*International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622*
*International Conference on Humming Bird ( 01st March 2014)*

RESEARCH ARTICLE OPEN ACCESS

# Image Enhancement for Non-uniform Illumination Images using PDE

Jenish Sherin.B.T[1], Jemimah Simon[2]
JenishSherin.B.T, studyingM.Tech in Vins Christian College of Engineering, jenish33@gmail.com.
2Jemimah Simon.M.E, Assistant Professor in Vins Christian College of Engineering.

**Abstract**—
Image enhancement is important for image processing and analysis. Among various image enhancement algorithms, Retinex based algorithm extract the reflectance as an enhanced image by removing illumination. But it fails to limit the range of reflectance and impossible to exactly remove the illumination. The naturalness is important for image enhancement but it cannot preserve the naturalness effectively. Brightness preservation algorithm, preserve the intensity in bright areas. In order to preserve the naturalness and enhance the details in both dark and bright images a Partial Differential Equation based image enhancement for non-uniform illumination image is proposed. First the Partial Differential Equation is applied to smooth the edges in the image. Second, the image is decomposed into reflectance and illumination using Bright Pass Filter. Third, uniform illumination is obtained by applying Discrete Cosine Transform in the illumination image. Finally, the weighted fusion method is used to combine both reflectance and uniform illumination. The effectiveness and the robustness of the proposed process are shown on numerical examples. It simple to calculate runs fast and provides guarantee for video applications.
**Keyword**—Image enhancement, bright pass filter, discrete cosine transform, weighted fusion, partial differential equation.

## I. INTRODUCTION

The main objective of image enhancement is to improve the quality of an image, so that the resultant image is better than the original image for a specific application such as medical images, remote sensing images etc. There are many image enhancement algorithms that have been proposed but the resulting image looks unnatural.

In this paper, a Partial Differential Equation for non-uniform illumination images is proposed. The purpose of the method is to enhance both dark and bright images and also preserve the naturalness for non-uniform illumination images. It follows four steps. First, the PDE image enhancement is applied to smooth the input image. Second, the image is decomposed into reflectance and illumination using bright pass filter. Then the illumination image is transformed using discrete cosine transform. Finally, combine the transformed illumination image and the reflectance image using weightedfusionmethod.

The paper is arranged as follows. Section II reviews the existing techniques. Section III describes the process and implementation of the proposed algorithm. Section IV deals with experimental result. Section V contains conclusion and remarks.

## II. EXISTING WORKS

There are many image enhancement algorithms that have been proposed such as;Retinex based algorithm, Unsharp masking algorithm, histogram equalization algorithm etc. These algorithms focus on detail enhancement. In [9], the Retinex theory assumes that the sensation of color have strong correlation with reflectance. The light reaching the eye depends on the product of reflectance and illumination.

In [1],MultiscaleRetinexwith color restoration algorithmprovides the necessary color restoration, eliminating the color distortions and gray zones evident in the MSR output. It extracts the reflectance as an enhanced image by removing the illumination from the image. But it does not exactly remove the illumination from unsmooth regions.

In [2], Center surround retinex algorithm takes the local difficulties of the lightness instead of illumination. But it fails to limit the range of reflectance. Reflectance is restricted in the range of 0 and 1, which means the surface does not reflect more light than it receives. In [3],MutiscaleRentinexalgorithm the retinex output is decomposed into subband then applies the subband gain based on the characteristics of each subband. But it contains halo artifacts around strong edges.

In [4], unsharp masking algorithm decomposes the image into high frequency terms and low frequency terms, and these two terms are processed separately. Finally it integrates these two processed terms together. It fails to achieve the tradeoffbetween the details and naturalness of an image.In [5], generalized unsharp masking user can adjust the two parameters controlling the contrast and sharpness to produce the desired results. So it improves the contrast and sharpness of an image.But it cannot consider the problem of avoiding enhancement of noise.

In [6], Histogram Equalizationis one of the common methods used for improving contrast in digital images. Many HE algorithms have been proposed such as brightness preservation and contrast limitation. Brightness Preservation is used to preservethe mean brightness of an image. It is not applicable for dark areas.

In [7], Exact Histogram Specification based upon strict ordering among image pixels via the calculation of local mean values for contrast enhancement. But the Strict Ordering is not possible in uniform areas. In [8], Automatic Exact Histogram Specification, the desired histogram is obtained by subjecting the image histogram to a Modification Process. But it is not efficiently enhance the details in abrupt edges.

In [10], Transform Based Image Enhancement is used for detection and visualization of objects within an image and it used to select best parameters and transform for each enhancement. But it doesn't extract the image in-depth features.

