

# **A Hybrid Optimization of Dual Tree Complex Wavelet Transform for Enhancement of Low Light Images**

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*Eiti Jain*

**Thesis**  
**Master of Technology in Electronics and Communication**  
**Engineering**  
**(Specialization in Communication Systems)**



**2019**

**Department of Electronics and Communication Engineering**  
**College of Technology and Engineering**  
**Maharana Pratap University of Agriculture & Technology, Udaipur**

# **A Hybrid Optimization of Dual Tree Complex Wavelet Transform for Enhancement of Low Light Images**

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**Thesis**

**Submitted to the**

**Maharana Pratap University of Agriculture & Technology, Udaipur**

**In Partial Fulfilment of the Requirement for**

**the Degree of**

**Master of Technology in Electronics and Communication**

**Engineering**

**(Specialization in Communication Systems)**



By

*Eiti Jain*

2019

**COLLEGE OF TECHNOLOGY AND ENGINEERING  
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE & TECHNOLOGY,  
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Date: 11/06/2019

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## ACKNOWLEDGEMENT

I take this opportunity to express my deep sense of gratitude and indebtedness towards my learned major advisor **Dr. Navneet Agrawal** for his valuable guidance, fruitful discussions, kind cooperation and encouraging attitude at all stages of this report making for its successful completion.

I am gratified to record sincere thanks to the members of the advisory committee; **Dr. Navneet Agrawal** (Department of Electronics and Communication Engineering) Major advisor, **Dr. Sunil Joshi** (Department of Electronics and Communication Engineering) Co-advisor, **Dr. Naveen Jain** (Department of Electrical Engineering) Advisor, and **Dr. K.K. Yadav** (Department of Soil and Water Engineering) DRI Nominee for their generous gestures and valuable suggestions in planning and execution of this study.

I would also like to devote my regards to **Dr. Sunil Joshi** Professor & Head, Department of Electronics and Communication Engineering, College of Technology and Engineering, Udaipur for providing support at every stage and providing all facilities at department level to carry out my research program.

I am privileged to express sincere and deep sense of gratitude to **Dr. Ajay Kumar Sharma**, Dean, College of Technology and Engineering, Udaipur for his due attention and encouragement during the study period and also for providing me the necessary facilities during the course of research.

Words can hardly register the sincere and heartfelt feeling which I have for staff members for their kind cooperation and help as and when needed.

I feel short of words to express my gratitude to my beloved **parents, brother** and **sister** for their utmost co-operation, sacrifice and encouragement during the course of this work.

Place: Udaipur

**Eiti Jain**

Date:

#### 1.1 General

Image processing is an imperative tool to know the specific details of image. Processing of image signal digitally is known as digital image processing. It is a technology to process digital image by applying a variety of computer algorithms. It is the method to convert an image into digitize format, in order to get a more enhance and improved image so as to extract some useful information from it. Image enhancement is one of the most important image processing techniques. It refers to the acumination of image features such as boundaries, edges, contrast to make graphical display more effective for analysis. Enhancement process increases the dynamic range which results in increasing the quality of the image.

Image enhancement comprises of various techniques that will enhance the image vision and convert the image to form it better for human or machine analysis. These techniques include contrast and gray level transformation, noise reduction, sharpening, edge detection, filtering, magnification and interpolation. Image enhancement techniques would simplify the task of processing of data extraction machine and focuses on characteristics of the original image. These techniques are proved useful for human observation and image analysis.

#### 1.2 Digital Image

An image is defined as two dimensional function,  $F(x,y)$  where  $x$ , and  $y$  are spatial coordinates and the amplitude of  $F$  at any coordinate is called the intensity or gray level of the image at that point  $(x,y)$ . If intensity value of  $f$ ,  $x$  and  $y$  are discrete and finite quantities, the image is then called as digital image. The digital image comprises of finite no. of the elements which are called the picture element, pels or pixel. Human perception is limited to visual band of the Electromagnetic Spectrum (EM). EM spectrum which is ranging from gamma to radio waves is almost cover by imaging machines (Jain, A. 1989).

### 1.3 Fundamental steps in Digital Image Processing (DIP)

In Digital Image Processing, fundamental steps are computerized generated processes which are divided into Low-Level processes, Mid-Level processes and High-Level processes where input is image and output can be image, attributes of the image or image analysis.

#### 1.3.1 Image Processing

It is mechanism of performing different operation on an image in order to extract some useful information and to get an enhanced image. It is form of signal processing where input is an image and output may be an image or characteristic related with that image. Nowadays, processing of image is among rapidly growing technologies. It forms a core research area within computer science and engineering too. In general image processing involves the following three steps: Pre-processing of image, Analysis and manipulating of the image, Output image or any characteristic related to image based on image analysis.

#### 1.3.2 Purpose of Image Processing

The purpose of image processing is classified as:

- **Visualization** – Examine the objects that are not visible.
- **Image sharpening and restoration** - To conceive a better image.
- **Image retrieval** - Pursue for the image of interest.
- **Measurement of pattern** – Identify different objects in an image.
- **Image Recognition** – Differentiate the objects in an image.

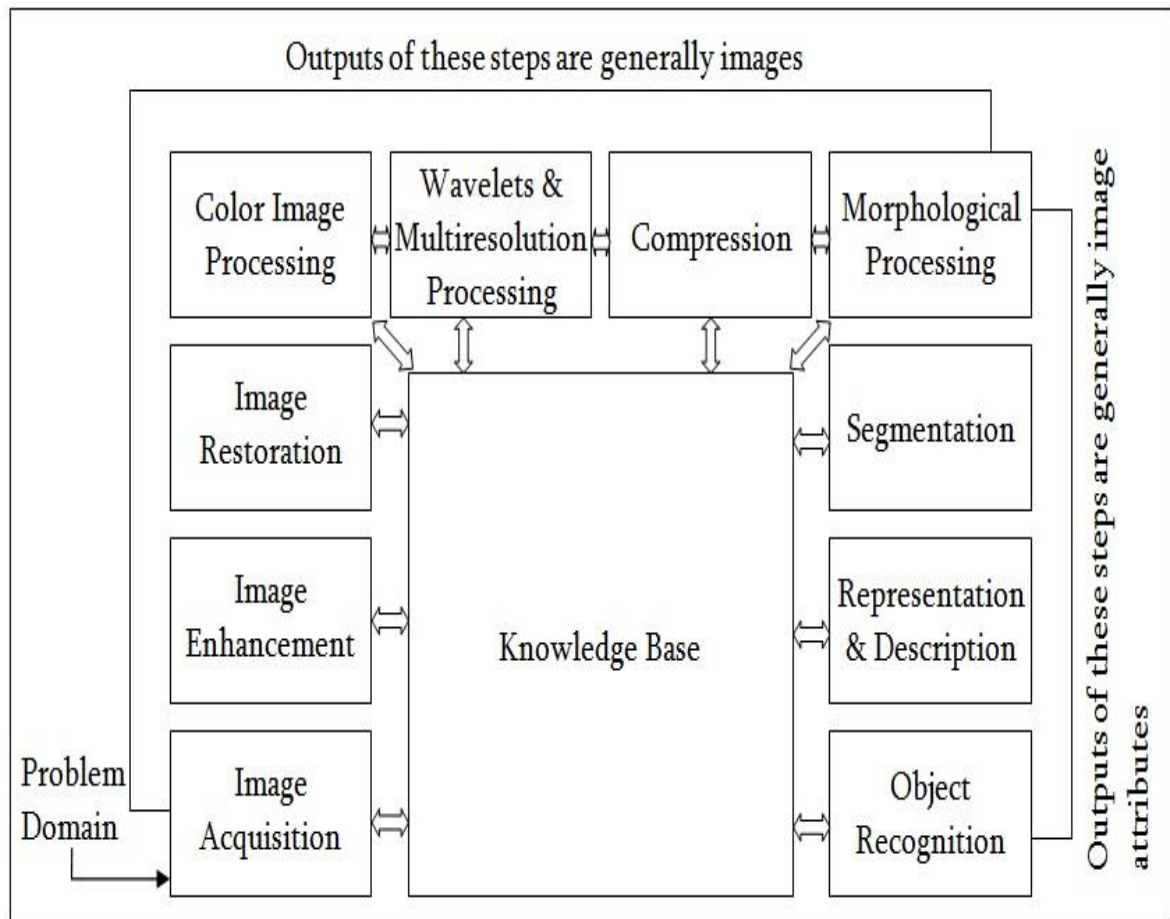
#### 1.3.3 Fundamental steps in DIP

Fundamental steps in digital image processing are represented in fig. 1.1 and description of these steps is discussed below:

##### (a) Image Acquisition

In digital image processing, image acquisition is defined as action of receiving an image from some source. It is hardware based source for image pre-processing. It is first and foremost step in sequence as without an image, processing is not possible.

Acquired image is completely unprocessed. Scaling is one of pre-processing step involves in image acquisition stage.



**Fig. 1.1: Fundamentals steps of DIP (Gonzalez, R.C. and Woods, R.E. 2004)**

### **(b) Image Enhancement**

It is software based digital manipulation of an image so that the resulting image is more specific than the original image. Image enhancement aims to improve the interpretability of information in images for better vision of humans and to provide better image for other processing system.

### **(c) Image Restoration**

Image restoration is the process of determining the corrupt and noisy image and then estimating original and clean image. Corruption of the image may have many forms such as noise, camera mis-focus, and motion blur. It attempts to restore the degraded image. Degradation process is identified and process is reversed. Image

restoration is similar to image enhancement but it is more objective. Although the original image is not similar to restore image but it is approximation of original image.

#### **(d) Colour Image Processing**

Colour image processing is an important growing area because of significantly increase in use of digital image over the internet. It covers the basics of colour processing in digital domain and fundamentals concept in color models. Color is also used as basics of extracting features of interest in an image.

#### **(e) Wavelets and Multi Resolution Processing**

Wavelets are more general way to analyse and represent multi resolution images. Wavelet processing is also applied to one dimensional signal. It is useful for removing of the noise and for image compression. Wavelets represent position and scale of features in an image.

#### **(f) Compression**

Image compression is applied to digital images to reduce the cost for transmission or storage. Image compression is a technique to convert or encode an image file so that it consumes less space than the primitive file. It reduces the size of image without demeaning or downgrading its quality to a large extent. Image compression is applied on image using various compression algorithm or codec. Redundancy of the image is reduced and data is transmitted or stored efficiently.

#### **(g) Morphological Processing**

Morphological image processing is done for removing the imperfections due to the binary regions which are produced by thresholding get distorted by texture and noise. Various non-linear operations related to the morphology or the shape of the features in image. Morphological operations are not only depends on the numerical values of the pixels but also on the relative ordering of the pixels, therefore morphology is best suited for the binary images. These operations may also be applied for gray scale images.

#### **(h) Segmentation**



Image segmentation is the process where an image is segmented into multiple parts. It is used to simplify the image into something that is easy to analyse and is more meaningful. It is used to detect boundaries and objects in an image. Image segmentation is the process of entitling a label to each pixel in an image such that element or pixel with same label shares characteristics.

#### **(i) Representation and Description**

After segmentation process, it is important to represent objects in order to describe them. Representation involves two options, first in terms of external characteristics such as boundaries, second in terms of internal characteristics such as pixels. Representation makes the data more useful and description define the region based on representation.

#### **(j) Object Recognition**

It is the last step of image processing. Its main objective is identifying and finding the objects in a video or image sequence. It involves detection, description, classification, identification, and understanding.

#### **(k) Knowledge Base**

Knowledge base is defined as detailing regions of an image where we have information of interest thus confine the search that has to be conducted in pursuing that information. It can be complex such as an interconnected list of all the major faults in the objects inspection problem or an image database comprising of high resolution satellite images of region (Gonzalez, R.C. and Woods, R.E. 2004).

### **1.4 Pre-processing of Low Light Image**

Pre-processing is the lowest level of abstraction for both type of input and output intensity images. Pre-processing is done for the improvement of the image abstract which reduces undesirable distortion and enhances features and characteristic of the image necessary for further processing. Low contrast in images is caused by poor quality of imaging device, user's operational error and low light condition. In low light quality, captured image has low dynamic range and hence distort the contrast and result in high noise levels. This leads to confusion of texture and object, poor detection, user fatigue and poor performance.

The main aim of the image pre-processing is removal of the noise and contrast image enhancement. Thus, it is very important to use correct and appropriate noise reduction and contrast enhancement technique which preserve the edges in image and suppresses the noise. Image enhancement is the alteration of the image by modifying the pixel brightness value to upgrade its visual impact. Image enhancement constitutes to various techniques that helps to improve the visual appearance of an image. It converts the image into better form which is more suitable for machine or human interpretation. Image enhancement is useful for image display, feature extraction, and image analysis (Sinha, G.R. 2009)

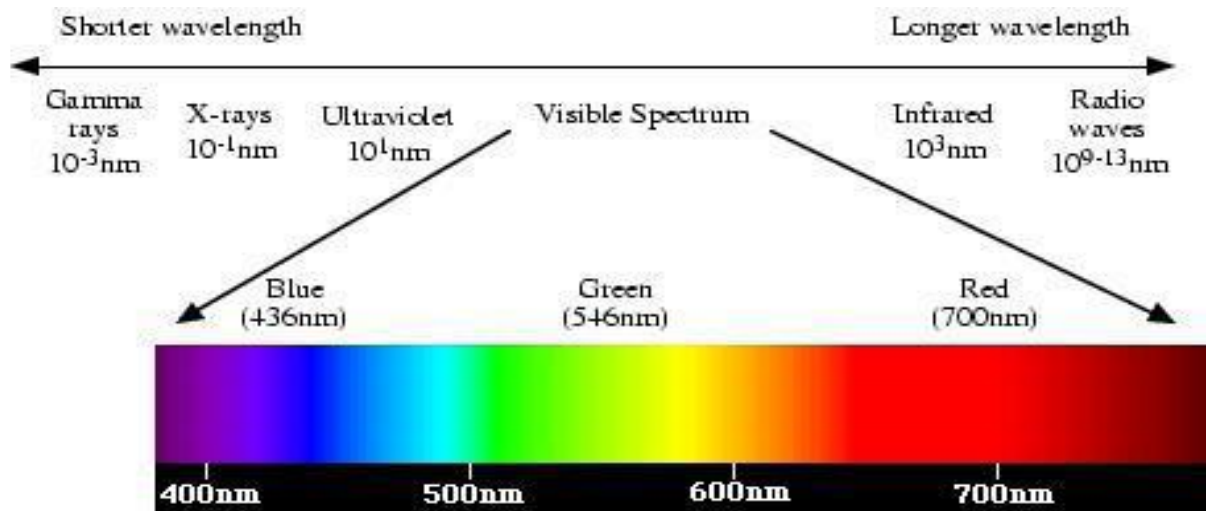
Pre-processing is broadly divided into 2 categories-

- (a) Colour image enhancement
- (b) Contrast image enhancement and noise reduction

#### **1.4.1 Color Image Enhancement**

Colour image enhancement is the process of removal of noise in color image and visual quality of the input image get enhanced. Perceptual quality of an image gets reduced due to the presence of noise in an image which reduces the performance of processing system. Origination of high quality of the color image is required for diversity of applications. Colour image enhancement is required to preserve the details of edges, structural content, and colour information and to reduce the noise. Improvement of colour balance or colour contrast is required in color image enhancement. Enhancement becomes more difficult due to added complexity of the colour perception.

Human eye can differentiate thousands of variety of colours. Range of the visible spectrum is lie between 400nm (violet) and 700nm (red) as shown in electromagnetic spectrum in fig. 1.2.



