# Contrast Enhancement for JPEG Images in the Compressed Domain

**Jaspreet Bhatia**

Department of Electronics and Communication Engineering
**National Institute of Technology Rourkela**

# Contrast Enhancement for JPEG Images in the Compressed Domain

*Thesis submitted in partial fulfillment*

*of the requirements of the degree of*

***Master of Technology***

*in*

***Electronics and Communication Engineering***
**(*Specialization*: *Signal and Image Processing*)**

*by*


***Jaspreet Bhatia***

(Roll Number: 214EC6422)


*based on research carried out*

*under the supervision of*

***Prof. Manish Okade***

May, 2016


Department of Electronics and Communication Engineering
**National Institute of Technology Rourkela**

Department of Electronics and Communication Engineering
**National Institute of Technology Rourkela**

May 27, 2016

# Certificate of Examination

Roll Number: *214EC6422*
Name: *Jaspreet Bhatia*
Title of Dissertation: *Contrast Enhancement for JPEG Images in the Compressed Domain*

We the below signed, after checking the dissertation mentioned above and the official record book (s) of the student, hereby state our approval of the dissertation submitted in partial fulfillment of the requirements of the degree of *Master of Technology* in *Electronics and Communication Engineering* at *National Institute of Technology Rourkela*. We are satisfied with the volume, quality, correctness, and originality of the work.

Manish Okade
Principal Supervisor

Department of Electronics and Communication Engineering
**National Institute of Technology Rourkela**

**Prof. Manish Okade**
Assistant Professor

May 27, 2016

## Supervisor's Certificate

This is to certify that the work presented in the dissertation entitled *Contrast Enhancement for JPEG Images in the Compressed Domain* submitted by *Jaspreet Bhatia*, Roll Number 214EC6422, is a record of original research carried out by her under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Technology* in *Electronics and Communication Engineering*. Neither this thesis nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

Manish Okade

# Dedicated to My Family and Gurjas

*Jaspreet Bhatia*

# Declaration of Originality

I, ***Jaspreet Bhatia***, Roll Number ***214EC6422*** hereby declare that this dissertation entitled ***Contrast Enhancement for JPEG Images in the Compressed Domain*** presents my original work carried out as a postgraduate student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections "Reference" or "Bibliography". I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

May 27, 2016
NIT Rourkela

*Jaspreet Bhatia*

# Acknowledgment

First and foremost, thanks to the **Almighty God**, for giving me this opportunity to do study and research. I would like to express my gratitude to my research guide **Prof. Manish Okade** , who has guided me in developing a research attitude ,writing research papers and always motivating throughout the ups and downs during research. I am really thankful to him for his endless efforts in teaching and guiding me with his innovative suggestions throughout the research project.He is very hard working ,disciplined and punctual person who believes in quality time devoted for quality work. He has always been a source of inspiration and motivation to me at many times .It has been a learning journey with him and I thank him for being my research guide here at National Institute of Technology , Rourkela.

I owe a lot to my teachers **Prof. Sukadev Meher** , **Prof. K.K.Mahapatra** , **Prof. D.P.Acharya** , **Prof. L.P.Roy** , **Prof. Samit Ari** , **Prof. A.K.Sahoo** , **Prof. Subroto Maiti** , **Prof.Siddharth Deshmukh** , **Prof. A.K.Swain** for teaching me and guiding me throughout my post-graduation.

I owe my complete research study to my **husband**, without whose support this wasn't feasible. He is and has always been a true friend that highlights your shortcomings so that you can improve them rather than showcasing your strengths. He has helped me convert my dream into reality.

I am grateful to my family members who have always supported my decision to study, especially my **Father-in-law**, who has always encouraged me throughout, my **mother-in-law**, who has helped a lot mentally as well as emotionally during this journey, my **mom** and last but not the least my loving daughter **Gurjas**, who has at every point prayed for the completion of my research degree with good credentials. I am really thankful to them for their love, sacrifice and support.

Lastly, I would like to thank my friends Nancy, Snigdha and Komal for their love and support and my seniors Anusha and Shobhan for encouraging me to do quality research and patiently answering to my innumerable queries about the research subjects.

May 27, 2016 — *Jaspreet Bhatia*

NIT Rourkela — Roll Number: 214EC6422

# Abstract

With the increase in digitization, there has been a great demand for data storage with effective techniques for data computation. As these days, a lot of data is being transferred over internet in the form of images, data storage is a prime concern, for which there is a requirement of image compression without losing the important details of the image. Digital image compression finds its applications in various fields like Medical, Automation, Defense, Photography etc. which also requires that the image produced should be visibly pleasing with sharp and clear details. The latter is achieved by a pre-processing technique called Image Enhancement.This research project is based upon the contrast enhancement of the color Images, where each color R-G-B channel is separately analyzed in the Y-Cb-Cr channel, in the compressed domain. The Discrete Cosine Transform is used as the compressed domain and further analysis is made on the block coefficients of the DCT where the block size considered is 8x8. Each DCT block contains one DC coefficient and 63 AC coefficients. The DCT coefficients are analyzed on the basis of their statistical behaviour. It is seen that the DC coefficient of each block DCT follow Gaussian distribution and the AC coefficients follow the Laplacian distribution .The DC coefficient being the mean value of the block DCT, is observed to be affecting the illumination of the image whereas the remaining 63 coefficients i.e. AC coefficients of the block DCT affected the contrast of the image. This thesis investigates a novel method for enhancing the image contrast based on the statistical behaviour of the block DCT coefficients.

Furthermore, we use the concept of coefficient of variation $(Cv)$ for arriving at a DC scaling factor required to modify the original DC coefficient value of each block. We also evaluate AC scaling factor by band analysis of each block based upon their contrast and entropy bands. The proposed work analyses both the DC coefficient and the 63 AC coefficients of each block separately.

***Keywords*: *Discrete Cosine Transform*; *JPEG*; *Entropy*; *Contrast*; *Coefficient of Variation*.**

# Contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction

**"A picture is worth a thousand words" -Anonymous**

## 1.1 Motivation

Image enhancement has always been a primary goal for image restoration in order to improve the image quality. It has been the process of improving the brightness, contrast and color of an image at the pre-processing, depending upon the application for better visual quality and rendering. A raw image data many a times requires to be processed before display. It may be that the dynamic range of the image is too large as compared to the bit-planes of the display equipment, presence of strong illumination in the background, insufficient lighting and many more. The complication arises when the scene illumination varies widely. In the aforementioned case, few regions of the image appear to be bright whereas few regions appear to be dark. As an example, in fig 1.1(a),where due to the bright sky, the details of the reflection on the glass window of the car are visibly unclear. Thus it requires improvement in the local contrast of the image .The image after being processed ,with improvement in display is shown in fig 1.1(b).

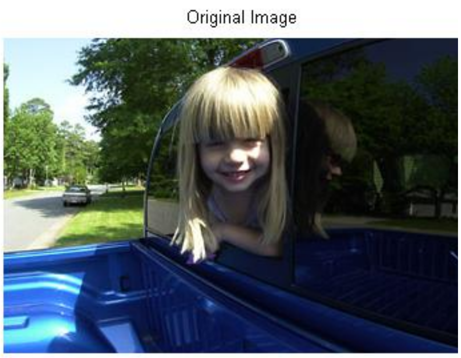



Figure 1.1: Original image


Figure 1.2: Enhanced image

Image enhancement is very often used for improving the contrast of the images as it deals with the sharpness of the details in an image. Such methods are designed by locally varying the color intensity of an image, to produce a visibly sharp image. This task can be carried out either using the pixels of the image also referred to as spatial domain or in the frequency domain also termed as transform domain. Each domain has its own pros and cons. The spatial domain method for image enhancement provides better picture quality but there is a lot of computational complexity as it works on each pixel of the image. On the other side ,the compressed domain offers less storage space and computations are faster and easier to interpret.

## 1.2 Problem Statement

Most of the data nowadays are shared with the help of images over internet ,so in order to maintain the subjective quality of the images ,image enhancement is used as the pre-processing tool. As discussed before, Contrast and brightness of the image are two vital properties of an image that describe the image in terms of its quality. It is the Contrast of the image that helps in distinguishing one object over the other in an image. This research aims to analyze the following practical issues :-

(a) Spatial domain [1, 2] and compressed domain[1, 3–7],methods offer various advantages and disadvantages. Since, the data size i.e image size is increasing these days there is a requirement of a method that is computationally effective and helps in providing less storage space .

(b) The increase in the usage of smart phones and new social networks like Facebook, Whatsapp, Twitter etc., there is a demand for storing images in compressed form without compromising for the image quality.

(c) Image compression degrades the quality of the enhanced image as compared to the image enhanced in the spatial domain due to the presence of artifacts while compression of data(image).

## 1.3 Research Plan

The research project aims at providing a computationally effective and faster technique for image enhancement. It also aims at reducing the storage space by making the use of compressed domain techniques. The project also presents a novel method of enhancing the images based upon the statistical analysis of their compressed domain coefficients. Further, the research objective can be summarized as :-

(a) Design of a generalized method to enhance the low contrast areas by analyzing various frequency components present in the compressed form of the image data. The method should be fast, computationally effective and provide better image quality in terms of its contrast.

(b) Design of a contrast measure depending upon the statistical analysis of the compressed domain coefficients.

## 1.4 Thesis Layout

The thesis organization is briefly described as follows :-

- Chapter 2 deals with the basics of image compression techniques and standards.
- Chapter 3 is focused on the various compressed domain based Image Enhancement Techniques outlining their advantages and disadvantages.
- Chapter 4 explains the detailed algorithm of the Proposed Image Enhancement method for JPEG color images followed by the qualitative and quantitative analysis of the Experimental results derived from the proposed method.
- Chapter 5 concludes the research work carried out, outlining the limitations and future scope of the work.

# Chapter 2

# Image Compression

## 2.1 Preview

Image Compression is an art of decreasing the size of data required to represent an image. It is one of the major commercial technology being used nowadays. This chapter deals with the basics of image compression techniques and standards followed the explanation of Discrete Cosine Transform ,which is one of the compression technique and Joint Picture Experts Group (JPEG) that is one of the Image Compression standard using Discrete Cosine Transform.

## 2.2 Fundamentals

'Compression' as the word states is a state of reducing something, with 'Data', it refers to reducing the size of data required to represent a piece of information. Since data is a way of representing the information, sometimes same information or irrelevant information is represented repeatedly by data, such a data content is termed as redundant data. Thus there is a need of removal of such a redundant content so that the data is compressed and contains useful information.

