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Image Haze Removal Using Hybrid Advanced Image Restoration & Image Enhancement Techniques

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***Abstract*—** Low contrast and blurring issues can influence the perception and recognition of images taken in low and poor light situations. Haze in the atmosphere also causes the same consequences. Enhancing and restoring such low-contrast images is therefore crucial. Numerous image algorithms have already been used to remove haze from images taken in a low-light, foggy setting. However, these algorithms did not dehaze and enhanced well using the current haze removal techniques. Based on this rationale, a new hybrid mechanism by fusing two methodologies, Dark Channel Prior (DCP) and Single Scale Retinex (SSR) technique, is proposed in this research work. DCP responds well to image restoration and Haze removal, while SSR performs post-enhancement. The hybrid technique overcame the problems occurring with the earlier techniques, e.g., high noise in images, low contrast, large haze gradient, low entropy, Halo Artifacts, detail loss, image blurring, edge preservation, etc. The calculations of the following parameters have been used to assess the effectiveness of the hybrid strategy, e.g., Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), Mean square error(MSE), Haze improvement index or Visibility Metric (VM). The generalized and image processing toolbox of MATLAB 2016a is used to implement the proposed methods.

Keywords: *Dehazed Image, Dark Channel Prior, Single Scale Retinex, Peak Signal to Noise Ratio, Mean Square Error, Structure Similarity Index Measure, Visibility Metric*

1. Introduction

When fog, haze, or smog is in the sky, many airborne particles have a radius between 1 and 10 microns. These aerosol particles absorb scene reflections and scatter sunlight. As a result, the quality of images captured during such conditions is diminished, with details lost, contrast decreased, and chromaticity changed. A key component of multimedia equipment is imaging, and haze-induced picture deterioration is troublesome for tools used in drone control, traffic surveillance, vehicle recognition, driving assistance, etc. [1]. By removing the haze layer from the given hazy image, the scene's clarity will be significantly increased. The dehaze image also has a pleasing aesthetic. Image dehazing also contributes significantly in many applications of image processing. Histogram equalisation, Retinex theory, homomorphic filtering, and wavelet-based techniques are a few enhancement-based techniques[2]. However, the majority of these methods have issues with color fidelity. Contrarily, defogging effects can be produced naturally using strategies based on picture restoration. However, the various techniques now in use either produce inaccurate results or cause halo effects in the final image. Retinex theory is the theory of the retinal cerebral cortex, which Edwin H. Land proposed in 1963. A novel DCP method was used by He et al. [2010] to identify black pixels inside an image patch whose intensity values are very near to zero for at least one colour channel. It has changed from SSR to a multiscale weighted average Retinex algorithm (MSR), its upgraded Retinex algorithm MSRCR, and others after decades of work. Combining classical algorithms with derived algorithms and other algorithms Due to its continual color thinking, Retinex theory is crucial to image improvement technology [3].

The remaining portions of the article are organised as follows. The literature review of the DCP and SSR approaches is discussed in Section 2. Section 3 explains the hybrid methodology of advanced image restoration & image enhancement techniques. Section 4&5 evaluates the proposed hybrid algorithm's performance and compares it to more conventional methods using a variety of randomization tests. Finally, the Summary & Future Scope of the Proposed Research are presented in Section 6.

2. Literature Survey

To eliminate haze from a single input image, He et al. (2020) presented a convincing image called "dark channel prior. In the dark channel, there is a type of statistics of the haze-free outdoor photographs. Most local patches in haze-free outdoor images contain pixels with extremely low brightness in at least one color channel. By combining this prior with the haze imaging model, the authors can measure the haze thickness directly and recover a high-quality haze-free image [4]. According to Das et al. (2020), the most recent fog removal techniques are filter-based, color correction-based, and learning-based. The authors compared the performance (qualitatively and quantitatively) of the most prevalent techniques in each category. It is discovered that filter-based approaches generally perform more admirably than other types [5]. Babu and Venkatram (2020) presented several different dehazing approaches already in use and real-time implementations of several haze removal methods [6]. Saxena and Bhadauria (2020) presented an efficient haze reduction algorithm. The proposed fog-removal method makes use of air scattering. To make the depth model linear, the intensity and saturation values in the input image are divided and added. The proposed method addresses edge preservation, white sections, and color accuracy [7].

