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Adaptive Dark Channel Prior Based Dehazing Algorithm with Semantic Optimization

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ABSTRACT:

The Dark Channel Prior (DCP) technique is popular for reducing haze in photos, but it has drawbacks such high processing costs, artificially brightening the sky, producing flickering in films, and inconsistently producing the best dehazing outcomes. To address these problems, we have devised fresh approaches to enhance the method.Prioritizing program performance, employing pre-calculated tables, and performing quick one-dimensional filtering are some of the strategies we plan to use in order to increase computation speed. We ensure the real- time processing of information by minimizing pointless computations, hence rendering our approach applicable to a multitude of domains. To further tackle the issue of over- enhancement in sky areas, we employ a particular section of the guided filter to accurately identify and preserve the sky area while avoiding overly enhancing the landscape to preserve its natural appearance. This tailored technique enhances the overall image's sharpness while preserving the sky's realism.Additionally, we address the flickering artifact problem in video processing by introducing a novel airlight update method and modifying the radius of the guided filter. The objective of these modifications is to guarantee uniformity in motion among frames, leading to more seamless transitions and dependable dehazing outcomes. Furthermore, we propose an improved airlight estimate technique to enhance the dehazing process, leading to higher-quality output and enhanced visibility under cloudy conditions. By fine-tuning ambient light estimation, our system achieves increased accuracy and consistency while eliminating haze.Overall, our new approach significantly outperforms thecompared to existing techniques, resulting in steady improvements in dehazing efficiency and processing speed. Our algorithm's enhanced features make it suitable for a variety of applications, including surveillance, monitoring, and Advanced Driver Assistance Systems (ADAS), where precise decision-making and in-depth analysis depend on clear visibility..

Index Terms—Dark Channel Prior (DCP), Dehazing, Sky Detection (Sky Detect.), Guided Filter, Airlight Update, Flickering Artifacts (Flicker Artifacts), Advanced Driver Assistance Systems (ADAS).

1. Introduction

The growing number of misty-environment-related disasters in recent years highlights the pressing need for real-time dehazing methods. This need is especially important for intelligent vision systems, which heavily depend on image quality to achieve accurate object detection. Examples of these systems include surveillance, monitoring, and Advanced Driver Assistance Systems (ADAS). Even while single-image dehazing algorithms have matured, modern dehazing techniques still face many difficulties, most notably high computing complexity and problems with temporal coherence when used for video dehazing .Mist, fog, and haze are phenomena that arise in many parts of the world due to the absorption or scattering of natural light by atmospheric particles, along with variables such as water droplets, air pollution, and changing weather. This ambient noise continuously decreases contrast in photographs, especially in outdoor environments, leading to visually degraded images that jeopardize the efficacy of monitoring and surveillance systems, including the more and more common ADAS and self-driving cars. The widespread use of remote sensing technologies, ADAS, and surveillance and monitoring systems highlights how deeply integrated these systems are into a variety of disciplines. But the caliber of the input images these algorithms use has a significant impact on how well they operate. As a result, improved image quality is desperately needed, which is commensurate with the state of technology today. Even with the fundamental knowledge of weather-induced image degradation going back to Koschmieder's work in 1740 and continuous progress in computer vision, there are still many unanswered questions. Although single-image dehazing techniques have advanced significantly in the last several years, applying these methods to video dehazing has challenges with temporal coherence and computational complexity, particularly in real-time application

2. Related Work

Background

In outdoor scenes without haze, the "dark channel" value (Jdark) is generally low, almost at zero, with the sky exception. This finding is used to combine the "dark channel prior" with the "imaging hazy model." For a small patch Ω(x) in the image, the
When dust, smoke, or other fine particles linger in the air, they create haze, making it difficult to see clearly. Objects captured in hazy scenes appear dim and washed out due to the mixture of light scattering and the original scene radiance. In the field of computer vision, removing haze poses a significant challenge because the extent of obstruction varies across the scene, making it a complex problem to solve.