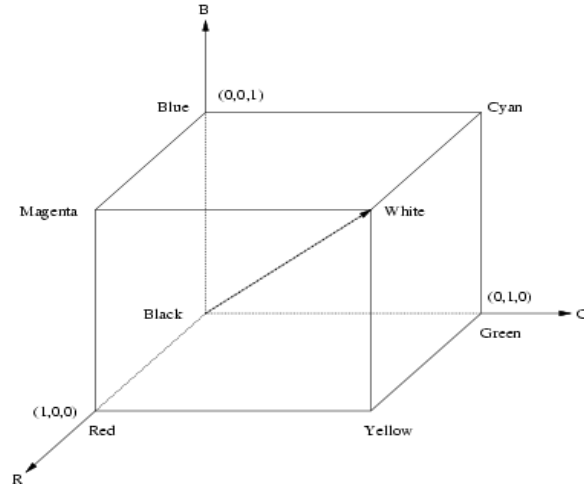
**Fig. 1.2: Electromagnetic spectrum of Color light**

Primary colours are usually visualized by the human eye which is red, green and blue. Brightness that is intensity of each colour is characteristic to distinguish the colours from one another. For users to understand the colour efficiencies of particular device or file then the colour space is very useful method. It represents what printer can print, a camera can see or monitor can display etc. There are different types of color models such as Red, Green and Blue (RGB) model, Luminance and Chrominance (YUV) model, Cyan, Magenta and Yellow (CMY) model, Hue, Saturation and Intensity (HSI) model explained below (Kassab, A. 2012).

#### **(a) RGB model**

In the RGB model, an image is composed of three autonomous image planes in each of the primary colours: red, green and blue. The standardize wavelengths for the three primary planes are as shown in fig 1.2. Specifying a distinct colour is by specifying the quantity of each of the primary components present in it. Fig. 1.3 represents the geometry of the RGB colour model for defining colours using a Cartesian coordinate system. The gray scale spectrum, i.e. the colours made from equivalent amounts of each primary, situated on the line joining the white and black vertices.

This is additive model, i.e. the colours exist in the light are summed up to form new colour. The RGB model is used most video cameras and colour monitors.



**Fig. 1.3: The RGB colour cube. The gray scale spectrum lies on the line joining the white and black vertices.**

### (b) YUV model

For the human visual perception, YUV represents the colour more closely than the standard RGB model. YUV colour spaces can reduce bandwidth more and provide a more efficient coding than RGB model. For this reason most of the video cards render directly using chrominance/luminance or YUV images. In the YUV, Y stands for brightness component that is luminance component and U&V stands for colour or chrominance components. The luminance is calculated as a weighted sum of blue, red and green components while the color difference, or *chrominance*, components are produce by deducting luminance from blue and from red.

The main advantage of this model in digital image processing is decoupling of color and luminance information. Significance of this decoupling is that the luma component of an image can be easily processed without affecting its chrominance component. For instance, the histogram equalization of the colour image in the YUV format is accomplished easily by applying HE to its Y component.

### (c) CMY model

CMY model is representation of three secondary colours that is Cyan (C), Magenta (M), and Yellow (Y). It deposits colour pigments so it is widely used in devices such as colour printers. It is derived from RGB model as

$$\begin{pmatrix} c \\ m \\ y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} r \\ g \\ b \end{pmatrix} \quad (1.1)$$

When the Cyan, Magenta and Yellow color combine it forms black colour. It is also known as subtractive color model because we obtain this model by subtracting primary colours R, G, B from white light.

#### **(d) HSI or HSV colour model**

In HSI the colour is defined in terms of its Hue (H), Saturation (S) and intensity (I) or value (V). The principle advantages of this model are that we can decouple Chrominance (H, S) and luminance (I). Hue and saturation is closely related to the way the human visual system perceives colour. It can be concluded that the RGB model is good for image color generation, while the HSI model is suited for image color description.

It is related to RGB model as:

$$V = 1/3 (R+G+B) \quad (1.2)$$

$$S = 1 - \frac{3}{(R+G+B)} [\min(R, G, B)] \quad (1.3)$$

$$H = \begin{cases} \theta & B \leq G \\ 360-\theta & B > G \end{cases} \quad (1.4)$$

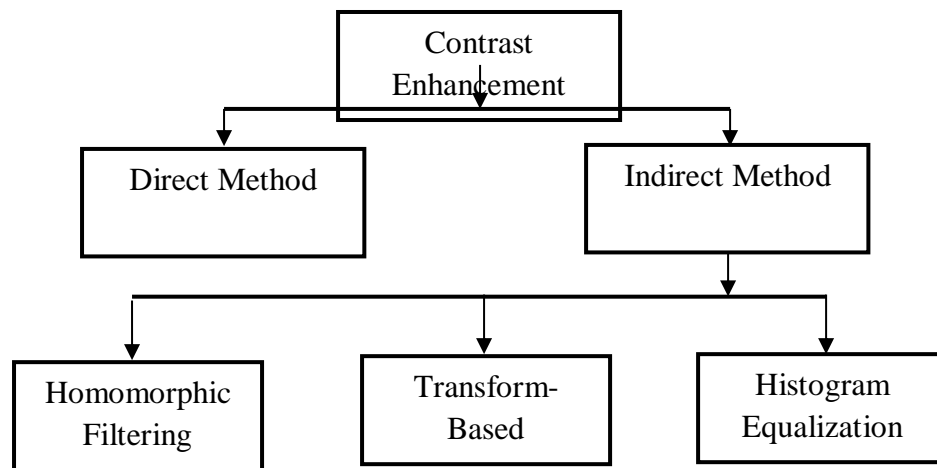
$$\Theta = \left\{ \frac{1/2[(R-G)+(R-B)]}{[(R-G)^2 + (R-B)(G-B)]^{1/2}} \right\} \quad (1.5)$$

#### **1.4.2 Contrast Image Enhancement**

In digital image processing image contrast enhancement play a significant role in computer vision application. Image enhancement make it easier for image features extraction, visual interpretation, understanding, and analysis by computer vision system. Contrast enhancement is most important factor to determine the quality of image and visual appearances. It is used to enhance the low illumination light. Lightening and brightness level are addressed by various contrast enhancement techniques. Processing of image is characterized by domain analysis. The two domains that are widely used are spatial and frequency domain. Spatial domain is associated with the plane of image and the pixels are operated directly in a given image. Frequency domain uses Fourier Transform of image. Spatial domain techniques are widely used

than frequency domain techniques because they are used directly on pixels value. Contrast image enhancement is accomplished through the histogram equalization i.e. redistribution of intensity values of an input image. Histogram equalization is the most popular method for contrast enhancement (Verma, N. And Dutta, M. 2017).

Image de-noising is very crucial pre-processing step for image analysis. Image de-noising refers to recreation of digital image that has been corrupted by noise. Noise present in an image is certain. It is introduced in digital image during transmission phase, formation, or recording. Pre-processing also requires that induced noise must be reduced or removed. When high accuracy is required that small amount of noise is also harmful. There are different types of noise. Some important noise are speckle noise, Poisson noise, impulse noise, additive white Gaussian noise etc. Major goal of image de-noising is preservation of useful information while removing the noise.



**Fig. 1.4: Taxonomy of Contrast Enhancement (Ariateja, D. et al. 2018)**

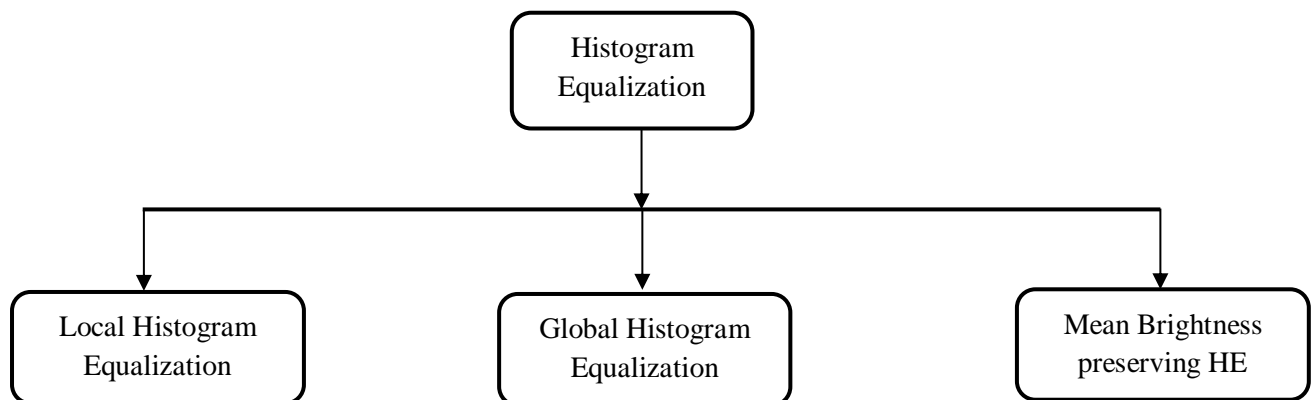
Various image contrast enhancement methods have been proposed over the years. They have been classified as direct and indirect methods. Amongst the indirect methods, the Histogram Modification Techniques have been greatly used because of its accuracy and simplicity where histogram equalization (HE) is among the widely used technique (Kotkar, V.A. and Gharde, S.S. 2013).

### **1.5 Histogram Equalization (HE)**

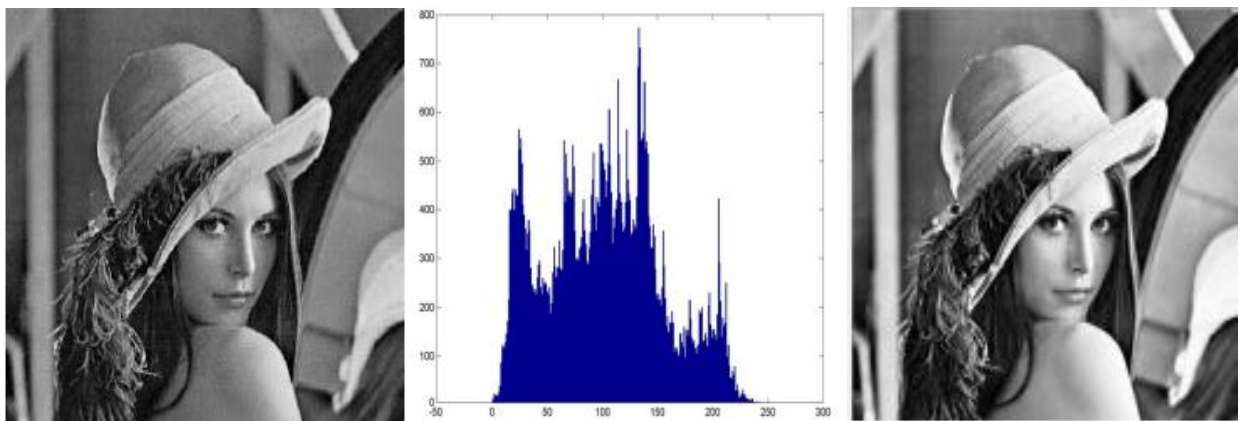
Histogram of an image is defined as a type of graph which displays the number of pixels for each intensity value present in an image. In other words, it is defined as

graphical uniform distribution of pixels or intensity values of an image. Low contrast or less dynamic range is shown by the narrow histogram. Histogram equalization is spatial domain contrast enhancement technique. It is used to improve the contrast of the image. This is done by spreading out the frequent intensity values i.e. extending out the intensity range of the image. It depends on the local and global variables so to enhance the contrast of an image. This method improves the global contrast of an image when its usable data is characterized by close contrast values and modifies the histogram of the image uniformly. This allows the low local contrast areas to gain higher contrast. Since HE is based on the total information of input image which is to be implement, the local details with less probability is not get enhanced. It preserves the brightness of resulting image. It mainly focuses on boundaries and edges for various set of images but degrading the local details of the image (Kotkar, D. et al. 2013).

Classification of Histogram Equalization methods are shown in fig. 1.5. It is divided into three sub groups as shown.



**Fig. 1.5: Taxonomy of Histogram Equalization**



(a)

(b)

(c)

**Fig.1.6: (a) Lena Image (b) Histogram of Lena image (c) Output of Histogram Equalization**

### **1.5.1 Local Histogram Equalization (LHE)**

In this technique, a small window is moved over each pixel of image. It helps in improving contrast by using local function based on intensity value of pixel and its neighbouring pixels. It mainly works on improving local texture of an image. Methods of LHE are discussed below (Tarika, B. et al. 2014):

#### **(a) Adaptive histogram equalization (AHE)**

Adaptive Histogram Equalization is augmentation of conventional Histogram Equalization method. Unlike HE, it works upon small data regions i.e. tiles, rather than whole image. The contrast of each region is reinforced, so that the histogram of the output region matches the specified histogram. The neighbouring regions are then connected using bilinear interpolation so to eradicate artificially induced boundaries. In AHE, the primary idea is to take into consideration histogram distribution over local window and merged it with global distribution. In this method the parameter is the size of the neighbourhood region. At smaller scales, contrast is enhanced while at larger scale, contrast is reduced. When the image region is homogeneous comprising a pixel's neighbourhood, its histogram is abruptly peaked, and the transformation function will design a narrow range of pixel values in comparison to the whole range of final image. This results AHE to over amplify small quantity of noise in large homogeneous regions of the image (Pizer, S.M. et al. 1987).



(a)



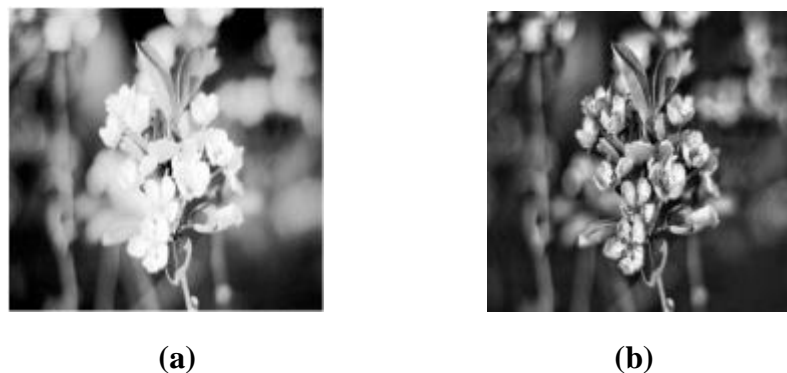
(b)



**Fig. 1.7: (a) Original image (b) AHE resulting image**

**(b) Contrast Limited Adaptive Histogram Equalization (CLAHE)**

CLAHE is extension of adaptive histogram equalization. AHE has a drawback of causing over-amplification in homogenous region due to mapping of narrow range of pixels onto entire visualization range. CLAHE differs by AHE by limiting the over amplification of noise by clipping the histogram to a predefined value called as clip limit before calculating the Commutative Distribution Function. It makes the image to appear more natural (Majumdar, J. and Kumar, S. 2014). CLAHE increases the brightness range to a specific level and hence make easy to compare different areas of the image. It varies from ordinary histogram method only in its contrast limiting. In CLAHE, the histogram is computed for contextual region of a pixel. CLAHE, given by Zuiderveld (Zuiderveld, K. 1994) has two important parameters i.e. block size and clip limit. The parameters are used to control quality of the image.



**Fig. 1.8: (a) Original Image (b) CLAHE Image**

**Syntax of CLAHE**

$$J = \text{adapthisteq}(I)$$

$$J = \text{adapthisteq}(I, \text{param 1}, \text{value 1}, \text{param 2}, \text{value 2}, \dots)$$

$$J = \text{adapthisteq}(I, \text{'Clip limit'}.0.02, \text{'Distribution' 'Rayleigh'})$$

**Steps for performing CLAHE**

- $J = \text{adapthisteq}(I)$  increases the contrast of gray scale image  $I$  by changing the value using CLAHE

- CLAHE works on small regions of the image which is called as tiles rather than whole image.
- Contrast of each tile is enhanced, so that the histogram of output region matches the histogram of distribution parameter.
- The neighbouring tiles are then joined using bilinear interpolation so to remove the artificially induced boundaries.
- To reduce the over amplification of noise that may be present in image, the contrast in homogeneous area should be limited.
- To reduce the contrast in homogeneous area, contrasting factor clip limit is used. These areas are denoted in histogram by high peaks for particular image tile. Without the clip limit, AHE gives the results that are worse than the original image.
- Range of clip limit  $[0,1]$ . Higher the value of limit it results in more contrast.
- Distribution is string which specifies the histogram shape of the image tiles.