Kaur et al.(2020) proposed gradient channel prior-based haze removal. The guided L0 filter refined the gradient channel's previous transmission map. Haze reduction based on gradient channel priors preserves color and texture. GCP put nine synthetic benchmark datasets and 190 live blurry photographs through given paces [8]. The pipeline picture haze reduction method was created using Li & He's cloud processing techniques and the dark channel earlier (2020). The authors use the system's user management module, system sitting module, cloud-based image management module, and image processing module to deliver the image utilizing the system's secure cloud data control mechanism [9]. Borkar and Mukherjee (2020) developed a novel mathematical method for reducing haze by focusing on the regularity of image pixels. The technique reduces haze without modifying the image hue. The suggested strategy outperforms state-of-the-art non-learning-based solutions by a wide margin[10]. Finally, a single-image haze reduction method with hardware implementation for real-time processing was proposed by Ngo et al. in 2020. The proposed system takes advantage of computationally effective image processing methods such as adaptive tone remapping, multiple-exposure image fusion, and detail enhancement. Compared to other methods, its low complexity and good performance stand out [11].

Shi et al. (2021) studied a common problem cloud effect on optical remote sensing images resulting in significant data loss. The authors described a new MDCP-based technique for removing heavy thin clouds from viewable images. Its main objective is to integrate DCP into MST and create images without the cloud by utilising the proper fusion rules and an updated Laplacian model. Experiments show that MDCP can cure amblyopia, maintain ground characteristics, and reduce color distortion[12]. Wang et al. (2021) presented a dark channel prior defogging method. Traditional dark track preceding defogging is time-consuming and ineffective. A four-point weighting approach is utilized to precisely estimate the atmospheric light value and rough transmittance while considering temporal complexity and edge influence. Using atmospheric scattering, a fog-free image is reconstructed. Edge detection and maximum inter-class variance are used to separate the sky from non-sky areas because the dark channel cannot process bright regions. Improved defogging is used in non-sky areas, while sequential decomposition is used in sky areas [13]. According to Anan et al., DCP can remove fog from cloudy photographs. Sky and non-sky sections were separated and restored independently. The hazy images became clearer after combining the corrected portions. Then, a framework comprised of five novel methods was proposed. Artificial and real-world images were used in each case. The SSIM index, PSNR values, and NIQE are used to analyze synthetic images, whereas entropy, contrast, and contrast are used to evaluate real-world images[14].

Ghate and Nikose (2021) investigated image restoration. First, a single image is processed to generate several images with distinct properties. Then, a single image with more accurate scene information is created using data from these images. The authors used the dark channel as a filter to preserve image details in well-lit areas. To remove undesirable qualities, images are blended and weighted. The final image is superior to the source images [15]. A new method for nighttime image dehazing was created by Tang et al. in 2021 using a dark channel prior and a Taylor series expansion based on Retinex.

The suggested method can properly correct color distortion, enhance image clarity, and provide more visually pleasing image details compared to existing methods [16]. Zhang et al. (2021) proposed a new haze removal method to improve dehazing in aqueous vapor regions. An optimal correction model is used in this method. The ideal correction is created by combining the aqueous vapor region's relative change and hazy distribution. To obtain a better dehazing effect in the aqueous vapor zone, a priority calculation approach for choosing an appropriate patch is also created [17].

Zhang et al. (2021) designed a new dark channel to extend its valid range. The previous ERC was created by distributing both dark and light channels. The most striking discovery is that extreme reflectance channel pixels have high intensities in haze-free images (very high or shallow). Due to haze, the extreme reflectance channel's intensity is approaching that of the world's atmospheric light [18].

An enhanced Retinex image enhancement technique based on the guided filter in IHS color space was proposed by Tang et al. in 2017. The authors used a guided filter to boost high-frequency information to get fine-scale detail. And then, they recovered low-frequency information by using a guided filter to decompose data in the log domain; in contrast, the retinex approach only extracts high-frequency information to improve the image. The authors created a composite image by combining the image's high- and low-frequency information [19]. Faraj and Abood (2017) discovered better contrast, edges, and image characteristics using single-scale retinex. Multiple scale retinex improved the image clarity and quality. MSR enhanced the images' contrast and features. This method proved helpful in all thermal images and significantly improved them [20]. The dual relationship between picture dehazing and nonuniform illumination separation was mathematically demonstrated by Galdran et al. (2018), who showed that applying a Retinex operation to an inverted image and then inverting the result dehazes the image and vice versa The authors have shown, theoretically and experimentally, that this holds for many Retinex procedures. Both quantitative and qualitative testing revealed competitive dehazing outcomes [21]. Li et al. (2018) proposed combining Retinex and a dark channel to defog sea cucumber images. The dark channel is used to pre-process the original RGB image, and a weighted average of the pixels is used to maintain the reflection property of the image. The image is convolved with a Gaussian template to enhance it. Adjusting the S and V parameters increases an HSV image's brightness and saturation [22]. Two models, hazy incident light and foggy reflected light were proposed by Liu et al. in 2020. The dark channel defogging algorithm recalculates the ambient light value, the transmittance of the fog incident light component, and fog reflected light component. As a result, Retinex's fog-free image has more contrast and brightness [23].

