# A Hybrid Approach for Image Enhancement Using Retinex and Guided Filter

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# CANDIDATE’S DECLARATION

I, **Kavinder Singh** (**2K16/ISY/06)** student of M.Tech **(Information System),** hereby declare that The project Dissertation titled **“A Hybrid Approach for Image Enhancement using Retinex and Guided Filter”** which is submitted by me to the **Department of Information Technology**, Delhi Technological University, in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any degree, Diploma Associateship, Fellowship or some other title or recognition.

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# CERTIFICATE

To the best of my knowledge, This is to certify that Mr. **Kavinder Singh (2K16/ISY/06)** has carried out the major project titled **“A Hybrid Approach for Image Enhancement Using Retinex and Guided Filter”** as a partial requirement for the award of **Master of Technology** degree in **Information System** by **Delhi Technological University, Delhi.**

The Major project is a bonafide piece of work carried out and completed under my supervision and guidance during the academic session 2016-2018. The Matter contained in this thesis has not been submitted elsewhere for the award of any other degree.

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# Abstract

In this project, we tried to proposed a novel method for image enhancement so that the image taken in certain circumstances can be improved in term of its quality. Till now, we have various methods present for the purpose of image enhancement but all are having some limitations so out of them we have chosen the best method known and made improvements in that so that its performance and quality can be improved. We used two methods that are retinex and guided image filtering. We used methods of these both to propose a new method, which can give better enhancement than both of them.

The proposed method is tested and compared with various other methods in the result section which can be referred to check the quality of results with respect to the other methods.

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# CHAPTER 1    INTRODUCTION

While catching an image with a gadget it can be conceivable that any sort of issue or problem can prompt the corruption of the characteristics of the image. While managing such images there are a few procedures available which can assist people with improving the characteristic of these images, such systems are known as image enhancement methods. The way toward managing corrupted images and enhancing their quality is known as image enhancement [1]. The essential motivation behind image improvement is to enhance the characteristics of an image for human vision. In today's world, we have different methods for image improvement out of them Retinex is an extremely powerful and productive procedure which can be utilized to fill the need of viable improvement of the low-quality image. In the human visual framework, when we see at a place then the image is shaped in our psyche with the assistance of human eye (Retina) and handling of brain (Cortex). The fundamental of Retinex is based with respect to this total situation that how a perspective is seen by the human visual framework. The blend of two words (which are "retina" and "cortex") prompted the development of the term known as "Retinex". While catching an image with the assistance of a machine it can be conceivable that because of a few conditions image can prompt a less dynamic range or poor colour consistency. Regarding image, the proportion of the most astounding pixel esteem and the least pixel esteem is known as Dynamic Range of that image. In the human visual framework, we see the shade of a protest as consistent with different illumination conditions, this is called as colour constancy. The order of Retinex is done through Land [2, 3] out of which Center/surround Retinex was used for the usage of Single Scale Retinex. Single Scale Retinex [4, 5] can be used on the off chance that you require one out of either total rendition or dynamic range compaction. SSR can't give both total rendition and dynamic range compaction meanwhile. We are trying to develop an enhanced version of multi-scale Retinex which can perform better image enhancement.

# CHAPTER 2 LITERATURE REVIEW

In literature survey we will study few methods which are based on the Retinex theory. These methods are giving good results when used to improve the image in terms of quality. Retinex is used for lessening the hole between the immediate perspective of a scene and the image caught of that scene. Jobson et al. proposed the basic Retinex which is single-scale Retinex (SSR). Be that as it may, SSR can just play out the constrained errand on an image at any given moment i.e. it either can give the total rendition or can be applied for the compression of the dynamic range of an image. After SSR they presented another method which is weighted sum of the past methodology (SSR) and known as Multi-scale Retinex (MSR). MSR can give both total rendition and compression of the dynamic range in the meantime for an image. MSR is the one with greater appropriateness to the gray-scale images. Thus, to defeat this constraint of MSR a stage is required for the rebuilding of the colour of a base image into the improved image. Multi-scale Retinex with colour restoration method was presented with the idea of the colour rebuilding of the image. MSRCR turned into the more viable strategy for improving the images which experiences insufficient light. After these, it is critical to discover the illumination of the background precisely with the goal that Retinex can play out its assignment viably so another strategy is introduced by Ling Tang et al. known as IRIE [6]. In IRIE it takes more than one frames of an image which are firmly related and after that play out an activity for illumination extraction on them. Haoning Lin and Zhenwei Shi presented an approach which is "improvement to the MSR for night-time image enhancement" (MSRINTE) [7]. In MSRINTE approach the log used in MSR is supplanted by the sigmoid function to lessen the data misfortune while image enhancement of night-time image with the assistance of MSR. Kaiqiang Xu and Cheolkon Jung presented "Retinex based approach using lumination adaptation" (RBCELA) in [8]. In RBCELA, it removes the illumination component from the picture. At that point, it performs lumination adjustment on illumination component and performs different activities based on that and finally it upgrades the contrast. Apart from these Retinex based methods we are also trying to understand the guided image filtering so that the in depth knowledge of the proposed method can be easily understand.

## 2.1 RETINEX THEORY

Land [9] began the Retinex method based on the physical image catching model. Retinex method expresses an image as an augmentation of the illumination and the reflectance of the protest. The attributes of the illumination rely upon the wellspring of illumination. The attributes of the reflectance rely upon the idea of the protest. Based on Retinex hypothesis, numerically we can state, illumination can be assessed by partitioning the image with the reflectance. However, as we realize that, it is unreasonable to have the data about either illumination or reflectance. It is difficult to gauge the illumination from the image with no earlier information about the reflectance. Thusly, unique assumptions and improvements about illumination or reflectance or both are proposed to deal with this issue. A normal presumption is that the edges are same for both scene and reflectance, and furthermore accepted that illumination spatially changes progressively in the scene. Because of this, in Retinex based techniques for the most part, the reflectance is figured as the extent of the image and smooth form of the image which is dealt with as the estimation of the illumination. In Retinex based strategy for image improvement, we for the most part compensate for the impact of illumination on the image. Based on image arrangement model of Retinex strategy:

$$I(m,n) = R(m,n) \cdot \mathrm{L}(\mathrm{m},\mathrm{n}) \tag{2.1}$$

Where I(m, n) denotes the image. R(m, n) denotes the reflectance of the object. L(m, n) represents the illumination. The logarithmic transformation of the image i.e. equation 2.1 is written as

$$\log I = \log R + \log L \tag{2.2}$$

We calculated equation 2.1 to 2.2 depending on the log function property. After looking at equation 2.2, we can deduce that logarithmic transform of the image is the addition of the logarithmic transform of reflectance and illumination. Then, we try to compute the reflectance by modifying equation 2.2 as

$$\log R = \log I - \log L \tag{2.3}$$

In equation 2.3 we get the log of the reflectance. By taking exponent of equation 3, we can compute the reflectance.

$$R = \exp(\log I - \log L) \tag{2.4}$$

Based on equation 2.4, we can state that reflectance is the type subtraction of log of image and log of illumination. As per equation 2.4, we can see that to assess the reflectance we should have the estimation of illumination alongside the image. So we can utilize different channels which are proposed for estimation of the illumination. Utilizing channels we can smooth the image and the smooth variant of the image can go about as the illumination in the majority of the Retinex based technique for image improvement.

The categorisation of Retinex algorithms are path-based, recursive and center/surround algorithm. The center/surround algorithm is implemented in the single-scale Retinex. Later single surround Retinex many algorithms presented over the center/surround algorithm. Multi-scale Retinex [10] and MSRCR [11, 12] are also based on the same center/surround algorithm as SSR.

## 2.2 SINGLE SCALE RETINEX

SSR is the main approach in view of the center/surround Retinex by Jobson et al. in 1997. In SSR it takes an image in logarithmic change and it accepts the illumination layer as the aftereffect of Gauss change over the image. In the wake of having the image and illumination layer, it subtracts the logarithmic change of both to get the outcome. In SSR, we will have an image as input whose quality is low and we need to improve the quality. So we will convolve the image with an appropriate filter which is shaped with the assistance of surround function, we will regard it as illumination. At that point to discover the reflectance by following the method of Retinex we will subtract the log of discovered illumination from the log of an input image. After that, the resultant will be dealt with as the improved image as yield. It is known as single scale Retinex since it utilizes just a single surround function for discovering the illumination by convolving picture.

Numerically it can be composed as:

$$R(m,n) = \log I_i(m,n) - \log[F(m,n) * I_i(m,n)] \quad (2.6)$$

Where $I_i$ speaks for the representation of image over i$^{th}$ colour plane in terms of pixel values in matrix form, * operator denotes the convolution if we want to show the image convolution by any filter then we use this operator, $F(m,n)$ indicates the surround function, and $R(m,n)$ indicates the output produced from Retinex method. The logarithmic change is done later the convolution activity over the image by surround function.

Surround function is can be numerically indicated by:

$$F(m,n) = K \cdot \exp(\frac{-r^2}{c^2}) \tag{2.7}$$

Where C indicates scalar-value. C can be known as either surround or Gaussian space constant. The determination of K depends on:

$$r = (m^2 + n^2)^{1/2} \tag{2.8}$$

$$\iint F(m,n) dm\, dn = 1 \tag{2.9}$$

The Surround space steady is in charge of the modification between the compaction of dynamic range and total rendition. The usage of scale with littler size can bring about more compaction of dynamic range and more steadiness of color can be accomplished by using the parts with high magnitude.

