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ADVANCED DEHAZING OF REMOTE SENSING IMAGES WITH GRAY WORLD OPTIMIZATION AND FAST ITERATIVE FILTERING

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Abstract
Generally remote sensing images are in hazy conditions such as fog, snow, thin cloud, dust etc., which results in contrast degradations in image. Dehazing is defined as the technique for the removal of haze or atmospheric impurities from an image to increase the quality of an image and to make it more pleasant to the client. But most of the state of art approaches failed to remove the atmospheric effects from the image perfectly. To solve this problem, this paper majorly focuses on the development of gray world optimization (GWO) algorithm is developed for the perfect estimation of atmospheric light. The work also develops the novel method for dark channel prior based transmission map estimation and refinement in the pixel wise and patch wise manner. Thus, the atmospheric effects are resolved in each pixel-based patch. Finally, to obtain smoothen output with dehazing properties, a fast iterative domain guided image filtering (ID-GIF) approach was developed. The simulation results show that the proposed work provides better quantitative and qualitative results compared to the state of art approaches.

Keywords: Satellite image dehazing, iterative domain guided image filtering¸ gray world optimization.

1. Introduction

Haze [1] is basically a natural weather process having a mixture of air light and attenuation process. On one hand, air light is responsible for increasing the whiteness in image and on the other hand attenuation decreases the contrast in image. The terms haze and fog are different from each other because haze is thick and transparent, whereas fog is thin and translucent. There are different haze removal techniques [2-3] for single image and multiple images. It is a matter of fact that the single image is more informative and accurate than multiple images and it contains all the necessary description. The methods used for single image are: contrast maximization technique [4], independent component analysis [5], dark channel prior [6] and antistrophic diffusion [7]. In the mechanism using fusion, they require more than one initial value from the unique image with the amendment of fair equilibrium and intensity level improving or increasing technique [8]. Image blending finds its applications in larger areas like in medical diagnostic, magnetic resonance image, and computed tomography or in remote sensing: herbal images, IR images, UV images [9]. With the help of image fusion, the given images are fused with each other to form a desired image whose quality is far better than any of input images. The different filters that are available for filter based dehazing [10] are local filters: bilateral filter, guided filter, and global filters: weighted least square.
Local filters have disadvantaged of less efficiency and halo artifacts. Halo artifacts introduces blur in digital images. So, global filters were introduced to remove halos artifacts and to preserve edges at the cost of high computational time and high expenses. This paper describes all the above-mentioned methods in detail. We will also conclude that which method is best for haze removal [11]. Remote sensing is basically defined as an art or technique to gather or acquire facts regarding earth devoid of any type of corporeal contact with it, this procedure of acquiring data depends upon the procedure of observing and recounting the total of imitated and extruded energy [12]. The practice of remotely observing consists of contact among the arriving energy and the target of interest. Remote sensing

occurs because of the factors [13] like energy source, atmosphere and radiation, intercommunication among the object and recounting of the imitated energy, transmission and ground level processing, interpretation, analysis and application. When the image is taken from a sensor then the quality of image is degraded due to presence of atmospheric impurities like moisture, dust, smoke, water droplet etc.