In [11], Naturalness preserved enhancement algorithm preserves the naturalness for non-uniform illumination image. It only enhances the details of dark images. It may introduce the slight flickering for video application because it do not consider the relation of illumination in different scenes.

In order to improve the details in both dark and bright images and also preserve the naturalness for non-uniform illumination images, a Partial Differential Equation based image enhancement algorithm for non-uniform illumination images is proposed.

## III.PROPOSED METHOD

In the above details, it was found that the existingalgorithms would not readily be able to restrict the reflectance and also cannot preserve the details in bright areas. It also introduces the slight flickering for video application and color artifacts. To handle this problem, a Partial Differential equation based image enhancement algorithm for non-uniform illumination images is proposed. It enhances the details for both dark and bright images.

The architecture of the proposed method is shown in figure 1.

It follows four steps. They are,

1. PDE Image Enhancement.
2. Image Decomposition.
3. Illumination Transformation.
4. Synthesis of reflectance and mapped illumination.

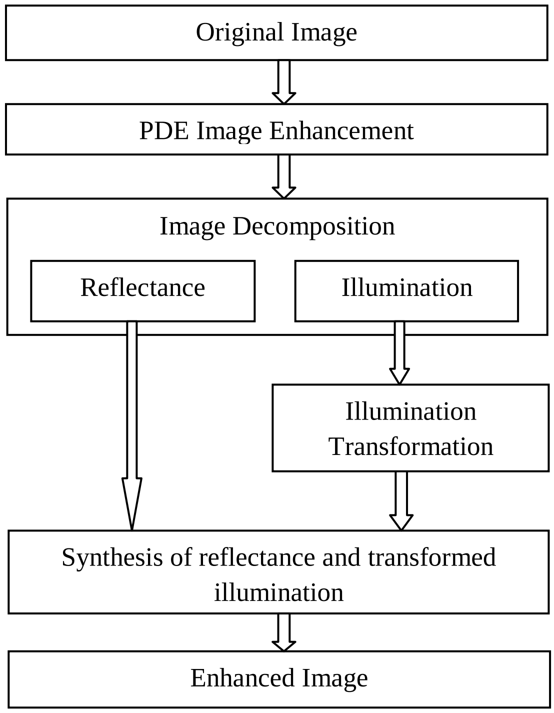



Fig. 1: Proposed system architecture

*A.PDE Image Enhancement*

The main aim of this module is to obtain the smoothed image. First, the input image is taken.Discrete wavelet Transform (DWT) is used to decompose an image into high-high, low-high and low-low frequency bands respectively. Framelet filter is used to find the mask value. By using this smooth the region of an image. Finally, PDE is applied to enhance the smooth region.

Partial differential equation (PDE) is a differential equation that contains unknown multivariable functions and their partial derivatives. PDEs are used to formulate problems involving functions of several variables.

For an image I, the equation can be defined as follows

$$\frac{\partial I(x,y,t)}{\partial t} = \Delta.(c(x,y,t)\nabla I(x,y,t)) \quad (1)$$

$$I(x, y, 0) = I_0(x, y) \quad (2)$$

In (1), $\Delta$ is the gradient operator, *C(x,y,t)* is the diffusion factor, ∇ is the divergence operator.If c has a constant value the obtained equation is called a diffusion equation with an isotropic diffusion factor. In this case, all points and edges would be smoothed as there is no difference between a pixel on an edge and other pixels. It is obvious that this is not an ideal solution.

To resolve this deficiency, the diffusion factor could be considered a function of x and y. Hence, the above equation is changed to a linear and anisotropic equation. If c is dependent on the image, the linear equation would be transformed to nonlinear equation. Two different equations for the diffusion factors are

$$c(x, y, t) = \frac{1}{(1 + \frac{|\nabla I|^2}{k^2})} \quad (3)$$

$$c(x, y, t) = \exp(-\frac{|\nabla I|^2}{2k^2}) \quad (4)$$

In (4), the diffusion factor c changes at different points in the image. For those points where the gradient of the image is large, this diffusion factor has a small value.

Consequently, the diffusion factor would be small around the edges, hence the edges are preserved from smoothing. In bothequationsk is used to control the diffusion factor. Equation is considered an efficient tool for noise removal and scale space analysis of images.

The smoothing process looks more and more like the heat equation. It defined as follows

$$\frac{\partial u}{\partial t} = \Delta u$$
$$u(x, o) = u_0(x) \quad (5)$$

Thus, using the Gaussian function to smooth an image is equivalent to applying the heat equation to the image. The heat equation is described in (5) is an isotropic, scale invariant and linear PDE smoothing model. It used to smooth the regions and to enhance the boundaries.

