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# Image Dehazing Technique Based On DWT Decomposition and Intensity Retinex Algorithm

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## ABSTRACT

Conventional designs use multiple image or single image to deal with haze removal. The presented paper uses median filer with modified co-efficient (16 adjacent pixel median) and estimate the transmission map and remove haze from a single input image. The median filter prior(co-efficient) is developed based on the idea that the outdoor visibility of images taken under hazy weather conditions seriously reduced when the distance increases. The thickness of the haze can be estimated effectively and a haze-free image can be recovered by adopting the median filter prior and the new haze imaging model. Our method is stable to image local regions containing objects in different depths. Our experiments showed that the proposed method achieved better results than several state-of-the-art methods, and it can be implemented very quickly. Our method due to its fast speed and the good visual effect is suitable for real-time applications. This work confirms that estimating the transmission map using the distance information instead the color information is a crucial point in image enhancement and especially single image haze removal.

**Keywords :** AF: Adaptive filter, AHE: Adaptive Histogram Equalization, LOE: Lightness Order Error

## I. INTRODUCTION

Restoration of hazy image is an important issue in outdoor vision system. Image enhancement and dehazing remain a challenging problem as well as an important task in image processing. Image enhancement is really an important issue in image processing applications such as digital photography, medical image analysis, remote sensing and scientific visualization [1]. Image dehazing and enhancement is the process by which the appearance and the visibility of an image are improved such that the obtained image is suitable for visual perception of human beings or for machine analysis. It is useful not only from an aesthetic point of view but also helps in image analysis and object recognition, etc. Image captured under bad visibility often has a contrast and many of its features are difficult to see.

## II. METHODOLOGY

In this paper, we proposed a new method for single image dehazing using the NAM (Non-symmetry and Anti-packing Model)-based decomposition and contextual regularization. We estimated the airlight by decomposing the image using non-symmetry and anti-packing model [11] to eliminate the false estimation at the boundary or the over-bright object. Then, the scene transmission was calculated using the combination of the boundary constraints, the contextual regularization and the optimization proposed by *Meng et al.* [12]. The proposed method had better color visual and haze-free image when it comes to the image dehazing problem, a dehazing model called Atmospheric Scattering Model is widely used in

$$I(x) = J(x)t(x) + A(1-t(x))$$

where $I(x)$ represents the hazy image, and $J(x)$ denotes the origin haze-free image(also called scene radiance). $A$ is the airlight which is the global light in the atmosphere while $t(x)$ denotes scene transmission function ($0<t(x)<1$). $t(x)$ usually correlates with the scene depth. When the observed object is further away from the camera, it's more affected by the haze. As a result, $t(x)$ is closer to zero when the object depth in the scene is greater. In the dehazing process, the goal is to estimate the $A$ (airlight) and construct the most optimal transmission function $t(x)$.

Then the haze-free image could be estimated:

$$J(x) = \frac{I(x) - A}{\max(t(x), \varepsilon)} + A$$

where $\varepsilon$ is usually a small constant (0.001) in order to avoid division by zero.

Proposed an algorithm which combines the merits of transform color space algorithm and wavelet transform algorithm.

First, the RGB image is converted to the HSI color space, Then histogram equalization is applied to intensity component I to enhance the contrast of image and the segmentation