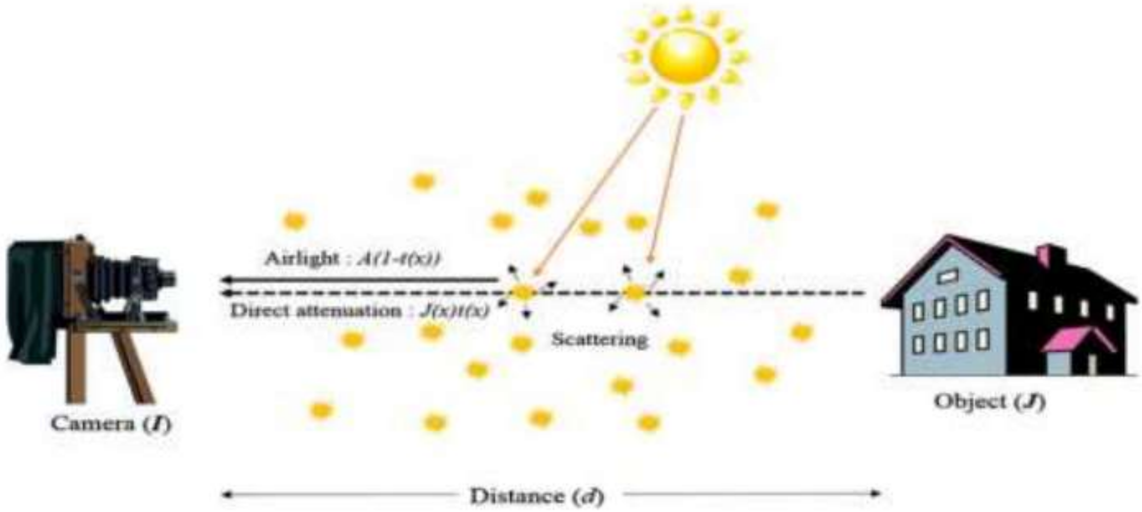

Figure 1: haze image creation

These factors [14] bring in air pollution which is named as haze. The presence of haze leads to the phenomenon of scattering of light before reaching at the receiving end of the other sensors. Due to the presence of these atmospheric impurities other systems like self-regulating supervising structure, identification scheme for outdoors and intelligent transport systems are badly affected. These atmospheric particles are within the range below of 1000m as shown in figure 1. There are two elementary phenomenon's which arise due scattering known as attenuation and air light. Haze is basically the mixture of these two factors, attenuation leads to decline in the contrast (intensity) of an image whereas air light leads to rise of whiteness in a scene. The solution to this issue is we can use certain haze removal algorithms [15] to reduce the attenuation or to hike the steadiness and sturdiness of vision arrangement. To solve this problem the contributions of this paper as follows.

- A novel transmission mapping and refining methodology has been developed with the use of dark channel prior to solve the atmospheric effects.
- The atmospheric light estimation is carried out by using the novel gray world optimization algorithm, it is effectively calculating the haze under various atmospheric environments.
- Finally, to enhance the image and to achieve the smoothening properties, iterative domain guided image filtering approach was developed.
- The simulations are carried out on both synthetic and real-time dataset such as satellite hazy images, synthesized hazy images and natural hazy images with indoor and outdoor databases. The results shows that the proposed method provides the better visual quality of output image and also provides the enhancive quality metrics compared to the various literatures such as ID-CNN [19], IDERS [29] and TME-MOF[25] respectively.

The rest of the paper as follows: section deals with the survey of various related works and identifies their problems. Section 3 deals with detailed analysis of the proposed methodology with mathematical analysis. Section 4 deals with detailed proposed simulation and comparative analysis with various existing works and finally section 5 concludes the proposed method with possible future enhancements.

2. Literature survey:

Many methods have been advised to remove haze from an image having single dominated light, especially in the daytime. But these approaches are not appropriate for images having non-uniform illumination of light i.e., at nighttime. There are very few methods that address nighttime dehazing. In [16] authors have provided a technique for visual renovation from solo image which is rooted by the technique using different filters. The method is dependent on the precise operations, and it requires certain guidelines for modification. The benefit of this technique is momentum that agrees to this technique to be used in real time applications.

In [17] authors have recommended a new fast dehazing technique based on the atmospheric dissipation imitation. In this paper they firstly acquired the coarse nearness of the atmospheric veil, the smoothening of the coarser computation with the help of new agile bilateral filtering technique that is preserving fringes. The complexity is just the linear function. In [18] authors have specified a new agile fog elimination dehazing mechanism for numerous images in regular dreadful climate circumstances is if relay on full of atmosphere dispersion form. In this paper they have provided a solution to deal with the transmission and global air light via an equation which is to be applied on a local hazy area and this algorithm works effectively to reduce the haze in an image. In [19] authors have provided a uncomplicated but proficient technique with the intention of eliminating fog on the image. This technique is useful for reducing blueness from a solo input provided. This approach is used for the measure of statistics of the outdoor fog free image. He et al performed an experimental examination on the attributes of the images without the presence of any kind of fog. In the experiment it is recorded that they lay certain shady image elements and these shady image elements can be accustomed to provide the estimation of smog conduction. This method can be used to find the thickness of haze. In [20] authors have presented a fast and physical scheme derived from DCP method. By using this technique, we can easily extort the parameters or factors like overall distinctive illumination and also leds to a near approximation of the distinctive veil with the shady conduit of the feeded foggy image. After extracting these parameters, we can further use the filter. In most of the cases we achieve good results as compared to other techniques.

In [21] authors have discussed regarding removal of error known as dehazing. In the given paper they have used simple and adaptive image fog elimination technique, the provided article majorly focusses on the enhancing the intensity level of the output received. In [22] authors have provided a fog removal algorithm to re-establish tint and dissimilarity of an image. In this paper they have provided certain techniques which are low and high pass filters, and another is a hue intensity saturation (his) model along with homomorphism filter and at the last masking with histogram equalization. This method provides better results and removes fog in an appropriate manner. In [23] authors have provided a technique for the removal of haze [19-21] in an image, in the given paper they have worked on dark channel prior technique in combination of gradient prior law. In this proposed method they have worked on improving profile of an image as well as keeping the fine points of a portrait in an accurate order. In [24] authors have proposed a colour transfer technique that transforms night-time haze image which is used as an input into a greyish image by mapping colons of night-time haze images with daytime haze images. With this approach, there is much improvement in visibility, but the final results are not great as the colours in the final output image are not realistic. Without using any physically valid model, colour transfer changes colours. Another model called the imaging model for night-time haze is proposed by Zang et al.‟s [3]. This includes dehazing, colour correction, and spatially varying illumination compensation. The results obtained by this method are more realistic than that of [2], but still, the problem is in glow effect, which can be easily noticed in the output. This method also contains variety of further improvised post processing steps like histogram stretching and gamma curve correction to reinforce the ultimate result.