*B. Image Decomposition*

Image is decomposed into reflectance and illumination is shown in fig. 2. Bright Pass Filter (BPF) is used to evaluate the illumination. From Retinex theory lightness is the product of reflectance and illumination is shown in (1). Illumination means light cast on the surface of the scene. Reflectance means surface reflects more than light than it receives.

$$I^c(x, y) = R^c(x, y).F(x, y)$$
(6)

where $I^c(x, y)$ is the lightness of the color channel c, $R^c(x, y)$ is the reflectance, *F(x,y)* is the illumination.

BPF limits the range of reflectance. Filtering results can be obtained by using connectivity property. BPF only take the neighbors that are brighter than the central pixel into account. Compared with darker areas, it is obvious that brighter areas are closer to illumination.

(a) (b) (c)

Fig. 2.Example for Image Decomposition. (a). Original Image. (b). Illumination Image. (c). Reflectance Image.

Illumination can be evaluated by using following equation.

$$L_r(x, y) = \frac{1}{w(x, y)} \sum_{(i,j)\in\Omega} (Q(L(x, y), L(i, j)).U(L(i, j), L(x, y).L(i, j)) \quad (7)$$

In (7), the lightness *L(x, y)* of an image is the maximum of its three color channel.*L(x,y)*. It defined as follows

$$L(x, y) = \max_{c\in[r,g,b]} I^c(x, y) \quad (8)$$

The frequency $Q'(k,l)$ for pixel values k and l to the neighbors all over the image is defined as follows

$$Q'(k,l) = \sum_{x=1}^{m} \sum_{y=1}^{n} NN_{k,l}(x, y) \quad (9)$$

where m and n arethe height and width of an image. In (9), frequency $Q'(k,l)$ of digital signal is prone to suffer from noise and varies roughly, its local mean *Q (k, l)*is utilized instead.

$$Q(k,l) = \sum_{i=l-win}^{i=l+win} Q'(k,l) \Big/ (2.win + 1) \quad (10)$$

where*win* is the window size. In (10), *win* should not be too small or too large. The window size is set as follows.

$$win = [\max(G(x, y)) - \min(G(x, y))] / 32 \quad (11)$$

Reflectance image is obtained by removing the illumination image from the smoothedimage.

$$R^c(x,y) = I^c(x,y)/L_r(x,y) \quad (12)$$

From (12), the reflectance image is obtained. As a result, the reflectance image presents the details and the illumination image presents the ambience of incident light.

*C. Illumination Transformation*

Naturalness Preservation is a nontrivial task with large illumination variations. Nevertheless illumination usually changes slowly compared with the reflectance. As a result, illumination variationsmainly lie in the low-frequency band. Illumination variations can be reduced by removing low-frequency components. Here, the DCT is used to transform the illumination.

The DCT can be used to transform an image from spatial domain to frequency domain. Low frequency components of an image can be removed simply by setting the low frequency DCT coefficients to zero. The resulting system works like a high-pass filter. Since illumination variations are mainly low frequency components.

Estimate the incident illumination on an image by using low frequency DCT coefficients. Setting the DCT coefficients to zero is equivalent to subtracting the product of the DCT basic image and the corresponding coefficient from the original image.

$$F'(x,y) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} E(u,v) - \sum_{i=1}^{n} E(u_i,v_i)$$

$$= F(x,y) - \sum_{i=1}^{n} E(u_i,v_i) \quad (13)$$

Illumination variation is expected to be low frequency components. In (13),$E(u_i,v_i)$ can be approximately regarded as the illumination transformation term.

where

$$E(u,v) = \alpha(u)\alpha(v)C(u,v)Cos\left[\frac{\pi(2x+1)u}{2M}\right] Cos\left[\frac{\pi(2y+1)v}{2N}\right]$$

The Discrete Cosine Transform(DCT) is defined as follows,

$$C(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} L_r(x,y) \times Cos\left[\frac{\pi(2x+1)u}{2M}\right] Cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (14)$$

In (14), the DCT coefficient or the DC component determines the overall illumination of an image. Therefore, the desired uniform illumination can be obtained by setting the DC coefficient to the same value, i.e.

$$C(0,0) = \log \mu\sqrt{MN} \quad (15)$$

where C (0, 0) is the DC coefficient. For the convenience of understanding and visualization, normally a value of near the middle level of $\mu$ for the original image is chosen.

*D. Synthesis of Reflectance and Illumination*

In order to enhance details and preserve naturalness, the uniform illumination is taken intoconsideration. WeightedFusion Method is used to synthesis the Reflectance and uniform illumination images together to get the final enhanced image. The resulting image is visually pleasing.

