A Novel Dehazing Method for Color Accuracy and Contrast Enhancement Method for Low Light Intensity Images

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Abstract- *Images captured through mobile devices often suffer from poor quality due to poor weather conditions. Especially in hazy weather, observed images lose clarity as well as they are prone to color shifts. In this paper, a novel dehazing method for color accuracy is presented which effectively removes the haze. In the first phase, based on white balance, region division is performed, in the second phase, the local atmospheric light is estimated, and, in the third phase, an iterative haze removal algorithm is developed to make the image free from haze. This paper also presents a contrast enhancement method for the images taken in dark, which are low light intensity images. It involves the following three procedures. First phase involves inverting the image, second phase involves applying dehazing algorithm and the third phase involves inverting the dehazed image to get an enhanced image. Experimental results validates that the proposed dehazing method and enhancement method can be effectively applied to the images taken in mobile devices and digital cameras, for enhancing visibility and contrast without color distortion.*

Keywords- White balance segmentation, Hue Saturation value, Contrast enhancement, region division, atmospheric light, iterative dehazing algorithm.

1. INTRODUCTION

An image which is captured through a smart phone or a digital camera experiences bad weather. For an image, it's visibility and contrast indicates the quality of the image. Although, the images which are captured outside are affected by low visibility and low contrast precisely in a hazy weather (Wang).

Getting rid of haze is a productive course of action since it can bring back an understandable image with high visibility. For that reason, it is required to establish a structured dehazing method to apply on the images obtained from digital cameras, outdoor security cameras and smart phones.

The presented novel dehazing method in the first phase, based on the white balance segmentation, divides the hazy input image into non-identical regions by merging the pixels which are in the company of indistinguishable haze densities. In the second phase, to ignore color imbalance and inconsistent brightness, the local atmospheric light in every region is considered to reduce the effects caused by complex and non-uniform atmospheric light. Next, the actual transmission map is calculated for every region by means of local atmospheric light and the dark channel prior. In the third phase, the haze is removed by an iterative dehazing algorithm which evolved to recover the realistic image. The experimental outcomes reveals that the proposed technique upholds details in the absence of sacrificing color accuracy, removes block artefacts, yields high characteristic object data, and is uncomplicated.

The process that builds the image features to appear more clearly by utilizing the colors accessible on the display is called contrast enhancement. This course of action plays an important role in the image processing to accentuate the information that exists inside the low dynamic range of that gray level image. It is required to perform the noise removal and contrast enhancement operations for a low light intensity image and hazy image respectively, to build a better quality of image (Dong, 2011).

The contrast enhancement approach presented in this paper involves three procedures. First inverting the image, second, applying dehazing algorithm, and finally, inverting the dehazed image to get an enhanced image. The experimental results reveals that the proposed enhancement method successfully and productively improves the quality and enhances the image and makes the image features stand out more clearly.

The remaining Sections here are arranged and demonstrated in the following fashion. Section II brings up the literature survey. Section III proposes a novel dehazing approach for color accuracy. Section IV proposes contrast enhancement method for low light intensity images. Section V reports the experimental outcomes of the presented methods and finally, section VI draws the conclusion.

2. LITERATURE SURVEY

In [1], Fattal first estimated the scene albedo presuming that the transmission and surfacing shading are locally uncorrelated and then further retrieved the scene using the inferred medium transmission. Although, this approach is physically sound and produces quality results, but still this approach is unsuitable for images with heavy haze.

In Gibson's approach [2], producing halo artefacts is ignored to a precise range. Still, the recovered image is not up to an expected quality. This approach is unable to completely clear the haze in gaps where there are discontinuities in the depth of the scene. Additionally, since, the transmission of each pixel is estimated by making use of fixed size rectangular patches, the restored image is prone to block artefacts.

In [3], a study of similarities and dissimilarities with other algorithms and quantitative evaluation is presented. An application is proposed to lane-making extraction in gray level images which illustrates the interest of the method.

In [4], the approach is concerned with reducing the contrast loss due to added lightness in an image. An algorithm is described for measuring the range of this lightness under the assumption that it is constant throughout the image. This approach is based on finding the minimum of a global cost function. This algorithm is applicable for both color and monochrome images.