Guo & Wang (2020) suggested a composite enhancer. The dark channel prior and retinex models are coupled using two customizable parameters to create DeRetinex. The second enhancement uses the DeRetinex model, eliminating the haze created by dehazing. The suggested approach avoids overexposure and provides rich texture features, low noise, and excellent color recovery [24]. To predict the illumination map, HUANG et al. (2020) presented an end-to-end network architecture based on Retinex. IEB incorporates an attention method to lessen image artifacts and smooth color transitions. The authors fused the image with the local grey mask to produce nonuniform illumination image pairings to promote data diversity and model generalization [25]. The contrast-to-noise ratio (CNR), which dehazes the original hazy images, was proposed by Saikumar et al. (2020) as a method for evaluating hazy and foggy images. The authors also suggested a special, original effective parameter based on an image-filtering method [26]. Using the White-Patch Retinex algorithm and an upgraded dark channel prior approach, Chung et al. (2020) proposed a method for removing haze from a single image (both heterogeneous algorithms). The algorithm's value grows as the architecture becomes more diverse. With its innovative design and excellent implementation, the suggested algorithm can restore a clean image while addressing the halo effect, color distortion, and lengthy operation times [27]. A Bayesian retinex technique was developed by Zhuang et al. in 2021 to enhance underwater images with multi-order reflectance and illumination gradient priors. To eliminate color casts and restore naturalness, simple color correction is applied. Next, optimize the color corrected image by utilizing multi-order gradient priors on reflectance and illumination [28].

Khalil and Ameen (2022) developed the SSR technique to improve nighttime image processing. First, it converted the RGB image to HSV and enhanced the V channel while leaving the H and S channels alone. Then it computed the illuminated and original images' logarithms and subtracted them using a different method [29].

3. Proposed Methodology

The proposed hybrid method combines the dark channel prior (DCP) and Single Scale Retinex (SSR) technique for image haze removal. The following is the description of the steps involved in the hybrid method:

3.1 Dark Channel Prior (DCP):

Using a single-image fog removal approach, fog from an image is eliminated. The DCP approach is the most common technique. It estimates both transmission map and air-light to recuperate the original image from foggy.

Equation (1) provides the atmospheric scattering model, which is often used to describe the creation of foggy images.

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

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

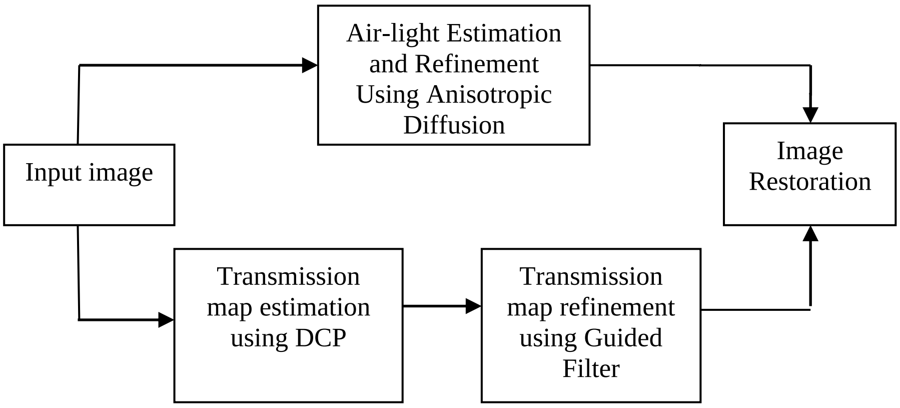


Fig1: Block Diagram of Existing DCP Method

I(x):Hazy Image
J(x): scene radiance
t(x): medium transmission
β: atmospheric attenuation coefficient
d(x): depth map or distance between an object in the image and observer.
A: Atmospheric Light

$$\text{Direct Attenuation}=J(x)t(x) \qquad (3)$$

$$\text{Air light} =A^*(1-t(x)) \qquad (4)$$

3.2 Dark Channel Creation

The lowest intensity pixel of a patch with a range of sizes in the three color planes of R, G, and B is used to create the dark channel. Equation (5) determines the dark channel for any image J.:

$$J_{dark}(x) = min_{c\in}\{r,g,b\}\left(min_{y\in p(x)}\left(J_c(y)\right)\right) \qquad (5)$$

Where J_c is a color channel of J and p(x) is a local patch centered at x. A dark channel ($J_{dark}(x)$) is the outcome of two minimum operators.

