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on

Enhancement of the degraded document image and inscription images

Submitted in

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Submitted
by

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CERTIFICATE

This is to certify that the report titled **"Enhancement of the degraded document image and inscription images "** is a bonafide record of Major Project-II submitted by Monika (Roll no: 2K13/VLS/12) as the record of the work carried out by him under my guidance. The said work has not been submitted anywhere else for the award of any other degree or diploma.

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ABSTRACT

Historical documents such as old books and manuscripts have a high esthetic value and highly appreciated. These documents must always be kept and conserve in good condition by organization like museum and national archive because it contains information and messages that become the evidence of human existence and a living community in the past.

Unfortunately, there are some documents cannot be read due to quality problems like faded paper, ink expand, uneven color tone, torn paper and other elements disruption such as the existence of small spots and others.

It is very important to preserve these kind of artefact as it were become references, research resources and learning materials for grown civilization. Some original manuscripts were prohibited to be displayed to public due to their condition or confidential issues. But, to show and expose these materials in other form is become first priority for the museum, so people can learn about their predecessors.

The project is aimed to design and develop work deals with this problem of enhancing the image to make recognition possible and achievable over such images. The work deals with enhancing the multi-lingual inscriptions using NGFICA technique. Multi-lingual here refers to images of inscriptions collected from different sites which have texts in multiple languages.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

Introduction

1.1 Overview

Historical documents such as old books and manuscripts have a high aesthetic value and highly appreciated. These documents must always be kept and conserve in good condition by organization like museum and national archive because it contains information and messages that become the evidence of human existence and a living community in the past.

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Therefore, this study focuses to convert the degraded document image to a new form that is binary image, which means a black and white image.

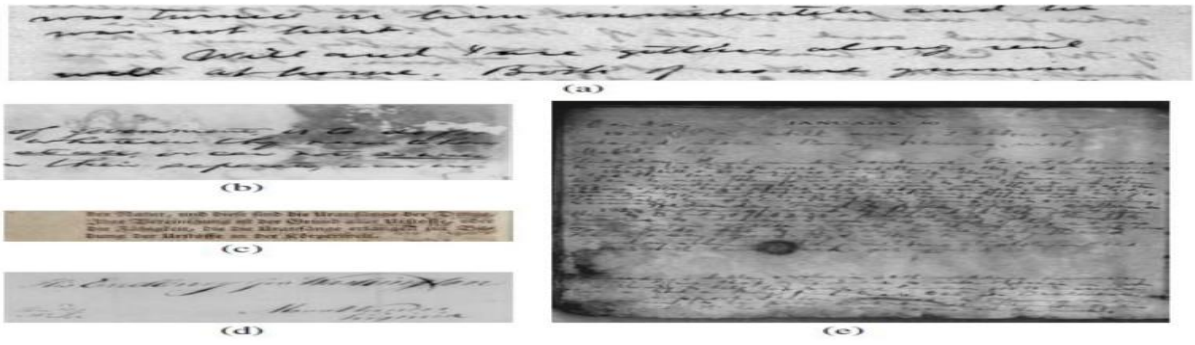

Figure 1.1 Degraded document images

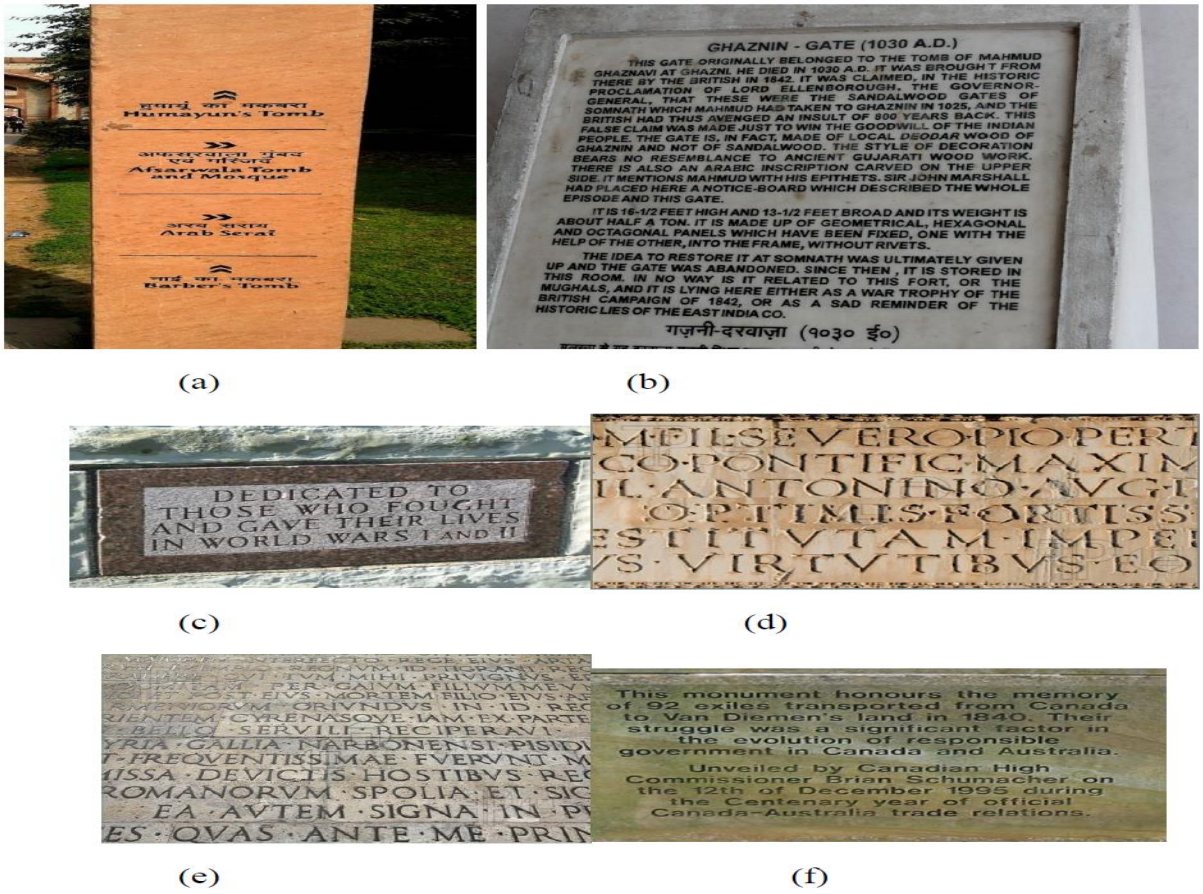

Figure 1.2 Inscription images of monuments

The use of inscription in the ancient world has importance in helping preserve information on those ancient culture for which we can find such artifacts. The use of inscription occurred in a variety of different ancient cultures. These ancient inscriptions provide insights into the history of the cultures that used them and they also act as a means of transmission of poetic and literary writings from the ancient to the modern world. Inscription refers to writing done on durable material, versus those on more commonly used material of later times such as paper and papyrus. When art is so engraved into durable material then that is known as epigraphy. Earliest writing most likely was done everywhere on such durable material, including ivory, bone, stones and clay. In modern times, society still uses inscription, typically when the intent is to provide for a permanent record.