SSR can give either total rendition or dynamic range compaction at once. SSR can't give total rendition and dynamic range compaction both in the meantime. Since it utilizes just one scale for discovering the illumination so it will most likely be unable to give tasteful outcomes for a few images by keeping up just a single property of either compacting dynamic range or total rendition. So to conquer this another approach was presented named as MSR (Multi scale Retinex).

## 2.3 MULTI SCALE RETINEX

In the event that the dynamic range of a scene is significantly bigger than that of picture catching gadget at that point, in these case, the non-recoverable data misfortune can happen. MSR was produced to defeat the constraints of the SSR. MSR consolidates the nature of various surround space to give a resultant picture great dynamic range compaction and total rendition both at same time.

In MSR, it utilizes different surround function on a solitary stage to discover the illumination. In the wake of figuring the illumination from every multiple scales by utilizing the convolution operation, we need to perform log operation. At that point, perform the log operation over the image and subtract the figured illumination from it for one scale and rehash this for all processed illumination. At that point, take the weighted total of the considerable number of results for every one of the scales which will give the last improved image as yield. The sum of weighted yields of different sizes of SSR is known as Multi scale Retinex. Numerically, MSR can be spoken to as:

$$R_{MSR}(m,n) = \sum_{j=1}^{N} w_j\{\log I_i(m,n) - \log[I_i(m,n) * M_j(m,n)]\} \quad (2.10)$$

Where i indicates the colour plane (i.e. R, G, B channel), N indicates the count of scales used in MSR, $M_j(m,n)$ shows the surround function & $w_j$ shows the weights of the respective scale. The surround function can be calculated by:

$$M_j(m,n) = K_j exp\left[\frac{-(m^2+n^2)}{\sigma_j^2}\right] \quad (2.11)$$

Where $\sigma_j$ shows standard deviations. The m & n are the pixel coordinates of the image.

MSR protects a large portion of the points of interest of a picture in the wake of improvement of the image. MSR is superior to anything SSR yet it can't create the natural image which is the essential idea of Retinex. MSR is fit for giving outcome having both total rendition and compaction of dynamic range yet separated from that it likewise has a confinement with respect to shading affectability. MSR is a decent way to deal with discover the improvement of a gray scale image however it has issues with colour images. In MSR we can't foresee that the colour which is created subsequent to handling the image is right or not. MSR have problems identified with the affectability of the color. In any case, we need Retinex to deliver an outcome in a way like human takes a gander at a view call attention to discover the correct subtle elements of the picture in regards to color and different viewpoints by modification through their brains. So for an outcome which seems same as the human vision we should need to utilize a procedure which will give you comes about with legitimate colour proliferation as the information picture into the yield picture. So to beat such restriction of MSR another approach was exhibited as MSR with shading Restoration (MSRCR).

## 2.4 MSR WITH COLOR RESTORATION

In gray-scale image in the wake of utilizing MSR for enhancement on that picture, it can dark out the picture in few area which can be local or global. So to defeat this there was a requirement for computation that can manage colour to keep up the colour of a picture. Colour reclamation ought to keep up the colour consistency, as this is the fundamental inspiration driving Retinex. Colour steadiness isn't ideal for human vision likewise, yet colour consistency ought to be adequate in rebuilding strategy.

In MSRCR, based on three-colour channel in the first picture and their respective intensities, the weights are presented for them. In this approach, it utilizes MSR with a change that it performs multiplication of the MSR yield with the colour-restoration capacity to accomplish the objective. In MSRCR, it will take include image at that point compute colour reclamation work for the image. In the wake of registering shading reclamation work it needs to play out the MSR activity on the picture. At that point, at the yield of MSR, it will perform augmentation task with the figured shading reclamation work. We can state, the colour restoration factor is given by:

$$\alpha_i(m,n) = f\left[\frac{I_i(m,n)}{\sum_{n=1}^{N} I_n(m,n)}\right] \qquad (2.12)$$

In this $\alpha_i(m,n)$ denotes the coefficient of colour-restoration of the ith spectral plane, N represents the spectral plane count. $I_i(m,n)$ is the $i^{th}$ spectral plane of input image. The mapping function denoted by f(). We can have the equation for MSRCR by consolidating (13) for colour-restoration factor with the MSR in (10), we have:

$$R_i(m,n) = \alpha_i(m,n) R_{MSR}(m,n) \qquad (2.13)$$

By utilizing the condition (14), we can state that it will have the capacity to deliver the outcomes as an improved picture with better colour restoration. To control the level of colour it required something so in the colour-restoration factor they presented gain and offset.

$$\alpha_i(m,n) = G_f log\left[\frac{I_i(m,n)}{\sum_{n=1}^{N} I_n(m,n)} - O_f\right] \qquad (2.14)$$

The $G_f$ and $O_f$ are known as gain and offset respectively. The gain and offset handles the degree of colour-restoration in a manner which deals the colour-restoration of the output image.

It is a superior approach than the past methodologies of enhancement of image however the issue with this approach is that in this it needs to control the level of colour reclamation and the estimation of offset. In MSRCR the estimation of gain and offset can prompt the data misfortune so it needs an appropriate method to manage gain and the balance of the reclamation procedure with the offset that powerful outcomes can be assembled from MSRCR. MSRCR is a better choice for colour images.

## 2.5 IMPROVED RETINEX IMAGE ENHANCEMENT

In the Retinex based technique, it has 2 noteworthy advances which are "illumination estimation and illumination normalization". Presently here the key issue is to assemble the illumination of background with precision. The precision of illumination estimation can be expanded on the off chance that we have neighbouring casings with a comparative background. In this approach, we are more centred on illumination estimation with the goal that we can play out the Retinex on image precisely. In this with the assistance of gauss filter having distinctive parameters and scale it channels the picture. In the wake of separating it use to blend the outcomes with the assistance of minimum strategy. In this technique, it utilizes closeness and connection between the picture outlines in a video. It registers the optical background of the considerable number of casings in the wake of separating with the assistance of the maximum technique. To improve the picture it utilizes this optical foundation for the procedure of Retinex since this has a uniform illumination. We can reason from the Retinex hypothesis that the exactness in the picture illumination estimation prompts increment in nature of the upgraded yield picture. In this low pass channel is utilized to assess the illumination. As we realize that in contrast with reflectance enlightenment is the part with low frequency.

In this method first we will take either successive image outline from the video or you can take the indistinguishable or same image to gather the background information. At that point on every one of these images it applies sifting with the assistance of multi-scale gauss veil channel so illumination for every one of the pictures can be procured in a viable way. Subsequent to applying the veil on the pictures for a similar image utilize the minimum technique and blend the yields after the progression of filtering. At that point, you will get an exceptional outcome for the individual interesting information image. On every single one of a kind, yield utilize the maximum technique and frame a background image which is uniform by blending every one of them. In the wake of following the procedure, it will give the yield in such a shape, to the point that you will have the illumination of the picture. On the evaluated illumination and the input picture take the log of them and after that subtract the illumination from the picture. It will give the log of reflectance at that point assess example of yield and you will get the yield result which is a picture with the enhanced quality.

In this methodology there are 3 major phases:

With the help of multi-scale Gauss-mask gather the background with distinct values of scale and variances.

By using the maximum technique, mix the illumination of the related frames of the image i.e. maximum value for the given inputs will be in the yield.

Use Retinex method to produce the enhanced image from the input image and calculated illumination of the input.

After using this method, one might say that the augmentation in the exactness of the image background extraction can prompt the greatly improved quality of the image. In this approach, the fundamental spotlight is on the estimation of illumination of the image and its background. After the estimation of illumination of the picture, it just uses the fundamental strategy for Retinex to locate the upgraded picture in the yield in the wake of handling with the assistance of Retinex.

## 2.6 MSR IMPROVEMENT FOR NIGHT TIME

In this approach, it depends on the basic MSR with some improvisation. The fundamental MSR is exceptionally touchy concerning the noise which is created by the camera while catching the picture in zones with low light. The Fundamental MSR gives a few impacts which are not acceptable in such territories. In the MSR gain-offset is utilized so that preceding showcase treatment can be given. Utilization of gain-offset in MSR can prompt information misfortune on pictures of night time.

In this method, it utilizes the MSR technique with one change which is the supplanting of the log with a sigmoid function which is altered. The sigmoid function is utilized with the goal that the loss of information can be limited. Likewise to adjust MSR with the pictures taken in the night time. The pictures taken in evening are hard to enhance since in that it needs to manage the diverse states of light. MSR utilizes the gain-offset, to cut the pixel with either as well high or as well low in esteem. In the picture taken in night time because of gain-offset, it might bring about the loss of information and shaping of a few curios. The modified sigmoid function is utilized to evacuate the scope of qualities which don't have sureness from the beginning. In sigmoid function, there is no need of the gain-offset and for the extraordinary pixel, it packs them as opposed to cut-out such pixels so information misfortune will be less however much as could be expected. A Sigmoid function which is being utilized as a part of this is pleasantly limited so information cutting isn't required.

