A RETINEX BASED LOW LIGHT IMAGE ENHANCEMENT METHOD FOR NATURALNESS PRESERVATION

A DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE
OF
MASTER OF TECHNOLOGY

IN

COMPUTER SCIENCE & ENGINEERING

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CANDIDATE'S DECLARATION

I, Anhad Pandit, Roll No. 2K20/CSE/28 student of M. Tech (Computer Science and Engineering), hereby declare that the project dissertation titled **"**A Retinex Based Low Light Image Enhancement Method for Naturalness Preservation.**"** which is submitted by me to the Department of Computer Science & Engineering, Delhi Technological University, Delhi 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 and Degree, Diploma Associateship, Fellowship or other similar title orrecognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled **"A Retinex Based Low Light Image Enhancement Method for Naturalness Preservation"** which is submitted by Anhad Pandit, 2K20/CSE/28, Department of Computer Science & Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge, this workhas not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date: 31 May 2022

Dr. Anil Singh Parihar

Professor

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ACKNOWLEDGMENT

The successful completion of this research project required the assistance & input of a lot of people and the organization. I am grateful to all the people who helped me in creating the final result of this research project report. I would like to give my sincere thankfulness towards **Dr. Anil Singh Parihar** and **Mr. Kavinder Singh** for providing me with the opportunity to take up this project under their guidance their effort towards getting me to the end this research. Without their sincere guidance and knowledge, this research would not at all have been possible. Their never-ending presence and motivation made me believe that the process of learning is much more important than the final outcome. I am also extremely thankful to the panel faculties during all the progress reports and intermediate evaluations for their directions, constant presence and for encouraging me to complete this research. They guided me through the whole process with new ideas, provided information necessary and pushed me to complete this research.

I also thank all my fellow students for helping me in times when I needed it the most. It is because of their constant support that made me fulfil my academic responsibilities. Last, but not at all the least I would like to thank my family for being there for me at times where no one is actually around. They have always tried to make it easier for me.

There have also been a numerous other people whom I cannot mention that have been a part of my life, directly or indirectly. I would like to thank them as well.

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ABSTRACT

Images captured in a poor environment is a big problem to deal with. The environment contains haze, fog, smog, rain or even the lighting conditions could be poor. One of these issues are images captured in low light as they are not fit for the viewability of human beings as well as pose an issue for various computer vision applications, where the image quality needs to high. This research proposes a low light photo improvement method based upon the Retinex theory. The proposed methodology firstly smoothens the image input and with edge preservation characteristic. Then the image is element wise divided by the smooth version of the image. To obtain the Reflectance component. These are then plugged into the structure and texture aware Retinex based equation. This way the low light photo improvement is achieved along with a good amount of naturalness preservation. However, there are pros and cons to this method, which have been discussed in this report.

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LIST OF ABBREVIATIONS

1. PDE: Partial Differential Equation
2. EMLV: Exponentiated Mean Local Variance
3. SIRE: Simultaneous Illumination and Reflection Estimation
4. WVM: Weighted Variational Model
5. LIME: Low Light Image Enhancement
6. RRM: Robust Retinex Model
7. STAR: Structure and Texture Aware Retinex
8. JieP: Joint intrinsic-extrinsic Prior

CHAPTER 1

INTRODUCTION

Capturing an image in today's times has become an extremely easy task ever since advent of smartphones and cameras. But with this also comes issues where the images captured are of poor quality. The viewability of the image is extremely low. Also, there are various computer vision applications such as surveillance camera systems, remote sensing devices and autonomous driving solutions, for these applications, the computer vision algorithms need great visibility for good quality performance [1]. The procedure of handling poor quality images and making it better upon the image quality is called image enhancement [2]. Hence, when the image enhancement techniques are applied to images of low visible quality, it is called low light image enhancement.

Fig1: An example of low light image enhancement [11]

For a long time now, researchers have been trying to read, learn and develop ways to make better the quality of low light images. In the past years, it has been the case that several low light image enhancement techniques have been developed by these researchers. Some of these models are: 1. Histogram Equalisation, 2. Dark Channel Prior, 3. Gray Transformation, 4. Image Fusion, 5. Retinex. All these are discussed in the Related Work portion of this report. Also, the proposed method is based on Retinex, so that topic has been discussed in detail.

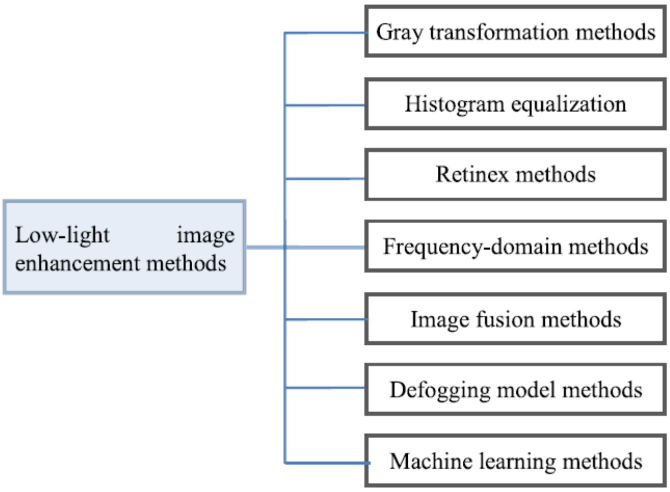

Fig2: A categorisation of different low light photo improvement methods [12]