Atmospheric dispersion model

McCartney's atmospheric scattering model is commonly used to explain the formation of blurry pictures.. This model is represented

transmission is assumed to remain steady, indicated by $\tilde{t}(x)$. The transmission can be estimated by applying a minimum operation to the hazy imaging equation within the patch, as shown in Equation (4).

$\min(\mathbf{I}^t(y)) = t(x)\min(J^t(y)) + (1 - t(x))\mathbf{A}^t$ (4)

Assuming that Equation (3) equals zero, we combine it with Equation (4). This gives us the coarse transmission, represented by Equation (5). ω (0<ω≤1), a constant parameter, is utilized to maintain some degree of haze in the distant view.
by equations (1) and (2). Equation (1) which describes the

$f^{\sim}(x) = 1 - \omega\min($ min

$I(y)$
$($ c $))$ (5)

relationship between the observed hazy image (I) as well as the haze free image (J). Itincludes factors such as the pixel index (x), Scene depth (d), scattering coefficient (β), atmospheric light (A), and medium transmission (t).The direct attenuation term, J(x) and t(x), accountsfor the reduction in scene radiance due to scattering along the path from the scene to the camera.Previously scattered light contributes to the observed results, and the remaining component, A(1-T(X)), represents the brightness of the atmosphere. This dehazing technique aims to determine A and t, which, when combined with the known I, can reconstruct the original scene J from the mathematical model.

$I(x) = J(x)t(x) + \mathbf{A}(1 - t(x)$ (1)

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

Dark Channel Prior

He et al. [4] found that in clear outdoor images, one or more colorshas extremely low level of intensity in the majority of the pixels innon-sky areas.
This observation led to the development of the Dark Channel Prior (DCP) algorithm, which has five steps: 1. Estimating the brightness
of the scene 2. Calculating the dark channel intensity 3. Estimating

$cy\in\Omega(x)$ A

By means of the rough transmission estimate $t^{\sim}(x)$ to reconstruct the scene can introduce pixelated artifacts. To address this, the soft matting technique is employed to improve the transmission estimate to t(x). The refined transmission is then used to recover the scene as shown in Equation (6). However, the directly restored illumination of the scene J be noisy. To mitigate this, a lower bound $t0$ is imposed on the transmission estimate, ensuring that some haze is retained in regions with heavy haze.

$I(x) - A$
$J(x) =+ A$ (6)
$\mathrm{Max}(t(x), t\ )$ 0

Instantaneous Dehazing of Pictures and Videos

LV and colleagues [5], replaced the intricate soft matting method in DCP [4] with a cross-bilateral filter. One of the main characteristics of DCP is that, aside from those spots where

the level abruptly changes, the enhanced transmission map is generally smooth.
the initial transmission 4. Refining the transmission 5. Recovering the clear scene The Dark channel is calculated using Eq (3), where

1

$t(x) = w(x)$

$\sum$

$y \in Q(x)$

$G\sigma_Z$

$(0x - y^0)GG\sigma$

$(|Ew_x$

$- E_y|)(x)$ (7)

z

Jc(y) is the channel of color of the image J and Ω(x) is a small area centered at x

To optimize the refinement process, they incorporated an edge- preserving filter. The cross-bilateral filter is expressed mathematically in Equation (7), where $\tilde{t}\ (x)$ and (x) denote the

$\mathrm{J}^{darkk\hat{}}(x) =$ min

$\varepsilon \in \{r,g,b\}$

(min

$y \in \Omega(x)$

$\mathrm{J}(y))$ (3)

coarse & refined transmission maps, respectively. G represents the standard Gaussian Function, while σs and σr indicate the spatial and range weights, respectively. In all results presented in[5], σs was set to 16 and σr to 0.1.