Uniform – flat histogram

Rayleigh – bell shaped histogram

Exponential – curved histogram

### **Advantages of CLAHE**

- (1) CLAHE is used to prevent over amplification of noise which is caused in AHE.
- (2) In comparison to other techniques CLAHE improves the contrast more than any other methods.
- (3) It introduces changes in pixels grey level.

### **Disadvantages of CLAHE**

- (1) It works on small data regions rather than the entire image.
- (2) It is expensive
- (3) It is computationally complex.
- (4) For hardware implementation, recursion methods can be complex.

(5) As recursions are performed sequentially, so it is time consuming.

### **1.5.2 Global Histogram Equalization (GHE)**

It expands the resultant histogram of the image to cover all the range of gray scale values. For the evaluation of transformation function it makes use of all intensities of original image. Entropy of the image increases up to maximum range .It is good for both foreground and background section of the image but sometimes increases the noise in the image. GHE pushes either towards bright or dark. This results in level saturation effects on some important visibly areas.

### **1.5.3 Mean Brightness Preserving Histogram Equalization**

This method is the extension of Histogram Equalization. It disintegrates the input image into sub images. Sub images are equalized individually. This technique conserves the artistic value of image without intensifying the artificial effects. Some popular methods for mean brightness preserving histogram equalization (Tarika, B. et al. 2014) are discussed below:

#### **(a) Dynamic Histogram Equalization**

Without deteriorating the image details this technique make enhancement in images. It is easy in computing and can be used on real time system. It is done using three steps. First is segmentation of histogram, second is allocation of gray level ranges, and third is histogram equalization on each sub histogram. This method divides the histogram into sub histograms which have dominating components. Then each sub histogram undergoes equalization and improves desired range of gray levels obtained in final image (Dahiya, R. 2015).

#### **(b) Brightness Bi Histogram Equalization (BBHE)**

It overcomes the drawback of histogram equalization method. This technique decomposes the original image by determining the mean function. A sub image comprises of values which are less than value of mean. Another sub image comprises of the values which are more than the values of mean. It yields natural enhancement of the original input image (Verma, M. and Dutta, N. 2017).

#### **(c) Minimum Mean Brightness Error Bi-Histogram Equalization**

This method is expansion of the brightness bi histogram equalization method (BBHE). In this method firstly the threshold level is searched and then images are decomposed into the sub images. After decomposition, Histogram Equalization is applied on each of the sub – images. The main objective behind this technique is to achieve minimum brightness between input and output images. Maximum brightness preservation is accomplished using this technique.

It consists of three steps:

- 1) For each threshold level, calculate the AMBE.
- 2) Find the threshold level that produces minimum brightness error.
- 3) Apply HE separately on the sub images obtained in step 2 (Tarika, B. et al. 2014).

#### **(d) Brightness Preserving Dynamic Histogram Equalization**

In this technique, image is decompose into sub images or sub parts by means of local maxima, then this equalization technique is applied to each sub images and outcomes of this is a combination of sub parts. Its produces the output image which has objective to find out mean intensities which is similar to mean intensity of original image. This method enhances the brightness of image and reduces the unnecessary artifacts.

It consists of following steps:

- 1) Segmentation of Histogram.
- 2) Mapping of new Dynamic Values.
- 3) Equalization
- 4) Normalization

#### **(e) Recursive Mean Separate Histogram Equalization**

It is expansion of BBHE, where image decomposition is done only once. In this method decomposition of input images is done in recursive manner depending on mean function. With the increase of number of recursive decomposition, preservation of brightness of images also increases. This results in producing highly brightness preserved image.

## **1.6 Objectives of the Thesis**

This thesis focuses on the improving the contrast of images captured under low illumination environment having low dynamic range and low contrast. The parameters are improved than existing approach by using hybrid optimization method. The thesis discusses the various techniques to improve the contrast for the enhancement of low light images.

Objectives of the thesis are summarised as-

- (1) Study and analysis of Contrast level Enhancement techniques in image processing.
- (2) To evaluate optimizing algorithm with Dual-Tree-Complex Wavelet Transform for enhancement of low light images and to optimize the design parameters.
- (3) Performance analysis of modified technique and its comparison with other technique.

The thesis work is implemented on MATLAB<sup>®</sup> 2018b environment for easy and fast computations of numerical and mathematical calculations.

## **1.7 Organization of the Thesis**

The Thesis is composed of five chapters. Chapter 1 discusses the introduction of digital image processing and contrast enhancement methods. Chapter 2 describes the literature survey done in order to build a basic understanding of the various kinds of contrast enhancement methods, optimization methods and various existing approaches to enhance the system performance. Chapter 3 delivers the brief overview of approaches adopted in order to fulfil the goal of creating the hybrid optimization approach for enhancement of low light images. It also describes the material of the experimental setup required in achieving the objectives of our work and lastly portrays the developed algorithm. Chapter 4 describes the results and discussions that are recorded during the simulation of the proposed algorithm. Chapter 5 defines the summary of the research work.

## **CHAPTER 2**

### **REVIEW OF LITERATURE**

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Comprehensive literatures Review is an essential for any scientific investigation and outlines an insight into the meaningful interpretation of findings, theoretical frame work as well as procedure and methods. This section deals with the review of the research work carried out in India and abroad in relation to the objectives of the proposed study. Various researchers proposed different contrast enhancement techniques and optimization methods for enhancement of Low light images which is discussed below:

Al-Allaf (2017) proposed two approaches for image watermarking, first is based on genetic algorithm and second is particle swarm optimization. Each of GA and PSO is based on co-relation coefficient and then watermark image is hiding in original image. In this paper small block size affect the image watermarking's quality based PSO/GA because search area of the watermarking is increased by small block size. Better results were obtained in PSO when using swarm size of 100.

Verma and Dutta (2017) presents contrast enhancement techniques. The contrast enhancement is more important when images are suffered from low illumination. The problems related to lightening and brightness level are solved by contrast enhancement techniques. According to the usage in various applications this paper discusses the number of contrast enhancement technique. This study not only examines different advantages and disadvantages of various contrast enhancement techniques but also discusses the different aspects for the analysis in an image.

Jung *et al.* (2016) proposed a low light enhancement based on DT-CWT. Low light images have low contrast, low dynamic range, and much noise. Considering the properties of low light images, they have employed DT-CWT to decompose the input image into low pass sub bands and high pass sub bands. Then, they performed TV diffusion in high pass sub bands to reduce noise. Moreover they have utilized CLAHE in low pass sub bands to improve the contrast of the image which preserves the details in high pass sub band.

Menghour and Meslati (2016) proposed bio –inspired hybrid approaches which is used for feature selection problem. The two hybrid methods are based on two optimization approaches that is Particle Swarm Optimization and Ant Colony Optimization. The performance of these methods are compared i.e. ACO, PSO and GA based on feature selection. The experimental results shows that the proposed approach efficiently improve accuracy and lessen the number of features.

Pal *et al.* (2016) proposed a combination of two approaches i.e. Ant colony optimization and Particle Swarm Optimization. In the first stage genetic algorithm is used to initialize the population. This proposed algorithm makes the complete use of the individual optimization approaches. In the proposed method, PSO is used to enhance the performance of ACO. The experimental results shows that this method not

only finds the shortest paths among the largest paths but also reduce the number of paths. This hybrid method outperforms than individual ACO and PSO.

Thangavel and Mohideen (2015) proposed novel ant histogram equalization for improving the contrast of digital mammograms. This method discusses the hybridisation between novel ant colony optimization with histogram equalization. Histogram equalization transfers the input intensities to output intensities which improve the visual content of the images and ACO is used for constructing the transfer function. A fitness function controls the transfer function in a balanced way.

Gu *et al.* (2014) examine the difficulty in contrast enhancement of image. Most prevailing and important technologies usually suffer from the disadvantage of excessive enrichment, thereby introducing noise and changing visual regions. One recurrently used solution is manual parameter modification, which is, however, impractical for many applications since it's time consuming and labour intensive. During research analysis, we discover that saliency preservation will facilitate to yield appropriately enhanced images, i.e., improved contrast without aggravating artifacts. We therefore strategize an automatic contrast enhancement approach with an automatic parameter selector and a whole histogram modification framework. This framework associates the original input image, its visually pleasing version created by a sigmoid transfer function, and its histogram equalized product that was developed in our work. Based on the conception of salience preservation a visual quality criterion is developed, which supports the automatic parameters selection, and finally enhanced image can be created accordingly. We test the proposed scheme on Video Quality Experts Group databases and Kodak, and compare with the conventional histogram equalization technique and its state-of-the-art contrast enhancement approaches as well as its variations. The results of the proposed work exhibit that our technique has exceptional enhancement effect and higher saliency preservation ability.

Sinha and Jana (2014) presents a study on wavelet transform and complex wavelet transform to determine their capabilities in de-noising application of digital images. Typical Discrete Wavelet Transform has some shortcomings like poor directionality, shift invariance, absence of phase information. To avoid these drawbacks, complex wavelet transform is used Complex wavelet transform is



augmentation of discrete wavelet transform. In this paper, complex wavelet transform's capabilities is discuss for the reduction of noise in different images.

Huang *et al.* (2013) presents effective contrast enhancement using adaptive gamma correction with weighing distribution. This paper discusses an efficient method to enhance contrast in images and modify the histograms. It plays an important role in pattern recognition, computer vision and digital image processing. Author proposes a technique of automatic transformation that will ameliorate the brightness of low light images via probability distribution of luminance pixels and gamma correction. To improve the video, the proposed approach uses temporal information regarding the difference between each frame to lessen the computational complexity. In comparison to previous methods, the proposed method yields the more enhanced image of high quality.

Gupta and Gupta (2012) proposed image enhancement using Ant Colony Optimization (ACO). The main aim of the proposed ACO is to maximize an objective fitness function so to enhance the details and contrast in an image. The proposed work is compared and demonstrated with Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) based enhancement technique. The results of the proposed work indicates that ACO produces better results in terms of both objective evaluation and maximizing the number of pixels in the edges. In comparison to PSO and GA, computational time is relatively small in ACO.

Pang *et al.* (2012) proposed the basic and the most common technique for contrast enhancement in the image is using histogram equalization. It is based on equalizing the histogram of the image and subsequently enhancing its contrast, and results in overall contrast enhancement. This paper introduces a combination of normal HE technique and particle swarm optimization algorithm for enhancing distorted image naturally. The process is as follows. The image is separated into red, green, blue (RGB) channels and PSO algorithm is applied into each channel in order to gets its best fitness value. The fitness value that is obtained then will be applied into HE, after that the proposed colour image will be merged back into RGB image. Experimental results have shown the efficiency in improving the contrast of input images without introducing disturbing outputs generated by normal HE.

Zhang *et al.* (2012) proposed a method which is designed specifically for enhancing images captured under very low light environment where the characteristics of images are nearly invisible and the noise is more. By applying an effective and improved image de-haze algorithm to the inverted input image, the intensity can be augmented so that the gloomy areas become bright and the contrast of an image get enhanced. Then, they combine bilateral filter with the pioneer green component as the edge image is introduced to reduce the noise. Experimental results of the proposed approach outperform than the existing approach.

Wu (2011) proposed a novel algorithmic approach of image enhancement via optimal contrast-tone mapping. In an elementary departure from the present method of histogram equalization for contrast enhancement, the proposed methodology will increase expected contrast gain subject to a peak limit on tone distortion and optionally to other constraints that suppress artifacts. The underlying contrast-tone optimization problem can be resolved effectively by linear programming. This advanced constrained optimization algorithm for image enhancement is general, and the user can fine tunes and add the constraints to accomplish required visual effects.

Arıcı and Dikbas (2009) reviewed on contrast enhancement methods which are posed as an optimization problem that minimizes the cost function. Histogram equalization is an efficient technique for contrast improvement. However, typical histogram equalization (HE) results in excessive contrast improvement, which in turn creates visual artifacts and yields the processed image an unnatural look. By introducing specifically designed penalty terms, the extent of contrast improvement can be adjusted. Noise hardness, white/black stretching and mean brightness preservation might simply be assimilated into the optimization. Analytic solutions for some of the important criteria are presented. Finally, a low complexity rule for contrast enhancement is conferred, and its performance is illustrated against a recently designed methodology.

Easley *et al.* (2009) proposed a shearlet formulation of the total variation method for de-noising image. Shearlets have been mathematically proven to represent distributed discontinuities such as curvelets with TV or diffusion methods aim at reducing Gibbs-type artifacts after obtaining a nearly optimal estimate. We show that it is possible to obtain much better estimates from the shearlet representation by constraining the residual coefficients using a projected adaptive total variation scheme

in the shearlet domain. We also analyse the performance of a shearlet-based diffusion method. Numerical examples indicate that these schemes are extremely effective at denoising complex images and perform better in terms of related technique based on the use of the curvelet transform. Furthermore, the shearlet-TV scheme requires far less iteration than similar competitors.

Malm *et al.* (2007) proposed a general procedure for contrast enhancement and noise reduction in very noisy image data with low dynamic range. Video footage recorded in extremely low light is specifically targeted. Smoothing kernels that mechanically adapt to the native spatial-temporary intensity structure in the digital image sequences are created in order to preserve and enhance fine spatial detail and forestall motion blur. In color image data, the chromaticity is restored of raw RGB input data is performed simultaneously with the noise reduction. The method is very general, contains few user-defined parameters and has been developed for efficient parallel computation using a GPU. The technique has been applied to image sequences with numerous degrees of darkness and noise levels, and results from number of these tests, and comparisons to alternative approach, are bestowed.

Wang and Tan (2007) studied a fast and effective method for image contrast enhancement based on weighted and threshold histogram equalization (WTHE). In this methodology, the probability distribution function of an image is modified by weighting and thresholding before the histogram equalization is performed. They show that such a method provides an efficient and convenient mechanism to supervise the enhancement approach whereas being adaptive to different forms of images.

Dorigo and Blum (2005) over-viewed the theory of Ant Colony Optimization. This paper discusses the review of convergence results. Then, they discuss the relation between ACO algorithms and other methods for optimization. The researchers try to focus on gaining some deeper understandings about the behaviour of optimization algorithm i.e. ACO.

Kim (1997) proposed a unique augmentation of histogram equalization to conquer the disadvantages of the original histogram equalization. The significance of the proposed method is to utilize freelance histogram equalizations independently over two sub images obtained by disintegrating the original input image based on its mean

with a constraint that the ensuing equalised sub images are confined by each other around the input mean. It will be shown mathematically that the developed methodology preserves the mean brightness of a given image considerably well compared to conventional histogram equalization whereas improving the contrast and, thus, provides abundant natural enhancement that can be used in consumer electronic merchandise.

## **CHAPTER 3**

### **MATERIAL AND METHODS**

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Contrast enhancement plays an important role in image processing, computer vision, and pattern recognition. Ambient light is an indispensable factor for the quality of images captured by imaging devices. Above all, images captured in the dark condition often have low and concentrated gray scale, thus making images of narrow dynamic range and low contrast. It is required to improve the contrast of images captured under low light condition. In general, contrast enhancement aims to make the image to have a perceptually more pleasing or visually more informative vision effect.

This chapter deals with the methodology of developed algorithm for enhancement of low light images captured in the dark condition which have low and


concentrated gray scale making the image of low dynamic range. The proposed algorithm is implemented on MATLAB<sup>®</sup> 2018b software and performance metrics are calculated and compared with the existing approach.



### 3.1 Image Database

Image database used in implementation of this work is obtained from HDR shop dataset and the Eden project Multi Sensor Dataset. These datasets are large collection of classified digitize images. The classification is done on the basis of basic character of images.

