“DARK CHANNEL PRIOR WITH DETAIL ENHANCEMENT ”

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DECLARATION

I, Sulaxna Gupta, 2K19/SWE/15, student of Mtech Software Engineering, hereby declare that the thesis titled "Dark Channel Prior with Detail Enhancement" which is submitted by me to the Department of Software Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the research work presented in this thesis titled "Dark Channel Prior with Detail Enhancement" which is submitted by Sulaxna Gupta, 2K19/SWE/15, Department of Software Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Atmospheric surroundings, mostly influenced by haze, obscure the scenes of outdoor photography and bring several kinds of troubles to computer vision and graphics applications. This becomes more problematic in applications like remote sensing, weather forecasting, etc. Hence, haze removal is a significantly and extensively accepted topic in the graphics field. Haze attenuates the light and blends with added features of the atmosphere. The main motive of "haze-removal" is recovering the image which is haze-free from such blended light. Proposed system is attempted to overcome the existing limitations like flickering artifacts, over-enhanced sky regions, high computational complexity and poor dehazing effects. The system uses a gradient filter-based Dark Channel Prior estimation (DCP) system for dehazing followed by a Detail Enhancement algorithm to further sharpen and highlight details. In detail enhancement, the image is smoothened out without affecting the edges. The amplitudes of the edges can be decreased but they are not blurred or sharpened. This prevents the halos and gradient reversals of the image.

Keywords: De-haze, haze removal, transmission map, dark channel prior, Detail enhancement

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The major things that demolish the images that are captured in public are mist, fog and other components present in our atmosphere, known as haze which reduces the contrast and color of the image. To overcome this problem, a method called "dark-channel prior" which is effective and simple for deleting the haze from the given image as input [1]. "Dark-channel prior" is the statistic-based method which helps in avoiding or removing haze in the images taken in public . The patches that are presented locally in the outdoor images that are free from haze show some components with less intensity that were noted recently with a minimum of one-color channel. Haze intensity is obtained using the haze imaging model, and we can get a clear image in the haze-free form. Comparing the various results of the image which has more components of haze illustrates the capability of the implemented model. In this proposed system, a gradient filter is integrated with the dark channel. In spite of the drawback in the dark channel prior, our proposed system is integrated with a gradient which helps in overcoming the issues. Along with this, detail enhancement is also applied to further improve the details [2].

1.2 HAZE

There are some small substances in the air like water drops, smoke and dust that are the reasons for haze, this results in increased brightness of pixels of an image. The deployment of a dehazing algorithm is used in many places for computer visioning tasks, i.e., to increase the performance of the sovereign systems by a single image dehazing algorithm and weather forecasting. After all this, the researchers found the importance of image restoration techniques. The situations, scattering and refraction surely trigger the images taken in the open air, and the absorption occurs on the opaque days, which results in the decrement of image information as well as contrast. These depraved images tend to cause some injury to the autonomous systems.

As stated earlier, haze is the most important factor that is responsible for the decadence of the open-air images and lowers both the contrast and color. It is inferred according to the main rule that the open air, which is free from haze, presents a local patch that includes some components whose depth is less in any one-color channel [1].

1.2.1 Haze image formation

The occurrence is due to the airlight and fading process as shown in figure 1.1. Whiteness will increase due to the airlight, and the fading process will degrade the disparity in an image [3]. The removal of haze approach is classified in two methods which are restoration and enhancement of image. For reducing the image clarity instantly, there should be an increment in the gap between camera and the gap where the object is placed.

Haze removal technique can mainly be used with efficiency to enhance the strength and the permanency of the sensor system. While collecting the outdoor images of an incomplete surrounding condition, the respective, accepted radiance of the photographer's camera will be attenuated from the sight series.

1.2.2 Haze removal

Haze removal algorithms are used to eliminate the haze of an image, which occurs due to light scattering via haze components. The haze created by the atmosphere has to be removed, to increase the details of saturation, which can release the color casts but will implement a blue cast which can be rectified later using other platforms by modifying the depth and strength. The most haze-infected area can be viewed by activating the depth map- with increasing color thickness; the dehazed area will also increase.

Contrast enhancement feature of image/captured video and improvement of visibility in the inappropriate weather is more helpful for an outside application for computer visions like recognition, tracking, long-range detection, video surveillance, air-based vision system, etc. The gathered images will be having a poor view because of inappropriate weather conditions like fog and haze, resulting in distorted and contrasting colors [4]. The traditional image and contrast enhancement techniques will suit well for some images but are not applicable to the image in depth region due to fog and haze relying on the depth of the image. The most challenging task is to find the exact intensity of haze or fog in a particular image in inappropriate weather. But the information of the image which is obtained at a low frequency can produce approximate relative thickness of fog or haze.

1.3 DEHAZING

Dehazing is one of the most effective techniques used to increase the viewing level of the low-rated images occurring due to bad weather conditions. Image dehazing is a technique used most of the time to show the presence of debasement of the image captured of greenery or atmosphere by less viewing weather, particles from the atmosphere and other components. Due to the up-gradation of systems and tools the importance of less complicated techniques has risen, along with the high-analysis of dehazing techniques. Moreover, the current findings and research on image dehazing techniques have instantly improved the performance of dehazing of the images, which has been much more of a struggle in rectifying the complication. Therefore, the prior-based techniques are more useful and persistent even though their performance is low.