Classic Retinex Model can be classified into 3 types:

1) Path Based
2) Recursive
3) Centre/Surround Retinex [6]

Also, it is seen that in simple/classic Retinex based models, where in the Reflectance is estimated directly from the image, the image quality is over-enhanced and seems to be a bit unnatural. For this purpose, some additional constraints are introduced in the model to make it more advanced and preserve the naturalness of the image. These could priors of shape, texture, exposure and noise etc. These can be encoded in the decomposition model to achieve naturalness preservation [5]. Similar to this approach, Jun Xu and Yingkun Hou among others in the paper [4] have proposed a model based on Retinex itself where they have generated a structure map as well as a texture map using exponentiated local derivatives of the image to regularise the illumination and reflectance parts of the image. This approach gives a spectacular performance in naturalness preservation of the image.

As it is known that for low light photo improvement using Retinex Model, the images are broken down into the illumination part and the reflectance part and these components are the estimated or generated using various techniques. For best quality results, the illumination and reflectance need to be in the ideal state. The illumination component needs to be piece-wise smooth whereas the reflectance component needs contain maximum fine details, also it is even better if it is free form noise [5]. While considering the derivatives of an image, within the image, the smaller derivatives emerge in the smooth illumination and the larger derivatives can be considered a feature of the reflectance of the image [4]. As it has been hinted above that the illumination component of the image needs to be piece-wise smooth in nature, the techniques to achieve this had also been studied. Wei Liu and Pingping Zhang among in the paper [7] have proposed a generalised method to smooth the image. The models proposed in the paper are robust and work on most kinds of images. Even our low light image data can be worked upon by one of the models where edge preservation is at a high priority.

The simple Retinex Models have been used in the past; the reflectance comes from the image itself by element wise dividing the image by the estimated illumination. Our method differs here a bit, the illumination method that has been used in the research is flexible with a generalized framework approach [7]. This way the illumination can be achieved by smoothing the image. This smooth version of the image is utilized as the illumination component. On the other hand, when the maximum pixel value of the image is element wise divided by the illumination component. We will get all the rough and small-scale textures of the image. This in essence is a characteristic of the reflectance of the image, which depends on the textural properties of the photo. Now, that both the components have been achieved, these are plugged into a Structure and Texture Aware Retinex model [4]. This way the obtained results would be of greater quality, the enhancement of the low light photo is expected to be high and along with appreciable amount of naturalness preservation.

CHAPTER 2

RELATED WORK

2.1 RETINEX THEORY

The word 'Retinex' comes from the mixing of the words: 1. Retina and 2. Cortex. It was developed by Land in the paper [3], where he coined the term. It is based on the perceptive working of the human vision system. As we know, when the eyes view a scene, the eyes sense (retina) the scene and sends a signal to the brain (cortex) where the image is understood. The Retinex Model can be considered more of a theory than a model and based on the theory several types of Retinex models/methods have been proposed by researchers over the years. The Retinex model can also be assumed as the basic theory for the intrinsic image decomposition problem [4].

In the Retinex Model, image decomposition takes place into 2 components namely: 1. Illumination and 2. Reflectance [4]. This can be represented as:

$$\mathbf{I} = \mathbf{L} \, . \, \mathbf{R} \qquad \dots (1)$$

In the above equation, **I** is the original image, **L** is the image illumination, **R** is the image's reflectance part. The Illumination component of the image should be piece-wise smooth and the Reflectance component should show the physical features of the image. Another point to be noted is that the illumination part is dependent on the source of light and the reflectance component depends upon the nature of the object. Which also leads us to the fact that the structural properties are associated with the illumination and the textural properties are associated with the reflectance component of the image.

As mentioned in the previous paragraphs, over the years many researchers have contributed to the Retinex models and these models have been studied in this research. After going through several research papers, it was found that Retinex model can be majorly split into 2 categories: 1. Classical and 2. Variational [4]. Within the Classical Retinex model, there is path based Retinex [8], Partial Differential Equation based [9] and center/surround based [10].

In the path based Retinex models, there are older path-based methods and the more recent ones. Early path-based approaches [17], [18] were developed upon the idea that the reflectance part could be estimated by multiplying ratios along the set of random pathways. These techniques necessitate meticulous parameter tweaking and have substantial computing costs. Later path-based methods [19], [20] replace prior random path calculation with recursive matrix computation techniques to enhance performance.