The altered sigmoid function can be written as:

$$Sig(x) = \frac{1}{1+ e^{-k.x+b} + c} \cdot \frac{1}{c+1} \quad (2.15)$$

Where k indicates the steepness. Bigger the estimation of k the more touchy the Retinex will rely upon k. the parameters b and c are there to guarantee that the sigmoid needs to experience the particular focuses and finishes at particular focuses.

After utilizing sigmoid the Equation of MSR can be composed as:

$$R_i(m,n) = \sum_{j=1}^{N} w_j \{ \text{Sig}[I_i(m,n)] - \text{Sig}[I_i(m,n) * M_j(m,n)] \} \quad (2.16)$$

In this, I indicates the input image. M indicates the surround function. R indicates the output.

In this technique, we simply need to take after the entire strides of the first Retinex with a minor change which is the utilization of a tweaked sigmoid function instead of the log function for the calculation of the estimations of illumination after convolution of the gauss channel on the input image and furthermore the input image for subtraction. In the last, it additionally needs to figure the weighted aggregate of consequences of the greater part of the scales to give the yield.

This approach can be utilized for images taken in evening time or typical time for getting the improved quality picture. Since it utilizes the modified sigmoid capacity so no pixel will experience the ill effects of information misfortune since it just the information as opposed to cut-out it.

## 2.7 RETINEX BASED PERCEPTUAL CONTRAST ENHANCEMENT USING LUMINATION ADAPTATION

In this method, it utilizes Retinex strategy to isolate an image into "illumination and reflectance layer" so that over the illumination layer the luminance adaptation can be connected to deal with it which leads to detail misfortune. It utilizes the gauss masks for sifting the image so the corona impacts can be expelled from it. In this approach, it uses to expel the illumination from the illumination layer amid MSR in a versatile way so information misfortune does not happen and subsequently points of interest can be safeguarded for the image. In the wake of expelling the illumination from the illumination layer it uses to play out the MSR for the outcomes with the contrast upgraded yield. Retinex is the approach which was acquainted with expel the impact of light and get the genuine nature for the image after image upgrade. The reflectance layer is taken as the inborn component of the image subsequent to expelling the illumination from the image based on Retinex hypothesis. Be that as it may, it can prompt having the commotion augment in the district with low light or dim area. Along these lines, to quit doing as such this strategy utilizes a control factor based on the luminance adaptation to evacuate the illumination relics adaptively. In this, it takes after the idea that the two luminance esteems converge into one if the distinction between 2 luminance esteems is not as much as basic since the distinction can't be seen by the human eye out of them two.

In this technique, it takes after the MSR as the Retinex strategy to play out the change in the nature of the image. In this approach, it performs versatile smoothing to get the illumination layer from the image with the goal that further task can be performed. Amid the procedure of versatile smoothing, it needs to utilize gauss channel with various scales to fulfill the criteria of multi-scale Retinex. After the extraction of illumination layer by utilizing adaptation we need to take after the rest of the piece of the Retinex procedure. So we need to remove the reflectance from the image subsequent to subtracting log of illumination from the log of the image. After the entire procedure of Retinex it will give the reflectance as the outcome on which it plays out the contrast upgrade with the assistance of luminance adaptation then this total procedure will give the enhanced nature of the info image as the outcome.

In this technique, it utilizes the approach presented by Jayant [13] on the relationship of JND display. Luminance adaptation is acquired by:

$$T_l(x,y) = \begin{cases} 17\left(1 - \sqrt{\frac{I(x,y)}{127}}\right) + 3 & \text{if } I(x,y) \leq 127 \\ \frac{3}{128}\left(I(x,y) - 127\right) + 3 & \text{otherwise} \end{cases} \tag{2.17}$$

Where Tl is a visibility threshold. I is background illumination of input.

In this strategy, it changes the RGB image to the HSV image. At that point it performs assignments onto the V band of the HSV show. It plays out the convolution by versatile gauss channel on the v band. At that point, it figures the edge of perceivability and the factor for debilitating at that point plays out the versatile gamma adjustment in the yield to give the improved outcomes.

Other than this various development are also done based on the Retinex methodology. “Image enhancement for outdoor long-range surveillance using IQ-learning multiscale Retinex” [14] is given by Haoting Liu et al. which focuses on the image grades effected because of the atmosphere. “Power-Constrained Contrast Enhancement Algorithm Using Multiscale Retinex” for OLED Display [15] is given by Yeon-Oh Nam. This approach make use of MSR so that satisfactory gain can be obtained and can be used for enhaced quality of image and power saving. Seonhee Park et al. presented “Low-Light Image Enhancement Using Variational Optimization-based Retinex Model” in [16]. It utilizes a modified retinex method to improve the dim-light images with lesser noises in dark region.“Variational Bayesian method for Retinex” [17] is given by Liqian Wang et al. it uses the Gibbs distribution and gamma distribution. Another approach is presented by Doo hyn et al. [18] in which they discussed about “the new information model”.

From above discussion, we can see the significant distinction between the different methodologies for image quality change in light of Retinex. SSR can just give either total rendition or compaction of dynamic range. MSR can give both total rendition & dynamic range compression in an image after improvement. It is because of the utilization of numerous scale gauss function whose size reason the aggregate version and the pressure of dynamic range. MSR can furnish the outcome with the two characteristics yet it isn't equipped for shaping the colour of yield as like the information image, which is essential thought of Retinex. So to beat this another approach was utilized to with the functionality of shading rebuilding and known as MSRCR. In this approach, it utilizes reclamation function to re-establish the shade of a yield image which is like the info image. IRIE was centred on figuring the illumination of an image with precision. It depends on the essential hypothesis of Retinex by which it subtracts the illumination from the image to get the improved yield. In MSRINTE it utilizes redid sigmoid function to enhance the nature of an image taken in evening too in light of the fact that in the improvement of evening image unique MSR flops because of the utilization of the log. The log function is utilized to cut the powers which are as well low or as well high yet sigmoid function use to pack them instead of section them. RBCELA is the technique which is utilized to enhance the nature of the image by luminance adaptation. In this it utilizes the versatile gauss channel to figure the illumination layer then on the aftereffect of MSR it plays out the gamma rectification for the contrast upgrade. All these Retinex based methodologies are not quite the same as each other and they all have their exceptional leeway and strategy for image upgrade they can be picked based on the application.

## 2.8 GUIDED IMAGE FILTERING

In guided image filtering [19], they proposed an edge-preserving filter. The guided filter is formulated using mean box filter which made its calculation easier. Since in guided filter it needs to calculate the variance and standard deviation which needs the mean i.e., mean filter helped in finding out the variance and standard deviation. In guided image filtering it performs smoothing over images on the basis that it maps the smooth version of the image from the value of a & b for respective pixels and uses them on the respective pixel of the guidance image. In guided image filtering guidance image and input image both can be same. This smoothing method is developed in such a way that when any edge occurs it remains as it is and when any plane region occurs filter smooth it using the value. In guided image filter a & b are distributed in the way that when region with extreme variation comes the value of a and b becomes in a form that the image remains same. On the other hand when any region occurs with low variation then a and b given a value which is used to smooth the region. For understanding the algorithm of the guided image filtering the reference paper can be referred. The general equation of the guided filter is:

$$O_i = a_j I_i + b_j \qquad (2.18)$$

Where O is the output image i.e., smooth image. I denotes the guidance image. a and b are some linear coefficients.

The equation for a and b for single image are:

$$a_j = \frac{\sigma_j^2}{\sigma_j^2 + \epsilon} \qquad (2.19)$$

$$b_j = (1 - a_j)\mu_j \qquad (2.20)$$

Where $\mu_j$ is mean and $\mu_j$ is variance. $\epsilon$ Denotes the regularisation parameter. By using these three equations we get the smooth version of image.

# CHAPTER 3 PROPOSED METHOD

In this proposed method we have worked with both Retinex and guided image filtering. After using these both methodologies we have proposed a new hybrid approach for image enhancement.

In traditional Retinex we have seen that Gauss filter is used for smoothing the original image which acts as the illumination of the image. But in taking Gauss smooth as the illumination, the change in intensities is regular which not a case in real world. If we will take Gauss smooth as the illumination then it will be like treating the image as the instance of a 2-Dimensional scene but in actual image is an instance of the 3-Dimensional scene. In real world, illumination of two objects can vary drastically. In an image, two objects seen near to each other can be far away from each other in the third dimension or having the illumination condition very different.

In this approach, we have taken guided filtering smooth of the image as the illumination in which it perform smoothing operation over the image on the basis of box filter. In guided image filtering it smooths the region where edges are not present in the image if an edge is there in the image then it leaves the region and continues on the other portion.

We have followed few steps in implementing our methodology which are:

1. Input
2. Illumination of image
3. Multiple Scales
4. log
5. Reflectance
6. Weighted sum of reflectance
7. Exponent

Now we will discuss these steps:

1. **Input**

   In the proposed method we have taken an image as the input on which our method can perform its operation and generate the enhanced output. In this method we can take either RGB (i.e. color image) or gray scale image. For color images we have done our work on all channels which are r-channel, g-channel and b-channel. Another approach can be used to work with the color images in which we can take RGB image then convert it into the

HSV image after that V-channel should be used for the enhancement and then it will be converted to the RGB image again. We have used the RGB image and RGB channel for color image.