Greenwich image are taken from HDR shop datasets (Tchou and Debevec, 2009). Landrover, Dusk, Ramp are taken from Eden Project Multi Sensor Dataset (The Eden sensor Dataset 2006). Image used in implementation and analysis of algorithm along with their format, size, and database sources are listed in table 3.1

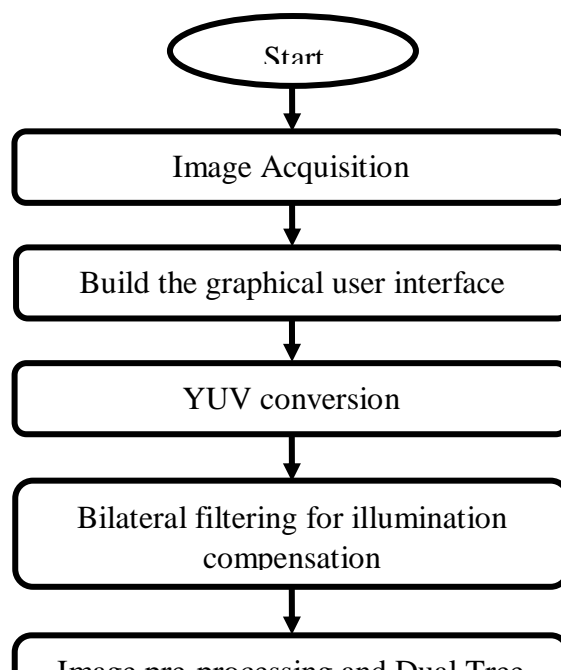
**Table 3.1: Image Database Details**

<b>Images</b>	<b>Format</b>	<b>Visual representation</b>	<b>Database source</b>
Greenwich	.png		HDR Shop

Landrover	.png		Eden project Multi Sensor Dataset
Dusk	.png		Eden project Multi Sensor Dataset
Ramp	.png		Eden project Multi Sensor Dataset

### 3.2 Developed Algorithm

The flowchart of complete process of proposed method is shown below in fig. 3.1. All the techniques used to develop the algorithm are mentioned in flowchart. The detailed discussion of these techniques is explained.



### **Fig. 3.1: Flowchart of Proposed Low Light Image Enhancement Technique**

Fig.3.1 shows the proposed methodology where the user interface is developed in the MATLAB environment. The image is uploaded and is converted into the YUV color space which normalizes the image and after normalization the bilateral filtering is performed. Then image detailing is performed using wavelet transformation. The wavelet transform performs the segmentation of the image which deals with the boundaries segmentation and detects the edges of the image. The hybrid optimization i.e. Ant Colony and Swarm Optimization is achieved on high intensity image and low light enhancement is done. The optimization increases the efficiency of the system and reduces the error rate probabilities which increases the PSNR and reduces the MSE.

Steps for performing proposed algorithm are explained below:

#### **3.2.1 Building of Graphical User Interface**

Graphical user interface (GUI) is a graphical display in one or more windows containing controls, so it's a group of build techniques which helps us to make a fast communication between the user and program, making the task easier and faster. GUI provides the users with similar environment. This environment contains toggle buttons, lists, menu, push buttons, and text boxes.

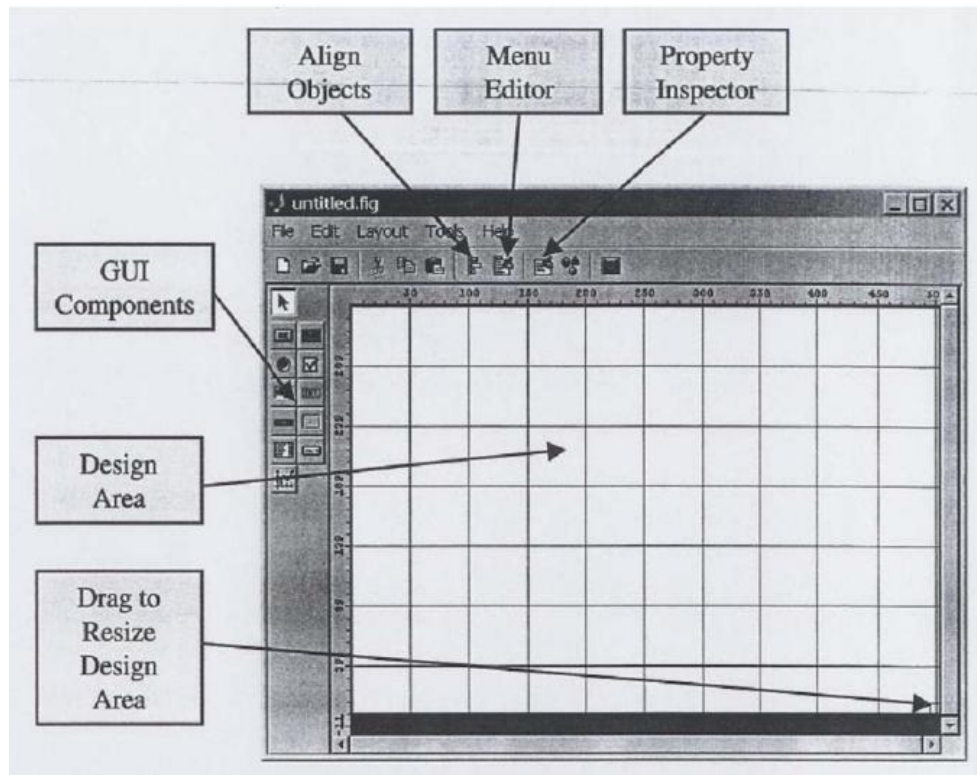
In MATLAB we have a very helpful tool called GUIDE, after clicking on the guide button in MATLAB appears a start window, then we have to choose 'Blank GUI',

then new window appears where we can design the GUI, it's possible to create the object by choosing the button from the left side list from the created figure, the list obtains pushbutton, axes, static, slider, radio button, check box, and edit texts. After creating objects in Guide, a window named property inspector is displayed. This is useful to set characteristics of each component such as color, displaying of text etc. (Kassab, A. 2012).

GUI provides the users with similar environment. MATLAB graphical user interface contains graphical components such as push buttons, menu, lists, labels, etc. The type of components includes static elements (frames and text strings), menus, graphical controls (push buttons, edit boxes, sliders, etc.) and axes. Static elements and graphical controls are designed by the function `uicontrol`. Menus are generated by the functions `uicontext menu` and `uimenu`. Axes are created by the function `axes` which are used to display input and output graphical data and users can change its setting using property inspector.

After saving any result of the created GUI the GUIDE save as two files `.fig` file which has description of the graphic part, and `.m` file, where we can find the code which controls the actions. Actions can be changed in the `.m` file, they are called 'callbacks', and each component has a 'Tag' property that refers the name of the callbacks (Mathswork).





**Fig. 3.2: The basic guide tool window (AL Ashi, R.Y. and AL Ameri, A. 2001)**

The Graphical user interface window for development of the proposed methodology for Greenwich image is shown below in fig. 3.3.

- Steps to create Graphical User Interface-
  - (a) In the MATLAB prompt type guide to start GUIDE.
  - (b) Select the **Blank GUI (Default)** template from the Quick Start dialog box in GUIDE and press OK.
  - (c) For Displaying the names of the components in the component palette for easy computation, select preference from file and choose show names in component pallet
  - (d) Add, align, and label all the components in the UI such as push buttons, static text area, axis, pop up menu etc.
  - (e) Label all the components using property inspector.
  - (f) When we save a design, it creates two files, a code file and a Fig-file. The code file, with extension .m, comprises MATLAB functions that regulate the app's behaviour. The Fig-file, with extension .fig, is a binary file that encompasses description of the layout.



**Fig. 3.3: GUI window developed for the proposed methodology for Greenwich Image**

### 3.2.2 RGB to YUV Conversion

The RGB color space in the input image is converted to the YUV color space to get the Y channel for noise reduction and contrast enhancement. We use the Y channel because chrominance channel U and V provides relatively less amount of information in low light condition compared with luminance channel Y.

$$Y = 0.299 * R + 0.587 * G + 0.114 * B \quad (3.1)$$

where R, G, and B are three channels in the RGB color space.

### 3.2.3 Bilateral Filtering for Illumination Compensation

Image acquired under poor illumination condition suffers from a low dynamic range that results in losing much detailed information in low light images. To solve this problem Illumination compensation is performed. For enhancing of detail information, bilateral filtering is used for decomposition of Y channel into base and detail layers. Base layer  $Y_b$  is obtained through smoothing by bilateral filtering. It preserves region boundaries and other structures in the luminance channel (Y). Detail layer  $Y_d$  which contains detail information in images, is obtained by subtracting  $Y_b$  from the Y channel

(Jung, C. et al. 2016). The obtained enhanced detail layer  $Y'_d$  from  $Y_b$  and  $Y_d$  as follows:

$$Y'_d = (1 + Y_d) \log(Y + 1) - \log(\log(Y_b + 1) + 1) \quad (3.2)$$

Where the range of  $Y$  is  $[0, 1]$ .

### **3.2.4 Image Preprocessing and Dual Tree Complex Wavelet Transform**

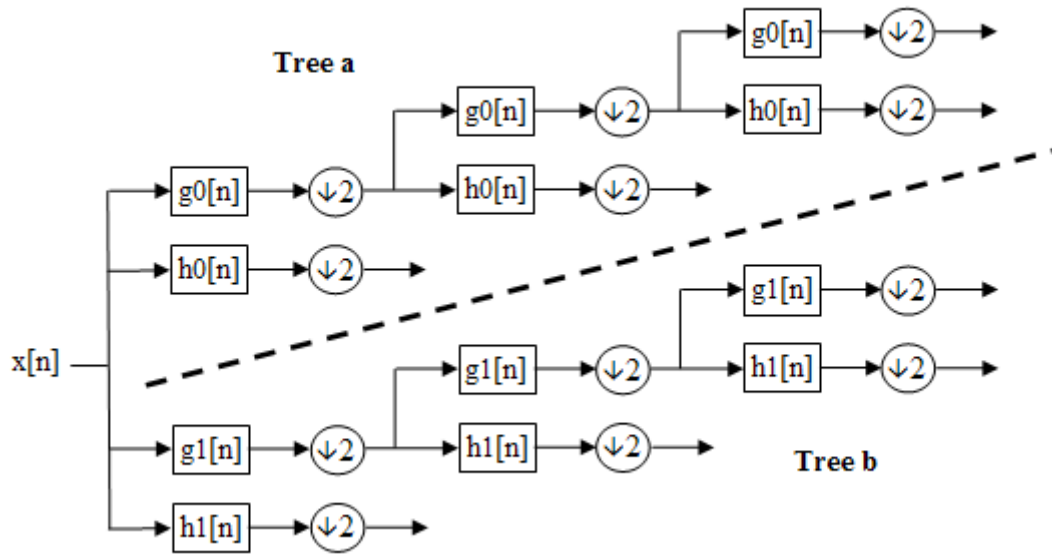
In this step we perform contrast level adaptive histogram equalization and denoising for the pre- processing of the image.

In digital image processing image contrast enhancement play a significant role in computer vision application. Image enhancement make it easier for image features extraction, visual interpretation, understanding, and analysis by computer vision system. Contrast image enhancement is accomplish through the histogram equalization i.e. redistribution of intensity values of an input image. We perform contrast level adaptive histogram equalization for contrast enhancement (Pizer, M.S. et al. 1987)

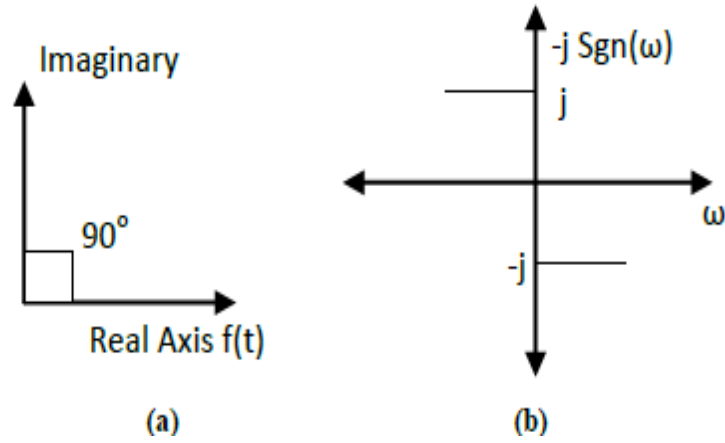
Adaptive histogram equalization is a computer image processing technique used to improve the contrast in image. It is suitable for improving the local contrast and enhancing the definition of edges in each region of an image. A variant of AHE is called as contrast limited adaptive histogram equalization which prevent over contrast and amplification. This feature can also be applied global histogram equalization, giving rise to contrast limited histogram equalization (CLHE) (Gupta, S. and Kaur, Y. 2014).

- **Dual Tree Complex Wavelet Transform (DTCWT)**

DTCWT is real valued wavelet filters produced real and imaginary parts of transform in parallel decomposition tree. It has high degree of directionality, shift invariance, and no aliasing property. Both the trees of DT-CWT are orthogonal or bi orthogonal to each other which means that they are Hilbert transform pair i.e. they are shifted by 90 degree in complex plane (Selesnick, W.I., et al. 2005).



**Fig. 3.4: Structure of 2D DT-CWT (Selesnick, W.I. et al. 2005)**



**Fig. 3.5: Hilbert transform pair (a) Polar Form (b) Frequency Domain (Sinha,K. And Jana, D. 2014)**

The wavelet  $\Psi_c(t)$  is composed of two sub wavelet :

Real wavelet =  $\Psi_r(t)$  and Complex wavelet =  $\Psi_i(t)$

Therefore we can write the equation as –

$$\Psi_c(t) = \Psi_r(t) + \Psi_i(t) \quad (3.3)$$

$$\Psi_i(t) = \text{HT} \{ \Psi_r(t) \} \quad (3.4)$$

$$\begin{aligned} &= \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{\Psi_r(\tau)}{t-\tau} d\tau \\ &= \Psi_i(t) * \frac{1}{\pi} \end{aligned} \quad (3.5)$$

## Implementation of DT-CWT

- (1) An input image is decompose up to desired level by 2 separable 2D DWT branches, branch a and branch b whose filters are designed to meet Hilbert transform requirement. Then 6 high pass sub bands are generated at each level.

$$HL_a, LH_a, HH_a, HL_b, LH_b, HH_b$$

- (2) Every two corresponding sub bands are linearly combined by either averaging or differencing:

$$\left(\frac{HL_a + LH_b}{\sqrt{2}}\right), \left(\frac{LH_a - LH_b}{\sqrt{2}}\right), \left(\frac{HL_a + HL_b}{\sqrt{2}}\right), \left(\frac{HL_a - HL_b}{\sqrt{2}}\right), \left(\frac{HH_a + HH_b}{\sqrt{2}}\right), \left(\frac{HH_a - HH_b}{\sqrt{2}}\right)$$

2D structures needs for tree for analysis and synthesis. The pairs of conjugate filters are applied to 2D (x,y) direction.

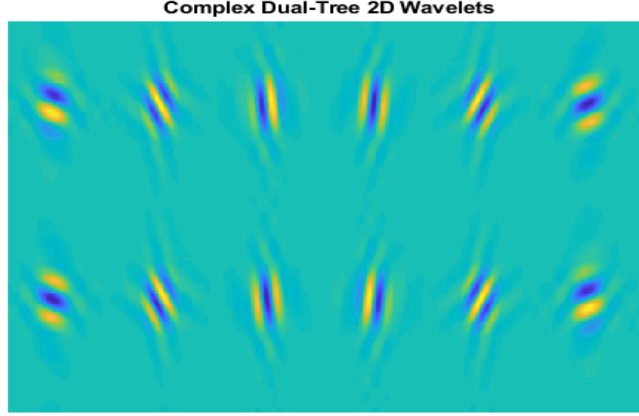
## Properties of dual tree complex wavelet transform

### 1. High directionality

Irrespective of discrete wavelet transform, DT-CWT provide six sub-images which result in six band pass images comprising of complex valued coefficients. The sub-bands are aligned in the directions  $\pm 15^\circ, \pm 45^\circ, \pm 75^\circ$ . The separation of negative and positive frequencies by filters is strongly depends on orientation. In each decomposition level DT-CWT decomposes an image into six wavelet sub bands and one scaling band oriented in the directions  $\pm 15^\circ, \pm 45^\circ$ , and  $\pm 75^\circ$ . Hence, in comparison to discrete wavelet transform, DT-CWT can achieve good directional selectivity.