In [25] authors have altered the atmospheric scattering model to model the glowing effect inside the light regions by adding an atmospheric point spreading term. By employing a layer separation algorithm, their model breaks down the glow from the hazy image. Their results accommodate fewer glow artifacts, but the output images look unnatural because the model is susceptible to cause excessive improvement of the light-source area. In [26-27] authors have introduced a maximum reflectance prior wherein by assuming the utmost intensities at each color channel have the worth of 1 in daytime haze -free images, they estimate the ambient illumination and for estimating transmission to recover haze-free image, DCP [3] is applied. In [28] authors have estimate the ambient illumination by employing a maximum operator on local patches and then multi-scale dark channels are fused alongside a Laplacian pyramid. To generate the weighting maps, Saturation and Contrast features are used. Existing methods of nighttime dehazing have achieved improved results. Nonetheless, these methods fail to estimate ambient illumination precisely. In daytime dehazing, they simply extend the brilliant pixel method in a local manner. Also, the ambient illumination is extremely near to the bright pixels within the sky region as per the atmospheric scattering model [29-30]. So, considering the situation at nighttime, the local bright pixel cannot be used to calculate ambient illumination because nighttime images do not contain sky regions. Also, a well-known dark channel prior cannot be used because there is no dark channel present in the light source region.

3. Proposed method:

Dehazing is defined as a technique for the removal of haze or atmospheric impurities from an image to increase the quality of an image and to make it more pleasant to the client. To eradicate this deprivation of figure a variety of haze elimination techniques are engaged to improve the excellence of an image. The haze can be removed via image restoration and image enhancement. The technique of image enhancement deals with the enrichment of the contrast (intensity) of an image whereas image re-establishment investigates the substantial procedure of imaging in fog. Dehazing is taken as a significant mechanism as the attenuation or fog free images are perceivably satisfying and it can perk up the computer vision tasks and client photography. The block diagram representation of an image dehazing method used in the proposed algorithm is shown in figure 2. It consists of mainly two broad steps: transmission map estimation and atmospheric light removal. The detailed operation of each stage as follows

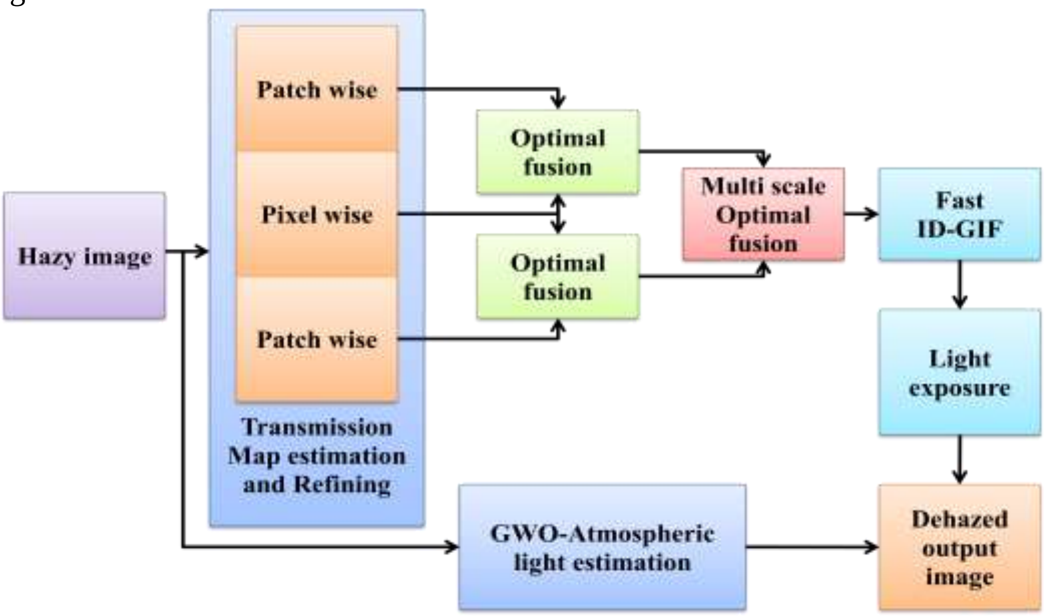

Fig 2. Proposed hybrid dehazing method

3.1 Transmission map estimation and refining

The components like attenuation and air-light can be interpreted with the help of the succeeding mathematical statement according to koschmieder's law as follows:

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

Here, $I(x)$ refers to the hazy image, $J(x)$ is the scene radiance or haze-free image respectively. A denotes the value of the climatic light such as global atmospheric light, and t is denoted as the communication medium that specify the segment of illumination which will neither be dispersed and grasp the receiving image sensor or camera. The part of mathematical statement $J(x) * t(x)$ is known as directed depletion and the other part of the equation $A * (1 - t(x))$ is named as air-light. And $t(x)$ is the transmission map with x as the image spatial coordinates is given by (2)

$$t(x) = e^{-\beta\, d(x)} \qquad (2)$$

Where β is the atmospheric scattering coefficient ($\beta \approx 0$ in case of clear weather condition) and d is the scene depth. The first term $J(x) * t(x)$ in eq. (1) defines a direct attenuation of the scene radiance which decreases exponentially when the scene depth increases. In contrast, the second term $(1 - t(x))$ which is called the atmospheric light increases with the increasing scene depth.