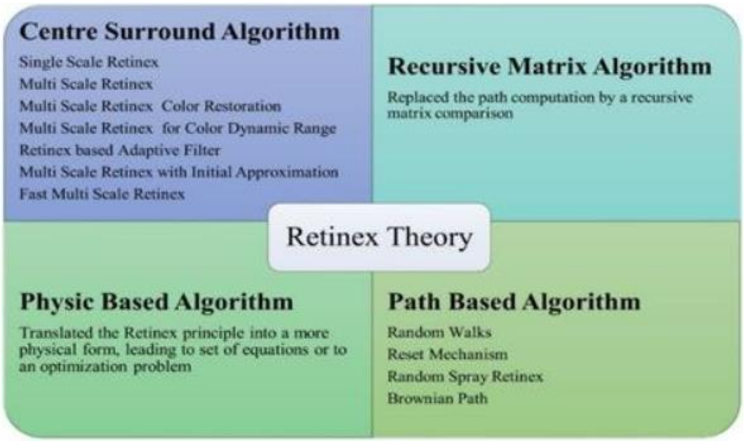

Fig3: The types of Retinex based methods [16]

PDE based approaches [21] take advantage of the fact that solutions of discrete Poisson equations are satisfied by Retinex model, resulting in a fast implementation of reflectance part estimate with just two Fast Fourier Transforms (FFTs). However, the lighting component's structure is harmed since the gradients formed from a vector field that is divergence-free and frequently lose piecewise smoothness.

The Single-Scale Retinex (SSR) [22] and multi-scale Retinex with colour restoration (MSRCR) [23] both come under center/surround approaches. The light component is assumed as smooth, while the reflectance part is assumed to be rough with textural details in these methods. MSRCR, on the other hand, produces halo artefacts around the edges because of the lack of an acceptable structure-preservation limitation.

Variational Methods have also been discussed [24], [25], [26]. The smooth assumption is used in one method [27] to estimate the lighting component in a variational model. However, this method is sluggish and does not take into account the regularization of the reflectance. Following that, another [28], a '1 variational model is developed, focuses on the estimation of the reflectance part. However, the lighting component is not regularized in this method. [29] The other method uses the logarithmic transformation as a step before the processing to reduce the gradient magnitude volatility in vivid places, although the reflectance part estimation with the logarithmic regularisation is over-smoothed. These are some of the variational methods for Retinex Model.

2.2 GAMMA CORRECTION

When it comes to image processing, the gamma transfer function is widely employed, and the related gamma transfer function is as follows:

$$G(x,y) = U(x,y)^{\gamma} \qquad \ldots(1.5)$$

here G (x, y) is the grey level of the improved image at location of pixel: (x, y), U(x, y) is the input image's grey level at the location of pixel (x, y), and G is the gamma transfer function parameter. The flow that are seen of the gamma transfer function are g parameter influenced; the figure below depicts the effect of various g values.

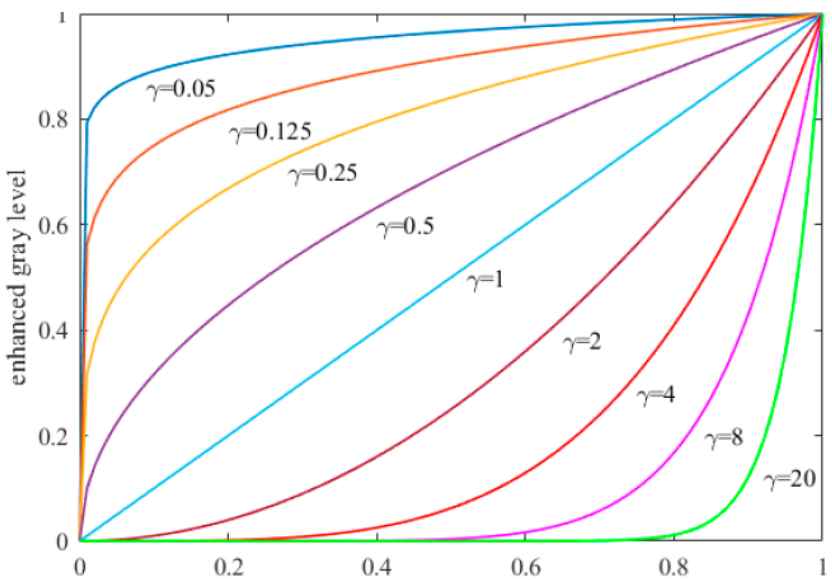

Fig4: How the gamma function changes with γ [16]

2.3 VARIOUS OTHER LOW LIGHT IMAGE ENHANCEMENT METHODS

Gray Transformation: It also known as a map-based approach, is a image enhancement procedure within the spatial-domain with a base on the notion of changing the gray values of each pixel into grey values of other pixels using a mathematic functions. This approach improves an image by changing the grey value flow of distribution and dynamic range of the pixels of image. Linear and nonlinear transformations are the two main subclasses of this type of approach [11].

Histogram Equalization: When an image's pixel values are evenly spread throughout all potential gray levels, it has a high contrast level and a wide dynamic range spectrum. The Histogram Equalization algorithm makes use of the cumulative distribution function (CDF) to adjust the output of the image’s grey levels to have a probability density function which will correspond to a uniformity in the distribution, which allows latent details in darker areas to appear again and the visual component of the input image to be enhanced effectively [11].