In Weighted Fusion Method, find the gradient field for each image. Compute the weighted function of each image by processing the gradient magnitude. The regions of high temporal variance between two images are computed by comparing the intensity gradients of corresponding pixels from the two images. The resulting image is visually pleasing.

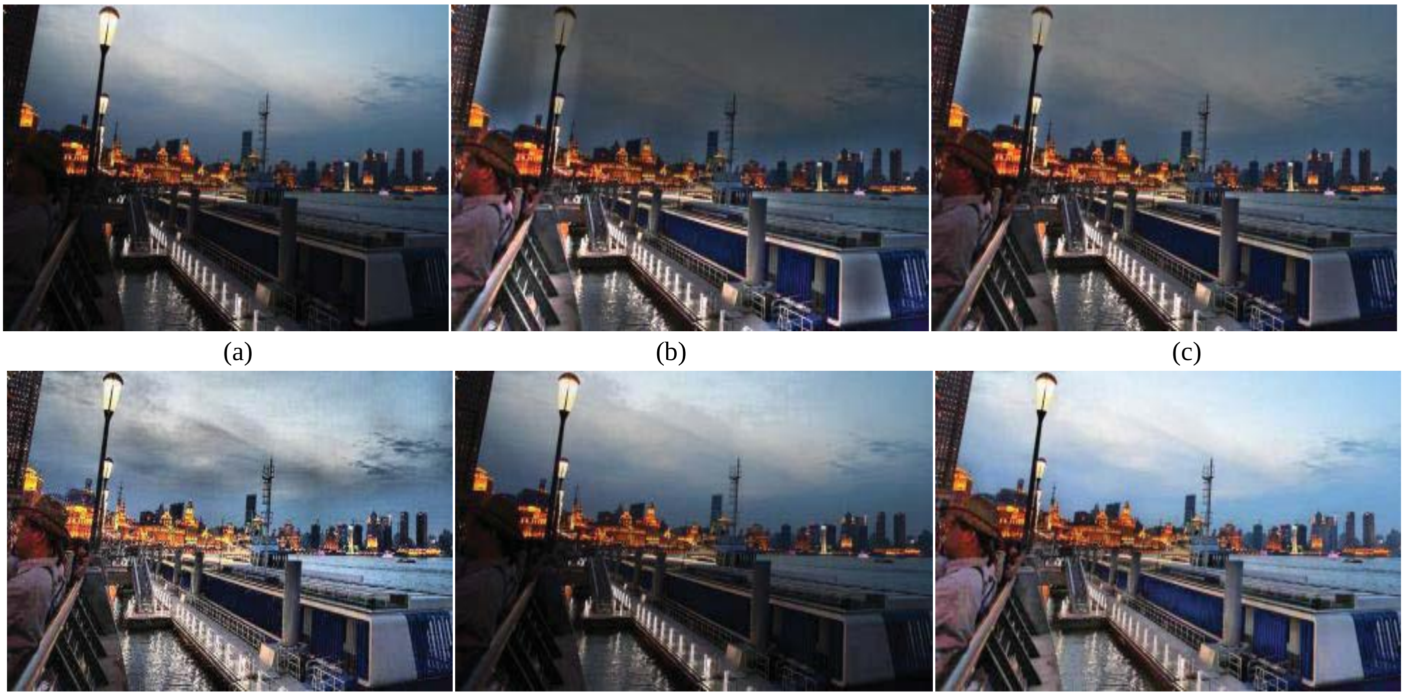
## IV. Experimental Results

In this section, simulation is carried out to evaluate the performance of the proposed algorithm with the existing algorithms reviewed in Section II. The Lightness Order Error (LOE) measure is calculated.

*A.LOE*

LOE measure is based on the lightness order error between original image *I* and enhanced image $I_e$.The LOE measure is defined as

$$LOE = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n} RD(i,j) \quad (17)$$



(a) (b) (c) (d) (e) (f)

Fig. 3 Results (a).Original Image. (b). Enhanced Image of SSR. (c). Enhanced Image of MSR. (d). Enhanced Image of GUM. (e). Enhanced Image of BPDHE (f). Enhanced Image of proposed system.

where m and n are the height and width of an image. *RD(x,y)*is the relative order difference. In (17), the relative order difference of the original image and enhanced image is defined as follows

$$RD(I,J)=\sum_{i=1}^{m}\sum_{j=1}^{n}(U(L(x,y),L(i,j))\oplus U(L_e(x,y),L_e(i,j)))$$