Inscriptions at the historical monuments are a common site that gives a rare sneak-peek into the history attached with it. The text or graphics in inscriptions may symbolize a sequence of events

from the past or may represent a story or culture of that era. Lot of work has been done to conserve the monuments which are precious from heritage point of view.

Several methods exist for detection, localization and extraction of text but the problem intensifies when the background foreground is similar or textured or there exists very minimal difference between them. Such as the case of camera held images of inscriptions where the difference between background and foreground creates problem in reading and leading to the problem of text extraction. The images of inscriptions have problems like illumination, wrapping, minimal difference of background foreground, multi-lingual text, complex backgrounds and perspective projection distortion. Due to these challenges extraction of text becomes very difficult.

When such images are passed to commercial OCR's (Optical Character Recognition), the recognition rate is 0% in maximum cases. Recognition of text is possible only when the images have distinctive backgrounds and foregrounds. Thus, there arises need to enhance these images so that the background and foreground appear distinctive and clear.

The proposed work deals with this problem of enhancing the image to make recognition possible and achievable over such images. The work deals with enhancing the multi-lingual inscriptions using NGFICA technique. Multi-lingual here refers to images of inscriptions collected from different sites which have texts in multiple languages. Two such examples are shown in fig3.

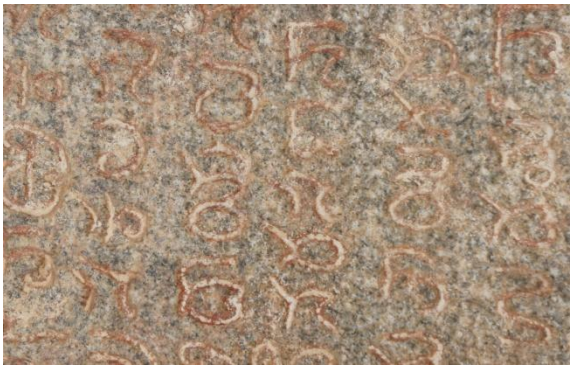


Figure 1.3 inscription from Hampi- heritage site and from an ancient temple in South

1.2 Related work

Text Extraction from document images has been of interest for the research community over a decade, but there has been very little work done in digitizing inscription images of historical monuments. High contrast edges between text and background is obtained using the red color component in the approach by Agnihotri et al. [4]. In [5], the "uniform color" blocks within the high contrast video frames are selected to correctly extract text regions. Kim et al. [6] used 64 clustered color channels for text detection where cluster colors are based on Euclidean distance in the RGB space. The method based on variance by M. Babu et al [4] makes use of the variance in the text and non-text regions. The variance is high at the text edges and vice versa. Variance method to extract the text as in [4] did not prove successful as the edges belonging to the text were not sharp and the distinction between text and non-text regions that was supposed to be there in order to get the desired results, was not present. The text in inscription images does not consist of a uniform color and there is low contrast between text and background thus making the use of [5] unsuitable. Simple edge-based approaches are also considered useful to identify regions with high edge density and strength. This method performs well if there is no complex background but the inscription images have complex background thus these methods cannot be used directly.

Garain et al [4] describe how to enhance image using FastICA algorithm which results in three independent components or layers which correspond to the contribution of text in them. The method is an enhancement method, which however is unable to enhance inscription dataset being dealt with in our method as FastICA is found inefficient in case of weak or highly spatially correlated sources[10]. More recently, its convergence has been shown to slow down or even fail in the presence of saddle points, particularly for short block sizes [11]. We have used natural gradient based independent component analysis learning algorithm with flexible nonlinearity as described in [12] which gives better results than other algorithms on the inscription images in our dataset. The above said methods were based on binarization, text extraction using variance or edge detection based methods. These methods depend upon pixel's threshold value based on difference between foreground and background part. But in case of

unclear and complex archaeological inscription images, there is no sharp distinction between foreground and background. Hence we propose an efficient multi-lingual inscription image enhancement method.

In our method we used NGFICA for minimizing the dependency between foreground and background of such inscription images and further the distinction enhancement technique based on global average is applied for enhancing the difference between foreground and background part of images.

1.3 Motivation

The work proposed here is a step towards preservation of our history. Digitalization helps in a better and efficient way of working. Taking the e.g. of inscriptions on the walls of monuments, digitalization can help in shaping the work of preservation in a better way. If the digital form of data is with us, then we can preprocess it, apply number of techniques for preserving them, extracting information out of them etc.

The main reason for tourism at ancient monuments is exploring past, learning the methods and techniques used by ancient people. After digitization, authorities looking after these monuments can build up their own databases where they can store the images, provide translation for the inscriptions in the user-desired language, provide an abstract about each sculpture and many such useful things that can help the past reach maximum people in the form convenient to them. For e.g. a blind person might be able to read inscriptions using Braille if there are some hand-held pads in front of these inscriptions, another tourist might like to know the history of a sculpture using ear phones or head phones.

All this can also be available online. That is, a user might just select his choice of sculpture or inscription from the dataset and he can translate it or read about it.

These are few practical applications and a major motivation behind this work.

1.4 Scope of work

As mentioned above, the monuments which bear such precious inscriptions on them are very old. So, it is very likely that the walls and stones of these historical monuments are decayed or broken or not in a condition that they can be read easily. Thus, the task of enhancing the text on them becomes more challenging due to bad illumination and decayed condition.

The enhancement of images in our work is done by first dividing the image into its independent components using ICA based NGFICA algorithm. Three independent components are referred as text layer, non-text layer and mixed layer. These three components have some content of text in them in an increasing order that is, the text layer has the highest text content and non-text layer has lowest text content. Then over these three components a consolidated average which is average of all the individual averages (of three components) is calculated. This consolidated average is referred as global average here. It is experimentally seen that the independent component whose individual average is farthest from the consolidated or global average, have a clearer distinction between background and foreground than the other components. This component is selected for further processing. Then various morphological and noise removal techniques are used to further enhance the image. The enhanced images are then passed to OCR for recognition. The results are discussed later.

Also, our work demonstrates the results of NGFICA algorithm and Fast-ICA algorithm, which are two variants of ICA algorithm. Fast ICA based enhancement proved efficient in the case of inscription images with a reasonable distinction between the background and foreground regions. But, in our case, most of the images do not have this distinctive property, making it difficult to enhance images (in order to perform text extraction and later text recognition). FICA seemed failing in the case of enhancement of inscription images of our dataset thus, we used NGFICA algorithm.

1.5 Areas of Research

The problem being used by the principle of ICA is the cocktail party problem. Using the same principle as in the case of inscription images we can device methods to extend this algorithm to other fields. Here are some of the fields in which ICA plays a major role but not anyway limited to these fields only.

1.5.1 EEG/MEG Data

ICA is used widely for EEG/MEG Data. EEG/MEG are a kind of brain data in which we use scalp data which are mutually independent and so using this principle of ICA where independence of the signals being mixed are important to successfully separate out the signals. Many literatures can be find in this field.

1.5.2 Financial Data

As we can see ICA is applied to the cocktail party problem where the motive to extract out the original voices from there observed mixtures but not only this we can also extend this principle for finding the hidden patterns in the data. So this being the usefulness of the principle of ICA when it comes to the field of financial data analysis. So using ICA we can do analysis on many things related to the financial data as like rate of foreign exchange or varying behavior of the stock exchange etc.