Methods of the Frequency Domain: Image enhancement methods have been taken from the spatially domain to the frequency-based domain as a result of the development of multiple scales-image analysis technology. Image enhancement approaches in the frequency-based domain change a photo to the frequency-based domain for filteration using Fourier-based analysis, and then inversely transform the finished image back into the spatial domain. Homomorphic filtering (HF) and wavelet transform (WT) are two common frequency-domain approaches [11].

Image Fusion Methods: This is another area of research in low-light image enhancement. Many of the photos of the similar scene are captured with multiple sensors in these methods, or some extra images are captured using the same sensor with different imaging methods or at various times. Finally, all images are mined for as much data as possible. create a high-quality image, hence increasing the image information's utilisation rate. The image that was created using software can reflect the original photos' multilayer information to provide a detailed description of the scene, allowing the reader to understand it accessible visual data in order to better satisfy the needs human observers as well as machine vision systems [11].

Defogging Model Based Methods: Defogging Techniques, comes under the image enhancement field, have made significant development and generated some impressive results. In recent times, we've had some good results. Kaiming [13] proposed the dark channel prior theory for photos in 2009, and it has since gained a lot of traction has been widely used. A low-light enhancement method, also known as a bright channel prior, was introduced in 2011. Dong et al. presented technique [14], [15] based on the defogging theory is a statistical analysis-based method. Therefore defogging algorithm with its base on the dark channel prior (DCP) is utilized to work on the inverted image; then, the image is re-inverted to get the enhanced image [11].

CHAPTER 3

PROPOSED METHOD

3.1 THEORY OF THE PROPOSED METHOD

The Model that is proposed in this research is based on the edge preserving image smoothing concept where a generalized method to smooth almost any type of image is used. Later the maximum pixel version of the image is element wise divided by the smooth version of this image. This resultant will have a lot of the texture details of the image and this can be treated as the reflectance of the image.

Now that we have a smoothened part of the photo and also a rough part of the photo, we need to utilize a model that will improve the low light image with consideration to the naturalness of the photo also.

For this purpose, the proposed method, inspired by a structure and texture aware Retinex model along with a generic framework for smoothening the image with edge preservation. These two methods put together to an image are supposed to result in high image enhancement as well as preserve the naturalness of the image.

3.2 PROPOSED METHOD

3.2.1 INTRODUCTION TO THE METHOD

The first concept that is introduced is about the Truncated Huber Penalty function [7]. The Truncated Huber Penalty function introduces a switch like characteristic to the original Huber Penalty Function. The switch is to enter a specific mode i.e. either edge preservation or edge sharpening. According to the demarcating values of certain variables, the function behaves like an edge preserver or an edge sharpener. The equation of the penalty function is as follows:

$$H(x) = \begin{cases} \frac{1}{2g}x^2, & |x| < g \\ |x| - \frac{g}{2}, & |x| \geqq g \end{cases} \quad \dots (2)$$

$$H_t(x) = \begin{cases} H(x), & |x| \leqq h \\ h - \frac{g}{2}, & |x| > h \end{cases} \quad \dots (3)$$

The objective function is defined in such a way that it is highly complex and useless, hence it is out of the scope of this research. Therefore, it is decided to skip the complex calculation and directly introduce the $\mathbf{H_t}$ in a new form for the sake of simplicity. It goes like:

$$H_t\left(\nabla^*_{m,n}\right) = min_{l^*_{m,n}}\left\{H\left(\nabla^*_{m,n} - l^*_{m,n}\right) + \left(h_* - \frac{g_*}{2}\right)|l^*_{m,n}|_0\right\} \quad \dots (4)$$

The minimum value of the right side of the equation is obtained at:

$$l^*_{m,n} = \begin{cases} 0, & |\nabla^*_{m,n}| \leqq h \\ \nabla^*_{m,n} & |\nabla^*_{m,n}| > h \end{cases} \quad , * \in (dt,\ sm) \quad \dots (5)$$

If the intensity values are present in a certain range, then based on the equations (3) and (4) it can be said that the $\mathbf{H_t}$ **(.)** degrades to **H(.).**

The above calculation suggests that the Huber Penalty function is the only function involved in the equations, this poses as a problem cause the dependance of the system is only on one equation which when changed will massively impact the result. Hence this can be solved by introducing 2 new functions:

$$H\left(\nabla^*_{m,n} - l^*_{m,n}\right) = min_{\mu^*_{m,n}}\left\{\mu^*_{m,n}\left(\nabla^*_{m,n} - l^*_{m,n}\right)^2 + \psi\left(\mu^*_{m,n}\right)\right\},\ * \in (dt,\ sm) \quad \dots (6)$$

The optimum of the equation is obtained at:

$$\mu^*_{m,n} = \begin{cases} \frac{1}{2g_*}, & |\nabla^*_{m,n} - l^*_{m,n}| < g_* \\ \frac{1}{|\nabla^*_{m,n} - l^*_{m,n}|} & |\nabla^*_{m,n} - l^*_{m,n}| \geqq g_* \end{cases}, \; * \in (dt,\ sm) \qquad \ldots (7)$$