The approach proposed by X. Tang [5] along with soft matting algorithm can produce compelling haze-free results. However, the restored image still contains some halo artefacts. Additionally, since, this approach uses soft matting algorithm, this method is computationally complex.

In [6], an hazy image is divided into super pixels to provide rich details and estimate artefacts based on the dark channel prior. Next, after refining the transmission map, based on the hazy imaging model, the image is restored. This method maintains rich details, but still the recovered image has less brightness and also the haze is still present in the local regions.

In [7], a logarithmic function is developed to estimate the smooth transmission for retrieving a haze-free image. This approach can produce haze-free images and is less complex. But the image is unclear and the details are dissipated.

In [8], to separate the sky regions and non-sky regions in an hazy image, a super-pixel segmentation algorithm is applied. This approach then estimates the transmission separately for those regions. Although, this approach lessens the block artefacts, it becomes unsuccessful in improving the image details.

In [9], a dehazing method based on explicating boundary constraints on the transmission function is presented by recovering only a few general assumptions. This approach produces good results provided a suitable sampling point should be selected. Also, this method needs human intervention. In case if the assumption do not hold, this method becomes unsuccessful.

In [10], the approach uses SLIC algorithm for super-pixel segmentation and estimates local atmospheric light via global atmospheric light and iterative dehazing algorithm is developed.

In [11], a guided filter which is called as a novel explicit image filter is proposed. By taking the contents of the guidance image into account, which can be either input image or another different image, it computes the filtering output.

In [12], the method proposes an adaptive guided image filter by including edge wave weighting which is derived from normalized local variance of a guidance image into an existing guided filter. It conveys that the presented filter protects sharp edges than the existing guided filter.

In [13], the paper begin by studying the visual manifestations of different weather conditions. For this, the authors draw on what is already known about atmospheric optics. Next, they identify the effects caused by bad weather that can be turned to an advantage. Since the atmosphere modulates the information carried from a scene point to the observer it can be viewed as a mechanism of visual information coding. Based on this observation, the paper develop models and methods for recovering pertinent scene properties, such as three-dimensional structure, from images taken under poor weather conditions.

In [14], the described method proposes a novel and effective video enhancement algorithm for a low lighting video. This approach works by first inverting the input video and then applying the optimized image dehazing algorithm on the video. Temporal correlations in between the subsequent frames are utilized to expedite the calculation of the key parameters so that faster computation is achieved. Experimental outcomes shows excellent enhancement results.

3. A NOVEL DEHAZING METHOD FOR COLOR ACCURACY

The flow process of the proposed novel dehazing method for color accuracy is shown in fig. 1 and it calls for three main procedures, namely: Region division, local atmospheric light estimation and iterative dehazing.

The model to describe a hazy image is,

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

Where $I(x)$ is a hazy image, $J(x)$ is haze-free image, $t(x)$ is transmission map and A is atmospheric light. Based on eq. (1), recovering $J(x)$ from $I(x)$ is the main objective of the image dehazing.

Based on the white balance, image is divided. Then, a local atmospheric light is estimated for every region and finally, an algorithm called iterative dehazing is deployed to perform dehazing for different regions. The coming subsections best describes every procedures in detail in the proposed novel dehazing method.

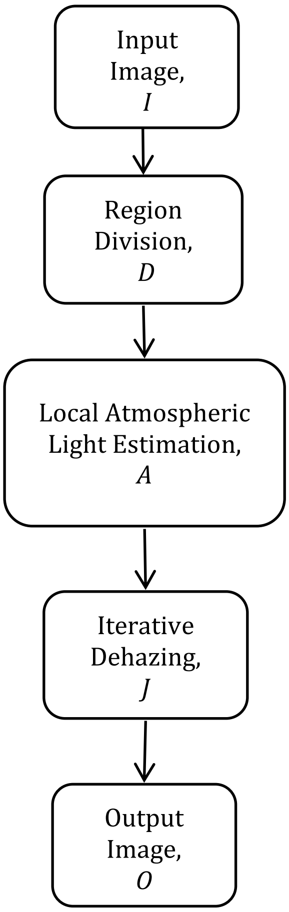


Fig-1 : Flow process of the novel dehazing method for color accuracy

3.1. Region Division

An input hazy image which is captured in the course of poor climate conditions do not always have a consistent haze density across the image. Here, first the input hazy image is converted to HSV(Hue Saturation Value) color space from RGB color space. In different regions of the image, the estimated atmospheric light values differs in accordance to the haze density. For each, the atmospheric light value is estimated. Then, white balance segmentation and bit-level processing are together used to split the regions and to merge the super-pixels of similar haze density.