### 2. Shift Invariance

For transform based image fusion shift invariance is important property. For making DT-CWT shift invariant and analytic, the two wavelets are selected such that they form Hilbert pair. By avoiding the sub sampling of standard DWT, shift invariance is achieved but that result in over completeness. In contrast with DWT, DTCWT reduced over completeness for obtaining the shift invariance



**Fig. 3.6: Impulse response of 2-D complex wavelet filters with six dominant orientations of  $\pm 15^\circ$ ,  $\pm 45^\circ$ , and  $\pm 75^\circ$  for the real part in upper row and the imaginary part in bottom row.**

### 3. Perfect Reconstruction

In Dual Tree Complex Wavelet Transform, both the filters satisfy the condition of perfect reconstruction. For the construction of filter pair the transform is approximately analytic. Let  $h_1(n)$  and  $h_0(n)$  are the high pass and low pass filters for the first wavelet ( $\Psi_h(t)$ ) and  $g_1(n)$  and  $g_0(n)$  are the high and low pass filters for second wavelet ( $\Psi_g(t)$ ) tree respectively. The dual tree complex wavelet  $\Psi(t)$  is shown as :

$$\Psi(t) = \Psi_h(t) + i \Psi_g(t) \quad (3.6)$$

### 4. Computational efficiency

Filters used in Dual Tree Complex Wavelet Transform are real valued. In the implementation of DT-CWT no computation on complex numbers is involved, which makes its computationally efficient (Adriaan, B. et al. 2012).

#### 3.2.5 Hybrid Optimization

Swarm Intelligence (SI) has attracted interest from several researchers in numerous fields. Bonabeau defined SI as “The emerging collective intelligence of teams of simple agents” (Deepa, O. and Senthilkumar, A. 2016). SI is the collective intelligence behavior of redistributed and self-organized systems e.g. counterfeit group of simple operators. Examples of SI are group cooperative transportation, nest-building of social insects, collective sorting and clustering, and foraging of social insects. Two

key concepts that are considered as vital properties of SI are division of labour and self-association. Self-association is characterized as the capacity of a framework to evolve its components or agents into an appropriate form with no outer help. Bonabeau (Bonabeau, E. et al. 1999) also stated that self-organization depends on four elementary characteristics of negative feedback, fluctuations, multiple interactions, and positive feedback. Negative and Positive feedbacks are helpful for stabilization and amplification respectively. Fluctuations are useful for randomness. Multiple interactions happen when swarms share the data among themselves around the searching plane. Another property of SI is division of labour which is characterized as the concurrent execution of different feasible and simple tasks by individuals. This division permits the swarm to handle complicated problems that need individuals to work together.

Optimization is the selection of a best element from a set of available alternatives. An optimization problem comprises of minimizing or maximizing a real function by consistently selecting input values from within an allowed set and estimating the value of the function. There are many techniques to solve the optimization problem.

#### **(a) Particle Swarm Optimization (PSO)**

Particle swarm optimization also known as swarm intelligence is an algorithm developed by Russell Eberhart and James Kennedy. It is a stochastic robust optimization technique based on the intelligence and movement of swarms. The idea of PSO was motivated by social behaviour of fish schooling, bird flocking, as well as swarming theory. PSO applies the approach of social interaction for problem solving. PSO is simple and efficient technique and yet very powerful technique. In this algorithm there are various numbers of particles which are moving in space to search for the optimum and the best value. These particles are provided with constants, values, and initial velocities at the beginning. In the basic PSO particles have a neighbourhood pixels affiliated with it. Fitness of those neighbourhood pixels is known by the particle. This knowledge is used further to know the better optimization solution or the position. This method combines the social experience as well as self-experiences (Pang, P.K. and Masra, S.M.W. 2012).

There are four types of values that are calculated to find best optimum solution-

- 1) Fitness value:- it is the best solution of the problem so that distorted pixel is removed
- 2) Global best value (gbest):- it indicates that which particle data is currently closest to the target.
- 3) Particle best value (pbest):- it indicates the particle best value near to the gbest.
- 4) Velocity value:- it indicates the direction and magnitude of each particle in each iteration.

Therefore, in PSO each particle in space is accelerated towards gbest and pbest locations with random weighted acceleration in each iteration. Each particle changes its position according to its current velocity, its current position, the distance between its current position and pbest, the distance between its current position and gbest (Gorai, A. and Ghosh, A. 2009).

#### Advantages of PSO

1. Less computational time and easy to implement.
2. It is effective in solving problems having difficulty to find precise mathematical models.
3. It has greater efficiency and possibility in finding the global optima.
4. It can converge fast due to which it doesn't mutate and overlap.
5. It has few parameters to adjust making it robust for various image processing techniques

Algorithm for PSO is as follows-

- 1) Firstly, create a population of agents or particles or pixel value to build a swarm, evenly distributed over the space X.
- 2) Estimate the position of each particle according to objective function.
- 3) If a particle's current position is better than its initial position, then upgrade it.



- 4) According to particle's previous position, determine the best particle.
- 5) Upgrade the particle's velocity value-

$$V_i^{t+1} = V_i^t + c_1 U_1^t (pb_i^t - p_i^t) + c_2 U_2^t (gb^t - p_i^t) \quad (3.7)$$

Where

$pb_i$  = particle's best position

$gb_i$  = swarm's best position

$c_1$  = cognitive learning constant

$c_2$  = social learning constant

$v_i$  = velocity of the particle

$c_1 U_1^t (pb_i^t - p_i^t)$  = it represent personal influence

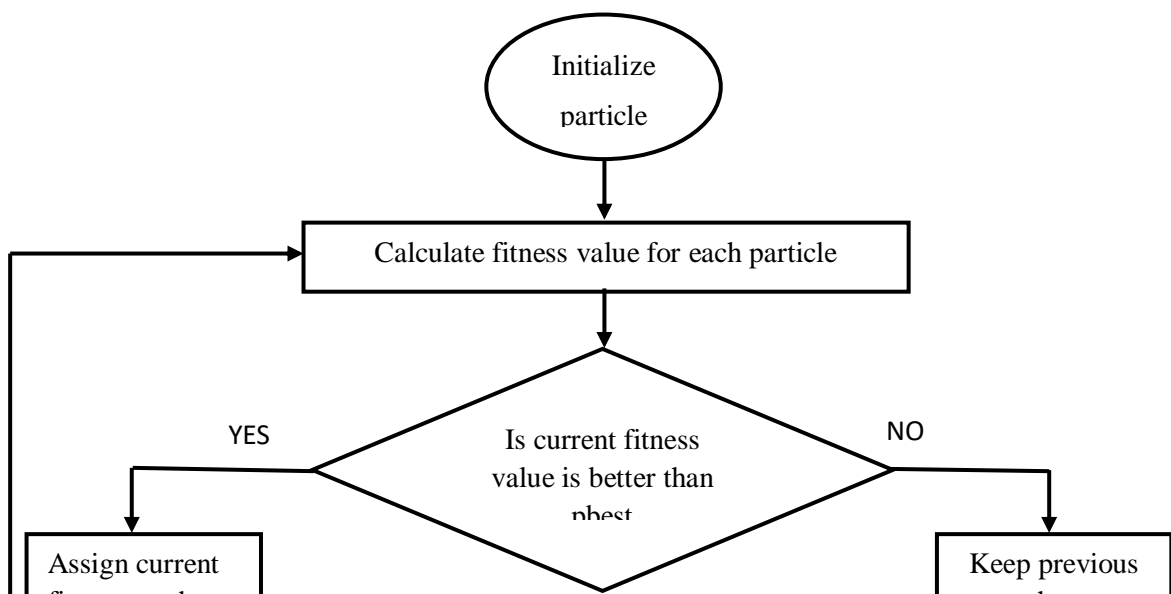
$c_2 U_2^t (gb^t - p_i^t)$  = it represent social influence

- 6) Particles are move to the new positions

$$P_i^{t+1} = P_i^t + V_i^{t+1} \quad (3.8)$$

- 7) Go to step 2, until target is reached.
- 8) Find the performance parameter.

Process of Particle Swarm Optimization is shown in fig. 3.7.



Yes

**Fig. 3.7: Flowchart of Particle Swarm Optimization**

#### **(b) Ant Colony Optimization (ACO)**

One of the most successful examples of swarm intelligent system is ant algorithms. It has been applied to various types of problems, ranging from ordinary travelling salesman problem, to routing in telecommunication networks. ACO algorithm is related to the category of meta-heuristics, the term *meta-heuristics*, is formed by two Greek words. *Heuristic* derives from *heuriskein* means ‘to find’, while *Meta* means ‘beyond, in an upper level’ (Blum, C. 2005).

Meta-heuristic is a basic algorithm framework which can be applied to various optimization problems with relatively few changes to make them adapted to a peculiar problem (Dorigo, M. and Blum, C. 2005). One of the important and best examples of ant algorithm is known as “Ant colony Optimization” or ACO, it is meta-heuristic in which a group of ants are capable of finding best solution to difficult optimization problem. It has been applied to NP- hard combinatorial problems. It is indirect local communication among the artificial ants. Ants communicate with each other through chemical pheromone trail, which empowers them to find shortest path between their food sources and nest. The main work of pheromone is to guide others artificial ant towards the target points.

ACO is comprises of three main phases- initialization, pheromone update, solution phase. These three phases makes the complete search to the global optimum. At the start of the first iteration, all ants searching randomly for best solution of a given problem among the feasible solution space and old ant colony is created at the first stage. In the second stage, quantity of pheromone is updated. In the last phase i.e. solution phase, new ant colony is generated based on the best solution from old ant colony. Then both the two colonies are compared based on best solution. By the end of the first iteration, feasible solution spaced is reduced by the vector. Now the optimum solution is researched in reduced space during the algorithm progress as shown in fig. 3.8.

### **Steps for Ant Colony Optimization:-**

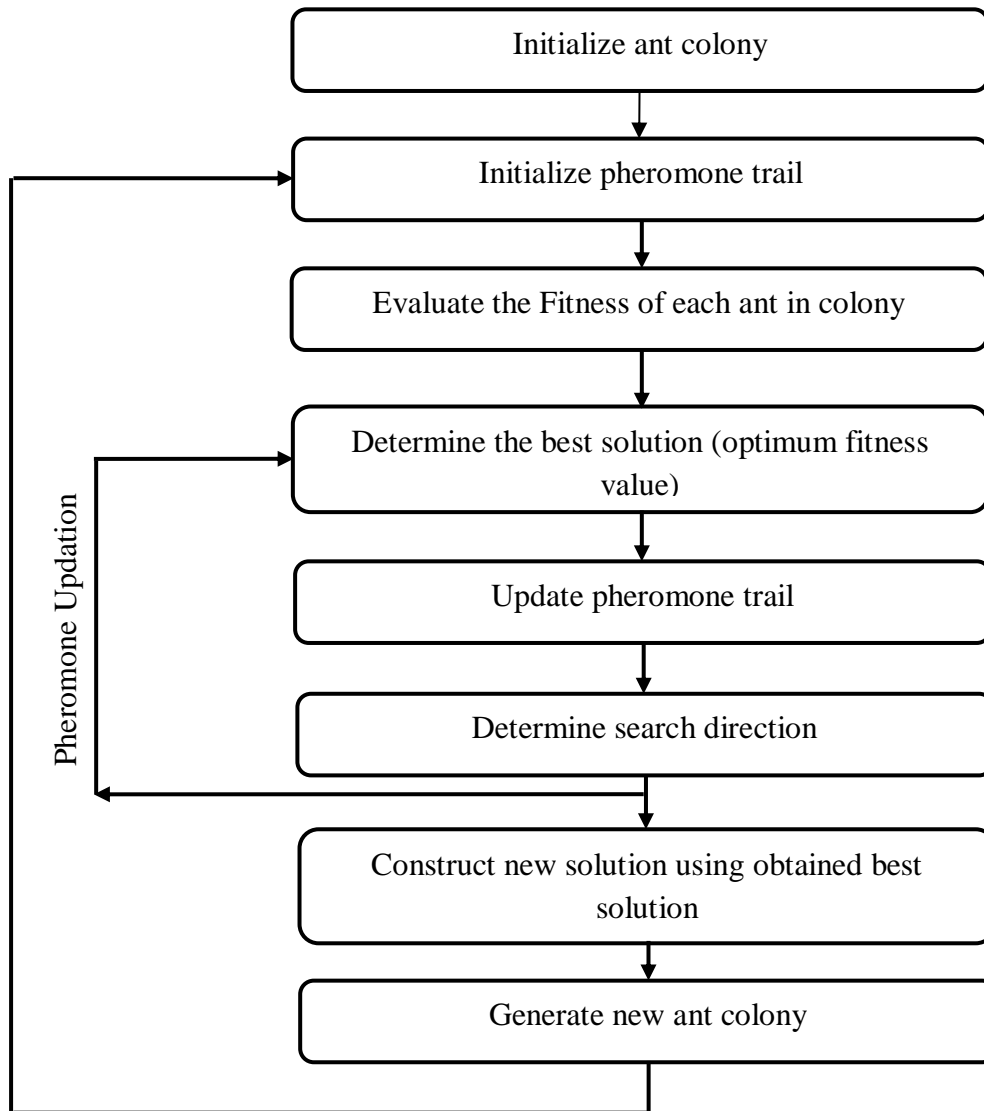
#### **1. Initialization of ant colony:**

Image is described as matrix of pixel values and for the hybrid filter combination the random population with optimal magnitude is obtained. The optimal magnitude of image is obtained by adaptive thresholding with background and foreground clustering algorithm.

#### **2. Initialization of pheromone trail:**

For proceedings into next iteration pheromone trail is most important. In this situation pheromone trail is group of hybrid filters combination that equal to the size of colony. The combinations of hybrid filters are randomly selected. The pheromone helps

the ant colony for further search in solution space by providing the direction for ant in the initialized colony. Pheromone has been upgraded in each iteration.



**Fig. 3.8: Flowchart of Ant Colony Optimization**

### 3. Evaluation of fitness:

The fitness of each ant in the colony is measured by summation of all intensities of edges in an enhanced image, because grey scale image having good contrast contains many intensive edges. The sum of intensities of edges  $E(k)$  in the enhanced image is calculated as -

$$E(K) = \sum_x \sum_y \sqrt{\delta h_k(x, y)^2 + \delta v_k(x, y)^2} \quad (3.9)$$

$$\delta h_k(x, y) = g_k(x+1, y-1) + g_k(x+1, y) + g_k(x+1, y+1) - g_k(x-1, y-1) - g_k(x-1, y) - g_k(x-1, y+1) \quad (3.10)$$

$$\delta v_k(x, y) = g_k(x-1, y+1) + g_k(x, y+1) + g_k(x+1, y+1) - g_k(x-1, y-1) - g_k(x, y-1) - g_k(x+1, y-1) \quad (3.11)$$

The fitness of the individual 'n' is achieved by:

$$F(X_n) = \text{rand}(X_n/E_k) \quad (3.12)$$

where  $X_n$  consist of all hybrid filter combination which gives optimal magnitude

#### 4. Determine the best ant in colony:

In this step, the best ant amid other ants in the colony is determined. An ant is mixed combinations of filters and on the basis of the fitness value, ants are compared. An ant with the best fitness value is stored and selected for further updating of solution space. The direction of search is depends on best ant.

#### 5. Updating of pheromone trail:

The pheromone trail is upgraded using neighbourhood search done for each ant that is in 10% range of the original fitness value of the ant. This trail is updated by choosing best of each neighbour comparing with primitive ant and best of these two ants are taken as the combination for later iteration.

$$\tau_{ij}(t) = p \tau_{ij}(t-1) + \Delta \tau_{ij}, t = 1, 2, \dots, T \quad (3.13)$$

Where T is the no of iteration and p is pheromone evaporation rate from 0-1

$\tau_{ij}(t)$  is updated concentration of pheromone at iteration t

$\tau_{ij}(t-1)$  is previous concentration of pheromone at iteration t-1

$\Delta \tau_{ij}$  is change in concentration of pheromone

#### 6. Determine search direction:

The way for finding the search space of solution is directed by pheromone trail and the best solution.