$(x) = \sum_{1} \quad G_\sigma\ ({}^0x - y^t)G_{0,}(E_x - E_0)$ (8)

$y \in P(x)$

PROPOSED ALGORITHM

Our suggested approach is built upon the Dark Channel Prior(DCP) method for image dehazing, which was first described by He et al. [4]. DCP has four drawbacks: Its use is limited to single-image dehazing, which means that it is not appropriate for real-time or video applications. Additionally, it tends to over- enhance the sky region, which causes flickering artifacts during video processing. Lastly, it may produce dim dehazed images.

Our suggested approach is to apply the DCP idea to real-time video dehazing settings. The suggested algorithm uses the following steps:

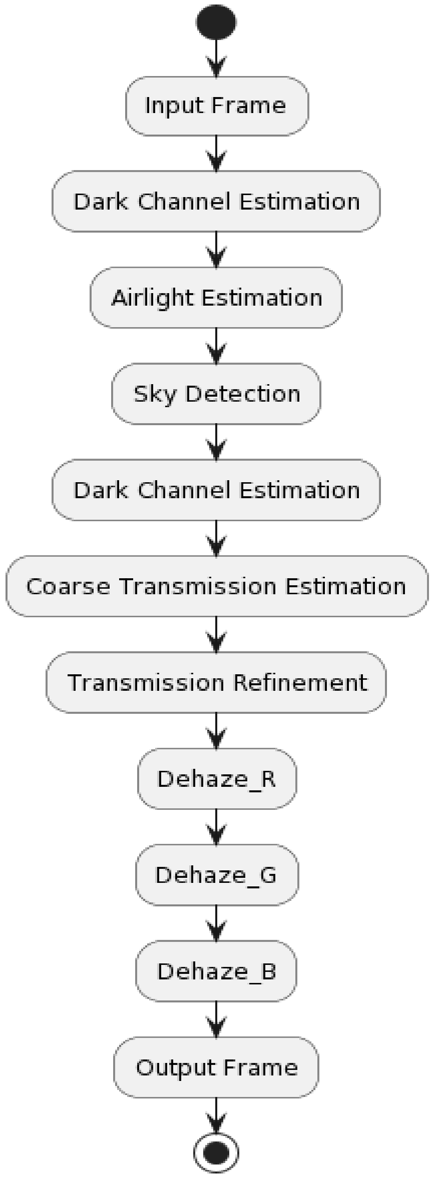


Fig.1

it averages the pixel values over the airlight estimate threshold and it replaces the image matting method with the fast guided filter , the guided filter for finding the region that is smooth in the sky; and it introduces A new update on airlight approach for temporal coherence; moreover, it reduces using the bigger meanfilter radius flickering artifacts.

Furthermore, the primary benefit of our video dehazing technique is its real-time processing. For the mean and minimum filters, we employ a one dimensional fast filtering in an effort to simplify the dehazing algorithm. Additionally included are look-up tables and downscaling.

The suggested algorithmic workflow is depicted in Fig. 1, and the complete method is covered in the sections that follow. These sections also provide information on how the embedded system implementation was done, its outcomes, and a comparison with our suggested algorithm.

Frame of Input:
This is the original fuzzy picture that has to be improved.

Dark Channel Estimation I :
The haze density of the image is revealed by the algorithm's estimation of the dark channel.
Airlight Estimation:
It determines how much light is in fuzzy picture.
Sky Detection:
Recognizes and handles the image's sky area.
Dark Channel Estimation II :
Following the identification of the sky, a second estimate of the dark channel is made.
Coarse Transmission Estimation:
Determines the scene's original brightness by distinguishing airlight from object brightness.
Transmission Refinement:
To improve accuracy, the transmission map is refined.
Dehaze (R, G, B): The color channels for red, green, and blue each require three distinct dehazing stages.
Airlight approximation

The difficulty of the computation resulting from recursive block based sorting computing is the main problem with most airlight estimations. Accordingly as demonstrated in Fig 2 ,