The color distance of HSV color space is given by,

$$D_{hsv} = \sqrt{(h_u - h_v)^2 + (s_u - s_v)^2 + (v_u - v_v)^2} \quad (2)$$

Where D_{hsv} is the color distance and $u, v \in [1, N]$, N stands for number of pixels.

3.2. Local Atmospheric light estimation

When there exists a multiple point light sources for instance, the sun, automobile light and street light, then a single estimation for global atmospheric light is not valid. By taking both complexity of light sources and haze thickness into account, the local atmospheric light by the way of an alternative to the global atmospheric light should be estimated necessarily.

From the output image of the region division algorithm, the top 0.1percent brightest pixels are selected in the dark channel prior, which is a sort of statistics of the haze free images taken in poor climate condition. It is based on the key factor that most of the local frames in the haze free image, which are captured outdoors contain some pixels which have very low intensities at least in one color channel. Among these brightest pixels in the dark channel, the global atmospheric light is selected which is the highest intensity pixel in the dark channel. Using this approach, A_i obtained for each super pixel. Afterwards, local atmospheric light value is estimated by performing the maximum operation on a super pixel in a region. The formula is given by,

$$A = max(A_1, A_2, \dots, A_i) \quad (3)$$

Where, $i \in N^+$ and $A_1, A_2, \dots A_i$ are atmospheric light values of the super pixels in one region. A is local atmospheric light value.

3.3. Iterative dehazing algorithm

To dehaze an image using eq. (1), an appropriate transmission $t(x)$ and local atmospheric light A is necessary. There are correlation present between these two physical quantities as described in eq. (1). This algorithm is proposed to improve the estimation method of these physical quantities. Here, the output image of the first iteration is considered as an input hazy image to the second iteration. Then, the output image of the second iteration is considered as an input hazy image for the next iteration. This process is repeated until the image is regarded as a haze free image.
From [10], for the iterative dehazing algorithm, the initial conditions are set as,

$$J_0 = I \quad (4)$$

$$t_0(x) = 1 - \omega\left(\frac{J_0^c(y)}{A_m}\right) \quad (5)$$

Where I is the input hazy image, A_m (m=1,2,...) is the local atmospheric light, t_0 represents the initial transmission map. To make the scene look more natural, a little amount of haze is preserved for distant objects in an image, for that reason, a constant parameter ω is used. Color channel is represented by c and $c \in \{R, G, B\}$. Then, the formula for an iterative dehazing algorithm is given by,

$$t_n(x) = 1 - \omega\left(\frac{J_n^c(y)}{A_m^n}\right)$$
$$J_{n-1} = J_n \cdot t_{n-1} + A_m^n \cdot (1 - t_{n-1}) \quad n = 1,2,\ldots \tag{6}$$

Where, J_n represents the nth iteration of the haze free image and $c \in \{R, G, B\}$. A_m^n represents the local atmospheric light value of n^{th} iteration and t_n represents the transmission map of the n^{th} iteration.

Equation (4) and (5) are substituted into eq. (6), then, the haze free image J_1 is obtained in the first iteration. A_m^1 and t_1 which are the local atmospheric light and transmission map of the first iteration are also obtained. Next, the output image of first iteration J_1, becomes input hazy image for the second iteration, then, J_2, A_m^2 and t_2 are obtained as the output of second iteration. This course of action is continued until the image is regarded as a haze free image. The percentage of dark pixels P in the image is calculated at the end of every iteration. The iteration is stopped when $P > \varepsilon$ and the can be regarded as a output haze free image represented by O.

4. CONTRAST ENHANCEMENT METHOD FOR LOW LIGHT INTENSITY IMAGES

The flow process of the proposed contrast enhancement method for low light intensity images is shown in fig. 2 and it involves following steps: Invert the input image, Apply the dehazing algorithm and invert the dehazed image. This method shows that after inverting the input image, pixels in the background regions of the inverted low light intensity image, usually have high intensities in all color channels while those of foreground regions usually have at least one channel whose density is low. This is very similar to the image captured in hazy climate. Thus, a dehazing algorithm can be applied for enhancement to the inverted image. Finally, a good quality, clear and enhanced image is obtained by inverting the output of the dehazed image.