Dehazing retains some issues in attaining the exact intensity of color, which is supported by the in-depth information in the input image, which is officially unavailable, particularly for single-image dehazing.

It will be cleared in two different classes as listed below:

- Multiple image dehazing techniques
- Single image dehazing technique

1) Multiple Image Dehazing method:

While this externally eliminates the haze, various or many images of a similar scene are taken. This model allows a variable with well-far-famed, and the unknown is avoided. Examples include images with different degree of haze [5], polarization [6], etc.

2) Single image Dehazing method:

An assumption of applied mathematics is required for this technique to retain the continuing information from the supporting information about the scene in a single image [7]. To determine the transmission, the most commonly used technique for a single image dehazing algorithm is both a learning-based feature or prior-based image processing derived technique. Learning-based methods use deep learning and neural networks for image processing. Prior-based methods use an assumption prior to any processing.

1.4 TRANSMISSION MAP ESTIMATION

The airlight and map transmission are the important components required to obtain and retain the ground level of the hazy image. The portion that is not scattered by light is explained with the help of a transmission map and reach to the camera. There will be the reflection of the information depth of the given scene due to the presence of continuous functions of depth in the transmission map.

1.5 DARK CHANNEL PRIOR

“Dark channel prior" known as one and only type of image statistic that is haze-free and taken outdoors. The main objective of the observation is that some components in the image will be present in the form of patches in an image, which is free from haze and has a very little intensity in a minimum of one-color channel. The implemented technique will conclude the various powers of the demonstrated hazy images. “Dark channel prior” particularly found on given content in an image that is haze-free: it also includes some components presented as non-sky patches with minimum one-color channel. The DCP is formulated from the significance of open-air images with the value of intensity zero for a minimum of one-color channel when there is zero in the local window. “Dark pixel” is one of the properties which is used in DCP, which results in the level of intensity is lower in minimum one color channel, excluding the region from the sky. Four different steps are included in dehazing based DCP: transmission map estimation, image reconstruction, transmission map refinement and atmospheric light estimation [1].

1.6 GRADIENT FILTER

To darken or to lighten up the highest portion of the image in the sky, the tool used is a gradient filter. It is generally located in place of the physical graduated filter, which is placed on the camera lens. This filter can be used to edit in a non-destructive manner and is also helpful to edit images like RAW.

An image gradient is a fractional thing used to change the intensity of image color. In image processing, the gradient of the image is one of the important blocks of architecture. Image gradients are mostly used in maps and other representations of visualizing the data to produce the needed information. Image gradient is used to extract the details from the image. For this usage, the gradient images are derived from the original image. Every component of the gradient image delivers the intensity change of the exact point in the input image in the provided direction. The gradient images are included with the *y*-axis and *x*-axis to obtain, whole value in a particular direction.

He et. al [6] proposed a different sort of filter which is known by the name guided filter that can be useful in several computer vision tasks which also include haze removal.

1.7 DETAIL ENHANCEMENT

It is implemented to smooth out images for better quality and removing out noise, but without the edges being sharpened or blurred. Due to these complications, the image is further divided in 2 layers, the first is base layer and second one is detail layer. During enhancement, if edges get sharpened, the result will be in gradient reversal and if sharpened edges get blurred, it will result in halos being generated.

1.8 MOTIVATION

Outside images are mostly employed in many uses and applications such as surveillance, sensing and standalone navigation. Moreover, these images are highly controlled by fog, haze and smog, which originate from suspending air particles and some other types of environmental pollution. Furthermore, light depletion provoked by hazing will lead to subjective or objective loss of information. The eradication of these degradations is more significant while implementing images in CAD (computer-aided design). Haze in the atmosphere where components are dissolved in capturing the picture's clarity and output with poor illumination. Dehazing is a difficult task after haze transmission as it relies on depth with fluctuation. Distortion eradication is a sign to provide input for different computer-aided designs. Many state-of-the-art methods employed unique de-haze algorithms to enhance the transmission maps prediction or depth maps. These transmission maps were discovered to be more related after they possessed direction related to image quality. Feature detection, surveillance, and target recognition suffered inevitable from the distorting lowest contrasted radiance effects. The removal of haze from the image helps in improving the visibility of the image and color bias because of "atmospheric light". Thus, recent researchers have paid more attention to removing haze in images, which is widespread in computer applications.

1.9 OBJECTIVES

This current study optimizes the dehazing algorithm for improving subjective visual clarity. This research study is attempted so that the visibility of images can be improved as well as improve details of an image. The major objective of conducting this study is

- To perform effective image-dehazing with the gradient-based DCP method, which utilizes the gradient filter which helps in improving image quality.
- Further, it improves detailing of images for use in various applications like target detection, remote sensing, etc.

1.10 THESIS ORGANIZATION

This research work is organized into five chapters; including an introduction, literature survey, methodology, result and conclusion.