1.5.3 Telecommunication

ICA has a very useful meaning for the mobile applications like in CDMA field. Here the interference is avoided like when two signal interfere by mixing then the ICA can be used to separate out the signals as individual signals. However this can be told as semi ICA as CDMA devices some information in advance but as in ICA we don‟t have any previous knowledge about the original data in advance. So this way the importance of ICA is increased very much when it comes to this field of application.

1.5.4 Biomedical

ICA having very much popularity in the field of biomedical field. We can use ICA when the situation comes for separating out the multi channel signals which are used in the

biomedical field into their individual components as original. Many toolboxes can be found for the processing of the signal which are of the field of biomedical. So principle of ICA being the same we can separate out the biomedical signals which are individually independent to each other and having no correlation between them.

1.5.5 Image Processing

ICA can be very effectively applied to the field of image processing like one being the field of image compression/denoising. Other application of ICA being as in my project also to ecncrypt the images using the very known principle of ICA which proves to be a very useful technique for the security enhanching ability of the images being transmitted through the different channels from source to the destination. So overall as in my project I am using the double encryption technique one being through ICA which is inherent property and second being through the convention encryption scheme being generally used. So by increasing importance of multimedia data like that of images it will be very useful to use the technique of ICA for image encryption. This provides a simple ,fast and efficient approach to the image encryption and hence providing the security to the multimedia data as image being one kind of the multimedia data being used.

1.6 Description of structure of the project report

Here is the description of the organization of the project report I have made for my master‟s thesis.

Chapter 1

In this chapter the problem definition is described related to the problem being solved and motivation for the problem. Here also I have given the areas of research in which the principle of ICA which is a BSS technique is being used extensively. So overall the chapter gives the description of the principle of ICA being used in different field and the specific field of image processing.

Chapter 2

In this chapter I have given the whole literature being surveyed by me for the formulation of the origin of the problem and different methodology being used in my project and some similar kind of project done in the past as surveyed by the literature. Like the whole detail of ICA, BSS, Fast ICA and NGFICA are being mentioned.

Chapter 3

In this chapter I have given the proposed methodology for my thesis work done. The whole description of the principle of ICA and selective encryption technique for images is given. So overall it‟s a proposal for implementing the technique being used for my masters thesis.

Chapter 4

In this chapter I have given the implementation details of the project. Software, Hardware and description of the tools being used is given in this chapter.

Chapter 5

In this chapter I have given the description of result of the project and discussion is also being given in the section just for analysis of result to evaluate its efficiency and importance as well. I have discussed the ICA and Structral content parameter Technique being used for the project's completion.

Chapter 6

In this chapter the overall conclusion is being given for the purpose of further analysis and research for the same topic to extend. Future work and scope relating to the thesis is proposed and it is told how ICA can be useful for future research and development in the field of image processing.

Chapter 2

Literature Survey

I have done a literature survey for identifying and solving the problem issues of my project which is based on ICA principle which is a BSS technique. So on the whole I have divided the literature survey in four sections which are as follows.

2.1 Independent Component Analysis Principle

2.2 Blind Source Separation Technique

2.3 Fast ICA Techniques

2.4 NGFICA Technique

2.1 Independent Component Analysis Principle[8]

Independent Component Analysis (ICA) is a principle which is based on Blind Source Separation (BSS) technique. So the objective of a BSS scheme is to separate out the original individual components of mixtures without knowing the coefficient of mixing in advance. Mixtures may be of Audio signals, images, EEG/ MEG data, Financial Data, Biomedical data etc. So the interesting thing in this technique of BSS is that we don‟t the ratio in which the signals are being mixed but using the principle of ICA we are able to separate out the individual components from their observed mixtures. ICA now a days is being applied to various fields like in the field of signal processing, image processing, video processing etc. however the principle has been explored in detail and extensively whenever we talk about audio signals like speech, telecommunication, brain data, biomedical etc but whenever it comes to the field of multimedia data like that of images or video frames the it has a less exploration. The reason being a motivation to do research in these fields of images and video frames. One general thing what I have observed like ICA principle has been widely applied to the signals which are of type 1D. but it has less been explored for the 2D signals like that of images/video frames. So this was a thing which motivated me do choose the field of images which is kind of multimedia data and due to the increase in things like communication through internet or world wide

web, its importance has also gone very high in the industry.

ICA is mainly based on two principles

1) Independence[8]:

It is the property by virtue of which we can‟t predict the value of other variable even if we know the value of one variable. These ways the two variables are being called independent. Independence property is having very much importance for the ICA principle to be implemented on any mixture of signals. If there is not the independence then no separation will be there using the principle of ICA. So it must be very seriously taken into consideration that the signals being mixed must be independent to each other and thus we‟ll be able to apply the principle of ICA and get back the original signal as in the case of images , speech or audio signals being mixed.

2) Nongaussianity[8]:

The guassian signals are forbidden in the principle of ICA the reason being in support of the fact, suppose we assume that the matrix of mixing is orthogonal and xi (the original source signals) are Gaussian and the y1 and y2(which are mixed signals) will be of having unit variance, having property of uncorelatedness and Gaussian in nature. Joint density can be given by

$$P(y1,y2)=(1/2\pi)*\exp(-(y1*y1+y2*y2)/2)$$

So what happens in this case is that the overall density what we get is symmetric so in this case it does not have any information for the direction of columns of the matrix A which being the mixing matrix. Thus we will not be able to estimate the A so hence the original signals will not be able to be separated out of the mixtures. So here it is proved that the signals being mixed must have an nongaussian property.

There are many things which are not obvious when we use the principle of ICA like there may be a some kind of ambiguity and this may be defined as follows

1) We are not able to determine the variances in the energy of the components which are independent. The reason being we do not know both the source signals i.e. x and also the mixing matrix A. so both being unknown what happens is that the components of xi which are multiplier form may be cancelled by the scalar ai of the mixing matrix which is A. so thus we get variances in the magnitude of the source signals.

2) It is not possible for us to determine any how the order of the independent component. The reason being again as we know both of the mixing matrix A and the source signals xi are being not known to us, we are very free to change the order in the equation yi=A*xi for independent components xi"s of source signals so that we may get a different permutation using a permutation matrix P by the following relation yi= AP^{-1}Pxi. So thus it is proved that the order of IC"s i.e. the Independent Components are not possible to determine.

3) The variables which are uncorrelated are not fully independent but these are partially independent. The uncorelatedness may be referenced as the weak form of the independence. If two variables say for instance x1 and x2 are uncorrelated then it is a sure that their covariance is 0. Suppose we know that the variables are independent then it is a very sure that the variable will be uncorrelated but vice versa is not true at all i.e. if we know anyhow the variables are uncorrelated then we are unable to tell that the variables will be independent or not. So this must be taken into consideration while dealing with the independence and uncorelatedness of the variables being used in the ICA technology.

The principle being used in estimation of ICA is as follows :

1) Nonguassianity is independent[8]

The main thing which is important to consider that the nonguassianity is the key for estimating the model being use by ICA. We are unable to estimate the ICA model anyhow if

the nongaussianity is not present in the signal being mixed.