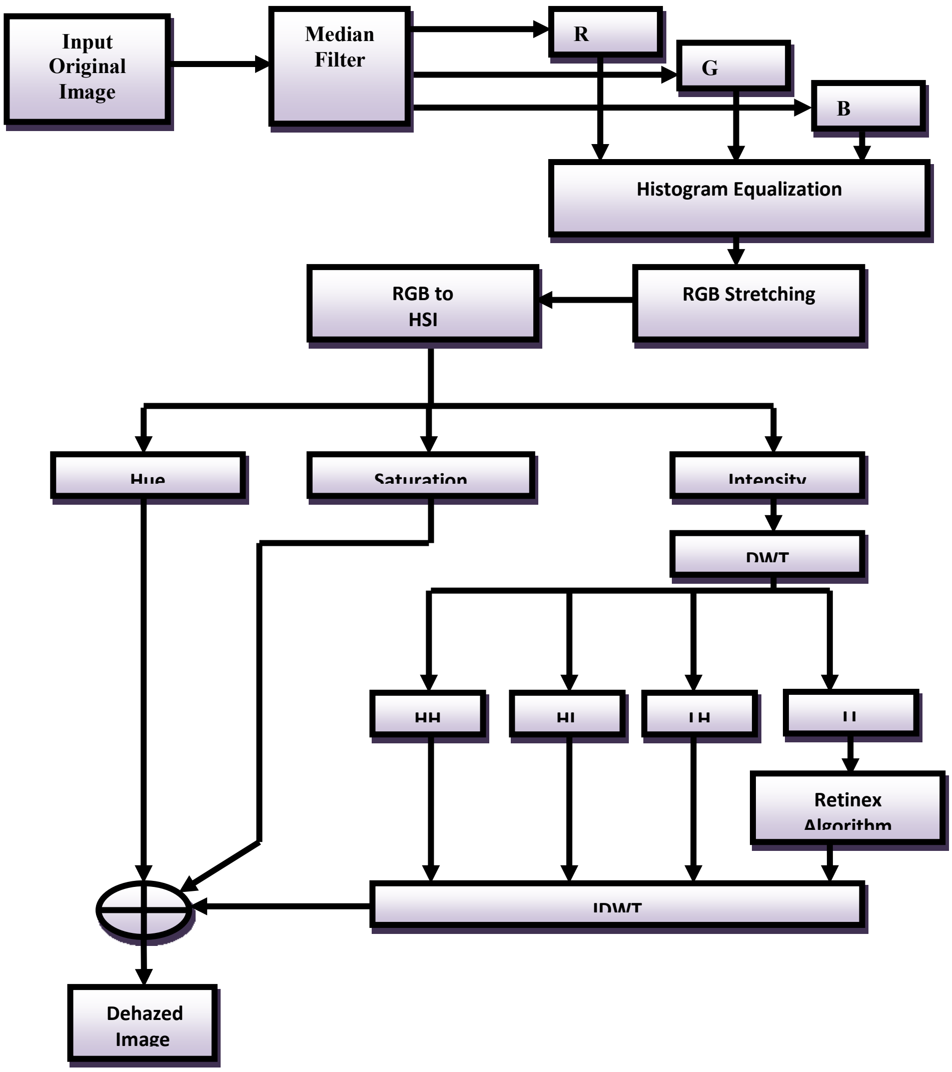


**Figure 1**. Flow diagram of proposed work

Exponential enhancement algorithm is applied to saturation component S, and then the intensity component I is divided into high and frequency sub-bands with wavelet transform and then Retinex algorithm is applied to the low-frequency sub-band to reduce the effect of haze and adjust image luminance, a fuzzy enhancement algorithm is applied to high-frequency sub-band to achieve the enhancement and de-noising for the image details.

Finally, utilize the inverse wavelet transform to reconstruct the I component and then the reconstructed component I will be synthesized with H and S components to get a clear RGB image, and the proposed algorithm is represented by following flowchart

Let input image is x which is a RGB image
First Histogram Equalization need to be done

$$I = \frac{1}{3}(R + G + B)$$

$$A = cos^{-1}\left(\frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2 + (R-B)(G-B)}}\right)$$

$$H = A \quad when\ G > B$$

$$H = 360 - A \quad when\ B > G$$

$$S = 1 - 3\left(\frac{Min(R,G,B}{I}\right)$$

Let 'img' is the HSI image and its intensity block is of 3x3 is as below, and the intensity need to enhance with K coefficient

$$I = \begin{bmatrix} a & b & a \\ c & d & b \\ d & b & e \end{bmatrix}$$

Table 3.1 Histogram equalization algorithm

| Pixel intensity | A | B | C | D | e |
|---|---|---|---|---|---|
| Pixel value | f1 | f2 | f3 | f4 | f5 |
| Probability | f1/9 | f2/9 | f3/9 | f4/9 | f5/9 |
| Cumulative probability | F1/9 | $\frac{f1+f2}{9}$ | $\frac{f1+f2+f3}{9}$ | $\frac{f1+f2+f3+f4}{9}$ | $\frac{f1+f2+f3+f4+f5}{9}$ |
| CP*k | K*F1/9 | $\left\{\frac{f1+f2}{9}\right\} * K$ | $\left\{\frac{f1+f2+f3}{9}\right\} * K$ | $\left\{\frac{f1+f2+f3+f4}{9}\right\} * K$ | $\left\{\frac{f1+f2+f3+f4+f5}{9}\right\} * K$ |
| Floor rounding | Na= floor(K*F1/9) | $Nb = floor\left[\left\{\frac{f1+f2}{9}\right\} * K\right]$ | $Nc = floor\left[\left\{\frac{f1+f2+f3}{9}\right\} * K\right]$ | $Nd = floor\left[\left\{\frac{f1+f2+f3+f4}{9}\right\} * K\right]$ | $Ne = floor\left[\left\{\frac{f1+f2+f3+f4+f5}{9}\right\} * K\right]$ |