'Digital image compression' relates to the reduction of the number of bits required to represent an intensity value of a pixel of a 2-D array. As images are nothing but a collection of intensity values collected to form a 2-D array, there are few pixels that contain similar information especially the neighbour pixels thus being redundant data. In case of video, the consecutive frames exhibit similarity. Thus, the two-dimensional image intensity arrays face three major types of data redundancies, termed as :-

- **Coding redundancy :** In an uncompressed image, all the pixels are coded by fixed length code. For example, 256 gray scale values of an image are represented by eight bit integers. But, there are few pixel intensities that are low and can be represented by lesser number of bits, thus it is better to make use of variable length coding like Huffmann coding ,arithematic coding that will help in data compression.

- **Psycho-visual redundancy :** Human vision depends completely upon how an individual interprets or views an image .It is independent of the analysis of each pixel intensity values. Human vision searches areas of distinct features and then frames a picture of it mentally. Thus it is clear that human eye does not respond with uniform intensity to the complete image information, thereby creating redundancy referred as psycho-visual redundancy.

- **Statistical redundancy :** In case of images it is possible that the neighbouring pixels follow a statistical relationship and produce similar data as the observed pixel, so the data in such a case is represented repeatedly that is also termed as 'spatial redundancy'. In video along with the spatial redundancy there also exists other statistical redundancy called 'temporal redundancy' which occurs due to the similarity of consecutive frames. Thus, higher the spatial resolution of the image or higher the frame rate in a video stream, the more is the redundancy.

## 2.3 The Image Compression Model

The digital image compression methods[8] are broadly defined under two main categories:

### 2.3.1 Lossy compression :

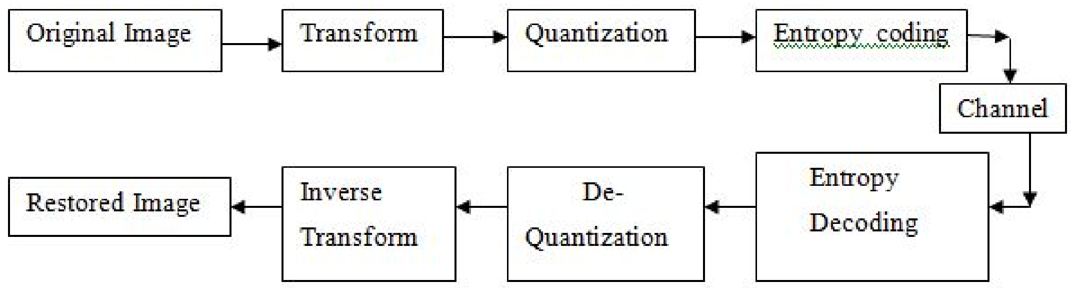



Figure 2.1: Basic lossy image compression model

In the lossy image compression model, the original image is processed firstly with an image compressor that converts the original image that is in the spatial domain to the frequency domain using transform in order to reduce the inter-pixel redundancy. Discrete Cosine Transform (DCT)[8] is used popularly in still image compression model like JPEG. Following the transform, there is a quantizer that helps in the reduction of the psycho-visual redundancy, in order to represent the reduced information with lesser number of bits.The quantization part is where losses in the data take place. Then the quantized bits are further encoded, which helps in more compression of the data (reducing the coding redundancy). Then the final encoded image data is passed over the transmission channel and at the decoder side it is passed through an image de-compressor which contains the reverse components that of the image compressor viz. entropy decoder, de-quantizer , inverse transform, thereby resulting in the restored image that is compressed as compared to the original image.

### 2.3.2 Lossless compression :

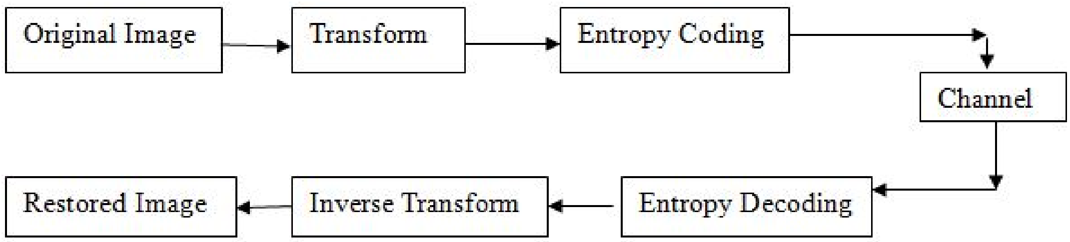



Figure 2.2: Basic lossless image compression model

The lossless image compression model does not uses Quantization process .It uses a two-step process for transmitting the compressed images over the channel. Firstly, it transforms the image to reduce the inter-pixel redundancy , the transformed data is further coded using entropy coding in order to reduce the coding redundancy. The de-compressor process is reverse that of the compressor process viz. entropy decoding, inverse transform, thus producing the compressed image.

## 2.4 Image Compression Standards

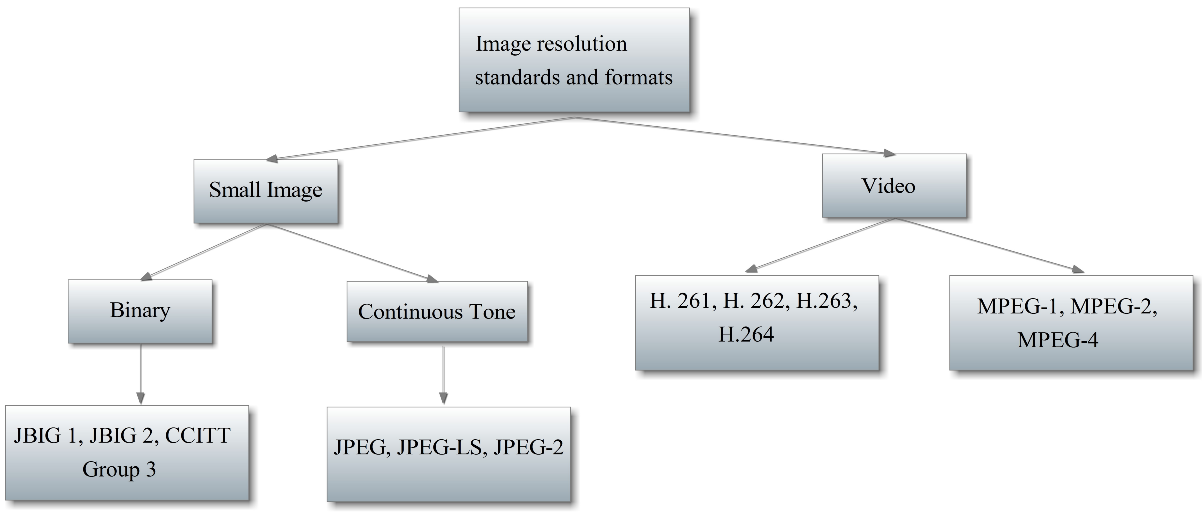



Figure 2.3: Image compression standards

With the rapid increase in the imaging technology, it is of prime importance to set a few standards so that there is compatibility as well as inter-operatibility between the image storage formats set by different manufacturing vendors and the image data that is communicated over the channels. Nowadays , as there is a lot of data being transferred in the form of images ,the encoders and decoders over the channels need to be in synchronization with respect to the coding standards .This has been made possible via many international standardization agencies, such as International Standards Organization (ISO), International

Telecommunications Union (ITU), International Electro-technical Commission (IEC) etc. that have defined Image compression standards[8] based upon the discussions with experts group and suggestions derived from various industries , universities and research groups. Depending upon the application whether the data is a still image or a video, there are different image compression formats and standards that are defined.

### 2.4.1 Joint Picture Experts Group (JPEG)

JPEG is one of the standards created for the coding of still images. It is a widely used ISO/IEC standard that uses block transform coding called Discrete Cosine Transform (DCT). The basic outline of the JPEG pipeline is shown in fig.2.4. The JPEG pipeline

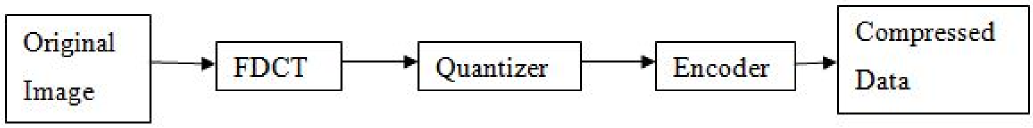



Figure 2.4: JPEG Encoder.

consists of Forward Discrete Cosine Transform (FDCT), Quantization of the compressed values by pre-defined quantisation tables followed by entropy coding of the quantised data. The de-compressor follows the inverse of the compressor process i.e. entropy decoding, de-quantisation and inverse Discrete Cosine Transform (IDCT).

### 2.4.2 Discrete Cosine Transform (DCT)

Discrete Cosine Transform is one of the Block Transform coding techniques. It transforms the spatial image data into the frequency domain. It expresses the information into a set of points expressed as a sum of cosine functions. The transform splits the spatial data into non-overlapping blocks of size n x n. The blocks constitute of $n^2$ coefficients out of which the first coefficient of the block is called DC coefficient and the remaining coefficients are termed as AC coefficients. In the proposed work, the overlapping blocks are of size 8x8, where the first coefficient is the DC coefficient, as it contains the average value of the complete block and the rest 63 coefficients are the AC coefficients, whose value starts decreasing as it approaches the higher frequencies.