2. **Illumination of the image**

In Retinex it needs illumination to generate the enhanced output of the image. it is very difficult to acquire the illumination of an image without any information about the condition of illuminance and/or the source of illumination. So in MSR, the smooth version of the input image is taken as the illumination. In previous methods of Retinex for image enhancement the Gaussian smooth of the image is taken as the illumination which have satisfactory results. In the proposed method we have used guided filtering method for smoothing (i.e. illumination). The guided image filtering is used for enhancement with better enhancement near the edges. The smoothing by guided image filter gives the smooth image with edge preservation i.e. edges are not blur in this technique. In smoothing by guided image filtering it perform smoothing on the basis of box and it gives the better result near the edges, which helps us to achieve the better result in our proposed approach.

3. **Multiple Scales**

We have taken multiple size for the box in smoothing to achieve the results for multiple scale which replaces the multiple values of sigma in Gaussian smooth. In the proposed approach it will take log of input image and all the smooth versions by separate sizes of box. Multiple scales are required to make our result having both color constancy and proper compression of dynamic range. Multiple sizes of boxes will act as same as the multiple scale in the traditional Retinex algorithm. Guided filtering approach is also a smoothing method which smooth the image but also preserves the edges of the image in the smooth image.

4. **Log**

By taking the log of both images and illumination it is easy for the calculation. If we will not take log of image and illumination then we have to perform a division operation. But by using the properties of log we are using simple subtraction operation instead of division operation. In this approach we can say that log is used to make calculation easier and faster since the complexity of subtraction is less than the complexity of division.

5. **Reflectance**

In this step of our proposed method it subtracts the log of smooth version of input image for low box size from log of input image. After that repeat this for other smooth version for different box sizes. If we will not use log then we have to divide original image with the smooth version of the image. But divide operation can lead us to complex and time consuming computations which is not desirable.

6. **Weighted sum of reflectance**

Now after previous step we have multiple reflectance for multiple size of box. Take the weight suitable for the specific reflectance and then multiply the weight with the all reflectance and then add all the reflectance together. After adding all the reflectance together finally we will have the log of original reflectance.

7. **Exponent**

In step 4, we have taken log of the image and the illumination to make our computation easier and faster. So, till now our image is in log form so to make it normal take the output of previous step and apply exponent operation on it. Performing exponent operation will give the original reflectance as the output. This reflectance is the final output which we want. In gray scale image it is our final result which we wanted. While dealing with color scale image we have to perform all the steps given above for all channels i.e. R-Channel, G-Channel and B-Channel. After performing these steps on all channels merge all channels together to get the final enhanced image as the result.

## 3.1 ALGORITHM

Input: Original Image

Output: Enhanced Image

Step 1: Divide the image into R, G and B channel

Step 2: Compute the distinct box sizes for filtering process and take suitable regularisation parameter.

Maximum box size should be equal or less than the height or width of the image if image is not in square form then take whichever is less. Other box sizes can vary from 3 to the maximum box size to get good results.

Step 3: Perform smoothing with the help of guided filtering with the help of different sizes of boxes.

Step 4: find the log transform of the image.

Step 5: subtract the log of illumination with log of image to find out the reflectance.

Step 6: calculate the weighted sum of the reflectance you get from operation after different gauss filters. Weight should be balanced among all the scales so that all scale can contribute to the result equally.

Step 7: take the exponent of result from step 6.

Step 11: combine the all 3 Component of image to form a color image.

### 3.2 FLOWCHART

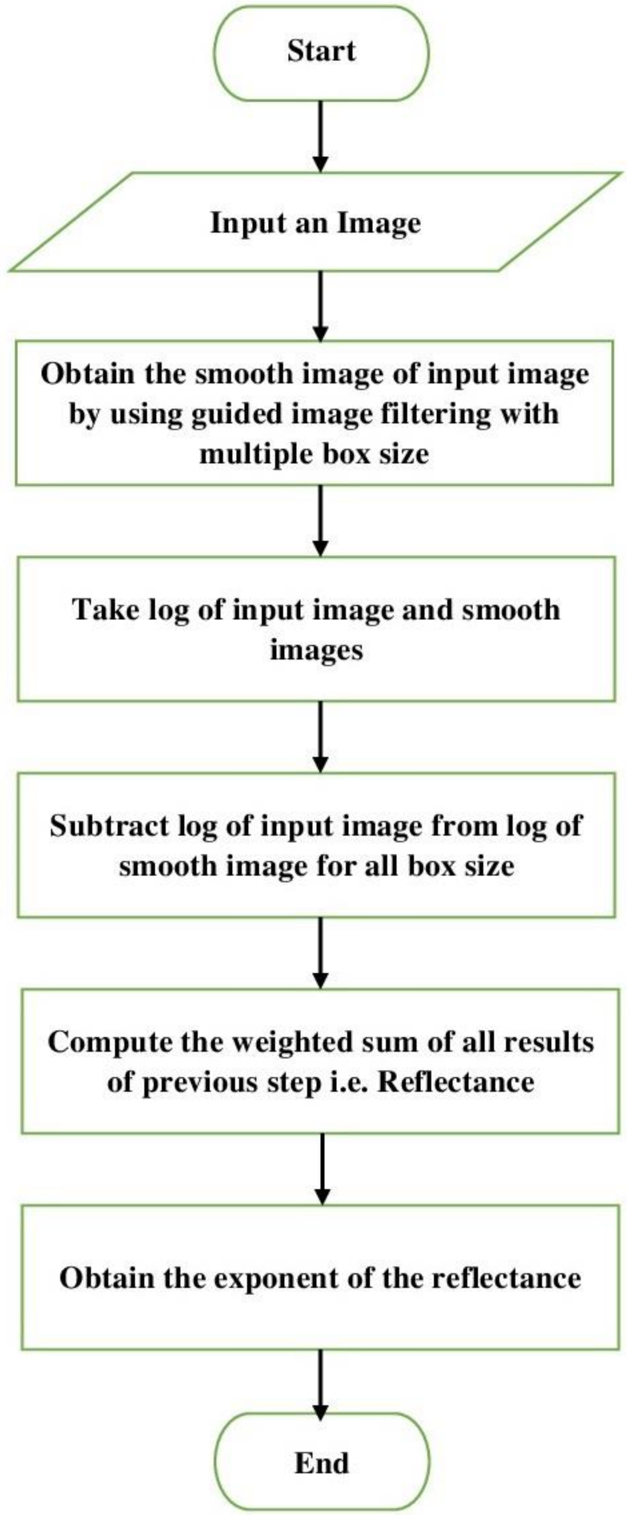



Fig 3.1: Flowchart of proposed method

# CHAPTER 4 RESULTS

The proposed approach is implemented in matlab and after implementation it was tested on images from data set from Berkeley image database [20] and University of South California-Signal and Image Processing Institute image database [21]. The Berkeley image database have 300 images which contains gray scale and color images. Basically it is used for the purpose of the image segmentation but we used its base images to test our method on those images. USC-SIPI is the collection of digital image for image processing and other tasks.

The proposed method is also compared with various contrast enhancement algorithms. The algorithms which are used for comparision are BBHE [22], BPDHE [23], BPFDHE [24], CVC [25], Guided image filering, LDR2D [26], Retinex, SECE [27], SECEDCT [27], SFHE, TDHE [28] and WFHE [29]. The algorithm is tested for the color and gray scale images. The analysis & comparision is done by quantitative and visual measurements of the output image.

## 4.1 QUANTITATIVE ASSESSMENT

The Quantitative assessment is required due to few limitation with human visual system. Contrast of the image cannot be quantitatively assessed very easily. Sometimes it is possible that human can have on subject oriented perception. There are various contrast assessment measure available but no measure is present which is universally accepted. We are using 2 measures for the contrast measurement of the images which are discrete entropy [30] and PSNR [31].

A statistical measure of randomness is known as the discrete entropy. The measure which is used for the image present in the image is known as entropy. The greater the value the more information is present in the image. Least value of entropy means the low information in the image. Sometimes the value of entropy is effected by the noise i.e., higher noise enhancement leads to the high value of the entropy. DE is the sum of product of the probability of result multiplied by the log of the inverse of the probability of results.

DE mathematically can be represented as:

$$H(x) = -\sum_{j=1}^{k} p(j) log_2 p(j)$$

Where p(j) denotes the probability of $i^{th}$ gray scale. K denotes the number of intensity levels in the image.