Chapter 1 is an introduction that includes the basic introduction about hazing, hazing formation and removal, dehazing, transmission map estimation, dark channel prior, gradient filter, and detail enhancement in dehazing

Chapter 2 is a literature survey that discusses various contingency analyses and existing research on haze removal methods, existing research on dark channel prior and existing research on detail enhancement.

Chapter 3 is the methodology that contains the core research work of proposed approaches such as gradient-based DCP and Detail enhancement.

Chapter 4 is the result and discussion that defines the transformation of haze images into dehazed clear images. This shows that in the proposed system gradient filter based DCP and detail enhancement is employed for removing haze in images and getting perfect final output.

Chapter 5 is the conclusion which includes the conclusion of the proposed work. The conclusion is defined for better comprehension of the proposed concepts that have been discussed in the chapter.

CHAPTER 2

RELATED WORK

Weather conditions can affect the outdoor scenes, with haze and fog. The captured images are affected by these phenomena; the quality of visibility in images is reduced. The visibility is influenced by air, and particles present in the air affect the visibility of the image. This is composed of the droplet of water or some other particles. Scattering of light due to the gasses and particles and absorption in atmosphere causes lowest visibility, as well as scattering of light, causes drastic damage to visibility than absorption of light. Due to this, objects which are at distance and some parts of the scene are not seen clearly. This creates a loss of contrast in images, color fidelity and loss of quality in visual images of the scene [8]. Various methods and techniques are used for removing haze and fog in images which are further discussed in this chapter.

2.1 VARIOUS HAZE REMOVAL TECHNIQUES

The captured images in a poor climatic situation such as fog, thin clouds, haze, and smog possess or include edge, color degradation, texture and heavy contrast. Techniques of haze removal can be efficiently employed to restore these distorted pictures. According to M. Kaur et. al [9], a gradient channel prior, had been used for reducing these problems such as wrongly estimating transmission, distorting texture and color, and degradation of edge. The transmission map was used for refining the guided L0 filter with fast computation. This has been involved in filtering edges and produced efficient transmission map refinement. The restoring techniques are also employed for reducing the over-saturation of pixels and were the most common prevailing methods.

The transmission map was used for refining the guided L0 filter with fast computation. This has been involved in filtering, edge and producing efficient transmission map refinement. The restoring techniques are also employed for reducing the over-saturation of pixels and were the most common prevailing methods.

The outcome of the work shows that this method restores hazy images despite the high density of haze. In addition, T. Cui et. al [10] utilized WNR (Weighted norm regularization) and developed a quadtree and "Linear transform" (LTQ) to estimate the scattering of atmospheric light. Though, this technique suffered for texture and sky region degrading issues. The two priors of airlight impacted the depth of edge to preserve the important information of hazy images and estimate the best transmission map to resolve sky region problems. Ngo et. al [11] suggested a single image haze removing algorithm with related hardware employment to facilitate real-world processes.

Dehazing a single image has been one of the significant and complex task in image-processing and computer-vision. S. Zhang et. al [12] proposed NLDN ("non-local dehazing network"), which maps in "haze-free" images and images with haze. The network architecture of this study includes three elements:

- Complete pointwise convolutional region
- Feature combination region
- Reconstruction region

CPCR (Complete pointwise convolutional region) archives regularities of non-local statistics. Then, the feature combination region discovers statistical regularities with spatial relation. Next, the reconstruction region restores hazy free images using the feature which is extracted from the second part. Using these elements, a high-quality result of dehazing was obtained.

This shows that the suggested system performs with excellent results when it has been compared with some other state-of-the-art methods.

2.2 DARK CHANNEL PRIOR TECHNIQUE FOR DEHAZING

In the inference of J. Zhang et. al [13], DCP confronted the brightness of distortion problems and adopted the enhancing parameter based on DCP design which was also managed by shy region problems. However, these researchers confronted various distortions in texture. This sky-region problem is solved by utilising ABC (Adaptive-bi-channel) before superpixel. The function of superpixels as in local region form, detecting the transmission map efficiently. This work incorporates center to surround filter to transmission map refinement from DCP and also effectively handles edges and colors when compared to other existing methods of haze removal. This study created an Error optimizing sparse framework to remove rain streaks in images.

The study estimates each and every image mask with the usage of dynamic mask error controls. Z li. et. al [14] strongly recommended that DCP had been exclusively implemented as the medium for estimating the transmission map. When processing the image augmentation in the medical field, the images have existed with the inference of noise and pseudo-Gibbs; these factors can enhance this specific effect.

CHAPTER 3

METHODOLOGY

The influence of haze in images may degrade the quality of captured images through camera sensors. Haze-removal is said to be dehazing and was typically performed under the physical degrading model that is needed for reversing or implementing new novel problem. To overcome these complexities, our proposed system suggested new algorithm for haze

removal with dark channel prior (DCP) with a gradient filter. The dehazed images are then applied with a detail enhancement algorithm. The result shows that hazy images are changed into haze-free images as clear images with enhanced details. In this chapter methodology of the proposed system is explained.