A final energy function defined gets to a condition where there is only involvement of Penalty function of the L_2 Norm with a closed-form solution. The optimal conditions in the above equations () and () contain the image (I), finally the solution can be yielded in an iteration-based algorithm. Changing these iterative variables in the equations () and (). The equation obtained is:

$$I^{N+1} = argmin_I\ E_{Il\mu}\left(I, (l^*)^N, (\mu^*)^N\right), \; * \in (dt,\ sm) \qquad \ldots (8)$$

The close form solution of the above equation is:

$$I^{N+1} = \left(A^k - 2\lambda W^k\right)^{-1}\left(D^k + 2\lambda S^k\right) \qquad \ldots (9)$$

3.2.2 ALGORITHM 1: EDGE PRESERVATION SMOOTHING ALGORITHM

Input: The image I is taken, along with guidance image G, iteration number K=10 and parameter with values λ=0.3, α=0.5, g_*=1e-3, h_*=0.075, r_*=2, I_0, ← I, with * ∈ {dt, sm}

Step 1: for loop k= 0 to K do

Step 2: Using I^k, calculate $(\nabla^*_{m,n})^k$, update $(l^*_{m,n})^k$ as shown in equation (5)

Step 3: With the value of $(l^*_{m,n})^k$ update $(\mu^*_{m,n})^k$, using equation (7)

Step 4: Using $(l^*_{m,n})^k$ and $(\mu^*_{m,n})^k$ solve I^{k+1} using the equation (8 or 9)

Step 5: end for loop

Output: The resultant image with smoothness I^{K+1}

3.2.3 CALCULATION OF THE REFLECTANCE COMPONENT

The Rough Reflectance (R) component of the image is gotten by element wise dividing the maximum pixel image by the Smoother version of the photo, which is the Illumination (L) of the photo. This is done as follows:

$$\widehat{R}_{ro} = max_{pixel}(I) \oslash \widehat{L}_{sm} \qquad \dots (10)$$

The equation can be rearranged as:

$$max_{pixel}(I) = \widehat{R}_{ro} \odot \widehat{L}_{sm} \qquad \dots (11)$$

3.2.4 EQUATION FOR OBTAINING ENHANCED IMAGE

The equation for the low light image improvement is:

$$min_{L,\,R}||I - L \odot R||_F^2 + \alpha||\widehat{L}_{sm} \odot \nabla L||_F^2 + \beta||\widehat{R}_{ro} \odot \nabla R||_F^2 \qquad \dots (12)$$

Similar to Algorithm 1, here also two iterative algorithms are used. But before that there are two equations used to calculate the intermediary reflectance and illumination components. These equations are as follows:

$$l_{N+1} = \left(Diag_{r_N}^T Diag_{r_N} + \alpha G^T Diag_{\widehat{L}_{sm}}^T Diag_{\widehat{L}_{sm}} G\right)^{-1} Diag_{r_N}^T o \qquad \dots (13)$$

$$r_{N+1} = \left(Diag_{l_{N+1}}^T Diag_{l_{N+1}} + \beta G^T Diag_{\widehat{R}_{ro}}^T Diag_{\widehat{R}_{ro}} G\right)^{-1} Diag_{l_{N+1}}^T o \qquad \dots (14)$$

3.2.5 ALGORITHM 2: DEATIL DECOMPOSITION ALGORITHM

Input: The image I is taken as the observed image, along with parameters α, β and maximum number of iterations is K.

Initial Values: I_0 as $O^{0.5}$, R_0 as $O^{0.5}$, 'S_0', 'T_0' are set using the output of the previous algo.

Step 1: **for** loop k= 0 to K-1 **do**

Step 2: Updating I_{k+1} using the eq. (13)

Step 3: Updating R_{k+1} using the eq. (14)

Step 4: if (Converged)

Step 5: break

Step 6: **end if**

Step 7: **end for loop**

Output: Estimation of illumination $\hat{\boldsymbol{I}}$ and reflectance $\hat{\boldsymbol{R}}$.

3.2.6 ALGORITHM 3: ALTERNATING UPDATION ALGORITHM

Input: The image I is taken as the observed image, along with parameters α, β and updation of the number L, max. iterating number K in previous Algorithm.

Initial Values: $\hat{\boldsymbol{I}}^0 = \hat{\boldsymbol{I}}, \hat{\boldsymbol{R}}^0 = \hat{\boldsymbol{R}}$ by previous Algorithm.

Step 1: **for** (l = 0 to L-1) **do**

Step 2: Updating $S_{l+1} = I^{k+1}$ using the equation Algorithm 1

Step 3: Updating $T_{l+1} = I \oslash I^{k+1}$ using the equation (11)

Step 4: Using DDA (Algorithm 2) method and yield $\hat{\boldsymbol{I}}^{l+1}$ and $\hat{\boldsymbol{R}}^{l+1}$

Step 5: if (Converged)

Step 6: break

Step 7: **end if**

Step 8: **end for loop**

Output: Finally, the illumination $\hat{\boldsymbol{I}}^{L}$ and reflectance $\hat{\boldsymbol{R}}^{L}$.

Using all the above methods and equations are put on work to receive the final improved image from the low light image.