$$I_e = \begin{bmatrix} Na & Nb & Na \\ Nc & Nd & Nb \\ Nd & Nb & Ne \end{bmatrix}$$

$I_e$ is the intensity frame of HSI image of MxN DWT applied on 'I'

Table 1 below shows the symlet type 4 HPF and LPF filter coefficients. Proposed work use 'sym4' type wavelet for decomposition of Cover image, figure 1 below shows HPF and LPF decomposition using DWT.

$$I_e(\boldsymbol{n})_L = \sum_{k=-\infty}^{\infty} I_e(\boldsymbol{k})\boldsymbol{g}(2\boldsymbol{n}-\boldsymbol{k})$$

$$I_e(\boldsymbol{n})_H = \sum_{k=-\infty}^{\infty} I_e(\boldsymbol{k})\boldsymbol{h}(2\boldsymbol{n}-\boldsymbol{k})$$

$$\text{let } I_e(\boldsymbol{n})_L = p$$

$$\text{let } I_e(\boldsymbol{n})_H = q$$

Retinex let (x,y) are the pixels coordinates of 'p' in space domain then W is the reflection component and Z illumination component then

$$\mathrm{p(x,y) = W(x,y)Z(x,y)}$$

$$where\ Z(x,y) = \sum_{r=-\infty}^{\infty}\sum_{s=-\infty}^{\infty} F(r,s).p(x-r,y-s)$$

$$F(x,y) = \lambda.e^{\frac{-(x^2+y^2)}{c}}$$

Where c is Gaussian scale and $\lambda$ is a constant that makes F(x, y) equal to 1.

$$\mathrm{p(x,y) = W(x,y)\{F(x,y) * p(x,y)\}}$$

$$w(x,y) = log_{10}(W(x,y)) = log_{10}(p(x,y)) - log_{10}(F(x,y) * p(x,y))$$

$$w(x,y)\ will\ be\ the\ ratinex\ enhance\ of\ p(x,y)$$

Let (u,v) are the pixels coordinates of 'q' in space domain

$$F_{(u,v)} = \frac{q_{(u,v)} - q_{min}}{q_{max} - q_{min}}$$

$$NF_{(u,v)} = \frac{1}{2} + \left(F_{(u,v)} - \frac{1}{2}\right)^{\frac{1}{3}}$$

$$MF_{(u,v)} = NF_{(u,v)}(q_{max} - q_{min}) + q_{min}$$

$$Mq = MF_{(u,v)} * q_{(u,v)}$$

Mq is the final enhanced high frequency component q

$$\mathrm{Mod\_I} = \sum_{n=-\infty}^{\infty}\left\{Mq\left(\frac{n}{2}\right)_L \pm W\left(\frac{n}{2}\right)_H\right\}$$

Outdoor images are degraded by haze. The degraded images have image contrast. This seriously affects many computer vision applications such as video surveillance systems and vehicle visual systems. Dehazing methods have attracted much interest in recent years. Generally, it is difficult to prevent the reflection of haze. To restore the image contrast, dehazing methods need to be performed. To accelerate the processing speed, a fast single image dehazing method has to be developed in near future which will be based on the atmospheric scattering model and gray projection. our future method will have transmission map is estimated roughly using minimum filtering which is based on dark channel prior and refined with fast average filtering. The gray projection method is adopted to obtain the atmospheric light. The subsection mechanism is designed to avoid the high light of sky region in recovered image, and Weber-Fechner Law is employed for color compensation in restored image. a optimized approach is planned to be develop in near future, in which the transmission map is roughly obtained with DCP and processed with a fast average filtering to improve the running speed. By gray projection, the atmospheric light is obtained. And after the restoration of haze-free image, the intensity compensation is employed to increase the visual effect. The designed algorithm must achieve satisfied result with a computation cost.