3.1 HAZE_IMAGING MODEL

$$I(X)=J(X)t(X)+A[1-t(X)] \quad \ldots(1)$$

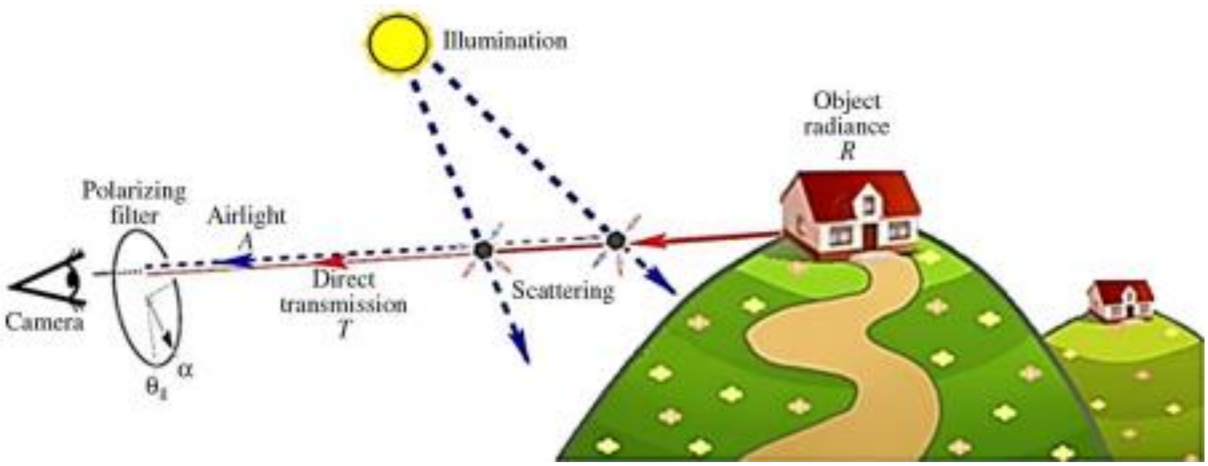


Figure 3.1: Atmosphere light scattering [15]

Here, I is denoted for watched image of haze, and $X = (x1, x2)$ Represents the observed color pixels of RGB-coordinates. The hazy model consisted of two major elements, a veiling light and direct attenuation. $J(x)$ either Represents the reflected light from surfaces or it will represent haze-free images. $t(x) \in 0,1$ Denotes values for transmission of reflected light. A denotes one of the major part that is Atmospheric light. $J(x)t(x)$ Denotes direct transmission or a direct attenuation of the scene radiance. These are attenuation results through inter-communication among particles and scene radiance while processing transmission. Additionally, it's corresponded to light reflected through the surface of the scene after that it reaches the camera straight without scattering. $A[1-t(x)]$ Denotes the realistic color of the scene owing to the atmospheric light scattering. t Represents the volume of transmission light among surface and observer. Let us take transmission t and homogenous medium, $t(x) = e^{-\beta d(x)}$ Here, β represents the medium attenuation coefficient. Distance between surface and observer is denoted by d. In this case, transmission is inversely proportional to depth. The above features attain the depth of image information without inputting sensing machines or devices. Hence, simply atmospheric light's color vector and transmission map are required to eliminate the image's hazy effects.

3.2 RECOVERING THE SCENE RADIANCE

Scene radiance $J(x)$ is being recovered by Transmission map and it is also recovered by atmospheric-light. With the help of transmission map, it is not possible to recover radiance in the desired scene as per the equation. With the direct-attenuation term J(x)t(x) which is closest to zero, when the transmission t(x) which is very closest to zero. Scene which is denoted by J is directly recovered is sensitive to noise. Therefore, transmission is being avoided and t(x) which is lower bound to t_0, it meant the region with the dense haze out of which only small amount of haze can be prevented. Radiance J(x) in the final scene is recovered by:

$$J(x) = \frac{I(x)-A}{max(t(x),t_0} + A \qquad \text{….(2)}$$

3.3 TRANSMISSION MAP ESTIMATION

Haze removal is needed for stand-alone vehicle applications to identify various objects on the road. Mostly the accessible methods are on the basis of various priors or constraints. The significant parameters are needed to recover the basic truth of hazy images in air light and transmission map. The transmission map shows total amount of light which has not been scattered and directly reached the camera. But, depth of the map has continuous function, & it reflects a scene of the depth information.

$$\tilde{t}\ (x) = 1 - \omega\ (\ (\frac{I^c(y)}{A^c}))\qquad \ldots(3)$$

3.4 ATMOSPHERIC LIGHT ESTIMATION

Atmospheric light which we estimated from "dark channel" when largest local patch has attained the dark channel. Hence, if the size of the local patch in DCP is not well enough, it is suggested to process and added DCP with the largest local patch size for atmospheric light estimation. The local entropy is used to improve the perfect estimation of "atmospheric light" from the brightest objects.

$$A\ =\ I\ (argmaxx\ (I\ dark\ (x)))\qquad \ldots(4)$$

3.5 GUIDED fILTER

General filtering process of linear translation-variant is done using "input-image" (*p)*, guidance Image (*I*), & output-image (*q*). According to application, both the *p* and *I* are given in advance and they can also be identical. Expression of filtering output at pixel i

$$q_i = \sum_j\ W_{ij}(I)p_j\qquad \ldots(5)$$

3.6 DETAIL ENHANCEMENT

Detail enhancement is process of smoothening the images without smoothening or sharpening the edges. According to W. Liu et. al [2], smoothening can be edge preserving or structure preserving. Detail enhancement is an edge preserving smoothing since edges are not affected by the smoothening process.

used as per W.Liu [2], fixed parameters are used given as follows: $a_d = \epsilon$, $b_d > I_m$, $a_s = \epsilon$, $b_s = I_m$, $r_d = r_s$, $\alpha = 0.2$, N=1, $\lambda = 20$.