In contrast to haze-free images, hazy images are brighter due to the additive atmospheric light and low transmission map. The dark channel of a hazy image is a good approximation of the thickness of the haze since it owns the high intensity values in the highly dense haze regions. Therefore, this property is used to determine atmospheric light and transmission map. Transmission map estimation on the hazy input image will be performed by pixel wise and patch wise manner. A transmission map gives the extent of light reaching the camera in a degraded image. The dark map derived out of red channel prior is used to obtain this transmission map. This is the main clue as to determine the extent and depth of the hazy image and light transmission in an image formation process. We obtain the equation for transmission map. In this equation, we introduce a constant parameter α. The equation used for obtaining the transmission map generated by using the dark channel prior is given by

$$t_{pa}(x) = 1 - \alpha \min_{y \in \Omega(x)} \left[\min_{C \in [r,g,b]} \frac{I^c(y)}{A^c} \right] \qquad (3)$$

Here, $t_{pa}(x)$ is the patch based transmission map, $\Omega(\boldsymbol{x})$ is a local patch centered at $\boldsymbol{x}$ and I^c is a color channel of I. min $\boldsymbol{y} \in \Omega(\boldsymbol{x})$ is a minimum filter and min $c \in \{r,g,b\}$ is performed on each pixel in the RGB space. The selection of parameter α is chosen to preserve some amount of haze so that the output image looks natural. A higher value of α results into the complete removal of haze making the image look unrealistic and exhibits colour distorted image whereas the lower value of w results into lower intensity image and makes it darker. The value of α ranges between 0 and 1 in an normalized image. Here, the image is divided into three transmission maps such as two patch wise and one-pixel wise transmission map. Here, the α is used to change the pixel intensities and Ω is used to change the patch size based on the user requirement respectively.

The I^c is a shading channel of j and $\Omega(x)$ is a local patch focused at x. Dark channels are processed utilizing a various patch sizes 3×3, 15 x 15 and more. Not many insights are given to characterize the patch size: the probability that patch contains dark pixel is increased with respect to bigger size. In this manner, dark channel could be precisely evaluated. In any case, with an enormous patch, the supposition that the transmission is steady in a patch turns out to be less proper and the hollow artifacts near depth edges become increased. Most transmission mapping based dehazing strategies figure the dark channel by essentially utilizing a local patch with a fixed size to fundamentally diminish the computation time and it also performs the operation by using pixel wise manner.

A portion of the transmission mapping based lining up strategies think about a patch with an alternate size from 15×15, which was fundamentally utilized. The patch size can be progressively adjusted dependent on the image content. In genuine over-satiation impacts happen in the recovered scene radiance when a little patch size is utilized in the first cloudy image including limited light. This prompts a disappointment in the recognizable proof of the environmental light source. Bigger size can resolve this issue, yet it prompts to halo effects and black artifacts, particularly along edges. In this manner, two patch sizes of 3×3 and 45×45, which are tentatively recognized, have been utilized in a procedure of transmission mapping.

Incorrect estimation of the transmission map may prompt a few mutilations, for example, square antiquities. The patch-based dark channel figuring prompts a foggy transmission map. This is

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fundamentally because of the presumption that t is a consistent incentive in a local patch. This isn't in every case genuine, particularly when the patch contains a sharp edge. This off-base supposition prompts clear edge artifacts. So as to get a refined map, numerous strategies have been utilized.
Refinement of transmission map: on account of the pixel-based operation, the transmission map generated appears pixelated. If used as it is in the eqn. (1) to recover the scene radiance, the final Dehazed image will thus look pixelated. This transmission map has to be smoothened. It can be observed that dark channel of hazy image is not dark whereas same dark channel image in case of a clear image is relatively darker. This image of whiteness which is observed in the dark channel image of hazy image is utilized to derive the depth map. Transmission map is inverse of dark channel image. This transmission map corresponds to the amount of light that travels from the object and reaches the camera plane in the presence or absence of haze. More the haze in the propagation path less is the amount of scene information reaching the camera and darker is the transmission map.
These improving calculations have been applied legitimately on the transmission map. Notwithstanding, different calculations apply a pre-preparing upgrading calculation to the foggy image so as to forestall the transmission map from obscure and incorrect surfaces. The main purpose of the image haze model is to obtain $J(x)$ from $I(x), A$ and $t(x)$. The $J(x)$ is derived from eq. (1) which is given by equation (3)

$$J^c(x) = \frac{I^c(x) - A^c}{t_{pa}(x)} + A^c \qquad (3)$$

The global atmospheric light A^c and transmission map $t_{pa}(x)$ are determined from the pixel and patch wise estimation. The evaluation of the dark channel is based on the property that the dark pixels of the haze-free images except sky regions have intensity value close to zero in at least one colour channel within an image various patches. The low intensity values in non-sky regions are occurred due to shades of roadside cars, buildings, leaves, trees and colourful and dark objects or surfaces. Thus, the dark pixel intensity value at the spatial location in an arbitrary image $J^c(x)$ is determined by using equation (4)

$$J^{dark}(x) = \min_{y \in \Omega(x)} \left[\min_{C \in [r,g,b]} J^c(y) \right] \qquad (4)$$