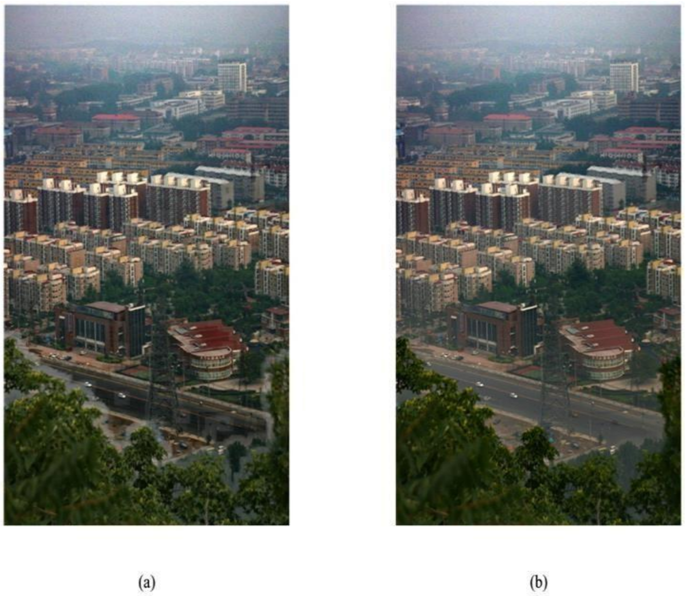

(a) (b)

Fig 2

The method shown in Figure 2 tackles the problem of computational complexity resulting from airlight estimations' recursive block-based sorting computations. The following explains the stages shown in the figure:

1. **Input Image:** The atmospheric scattering-affected input hazy image, which appears hazy or foggy, is where the process starts.
2. **Block Partitioning:** To enable local processing, the input image is split up into blocks or patches. A portion of the original image's pixels are contained in each block.
3. **Calculation of Dark Channel Prior (DCP):** The DCP method is used within each block to estimate the airlight or atmospheric light. The least foggy areas of the image are usually the pixels with the lowest intensity values, which are found by the DCP method. It is believed that the ambient light in the scene is represented by these pixels.

Airlight Estimation: An estimate of the airlight for the entire image is produced based

4. on the DCP findings from each block. The pixels that were found to have the lowest intensity values in all blocks are used to get this estimate.
5. **Airlight Refinement:** To improve its accuracy, the estimated airlight is refined. The purpose of this phase is to reduce the errors caused by block-based computations and enhance the dehazed image's overall quality
6. **Final Dehazing:** The input image is subjected to the dehazing procedure using the refined airlight estimation. Reversing the effects of atmospheric scattering yields an output image that is cleaner and free of haze.

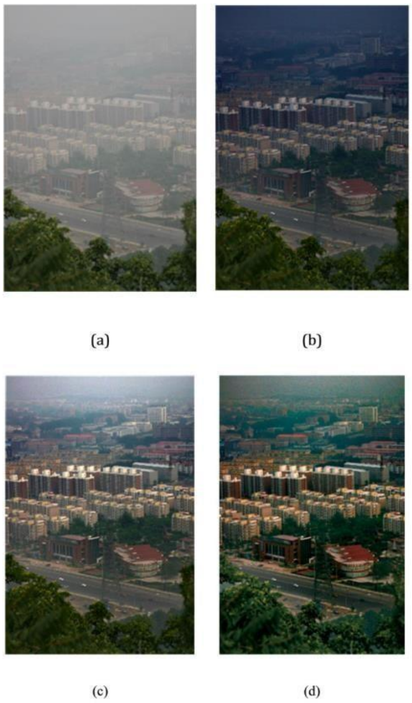


Fig 3
Comparison of Dehazed Images/photos:
(a) Hazy Image , (b) with Airlight (θ) = 15,
(c) with Airlight (θ) = 60, (d) Image given by DCP