3.3 Transmission Map Estimation

Firstly, the haze image equation which is given by (1) is normalized by A as:

$$\frac{I^c(x)}{A^c} = \frac{t(x)J^c(x)}{A^c} + (1 - t(x)) \qquad (6)$$

Where $I^c(x)$ is the intensity of foggy image I of x^{th} pixel; t(x) is the transmission map; $J^c(x)$ is the scene radiance of haze-free image; and A is global atmospheric light. It is observed that the dark channel of an image is close to zero. Since A is some positive quantity.

$$J^{dark}(x) = min_{c\in\{r,g,b\}}\left(min_{y\in p(x)}\left(J^c(y)\right)\right) \qquad (7)$$

As t(x) is constant in a patch. Therefore, (6) for the estimation of transmission map may be written as:

$$\acute{t}(x) = 1 - min_{y\in p(x)}\left(min_c\left(\frac{I^c(x)}{A^c}\right)\right) \qquad (8)$$

Some amount of haze is kept in an image by adding a factor called w ($0<w\leq 1$) so that image looks natural. Hence, the new estimated transmission map is given by (9):

$$\check{t}(x) = 1 - w * min_{y\in p(x)}\left(min_c\left(\frac{I^c(x)}{A^c}\right)\right) \qquad (9)$$

For refinement of the transmission map, the Guided filter is used.

3.4 Single Scale Retinex (SSR):

According to retinex theory, an image I comprises lighting information L, which establishes the image's dynamic range, and reflection information R, which is the object's reflection information. Let *I* (*x*, *y*) represent a pixel in the image *I*, *I* (*x*, *y*) can be denoted by

$$I(x, y) = L(x, y).R(x, y) \qquad (10)$$

Retinex-based picture enhancement involves keeping the reflection information while removing or reducing the effect of light information from the original image. Equation (10) may be written as follows:

$$R(x, y) = I(x,y) / L(x, y) \qquad (11)$$

For the convenience of calculation, logarithmic transformation is implemented on both sides of (11) to estimate *R*(*x*, y):

$$\log R(x, y) = \log I(x, y) - \log L(x, y) \qquad (12)$$

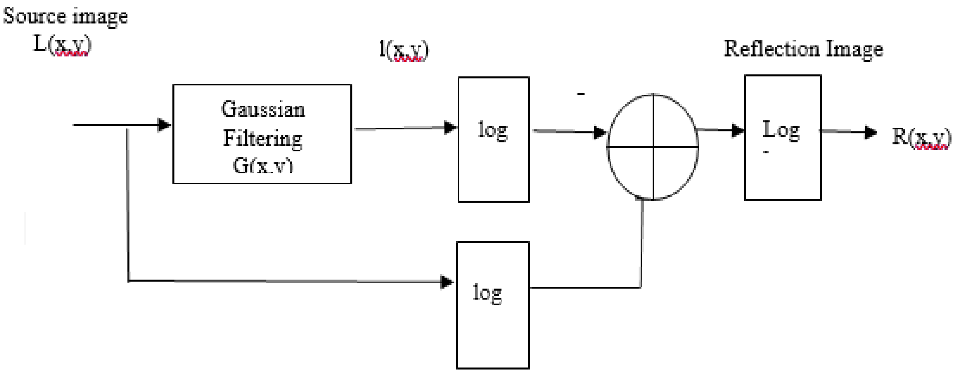


Fig 2: Basic flowchart of Retinex

L(*x*, *y*) can be estimated by convolving *I*(*x*, *y*) with a Gaussian function $G_\sigma(x, y)$

$$L(x, y) = I(x, y) * G_\sigma(x, y) \qquad (13)$$

Where σ is the standard deviation of the Gaussian function, "*" denotes convolution operation, $G_\sigma(x, y)$ is given by

$$G_\sigma(x, y) = \frac{1}{\sqrt{2\pi\sigma}}\exp(-\, x^2 + y^2 / 2\,\sigma 2) \qquad (14)$$

Put (13) and (14) to (12), SSR is obtained as:

$$logR(x, y) = logI(x, y) - log[I(x, y) * G(x, y)] \qquad (15)$$

Then, the reflection information $R(x, y)$ is computed by linear stretching log $R(x, y)$ instead of implementing exponent arithmetic:

$$R(x, y) = 255.\frac{\log R(x,y) - \min(\log R(x,y))}{\max(\log R(x,y)) - \min(\log R(x,y))} \qquad (16)$$

Where *min* (*log* $R(x, y)$) indicates the least of *log* $R(x, y)$, *max* (*log* $R(x, y)$) means the highest possible of *log* $R(x, y)$