CHAPTER 4

WORKING AND ANALYSIS

As the research is about to enter the experimentation ns result section, it is important to understand the proper functioning of all the algorithms that have been proposed in the report. For convenience and proper understanding, 2 images have been picked up from the data set of the paper [4]. The two images were plugged into the implementation code and the and the intermediate results were pulled out to observe what exactly happens to the images that the code is run on.

In each and every step a task is performed on the image shows that how the code is modifying the image at every step.

One thing that is to be noted is that for all the implementation of the code, MATLAB software has been used. MATLAB is a great performance language for computer and mathematics related problem solving. It combines the power of programming, computation and visualization into one software platform with high ease-of-use.

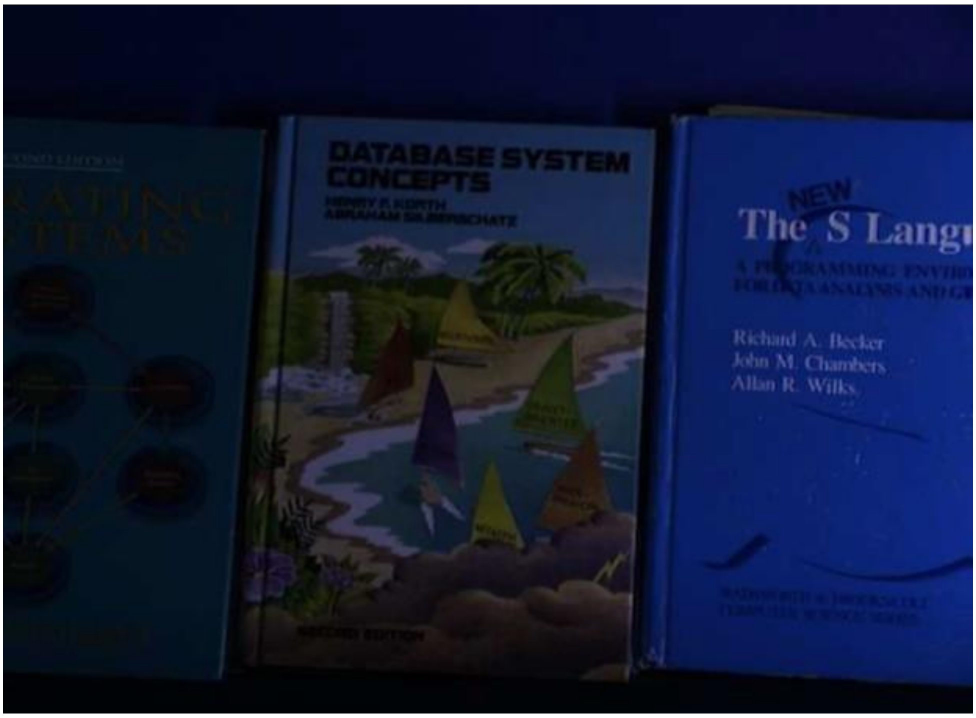

Fig5: Original Image: books [7]

Fig6: Original Image: juice [7]

ALGORITHM 1: EDGE PRESERVATION SMOOTHING ALGORITHM

The images when worked on by the Edge Preservation Smoothing Algorithm result in a smooth version of the image. The smoothing algorithm has a property of the Huber Penalty function. Also, in the paper [12], there is the Truncated Huber Penalty function that has a switching property. The function values have been discretized. There are conditions that have been put in the function, on this basis the decision is made that whether the edges are preserved or they are sharpened.

The resultant of the algorithm is to be smooth and these images have been shown in the figure.

Step 1: Insert the image I, the guidance image g and iteration number K. Also, there are parameters that need to be specified with values that focus on the working of the algorithm. For the purpose that our method is solving, it is ideal that the values that are plugged in are:

1) λ = 0.3
2) α = 0.5
3) g_* = 0.001
4) h_* = 0.075
5) r_* = 2

These values specified in the algorithm are responsible for the edge preserving smoothing of the image. This is inspired the compression of clip art images. Also, all the images have been processed and taken out of the code in the (.png) format.

Step 2: I^k is used to calculate the gradient of the image and then the image is updated using the equation (5).

Step 3: Using the value of $(l^*_{m,n})^k$, the value of $(\mu^*_{m,n})^k$ is updated using equation (7)

Step 4: Using $(l^*_{m,n})^k$ and $(\mu^*_{m,n})^k$ solve I^{k+1} using the equation (8 or 9)

When Algorithm 1 works on the image, the final result is (which is I^{K+1}):