As per the given details, guided image I is denoted by g and input image is denoted by f, the solution for following objective function is given by smoothed output-image u *and* h_T is defined as

$$h_T\,(x) = \left(\frac{h(x)}{b - \frac{a}{2}},\ \frac{|x| \le b}{|x| > b} \right),\ \ b\ s.t.\ a \le b \qquad \ldots(6)$$

$$E_u(u) = \sum_i \left(\sum_{j \in N_{d(i)}} h_T\big(u_i - f_j\big) + \lambda \sum_{j \in N_{s(i)}} \omega_{i,j}\, h_T\,(u_i - u_j\,) \right) \qquad \ldots(7)$$

Where h_T is already being defined previously inequation 6; $N_d(i)$ is a 'square patch' with $(2r_d + 1) \times (2r_d + 1)$ which is centered at fixed location that is *i;* $N_s\,(i)$ which is a $(2r_s + 1) \times (2r_s + 1)$ 'square patch' centred at *i ;* the complete smoothing strength is controlled by a parameter which is denoted by λ. To denote parameters of h_T with respect to smoothing and data term we have adopted $\{a_s, b_s\}$ and $\{a_d, b_d\}$. 'Guidance weight' $\omega_{i,j}$ is defined by:

$$\omega_{i,j} = \frac{1}{(|g_i - g_j\,| + \delta)^{\,\alpha}} \qquad \ldots(8)$$

The sensitivity at the edges of g is determined by α, which also has an input image which is g = f. Absolute value is denoted by $|\cdot|$. Small level of constant has been set where $\delta = 10^{-7}$.

For strong flexibility we have adopted $h_T(\cdot)$ in equation 7.

In the property analysis strong flexibility will be shown using different settings of parameters. This will help our model in achieving different levels of smoothing behaviors. This model is capable enough to perform different tasks such as 'structure-preserving' smoothing or 'edge-preserving' smoothing.

3.6.1 Numerical Solution

As according to the model we used in Equation 8, is not just 'non-smooth' but 'non-convex' as well which emerges from h_T. To solve the optimization problems in 'non-convex' the approaches which have been used commonly doesn't work. To overcome this sort of issue, we have to rewrite $h_T(\cdot)$ which is equivalent.

First we have to define, $\nabla^d_{i,j} = u_i - f_j \; and \; \nabla^s_{i,j} = u_i - u_j$

We have,

$$h_T\,(\nabla^*_{i,j}) = \{h(\nabla^*_{i,j} - l^*_{i,j}) + (b_* - \tfrac{a_*}{2})|l^*_{i,j}|0\,\} \qquad \ldots(9)$$

where $*\in \{d, s\}$, $\left|l^*_{i,j}\right|_0$ is the L_0 norm of $l^*_{i,j}$. With the help of given values for the right side equation minimum is obtained under conditions.

$$l^*_{i,j} = \{0, \left|\nabla^*_{i,j}\right| \le b_* \; \nabla^*_{i,j}, \left|\nabla^*_{i,j}\right| > b_*, *\in \{d, s\}. \qquad \ldots(10)$$

In equation 9 and 10, validation on the basis of theoretical analysis has been done. If intensity values are $[0, I_m]$ then we have $\left|\nabla^*_{i,j}\right| \in [0, I_m]$.

On the basis of equation 9 and 10 if $b > I_m$ then in that case we will always get $h_T\left(\nabla^*_{i,j}\right) = h\left(\nabla^*_{i,j}\right)$ which only leads us to one conclusion that is $h_T(\cdot)$ is being degraded to $h(\cdot)$.

On the basis of above data new 'energy function' is defined:

$$E_{ul}(u, l^d, l^s) = \sum_{i,j} \left(h\left(\nabla^d_{i,j} - l^d_{i,j}\right) + \left(b_d - \frac{a_d}{2}\right)\left|l^d_{i,j}\right|_0\right) \quad +\lambda \sum_{i,j} \; \omega_{i,j}\left(h\left(\nabla^s_{i,j} - l^s_{i,j}\right) + \left(b_s - \frac{a_s}{2}\right)\left|l^s_{i,j}\right|_0\right) \qquad \ldots(11)$$

On the basis of equation 9 and 10 we have:

$$E_u(u) = \min_{l^*} E_{ul}(u, l^d, l^s), * \in \{d, s\} \quad \ldots(12)$$

As per the given data, equation 5 is 'optimum condition' of equation 8 with respect to $'l^{*}'$, for the optimization of $E_{ul}(u, l^d, l^s)$ with respect-to 'u', only works with "Huber-penalty function" $h(\cdot)$.