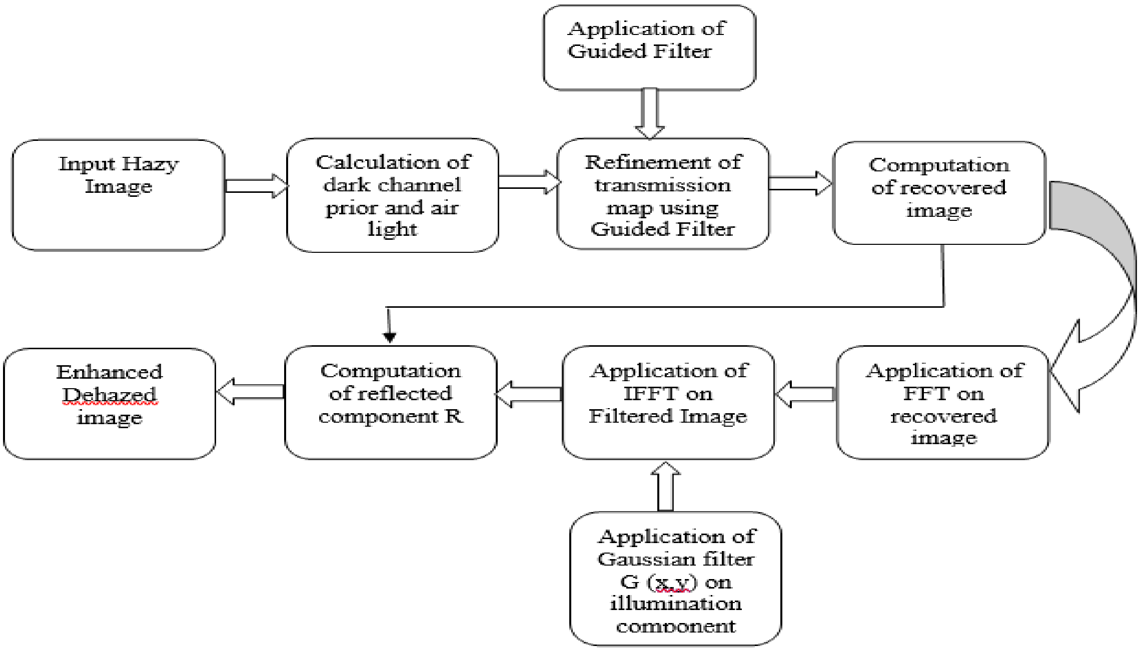


Fig 3: Block Diagram of Proposed Methodology Hybrid DCP with SSR

Listed below are some implementation steps

1. Insertion of a Hazy Image
2. Calculating Dark Channel Prior from a Hazed Image

$$J^{dark}(x) = \min_{c\in\{r,g,b\}}\left(\min_{y\in p(x)}\left(J^c(y)\right)\right) = 0$$

Where

J^c is a color channel of J and $p(x)$ is a local patch centred at x

J^{dark} Dark channel of J and its low and tends to be zero

J is Haze free outdoor image

3. Atmospheric light computation
4. Estimation of transmission map

$$\acute{t}(x) = 1 - min_{y\in p(x)}\left(min_c\left(\frac{I^c(x)}{A^c}\right)\right)$$

Where

$I^c(x)$ is the intensity of foggy image I of x^{th} pixel

Transmission map is t(x).

Global atmospheric light is A.

5. Guided filter Application
6. The process of computing the final recovered image using the final scene radiation (J)

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

7. Application of FFT on recovered Image through DCP

8. Application of Gaussian Filter on illumination component of the recovered image
9. Application of IFFT on Filtered image
10. Computation of the Reflected component of the image
11. Application of adaptive histogram equalization on Reflected Components
12. Obtaining the recovered enhanced Haze free image

3.5 Embedding Tests

As discussed above, performance assessment parameters, i.e., PSNR, MSE, SSIM, and VM have been taken to assess the operational effectiveness of the proposed hybrid DCP with SSR method with the existing DCP method.

PSNR: To evaluate the quality of the reference and dahazed images, the PSNR is used. The MSE between the pixel estimations of the referenced image (I) and the dehazed image (I_w) serves as a measure of PSNR

$$\mathrm{PSNR} = 10 \log \frac{\max{(\mathrm{I,Iw})}^2}{\mathrm{MSE}} \qquad (17)$$

Where $\max(I, Iw)$ is the highest valued pixel of the image, in a grayscale image, this value is equivalent to 255. Better results are achieved with higher PSNR values.