1) The following being used as the measure of Non gaussianity[8]

2.1 Kurtosis :

If we anyhow want to measure the non gaussianity of the signals the the Kurtosis may be of a great help in doing all these. Kurtosis is a kind of fourth order cumulant which is used as a measure of non gaussianity. Kurtosis of a variable say for instance x can be defined as follows

$$\text{Kurtosis}(y) = E(y^4) - 3(E(y^2))^2$$

Since we have already assumed that the variance is unity of y so in this case what we get is

$$\text{Kurtosis}(y) = E(y^4)$$

This shows a fact of importance that Kurtosis is normally the fourth moment which is in the normalized form. The problem with the Kurtosis is that it is very sensitive to the outliers but it is robust.

2.2 Negentropy[8]

Negentropy is simply may be called as the negative entropy which may also be used as a measure of the nongaussianity . It is basically based on the differential entropy. Entropy is a very basic concept which is being used in the field of Information Theory. How we can define the Entropy of a random variable?

It‟s what the information we get from observing the variable like seeing the variable the number of information what we get from the random variable can be given a noun as entropy. The more is the randomness of the variable the more will be the entropy of the variable as a result. The very fundamental result of the information theory is that suppose we have the set of random variables of equal

variance and we want to get that variable which having the largest entropy and suppose if one variable is gaussian out of all these variables and others are nongaussian in nature. So the Gaussian variable will be having the highest entropy among them.

$$J(\mathbf{y}) = H(\mathbf{y}gauss) - H(\mathbf{y})$$

If x is gaussian random variable then the negentropy will always be zero but as when the case of nongaussian variable the it will always be non-negative.

The main advantage of the Negentropy is that for invertible linear transformation it is invariant. Measurement of negentropy is computationally very difficult. It is the problem of using it as a measure so we must have some kind of device by virtue of which we may be able to have some kind of simpler measurement of the negentropy.

2.3 Negentropy Approximation[8]

As we have already discussed above that the estimation of the negentropy is very difficult so the problem of estimation is not theoretically possible. So thus in advance we have to approximate the negentropy somehow for the practical purposes.

$$J(y) \approx (1/12) * E(y^3)^2 + (1/48) * \text{kurtosis}(y)^2$$

What we assume here is that the random variable y is of unit variance and 0 mean. However this method is less robust than that of kurtosis. So a new approximation method was developed by Hyvarinen in 1998 to avoid this nonrobustness issue to solve and formula for the same can be given as follows

$$p$$

$$J(y) \approx \sum_{i=1} ki[E(Gi(y)) - E(Gi(v))]2$$

Here the variable ki is some positive kind of constant being used,v is a kind of gaussian variable having a mean of 0 and variance equal to unity. Whereas y is having a mean of zero and variance is of unity. The Gi‟s are some kind of functions which are nonquadratic.

This method of approximation we have used in our project which is robust as well as not sensitive to the outliers and performs well in the situations.

Mandatory Preprocessing for ICA to Implement[8]:

In the preceding section as we had discussed something about the concept of statistics related to the ICA. Many algorithm can be find in the literature for ICA. But one thing must always be considered in mind that some kind of processing of data is always required as usual because as we have the restriction on ICA to be used that the source signals must have no correlation and having unit variance i.e. the signals must be independent to each other and they must be having some nongaussian kind of distribution. So taking this fact into consideration in mind we preprocess the data as usual. Following are the steps of processing which are done before implementing the ICA principle.

1) Zero Mean Processing:

This is the most basic kind of processing which is usually done with the data before applying ICA on it. We first find the mean of x i.e. E(x) and subtract it from the each element of the vector x to make it a zero mean. It is the very basic kind of processing of data which is must for good results.

2) Whitening:

The second step of preprocessing is to make the whitening of the observed variables. So before applying the principle of ICA what we do in whitening is like we linearly transform x

(observed data vector) which is already centered (done zero mean) in the previous step of processing. By obtaining the transformed vector say for instance x‟‟ which is totally white. Totally white mean to say that the components of the data are not correlated to each other and also variance of the data is found to be of unity. In the mathematical language of modeling what we can say is that the data satisfying the following equation

$$E(x''*x''^{T}) = I$$

It is always very easy to whiten the data. One very useful method of doing so is to use the eigen value decompose of the Covariance matrix

$$E(x''*x''^{T})=E*D*E^{T.}$$

2) Other Preprocessing of the data:

It is very worth to note that the ICA to be successful has to go through many other preprocessing of the data which is basically very dependent on the application in what we are going to use ICA so that‟s being a thing of importance we must take care about it.

2.2 Blind Source Separation Technique[1]

Blind Source Separation is a Technique in what we do is that like as we have given examples earlier also of cocktail party problem so what happens is that we have a independent sources of audio voices in a party and all are generating the voices at the same time so what happens is we get a mixture of the voices in our ear and not the individual voices separately so here is the technique of BSS is being used to get back the original voices out of the mixture of the voices being mixed. Here the beauty of the BSS principle is that we don‟t even know the sources and not the mixing ratio in which it is being received by our ears but still we are able to figure out the original voices in their individual form for output so Its all the motivation that comes from the cocktail party problem in which the mixture is separated by using the BSS principle. ICA is principle which is based on BSS i.e. you can say that BSS is a generalized kind of technology and being used many where but as in the case of ICA it is applicable only where the signals are the independent and having the non-gaussian distribution. But BSS as far as in concerned may having wide applicability like in case of related data which are not totally independent but

having some kind of correlation between them. That is why BSS plays a major role when it comes to the data which are related and even then also we become able to separate out them individually.

As a general discussion on BSS what we can say is that BSS is a superset of ICA and ICA being a specific thing where independence and nongaussianity are the properties for consideration but no such case specific exist when we talk as in general for the BSS. So BSS is more general and ICA is specific what we can say in general. ICA however is not different thing it‟s based on BSS technique which is very interesting technique on which ICA works and has a wide range of application. The application ranges from images, audio, speech, EEG/MEG data, financial data, biomedical data and image compression/denoising, telecommunication etc. are the field where the BSS is extensively being used .

The main objective of BSS as we already know is to uncover the source signals from the mixture of these source signals and even it becomes a hard in general because in advance we do not know either the coefficients of mixing in which the source signals are being mixed and also we don‟t having any information in advance about the original source signals.

2.3 FastICA [4]

In our discussion so far we have discussed many measurement of the nongaussianity which is the main objective function for ICA principle ot implement. Now we assume here is that the data on which we will implement the FastICA algorithm is already preprocessed i.e. the data has already been centered(done zero mean) and also the data is whitented(not correlated and unity variance).

Some useful Properties of FastICA Algorithm:

As we have already got to know how importance of the ICA based algorithm is for separating out the data which are mixed in any unknown mixing coefficients and even the sources being also unknown. Here we present some of the very useful properties of Fixed-Point-Algorithm

of ICA which is one of the very useful and having the wide applicable variant of ICA algorithm. It was originally given by Aapo in 90‟s and then onwards it became very popular as per the wide applicability as well as fast computationally.

Following are some of the very important properties[4] of the Fast-ICA algorithm:

1) The first property of ICA is that the convergence is assumed to be of quadratic or cubic . This is not in accordance with other ICA based algorithms like method of gradient where the convergence is always assumed to be of linear convergence. So that‟s why it is a advantage of ICA algorithm is that it is converging very fast when it is being compared to the other ICA algorithms which are implemented.