#### 7. Generate new colony:

From the above steps, search direction is determined and search space has been explored. With the increase of search space, probability of getting optimum solution increases.

## **8. Completion for evolution:**

Using evolutionary rules the population evolved by ACO algorithm is described above. In the first generation random ant's information is given to each individual. The individual with best fitness value is selected in each cycle (Gupta, K. and Gupta, A. 2012).

### **(d) Hybrid of ACO-PSO**

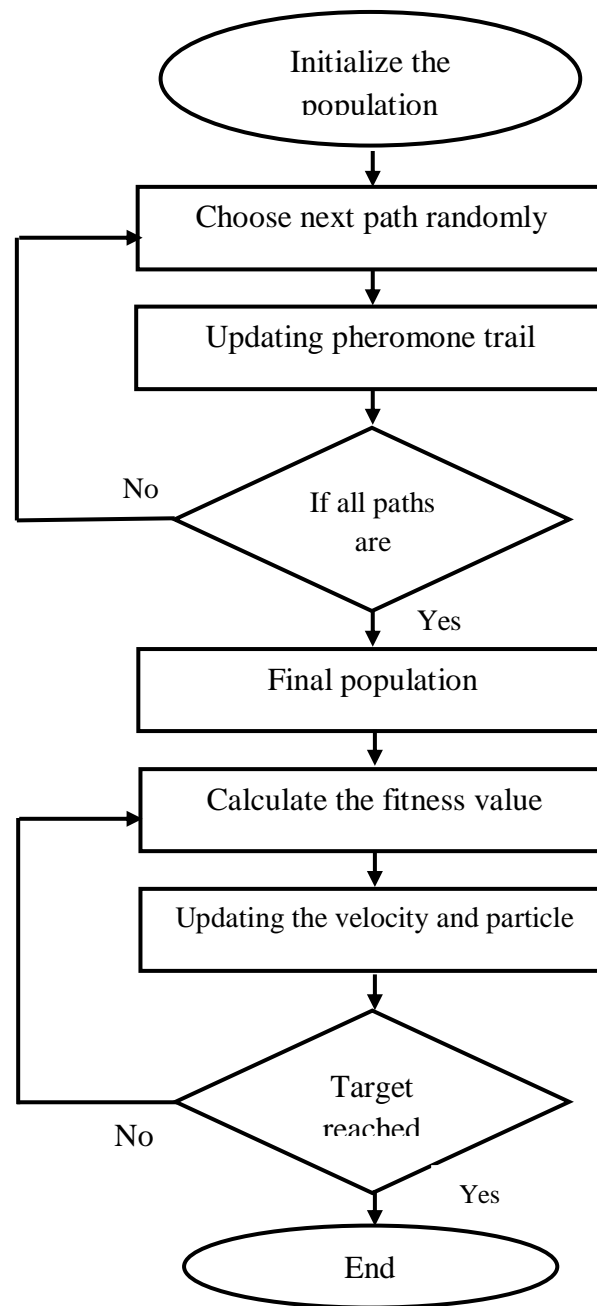
Hybrid optimizing algorithm is the combination of Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO). Hybridization makes the complete use of parameters of both the optimization techniques. In this algorithm, PSO enhance the characteristics of ACO, it define that the choosing of parameters doesn't relies on artificial experience, but depends on the robust search on the particles in PSO. Optimizing algorithms not only reduce the number of the paths but also finds the shortest paths amongst the largest paths (Pal, D. et al. 2016)

### **Algorithm for hybrid ACO-PSO**

- In the first stage of Hybrid ACO-PSO algorithm,
  - (a) Population is initialized using Ant colony optimization.
  - (b) Initialize the heuristic information and pheromone.
  - (c) Randomly choose the next path.
  - (d) Update the pheromone trail.
  - (e) Travel the ant through each path until we find global path which is better than local path.
- In the second stage of hybrid ACO-PSO algorithm
  - (a) Final population is retrieved from ACO having the global path.
  - (b) With the help of the objective function compute the fitness value.
  - (c) If the particle's current position is better than former best position then, consider the current position as gbest position.

(d) Upgrade the particle and velocity position.

(e) Stop, when all paths is traversed and final best population is obtained



**Fig. 3.9: Flowchart of hybrid ACO-PSO Algorithm**

### 3.3 Software used

MATLAB® 2018b is used for the development of the proposed algorithm for Enhancement of Low Light Images . MATLAB® 2018b is a high staging, interactive, and computational language for technical computing. It is used for computation,

visualisation, and programming and is very easy to use where issue and way outs are expressed in familiar mathematical notations.

### **3.3.1 MATLAB® 2018b**

MATLAB is an abbreviated form of MATrix laboratory. The fundamental data element in MATLAB is matrix. MATLAB is technical computing environment with high performance used for visualization, computation and application development. It yields feasible environment to express problems and solutions mathematically. MATLAB integrates numerical analysis, matrix computation, signal and graphic processing. It is an interactive system which enumerates the solutions accurately and quickly.

MATLAB is endorsed by users because of its well written documentation, fast prototyping ability, user friendly syntax and all in one platform feature. It have a large number of functions and algorithm to address several areas of application such as financial analysis, statistics, image processing, control system, signal processing, communication etc. Its immense capacity of mathematical operation and analysis which makes its more preferable than any other application development platform.

The matrix basic element on which MATLAB operates and the fixed variables are also saved as matrix. It can transmit and receive data to external environment and display the values held by these matrices

MATLAB ease by performing mathematical operations using code writing and formulation of application through simulation. Real time applications can be accomplish by combining simulations to systems (Eker, B. and Eker, A.A. 2013).

The facilities and features provide by MATLAB are follows:

#### **(a) Numeric computation**

MATLAB provides ample range of mathematical functions and numerical computation methods. These method are used for model creation, data analysis and algorithm development to support engineering and common science operations. The computations methods are as follows:



- Differentiation and integration
- Regression and interpolation
- Linear system of equations
- Fourier analysis
- Sparse matrices
- Singular values and Eigen values
- Classical differential equations

**(b) Data Visualization and Analysis:**

MATLAB is comprises of the tools that enables to gain inside the data in less amount of time as compared to time taken by traditional programming languages and spread sheets to visualize and analyse the data.

- Acquisition of data- MATLAB enables to access the data from external devices, databases, files and other applications. File formats are used to read the data which includes sound, image, video, binary files or text, scientific files and Microsoft excel.

Data can also be collected from different communication devices such as function generators, oscilloscope and signal analysers and can also be acquired from various hardware devices.

- Analysing data- MATLAB facilitate filtering, pre-processing and managing of data. Image analysis, spectral analysis, system identification and other analysis can also be performed by MATLAB. Descriptive models can be built by MATLAB.
- Visualizing data- volume visualization function, 2D, 3D plotting functions are built in functions in MATLAB to understand, communicate data and results and to visualize. Customization of plots is done interactively or programmatically.
- Sharing and documenting Results- Results can be analyse in the form of reports or plots. Plots are saved in common file format and they can be customized. Reports are comprises of comments, program results, code and plots which is executed with the generation of program. Results are published in different formats such as PDF, Word, HTML, etc.

### **(e) Programming and Algorithm Development**

MATLAB provides development tools and high level language for analysis and fast development of algorithms and applications.

- **MATLAB Language-** Grant support for matrix and vector operations to solve engineering and scientific problems, which facilitate execution of algorithms and rapid development. The features of traditional programming language are provided by MATLAB such as error handling, object-oriented programming and flow control. MATLAB supports custom data types, fundamental data type and advanced data structures. With the implementation of the commands, immediate results can be produced one at a time.
- **Development tools-** MATLAB provides different development tools which are listed as follows:
  - (a) **Command window-** provides a space to insert data, implementation of programs and commands and demonstration of results.
  - (b) **MATLAB Editor window-** It allow features such as debugging and editing (provide breakpoints and go down to individual code lines)
  - (c) **Code analyser-** It checks the code and provide modifications.
  - (d) **MATLAB profiler-** It estimates the performance of MATLAB programs and identifies the segments of the code that need modification for augmentation.
- **Integration with other applications and languages-** it is compatible with the codes written in another language such as Java, C, C++ and .NET.

### **(d) Application Development**

For the development of application, a wide range of options are given by MATLAB tools. Graphical User Interface Development Environment (GUIDE) and MATLAB functions are used to create GUIs programmatically. With GUIDE, GUIs can be edited, designed and laid out (Mathworks, 1994-2018).

#### **3.3.2 Image Processing Toolbox**

Image Processing Toolbox provides workflow apps for image processing, analysis, visualization, and algorithm development and comprehensive set of reference-

standard algorithms. We can perform image enhancement, image segmentation, noise reduction, geometric transformations, 3D image processing, and image registration.

Image Processing Toolbox apps let us automate common image processing workflows. We can interactively segment image data, batch-process large datasets and compare image registration techniques. Visualization functions and apps let us generate histograms, discover images, 3D volumes, and videos; operate regions of interest (ROIs); and modify contrast.

The array which is the basic data structure in MATLAB is suited for representation of images that are real valued and ordered sets of intensity data. MATLAB stores gray scale images as 2D arrays or matrices in which each element corresponds to a single pixels. RGB images are stored as 3D arrays with red, green, and blue plane of red, green, blue pixel intensities respectively.

There are four basic types of images supported by image processing toolbox which are as follows:

- **Intensity Images:** These are stored as single matrix where each element corresponds to one pixel of image. If the image is of class double, the value it holds are in range [0 1] and if it is of class uint8 the values are in range [0 255]. Various intensities or gray levels are represented by matrix elements where black is represented by intensity 0 and white is represented by intensity 1 (or 255).
- **RGB Images:** In RGB images each pixel colour is a set of 3 values (red, green and blue intensities) RGB images are represented as m-by-n-by-3 matrix where third dimension has three planes containing red, green, blue intensities.
- **Binary Images:** Binary images are stored as 2D matrices containing values 0 and 1 thereby representing black and white intensity only.
- **Indexed Image:** An indexed image consist of an image matrix and a colour map which represents the colours in an image. The value of an image matrix element is an indexed into the colour map. Each row of an m-by-3 matrix of colour map specifies red, green, blue values for a single colours

The graphics file formats supported by the MATLAB are JPEG, TIFF, BNP, XWD, PCX, PNG and HDF (Mathworks, 1998).

## **CHAPTER 4**

### **RESULTS AND DISCUSSION**

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This chapter discusses the experimental results and presents the performance analysis of proposed method of enhancing image by optimizing complex wavelet transform. The simulation and implementation of this research work is performed on MATLAB® 2018b. In this research work, evaluation of hybrid optimizing algorithm with Dual Tree Complex Wavelet Transform for enhancement of low light images has been observed.

The experimental results of proposed approach are compared with the results of existing approach –low light enhancement using Dual Tree Complex Wavelet Transform (Jung, C. *et al.* 2016). Performance of the algorithm is analysed on the basis of five performance metrics.

#### 4.1 Performance Metrics

Performance indicators decides the quality and quantity of algorithm. A performance metric is computable and meaningful measure used for volumetric analysis of performance of the algorithm. Metrics could be used to optimize or monitor image quality in digital camera and to evaluate image enhancement algorithm. These are the mathematical computation to study particular method and its behaviour in introduced changes.

To evaluate the performance of the adopted algorithm we will focus on the following parameters:

- **Denoising**

It is the method of eradicating noise from an image. The primary aim of an image denoising algorithm is to accomplish both reduction of noise and feature preservation.

The denoising is measured using following parameters

- (a) Peak Signal to Noise Ratio (PSNR)
- (b) Root Mean Square Error (RMSE)

##### 4.1.1 Peak Signal to Noise Ratio

It is the ratio between the reference signal and distorted signal in an image. It indicates the quality of reconstructed image. Higher the value of PSNR, the distorted image is more nearer to the original image. PSNR is calculated as

$$PSNR = 10 \log_{10} \left( \frac{MAX^2}{MSE} \right) \quad (4.1)$$

Where, MSE is the mean square error between the original image and distortion image.

MAX is the maximum pixel value of the image that is MAX = 255.

#### 4.1.2 Root Mean Square Error

Mean square error is the summative squared error between original image and compressed image. Root mean square error is square root of MSE.

$$MSE = \frac{\sum_i \sum_j \{Y(i,j) - X(i,j)\}^2}{M * N} \quad (4.2)$$

where  $M*N$  represents the size of an image.

$X$  denotes the restored image.

$Y$  denotes the original image.

- **Contrast Enhancement**

It is the improvement of visual quality of low light images. The main aim of contrast enhancement is to make the image visually more informative to improve the readability. The contrast enhancement is measured using following parameters.

- (a) Discrete Entropy (DE)
- (b) Absolute Mean Brightness Error (AMBE)
- (c) Colorfulness metric (CM)

#### 4.1.3 Discrete Entropy

It computes the amount of information in an image. Large Value of Discrete Entropy indicates that the image contains more details.

Mathematically, discrete entropy is written as-

$$H(P) = -\sum_{i=0}^{L-1} p(i) \log_2 p(i) \quad (4.3)$$

Where  $p$  is probability density function

#### 4.1.4 Absolute Mean Brightness Error

It is the absolute difference between input and output means. Mathematically it is written as-

$$AMBE(X, Y) = |X_M - Y_M| \quad (4.4)$$

Where  $X_M$  is mean of input image and  $Y_M$  is mean of output image.

#### 4.1.5 Colorfulness Metric

CM is used to calculate the perceived color of an image and it is measured on the basis of mean ( $\mu$ ) and standard deviations( $\sigma$ ) where  $\alpha = R-G$ ,  $\beta = 0.5*(R + G) - B$

$$M = \sqrt{\sigma_{\alpha}^2 + \sigma_{\beta}^2} + 0.3 \sqrt{\mu_{\alpha}^2 + \mu_{\beta}^2} \quad (4.5)$$

## 4.2 Experimental Results





The designing and simulation of proposed algorithm is performed using MATLAB® 2018b software. The image processing toolbox and graphical user interface (GUI) are used for various computation and processing operation. The algorithm is designed for processing of RGB images (.png format).

### 4.2.1 Existing Approach

The approach of low light enhancement using Dual Tree Complex Wavelet Transform is used as basis to compare the proposed approach. Experimental results of one of the four images (Greenwich.png) are depicted below and the experimental results of the rest of the images are summarized in the table 4.2. Various steps of existing method with the resulting images are shown in table 4.1.

**Table 4.1: Steps and intermediate results of Existing approach**

Original image	
----------------	--

YUV Image	
Illumination Compensation	
Contrast Enhancement	
Complex Wavelet Transform	

The experimental results of existing method on the basis of performance parameters such as PSNR, MSE, DE, AMBE and colorfulness are tabulated as shown in table 4.2.

**Table 4.2: Experimental results of Existing Method**









<b>Image</b>	<b>PSNR</b>	<b>MSE</b>	<b>DE</b>	<b>AMBE</b>	<b>CM</b>
Greenwich	39.8803	6.5278	10.48	55.49	42.014
Ramp	41.7128	1.556	2.57	60.59	23.70
Dusk	41.82	4.26	5.64	27.77	28.78
Landrover	46.1058	1.544	2.57	35.43	13.09

#### **4.2.2 Proposed Approach**

The method proposed in this work is hybrid optimization of Dual Tree Complex Wavelet Transform for enhancement of low light images. The developed algorithm used image processing applications for performing different types of processing operations on various images. Steps of proposed method along with resulting images are shown in table 4.3.