## III. RESULTS AND DISCUSSION

LOE measure is based on the lightness order error between original image X and enhanced image Y .The LOE measure is defined as

$$LOE = \sum_{i=1}^{RW}\sum_{j=1}^{CL} RD_{ij}$$

$RD_{ij}$ is the relative order difference

$$RD_{ij} = \sum_{i=1}^{RW}\sum_{j=1}^{CL}\left(U\left(L_x, L_{ij_x}\right) \oplus U(L_y, L_{ij_y})\right)$$

The lightness L of an image is the maximum of its three color channel.

$$L = MAX_{(r,g,b)}(X_{ij})$$

Simulation is been taken for Crop image

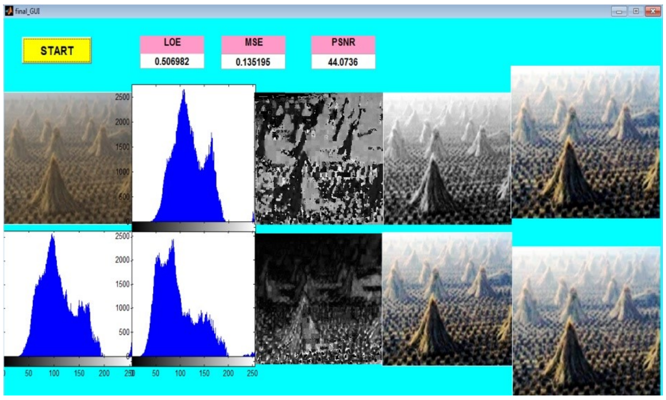


Figure 2. GUI for the test image Crop

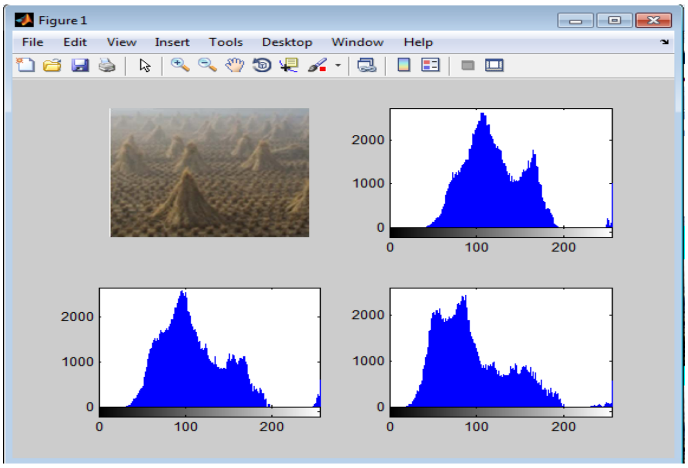


Figure 3. Histogram analysis of test image Crop

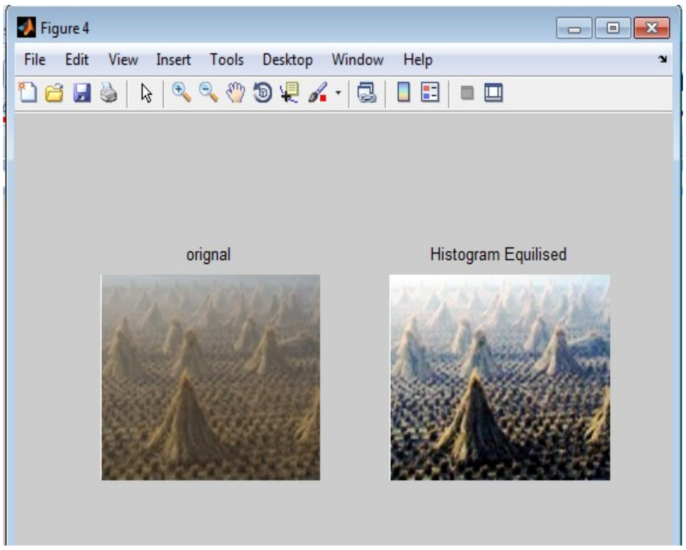


Figure 4. Test image Crop RGB to HSI with haze enhancement

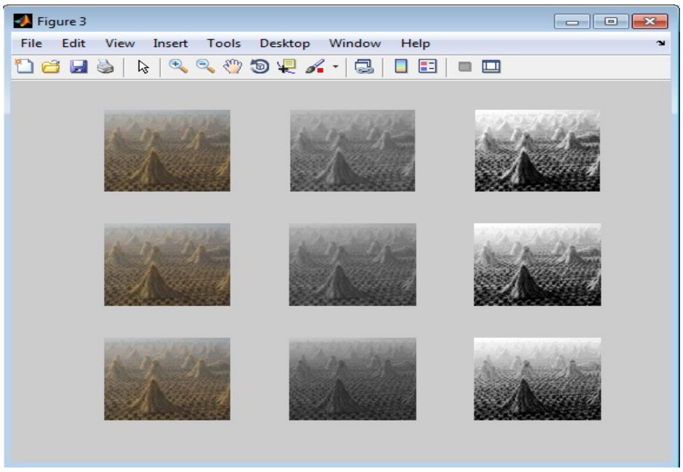


Figure 5. Test image Crop with histogram enhancement

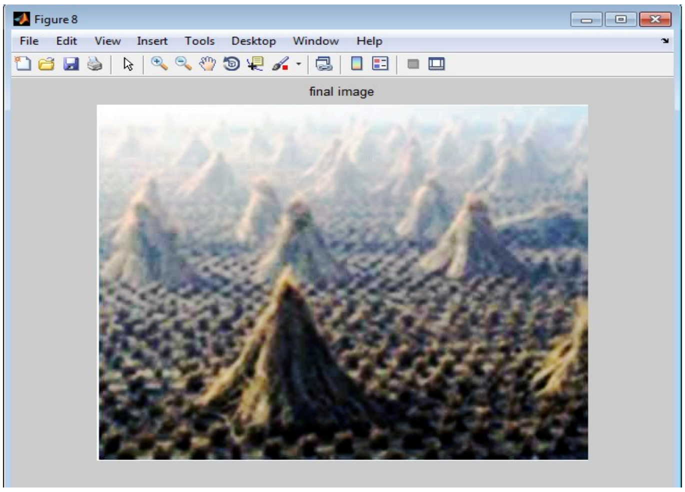


Figure 6. Enhanced test image Crop

Tables below shows the observed results of the proposed simulation for test images 'house', ‘building’, ‘Man’, Crop’ and 'Ground’.

Table 1 Observed results of MSE, PSNR and LOE

| SN | Test Image | MSE | PSNR | LOE |
|---|---|---|---|---|
| 1 | House | 0.237564 | 48.97 | 0.890866 |
| 2 | Building | 0.223472 | 48.4388 | 0.838019 |
| 3 | Man | 0.300008 | 50.997 | 1.12503 |
| 4 | Crop | 0.135195 | 44.0736 | 0.506982 |
| 5 | Ground | 0.202547 | 47.5849 | 0.759551 |
| | Average | 0.19652 | 47.234 | 0.862502 |

Table 2 LOE comparison for Building image

| Author/ Journal/Year | LOE for Image of Building |
|---|---|