MSE: To anticipate the inaccuracy between the referenced image (I) and the restored dehazed image(Iw), a well-known quality metric is needed. It is the mean squared difference between the original and degraded images. MSE's value ranges from 0 to ∞. Consequently, to reduce inaccuracy, it should be close to 0. The following mathematical formula can be used to calculate MSE:

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{\mathrm{i=1}}^{\mathrm{M}} \sum_{\mathrm{j=1}}^{\mathrm{N}} (\mathrm{I(i,j)} - \mathrm{Iw(i,j)})^2 \qquad (18)$$

I(i, j) and Iw(i, j) represent the pixel intensities of a haze-free referenced image and restored dehazed images; i and j represents the pixel coordinates; The parameters M and N specify the number of columns and rows. The highest possible value of R for an RGB image is 255.

SSIM: Structure Similarity Index Measure is a perception-based model that takes into account key perceptual phenomena like brightness and contrast masking terms and views image deterioration as a perceivably altered structural aspect of the information.

$$\mathrm{SSIM\ (I, Iw)} = \frac{(2\mu x\mu y + \mathrm{C1})\ (2\sigma xy + \mathrm{C2})}{(\mu x2 + \mu y2 + \mathrm{C1})\ (\sigma x2 + \sigma y2 + \mathrm{C2})} \qquad (19)$$

μ_x, μ_y, σ_x, σ_y represents the corresponding average and variance values between the original referenced image I and the restored dehazed image I_w.

σ_{xy} represents the covariance between I & I_w, C_1& C_2 are constant factors.

4. Experimental Setup

For proving the efficiency and effectiveness of the proposed method, the experiment has been done on four images (House.jpg, Ground.jpg, Crop.jpg, Road.jpg), Table 1, Table 2 and Table 3 in proceeding section. The above said three performance assessment parameters, i.e., MSE and PSNR, SSIM are used for the comparisons to evaluate the performance of the proposed method.

5. Experimenntal Results & Analysis

In this research work, a novel hybrid mechanism that combines the DCP and SSR methodologies is proposed. DCP is the image restoration technique and SSR is the image enhancement technique. In the hybrid technique, a guided filter has also been applied with a proposed method that works efficiently on low and high-frequency image components in contrast to the Gaussian filter. Adding this filter removes Halo Artifacts, preserves edges, and improves image blurring and contrast. Furthermore, the hybrid technique overcame the problems occurring with the earlier techniques, e.g., high noise in images, low SSIM, low haze improvement index, low entropy, and standard deviation. The computations of the following parameters, such as PSNR, SSIM, MSE, and VM, have been used to assess the performance of the hybrid technique.

In a hazy image, the dark channel is first estimated for the area with the most haze. The dehaze image is then calculated using estimates for the transmission map, depth map, and air light.

The dehazed image obtained by the DCP method is applied to the SSR method in the Second Step, where the dehaze image is received with improved enhancement after the illumination component and reflected components of the image are obtained, and the radiance image is received by estimate of the illumination component using the Gaussian component.

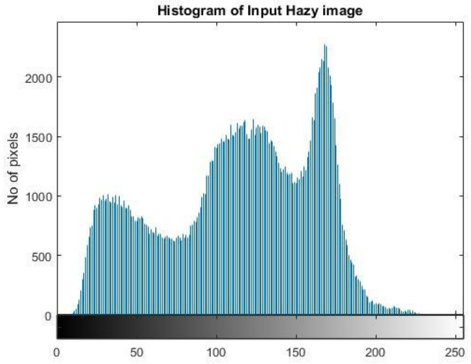
Fig. 4 displays the outcomes of the proposed method for a single input hazy image. A histogram is a graph that displays how the intensities in an image are distributed. In contrast to the histogram graph in fig. 4b for the hazy input image, the hybrid suggested technique demonstrates from the histogram graph in fig. 4g that the intensity is equally distributed for the final recovered improved output image.

Fig 5 compares the output images received from the existing DCP and the proposed hybrid methods. Fig 5a shows the four input hazy images, Fig 5b shows the output images through the existing DCP method, and the result images from the proposed hybrid DCPSSR approach are shown in Fig. 5c.

It is evident that the output images from the proposed hybrid approach are significantly improved and dehazed and have better contrast than those received through the existing DCP method.