**Table 4.3: Steps and intermediate results of proposed approach**

Original Image	
RGB to YUV Space Conversion to get Y channel	
Illumination Compensation using bilateral filtering	
Contrast enhancement	

Complex Wavelet Transform	
Hybrid Optimization	

The experimental results of proposed approach of proposed method on the basis of performance metrics PSNR, MSE, DE, AMBE and colorfulness are tabulated as shown in table 4.4

**Table 4.4: Experimental results of Proposed Approach**

Image	PSNR	MSE	DE	AMBE	CM
Greenwich	54.144	0.2310	9.0458	60.9847	53.28
Ramp	60.733	0.0189	5.89	96.78	59.3426
Dusk	60.0785	0.01432	1.2495	94.716	59.592
Landrover	60.8676	0.01194	1.2596	87.0561	60.54




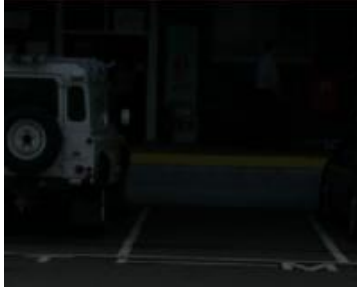





### 4.3 Comparison of Existing and Proposed Approach




For evaluating the performance of proposed method, its results are compared with the results of existing method. The comparison between existing and proposed method is carried out on the basis of objective and subjective performance analysis.

#### **4.3.1 Comparison on the Basis of Visual Appearances**

Comparison of two methods on the basis of visual appearances is shown in table 4.5.

**Table 4.5: Visual Comparison of Existing and Proposed Approach**

Original Image	Results of existing approach	Results of proposed approach
 <p>Greenwich</p>	 <p>PSNR 39.88      AMBE 55.49 MSE 6.527      DE 10.48 CM 42.041</p>	 <p>PSNR 54.149      AMBE 60.98 MSE 0.2310      DE 9.04 CM 53.28</p>
 <p>Ramp</p>	 <p>PSNR 41.78      AMBE 60.59 MSE 1.556      DE 2.57 CM 23.70</p>	 <p>PSNR 60.733      AMBE 96.78 MSE 0.0180      DE 5.89 CM 59.34</p>
 <p>Dusk</p>	 <p>PSNR 41.82      AMBE 27.77 MSE 4.26      DE 5.64 CM 28.78</p>	 <p>PSNR 60.078      AMBE 94.716 MSE 0.01432      DE 1.24 CM 59.592</p>

		
Landrover	PSNR 46.105      AMBE 35.43 MSE 1.544      DE 2.57 CM 13.09	PSNR 60.867      AMBE 87.05 MSE 0.01192      DE 1.2455 CM 60.54

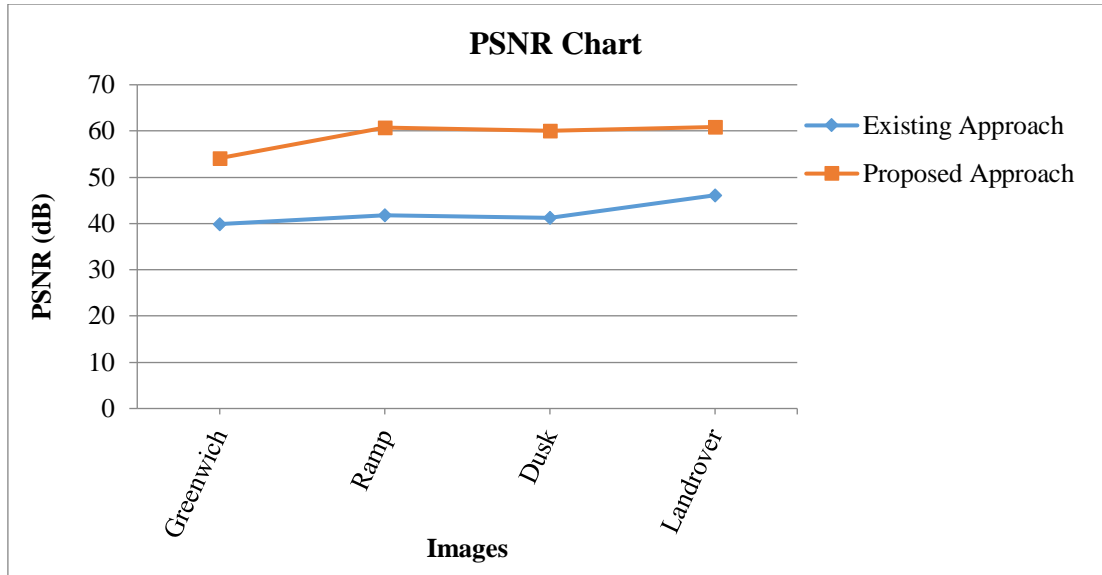
#### 4.3.2 Comparison on the Basis of PSNR

Comparison of proposed and existing approach on the basis of values of performance evaluation parameter PSNR are shown in table 4.6.

**Table 4.6: Comparison on the basis of PSNR**

Image	Existing Approach (dB)	Proposed Approach (dB)
Greenwich	39.8803	54.144
Ramp	41.7128	60.733
Dusk	41.289	60.0785
Landrover	46.1058	60.8676

The PSNR chart showing the comparison of existing approach and proposed approach is shown in fig 4.1



**Fig. 4.1: Comparison Chart for PSNR**

From table 4.6 and fig. 4.1, it is evident that the PSNR values of proposed approach are greater than the result of existing approach. Higher value of PSNR implies better quality of reconstruction. So, proposed approach outperforms the existing approach in terms of PSNR.

#### 4.3.3 Comparison on the Basis of MSE

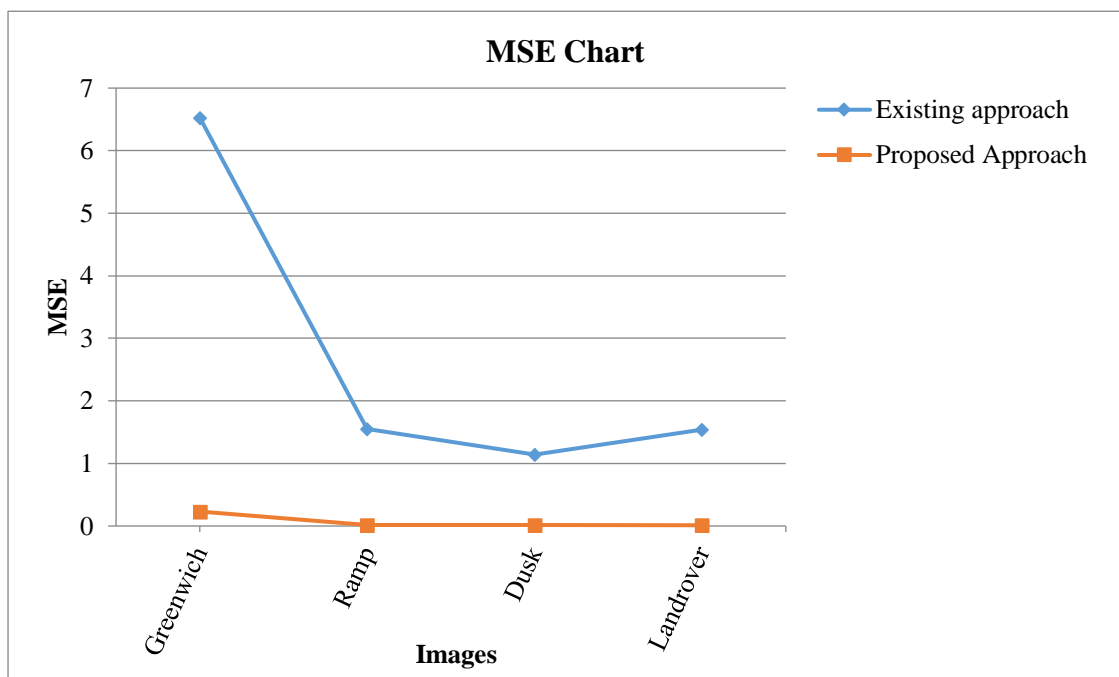
Comparison of existing approach and proposed method on the basis of values of performance parameter MSE are shown in table 4.7.

**Table 4.7: Comparison on the basis of MSE**

Image	Existing Approach	Proposed Approach
Greenwich	6.5278	0.23107
Ramp	1.556	0.0189

Dusk	1.142	0.01432
Landrover	1.544	0.01194

The MSE chart in fig. 4.2 shows the comparison of existing approach and proposed approach on the basis of mean square error.



**Fig 4.2: Comparison Chart for MSE**

Table 4.7 and fig. 4.2 shows that proposed approach is achieving good results and achieve low mean square error rate. The mean square error must be low for high signal to noise ratio. So the proposed approach performs better then the existing approach in terms of MSE.

#### 4.3.4 Comparison on the basis of Discrete Entropy

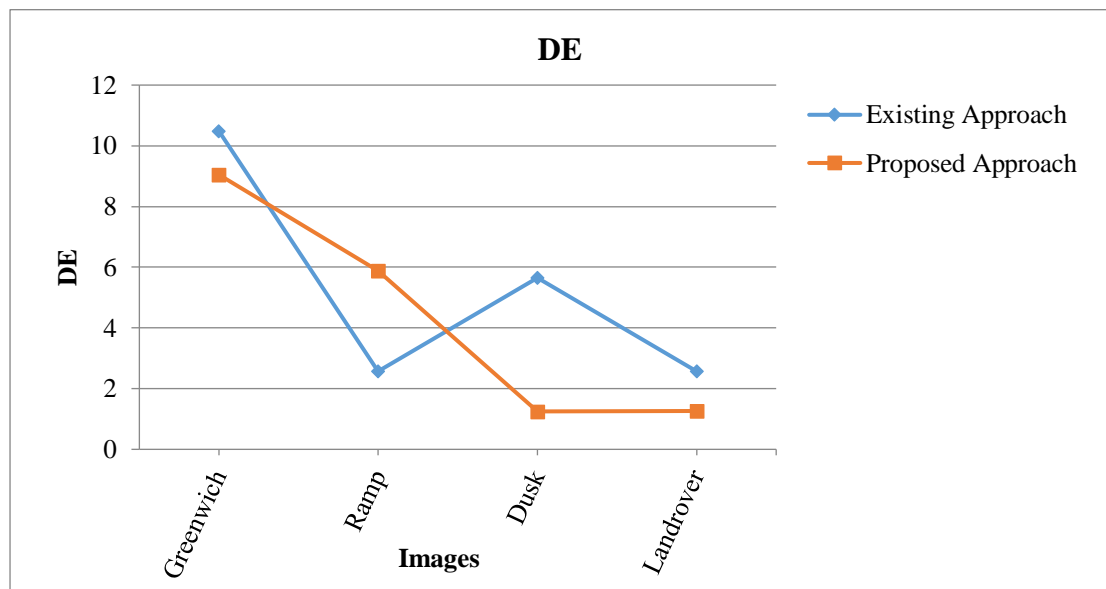


Comparison of existing approach and proposed method on the basis of values of performance parameter DE are shown in table 4.8.

**Table 4.8: Comparison on the basis of DE**

Image	Existing Approach	Proposed Approach
Greenwich	10.48	9.0458
Ramp	2.57	5.89
Dusk	5.64	1.2495
Landrover	2.57	1.2596

The DE chart in fig. 4.3 shows the comparison of existing approach and proposed approach on the basis Discrete Entropy



**Fig. 4.3: Comparison Chart for DE**

From table 4.8 and fig. 4.3, it is evident that discrete entropy for images in existing approach outperforms than the proposed approach. This implies that existing method improves the brightness of the image as compared to proposed approach.

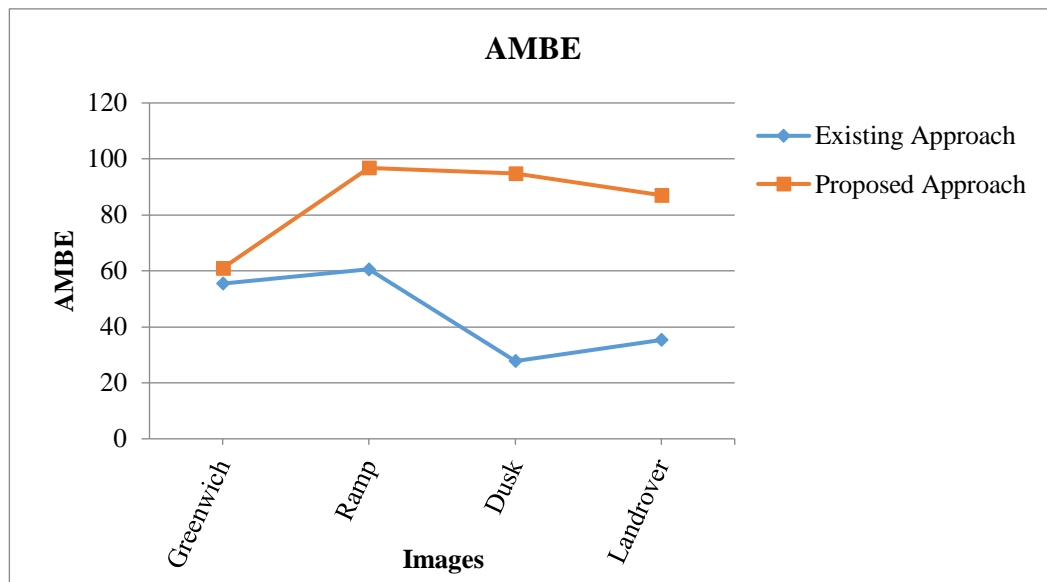
#### 4.3.5 Comparison on the basis of Absolute Mean Brightness Error

Comparison of existing approach and proposed method on the basis of values of performance parameter AMBE are shown in table 4.9.

**Table 4.9: Comparison on the basis of AMBE**

Image	Existing Approach	Proposed Approach
Greenwich	55.49	60.9847
Ramp	60.59	96.78
Dusk	27.77	94.716
Landrover	35.43	87.05

The AMBE chart in fig. 4.4 shows the comparison of existing approach and proposed approach on the basis Absolute Mean Brightness error.



**Fig. 4.4: Comparison Chart for AMBE**

Table 4.9 and fig. 4.4 shows that proposed approach is achieving good results and achieve high AMBE. So the proposed approach performs better than the existing approach in terms of AMBE.

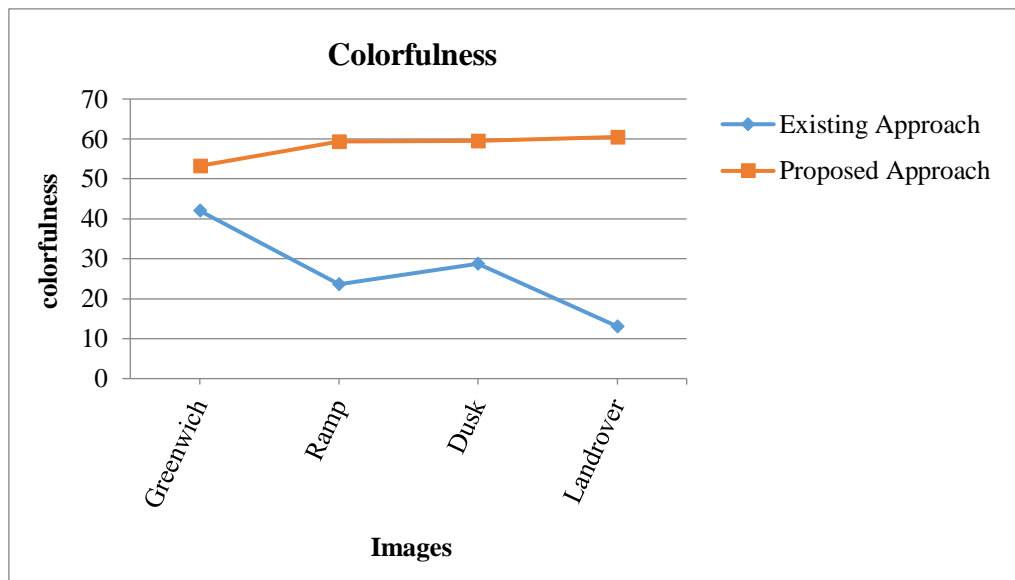
#### 4.3.6 Comparison on the basis of Colorfulness

Comparison of existing approach and proposed method on the basis of values of performance parameter colorfulness are shown in table 4.10.