**Table 4.1 Discrete Entropy of sample images of distinct methods**

| | Img1 | environment | plane | cactus | tower | monument | trolley |
|---|---|---|---|---|---|---|---|
| **BBHE** | 0.471 | 0.456 | 0.487 | 0.470 | 0.461 | 0.487 | 0.461 |
| **WFHE** | 0.484 | 0.429 | 0.495 | 0.483 | 0.479 | 0.497 | 0.476 |
| **Proposed** | 0.530 | 0.518 | 0.528 | 0.625 | 0.484 | 0.802 | 0.681 |
| **Retinex** | 0.556 | 0.552 | 0.611 | 0.615 | 0.523 | 0.803 | 0.719 |
| **Guided filter** | 0.668 | 0.625 | 0.602 | 0.723 | 0.654 | 0.905 | 0.725 |
| **CVC** | 0.498 | 0.452 | 0.499 | 0.484 | 0.490 | 0.490 | 0.470 |
| **LDR2D** | 0.498 | 0.482 | 0.499 | 0.497 | 0.494 | 0.496 | 0.492 |
| **SECE** | 0.499 | 0.477 | 0.499 | 0.457 | 0.487 | 0.483 | 0.460 |
| **SECEDCT** | 0.727 | 0.643 | 0.659 | 0.635 | 0.605 | 0.755 | 0.627 |
| **TDHE** | 0.489 | 0.443 | 0.495 | 0.488 | 0.484 | 0.497 | 0.480 |
| **BPDHE** | 0.463 | 0.429 | 0.490 | 0.454 | 0.428 | 0.457 | 0.431 |
| **BPFDHE** | 0.298 | 0.315 | 0.459 | 0.353 | 0.295 | 0.295 | 0.453 |
| **SFHE** | 0.704 | 0.591 | 0.544 | 0.621 | 0.598 | 0.673 | 0.729 |

Peak signal-to-noise ratio (PSNR) is the ratio between the highest present intensity of the image & the intensity of corrupting noise that affects the fidelity of its representation. PSNR actually talks for the strength of correct information with respect to the noise or corrupt data. Since it is possible that DE can be very high due to the high amount of noise so to know that what the reason behind high discrete entropy is. If the PSNR value is higher then high value of the discrete entropy is better otherwise it may or may not be good quality. If PSNR of the enhanced output is low and Discrete entropy is high then we have to go with the visual assessment discussed below.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

$$PSNR = 20.log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

$$PSNR = 20.log_{10}(MAX_I) - 10.log_{10}(MSE)$$

In PSNR, the higher the value for an image it will give more effective the technique.

**Table 4.2 PSNR of sample images from distinct images**

| | environment | plane | cactus | tower | monument | trolley |
|---|---|---|---|---|---|---|
| **BBHE** | 37.258 | 39.069 | 38.432 | 39.308 | 38.088 | 38.093 |
| **WFHE** | 39.099 | 39.355 | 38.739 | 39.358 | 37.688 | 38.443 |
| **Proposed** | 46.544 | 66.617 | 41.838 | 46.137 | 39.099 | 41.601 |
| **Retinex** | 37.134 | 57.989 | 37.160 | 38.317 | 38.269 | 38.435 |
| **Guided filtering** | 38.838 | 39.877 | 38.852 | 38.850 | 38.347 | 38.318 |
| **CVC** | 42.411 | 54.226 | 40.144 | 41.594 | 40.132 | 39.740 |
| **LDR2D** | 38.521 | 54.871 | 39.009 | 39.485 | 38.133 | 38.919 |
| **SECE** | 39.236 | 61.353 | 39.342 | 40.578 | 38.514 | 39.787 |
| **SECEDCT** | 38.542 | 44.756 | 38.765 | 39.185 | 38.377 | 38.946 |
| **TDHE** | 38.964 | 39.414 | 38.806 | 39.514 | 37.836 | 38.494 |
| **BPDHE** | 39.978 | 38.291 | 40.488 | 38.278 | 41.000 | 38.285 |
| **BPFDHE** | 38.413 | 38.262 | 39.006 | 38.439 | 38.617 | 37.729 |
| **SFHE** | 38.522 | 47.747 | 38.304 | 38.951 | 37.512 | 39.018 |

## 4.2 VISUAL ASSESSMENT

The measurement of contrast improvement can’t be determined only by Quantitative assessment. Most of the times, these method fails in distinguishing between the better contrast & over-enhancement or noise-enhancement. That’s the reason a visual assessment is required for measuring the contrast enhancement. Visual assessment is also needed to find out that no artefacts occurred in the result due to application of the algorithm. The output from the algorithm is given from fig 2-8 for few sample images. The improved contrast images utilising distinct methods are compared in this section on the basis of visual representation.

In fig 4.1 the sample image 1 and its enhanced versions by multiple algorithms are shown. In BBHE and BPDHE some region of the image is enhanced normally but in the other portion it decreased the quality instead of increasing it. CVC and LDR2D are giving similar results but the enhancement is not good. In guided filtering enhancement it is giving more details about the image but contrast enhancement is not good in this. SECE and SECEDCT are giving better results than other algorithms except Retinex and proposed method. In Retinex it enhanced the image in a very good manner but while comparing its contrast with the proposed method we can see that proposed method is giving better results than Retinex.

In fig 4.2 the environment image and its enhanced output from various algorithms are shown. In this BBHE is giving enhanced results but failing in dark regions. Where in BPDHE and BPFDHE the details near grass is lost. In CVC the enhancement is done where the brightness of the image is high. In guided it enhances the details of the image. SECE and SECEDCT are giving similar results with enhancement all over. In Retinex the colour of sky changed which should not be the case but in our proposed method the image enhancement is done better where colour of sky is also in the better position than the retinex.

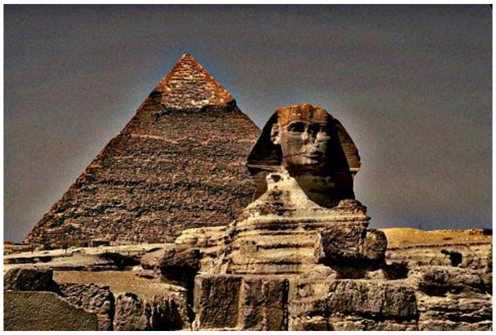
In fig 4.3 the image of a plane and its enhanced versions from distinct algorithms are shown. In this BBHE, BPDHE, BPFDHE, CVC, TDHE, WFHE & guided filtering failed in producing the enhanced results. LDR2D is giving enhanced results but in some portion of the image it is not maintaining colour constancy. In SECE and SECEDCT the results are better but it failed to produce better results in the dark region. Retinex is giving enhanced results but the contrast of the proposed method is better then the results of Retinex.

BBHE

BPDHE

BPFDHE

Cvc

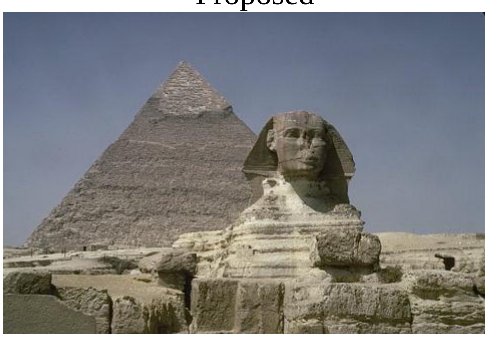


Guided

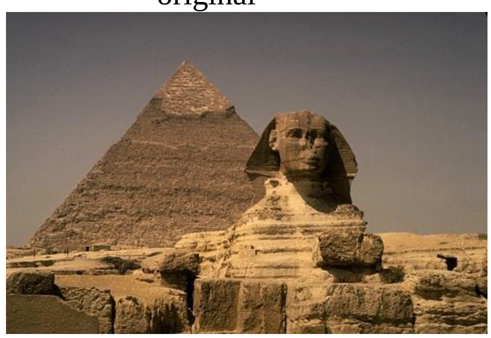
LDR2D

Proposed

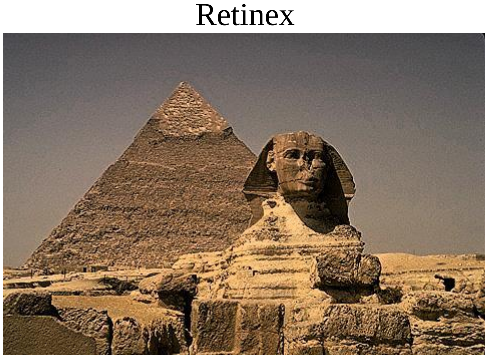
original



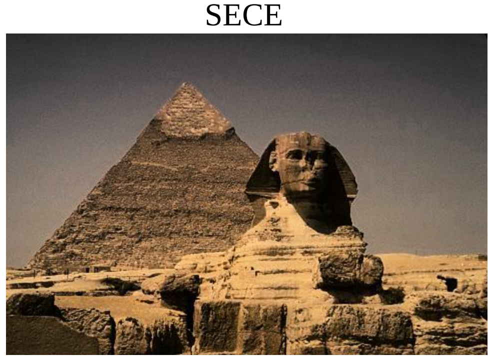
Retinex



SECE



SECEDCT



SFHE


TDHE


WFHE

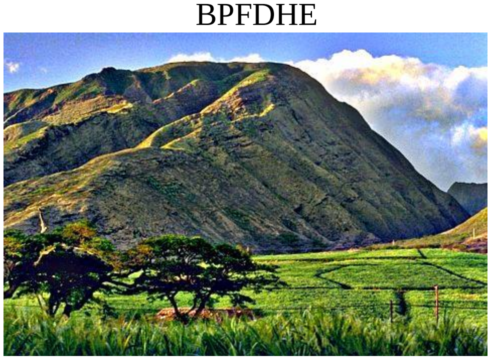
Fig 4.1: ‘Sphinx’ image & contrast enhancement using distinct algorithms