There are various forms of the Discrete Cosine Transform but the Type II DCT is the most often form of DCT used in the image compression algorithms. For a 2-D image I(x,y) 0≤x,y≤N-1, the Type II DCT is defined as,

$$d_{(k,l)} = \alpha(k)\alpha(l)\sum_{x=0}^{7}\sum_{y=0}^{7} I(x,y)cos((2x+1)k\pi)/16cos((2y+1)k\pi)/16 \tag{2.1}$$

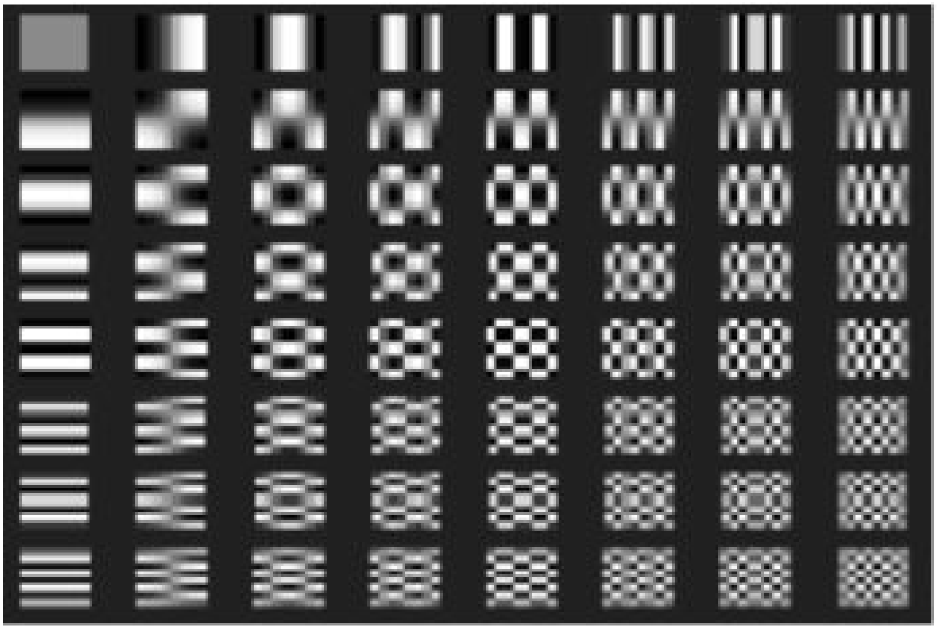


Figure 2.5: DCT 8x8 block.

where,

$$\alpha(k) = \alpha(l) = \begin{cases} \sqrt{\frac{1}{N}}, \text{fork} = \text{l} = 0 \\ \sqrt{\frac{2}{N}}, \text{fork} = \text{l} = 1, 2, ...., 7 \end{cases} \tag{2.2}$$

DCT is a widely used in image compression (e.g. JPEG) ,audio compression (e.g.MP3) etc. The following section outlines few properties of the DCT which are of particular value in the image processing applications :-

- **Decorrelation –** As described in the earlier sections the principal requirement of a transform is to reduce the inter-pixel redundancy .This results in uncorrelated transform coefficients that can be independently encoded. The DCT provides excellent decorrelation properties.
- **Energy Compaction –** Efficiency of a transformation technique depends upon the fact that how compact the input data be packed so that the data is represented in as few bits as possible. It has been observed that for highly correlated images DCT provides far better energy compaction.
- **Symmetry** –As seen in eq.(2.1) , the Type II DCT can also be achieved by successive application of 1-D DCT on the rows and columns of the image.
- **Orthogonality** –The DCT[8] basis functions are orthogonal in nature which helps in some reduction in the computation complexity.

### 2.4.3 Quantization

Quantization is a lossy step that is applied to each of the DCT block .Each of the frequency terms in the DCT block are operated with uniform scalar quantization in order to remove code redundancy . The human eye being more sensitive to lower frequencies as compared to others, the JPEG quantization table[8] provides variable scaling factor for each frequency component. JPEG standard defines two quantization tables one for the luminance component and other for the chrominance component.

Table 2.1: Quantisation table

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | 11 | 10 | 16 | 24 | 40 | 51 | 61 |
| 12 | 12 | 14 | 19 | 2 | 58 | 60 | 55 |
| 14 | 13 | 16 | 24 | 40 | 57 | 69 | 56 |
| 14 | 17 | 22 | 29 | 51 | 87 | 80 | 62 |
| 18 | 22 | 37 | 56 | 68 | 109 | 103 | 77 |
| 24 | 35 | 55 | 64 | 81 | 104 | 113 | 92 |
| 49 | 64 | 78 | 87 | 103 | 121 | 120 | 101 |
| 72 | 92 | 95 | 98 | 112 | 100 | 103 | 99 |

### 2.4.4 Encoder

The quantized DCT coefficients are ordered in the 'zig-zag' sequence as shown in the above figure. The DCT coefficients of a block are broadly classified as DC coefficient and AC coefficients. The first coefficient is called the DC coefficient as it contains the average value of the block whereas the rest coefficients are termed as AC coefficients. The DC coefficients have the largest value in the block whereas the AC coefficients have significant but low values out of which most of the coefficients have nearly zero magnitude. Due to the variation in the behaviour of the DCT coefficients, different encoding schemes are applied on the coefficients. The DC coefficient of the blocks are encoded via Differential Pulse Code Modulation (DPCM) whereas the AC coefficient of the blocks are encoded via Run Length Encoding (RLE).

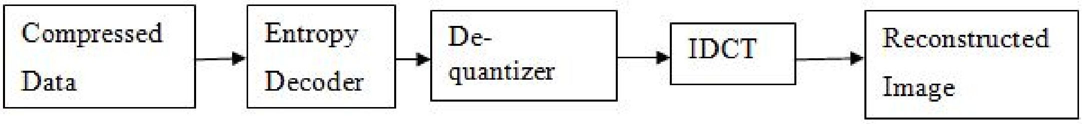



Figure 2.6: JPEG decoder.

The decoding process is reverse of the process carried out in the JPEG encoder. The image compression is achieved in the reconstructed image.

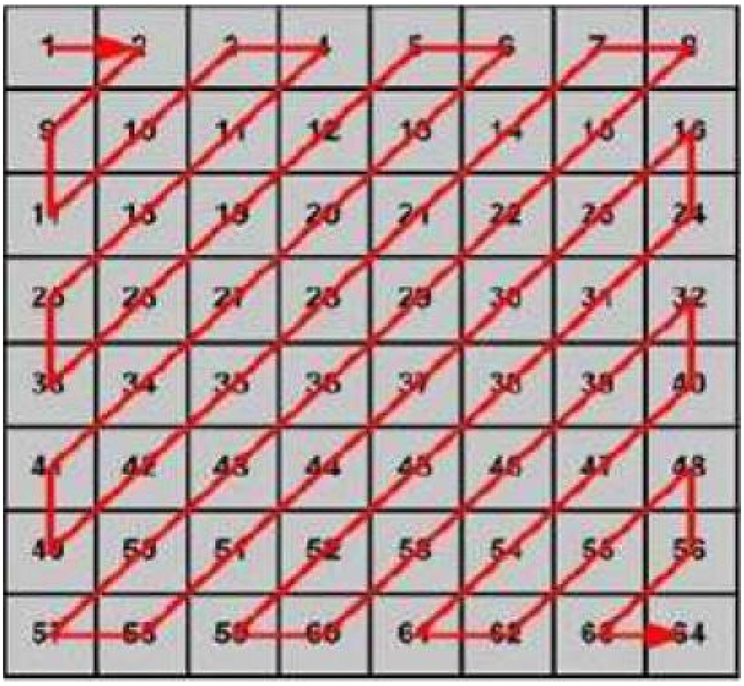


Figure 2.7: Zig-Zag scanning order.

## 2.5 Summary

This chapter gave an overview of one of the commonly used image compression standard called JPEG. The latter is widely used for still images, in video applications like MPEG4 etc. The Discrete Cosine Transform (DCT) helps in providing low computational complexity as its most of the high frequency components are of almost negligible magnitude. The statistical properties of DCT coefficients are further studied and utilized in the most of the image enhancement techniques to be discussed in the next chapter.

# Chapter 3
# Image Enhancement

## 3.1 Preview

Image enhancement, as introduced in the previous chapter, is an important pre-processing tool for improving the image contrast for better visual quality. There have been a lot of image enhancement techniques developed so far in the pixel domain (also known as spatial domain) .The spatial domain methods include adaptive histogram equalization, unsharp masking, constant variance enhancement , filtering techniques such as homomorphic filtering, high-pass, and low-pass filtering, etc.(references) .These methods have not only been adapted for the gray-scale images but also for the color images wherein the chromatic components of the color images have also been enhanced. The R-G-B color space is highly correlated thus enhancement operation on individual space component may result in a loss of information .To prevent this, the R-G-B color space is transformed into Y-Cb-Cr ,H-S-V color space etc. ,where the components i.e. chromatic and achromatic components are decorrelated from each other. This decorrelation helps in analyzing the hue ,saturation and intensity which describe the color processing of the human visual system.

The above mentioned image enhancement techniques are all pixel-domain based methods. These spatial domain techniques are computationally intensive and time consuming. Today, with the increase in data sharing in the form of images there is a huge requirement of methods that are faster and efficient in terms of image storage and transmission as discussed earlier. The compressed domain methods have been adopted by most researchers to overcome the shortcomings of the spatial domain methods. The compressed domain also helps in the spectral separation of the image data, which makes it easier to treat different frequency components in a different manner .Many enhancement techniques have been developed so far namely contrast enhancement by scaling[5] ,alpha rooting[9] , retinex[3] ,logarithmic image enhancement[9] etc. Mostly the compressed domain methods have treated the intensity components and achieved visually pleasing image results but a few of them also treat the chromatic components for more sharp and better contrast images. As in the compressed domain techniques each block is treated separately ,there exist blocking artifacts which become visible in the processed data. Further, in the following sections few of the image enhancement methods are discussed along with their advantages and disadvantages.

## 3.2 Alpha Rooting

### 3.2.1 Method

Alpha Rooting technique for image enhancement put forward by Jain[9] is an effective technique of enhancing the images in the compressed domain. It can be applied to various two dimensional orthogonal transforms such as Fourier, Discrete Cosine, Hartley transforms etc. Let the transformed coefficients $d_{(k,l)}$of an image be represented as,

$$d_{(k,l)} = |d_{(k,l)}|e^{j\theta_{k,l}} \tag{3.1}$$

where,$|d_{(k,l)}|$ and $\theta_{k,l}$ represent the magnitude and phase of the transformed coefficients $d_{(k,l)}$ respectively. This method treats the α-root of the magnitude component of the transformed coefficients $d_{(k,l)}$ retaining their phase component. Generally, the transformed coefficients have low amplitudes at higher spatial frequencies and high amplitudes at lower spatial frequencies, this method enhances the amplitude of the higher spatial frequencies more than that of the low spatial frequencies. Due to this, the resulting out has a higher emphasis on the details such as edges. The transformed coefficients are raised to some value '$\alpha$',where $0 < \alpha \leq 1$, that reduces the amplitude of the low frequency components having higher values, more than the higher frequency components containing lower amplitudes. The alpha rooting operation[9] is defined as,

$$d(k,l)' = |d(k,l)|^{\alpha} e^{j\theta_{k,l}} \tag{3.2}$$

### 3.2.2 Advantages

- Easier image enhancement technique in the compressed domain, no computational complexity.
- The image obtained after the rooting operation has more sharper features and clearly defined edges.
- The information contained in the rooting-operated image is more decipherable as compared to the original image.