TABLE I
RESULTS OF LOE

| Image | Original | SSR | MSR | GUM | BPDHE | Prop |
|---|---|---|---|---|---|---|
| 1 | 0 | 50.75 | 35.50 | 36.83 | 0.09 | 9.41 |
| 2 | 0 | 49.34 | 19.66 | 9.53 | 0.03 | 3.25 |
| 3 | 0 | 38.47 | 21.14 | 32.30 | 0.89 | 4.43 |
| 4 | 0 | 5.25 | 2.46 | 2.77 | 0.16 | 1.17 |
| 5 | 0 | 39.45 | 20.74 | 18.70 | 0.23 | 6.12 |

where*L(x,y)* is lightness of an image. It calculated from equation (8). *U(x,y)* is the unit step function. It defined as follows

$$U(x,y)=\begin{cases}1, & for\, x\geq y\\ 0, & else\end{cases}$$

From the definition of LOE measure, if the LOE value is small then the better lightness order is preserved. Here, the naturalness preservation is evaluated through the LOE measure. Table I demonstrates the measure of LOE. It evaluates the naturalness preservation quantitatively. The proposed algorithm preserves the lightness order, outperforming SSR, MSR, MSRCR, and GUM.However, BPDHE gets the lowest value. But it cannot enhance the local details effectively sometimes.

In summary, compared with the existing enhancement algorithm it not only enhances the details of both dark and bright images and also preserves the naturalness for non-uniform illumination images. The proposed algorithm can achieve good quality.

## V. Conclusion

A Partial Differential Equation based Image Enhancement algorithm for Non-uniform illumination images is proposed. In order to reduce the color artifact in the image, edges of an image are smoothed using Partial Differential Enhancement method. To obtain a uniform illumination, image is decomposed into reflectance and illumination using Bright Pass Filter. Then the Discrete Cosine Transform is applied in the illumination image. Finally the enhanced image is obtained by combining reflectance and uniform illumination using fusion method. It not only enhances the details of dark images but also enhance the bright images. It also preserves the naturalness for images. The application scope is wider, and the visual effect is better and processing is more efficient. It simple to calculate, runs fast, and provides a guarantee for real-time video image enhancement processing.

## REFERENCES

[1] D. J. Jobson, Z. Rahman, and G. A. Woodell, "A multi-scale retinex for bridging the gap between color images and the human observation of scenes", IEEE Trans. Image Process., vol. 6, no. 7, pp. 965–976, July 1997.

[2] L. Meylan and S. Süsstrunk, "High dynamic range image rendering with a retinex-based adaptive filter", IEEE Trans. Instrum. Meas., vol. 15, no. 9, pp. 2820–2830, Sep 2006.

[3] J. H. Jang, S. D. Kim, and J. B. Ra, "Enhancement of optical remote sensing images by subband-decomposed multiscaleretinex with hybrid intensity transfer functions",IEEEGeosci. Remote Sens. Lett., vol. 8, no. 5, pp. 983–987, Sep 2011.

[4] A. Polesel, G. Ramponi, and V. J. Mathews, "Image enhancement via adaptive unsharp masking", IEEE Trans. Image Process., vol. 9, no. 3, pp. 505–510, March 2000.

[5] G. Deng, "A generalized unsharp masking algorithm," IEEE Trans. Image Process., vol. 20, no. 5, pp. 1249–1261, May 2011.

[6] H. Ibrahim and N. Kong, "Brightness preserving dynamic histogram equalization forimage contrast enhancement", IEEE Trans. Consum.Electron., vol. 53, no. 4, pp. 1752–1758, Nov 2007.

[7] D. Coltuc, P. Bolon, and J. M. Chassery, "Exact histogram specification", IEEE Trans. Image Process., vol. 15, no. 5, pp. 1143–1152, May 2006.

[8] D. Sen and S. K. Pal, "Automatic exact histogram specification for contrast enhancement and visual system based quantitative evaluation", IEEE Trans. Image Process., vol. 20, no. 5, pp. 1211–1220, May 2011.

[9] E. H. Land and J. J. McCann, "Lightness and retinex theory", J. Opt. Soc. Amer., vol. 61, no. 1, pp. 1–11, Jan. 1971.

[10] S. Agaian, K. Panetta, and A. Grigoryan, "Transform based image enhancement algorithms with performance measure", IEEE Trans. Image Process., vol. 10, no. 3, pp. 367–382, March 2001.

[11] Shuhang Wang, Jin Zheng, Hai-Miao Hu, and Bo Li, "Naturalness preserved enhancement algorithm for non-uniform illumination images",IEEE Trans. Image Process., vol. 22, no. 9, Sep 2013.