Therefore, the pixel intensity value in the dark channel image $J^{dark}(x)$ is defined as the minimum intensity value in (x) among three channels {r, g, b}. If $J^c(y)$ is the haze-free image then equation (5) indicates, there will be decrement of dark pixels and tentative to zero.

$$J^{dark} \rightarrow 0 \qquad (5)$$

3.2 Atmospheric light estimation:
The main idea behind the estimation of the atmospheric light A is to detect most blurred region in the hazy image. This region is detected with the help of Transmission map estimation since as stated above; it provides a good estimation of the haze thickness. First, the top 0.1% bright pixels of the dark channel of a hazy image are determined. Then among these pixels, the highest intensity pixels in the input image are located. In fact, these pixels compose the most blurred region and are considered as an atmospheric light. It is the method of removing additional and unrealistic colour casts produced by the environment. In atmospheric environment due to scattering and wavelength selective absorption, additional colour casts are introduced. The most common and widely used atmospheric light estimation algorithm is gray world theory. The brightest pixels in the hazy image are the most haze-opaque, if and only if, the weather is overcast, and the sunlight denoted by s is ignored and only the atmospheric light is considered.
This operation mainly focuses on the estimation of air light values for generation of transmission matrix. In the first step color image is converted into three indexes such as red, green, and blue color channels such as $\{A^R, A^G, A^B \in A^c\}$. Then extract the low intensity pixels by using the color division approach, for satellite images cluster count will be more and vice versa for normal images. Then the clusters must be rearranged for the new transmission map estimation. Depending upon the air light values these clusters will be divided into three weight of each color channels (W_R,W_G and W_B). Then

air light values (A_R, A_G and A_B)) will be generated based on updating of old air light values as show in Figure 3. In this work, shade of gray world optimization algorithm based on the minkowski normalization is used to perform Atmospheric light estimation process. The minkowski norm is used to normalize the result and to form the estimated illuminated image. Minkowski norm computes a weighted mean of the pixel values and allots higher weights to pixels with higher intensities. This algorithm is based on the property that average colour of the image is gray. These conditions do not hold by the hazy images, because as the depth of the sky increases the red channel of the image attenuates faster than the other colour channels. The weight function proposed by this algorithm is based on the minkowski-norm, and it is defined using the following formula:

$$W_R = (\sum\sum((I^R(x))^P . M)^{\frac{1}{P}} \quad (6)$$

$$W_G = (\sum\sum((I^G(x))^P . M)^{\frac{1}{P}} \quad (7)$$

$$W_B = (\sum\sum((I^B(x))^P . M)^{\frac{1}{P}} \quad (8)$$

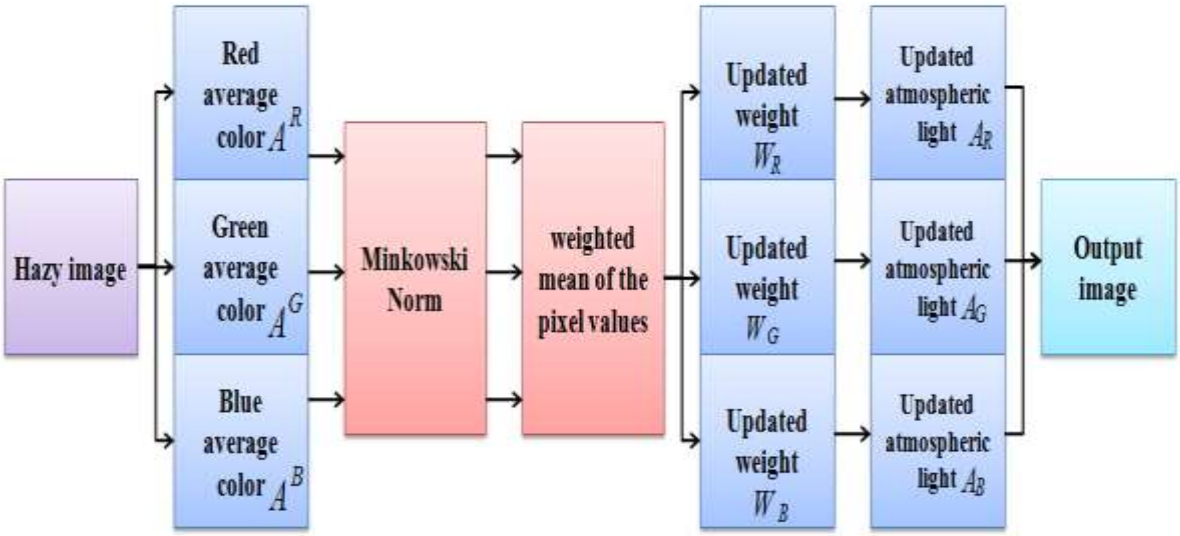


Figure 4: Process of Atmospheric light estimation

Here, $I^R(x)$, $I^G(x)$and $I^B(x)$ represent the red, green, and blue channels of the red hazy image. M represents a mask which contains atmospheric light saturated pixels. "P" represents the minkowski norm. Shades of gray algorithm give the best result when the value of p is equal to 6. And W_R,W_G and W_B, are enhanced red channel, green channel and blue channel weights respectively.