### 3.2.3 Disadvantages

- The method is not effective on all the images as it brings about a tonal change in the original image. The method results in overall graying of the image and the effect is clearly observable in the case of images that are originally darker.

- The alpha rooting operation many a times produce sharper but darker images, that result in a poor contrast and badly illuminated images which is not desired out of a good enhancement method.
- The method also results in ugly artifacts.
- The undesired component i.e. noise in the image also gets enhanced.

## 3.3 Retinex

### 3.3.1 Method

The Retinex theory[3] put forward by Edwin Land in 1964 is one of the effective model used from much time in order to represent the human visual system. The word ‘Retinex’ is itself a combination of ‘retina’ and ‘cortex’, two of the major parts in the human eye responsible for its visual perception. The theory emphasizes specifically on the human visual ability to view the objects under different illumination conditions, such as in direct sunlight, in case of a shadow or in some kind of artificial illumination conditions. The Retinex[3], also operates on the transformed coefficients $d_{(k,l)}$ of the image $I_{x,y}$ using Discrete Cosine Transform. The transformed coefficients are then segregated into blocks of size 8x8. The 8x8 DCT block containing one DC coefficient and 63 AC coefficients are seen to be responsible for the illumination $L_{x,y}$ and reflectance $R_{x,y}$ of the image respectively. The image $I_{x,y}$ is represented as,

$$I_{x,y} = L_{x,y} \cdot R_{x,y} \tag{3.3}$$

The method involves estimation of the illumination component as $\mathrm{L}'_{\mathrm{x,y}}$ of the scene. Then, it estimates the reflectance component $\mathrm{R}'_{\mathrm{x,y}}$of the scene as a ratio of the original luminance $\mathrm{I}_{x,y}$ of the scene to the estimated illumination $\mathrm{L}'_{\mathrm{x,y}}$ . This is given as,

$$\mathrm{R}'_{\mathrm{x,y}} = \mathrm{I}'_{\mathrm{x,y}}/\mathrm{L}'_{\mathrm{x,y}} \tag{3.4}$$

Then the output image is obtained as a product of the estimated reflectance component and the modified illumination $\mathrm{G}(\mathrm{L}'_{\mathrm{x,y}})$ which is the result of the estimated illumination component being operated by any non-linear operator $\mathrm{G}(.)$ such as a low pass filter, for compressing the dynamic range of the image. The final output image $\mathrm{O}_{\mathrm{x,y}}$ is given as,

$$\mathrm{O}_{\mathrm{x,y}} = \mathrm{R}'_{\mathrm{x,y}} \cdot \mathrm{G}(\mathrm{L}'_{\mathrm{x,y}}) \tag{3.5}$$

The output image is the enhanced image primarily based upon dynamic range compression.

### 3.3.2 Advantages

- A simple, fast and effective technique in the compressed domain.
- Reduction of computational complexity and storage requirements.
- Improvement in the illumination and dynamic range of the image.
- Less affected by noise in the environment.

### 3.3.3 Disadvantages

- Though the output image obtained is improved in terms of illumination but the method does not provides good tonal rendition.
- The output image also suffers from a ‘washed-out’ appearance.

## 3.4 Multi-Scale Contrast Enhancement

### 3.4.1 Method

The human vision is sensitive to the low frequency components as compared to the high frequency components. Based on this idea, a multi-scale contrast enhancement algorithm is defined by Tang et. al.[7], where he analyzes each DCT block of the image in detail as follows:

- **Diagonal band analysis -** Each 8x8 DCT block is divided into 14 diagonal bands, excluding the DC coefficient of the block and each diagonal band is known as energy band $E_n$ as shown in fig.(4.4). Based upon the energy band magnitude of the bands the contrast of each band is calculated.
- **Band Contrast** – The contrast for each band is evaluated as a ratio of the high-frequency content to the low frequency content in the bands of the DCT block. This contrast measure[7] also results in a multi-scale structure which is in accordance with the human visual system. Depending upon the contrast values obtained, a scaling factor is evaluated for each successive diagonal bands which remains constant for every block.

### 3.4.2 Advantages

- The multi-scale contrast enhancement structure[7] corresponds to the human vision model.
- The method analyzes each 8x8 DCT matrix in detail.
- The algorithm does not affects the compressibility of the image.

### 3.4.3 Disadvantages

- The contrast measure[7] emphasizes mostly on the AC coefficients of the DCT matrix as DC coefficients are ignored.
- Computation of different scaling factors for each of the 14 diagonal bands of AC coefficients in a block increases computational complexity.

## 3.5 Contrast Enhancement by Scaling (CES)

### 3.5.1 Method

The image enhancement techniques described above either concentrate on improving the illumination of the images by reducing the dynamic range by analyzing the DC coefficient of the DCT blocks or on improving the contrast of the images by analyzing the AC coefficients of the DCT block. This method of contrast enhancement by scaling (CES)[5] treats both the DC coefficient and the AC coefficients of the 8x8 DCT block with a common scaling factor thereby improving both the brightness and contrast of the image. The algorithm not only considers the intensity component of the image but also takes into account the chrominance components of the image. The method is defined in four steps as:

- Improvement in the background illumination.
- Improvement in the local contrast.
- Preservation of colours in the image.
- Removal of the blocking artifacts.

The algorithm makes use of a few external functions such as twicing function, S-function etc. for the evaluation of a scaling factor required for image enhancement.

### 3.5.2 Advantages

- Low computational complexity.
- The method helps in enhancing the image by improving the illumination and contrast of the image.
- It also takes care of the chrominance components in the image.
- The algorithm helps in suppressing the blocking artifacts resulting due to the block-wise analysis of images.

### 3.5.3 Disadvantages

- The CES method [5] uses same scaling factor for both the DC coefficient and the AC coefficients of the each DCT block.
- It does takes into account the varied statistical behaviour of the DCT coefficients i.e. DC coefficient and the AC coefficients.

## 3.6 Summary

The chapter showed the pros and cons of various image enhancement techniques in the compressed domain. It is evident that though the DCT coefficients are utilized for the enhancement process but still there is a requirement to treat both the coefficients differently depending upon their varied statistical behaviour. The proposed work is motivated by the multi-scale contrast enhancement[7] and the contrast enhancement by scaling method[5]. The multi-scale contrast enhancement method[7] provides a good solution to the analysis of the AC coefficients broadly.

# Chapter 4

# Proposed Image Enhancement Algorithm

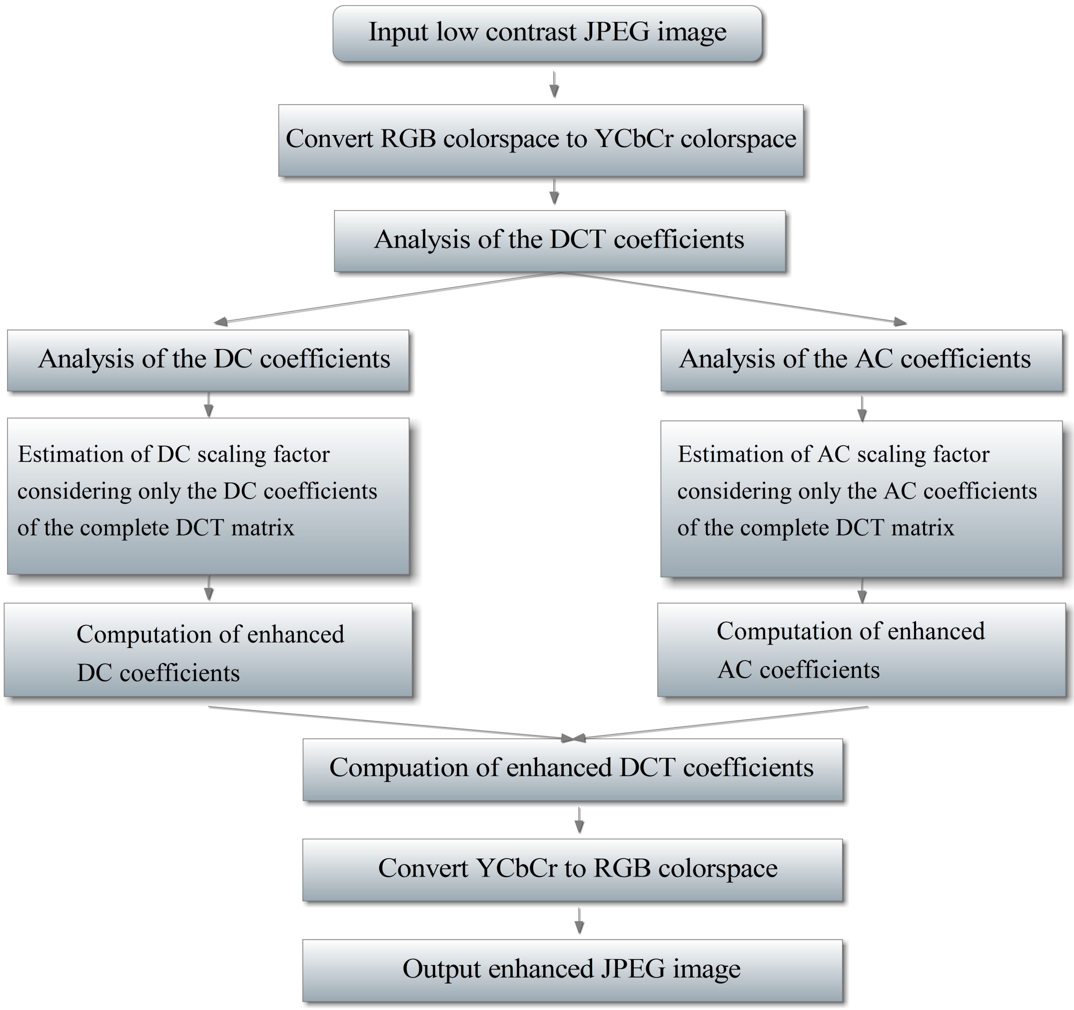
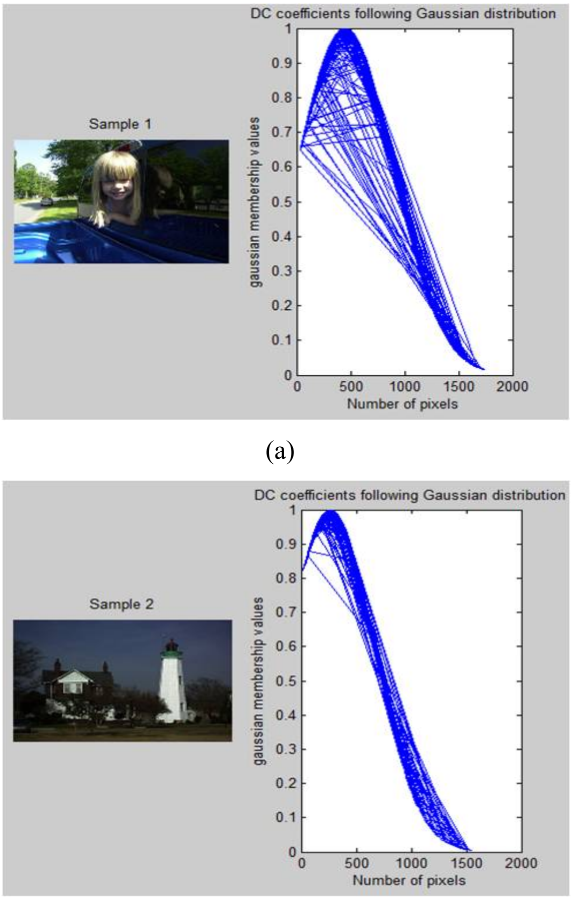