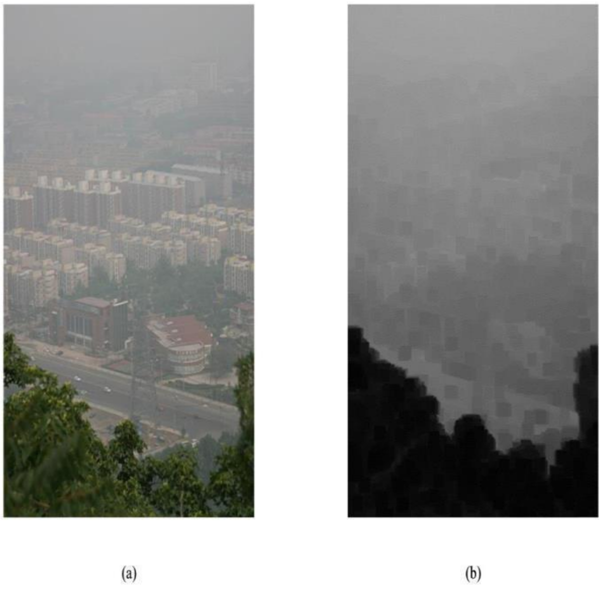
When evaluating dehazing result images, we assess the visual quality and effectiveness of various dehazing methods or parameter settings. In this comparison, four images are analyzed: in the scene, typically with reduced contrast, color distortion, and poor visibility caused by atmospheric particles like haze, fog, or smog. (b) θairlight = 15: This image shows the dehazed result achieved using an airlight parameter value of 15. The airlight parameter is crucial in dehazing algorithms as it determines the light scattering intensity and haze removal.

a threshold of 255 – θ airlight is suggested, which, above the average Value of pixel intensity for airlight estimation can be produced. The threshold's value is determined by the input's exposure. Our suggested threshold θ airlight produces a an improved dehazing outcome image than DCP [4], as Fig. 3 illustrates. With original DCP, a dime image is always generated, but with our approach, different θ airlights result in different kinds of clear images .

Sky detection

Particularly in areas with dense haze and the sky, DCP [4] is ineffective against noise. Thus, we anticipate that the retrieved Eq will retain some haze, just like in Eq. (6). A technique for

segmenting the sky region was presented by Wang et al. [7]. However, it will not work with photographs that do not have a sky, and it is also rather sophisticated. As a result, we provide a straightforward concept for sky identification that is based on the guided filter [9] and the block-based airlight estimation approach [8]. In order to evaluate a smooth region, kim et al [8] determined the value of the score by removing the mean and the Standard deviation . He et al. [9] used the particular technique shown in technique the variance and mean and variance of the input photos..


(a) (b)

Dark channel estimation

Fig. 4

Adopting the Suggested Refined Transmission and Its Effects:

(a) Without Enhanced Transmission &

(b) Utilizing Enhanced Transmission

A useful method for obtaining the coarse transmission $\tilde{t}(x)$ is to estimate the dark channel using Equation (3). It plays a crucial role in determining how much light passes through the atmosphere in a scene.

In the fig 4, we used a higher airlight value of 60 to get a clearer result compared to the previous one. The higher airlight parameter helps in reducing the impact of atmospheric effects and improving the clarity and visibility of the image. The image generated using the Dark Channel Prior ,(DCP) method is a common dehazing technique. DCP uses the dark channel properties in hazy images to estimate scene transmission and effectively remove haze Lower values of f(x) indicate more obstruction caused by haze or fog, affecting the visibility of objects in a scene.

Put simply, coarse transmission measures the impact of atmospheric conditions on object visibility. Estimating coarse transmission is vital in dehazing algorithms for removing haze or fog from images effectively. Understanding the amount of light scattered or absorbed by the atmosphere between the camera and scene objects allows for
accurate restoration of true colors and details in the scene. In this phase, the minimal filter is used. We tested a number of different combinations of $rmin$ in our research, and the optimal combination, $rmin$ = 7, is employed in our suggested algorithm. A popular technique used to estimate the unreliable transmission by using the dark channel prior. This method leverages the statistical characteristics of natural images to detect areas of low intensity in the image being observed. These dark areas usually indicate regions with thick haze or fog. By examining the dark channel, algorithms are able to calculate the rough transmission map, which helps in the dehazing process by showing where and how much haze removal should be performed.