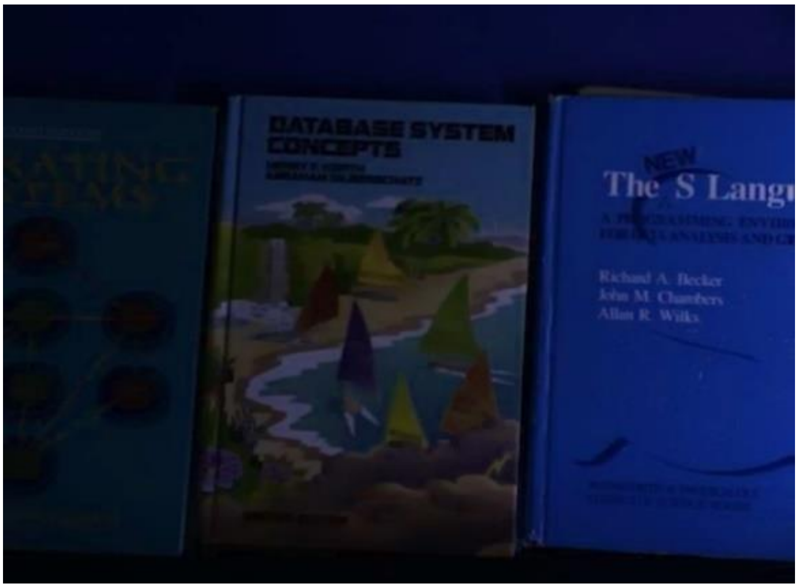

Fig7: Image's smooth version (books)

Fig8: Image's smooth version (juice)

ALGORITHM 2: DEATIL DECOMPOSITION ALGORITHM

Step1: Input the image I is taken as the observed image, along with parameters α, β and maximum number of iterations is K. and Initial Values: I_0 as $O^{0.5}$, R_0 as $O^{0.5}$, ‘S_0’, ‘T_0’ are set using the output of the previous algo.

Step 2: Update I_{k+1} using the eq. (13)

Step 3: Update R_{k+1} using the eq. (14)

Step 4: if the convergence of the image is achieved.

Step 5: then the algorithm is stopped.

As a result of the algorithm, we get:

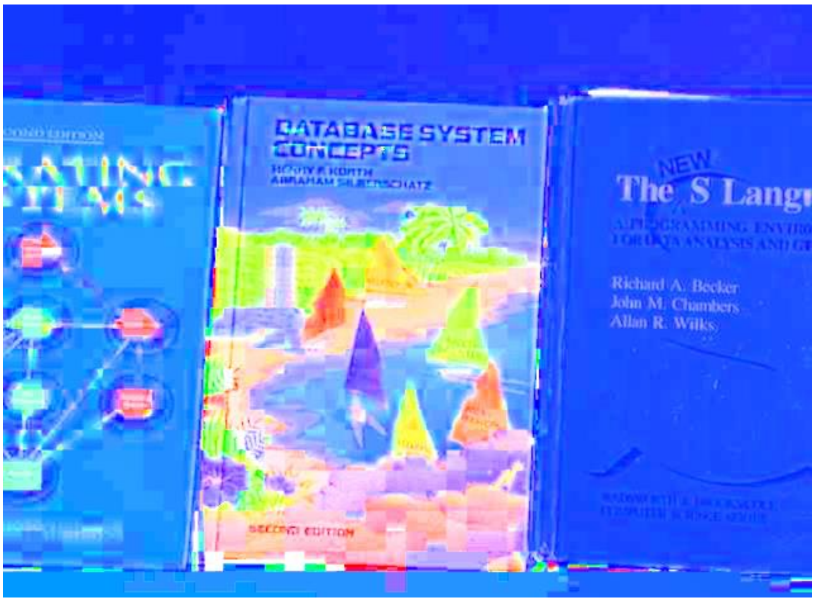

Fig 9: The Texture of the image (books)

Fig 10: The Texture of the image (juice)

ALGORITHM 3: ALTERNATING UPDATION ALGORITHM

Step 1: The input image I is taken as the observed image, along with parameters α, β and updation of the number L, max. iterating number K in previous Algorithm. Initial Values are set as $\hat{I}^0 = \hat{I}$, $\hat{R}^0 = \hat{R}$ by previous Algorithm 2

Step 2: Update $S_{l+1} = I^{k+1}$ using the equation Algorithm 1

Step 3: Update $T_{l+1} = I \oslash I^{k+1}$ using the equation (11)

Step 4: Using DDA (Algorithm 2) method and yield $\hat{\boldsymbol{I}}^{l+1}$ and $\hat{\boldsymbol{R}}^{l+1}$

Step 4: if convergence is achieved

Step 5: then the algorithm is stopped.

The Final result of the algorithm is:

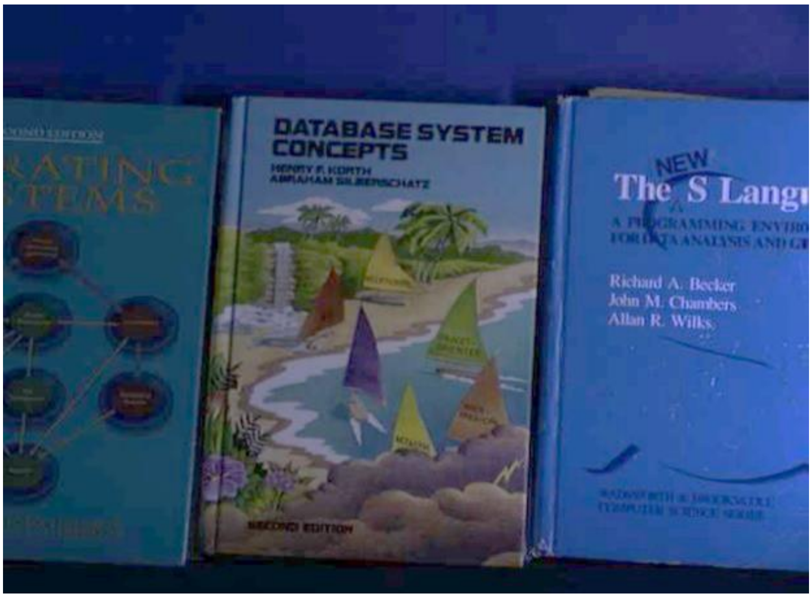

Fig 11: Final Resultant image (books)