(a)Hazy Input Image

(c)Dark Channel of Hazy Image

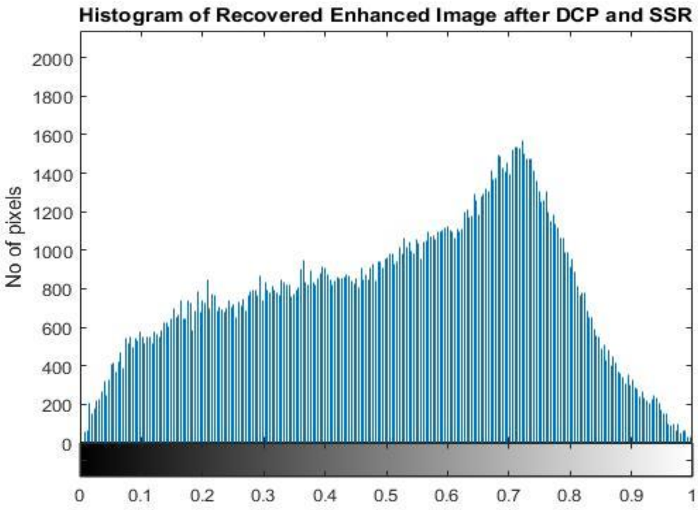


(d)Transmission Map of Hazy Image

(b)Histogram of Hazy Input Image

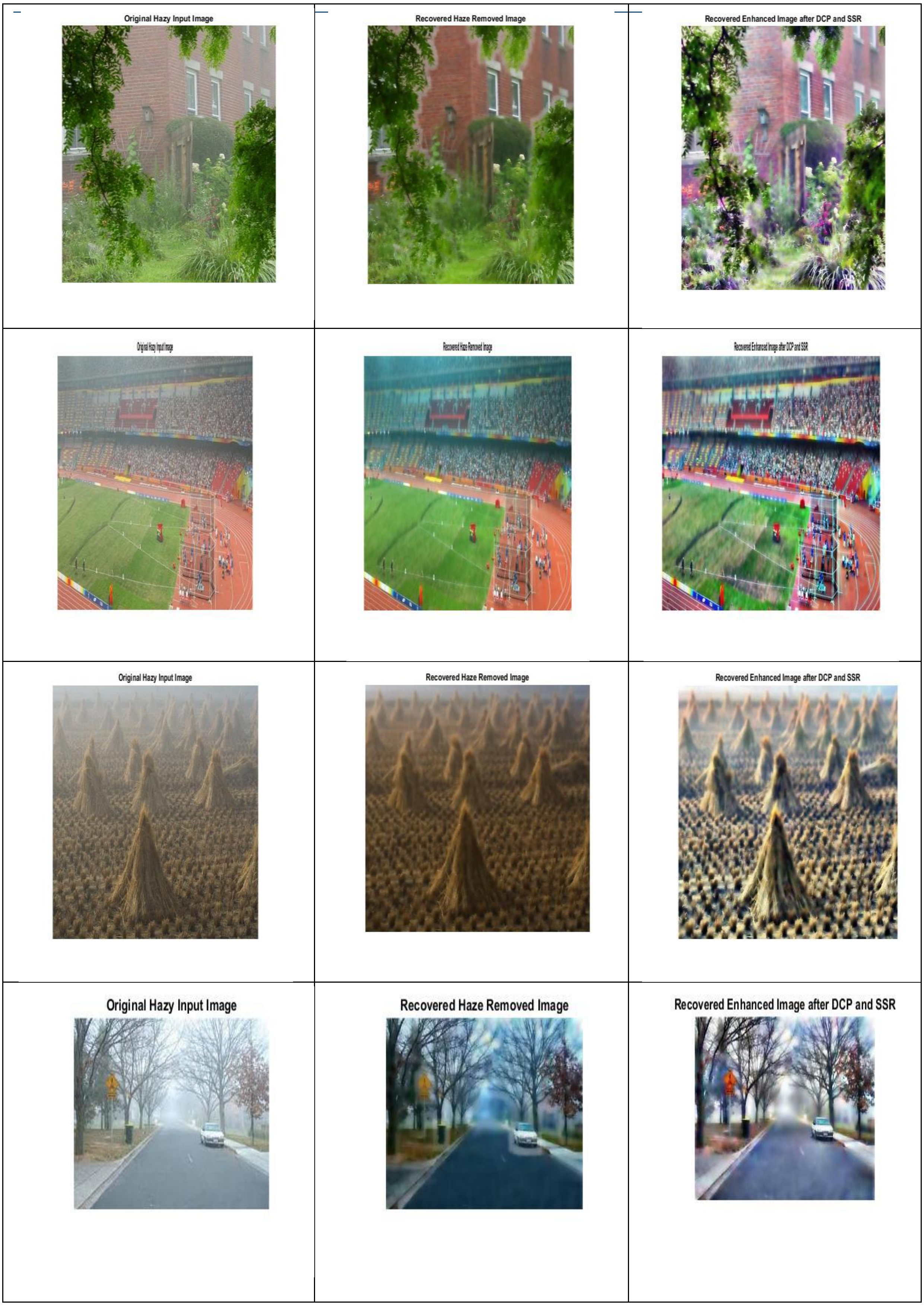
(e)Transmission Map after Filtration through Guided Filter