Figure 4.1: Flow-chart of the Proposed method

Fig.4.1 represents the flowchart of the proposed method. The proposed method takes into consideration the statistical behaviour of the Discrete Cosine Transform (DCT) coefficients that are extracted from the input image which is in the JPEG format[10]. This statistical behaviour of the DCT coefficients[11] is considered because the DC coefficient and the AC coefficients have different statistical distribution. The DC coefficient follow Gaussian distribution whereas the 63 AC coefficients of a block follow Laplacian distribution due to which they are analyzed separately . The proposed method utilizes this fact and evaluates scaling factors for each DC coefficient and AC coefficients. The scaling factors computed are then used to evaluate the enhanced DCT coefficients. The enhanced DCT coefficients produce better results quantitatively and qualitatively in comparison with the existing state-of-the-art technique i.e. Contrast Enhancement by Scaling(CES)[5].

## 4.1 Statistical Behaviour of DCT coefficients

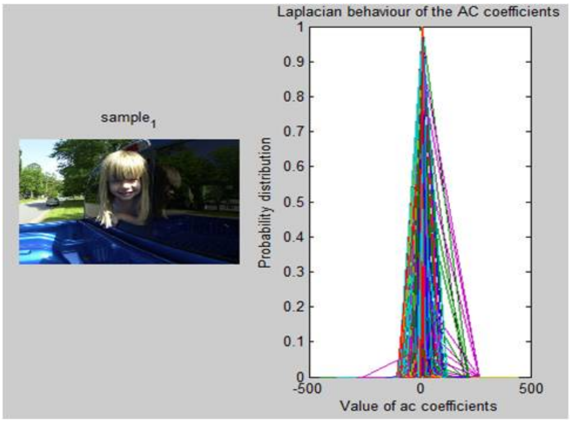



(a)

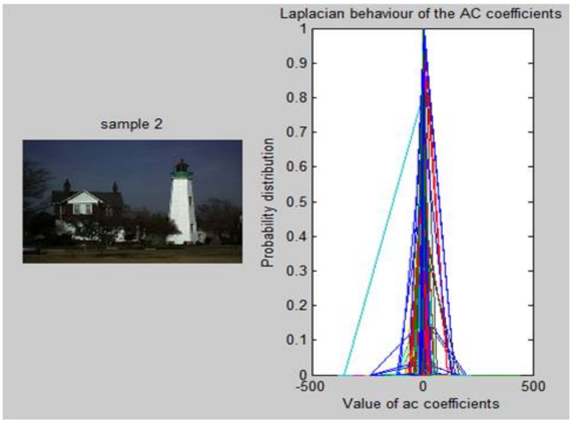
(b)

Figure 4.2: Gaussian behaviour of DC coefficients (a)Image16 (b)Image22

Fig. 4.2 and 4.3 show the statistical behaviour of the DC coefficient and AC coefficients of a DCT block. The DCT block is of size 8x8. The input image bit stream is divided into 8x8 DCT blocks and then each block is analyzed separately. The figure shows the analysis done on one of such blocks. The inference drawn from the experiments on the blocks of the sample images was that the DC coefficient of each block when collected together tend to follow a Gaussian distribution whereas the 63 AC coefficients of each block tend to follow a Laplacian distribution. We can see that there are a few coefficients which tend to deviate from the actual distribution curve. These coefficients need to be fit in the actual distribution




(a)




(b)

Figure 4.3: Laplacian behaviour of AC coefficients (a)Image16 (b)Image22

curve in order to produce enhanced results. For this purpose, one of the statistical property called Entropy of the DCT coefficients was studied.

Entropy of an image is the description of the amount of information which is used for coding by the image compression techniques. The images, for example, having a lot of uniformity in pixel intensity values , tend to have low contrast values as well as they have low entropy too. A perfectly flat image is seen to possess zero entropy, as they contain similar information and can be compressed to relatively smaller size. On the other side , for example, the image of a moon has been observed to have heavily cratered areas thus there is a difference of pixel intensity vales thereby resulting in high contrast and as there is a randomness in intensity values, the information conveyed by the pixels is also high thereby resulting in high entropy.

The study of entropy was made over the DCT coefficients and it was observed that the DC coefficient resulted in negligible entropy whereas the 63 AC coefficients of each block resulted in considerable entropy values. Also the AC coefficients were seen to be responsible for the varied contrast in an image whereas the DC coefficient were observed to be responsible for the illumination in an image. Thus keeping in consideration their varied distribution and effect on the image properties , different scaling factors for the DC and AC coefficients were evaluated, as described in the following sub-sections.

The proposed method is described in detail in the following sub-sections. The algorithm of the proposed method is as follows :

- Statistical distribution analysis of the DC coefficient and AC coefficients[12, 13] of the DCT matrix of the original JPEG image bitstream.
- Analysis of the DC coefficient of the DCT 8x8 blocks followed by the evaluation of the DC scaling factor.
- Analysis of the 63 AC coefficients of each of the DCT blocks followed by the evaluation of the AC scaling factor.
- Computation of the enhanced values of each DCT block coefficients.

Table 4.1: 8x8 DCT block

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $d_{00}$ | $d_{01}$ | $d_{02}$ | $d_{03}$ | $d_{04}$ | $d_{05}$ | $d_{06}$ | $d_{07}$ |
| $d_{10}$ | $d_{11}$ | $d_{12}$ | $d_{13}$ | $d_{14}$ | $d_{15}$ | $d_{16}$ | $d_{17}$ |
| $d_{20}$ | $d_{21}$ | $d_{22}$ | $d_{23}$ | $d_{24}$ | $d_{25}$ | $d_{26}$ | $d_{27}$ |
| $d_{30}$ | $d_{31}$ | $d_{32}$ | $d_{33}$ | $d_{34}$ | $d_{35}$ | $d_{36}$ | $d_{37}$ |
| $d_{40}$ | $d_{41}$ | $d_{42}$ | $d_{43}$ | $d_{44}$ | $d_{45}$ | $d_{46}$ | $d_{47}$ |
| $d_{50}$ | $d_{51}$ | $d_{52}$ | $d_{53}$ | $d_{54}$ | $d_{55}$ | $d_{56}$ | $d_{57}$ |
| $d_{60}$ | $d_{61}$ | $d_{62}$ | $d_{63}$ | $d_{64}$ | $d_{65}$ | $d_{66}$ | $d_{67}$ |
| $d_{70}$ | $d_{71}$ | $d_{72}$ | $d_{73}$ | $d_{74}$ | $d_{75}$ | $d_{76}$ | $d_{77}$ |

Table 4.1 represents the general DCT block of size 8x8 considered in the analysis of the image in the compressed domain. Here, '$d_{00}$' is the DC coefficient and the remaining 63 coefficients are called AC coefficients.

## 4.2 Modeling of DC coefficient

The first coefficient of each DCT block i.e. '$d_{00}$' is the DC coefficient. Given an input image with image height as 'H' and image width as 'W'. The number of blocks 'M' required to be analyzed are evaluated as $\mathrm{M} = \frac{\mathrm{H} \times \mathrm{W}}{8}$. Let the DC coefficient of an arbitrary block 'm' be

Table 4.2: DC Matrix

| | | | | |
|---|---|---|---|---|
| $DC_0$ | $DC_1$ | .. | .. | .. |
| .. | .. | .. | .. | .. |
| .. | .. | .. | .. | .. |
| .. | .. | .. | .. | .. |
| .. | .. | .. | .. | $DC_M$ |

represented as '$d_{00}^{m}$' where m ϵ 1,2,. . . . ,M. DC coefficient of all 'M' blocks are collected together to form an array of 'p' rows and 'q' columns, consisting of all DC coefficients only.

Further, the DC matrix is analyzed to compute a '$\psi$' matrix. The coefficients of the '$\psi$' matrix are obtained by evaluating the ratio of maximum value of a DC coefficient in a 4x4 window to the minimum value of the DC coefficient in the same window. This window is passed over the complete DC matrix and results in a new '$\psi$' matrix. Mathematically, '$\psi$' matrix is represented as ,

$$\psi(i,j) = \frac{\max DC_{4x4}(i,j)}{\min DC_{4x4}(i,j)} \tag{4.1}$$

where i = 1,2, . . . , p/4 and j = 1,2, . . . , q/4 . This matrix is obtained as a result of the above analysis. Further, the evaluation is done on the '$\psi$' matrix. As the DC coefficients of each DCT 8x8 block carry the average value of that block , they have the highest value and are highly correlated with the DC coefficient values of the respective blocks . Due to this when the '$\psi$' matrix is evaluated as a result of the ratio of the maximum value of a DC coefficient to the minimum value of the DC coefficient in a 4x4 block, it is observed that the coefficients of the '$\psi$' matrix are also highly correlated with each other. The amount of correlation is further analyzed by evaluating the coefficient of variation of the '$\psi$' matrix. The Coefficient of Variation '$C_v$' is a dimensionless quantity that gives a relative measure of dispersion of a distribution under consideration. It is defined as the ratio of the standard deviation of the distribution to the mean of the distribution .

$$C_v = \frac{\sigma}{\mu} \tag{4.2}$$

where, $C_v$ = Coefficient of Variation
$\sigma$ = Standard deviation of the '$\psi$' matrix.
$\mu$ = Mean of the '$\psi$' matrix. The Coefficient of Variation ($C_v$) evaluated above is chosen to be the scaling factor for the DC coefficients present in all the 'M' blocks. The DC scaling factor is represented as '$\lambda$', where,

$$\lambda = C_v = \frac{\sigma}{\mu} \tag{4.3}$$

It is this DC scaling factor that is utilized further for the estimation of enhanced DC coefficient values for all the 'M' blocks.