2) We don‟t require to select any kind of parameters like in other ICA based algorithms like that in the gradient based ICA algorithm we choose a parameter called as the step-size. This shows that no extra parameters to use so the algorithm is very easy for implementation.

3) Another advantage of using this algorithm is that we have not to find the independent components. The algorithm has itself device to choose the IC‟s i.e. Components which are independent and also their nongaussian distribution using any kind of nonlinerity g. This is very much in contrast to the other ICA algorithms being used.

4) We have a freedom to choose the functions of nonlinearity according our suitability like say for instance g is a nonlinear function which we choose according to our suitability. We are able to obtain both the robustness and minimum variance at the same time of implementation.

5) A very useful advantage is that we having the estimation of IC‟s one after another. It is distributed kind of algorithm in parallel , having very simple computations and requires only a very little space. It having many advantages of the neural network paradigm too.

2.4 NGFICA BASED INSCRIPTION ENHANCEMENT

Performing enhacement of the noisy inscription images is a difficult task because of the challenges stated earlier. The proposed method works on the images captured at Hampi (a heritage site in South), images from India Gate (New Delhi), images of inscriptions in multiple languages from INTERNET (namely, European inscriptions, Islamic inscriptions, Telgu inscriptions from temples etc). Our work deals with the enhancement of images so that they can be recognized by their respective language OCR's. As stated above, the images of inscriptions bear many problems due to bad illumination, decaying or breaking of stones or walls etc. When such images are tried over their respective OCR's, then the recognition rate is nearly 0%. This is obvious because of the bad quality of the images and amount of information it contains. A human readable form of such inscriptions is not clear enough to be processed or OCR-ed. There is not much work done in this field and the work that is somehow related, does not give the desired results. The proposed work deals with using NGFICA that is, Natural Gradient based Fast ICA (Independent Component Analysis). We have used this method to separate out the independent components and use the best out of them which contains minimal noise and whose average is farthest from the average of averages of all ICs. This is explained in detail in later section. The ICA algorithm mainly belongs to signal processing domain but, we have used it in our work of image processing. We have also compared our work using NGFICA to another variant of ICA called FICA (Fast ICA). Below are few details of the techniques and algorithms that are related.

NGFICA (Natural Gradient based flexible ICA) has been extensively used in separating highly correlated signals as it minimizes dependency among the different signals present in the source signal. Mathematical formulation of the same is explained later. The algorithm adopted by the proposed work is NG-FICA (Natural Gradient - Flexible ICA) [5]. NG-FICA uses kurtosis as independency criterion and uses natural gradient for the learning algorithm. This algorithm is implemented as a part of the package, "ICALAB for signal processing" [7]. In NG-FICA, input data of vector x is applied sphering (prewhitening) as a linear transformation.

$$z = Q\,.(x - x'), \quad Q = \{E[(x - x')(x - x')^T]\}^{-1/2}$$

where vector x' is the mean of x. Q is calculated by Principal Component Analysis (PCA).

The presumption method uses vector z as the input data. The update nonlinear functions are based on the following expressions.

$$\Delta W = \eta \, \Delta W = \eta \, (I - E \, [yy^T - (\varphi y^T + y\varphi^T)])W$$

$$\varphi_i = |y_i|^{\alpha_i - 1} sgn(y_i) \; (i = 1,2, \ldots\ldots, n)$$

where η is the appropriate learning rate (constant number), y is the temporary estimated signal (= Wz), and sgn(y_i) is the signum function of y_i. Gaussian exponent α_i is decided based on the kurtosis κ_i (= $\frac{E|y_i^4|}{\{E|y_i^2|\}^2}$ – 3) of y_i; α_i is decided near 0 if κ_i is big, but α_i is decided 4 if κ_i is small. Finally, the independent components y are estimated as:

$$y = WQx.$$

Chapter 3

Proposed Methodology

Our work deals with the enhancement of images so that they can be recognized by their respective language OCR's. The need to enhance the images of inscription arises because of the non-recognition or nearly 0% recognition of inscription-text on their respective language OCRs. Thus, we have tried to apply independent components separation over the images.

The enhancement method requires the image to be separated into three components. This is achieved using NGFICA based method. This results in three mutually independent components. From these components, a Structural content parameter is calculated. This Structural content parameter is used to select the best component out of three for further processing. It is experimentally seen that the component with maximum difference between the consolidated (or original) structural content and its individual structural content , gives best results. A set of morphological operations and noise removal techniques are applied to this image which results in distinctive and clear text and non-text regions. The image is then recognized after being passed to OCR.

Performing enhancement of the noisy inscription images is a difficult task because of the challenges stated earlier. The proposed method works on the images captured at Hampi (a heritage site in South), images from India Gate (New Delhi), images of inscriptions in multiple languages from INTERNET (namely, European inscriptions, Islamic inscriptions, Telgu inscriptions from temples etc). Our work deals with the enhancement of images so that they can be recognized by their respective language OCR's. As stated above, the images of inscriptions bear many problems due to bad illumination, decaying or breaking of stones or walls etc. When such images are tried over their respective OCR’s, then the recognition rate is nearly 0%. This is obvious because of the bad quality of the images and amount of information it contains. A human readable form of such inscriptions is not clear enough to be processed or OCR-ed. There is not

much work done in this field and the work that is somehow related, does not give the desired results. The proposed work deals with using NGFICA that is, Natural Gradient based Fast ICA (Independent Component Analysis). We have used this method to separate out the independent components and use the best out of them which contains minimal noise and whose average is farthest from the average of averages of all ICs. This is explained in detail in later section. The ICA algorithm mainly belongs to signal processing domain but, we have used it in our work of image processing. We have also compared our work using NGFICA to another variant of ICA called FICA (Fast ICA). Below are few details of the techniques and algorithms that are related.

3.1 ICA

Nowadays, performing statistical analysis is only a few clicks away. However, before anyone carries out the desired analysis, some assumptions must be met. Of all the assumptions required, one of the most frequently encountered is about the normality of the distribution (Gaussianity). However, there are many situations in which Gaussianity does not hold. Human speech (amplitude by time), electrical signals from different brain areas and natural images are all examples not normally distributed. The well-known "cocktail party effect" illustrates this concept well. Let us imagine two people standing in a room and speaking simultaneously. If two microphones are placed in two different places in the room, they will each record a particular linear combination of the two voices. Using only the recordings, would it then be possible to identify the voice of each speaker. If Gaussianity was assumed, one could perform a Principal Component Analysis (PCA) or a Factorial Analysis (FA). The resulting components would be two new orderly voice combinations. Therefore, such a technique fails to isolate each speaker's voice. On the other hand, if non-Gaussianity is assumed, then Independent Component Analysis (ICA) could be applied to the same problem and the result would be quite different. ICA is able to distinguish the voice of each speaker from the linear combination of their voices. This reasoning can be applied to many biological recording involving multiple source signals (e.g. EEG). However, the readers must bear in mind that there are two main differences in the interpretation of extracted components using ICA instead of PCA. First, in ICA, there is no order of magnitude associated with each component. In other words, there is no better or worst components (unless the user decides to order them following his own criteria). Second, the

extracted components are invariant to the sign of the sources. For example, in image processing, a white letter on a black background is the same as a black letter on a white background.