$$S = \sqrt{(W_R{}^2 + W_G{}^2 + W_B{}^2)} \quad (9)$$

Here, S is the root sum square of Wr, Wg and Wb indicates weighted mean of the pixel values. Then atmospheric light channels are normalized using S and weights and generates the new atmospheric light levels as follows:

$$A_R = \frac{W_R}{S}, A_G = \frac{W_G}{S}, A_B = \frac{W_B}{S} \quad (10)$$

Here, A_R , A_G and A_B represent Updated atmospheric light red channel, green channel, and blue channel respectively. Finally, the proposed algorithm calculates the light enhanced output image by using three colour channels o as follows:

$$I_{new}{}^R = \frac{I^R}{A_R.\sqrt{3}}, I_{new}{}^G = \frac{I^G}{A_G.\sqrt{3}}, I_{new}{}^B = \frac{I^B}{A_B.\sqrt{3}} \quad (11)$$

3.3 Multi-scale optimal fusion dehazing model

Multi-scale fusion technique is used to improve the visibility of poorly illuminated areas by using multi-scale fusion-based strategy. The fundamental principle of this method is extracting the best pixel and patch features from the Transmission map estimation and refined image and then to apply the estimated perceptual based qualities called weight maps to them and finally fuses them together to form the enhanced output. In the fusion-based strategy, three inputs derived from the single image will be by two patch images and one-pixel wise image by using estimation of three weight maps is done. One is exposedness weight map, which measures the exposedness of pixels not exposed to atmospheric constraints. Laplacian weight map assigns high values to textures as well as edges. Colour cast weight map, introduced newly, increases red channel value thereby reducing colour cast. Saliency weight map measures the amount of discernible concerning other pixels. These weight maps are computed and applied to both the derived inputs. This method is a per pixel implementation. Fusion is a process of combining the relevant information from a set of input images into a single image, where the resultant fused image will be more informative and complete than the input images. In this work, there are three weight maps based on luminance channel and one based on chrominance-red channel. The effective weight map from the three weight maps are combined by averaging the weight map values as mentioned in following equations

$$W_{avg}{}^{k} = \frac{1}{N}\sum_{i=1}^{N} W_i{}^{k} \qquad (12)$$

$$W_{norm}{}^{k} = \frac{W_1{}^{k}}{\sum_{i=2}^{N} W_i{}^{k}} \qquad (13)$$

as a result of this operation, two weight maps are obtained for each derived input. Two colour cast weight maps from the derived inputs are considered separately. Then these weight maps are normalised as shown in equation (13). These are the two normalised weight maps for luminance and chrominance-red channel respectively. Finally they are fused using luminance channel and chrominance-red channel to obtain the fused image.

$$t_{mof}(x) = W_{avg}{}^{k}(x).\, t_{pi}(x) + W_{norm}{}^{k}(x).\, t_{pa}(x) \qquad (14)$$

3.4 Fast iterative domain GIF:

Smoothing of the output image takes place with the help of guided filters in several dehazing techniques. Some others have utilized rather than the bilateral filter, which is fundamentally the same as guided convolution, however pixels are dealt with dependent on close by area and comparative qualities. Guided filter is a smoothing channel with edge protecting properties and it has a superior activity close to edges. Since the use of the soft matting, this has been utilized in the transmission refining strategy.