## 4.3 Modeling of AC coefficients

Figure 4.4 represents the coefficients of an arbitrary $m^{th}$ DCT block of size 8x8, where the first coefficient also called DC coefficient of the block is neglected ,for the modeling of AC coefficients. The figure displays fourteen diagonal energy bands named as$E_n$ = $E_1$ , $E_2$ , . . . . , $E_{14}$, where n = 14. These energy bands represent the diagonal AC coefficients of the block and further these diagonal bands are analyzed on the basis of their contrast and entropy. This band analysis is introduced in order to make the scaling factor for the AC coefficients independent of any pre-defined functions. As discussed in the previous sections, that an

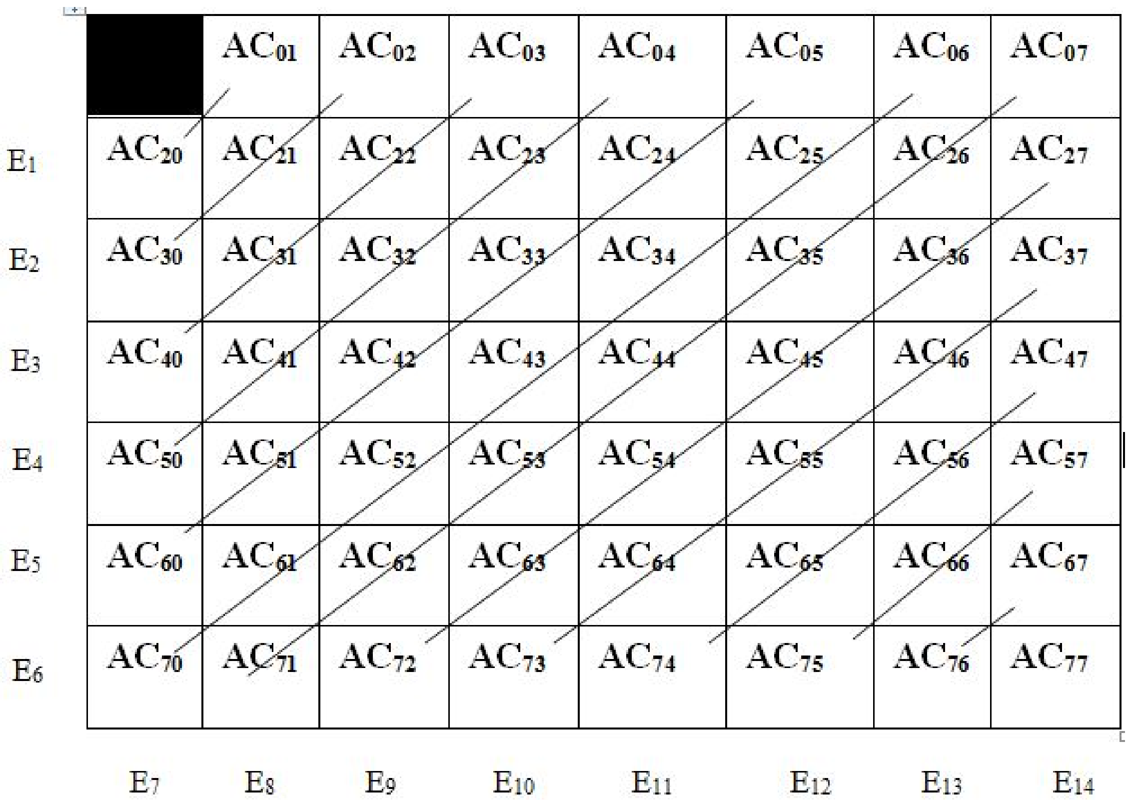



Figure 4.4: Diagonal band representation of AC coefficients in a DCT block.

image having high contrast also results in high entropy and a low contrast image produces low entropy i.e the amount of information conveyed by a high contrast image is more than the information conveyed by a low contrast image. This relationship of entropy and contrast for still images is utilized for evaluating the scaling factor for the AC coefficients. The entropy [2], [9] with respect to this context is defined as,

$$H = -\sum_{\forall i} p(x_i) \log p(x_i) \tag{4.4}$$

where, xi is the $i^th$ dct coefficient of the given block . The method for evaluation of the AC coefficients is inspired from the work of Tang et. al. [6]. The concept of diagonal band analysis of the AC coefficients is derived by Tang et. al.'s[6] work with a modification . As shown in fig.(4.4) ,the 63 AC coefficients of each block of 'M' DCT blocks containing all the coefficients $d_{k,l}$ where $0 \leq \mathrm{k}, \mathrm{l} \leq 7$ are divided into fourteen diagonal bands except for $d_{0,0}$ which is the DC coefficient of the matrix and has been already analyzed separately .

The diagonal bands are represented as

$$E_n = E_1, E_2, ...., E_{14}$$

where n = 14, as described diagrammatically earlier in this section. Each of the AC coefficients of nth band comprise of n = k + l number of AC coefficients. For example , for the 2nd band ,the coefficients collected are $d_{0,2}$ , $d_{1,1}$ and $d_{2,0}$ , in all cases k and l values sum upto 2,which is the value of the band.

The diagonal bands once grouped are further analyzed for their individual band contrast and band entropy. The relationship between the band contrast and band entropy of a nth band decides the scaling factor for the AC coefficients. The contrast for the nth band is termed as $C_n$ (n $\geq$ 1),

$$C_n = \frac{E_n}{\sum_{t=0}^{n-1} E_t} \tag{4.5}$$

where,

$$E_t = \frac{\sum_{k+l=t} E_t}{N} \tag{4.6}$$

$$N = \begin{cases} t+1, \text{fort} < 8 \\ 14-t+1, , \text{fort} \geq 8 \end{cases} \tag{4.7}$$

The above expressions evaluate the local contrast$C_n$ of the band structure , the average spectral amplitude of the diagonal band i.e. En .This local contrast measure presents a multiscale structure[7] and can be broadly defined as the ratio of spectral content present in a bandpass version of an image obtained by the nth band to the spectral content of the lowpass version of the image block obtained by collecting all those bands having value of the bands lesser than n.

This multiscale structure[7] is utilized in this work for the evaluation of contrast as well as entropy .The detailed analysis for the computation of the scaling factor of AC coefficients is explained as follows:

### 4.3.1 Estimation of Band Contrast values

The individual Discrete Cosine Transform blocks are evaluated based on the fourteen bands that are diagonally grouped , containing only the AC coefficients. The diagonal bands are analyzed using the contrast measure as defined in the above sections, which gives,

$$C = [C_1, C_2, C_3, ......., C_{14}]$$

### 4.3.2 Estimation of the Band Entropy values

As the Contrast of the diagonal bands is analyzed and evaluated , similarly the 14 diagonal bands are analyzed for their respective entropies. The diagonal entropy ratio for each band

($n \geq 1$) is represented as $H_n^{'}$ ,where,

$$H_n^{'} = \frac{H_n}{\sum\limits_{t=0}^{n-1} H_t} \tag{4.8}$$

where,

$$H_t = \frac{\sum\limits_{k+l=t} H_t}{N}$$

$H_n$ is the Entropy of the $n_t h$ diagonal band given by equation (4.6),that results in a collection of band entropy ratios of a block as,

$$H^{'} = [H_1^{'}, H_2^{'}, H_3^{'}, ....., H_{14}^{'}]$$

## 4.4 Analysis of Band Contrast and Band Entropy

Entropy and Contrast of an image are highly correlated with each other. On these terms, an analysis is done on all the 14 diagonal bands. The difference in Contrast ($C_n$) and Entropy ($H_n^{'}$) is calculated . The scaling factor for the 63 AC coefficients is chosen to be the maximum difference in the contrast and entropy ,of the 14 diagonal bands for the DCT block under consideration . The difference is represented as,

$$\phi = max[H^{'} - C] \tag{4.9}$$

## 4.5 Estimation of AC Coefficients Scaling factors for all DCT blocks

The image in the compressed domain is grouped into ‘M’ blocks. These blocks contain the values of DCT coefficients i.e a DC coefficient and 63 AC coefficients, as described in the previous sections. The complete analysis and evaluation of 63 AC coefficients is done by repeating steps (1)-(3). For each DCT block ‘m’ out of ‘M’ blocks , a scaling factor ‘$\phi_m$’ is calculated (m ϵ 1,2,3, . . . , M ).