In other words, ICA (Independent Component Analysis) is a signal processing algorithm that separates a signal into its independent components. It is based on an assumption that a signal has few independent components that are mutually independent. ICA is transformations that rely on statistics of the given data set. ICA is based on the information given by high order statistics. Therefore the result obtained by ICA is assumed to be more meaningful. ICA is often perceived as an extension of PCA. ICA has recently become popular tool in various fields, e.g. blind source separation, feature extraction, telecommunication, finance, text document analysis, seismic monitoring and many others. All successive ICA experiments were designed in MATLAB environment using FastICA package proposed by Aapo Hyv¨arinen et al.

General strategy for implementing ICA

The general strategy underlying ICA is given in various literatures and it is summarized as:

- It is assumed that different physical processes give rise to unrelated source signals. Source signals are then assumed to be statistically independent.
- A measured signal usually contains contributions from many different physical sources, and therefore consists of a mixture of unrelated source signals.
-It is assumed that if a set of signals with "maximum entropy" can be recovered from a set of mixtures then such signals are independent.

In practice, independent signals are recovered from a sets of mixtures by adjusting the separating matrix W until the entropy of the fixed function (say, g) of the signals recovered by W is maximized.["g"is assumed to be the cumulative density function (cdf) of the source signals.] Hence, the independence of a signals recovered by W is achieved indirectly, by adjusting W in order to maximize the entropy of a function g of signals recovered by W (as maximum entropy signals are independent).

Fast ICA algorithm: Fast ICA algorithm is based on the maximum principle of non-Gaussian character, uses fixed-point iterative theory to look for non-Gussian character maximum of WTx,

this algorithm adopts Newton iterative algorithm and carries out batch to amount of sampling points of observed variables *x*, isolates a independent component from observation signal every times. In order to reduce the estimate parameters of the algorithm and simplify the calculation of algorithm, before running Fast ICA algorithm, we need carry out data pretreatment, that is removing mean value and bleaching process. The solving process of the Fast ICA algorithm is shown as bellow: (Jutten and Herault, 1996):

- Randomly selecting chosen initialized weights vector W_0 and k = 0
- Using formula $w^{k+1} = w^{k+1} - \sum_{j=1}^{k} w_{k+1}{}^T w^j w^j$,

  $w^{k+1} = w^{k+1} / (w_{k+1}{}^T w_{k+1})^{1/2}$ to update weights vector w_{k+1} :
- Normalized w_{K+1} and $w_{k+1} = w_{k+1}/\|w_{k+1}\|$
- If $|w_{k+1}-w_K|>\varepsilon$ then the algorithm is not convergence, return, or Fast ICA algorithm estimate a independent component and the algorithm is over.

3.2 NGFICA

NGFICA (Natural Gradient based flexible ICA) has been extensively used in separating highly correlated signals as it minimizes dependency among the different signals present in the source signal. Mathematical formulation of the same is explained later. The algorithm adopted by the proposed work is NG-FICA (Natural Gradient - Flexible ICA) [5]. NG-FICA uses kurtosis as independency criterion and uses natural gradient for the learning algorithm. This algorithm is implemented as a part of the package, "ICALAB for signal processing" [7]. In NG-FICA, input data of vector x is applied sphering (prewhitening) as a linear transformation.

$z = Q .(x - x'), \quad Q = \{E[(x - x')(x - x')^T]\}^{-1/2}$

where vector x' is the mean of x. Q is calculated by Principal Component Analysis (PCA).

The presumption method uses vector z as the input data. The update nonlinear functions are based on the following expressions.

$$\Delta W = \eta \, \Delta W = \eta \left(I - E \left[yy^T - (\varphi y^T + y\varphi^T) \right] \right) W$$

$$\varphi_i = |y_i|^{\alpha_i - 1} sgn(y_i) \; (i = 1,2, \ldots\ldots, n)$$

where η is the appropriate learning rate (constant number), y is the temporary estimated signal (= Wz), and sgn(y_i) is the signum function of y_i. Gaussian exponent α_i is decided based on the kurtosis κ_i $\left(= \frac{E|y_i^4|}{\{E|y_i^2|\}^2} - 3 \right)$ of y_i; α_i is decided near 0 if κ_i is big, but α_i is decided 4 if κ_i is small. Finally, the independent components y are estimated as:

$$y = WQx.$$

3.2.1 Finding independent components

Images of inscriptions were noisy, complex because of the earlier stated set of problems. The illumination, shadow etc added to the problem of clarity in images. So, we performed Gaussian smoothing using a 5x5 kernel. This removed small scale noise and other irrelevant details from the image. R, G, B components (red, green, blue) of the smooth image were extracted. On these RGB components NGFICA algorithm was used to separate mutually independent components of the image considered. For reference these independent components were named text layer, non-text layer and mixed layer on the basis of the text part present in them.

The dependency among the sources are minimized by minimizing the partial differential function L(W) as explained above. The three independent components are shown in fig. 3.

3.2.2 Distinction enhancement

As visible in fig 3, the text part cannot be separated from NGFICA output images as range of pixel values of the text region is still distributed over the three output images. Hence a structural content (X) of pixel values of three images can be used to determine the threshold of the text region. It was observed that this threshold was not numerical but a criterion based on the maximum ratio of X (structural content of original image) and structural content of individual of three images of ICA outputs . Image with maximum structural content was selected.

Structural content is defined as the ratio between the sum of the pixels in the orginal image at location (m,n) to the sum of the pixels in the processed image at the same location (m,n).

The structural content value of each component is calculated as:

$$sc = \sum_{m=1}^{M} \sum_{n=1}^{N} X(m,n)\text{^}2 \,/\, \sum_{m=1}^{M} \sum_{n=1}^{N} Y(m,n)\text{^}2$$

where X(m,n) is the pixel value of the of original image at location (m,n) of the image with size MxN.

Y(m,n) is pixel values of the individual image of ICA output at location (m,n) of image with size MxN.

where n is the number of components and i varies from 1 to n.

Structural contentis defined as the ratio between the sum of the pixels in the orginal image at location (m,n) to the sum of the pixels in the processed image at the same location (m,n).

The image selected for further processing and with maximum structural content is shown in fig

3. This image is further processed using noise filtering by applying median filtering and then applying morphological operations for further enhancement. Sobel edge detection is applied too for edge detection.

The resultant image is shown in fig 4.

The final algorithm appears as:

- Take the image to be considered
- Extract the three components of that image. That is, the red, green, blue components.
- Pass the components to ICALAB image processing tool as input.
- Apply ICA variant called the NGFICA algorithm.
- This results in three independent components of the image
- Store these three components and use the individual structural content of the three ICs for finding best image from these three images.
- Now, the best suitable component out of the three is one which has the structural content ratio is greater than one.
- The best component (image) is selected and converted to binary image.
- It is then processed morphologically using operations like dilation, erosion etc. Connected components are sorted based on their sizes and unwanted noisy particles are removed.

- The image after processing is passed to OCR software which now recognizes it as the image has clear distinction between foreground and background and the noise is also removed.