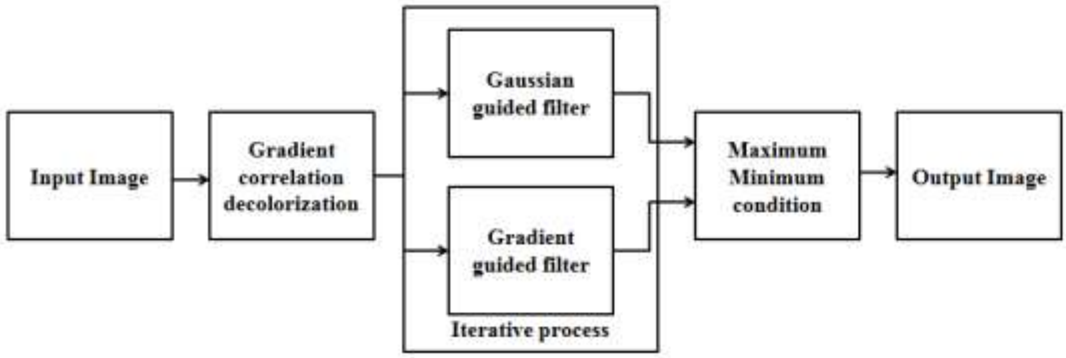


Fig 5.process of Fast iterative domain GIF

In Fast ID-GIF as shown in figure 5, de-colorization operation will be performed to remove the white levels or else here excessive color levels will be removed. For this purpose, three methods can be suitable such as Gradient correlation, state contrast preserving de-colorization, RGB to gray conversion. Among these three methods Gradient correlation de-colorization performs effectively because it provides the combined properties of pixel and patch transmission mapping. Here global and local contrasts are generated using image adjust methodologies. Global contrast will modify patch level image properties, local is for pixel level based on three new contrast levels, new color composites operations will be performed with respect to both x and y direction in the matrix. Initialize the iterative environment and generate the new kernel matrix for every iteration. Thus, every time updated kernel matrix will be convolved with the Gaussian guided filter and gradient guided filters. The maximum and minimum conditions will be applied on both filters by using absolute concept. After applying the maxima-minima conditions, the resultant output image will be generated by using the best properties of each filter patch respectively.

3.5 exposure enhancing:

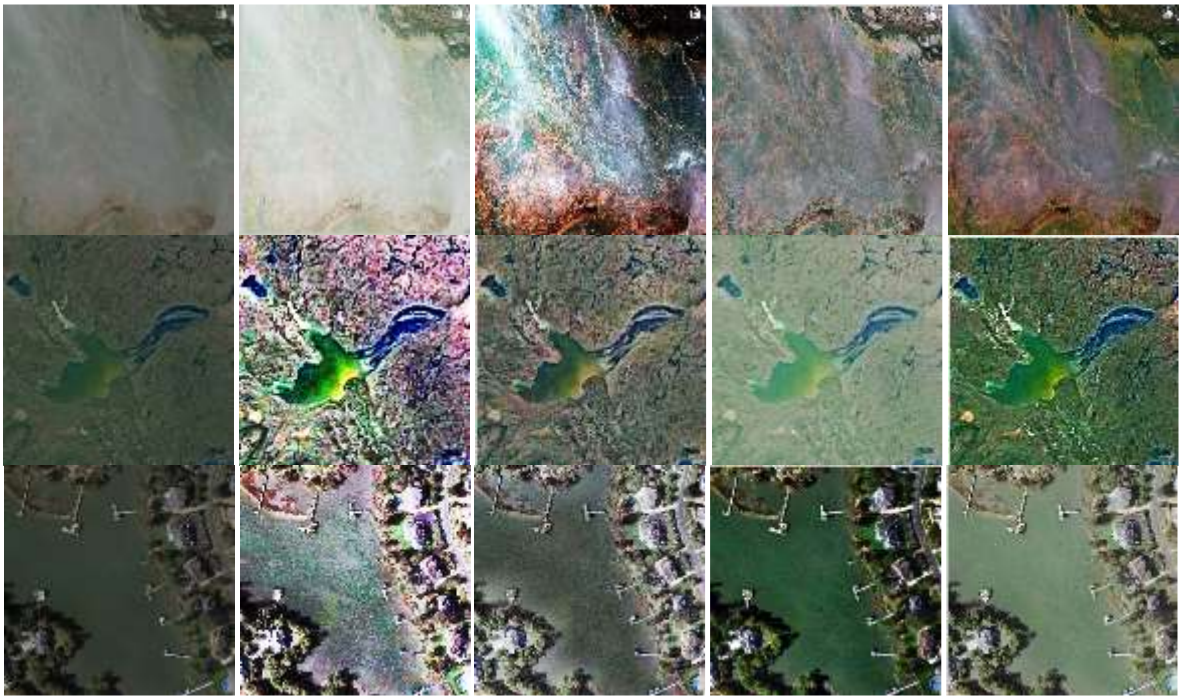
Light temperature is increased or decreased when compared with original image will be identified in this step for further enhancement operations. By applying the light exposure or low light image enhancement concept light levels will be automatically adjusted. Within the image only the mid value is considered then it is adjusted to middle value only, finally results in the light enhanced output image.

4. Simulation results:

This section deals with the detailed analysis of the simulations on various datasets. For evaluating the performance of the proposed work the three kinds of datasets are considered they are satellite, synthesized and natural hazy images. The qualitative and quantitative evaluation of proposed work is compared with various state of art approaches such as ID-CNN [19], IDERS [29] and TME-MOF [25]. We equate our results with other reference approaches, followed by our subjective analysis. On both synthetic and specific benchmark images Dehazed outcomes are compared to our process with traditional methods.

4.1. Evaluations on satellite hazy images

In the satellite dataset, totally 140 images are considered for the simulation. This is the remote sensing image dataset, so by performing the experimentations on this dataset, effective haze removed outcomes will generate. The resultant output images will be useful for further hyper spectral image segmentation and classification.



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

Figure 6: (a) satellite input images (b) ID-CNN [19] (c) IDERS [29] (d) TME-MOF [25] and (e) proposed Dehazed image

From the figure 6, it is observed that each row represents experimentations on individual images and columns are the Dehazed output images of proposed and existing works respectively. From the figure it is observed that, the existing works are failed to remove the haze from input images, and the

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existing works are suffering with the colour casting (increasing) problems. Thus, it will cause to eliminate the important data of remote sensing satellite images. And finally the proposed method generates the perfectly Dehazed output image with perfect colour levels.