BBHE


BPDHE


BPFDHE

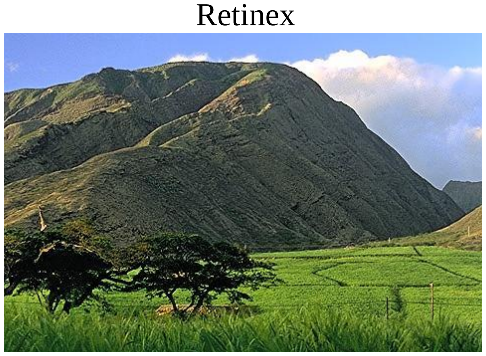

Cvc


Guided

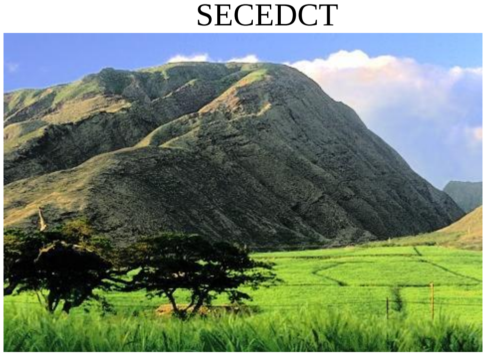

LDR2D


Proposed original


Retinex SECE




SECEDCT SFHE




TDHE WFHE

Fig 4.2: ‘environment’ image & contrast enhancement using distinct algorithms

BBHE

BPDHE

BPFDHE

Cvc

Guided

LDR2D

Proposed

original

Retinex

SECE

SECEDCT

SFHE

TDHE

WFHE

Fig 4.3: ‘plane’ image & contrast enhancement using distinct algorithms

BBHE

BPDHE

BPFDHE

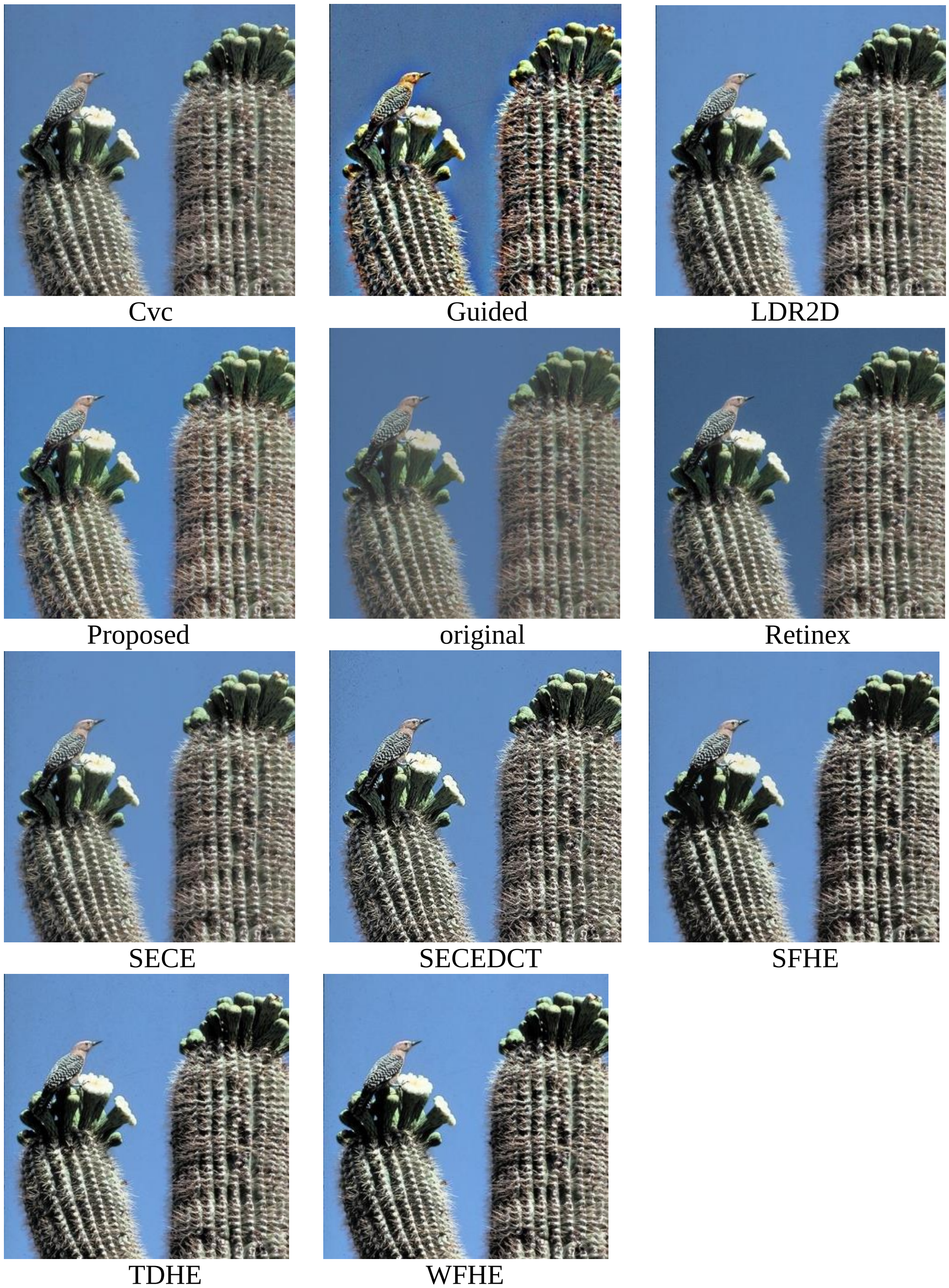
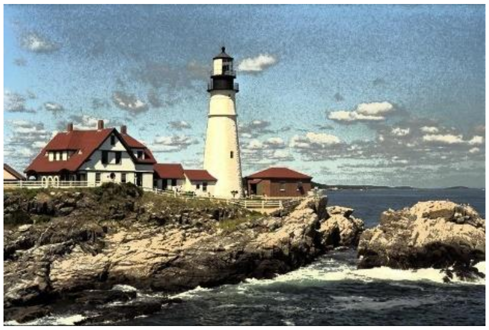