Coarse Transmission Estimation

As described in Eq (5) The course transmission value is approximated using the dark channel method . A lower bound of
$tsky$ = 0. 35 is imposed for the pixels identified in sky detection since the DCP is ill-suited for the area of the sky.. The outcome is displayed in Fig. 5. The suggested strategy, which we selected from the experiments, uses a value ω of 0.95 in Eq. (5). Determining how much haze, fog, or smoke is affecting visibility in images is a key aspect of image dehazing algorithms. This involves using the Dark Channel Prior (DCP) principle, which looks at the dark regions in natural outdoor scenes where a single channel of color often have extremely low intensity. The image is first split into small patches, and the darkest pixel values across all color channels is calculated for each patch to create a map showing areas that maybe obscured by atmospheric conditions.

Fig.5
The Result of Coarse Transmission Estimation:
(a) Dark Channel Image
(b) Result Image

The procedure(fig5) involves figuring out the transmission map and estimating the transmission of fuzzy images by computing the Dark Channel Image (DCI). The steps are as follows: 1.Calculation of Dark Channel Image (DCI): Utilizing a sliding window, determine the lowest pixel intensity in specific areas of the fuzzy image to determine the DCI.2. Estimating Transmission Maps: The transmission map, which displays the degree of atmospheric scattering or haze in the scene, is estimated with the assistance of the DCI.The amount of airlight present mostly determines how clear a scene is; the less airlight present, the higher the clarity. The dark channel prior is used to take use of the statistical regularity present in outdoor images in order to establish the transmission map, which is essential for dehazing the image. The estimated transmission map is then used to create the final image, which improves the visibility of details in the fuzzy image. The haze is efficiently eliminated by dividing each pixel value of the fuzzy image by the matching transmission map value. To summarize, estimating the transmission map and computing the dark channel picture are steps in the coarse transmission estimate procedure.constructing the final image to mitigate the effects of the fog in the original.

Refinement of transmission

In our work, we employ a guided filter because of its refined quality and cheap computing complexity. For the purpose of sky detection, a portion of the directed filter is calculated. As a result, it just requires the remaining guided filter to be calculated, saving some computational expense. The mean filter is used to create the guided filter. Our research indicates that the mean filter's radius performs best when it is four times greater than the minimum filter's radius.

Therefore, based on the trials The mean filter's radius $rmean$ is fixed at 28.

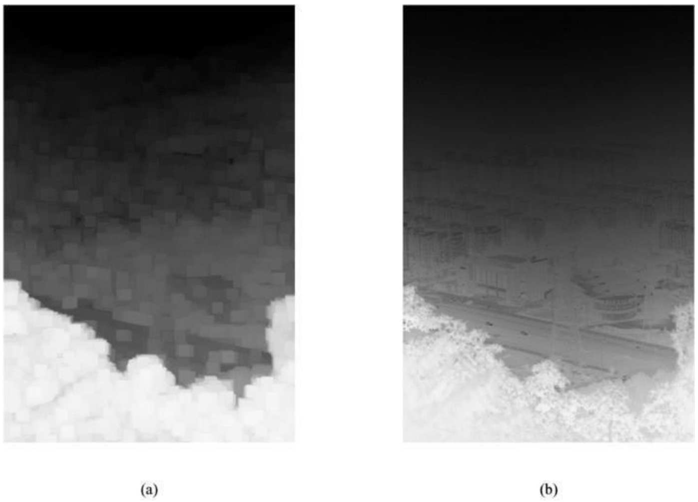


Fig.6

The following are the results of estimating coarse transmission:

(a) Dark Channel Image: This picture is produced by figuring out the dark channel, which displays the localized areas of the fuzzy input image with the lowest intensity values. Areas with lesser

intensity are emphasized in the dark channel image, which typically indicates less hazy or non-hazy parts of the scene.