| **Yuhei Kudo / IEEE 2018** | 1.932 |
| **Proposed** | 0.838019 |

Table 3 Mean Square Error comparison of Crop Image

| Work | MSE for image of Crop |
|---|---|
| **Proposed** | 0.135195 |
| **Yunping Zheng/ IEEE 2017** | 0.1393 |

## IV.CONCLUSION

The proposed work studies different types of methods and technologies that have been used for image dehazing and observed that the low contrast and noise remains a barrier to visually pleasing images in dehazing conditions. In that condition, to find out a more accuracy in image enhancement process there is need to detect and measure the intensity level of individual pixel channel as well as have to present an appropriate enhancement factor for enhancement purpose, so that effective and efficient image enhancement process will be created. A new method for image dehazing based on DWT Decomposition and intensity Retinex. The air-light of image is estimated by decomposing the image using non-symmetry and anti-packing model to refine the illumination value. Next, the scene transmission function is calculated using the combination of the boundary constraints and the contextual regularization. The proposed method produces high quality dehazed picture in most cases and decrease artifact. What's more, the tone of the image is natural. But there's still some points needing to be improve such as the time consuming and the tone's changing when the homogeneity of RGB channels have a big difference. The results obtains for the thesis work are better in terms of LOE and SNR then available works.

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