Let us assume $I(x)$ is an input image and is a low light intensity image. Where $x=(m,n)$, x represents the number of pixels across the height and y represents the number of pixels across the width. The expression for inverting an input image is given by,

$$Inv = {\sim}I(x) \tag{7}$$

Where Invert is denoted by Inv and $\sim I(x)$ is complementary image of input image. In the output image, light color areas appear dark and dark areas appear light. Colors are replaced by their reciprocal colors. Hence, green color areas appear in magenta color after inverting, Similarly, blue color areas appear in yellow color, red color areas appear in cyan color and vice versa. To the eq. (7), the dehazing method D is applied. It is given by the formula,

$$D(x) = \frac{(Inv) - A}{max(t(x), t_0)} + A \tag{8}$$

Where Inv is inverted image of input low light intensity image, $t(x)$ represents transmission map, air light A is set to 255. The value of t_0 is set to 1. Next, the dehazed image D, is considered as input image and then eq. (7) is again applied by replacing $I(x)$ by D which is invert formula.The output of Inv is regarded as the output image O.

$$O = {\sim}D(x) \tag{9}$$

Where $D(x)$ represents the Dehazed image, $\sim D(x)$ represents inverting of dehazed image and O represents the output Enhanced image.

Fig. 3 illustrates this process. As illustrated in the fig. 3, an input (a) is a low light intensity image denoted by $I(1080x1920)$, where 1080x1920 is the size of the image and (b) is the inverted image denoted by Inv and is obtained by inverting the input image I. The dehazed image denoted by D is (c), It is obtained by applying dehazing algorithm on the inverted image Inv. The final output image is denoted by O is (d), it is obtained by inverting the D, which is a dehazed image. Then, this output image is regarded as an enhanced image which is more clear than the input image.

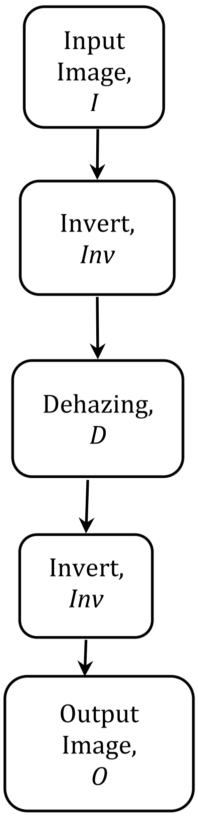


Fig-2 : Flow process of contrast enhancement method for low light intensity images

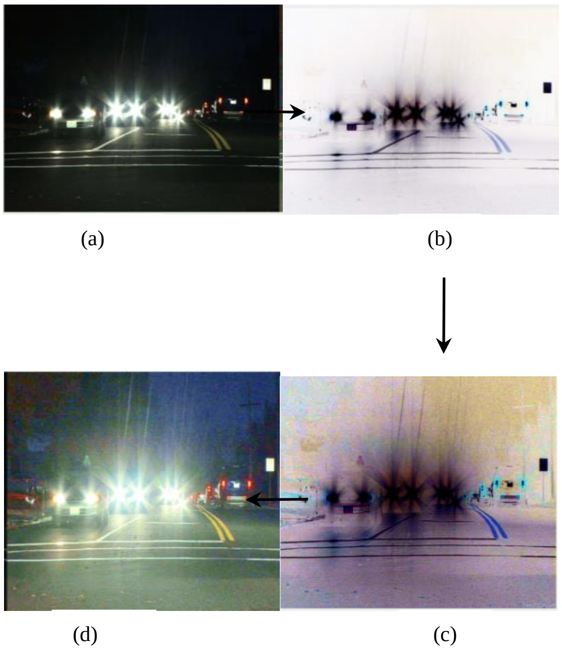


Fig-3 : Illustration of contrast enhancement method on a *m* x *n* low light intensity image: (a)The low light intensity input image, *I*. (b)The inverted image of input, *Inv*. (c)The dehazed image, *D*. (d)The final output image, *O*.

5. EXPERIMENTAL RESULTS

The performance of the proposed novel dehazing method and the proposed contrast enhancement method are demonstrated in this section. The experiments are conducted in MATLAB. When the code is run, a menu opens and asks the user to choose between Dehazing mode and Enhancement mode.