**Table 4.10: Comparison on the basis of Colorfulness**

Image	Existing Approach	Proposed Approach
Greenwich	42.014	53.28
Ramp	23.70	59.3426
Dusk	28.78	59.592
Landrover	13.09	60.54

The chart in fig. 4.5 shows the comparison of existing approach and proposed approach on the basis colorfulness



**Fig 4.5 Comparison Chart for Colorfulness**

Table 4.10 and fig. 4.5 shows that proposed approach is achieving good results and achieve high colorfulness. So the proposed approach performs better than the existing approach in terms of colorfulness. High value of colorfulness shows the fidelity of perceived colour in colour enhancement.

#### 4.4 Discussion

From the comparisons between existing and proposed approach it can be concluded that

- The results of proposed method are not showing over enhancement in terms of visual appearances therefore improving the images in more balanced manner preserving the similarity with original image
- The proposed approach is better than the existing method in terms of MSE, PSNR, AMBE and Colorfulness
- The developed algorithm has improved reconstruction quality in terms of higher PSNR, low error rate probabilities in terms of MSE, improved AMBE and better color preciseness in terms of colorfulness.
- The existing approach is better in terms of Discrete Entropy than the proposed approach.
- The Discrete Entropy is although not improved but it is marginally less as compared to existing method. The lesser value of DE does not much effect as the parameters PSNR, MSE, AMBE, and colorfulness are improved significantly providing better visual appearance and quality in image.

In this thesis, a method for hybrid optimization of Dual Tree Complex Wavelet Transform (DT-CWT) for enhancement of low light images is developed. It is used for maximizing the performance in low intensity scenarios.

In this method, firstly image is captured under low light condition and it is converted to YUV color space. Y channel is used for noise reduction and contrast enhancement. Luminance channel Y provides more amount of information in low light condition as compared to chrominance channel U and V. After that the bilateral filtering is done for illumination compensation. It decomposes Y channel into base and detail layers where base layer is obtained through smoothing and detail layer is obtained by subtracting Base layer from Y channel. Low intensity image is then pre-processed using Contrast Level Adaptive Histogram Equalization (CLAHE). It reduces undesirable distortion and enhances features and characteristic of the image necessary for further processing. Contrast enhancement technique preserves the edges in image and suppresses the noise. Image de noising is done using wavelet transformation. The Dual Tree Complex Wavelet Transform deals with the boundaries segmentation and detects the edges of the image. Furthermore the hybrid optimization is executed using ACO and PSO. It exploits the advantage of both ACO and PSO. In this algorithm, PSO enhance the characteristics of ACO, it define that the choosing of parameters doesn't relies on artificial experience, but depends on the robust search on the particles in PSO. The optimization increases the efficiency of the system and reduces the error rate probabilities. Optimizing algorithm not only reduces the number of the paths but also finds the shortest paths amongst the largest paths.

The proposed method is evaluated on the basis of performance metrics such as Peak Signal to Noise ratio (PSNR), Mean Square Error (MSE), Discrete Entropy (DE), Absolute Mean Brightness Error (AMBE), Colorfulness(CM).

## **Conclusion**

Our first objective is” Study and analysis of Contrast level Enhancement techniques in image processing” and it has done in chapter 1 and chapter 2 of the thesis. The benefits and drawbacks of previous techniques have also been discussed in these chapters.

Our second objective is “To evaluate optimizing algorithm with Dual-Tree-Complex Wavelet Transform (DT-CWT) for enhancement of low light images" and Hybrid Optimization with DT-CWT has successfully been achieved in Chapter 3 of thesis.

Our third objective is “Performance analysis of modified technique and its comparison with the Existing Technique” and it has been done in Chapter 4 of the thesis.

## **PUBLICATION**

Jain, E. and Agrawal, N. 2019. Hybrid Optimization of Dual Tree Complex Wavelet Transform for Enhancement of Low Light Images. *International Journal of Scientific and Engineering Research*, **10**: 10-14.

**LITERATURE CITED**

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## **ABSTRACT in ENGLISH**

With the popularity of digital cameras and smart phones, digital images play an important role in day to day life. However, when images are captured in low light environment, generally at night, the quality of image descends rapidly because of loss of contrast, low dynamic range and noise. Besides deteriorating visual quality of the images, this low light images also results in degrading the performance of many computer algorithm that are responsible for high quality input. Thus, image enhancement of low light images is very important.

Contrast enhancement is one of the most essential and significant spatial based image enhancement technique. The main aim of this technique is to adjust the local contrast in the image and increase the dynamic range so to get the clear regions in an image. The contrast enhancement changes the intensity of the pixel for obtaining a more enhanced image. So it is required to improve the contrast in an image to get perceptually more pleasing or visually more informative vision effect.

This thesis report presents an effective approach is required for maximizing the performance in low intensity scenarios. In this research work, we proposed hybrid optimization algorithm with Dual Tree Complex Wavelet Transform (DT-CWT) for enhancement of low light images. More concretely, low intensity image is pre-processed using Contrast Level Adaptive Histogram Equalization (CLAHE) and Bilateral Filtering. Furthermore, the complex wavelet transform (CWT) is performed for normalization which is followed by hybrid optimization of Ant Colony (ACO) and Particle Swarm intelligence (PSO). Optimization is done for achieving high peak signal to noise ratio and reducing error rate probability.

The proposed method is evaluated on the basis of performance metrics such as Peak Signal to Noise ratio (PSNR), Mean Square Error (MSE), Discrete Entropy (DE), Absolute Mean Brightness Error (AMBE), Colorfulness.

### ABSTRACT in HINDI

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## Appendix A: Abbreviations

DIP	Digital Image Processing
RGB	Red, Green, Blue
CMY	Cyan, Magenta, yellow
YUV	Luminance and Chrominance
HSI or HSV	Hue, Saturation, Intensity or Value
HE	Histogram Equalization
LHE	Local Histogram Equalization
GHE	Global Histogram Equalization
AHE	Adaptive Histogram Equalization
CLAHE	Contrast Level Adaptive Histogram Equalization
BBHE	Brightness Bi Histogram Equalization
ACO	Ant Colony Optimization
PSO	Particle Swarm Optimization
DT-CWT	Dual Tree Complex Wavelet Transform
DWT	Discrete Wavelet Transform
GA	Genetic Algorithm
TV-Diffusion	Total Variation Diffusion
MATLAB	Matrix Laboratory
GUI	Graphical User Interface
GUIDE	Graphical User Interface Development environment
2D	Two Dimensional
3D	Three Dimensional

PSNR	Peak Signal to Noise Ratio
MSE	Mean Square Error
DE	Discrete Entropy
AMBE	Absolute Mean Brightness Error
Gbest	Global Best value
Pbest	Particle Best Value

## APPENDIX B : Code

```

function varargout = main_file_run(varargin)
% MAIN_FILE_RUN MATLAB code for main_file_run.fig
%     MAIN_FILE_RUN, by itself, creates a new MAIN_FILE_RUN or raises the
existing
%     singleton*.
%
%     H = MAIN_FILE_RUN returns the handle to a new MAIN_FILE_RUN or the
handle to
%     the existing singleton*.
%
%     MAIN_FILE_RUN('CALLBACK',hObject,eventData,handles,...) calls the local
%     function named CALLBACK in MAIN_FILE_RUN.M with the given input
arguments.
%
%     MAIN_FILE_RUN('Property','Value',...) creates a new MAIN_FILE_RUN or
raises the
%     existing singleton*. Starting from the left, property value pairs are
%     applied to the GUI before main_file_run_OpeningFcn gets called. An
%     unrecognized property name or invalid value makes property application
%     stop. All inputs are passed to main_file_run_OpeningFcn via varargin.

```



```

%
%      *See GUI Options on GUIDE's Tools menu. Choose "GUI allows only one
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help main_file_run

% Last Modified by GUIDE v2.5 22-Oct-2018 18:34:21

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',   gui_Singleton, ...
                  'gui_OpeningFcn', @main_file_run_OpeningFcn, ...
                  'gui_OutputFcn',  @main_file_run_OutputFcn, ...
                  'gui_LayoutFcn',  [], ...
                  'gui_Callback',    []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before main_file_run is made visible.
function main_file_run_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure

```

```

% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
% varargin command line arguments to main_file_run (see VARARGIN)

% Choose default command line output for main_file_run
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

% UIWAIT makes main_file_run wait for user response (see UIRESUME)
% uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.
function varargout = main_file_run_OutputFcn(hObject, eventdata, handles)
% varargout cell array for returning output args (see VARARGOUT);
% hObject handle to figure
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;

% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject handle to pushbutton1 (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
global main_im
[fn,pn]=uigetfile('*.png','Select a File to Upload');
fullpath=[pn fn];
[main_im, map]=imread(fullpath);

```

```

subplot(231);
imshow(main_im);
title('Original Image','Color','w');
save('main_image','main_im')
msgbox('Image Uploaded Sucessfully');

```

```

% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

```

```

load('YUV_Data','yuv_image');
det_image(:,:,1) = (1+logical(yuv_image(:,:,1)))*log(0.9+1) -
log(log(logical(yuv_image(:,:,1))+1)+1);
det_image(:,:,2) = yuv_image(:,:,2);
det_image(:,:,3) = yuv_image(:,:,3);
subplot(233);
imshow(uint8(det_image));
title('Detail image','Color','w');
save('Det_image','det_image');

```

```

% --- Executes on button press in pushbutton4.
function pushbutton4_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global main_im
load('Det_image','det_image');
d_image = double(rgb2gray(main_im));
d_image = imresize(d_image, [512 512]);

```

```

sigmar = 5;
sigmas = 40;
eps = 0.001;
[moutput,N] = bi_lat(d_image, sigmar, sigmas, eps, 'Gauss');
subplot(234),
imshow(uint8(moutput));
title('BILATERAL FILTERING','FontSize', 10,'color', 'w'),
axis('image', 'off');
save('bilat_im','moutput');

% --- Executes on button press in pushbutton5.

% hObject    handle to pushbutton5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles     structure with handles and user data (see GUIDATA)

load('denoise_image','denoise_im');
load('main_image','main_im')
gray_im= rgb2gray(main_im);
[rs,cs]=size(gray_im);
mse=sqrt(sum(sum(double(gray_im)))-sum(sum(denoise_im)))/((rs)*(cs));
if real(mse)==0
    msgbox(['Proposed MSE IS: ',num2str(imag(mse))]);
else
    msgbox([' Proposed MSE IS: ',num2str(mse)]);
end

pause(1);
if real(mse)==0
    psnr=10*log10(max(max(denoise_im)).^2/(imag(mse)));
else
    psnr=10*log10(max(max(denoise_im)).^2/(mse));

```

```

end
msgbox([' Proposed PSNR IS : ',num2str(psnr),' dB']);

gray_im = imresize(gray_im,[512 512]);
ambe = abs(mean(mean(uint8(gray_im)))- mean(mean(uint8(denoise_im))));
ambe = ambe+abs((cs-rs));

alpha = uint8(main_im(:, :, 1) - main_im(:, :, 2));
beta = uint8( 0.5 * (main_im(:, :, 1) + main_im(:, :, 2)) - main_im(:, :, 3));
M = sqrt(std(std(double(alpha)))^2+ std(std(double(beta)))^2) + 0.3 +
sqrt(mean(mean(double(alpha)))^2+ mean(mean(double(beta)))^2);
if M<50
    M= psnr- (2*rand);
end

lambda = 4;
pd = makedist('Poisson',lambda);
DE = pdf(pd,pdf(pd,denoise_im))*log2(log2(exp(denoise_im)));
msgbox([' Precieved DE is : ',num2str(min(min(DE/lambda)))]);
msgbox([' Precieved Colour Image is : ',num2str(M)]);
msgbox([' Proposed Absolute Difference is : ',num2str(ambe)]);

% --- Executes on selection change in listbox1.
function listbox1_Callback(hObject, eventdata, handles)
% hObject handle to listbox1 (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)

% Hints: contents = cellstr(get(hObject,'String')) returns listbox1 contents as cell array
% contents{ get(hObject,'Value')} returns selected item from listbox1

% --- Executes during object creation, after setting all properties.

```

```

function listbox1_CreateFcn(hObject, eventdata, handles)
% hObject    handle to listbox1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: listbox controls usually have a white background on Windows.
%    See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

```

function edit1_Callback(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit1 as text
%    str2double(get(hObject,'String')) returns contents of edit1 as a double

```

```

% --- Executes during object creation, after setting all properties.
function edit1_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%    See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

end

```
% --- Executes on button press in pushbutton6.
function pushbutton6_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton6 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global main_im
R = main_im(:,:,1);
G = main_im(:,:,2);
B = main_im(:,:,3);
yuv_image(:,:,1) = 0.299 * R + 0.587 * G + 0.114 * B;
yuv_image(:,:,2) = G;
yuv_image(:,:,3) = B;
subplot(232);
imshow(yuv_image);
title('YUV Image','Color','w');
save('YUV_Data','yuv_image');
```

```
% --- Executes on button press in pushbutton7.
function pushbutton7_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton7 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global main_im
load('cwt_im','enhanced_det_layer');
num_of_ants=enhanced_det_layer(1,1:end);
max_iteration=50;
[cost,ant_opt]=run_aco(max_iteration,num_of_ants);

[rs,cs]=size(ant_opt);
```

```

% Initialization
% Parameters

iterations = rs;
swarm_size = cs;

% initial swarm position
index = 1;
for i = 1 : rs
    for j = 1 : cs
        swarm(index, 1, 1) = i;
        swarm(index, 1, 2) = j;
        index = index + 1;
    end
end

swarm(:, 2, :) = 0;          % initial velocity

enhanced_det_layer = double(enhanced_det_layer)

% Iterations
for iter = 1 : iterations
    gbest=[];
    p=1;
    % evaluating position & quality ---
    for i = 1 : swarm_size
        swarm(i, 1, 1) = swarm(i, 1, 1) + swarm(i, 2, 1)/1.3;    %update x position
        swarm(i, 1, 2) = swarm(i, 1, 2) + swarm(i, 2, 2)/1.3;    %update y position
        x = swarm(i, 1, 1);
        y = swarm(i, 1, 2);
        inertia =5*rand;
    end
end

```



```

        val = sqrt((enhanced_det_layer(iter,i) -
mean(enhanced_det_layer(iter,:))^2)*inertia; % fitness evaluation (you may
replace this objective function with any function having a global minima)
        if val < mean(enhanced_det_layer(iter,:)) % if new position is better
            inertia =10*rand;
            swarm(i, 3, 1) = swarm(i, 1, 1); % update best x,
            swarm(i, 3, 2) = swarm(i, 1, 2); % best y postions
            gbest(p) =val*inertia; % global best position
            p=p+1;
        end
        disp(['Optimization terminated for column no: ',num2str(i)]);
    end
end

```

end

```

opt_data(1,1:15)=gbest(1:15);
opt_data=reshape(opt_data,5,3);
opt_data=abs(opt_data);
main_image = rgb2gray(double(main_im));
main_image = imresize(main_image,[512 512]);
nhoodSize = 3;
smoothValue = sum(sum(opt_data));
denoise_im = imguigedfilter(enhanced_det_layer, main_image,
'NeighborhoodSize',nhoodSize, 'DegreeOfSmoothing',smoothValue);
subplot(236);
imshow(uint8(denoise_im));
title('Denoise Image','Color','w');
save('denoise_image','denoise_im');

```

% --- Executes on button press in pushbutton9.

function pushbutton9\_Callback(hObject, eventdata, handles)

% hObject handle to pushbutton9 (see GCBO)

```

% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
load('bilat_im','moutput');
lb = -5;
ub = 5;
n = 1000;
order = 4;
[psi,x] = cgauwavf(lb,ub,n,order);
enhanced_det_layer = adapthisteq(uint8(moutput),'clipLimit',max(imag(psi))/(n/(ub-
lb+order))));
subplot(235)
imshow(uint8(enhanced_det_layer))
title('Enhanced Detail Layer','Color','w');
save('cwt_im','enhanced_det_layer');

```