With the help of "half-quadratic (HQ) optimization technique" the arising issue is optimized.

a function $\psi\left(\mu_{i,j}^*\right)$ and a variable $\mu^*(* \in \{d, s\})$ with respect-to 'μ^*'.

$$h\left(\nabla_{i,j}^* - l_{i,j}^*\right) = \min_{\mu_{i,j}^*} \left\{\mu_{i,j}^*\left(\nabla_{i,j}^* - l_{i,j}^*\right)^2 + \psi\left(\mu_{i,j}^*\right)\right\}, \quad \ldots(13)$$

hence optimization is done under the condition:

$$\mu_{i,j}^* = \{\frac{1}{2a_*}, \ _1, \left|\nabla_{i,j}^* - l_{i,j}^*\right| < a_* \ \frac{2\left|\nabla_{i,j}^* - l_{i,j}^*\right|}{}, \left|\nabla_{i,j}^* - l_{i,j}^*\right| \geq a_* \ , * \in \{d, s\}. \quad \ldots(14)$$

Further new energy function is further defined with the help equation 13 and 14:

$$E_{ul\mu}(u, l^d, l^s, \mu^d, \mu^s) = \sum_{i,j} \left(\mu_{i,j}^d\left(\nabla_{i,j}^d - l_{i,j}^d\right)^2 + \psi\left(\mu_{i,j}^d\right) + \left(b_d - \frac{a_d}{2}\right)\left|l_{i,j}^d\right|_0\right) + \lambda \sum_{i,j} \omega_{i,j}\left(\mu_{i,j}^s\left(\nabla_{i,j}^s - l_{i,j}^s\right)^2 + \psi\left(\mu_{i,j}^s\right) + \left(b_s - \frac{a_s}{2}\right)\left|l_{i,j}^s\right|_0\right) \quad \ldots(15)$$

On the basis of equation 13 and 14 we have;

$$E_{ul}(u, l^*) = \min_{\mu^*} E_{ul\mu}(u, l^*, \mu^*), * \in \{d, s\}. \quad \ldots(16)$$

As Given in the Eq. 15 optimum-condition of μ ∗ for Eq. 17, while optimizing $E_{ul\mu}(u, l^d, l^s, \mu^d, \mu^s)$ in respect of u which only works with the L2 norm penalty function, and have "closed-form" sol.

Optimization condition in equation 5 and 9 both have the involvement of u, the full and final solution for u optains in iterative manner.

As per the taken assumptions, we have u^k, after that we have $(\mu^*)^k$, and $(l^*)^k$. $(* \in \{s, d\})$ get updated with the help of Eq. 10 and 14 with u^k. thus, u^{k+1} is obtained:

$$u^{k+1} = \min_u E_{ul\mu}(u, (l^*)^k, (\mu^*)^k), \quad \ldots(17)$$

A “close form” solution is extracted from equation 12,

$$u^{k+1} = (A^k - 2\lambda W^k)^{-1}(D^k + 2\lambda S^k) \quad \ldots(18)$$

W^k is “affinity matrix” with $W_{i,j}^k = \omega_{i,j}\left(\mu_{i,j}^s\right)^k$

A^k is “diagonal matrix” with $A_{ii}^k = \sum_{j \in N_d(i)}\left(\mu_{i,j}^d\right)^k + 2\lambda \sum_{j \in N_s(i)} \omega_{i,j}\left(\mu_{i,j}^s\right)^k$

D^k is “vector” with $D_i^k = \sum_{j \in N_d(i)}\left(\mu_{i,j}^d\right)^k \left(f_j + \left(l_{i,j}^d\right)^k\right)$

S^k is “vector” with $S_i^k = \sum_{j \in N_s(i)} \omega_{i,j}\left(\mu_{i,j}^s\right)^k \left(l_{i,j}^s\right)^k$

The optimization that has been used above effectively decrease monotonic value of $E_u(u)$, the convergence of this is theoretically possible.

As per the given u^k in $* \in \{s, d\}$ and kth iteration,

We have,

$$E_u(u) \leq E_{ul}(u, (l^*)^k), E_u(u^k) = E_{ul}(u^k, (l^*)^k), \quad \ldots(19)$$

$$\{E_{ul}(u, (l^*)^k) \leq E_{ul\mu}(u, (l^*)^k, (\mu^*)^k)\ E_{ul}(u^k, (l^*)^k) = E_{ul\mu}(u^k, (l^*)^k, (\mu^*)^k) \quad \ldots(20)$$

The given value of $(l^*)^k$ in equation 10 and 19 has been updated on the basis of equation 12 and 9.

Again, the given value of $(\mu^*)^k$ in equation 14 and 20 has been updated on the basis of equation 16 and 14. We have

$$E_{ul}(u^{k+1}, (l^*)^k) \leq E_{ul\mu}(u^{k+1}, (l^*)^k, (\mu^*)^k) \leq E_{ul\mu}(u^k, (l^*)^k, (\mu^*)^k) = E_{ul}(u^k, (l^*)^k) \ldots(21)$$

Two inequalities that has been followed from equation 20 and 17, We finally get:

$$E_u(u^{k+1}) \leq E_{ul}(u^{k+1}, (l^*)^k) \leq E_{ul}(u^k, (l^*)^k) = E_u(u^k), \qquad \ldots(22)$$

Both the equalities that has been followed from Equation 14 and 16.