5.1. Results of a novel dehazing method for color accuracy

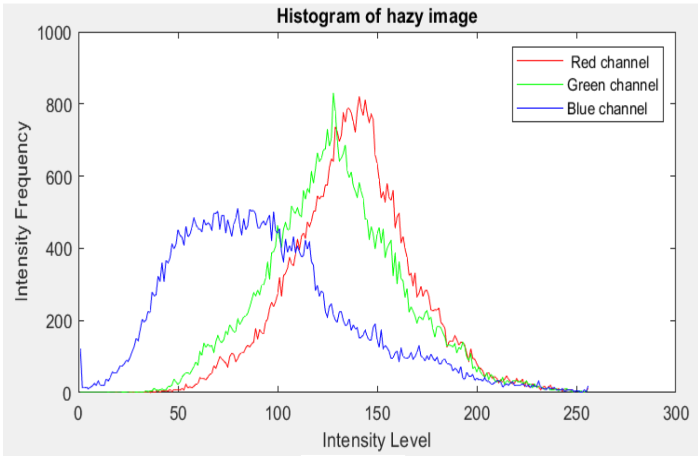
The following fig. 4-6 demonstrates the outcomes of the proposed novel dehazing method. The input hazy images and the output haze free images are at the left and right side of the result respectively.

From the fig. 4-6, which gives the results of the proposed novel dehazing algorithm, it is clear that the proposed novel dehazing method effectively eliminates the haze and improves the visibility of the haze free image.

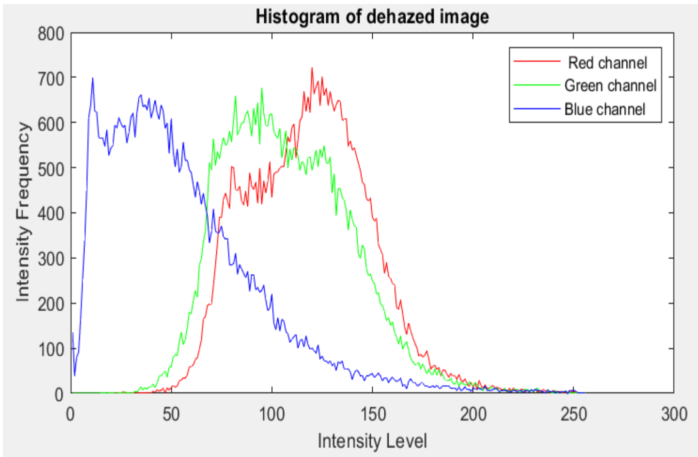
The fig. 4.1, 5.1 and 6.1 shows the Color Histograms of respective input and output images. The color histograms presents the color characteristics of the image. The color histogram distribution becomes more even and are enhanced in color intensity after the haze removal. Hence, the hazy and haze free color histograms should be structurally similar.

Input Output

Fig-4 : Image Dehazing result of park image



(a)



(b)

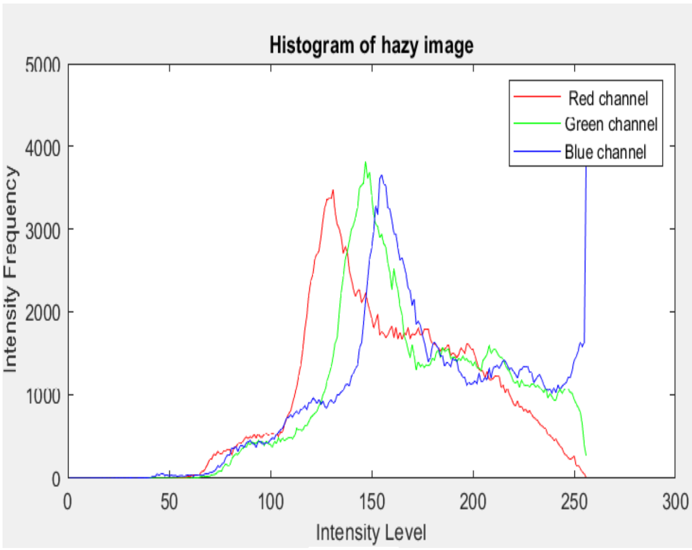
Fig-4.1 : Histograms of park image. (a)Hazy input image. (b)Dehazed output image.