(f)Recovered Enhanced Image after DCPSSR



(g) Histogram of Final Recovered enhanced Image after DCPSSR

Fig4: Results of Proposed Hybrid Method (a) Hazy Input Image (b) Histogram of Hazy Input Image (c) Dark Channel of Hazy Image (d) Transmission Map of Hazy Image (e) Transmission Map after Filtration through Guided Filter (f)Recovered Enhanced Image after proposed DCPSSR (g) Histogram of Final Recovered enhanced Image after proposed DCPSSR



5a 5b 5c

Figure 5: 5a(Far Left) Hazed Input Images, 5b(Middle)DCP Output Images, 5c(Far Right) Proposed Method DCPSSR Output Images.

The experiment has been done on four dehazed images (House.jpg, Ground.jpg, Crop.jpg, Road.jpg). The above four performance assessment parameters, i.e., MSE, PSNR, SSIM &VM, are used for the comparisons and given in Tables 1 and 2.

Table 1: Experimental Result with Existing DCP Method with Guided Filter

IMAGE NAME	PSNR	MSE	SSIM	Visibility Metric Haze Improve
House.jpg	66.35	0.0151	0.810	26.91
Ground.jpg	70.80	0.0054	0.810	15.67
Crop.jpg	66.55	0.0144	0.730	90.38
Road.jpg	60.74	0.0540	0.458	11.23

The value of all parameters for all four images is shown in table 1 for the DCP method with a guided filter.

Table 2: Experimental Results With Proposed Hybrid DCP And SSR

IMAGE NAME	PSNR	MSE	SSIM	Visibility Metric Haze Improve
House.jpg	69.34	0.0076	0.612	114.75
Ground.jpg	69.97	0.0066	0.611	102.66
Crop.jpg	69.07	0.0081	0.533	81.16
Road.jpg	67.46	0.0117	0.653	73.83

Table 2's value for each parameter for each of the four Images amply demonstrates the efficacy of the suggested approach. In table 3, a comparison between the proposed method and the DCP method is shown.

Table 3: Comparison Of Existing Method And Proposed Method

IMAGE NAME	MSE		PSNR		SSIM		VM	
	DCP	**Proposed Method**	**DCP**	**Proposed Method**	**DCP**	**Proposed Method**	**DCP**	**Proposed Method**
House.jpg	0.0151	0.0076	66.35	**69.34**	0.810	0.612	26.91	**114.75**
Ground.jpg	0.0054	0.0066	70.80	69.97	0.810	0.611	15.67	**102.66**
Crop.jpg	0.0144	0.0081	66.55	**69.07**	0.730	0.533	90.38	**81.16**
Road.jpg	0.0540	0.0117	60.74	67.46	0.458	0.653	11.23	**73.83**

Table 3 shows that the PSNR quality index values for the proposed hybrid method are much higher than those for the existing DCP techniques, which implies that the proposed method tremendously enhances visibility. The proposed hybrid method's average PSNR value over the DCP is 4.32%. The average VM value of the proposed hybrid method is 158.25 % over the existing DCP. It is observed that for image Road.jpg proposed hybrid method PSNR value is 11.07% over the existing method. Also, observed that for Road.jpg, proposed hybrid method VM value is 557.44% over the existing method.

The computed values of performance assessment parameters in Table 3 show that the proposed hybrid method is prominent to the DCP method. The assessment value of all four performance evaluation parameters for the proposed method is better than the existing one.

6. Conclusion

This paper proposes a hybrid technique: the combination of the DCP Technique and SSR technique. The experiments have shown that the proposed technique induced less distortion and low noise, better enhancement, and contrast in recovered dehazed image. The most significant proofs of the above statement are PSNR and VM values. The PSNR value of images ranges from 67.46 to 69.97 whereas VM values range between73.83 to 114.75 and MSE value ranges from 0.0066 to 0.0117 i.e., almost near the ideal value of 0. This proves that the proposed method outperforms with nearly 100% similarity between the matching quantities and poses robustness and efficiency. This is also found that the existing DCP method alone is not performing effectively. The addition of SSR image enhancement method has brought more optimization and effectiveness for image dehazing in terms of PSNR and VM. Some illustrative examples demonstrating the advantages of the proposed method have also been given. The proposed method may be used effectively for the practical image haze removal compared to existing methods for dehazing.

A promising direction for further research is to replace the DCP method with a new proficient method,Color Attenuation Prior (CAP). This replacement would bolster the researcher in image restoration and introduce new horizons to image haze removal.

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