Fig 4.4: ‘cactus’ image & contrast enhancement using distinct algorithms

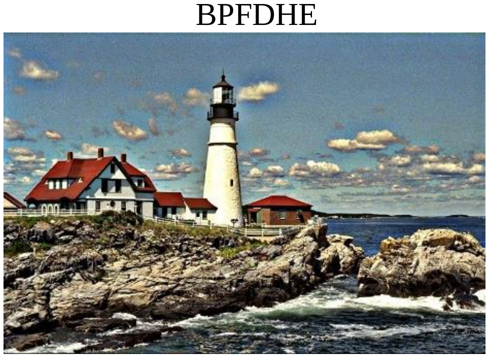


BBHE

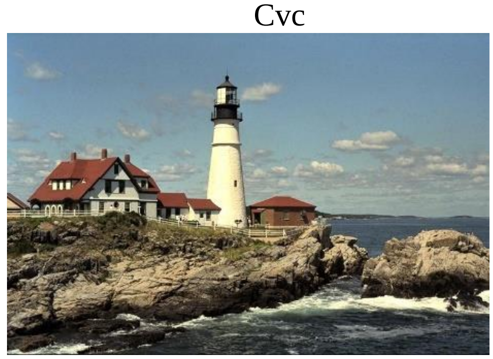
BPDHE

BPFDHE

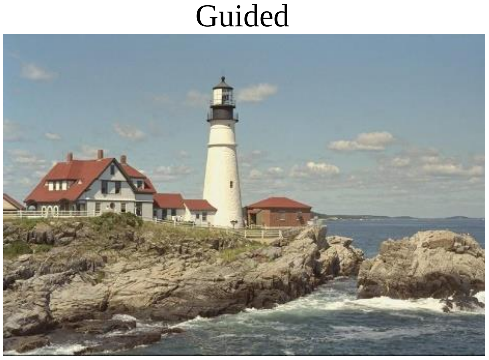
Cvc



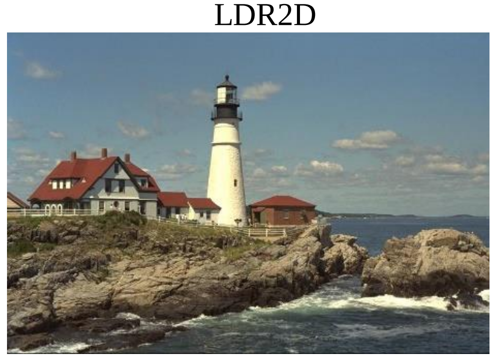
Guided



LDR2D



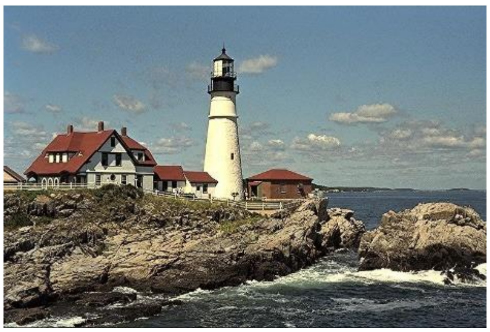
Proposed



original

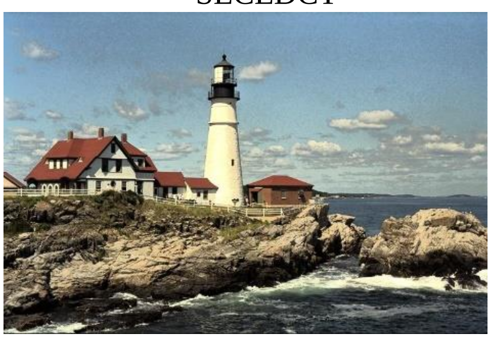
Retinex

SECE

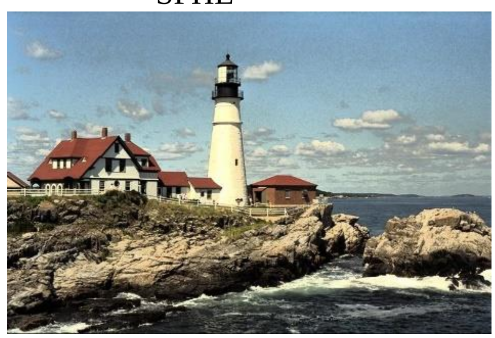


SECEDCT

SFHE



TDHE



WFHE

Fig 4.5: ‘tower’ image & contrast enhancement using distinct algorithms

BBHE

BPDHE

BPFDHE

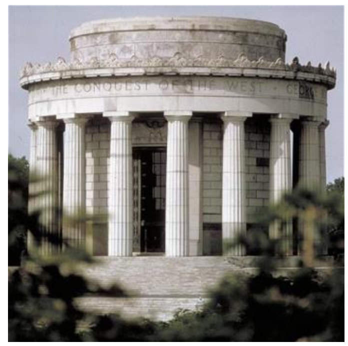
Cvc

Guided

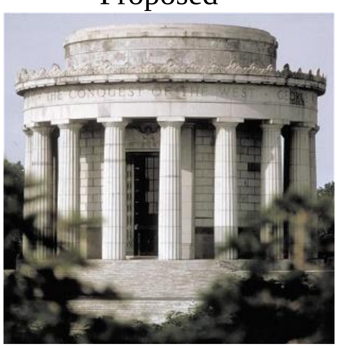
LDR2D

Proposed

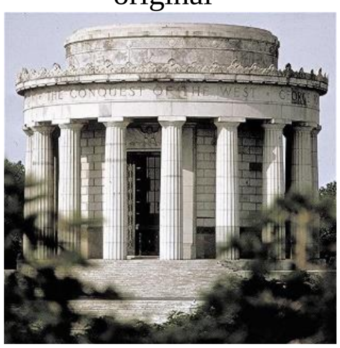
original



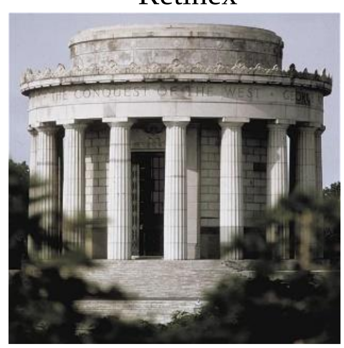
Retinex



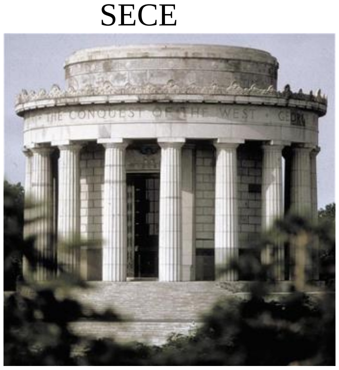
SECE



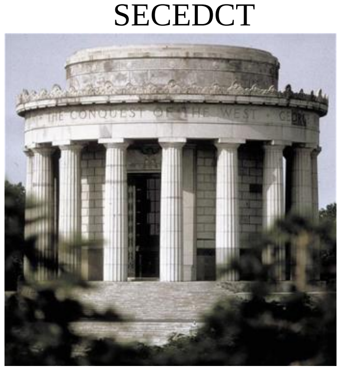
SECEDCT



SFHE

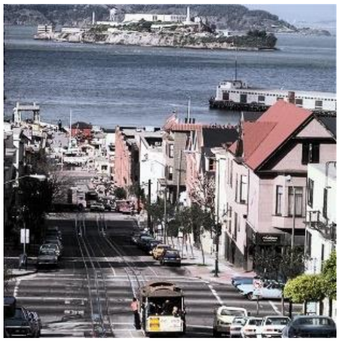
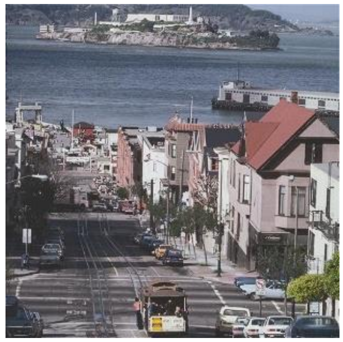


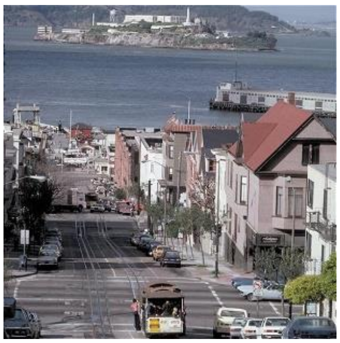
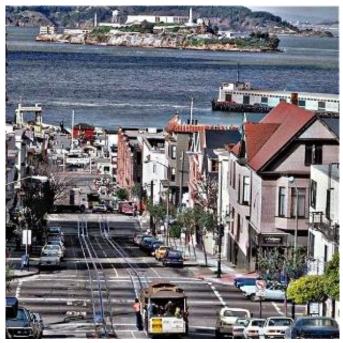
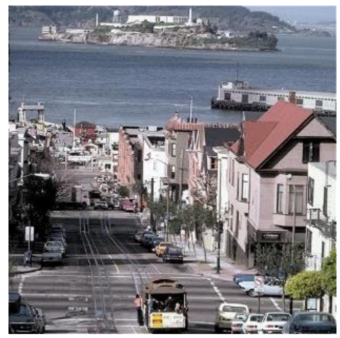
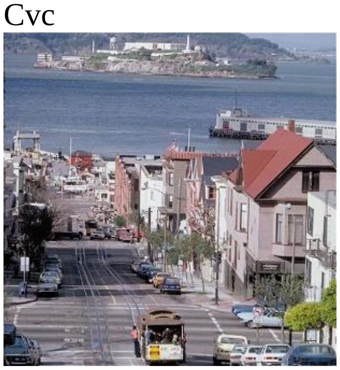
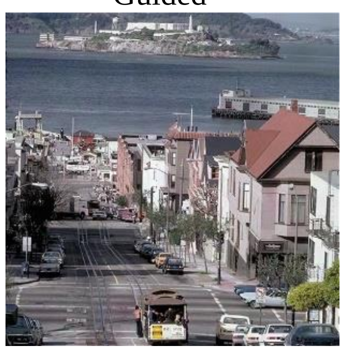
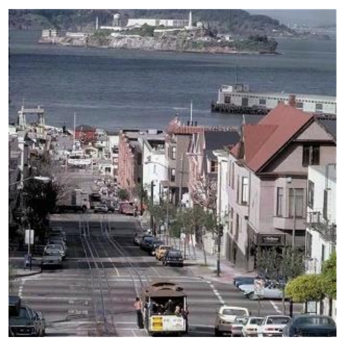
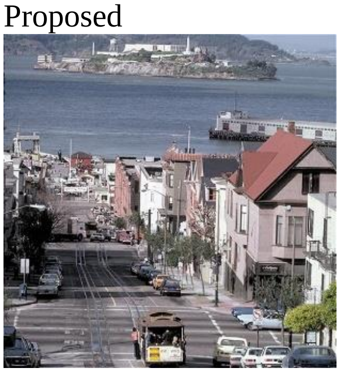
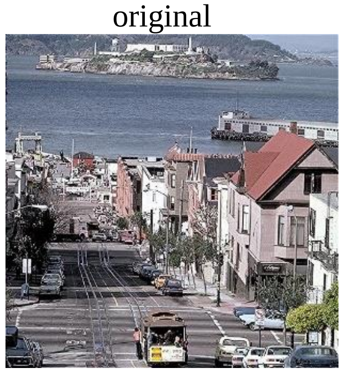
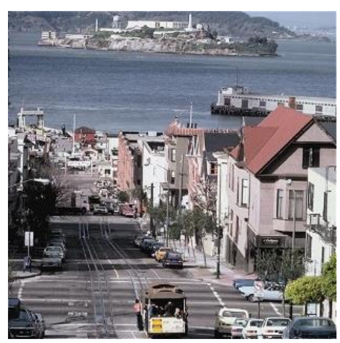
TDHE

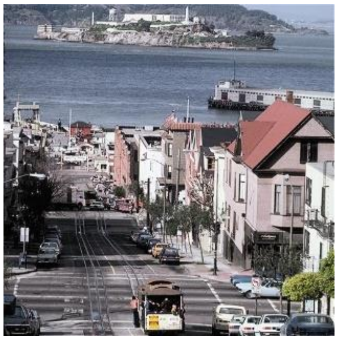


WFHE

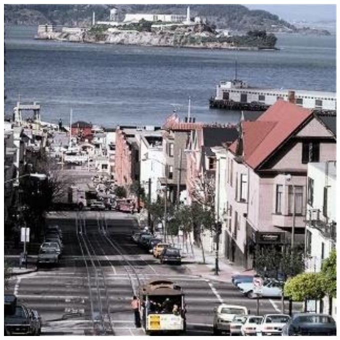
Fig 4.6: ‘monument’ image & contrast enhancement using distinct algorithms


BBHE

BPDHE

BPFDHE

Cvc

Guided

LDR2D

Proposed

original

Retinex

SECE

SECEDCT

SFHE



TDHE



WFHE

Fig 4.7: ‘trolley’ image & contrast enhancement using distinct algorithms

In fig 4.4, the image of cactus and its enhanced output are shown. In this BBHE, BPDHE & BPFDHE are not showing got visualisation, there are some artefacts came in the image which are not desirable. Where all the other algorithms are producing acceptable results where there in a change in contrast of all outputs. But by looking at all the images closely you can deduce that the output of the proposed method is having better colour constancy and total rendition.