Input Output

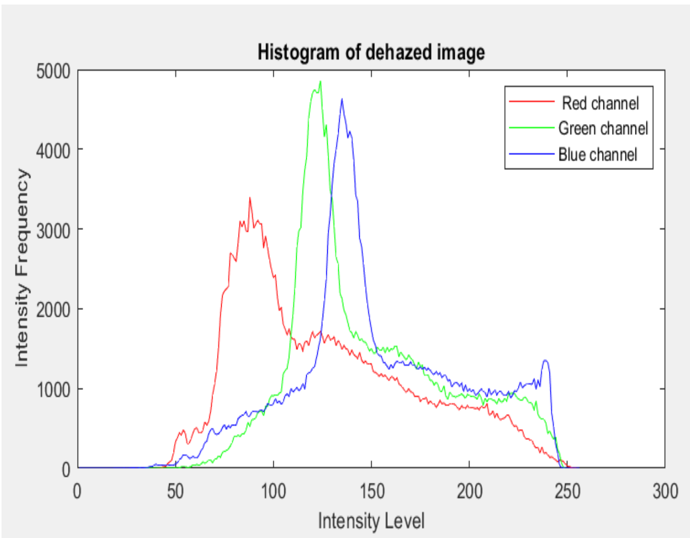
Fig-5 : Image dehazing results of road image.

Input Output

Fig-6 : Image Dehazing result of Forest image.

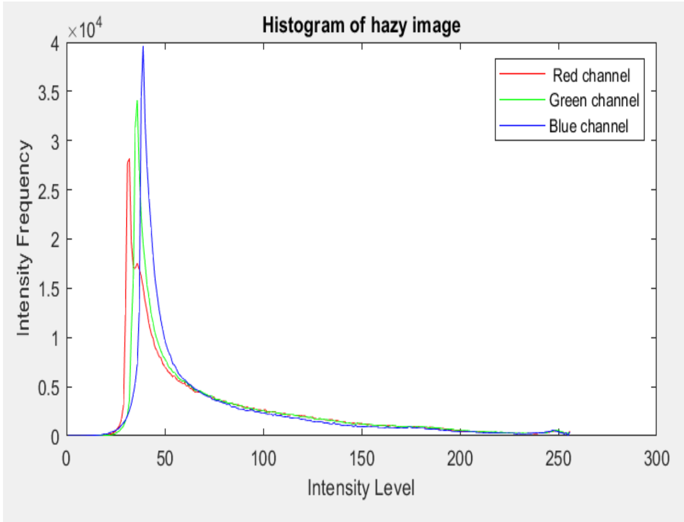


(a)

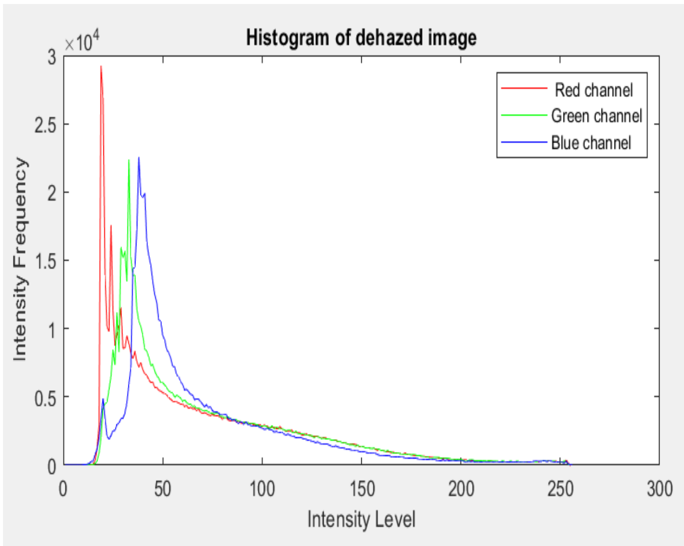


(b)

Fig-5.1: Histograms of road image. (a)Hazy input image. (b)Output dehazed image.



(a)



(b)

Fig-6.1 : Histograms of forest image. (a)Hazy input image. (b)Output dehazed image.