Chapter 4

Results and Discussion

The dataset for validating the proposed method was prepared by gathering images of inscriptions belonging to historical monuments (India Gate, Delhi), heritage sites (Hampi, Karnataka), ancient temples (Vishnu temple, Tamil Nadu) etc. Such inscriptions are found engraved into or projected out from stones or other durable materials. Some of the images were manually clicked using a 10 mega pixel camera and few were taken from the Internet. Problems like uneven illumination, wrapping, perspective distortion, multi-lingual text etc existed in the images. Images of India Gate(English) without enhancement were tested on web based OCR and the results are shown in table 1 whereas these images after enhancement using proposed method is shown in table 2. The enhanced outputs of India Gate images using the proposed method is shown in fig 5 and 6. We have also compared the proposed method with Fast ICA based enhancement [3] .

A novel method for enhancement of complex and unclear archaeological inscription images has been proposed and validating using 650 word images. This method establishes the important role of NGFICA in digitizing inscription images which has been extensively used for signal processing till now. The method improved character recognition accuracies from 10.1% to 75.4% and from 32.4% to 86.7% respectively. The method enhanced multi-lingual inscription images efficiently. This method can be further extended for digitization of ancient coins, manuscripts and archaeological sculptures.

Fig. 4.1 Image of inscriptions and corresponding OCR output

Method	Accuracy of words	Accuracy of characters
ICA	**0.9%**	**1%**
Proposed Method	**75.4%**	**86.7%**

Table I Comparison of accuracies before and after the proposed method

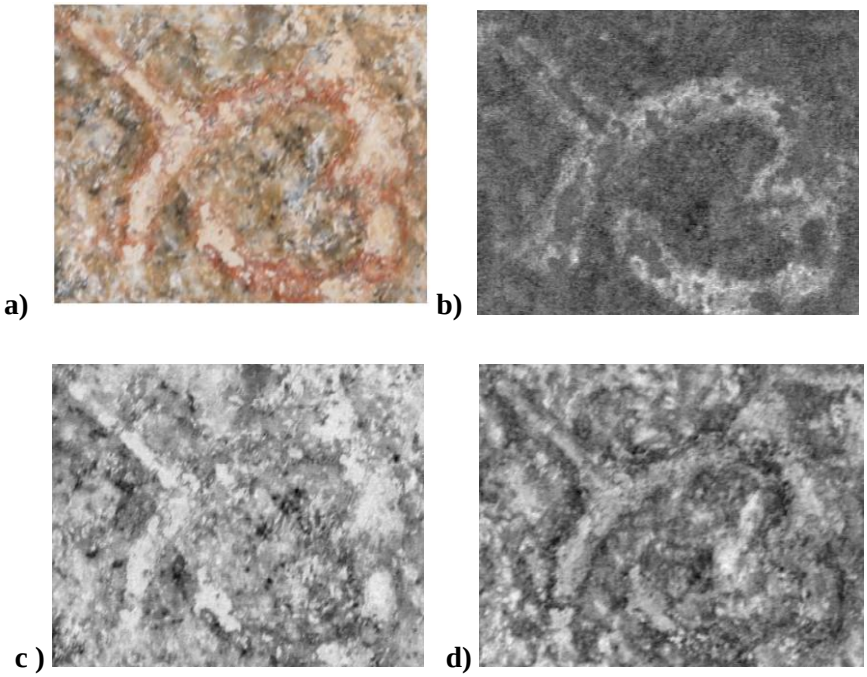

Fig. 4.2 a) Source image (b) (c) and (d) NGFICA output images

Input Image	Number	Rec. by OCR before enhancement	Accuracy in % before enhancement	Rec. by OCR after enhancement	Accuracy in % after enhancement
Words	550	56	10.1%	415	75.4
Characters	2578	835	32.4%	2235	86.7

TABLE II OCR's word and character accuracy before and after enhancement

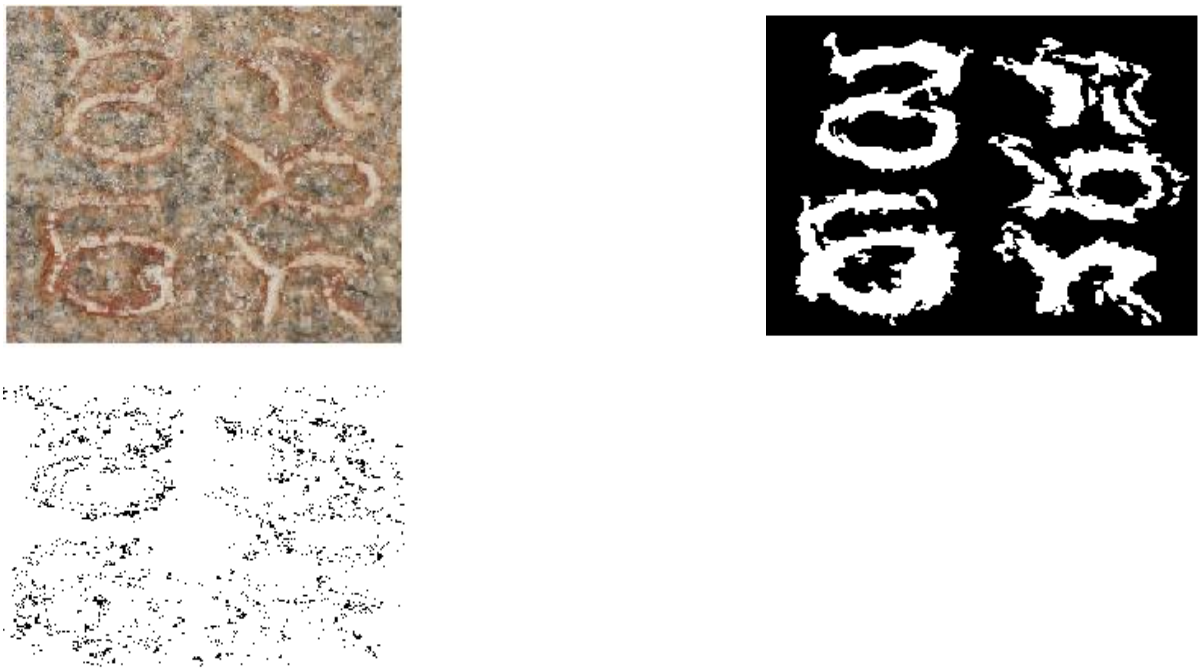

Fig. 4.3. (a) Original image (b) Output image of proposed method and (c) Output after Fast ICA based enhancement

Discussion :

Finally as we can say is that the performance results totally depends upon the independence property of the original source images being used. For performance measure we can use the pixels count of the original images and the final image being obtained. So getting the total number of pixels being matched we can get the overall accuracy of the algorithm. But It is worth to note that if the components are independent then only we will be able to separate out the images totally if they are not independent then we‟ll not be able to separate out the sources.