4.2. Evaluations on synthesized hazy images

The second categories of datasets are manually synthesized from hazy images, for these purpose 250 images are considered for experimentation. So from this experimentation, the performance of the proposed method can be effectively analyzed, and subjective quality will be used as the reference standards.

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

Figure 7: (a) synthesized input images (b) ID-CNN [19] (c) IDERS [29] (d) TME-MOF [25] and (e) proposed Dehazed image

From the figure 7, it is observed that each row represents experimentations on individual images and columns are the Dehazed output images of proposed and existing works respectively. From the figure it is observed that, the existing works are suffering with the contrast and brightness based problems, hence the existing works are failed to remove the haze from input images. And finally the proposed method generates the perfectly Dehazed output image with appropriate brightness, contrast, saturation and hue levels.

4.3 Evaluation on natural hazy images

In the natural image datasets, there are two special kinds of scenarios are captured using the high definition cameras and totally 400 images are captured. The two scenarios are results in the indoor dataset and outdoor dataset respectively. This datasets are useful specifically for the analyzing the performance of the proposed method under various atmospheric light scenarios. As the atmospheric light changes, the proposed haze removing capacity of various works changes differently. Thus this experimentation gives the detailed analysis of atmospheric light environments of indoor and outdoor scenarios. As indoor datasets are consisting of low light levels or else contains artificial lights, where as outdoor datasets are consisting of high excessive light levels.

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

Figure 8: (a) satellite input images (b) ID-CNN [19] (c) IDERS [29] (d) TME- MOF [25] and (e) proposed Dehazed image

From the figure 8, it is observed that each row represents experimentations on individual images and columns are the Dehazed output images of proposed and existing works respectively. From the figure it is observed that, the existing works are suffering with the atmospheric light based problems, hence the existing works are failed to remove the atmospheric related environment hazards from the hazy input images on both indoor and outdoor datasets. And finally the proposed method generates the perfectly Dehazed output image with effective removal of atmospheric lights and environmental hazards respectively.

4.4 Comparison of complexities

For evaluating the performance of proposed method, qualitative evaluation was carried out using the various full reference image quality assessments (FRIQA) metrics. The FRIQA metrics are compared with the state of art approaches for analyzing the proposed method quality standards. The FRIQA metrics are feature similarity index for colour image (FSIMc), visual signal-to noise ratio (VSNR), structural similarity index (SSIM) and peak signal-to-noise ratio (PSNR) respectively. From the table, it is observed that the proposed method gives the enhancive performance in both quality wise (PSNR & VSNR) and similarity wise (SSIM & SSIM) for various datasets. The proposed method gives the better performance compared to the ID-CNN[19], IDERS [29] and TME-MOF[25] respectively.

Table 1: Comparison table

Dataset	Metric	ID-CNN [19]	IDERS [29]	TME-MOF	Proposed
Satellite hazy images	PSNR	13.247	14.218	16.888	**21.918**
	VSNR	7.783	10.355	11.163	**14.317**
	SSIM	0.590	0.758	0.775	**0.914**
	FSIMc	0.813	0.856	0.916	**0.933**
	Running time (sec)	14.901	9.553	7.468	**6.612**
sy nt hes	PSNR	13.057	14.132	15.307	**17.420**
	VSNR	5.200	7.223	6.268	**15.429**

	SSIM	0.55	0.613	0.801	**0.955**
	FSIMc	0.774	0.808	0.855	**0.905**
	Running time (sec)	12.918	11.091	9.655	**5.225**
Indoor and outdoor hazy images	**PSNR**	16.464	14.336	17.659	**23.536**
	VSNR	10.812	9.337	11.259	**18.889**
	SSIM	0.616	0.795	0.817	**0.939**
	FSIMc	0.794	0.916	0.928	**0.945**
	Running time (sec)	16.536	13.889	9.426	**4.205**

5. Conclusion

Existing methods of dehazing have achieved considerable results but failed to estimate ambient atmospheric light precisely. In daytime dehazing, they simply extend the brilliant pixel method in a local manner. Also, the ambient atmospheric light is extremely near to the bright pixels within the sky region as per the atmospheric scattering model. To solve these problems, in this paper, a fusion based approach is proposed to not only increase the quality of the image by removing haze but also maintain the colour tone of the original image. To achieve this, firstly same input image goes through two parallel stages of dark channel prior based transmission map estimation and refinement in the pixel wise and patch wise manner. Secondly these images go through slightly different versions of Exposure Fusion (with respect to their Enhancement stage) wherein dehazing is done using GWO algorithm. Then, outputs of both fusion processes are averaged out to obtain underexposed haze free image using the ID-GIF approach. At last, brightness enhancement of this haze-free image is done by estimating the brightness of the original image to get final enhanced haze free image. The simulations are carried out on both synthetic and real-time dataset such as satellite hazy images, synthesized hazy images and natural hazy images with indoor and outdoor databases. The results shows that the proposed method provides the better visual quality of output image and also provides the enhancive quality metrics compared to the various literatures such as ID-CNN [19], IDERS [29] and TME-MOF [25] respectively.

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