 February'2010 titled "**A Novel Method for Currency Recognition**".

2. Published paper at National Conference on Convergence of Technologies: Futuristic Approach held at Gurukul Vidyapeeth on 11th June'2010 titled "**Image Processing Based Feature Extraction of Indian Currency Notes**".