Fig. 4.4 (a) Source (b) result

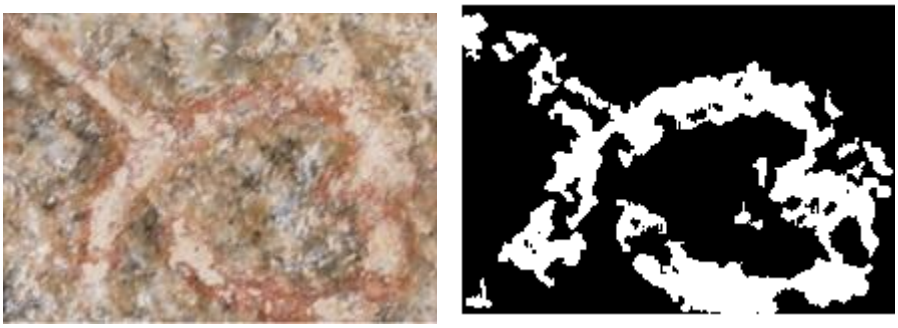

Fig. 4.5 Other language results

Chapter 5

Future work

Historical monuments are a great source of information of past. The work described here deals with inscriptions and sculptures present on walls of monuments, temples etc. They need to be nurtured and preserved. Many monuments of historical importance have various inscriptions in different languages. So, it is an important step to work in this direction. Like the inscriptions dealt with in this work, many other inscriptions from ancient temples, monuments etc hold a precious place and value in India's history. These monuments hold an importance to the tourism departments of respective states. So, work can be done for increasing tourism and adding convenience to tourists visit to these monuments by either converting these texts to multiple languages for better understanding or designing Braille-aided readable text equipments for blinds.

A better system can be designed that can help tourists in reading the inscriptions on the walls in their preferred language. For e.g. a tourist not knowing Tamil might not take interest in visiting a temple which has Tamil inscriptions or where he may find problem in understanding the language. For this purpose, a system can be built that can translate the inscriptions. This will be an innovative step towards taking the Indian cultural heritage to places and make people aware of the past.

References

[1] Lin Qiu-Hua, Yin Fu-Liang, Mei Tie-Min, Liang Hualou, "A blind source separation
based method for multiple images encryption", Image Vision Comput 2008;26:788–98.

[2] Anil Kumar, Rhouma Rhouma, Yong Wang, Nicolas Sklavos, M.K. Ghose, "Comments on, „„A blind source separation-based method for multiple images encryption"", Commun Nonlinear Sci Numer Simulat 16 (2011) 1675–1686.

[3] Aapo Hyvärinen and Erkki Oja, "Independent Component Analysis: Algorithms and Applications", Neural Networks, 13(4-5):411-430, 2000.

[4] P. Tichavsky, Z. Koldovsky, and E. Oja, "Performance analysis of the fast ica algorithm and cram rao bounds for linear independent component analysis," IEEE Transactions on Signal Processing, vol. 54, no. 4, pp. 1189–1203, April 2006.

[5] L. Agnihotri and N. Dimitrova, "Text detection for video analysis," Proc. IEEE Int. Workshop on Content-Based Access of Image and Video Libraries, pp. 109–113, June 1999.

[6] X. S. Hua, P. Yin, and H. J. Zhang, "Efficient video text recognition using multiple frame integration," Proc. Int. Conf. Image Processing, vol. 2, pp. 22–25, Sept. 2004.

[7] K. C. K. Kim, "Scene text extraction in natural scene images using hierarchical feature combining and verification," in Proceedings of International Conference Pattern Recognition, vol. 2, pp. 679–682, August 2004.

[8] A. Mansour, A. K. Barros, and N. Ohnishi, "Blind separation of sources: Methods, assumptions and applications," IEICE Trans. Fundamentals, vol. E83-A, no. 8, pp. 1498– 1512, 2000.

[9] X. Wen and D. Luo, "Performance comparison research of the fecgsignal separation based on the bss algorithm," Research Journal of Applied Sciences Engineering and Technology, vol. 4, no. 16, pp.2800–2804, March 2012.

[10] P.Chevalier, L. Albera, P. Comon, and Ferreol, "Comparative performance analysis of eight blind source separation methods on radio communications

signals," Proc. International Joint Conference on Neural Networks, vol. 8, no. 2, pp. 251–276, July 2004.

[11] P. Tichavsky, Z. Koldovsky, and E. Oja, "Performance analysis of the fast ica algorithm and cram rao bounds for linear independent component analysis," IEEE Transactions on Signal Processing, vol. 54, no. 4, pp. 1189–1203, April 2006.

[12] S. Choi, A. Cichocki, and S. Amari, "Flexible independent component analysis," Journal of VLSI Signal Processing, vol. 26, no. 2, pp.25–38, August 2000.

[13] A. Hyva¨rinen, E. Oja, Independent component analysis: algorithms and applications, Neural Networks 13 (4–5) (2000) 411–430.

[14] P. Comon, Independent component analysis, a new concept? Signal Processing 36 (7) (1994) 287–314.

[15] S. Amari, A. Cichocki, Adaptive blind signal processing – neural network approaches, Proc. IEEE 86 (14) (1998) 2026–2048.

[16] J.F. Cardoso, Blind signal separation: statistical principles, Proc. IEEE 86 (14) (1998) 2009–2025.

[17] X.R. Cao, R.W. Liu, General approach to blind source separation, IEEE Trans. Signal Processing 44 (7) (1996) 562–571.

[18] Q.H. Lin, F.L. Yin, Image cryptosystems based on blind source separation, Proc. IEEE Int. conf. Neural Networks & Signal Processing. II (2003) 1366–1369.

[19] Xiling Wen, Manxiang Miao, "Research and Simulation on Blind Separation Algorithm in Mixing Image Based on ICA", Information Technology Journal 11 (4): 456-460, 2012.

[20] A. Cichocki, S. Amari, K. Siwek, et al. ICALAB for Image Processing, version 2.0a, March 20, 2004. <http://www.bsp.brain. riken.jp/ICALAB/>.

[21]https://lh5.ggpht.com/k1Dk_GEbE54OploJxENgqDq4H39uNHFkaJq5EDu0h7DvA6tE6PiEDfxUg6q6DK3UCtzT8Zc=s85

[22]https://lh4.ggpht.com/itD2c70X_KXQpmidPePoTZ8O_Kp9ubi6mYgQh4yagwLeWwOqMOH1TWze8FOlpUQmSgrA=s 85

APPENDIX

1. Description of Tools being used

Here in this chapter we will define the the implementation details like the tools, software and hardware being used for the project. Overall our project is a combination of software, hardwares and toolboxes.

1.1 Hardware Tools being used

In our project hardware as such are not been used but they are required to transmit the Image data in ciphered form from the sender to the receiver end. Like we will have to use all the networking technology for transmission in real time and for all those h/w‟s are required like cables, sender device, receiver device , networks, router etc. will be required as such for the real time implementation. But as our project focus is on the s/w technology to develop for securing of images so as far as our project is concerned we have not used the H/w‟s.

1.2 Software Tools being used

In our project we have used matlab software and other ICALAB toolbox for performance check of my systems for completion of the project. The details for the same are as follows.

Matlab:

Matlab we have used in our project for coding the algorithms for mixing, demixing, encryption and decryption purposes. I have used my own code as far as possible and less I have used the library functions. Matlab is a very good tool for processing images and all so that‟s why it has been very helpful for my project completion. All simulations and test has been performed using the Matlab toolbox.

ICALAB :

ICALAB toolbox is given separately for performing the ICA algorithm for signal-processing and image processing. I have used the standard toolbox of ICALAB for image processing given by Andrej Cichocki[20]. It is a very standard toolbox for performing ICA on images. It is also very useful to compare own algorithm for excellency match. Many algorithm related to ICA is inbuilt in the ICALAB and we can use any of them accordingly as per the requirement of the application.

LIST OF TABLES