## 4.6 Computation of the Enhanced DCT Matrix values

The coefficients of each DCT block ,after being investigated in detail for finding the enhancing factors for the coefficients of each block , are finally scaled by those values. The new DCT block matrix is obtained by performing the following operation on the original DCT blocks :

### 4.6.1 Enhanced DC coefficient :

The original DC coefficient of all the blocks are collectively scaled by a common scaling factor as found by equation (4.3). It is represented as $d_{00}^{enh}$,

$$d_{00}^{enh} = \lambda \times d_{00} \tag{4.10}$$

### 4.6.2 Enhancing AC coefficients

Since the contrast and entropy of the AC coefficients are analyzed using diagonal bands in each block, the factors that are computed are variable for each block. This variation results in different AC scaling factors($\phi_m$) for different blocks, that are further used to scale the original AC coefficients of each block, represented as $d_{k,l}^{enh}$,

$$d_{k,l}^{enh} = \phi_m \times d_{k,l} \tag{4.11}$$

### 4.6.3 Final Enhanced DCT matrix

Formation of the complete enhanced DCT matrix is done by replacing the original coefficients in a '$m_t h$' block i.e. DC coefficient $d_0 0$ and 63 AC coefficients $d_(k,l)$ by their respective enhanced coefficients i.e enhanced DC coefficient $d_{00}^{enh}$ and enhanced 63 AC coefficients $d_{k,l}^{enh}$ , as shown below,

Table 4.3: Enhanced DCT coefficients matrix

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\lambda DC_{00}$ | $\phi AC_{01}$ | $\phi AC_{02}$ | $\phi AC_{03}$ | $\phi AC_{04}$ | $\phi AC_{05}$ | $\phi AC_{06}$ | $\phi AC_{07}$ |
| $\phi AC_{10}$ | $\phi AC_{11}$ | $\phi AC_{12}$ | $\phi AC_{13}$ | $\phi AC_{14}$ | $\phi AC_{15}$ | $\phi AC_{16}$ | $\phi AC_{17}$ |
| $\phi AC_{20}$ | $\phi AC_{21}$ | $\phi AC_{22}$ | $\phi AC_{23}$ | $\phi AC_{24}$ | $\phi AC_{25}$ | $\phi AC_{26}$ | $\phi AC_{27}$ |
| $\phi AC_{30}$ | $\phi AC_{31}$ | $\phi AC_{32}$ | $\phi AC_{33}$ | $\phi AC_{34}$ | $\phi AC_{35}$ | $\phi AC_{36}$ | $\phi AC_{37}$ |
| $\phi AC_{40}$ | $\phi AC_{41}$ | $\phi AC_{42}$ | $\phi AC_{43}$ | $\phi AC_{44}$ | $\phi AC_{45}$ | $\phi AC_{46}$ | $\phi AC_{47}$ |
| $\phi AC_{50}$ | $\phi AC_{51}$ | $\phi AC_{52}$ | $\phi AC_{53}$ | $\phi AC_{54}$ | $\phi AC_{55}$ | $\phi AC_{56}$ | $\phi AC_{57}$ |
| $\phi AC_{60}$ | $\phi AC_{61}$ | $\phi AC_{62}$ | $\phi AC_{63}$ | $\phi AC_{64}$ | $\phi AC_{65}$ | $\phi AC_{66}$ | $\phi AC_{67}$ |
| $\phi AC_{70}$ | $\phi AC_{71}$ | $\phi AC_{72}$ | $\phi AC_{73}$ | $\phi AC_{74}$ | $\phi AC_{75}$ | $\phi AC_{76}$ | $\phi AC_{77}$ |

## 4.7 Simulation and Result

The proposed work is implemented using Matlab R2014a. The method is tested for the images which have been previously used for the studies related to image enhancement. The proposed method is also tested for the images provided in the UCID v2[14] dataset. The method is compared with a standard technique i.e. Contrast Enhancement by Scaling(CES)[5] , as the proposed method is motivated from the same. As discussed earlier, in the proposed method the DC coefficient and the AC coefficients of each block are treated separately in order to obtain different scaling factors one each for DC coefficient and AC coefficients. The different scaling factors that are obtained by treating the DC coefficient and the AC coefficients separately are thus independent of any pre-defined functions like twicing function, S-function etc. as used in CES[5]. These factors are then used further for modifying the DCT coefficients in order to obtain a better contrast and enhanced image. The proposed method offers various advantages over other enhancement techniques as discussed in detail in the following sections. The results obtained through the proposed method are presented qualitatively as well as quantitatively and are compared with CES method[5] ,for the validating the effectiveness of the proposed method.

### 4.7.1 Qualitative Analysis

This section deals with the qualitative i.e. subjective analysis of the proposed method. Fig.(4.6-4.7) displays the effect of the proposed method on a few images, used for test in the study. As seen in the Fig.(4.6-4.7) ,it is evident that for the tested image dataset, the proposed method is subjectively and visually better than the CES method[5]. For instance , the test image name 'image16', in which a girl child is shown looking out of a car window, it is seen that the proposed method shows improvement in areas like the reflection of the girl's face on the car window as well as the sun's illumination on the girl's hair is enhanced better as compared to the CES method[5].

Similarly, the sunlight on the road is observed to be balanced when treated with the proposed method as compared to the CES method[5]. The UCID image dataset[14] also shows interesting results when tested with the proposed work. As shown in Fig.(4.7), the proposed method when applied to the ucid00470 image, seems to preserve the subtle details of the glass pane in the image, where the green color of few of the glass panes that are below and above the eagle are more enhanced in comparison to the CES work[5].

Also, in the ucid00155 image, it is observed that on treatment of the image with the proposed work the sun's illumination on the playground becomes much better and even there is a sharp change in the overall contrast of the image as compared to the CES work[5]. Similarly, improvement in illumination and contrast can be viewed for the rest of the test images in Fig(4.6-4.7). These improvements in terms of brightness and contrast has been made possible in the proposed method, as it treats the DC coefficient and AC coefficients of each block separately, depending upon the statistical distribution of the DCT coefficients. It is seen that the proposed method achieves comparable results to that of the CES[5] , independent of use of any external functions as that utilized in the CES work[5] which is one of the novel feature of the proposed work.

### 4.7.2 Quantitative Analysis

Here a comparative and quantitative analysis between the proposed work and the CES method[5] is presented in detail. As there are many DCT blocks in an image and in each block each of the 14 diagonal bands are analyzed in terms of their contrast and entropy, so a graphical analysis of the behaviour of band contrast($C_n$) and band entropy($H_n^{'}$) with respect to the 14 diagonal bands,is presented in Fig.(4.4). The analysis in Fig.(4.5) is shown for the AC coefficients belonging to the block number 600 of image16.

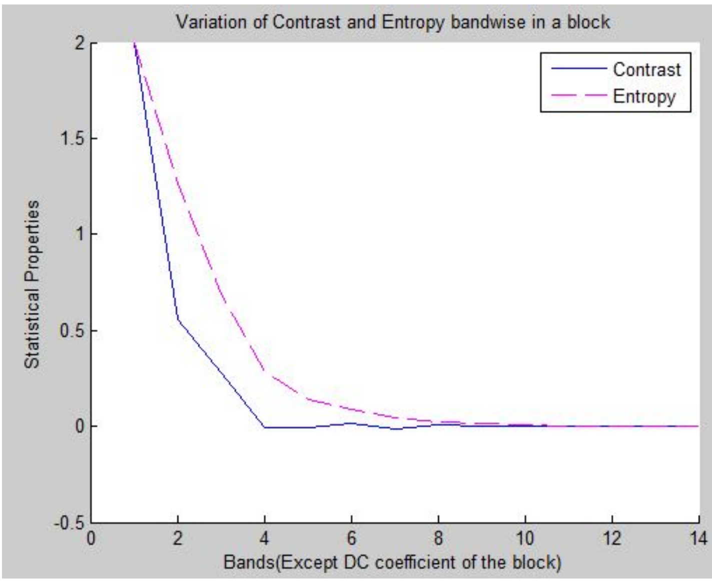



Figure 4.5: Contrast and Entropy behaviour of Diagonal bands in a block

Fig.() shows that in the given DCT block, the band contrast and band entropy of the diagonal bands in the DCT block follow each other and this diagonal band analysis also shows that both the key features of the DCT block i.e. contrast and entropy have significant value in the mid-range. This graphical analysis has been utilized in the proposed work for the selection of the scaling factor for the AC coefficients. This concept is also with reference to the multiscale structure of the DCT bands as discussed in Tang et al.'s work[7]. As described in the previous sections, this diagonal band analysis is utilized in the proposed work for arriving at the AC scaling factor ($\phi$) by choosing the maximum value out of the difference between $H_n^{'}$ and $C_n$ for all the 14 diagonal bands. The proposed method is quantitatively analyzed using a measurement metric called Contrast Enhancement Factor (CEF). The factor is chosen in order to compare the results with the CES work[5]. The Contrast Enhancement Factor is defined below as :-

$$CEF = \frac{CM(I_{enhanced})}{CM(I_{original})} \tag{4.12}$$

where,

$$CM(I) = \sqrt{\sigma_\alpha^2 + \sigma_\beta^2} + 0.3\sqrt{\mu_\alpha^2 + \mu_\beta^2}$$

Here, $\alpha$ and $\beta$ represent channels whose values are derived from the red, green and blue components of the image, denoted as R, G and B respectively. Here, $\alpha = \mathrm{R} - \mathrm{G}$ and $\beta = ((\mathrm{R} + \mathrm{G})/2) - \mathrm{B}$ .The mean and standard deviation of the α channel is represented by

$\mu_\alpha$ and $\sigma_\alpha$ respectively. Similarly, the mean and standard deviation of the β channel is represented by $\mu_\beta$ and $\sigma_\beta$ respectively.

Table 4.4: Contrast Enhancement Factor (CEF) Evaluation

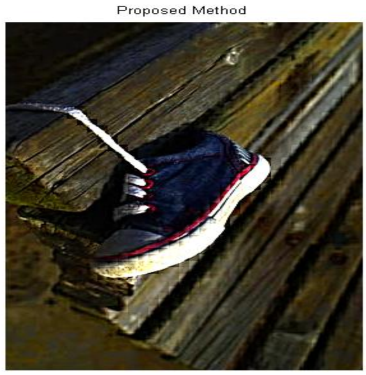
| IMAGE NAME | CES[1] method | Proposed method |
|---|---|---|
| Image16 | 1.38 | 1.50 |
| Image22 | 1.72 | 1.92 |
| Image24 | 1.76 | 1.93 |
| Ucid00196 | 1.46 | 1.69 |
| Ucid00018 | 1.02 | 1.30 |
| Ucid00095 | 1.40 | 1.78 |
| Ucid00146 | 1.73 | 1.97 |
| Ucid00470 | 1.42 | 1.76 |
| Ucid00503 | 1.37 | 1.57 |
| Ucid00564 | 1.38 | 1.49 |
| Ucid00607 | 1.42 | 1.50 |
| Ucid00609 | 1.58 | 1.86 |
| Ucid00030 | 1.18 | 1.70 |
| Ucid00155 | 1.74 | 1.92 |
| Ucid01194 | 1.59 | 1.87 |

As seen from Table (4.4), the proposed method achieves much better CEF values as compared to the CES method[5]. The CEF values are observed for all the images taken from the CES work[5] and the UCID dataset[14]. This improvement in the measurement metric is made possible by considering the statistical behaviour of the DC coefficient and AC coefficients of the DCT blocks individually for arriving at their respective scaling factors. Though, the CES method[5] also gives good results, still modifying both the DC coefficient and the AC coefficients with a single scaling factor with the use of few external functions, is unable to utilize the DCT block behaviour. The proposed method, on the other side, is though motivated from the CES method[5], but the method utilizes the statistical behaviour[13] of the individual coefficients i.e. DC coefficient and the AC coefficients of each block irrespective of any external function for arriving at different scaling factors for the DCT coefficients of each block.