(b) Outcome Image: The estimated transmission map obtained from the dark channel image is used to create the outcome image. Because the transmission map lessens the effect of haze in the input image, it presents the scene with less haze and with greater clarity and sharpness.

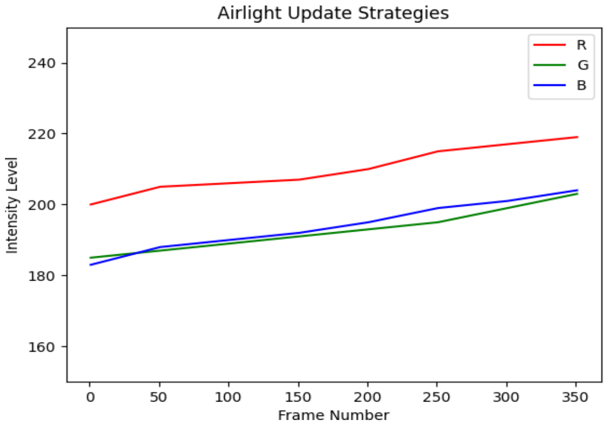
Airlight update plan

The airlight as it exists assess the airlight separately for every frame, which leads to an uneven change and flickering outcomes. Consequently, the coherence problem should take the temporal information into account. The updated formula is given in Eq (9) where At is the current frame t's airlight value.. The revision approach By embracing the historical significance value is described in [10] . The airlight value from the preceding frame, t-1, is represented by $At-1$, and $A\ new$ is a ratio co-efficient method , λ, combined linearly whose value that ranges from 0 to

1. The suggested technique sets λ to 0.95 because humans have a tendency to trustthe prior airlight value as the comparable valuemore.

$$A_{n\kappa} = \lambda A_{t-1} + (1 - \lambda) \qquad (9)$$

Fig.7 Airlight update Strategies



Frame Number	Intensity level		
	R	G	B
100 200 300	203 208 218	182 198 190	191 197 199

TABLE I Airlight update Strategies

Even so, if there is a sudden movement in the airlight value, it still results in color shift, therefore if the difference two neighboring frames is more than a cutoff , a constraint needs to be applied to limit it.

Based on our research, $\theta diff$ needs to be close to 5 in order to maintain luminance coherence across the entire video. Therefore, in the suggested algorithm, $\theta diff$ is set to 5.

coherence of transmission

For a smooth video output, temporal coherence should be maintained when prolonging a single picture reducing haze in videos removing hazards. Temporal coherence is achieved through the use of numerous known techniques, including the block matching approach [11], Markov random field [MRF][12] optical flow [13], and cost function optimization [8]. We have observed that moving white items cause flickering artifacts and impair the transmission coherence.The prior that we employed in the algorithm also contributes to the cause. When confronting a white object, Attenuation of color and DCP [4] and before [14] will not work. The erroneous patch created by the white items in the transmission map can be easily fixed with the minimum filter.Relying on filter radius adjustment, we suggest a technique to minimize flickering artifacts, departing from the prior ideas. The filter's receptive field is where the idea originates. A big filter radius, for example, will lessen the locality, whereas a short filter radius highlights the locality surrounding the filter anchor point. Considering that it can lessen the abrupt alteration caused by the white item inside the map of transmission, the high filter radius thus improves transmission coherence.