The indication taken from equation 22 concluded that it is possible to prove convergence of iterative schemes theoretically. Complete optimization procedure was performed N times to get desired output u^N. To achieve the promising results in each performed application. We have the set the $u^0 = f$.

3.7 ALGORITHM

Step 1: Calculation of dark pixel using $J^{dark}(x) = min_{c\in\{r,g,b\}}(min_{y\in\Omega(x)}(J^c(y)))$
Step 2: Calculation of atmospheric light using equation (4)
Step 3: transmission map estimation using equation (3)
Step 4: Applying guided filter using equation (5)
Step 5: Scene radiance recovery using equation (2)
Step 6: Input image to detail enhancement algorithm $\lambda, \alpha, a_*, b_*, r_*, u^0 < -f$, with $* \in \{d, s\}$.
Step 7: Enter for loop k= 0 to N
Step 8: With u^k , compute$(\nabla^*_{i,j})^k$, update $(l^*_{i,j})^k$
Step 9: With $(l^*_{i,j})^k$, update $(\mu^*_{i,j})^k$
Step 10: With $(l^*_{i,j})^k$ and $(\mu^*_{i,j})^k$, solve for u^{k+1}
Step 11: End for loop

3.8 FLOWCHART

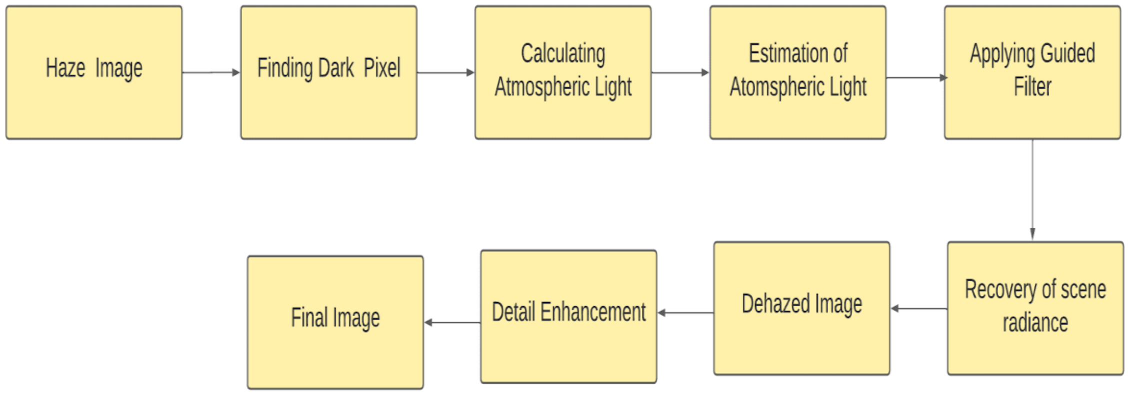


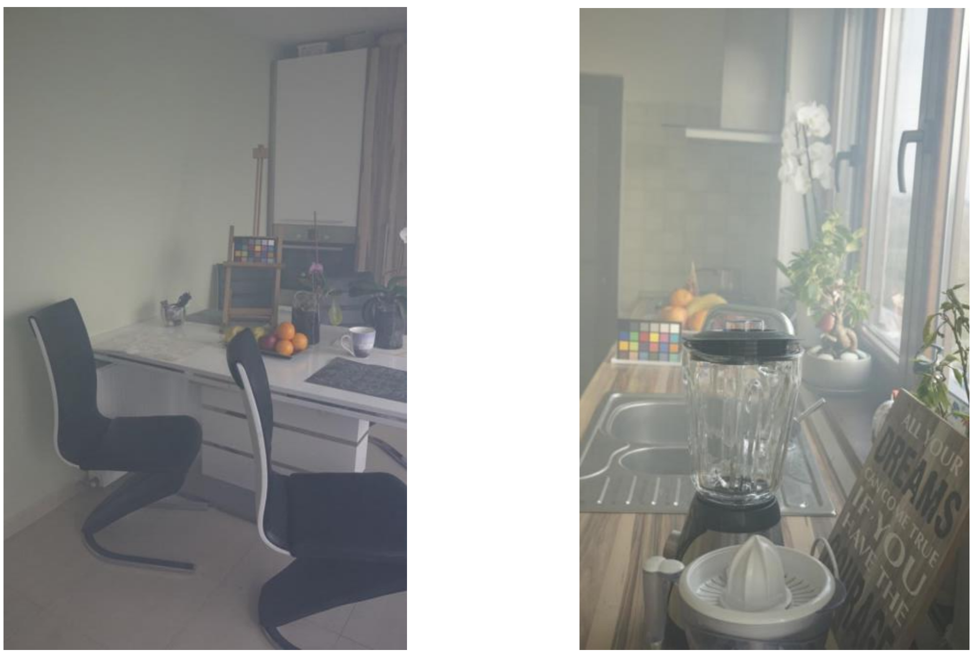
Figure 3.2: Flowchart for proposed methodology

CHAPTER 4

RESULTS

This section provides the results and discussions that provide insights on the performance analysis of the proposed methodology.