Fig 12: Final Resultant image (juice)

CHAPTER 5

EXPERIMENTS AND RESULTS

The method that has been proposed in this research has shown to have performed better than all the previous methods that exist for Low Light Image Improvement Models. For the sake of simplicity, we have decided a few of them these are the original images:

Fig 13: Original Images [4]

The resultant of the Simultaneous Illumination and Reflection Estimation Model (SIRE):

Fig 14: SIRE Model result [4]

The resultant of the Weighted Variational Model (WVM)

Fig 15: WVM Model result [4]

The resultant of the Low-light IMage Enhancement (LIME):

Fig 16: LIME Model result [4]

The resultant of the Joint intrinsic-extrinsic Prior (JieP):

Fig 17: JieP Model result [4]

The resultant of the Robust Retinex Method (RRM):

Fig 18: RRM Model result [4]

The resultant of the Structure and Texture Aware Retinex Model (STAR):

Fig 19: STAR Model result [4]

The resultant of the Proposed Method:

Fig 20: Proposed Method result

Additional Metrics to measure the image enhancement:

Methods	NIQE (lower is better)	VIF (higher is better)
Original Image	3.74	1.00
SIRE	3.06	2.09
WVM	2.98	2.22
LIME	3.24	2.76
JieP	3.06	2.67
RRM	3.08	2.69
STAR	2.93	2.96
Proposed Method	2.78	3.10

Table 1: Comparison of Average Natural Image Quality Evaluator (NIQE) and average Visual Information Fideltiy (VIF).

Methods	Computational Speeds
SIRE	2.83
WVM	58.48
LIME	5.69
JieP	16.40
RRM	107.72
STAR	23.52
Proposed Method	38.33

Table 2: Comparison of Computational Speed of various methods.

CHAPTER 7

CONCLUSION

The model that has been proposed in this research shows that the replacement of the Structure map matrix and the Illumination map matrix in the STAR Model definitely has quality improvements. The Generalized framework that has been introduced in the model reduces the computational complexity of the original STAR Model. The edge – preservation properties in the first category of image smoothing was found to be most suited when it comes to the illumination smoothing task in the Retinex based approach. Overall the results are up to the mark and the naturalness is also preserved.

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LIST OF PUBLICATIONS

[1] Pandit A., Parihar A., “Detail Decomposition for Low Light Image Enhancement”. Accepted at the 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N–22).

Indexed by Scopus

Paper Id: ICAC3N-22_896

Abstract- Images captured in a poor environment is a big problem to deal with. The environment contains haze, fog, smog, rain or even the lighting conditions could be poor. One of these issues are images captured in low light as they are not fit for the view ability of human beings as well as pose an issue for various computer vision applications, where the image quality needs to high. This research proposes a low light photo improvement method based upon the Retinex theory. The proposed methodology firstly smoothens the image input andwith edge preservation characteristic. Then the image is element wise divided by the smooth version of the image. To obtain the Reflectance component. These are then plugged into the structure and texture aware Retinex based equation. This way the low light photo improvement is achieved along with a good amount of naturalness preservation. However, there are pros and cons to this method, which have been discussed in this report**.**

[2] Pandit A., Parihar A., “A Systematic Analysis on various Retinex based Low Light Image Enhancement Methods”. Accepted at 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N–22).

Indexed by Scopus.

PaperId: ICAC3N_897

Abstract- In this paper, the emphasis is on the latest Retinex based methods for low light image enhancement. Though there has been a lot of research in the area of low light image enhancement based on the Retinex theory, in this paper we have studied only a few methods. Retinex method is based on the exact functioning of how a human perceives an object in nature, using their eye (retina) and their mind (cortex). Retinex theory proposes that an image can be split into two components, namely, the illumination and the reflectance. Hence, the image is represented as the product of these two components. Retinex is concerned with an image’s dynamic range and colour consistency. Low Ligtht Image Enhancement based on Retinex has had a lot of re- searchers work on it. But in this paper there are 5 methods: Multi – Scale Retinex with Frame Accumulation (MSRFA), Retinex based Dual Guided Network (RBDGN), Retinex based method with Attention Mechanism (RBMAM), Retinex based method with Structure Extraction (RBMSE), Retinex based method with Adaptive Reflectance Estimation and LIPS postprocessing (RBMARELIPS).

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Notification 4th IEEE ICAC3N-22 & Registration: Paper ID 896

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To: Anhad Pandit <anhadpandit_2k20swe03@dtu.ac.in>

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