Quick filtering

The lowest filter, mean filter, and guided filter are the three filters that are part of the suggested algorithm, which is based on DCP [4]. We therefore use quick filtering from [6], [15], and [16] in order toreduce the computational overhead Furthermore, there is a trade- off between computing efficiency and the accuracy of the transmission refinement when determining the fast guided filter's scaling ratio. As a result, based on our experiments, the quick guided filter ratio is established at 0.5 . Additionally, 1-D filteringtakes the place of 2-D filtering. In addition to the quick filtering methods used from references [6], [15], and [16], the algorithm based on DCP [4] stands out for integrating 1-D filtering instead of 2-D filtering. This change improves computational efficiency and streamlines the transmission refinement process. Our experimental evaluation shows that setting the scaling ratio for the fast guided filter at 0.5 achieves the best balance between computational speed and accuracy of transmission refinement. This precise calibration highlights the importance of balancing efficiency and effectiveness in algorithm design.

IV COMPARISON AND RSULTS

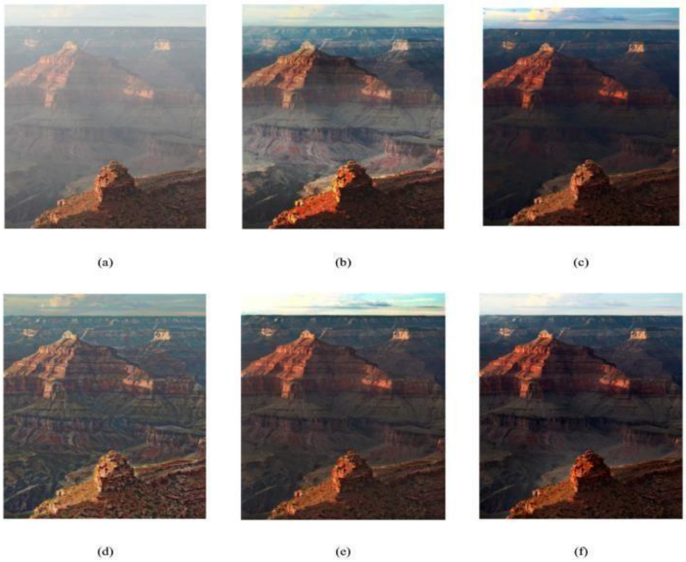


Fig.8
Comparison of results from multiple approaches on a singlefuzzy image. .

(a) Input Hazy Image
(b) DLCE [17]
(c) DCP [4]
(d) Tarel and Colleagues [19]
(e) Meng & Wang [18]
(f) Our Proposed Approach

(a) Input Hazy Image: This is the original image that has lost contrast and visibility due to air scattering or haze.

(b) DLCE [17]: The outcome of using the Dark Channel Low- light Enhancement (DLCE) technique, which makes use of the dark channel before to improve low-light photos. The result of the Dark Channel Prior (DCP) method, which is a popular technique for single-image dehazing based on the statistical regularity of dark channels in natural situations, is

(c) DCP [4].

(d) Tarel and Colleagues [19]: The outcome of the dehazing technique presented by Tarel and colleagues, which most likely makes use of a unique strategy or algorithm to eliminate haze.

(e) Meng and colleagues' dehazing technology, which might entail a unique algorithm or method for reducing haze, was presented in their work.

(f) The output of our suggested strategy displays the outcomes of our own dehazing technique, which may contain new algorithms or improvements intended to address particular haze removal challenges.

Fig.9

Fig 8 : Input Hazy Image: This is the original Frame from video that has lost contrast and visibility due to air scattering or haze.

Fig.10

The output of our suggested strategy displays the outcomes of our own dehazing technique, which may contain new algorithms or improvements intended to address particular haze removal challenges.

3. CONCLUSION

The new algorithm explicitly addresses problems with the current DCP method, making it a significant advancement in image dehazing techniques. It presents improved techniques for managing temporal coherence in films, precisely detecting sky regions, and estimating airlight. These improvements aid in resolving issues such as subpar dehazing outcomes, warped sky, flickering artifacts, and heavy processing requirements. Fast filtering and parallel programming make the algorithm even more real-time-optimized. Overall, it results in much clearer, more aesthetically pleasing images and significantly increases image quality.

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