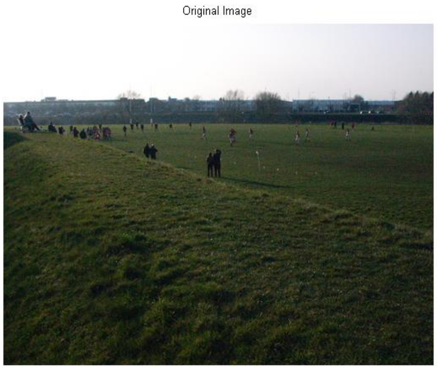
## 4.8 Discussion

Each block of the compressed form of the image is analyzed on the basis of the statistical behaviour of the DC coefficient and AC coefficients of each block as both the coefficients of a DCT block affect the image in a different manner i.e. the DC coefficient affect the illumination of the image and the AC coefficients affect the contrast of the image, as described in detail in the earlier sections. This difference in the behaviour of the DCT coefficients is the base of our study, thereby producing a better result for the performance metric i.e. Contrast Enhancement Factor (CEF) as that compared to the CES work[5]. This method removes the dependence of the DCT coefficients on the external functions and analyses the behaviour of each coefficient of a DCT block in detail. This helps in the producing visually pleasing and sharp contrast images. The proposed method has helped in producing images with better subjective quality as compared to the CES method[5].


(a)

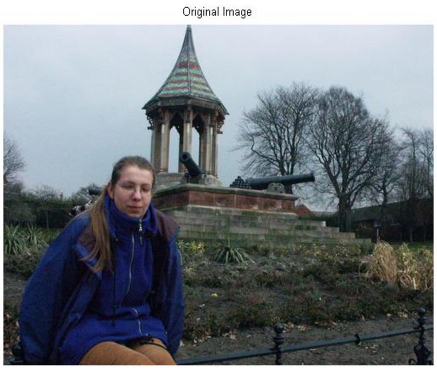



(b)

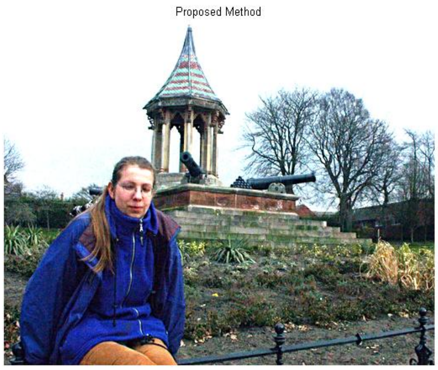



(c)


(d)

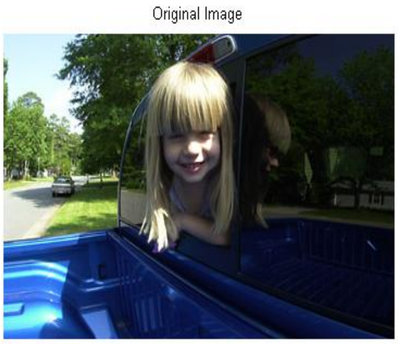



(e)




(f)

Figure 4.6: Enhanced images using proposed method (a)original Image24 (b)Enhanced Image24 (c)original Ucid00155 (d)Enhanced Ucid00155 (e)Original ucid00196 (f)Enhanced ucid00196

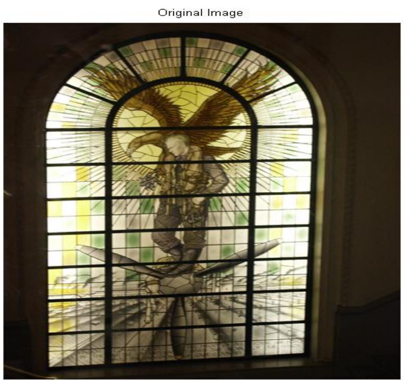


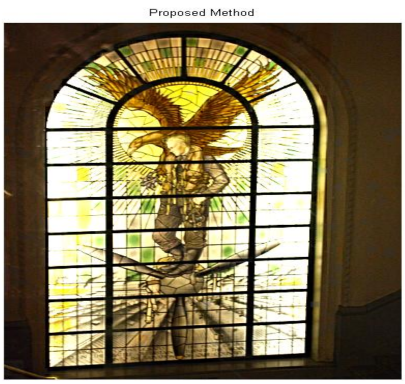


(a) (b)



(c) (d)




(e) (f)

Figure 4.7: Enhanced images using proposed method (a)original Image16 (b)Enhanced Image16 (c)original Image22 (d)Enhanced Image22 (e)Original ucid00470 (f)Enhanced ucid00470

# Chapter 5

# Conclusion and Future work

The proposed algorithm is investigated to achieve a novel method for image enhancement for the JPEG compressed images. Experimental observations show better performance of the proposed algorithm as compared to an existing technique for image enhancement i.e. CES method[5].The research study utilized the statistical behaviour of the DC coefficient and the AC coefficients of each DCT block of the image in order to determine the different scaling factors for each i.e. the DC coefficient and the AC coefficients. Prior to finding a method for finding the scaling factors for the DCT coefficients, a study is carried on the statistical behaviour of the block DCT coefficients. It was found that the DC coefficient of each block when collected together tend to follow a Gaussian probability distribution function whereas the AC coefficients of each DCT block tend to follow the Laplacian probability distribution function[13]. As the DC coefficients of each block contain the average value of that block and it is observed that the variation of the DC coefficient they are analyzed in terms of their coefficient of variation$(C_v)$ also known to be relative standard deviation. The coefficient of variation $(C_v)$ gives an idea about the deviation of the DC coefficient of each with respect to each other and this is utilized further in our study for arriving at the scaling factor for the DC coefficient of each block. On the contrary, the AC coefficients of each block are analyzed different to the DC coefficient. As the AC coefficient are found to be responsible for the contrast of an image, a multi-scale contrast [7] is utilized for its analysis, which is further used for analyzing the measure of information content using the multi-scale structure[7]. This helps in finding thestructure scaling factor for the AC coefficients of a DCT block. The DC scaling factor is same for all the blocks whereas the AC scaling factor varies from block to block. In both the cases, the proposed algorithm utilizes the statistical properties of the DCT coefficients to arrive at their respective scaling factors. The algorithm works upon the DCT coefficients and is independent of use of any external functions as utilized in the CES work[5].

## Scope for Further Research

The proposed work treats the DCT coefficients based upon their varied statistical behaviour and the DC coefficient and AC coefficients are scaled differently for each DCT block thereby producing better results subjectively and quantitatively than CES[5]. Though the algorithm has shown better results to CES[5] yet there are a few limitations to the proposed study. As the study is based upon the analysis of individual bands of each DCT block, the computation time taken for obtaining the scaling factor for AC coefficients of each block is higher. As the DC coefficient and AC coefficients are scaled by different factors for different blocks, there exist blocking artefacts in few cases which should be removed for obtaining a much better image.

# References


[1] T. Celik, “Spatial entropy-based global and local image contrast enhancement,” *IEEE Transactions on Image Processing*, vol. 23, no. 12, pp. 5298–5308, dec 2014.

[2] J. Jiang and G. Feng, “The spatial relationship of dct coefficients between a block and its sub-blocks,” *IEEE Transactions on Signal Processing*, vol. 50, no. 5, pp. 1160–1169, may 2002.

[3] Z.-u. R. D. Jobson and G. Woodell, “Properties and performance of a center/surround retinex,” *IEEE Transactions on Image Processing*, vol. 6, no. 3, pp. 451–462, mar 1997.

[4] J. K. J. Tang and E. Peli, “Image enhancement in the jpeg domain for people with vision impairment,” *IEEE Transactions on Biomedical Engineering*, vol. 51, no. 11, pp. 2013–2023, nov 2004.

[5] J. Mukherjee and S. Mitra, “Enhancement of color images by scaling the dct coefficients,” *IEEE Transactions on Image Processing*, vol. 17, no. 10, pp. 1783–1794, oct 2008.

[6] S. Lee, “An efficient content-based image enhancement in the compressed domain using retinex theory,” *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 17, no. 2, pp. 199–213, feb 2007.

[7] E. P. J. Tang and S. Acton, “Image enhancement using a contrast measure in the compressed domain,” *IEEE Signal Processing Letters*, vol. 10, no. 10, pp. 289–292, oct 2003.

[8] R. C. Gonzales and E. Woods, *Digital Image Processing*. Reading,MA: Addison-Wesley, 1992.

[9] S. Aghagolzadeh and O. K. Ersoy, “Transform image enhancement,” *Optical Engineering*, vol. 31, no. 3, pp. 614–626, 1992.

[10] S. J. Sangwine and R. E. N. Horne, *The Colour Image Processing Handbook*. Horne, Eds. London, U.K.: Chapman & Hall, 1998.

[11] E. Lam and J. Goodman, “A mathematical analysis of the dct coefficient distributions for images,” *IEEE Transactions on Image Processing*, vol. 9, no. 10, pp. 1661–1666, oct 2000.

[12] F. Muller, “Distribution shape of two-dimensional dct coefficients of natural images,” *Electronics Letters*, vol. 29, no. 22, pp. 1935–1936, oct 1993.

[13] R. Reininger and J. Gibson, “Distributions of the two-dimensional dct coefficients for images,” *IEEE Transactions on Communications*, vol. 31, no. 6, pp. 835–839, jun 1983.

[14] G. Schaefer and M. Stich, “in proc. spie,” in *Ucid: an uncompressed color image database*, vol. 5307, 2003, pp. 472–480.

[15] C.-R. C. W.-M. Ke and C.-T. Chiu, “Bita/swce: Image enhancement with bilateral tone adjustment and saliency weighted contrast enhancement,” *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 21, no. 3, pp. 360–364, mar 2011.

[16] H. Cheng and H. Xu, “A novel fuzzy logic approach to contrast enhancement,” *Pattern Recognition*, vol. 33, no. 5, pp. 809–819, 2000.

# Dissemination

**Conferences**

1. Jaspreet Bhatia, Manish Okade, ”A Novel Image Enhancement Technique based on Statistical Analysis of DCT coefficients for JPEG Compressed Images”, *Proc. of IEEE National Conference on Communications (NCC)*, IIT Guwahati, Mar 4-6th 2016, pp148-153.