In fig 4.5, the image of tower and its enhanced results from the various methods are given. In this image if you will see the output of proposed method than you can see that it is giving better results for complete image. The dark regions are also better enhanced then in any other technique. Also the colour quality of the image is better in terms of contrast. Where in the other algorithms few are not been able to give the acceptable results and few failed in the region where image is dark.

In fig 4.6, the image of monument and its enhanced output from various methods are shown. BBHE is giving acceptable results where BPDHE & BPFDHE are giving results which are not of good quality. Other algorithm are giving better results for normal region but failing in dark region. Retinex is giving good results for complete image but the proposed method is giving results better than Retinex in the dark region.

In fig 4.7, the image of trolley and its enhanced output from distinct images are shown. The result of BPDHE is of bad quality than the original image itself. While other algorithms are producing better results. In some of the results the dark region is not giving better details. But in output of Retinex and proposed method the dark region is giving better information comparing with the other methods.

# CHAPTER 5 CONCLUSION

In this proposed method, a hybrid approach for image enhancement using Retinex and guided filter is proposed. In the proposed method, gave a method where multiscale Retinex is utilized with a change. In this guided filter is used to find out the illumination. The presented algorithm has advantages:

1. The size box is defined for all the scales since in Retinex the value of sigma is not properly defined which can lead to low quality enhancement.
2. The method is giving better results for all regions of the image i.e., both dark and light region.
3. The utilization of the guided filter instead of lead us to the better overall image enhancement.

The proposed method is compared with multiple other methods for the contrast enhancement. The proposed method was tested by using large number of images from standard databases for image enhancement to check its performance. The assessment of results are done in quantitative manner and in visual manner both. After looking at all the results and their assessment over sample images we have concluded that the performance of the proposed method is better than other methods.

# CHAPTER 6 REFERENCES


[1] R. C. Gonzalez and R. E. Woods, Digital Image Processing, New Delhi: Pearson, 2009.

[2] E. H. Land, "Recent advances in retinex theory and some implications for cortical computations," *Proc. Natl. Acad. Sci. U.S.A.,* vol. 80, pp. 5163-5169, 1983.

[3] E. H. Land, "Recent advances in retinex theory," *Vision Research,* vol. 26, no. 1, pp. 7-21, 1986.

[4] J. D. J, R. Z and W. G. A., "Properties and performance of a center/ surround Retinex," *IEEE Transactions on Image Processing,* vol. 6, no. 3, pp. 451 - 462, 1997.

[5] N. L. J. M and Shiny.C, "Color Image Enhancement Using Retinex Algorithm," *IOSR Journal of Computer Engineering,* pp. 30-35, 2014.

[6] L. Tang, S. Chen, W. Liu and Y. Li, "Improved Retinex Image Enhancement Algorithm," *Procedia Environmental Sciences,* vol. 11, pp. 208-212, 2011.

[7] H. Lin and Z. Shi, "Multi-scale retinex improvement for nighttime image enhancement," *optik,* vol. 125, pp. 7143-7148, 2014.

[8] K. Xu and C. Jung, "Retinex-based perceptual contrast enhancement in images using lumination adaptation," *Acoustics, Speech and Signal Processing (ICASSP),* pp. 1363-1367, 2017.

[9] L. E. H and M. J, "Lightness and retinex theory," *Journal of Op tical Society of America,* vol. 61, no. 1, pp. 2032-2040, 1971.

[10] Z.-u. Rahman, D. Jobson and G.A. Woodell, "Multi-scale retinex for color image enhancement," *IEEE International Conference on ImageProcessing,* vol. 3, p. 1003–1006, 1996.

[11] Z.-u. Rahman, D. J. Jobson and G. A. Woodell, "A multiscale retinex for bridging the gap between color images and the human observation of scenes.," *IEEE Transactions on Image Processing,* vol. 6, no. 7, pp. 965-976, 1997.

[12] Z.-u. Rahman, D. J. Jobson and G. A. Woodell, "Retinex processing for automatic image enhancement," *Journal of Electronic Imaging,* vol. 13, no. 1, p. 100–110, 2004.

[13] N. Jayant, "Signal compression: Technology targets and research directions," *IEEE Journal on Selected Areas in Communications,* vol. 10, no. 5, pp. 796-818, 1992.

[14] H. Liu, H. Lu and Y. Zhang, "Image enhancement for outdoor long-range surveillance using IQ-learning multiscale retinex," *IET Image Processing,* vol. 11, no. 9, pp. 786-795, 2017.

[15] Y.-O. Nam, D.-Y. Choi and B. C. Song, "Power-Constrained Contrast Enhancement Algorithm Using Multiscale Retinex for OLED Display," *IEEE TRANSACTIONS ON IMAGE PROCESSING,* vol. 23, no. 8,

pp. 3308-3320, 2014.

[16] S. Park, S. Yu, B. Moon, S. Ko and J. Paik, "Low-Light Image Enhancement Using Variational Optimization-based Retinex Model," *IEEE Transactions on Consumer Electronics,* vol. 63, no. 2, pp. 178-184, 2017.

[17] L. Wang, L. Xiao, H. Liu and Z. Wei, "Variational Bayesian Method for Retinex," *IEEE TRANSACTIONS ON IMAGE PROCESSING,* vol. 23, no. 8, pp. 3381-3397, 2014.

[18] D. H. Choi, I. H. Jang, M. H. Kim and N. C. Kim, "color image enhancement using single scale retinex based n an improved image formation model," in *European Signal Processing Conference*, Lausanne, Switzerland, 2008.

[19] K. He, J. Sun and X. Tang, "Guided Image Filtering," *IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE,* vol. 35, no. 6, pp. 1397-1409, 2013.

[20] C. F. a. D. M. Pablo Arbelaez, "berkeley segmentation dataset and benchmark," [Online]. [Accessed 2018].

[21] USC, "USC-SIPI Database," USC-SIPI Database, [Online]. Available: http://sipi.usc.edu/database/. [Accessed 2018].

[22] Y.-T. Kim, "Contrast Enhancement using Brightness Preserving Bi- Histogram equalization," *IEEE trans. on consumer Electronics,* vol. 43, 1998.

[23] H. Ibrahim and N. S. P. Kong, "Brightness Preserving Dynamic Histogram Equalization for Image Contrast Enhancement," *IEEE Transactions on Consumer Electronics,* vol. 53, no. 4, pp. 1752 - 1758, 2007.

[24] A. Sarrafzadeh, F. Rezazadeh and J. Shanbehzadeh, "Brightness Preserving Fuzzy Dynamic Histogram Equalization," in *Proceedings of the International MultiConference of Engineers and Computer Scientists*, Hong Kong, 2013.

[25] T. Celik and T. Tjahjadi, "Contextual and variational contrast enhancement," *IEEE Transactions on Image Processing,* vol. 20, no. 12, pp. 3431 - 3441, 2011.

[26] C. Lee and C.-S. Kim, "Contrast enahancement based on layered difference representation of 2D histograms," *IEEE Transaction Image processing,* vol. 22, no. 12, pp. 5372-5384, 2013.

[27] T. Celik, "Spatial Entropy-Based Global and Local Image Contrast Enhancement," *IEEE Transactions on Image Processing,* vol. 23, no. 12, pp. 5298 - 5308, 2014.

[28] T. Celik, "Two-dimensional histogram equalization and contrast enhancement," *Pattern Recognition,* vol. 45, p. 3810–3824 , 2014.

[29] A. S. Parihar, O. P. Verma and C. Khanna, "Fuzzy-contextual contrast enhancement," *IEEE Transactions on Image Processing,* vol. 26, no. 4, pp. 1810-1819, 2017.

[30] Z. YE, H. MOHAMADIAN, S.-S. PANG and S. IYENGAR, "Image Contrast Enhancement and Quantitative Measuring of Information Flow," in *6th WSEAS International Conference on Information Security and Privacy*, Tenerife, Spain, 2007.

[31] "wikipedia," wikipedia, [Online]. Available: https://en.wikipedia.org/wiki/Peak_signal-to-noise_ratio. [Accessed 2018].

[32] T. Celik, "Spatial Entropy-Based Global and Local Image Contrast Enhancement," *IEEE Transactions on Image Processing,* vol. 23, no. 12, pp. 5298 - 5308, 2014.

# CHAPTER 7 LIST OF PUBLICATION

[1] Anil Singh Parihar, Kavinder Singh,” A study on Retinex Based method for Image Enhancement”, in International Conference on Inventive Systems and Control , Coimbatore INDIA, 2018.