4.1 DATASET DESCRIPTION



(a) (b)

(c) (d) (e)

Figure 4.1 Images taken from O-Hazy and I-Hazy datasets [15,16].

(a) (b) (c)

(d) (e)

Figure 4.2 Output of DCP with guided filter

(a) (b) (c)

(d) (e)

Figure 4.3 Output of Proposed algorithm with enhanced details

In fig. 4.3, it can seen that the details are enhanced when we compared it with original hazy images. Shadows of oranges is more visible in (a), we can see the object outside the window more clearly in (b), similarly in others.

4.2. PERFORMANCE METRICS

4.2.1 MSE (Mean Square Error)

The MSE is one of the most popular estimate that is used when measuring the quality of images. It's a complete reference measure, and closer the numbers are to zero, more better they are.

MSE among 2 images for example $g(x, y) and\ \hat{g}(x, y)$ is definite as

$$MSE = \frac{1}{MN} \sum_{n=0}^{M} \sum_{m=1}^{N} [\hat{g}(n, m) - g(n, m)]^2 \qquad \ldots(23)$$

From Eq. (23), we can observe that MSE represent absolute error.

4.2.2 PSNR (Peak Signal to Noise Ratio)

To determine, quality of signal's representations, the PSNR is used for computing ratio among highest potential signal-power as well as power of distorting noise. When comparing two photographs, the decibel ratio is used to calculate the difference between the two. The logarithm term of decibel scale is often used to compute the PSNR because of the vast dynamic range of the signals being measured. Between the greatest and the lowest conceivable values, this dynamic range may be changed by their quality. In terms of PSNR:

$$PSNR = 10log_{10}(peakval^2)/MSE \qquad \ldots(24)$$

4.2.3 Structure Similarity Index Method (SSIM)

SSIM is a technique that relies on people's subjective perceptions of similarity. Images are thought to be degraded when their structural information is altered. Other key perception based facts such as luminance or contrast masking are also involved in this process. The phrase "structural information" refers to pixels that have a high degree of interdependence or are located in close proximity to one other. It is a technique for the determination of the obtained image quality and employed for the similarity measurement between the two images. This prediction depends on the reference distortion-free image.

$$SSIM = \frac{(2_{m1m2}+c1)(2_{s1s2})}{(m1^2+m2^2+c1)(s1^2+s2^2+c1)} \qquad \ldots(25)$$

Where

$m1\ and\ m2 =$ Average of row and column data

$s1\ and\ s2 =$ Variance of row and column data

$c1\ and\ c2 =$ Stabilize variables with weak denominator

Table 1: Comparison of PSNR and SSIM values for Original Hazy images, Histogram Equalisation, Dark Channel Prior and Proposed Method

IMAGES	Original Hazy	Histogram Equalization	Dark Channel Prior	Proposed Method
Image1	PSNR - 28.09 SSIM - 1.00	PSNR - 28.17 SSIM - 1.00	PSNR - 27.89 SSIM - 1.05	PSNR - 28.10 SSIM - 1.00
Image2	PSNR - 28.30 SSIM - 0.95	PSNR - 27.68 SSIM - 1.10	PSNR - 27.51 SSIM - 1.15	PSNR - 28.03 SSIM - 1.02
Image3	PSNR - 28.08 SSIM - 1.00	PSNR - 27.77 SSIM - 1.08	PSNR - 27.70 SSIM - 1.10	PSNR - 27.88 SSIM - 1.05
Image4	PSNR - 28.41 SSIM - 0.93	PSNR - 29.94 SSIM - 1.04	PSNR - 27.49 SSIM - 1.15	PSNR - 27.81 SSIM - 1.07
Image5	PSNR - 28.42 SSIM - 0.93	PSNR - 27.84 SSIM - 1.06	PSNR - 27.60 SSIM - 1.12	PSNR - 27.88 SSIM - 1.05

In table 1, PSNR and SSIM are shown for the proposed method and compared with original images, histogram equalisation and DCP

CHAPTER 5

CONCLUSION

Haze removal is an important application among the huge number of applications like remote sensing, surveillance and autonomous navigation. To remove haze, the proposed method is not only effective but simple in nature to delete the haze from the given image as an input. Image dehazing becomes a challenging issue that aims to retain clear images from hazy images. Dehazing is the technique used to increase the viewing level of the low-rated image that occurred due to bad weather conditions. An image gradient is a fractional thing used to make a change in the intensity of image color. The air light and transmission map which are one of the most important components required to retain the ground level from the image that is hazy. The portion that is not scattered by light is explained with the help of a transmission map and its reach to the camera. There will be the reflection of the depth information given in the scene due to the presence of continuous function in the depth map. The proposed algorithm further includes a detail enhancement method to further highlight objects in the scene. Detailed image is required for the investigation of crime scenes, reading the number plates in traffic or focusing on a target. Hence the proposed algorithm can be used for such applications.

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