Table-1 presents the comparison between the visibility metric of input Hazy and output Haze-free images for fig. 4-6. As shown in Table -1, the visibility metric of the input image in fig. 4 is 113.2086 and after applying the proposed dehazing method, the visibility metric increased to

184.377. Similarly, the input image visibility metric of fig. 5 and 6 was 63.5884 and 187.1041 respectively and their respective visibility metric of output images increased to 134.6573 and 246.7837 respectively. Based on the reading in Table -1, it is clear that the proposed novel dehazing approach increases the visibility of the image.

TABLE -1 : COMPARISON OF VISIBILITY METRIC OF HAZY AND HAZE-FREE IMAGES

Image	Image Size	Visibility Metric		Increment in visibility metric
		Input Hazy Image	Output Haze-free image	
Park	194x259	113.2086	184.377	71.1684
Road	400x600	63.5884	134.6573	71.0689
Forest	662x1000	187.1041	246.7837	59.6796

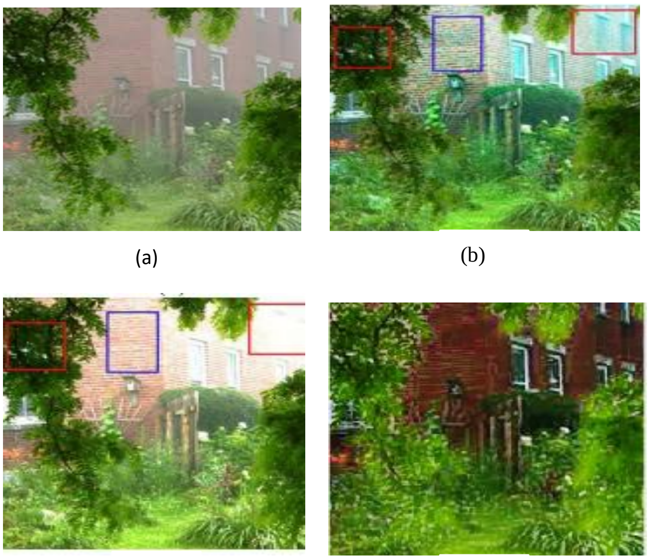


Fig-7 : Comparison of results on house image. (a) Hazy input image. (b)Meng's method output. (c)Gibson's method output. (d)Proposed novel dehazing method.

The image above used to compare the results of various methods is of size 223x226 and is shown in fig. 7. The proposed novel dehazing method is compared with Meng's approach and Gibson's approach. Fig. 7 (b) and (c) suffer from color shifting and also contains some artefacts. The proposed method clearly removes the haze without any color shift.

TABLE -2 : COMPARISON OF ELAPSED TIME

Method	Elapsed Time (s)
Gibson's	0.6616
Wang's	5.4169
Jeong's	2.9743
Fattal's	0.9685
Proposed	0.6428

Table -2 presents the comparison of Elapsed time. The duration from when the process started until the time it terminated is Elapsed time. By studying the above table of the elapsed time, it is clear that the elapsed time of the proposed novel dehazing method is competitive with those of other methods.

5.2. Results of contrast enhancement method for low light intensity images

The following fig. 8-10 shows the results of the proposed enhancement method. The images on the left are input low light intensity images and the images on the right are enhanced output images.

From the fig. 8-10, which shows the results of the proposed enhancement method on low light intensity images, it is clear that the proposed method enhances the low dynamic range images, it increases the quality of the image and makes it stand out more clearly

Input Output

Fig-8 : Enhancement method result on River image of size 667x1000.

Input Output

Fig- 9 : Enhancement method result on Road image of size 667x1000.

Input

Output

Fig-10 : Enhancement method result on Lion image of size 530x800.

6. CONCLUSION

A novel dehazing approach is presented in this paper in favour of the color accuracy of the images taken on the smart phones or digital cameras. And a contrast enhancement method is proposed for the low light intensity images. The proposed dehazing method first performs region division based on white balance segmentation and bit-level processing. Then local atmospheric light is estimated in each region. Finally, iterative dehazing is performed until the image is haze free. The proposed enhancement method first inverts the low light image, then performs the dehazing on the inverted image and again inverts the result of the dehazing image to obtain the enhanced image. Experimental results indicates that the presented novel dehazing method and enhancement method can be applied to the extended areas of image processing and are computationally efficient.

ACKNOWLEDGMENT

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