Multi-Objective Differential Evolution based Gradient Profile Prior Technique for Haze Removal in Remote Sensing Images

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Abstract— **Due to haze or fog weather condition the quality of remote sensing images are usually downgraded. The various researchers have presented a number of techniques based upon dark channel prior to remove the haze from remote sensing images The aim of this study is to enhance the vision quality of image by reducing haze and other vision artefacts effectively as compared to present techniques. In this paper we had proposed" Multi-Objective Differential Evolution based Gradient Profile Prior (MODEGPP)" de-hazing technique to overcome the issues of existing technique. The proposed method has been implemented and analyzed on available datasets of remote sensing hazy images and also compared with existing Fourth-Order Partial Differential Equations (FPDE) based de-hazing technique. The experimental result revealed that the proposed method outperforms in the term of parameters viz. contrast gain, Percentage of saturated pixels, Mean Square Error, Peak signal to Noise Ratio and Bit Error Rate. In conclusion, the proposed method is much capable in enhancing the visibility of hazy images along with reduced vision artifacts.**

Index Terms—**Haze Removal, Gradient Profile Prior, Multi-Objective Differential Evolution, Dark Channel Prior, Filtering.**

1. INTRODUCTION

Poor visibility downgrades image quality as well as the interpretation of the computer vision algorithms such as surveillance, object detection, tracking and segmentation. Poor visibility is due to occurrence of atmospheric substances which absorbed the light in between the camera and the object. They can be the water droplets that are there in the air. These droplets are very small in size and they continuously float in the air and leads to the dirt of the image when clicked in the bad weather conditions such as fog, haze and smoke etc. Fog is cloudiness or partial opacity in a developed photographic image caused by chemical action or stray radiations near the Earth's surface. [1]. In order to overcome the deterioration in the image, visibility restoration approaches are workable to the image so as to obtain a better quality of image. Visibility restoration model can be considered as the different methods that aim to decrease or eradicate the degradation that have occurred while the digital image was being obtained [2].Haze removal is a difficult task because it depends upon the unknown scene depth information. Hence removal of fog/haze requires the estimation of air light map or depth map [3].

Single image approaches for the fog/haze removal uses approximation and assumptions. These methods restore the foggy/hazy images by maximizing the contrast of the image based on the fact that the fog/haze free images don't lose its visual quality. These methods use a single image for the restoration of the image along with the key assumptions. Even so single image haze removal is difficult assignment because no prior information is acquirable about the scene [3].

Image dependent brightness preserving histogram equalization technique was utilized by [4] in 2010, which had resulted with preserved brightness along with enhanced local contrast of the analyzed images., but the results included halo and gradient reversal artefacts. Further, Authors [5] had investigated a Single haze removal technique using dark channel prior algorithm for removing the artefacts by soft matting but this technique was not applicable for large images. Xu et al.[6] had presented fast image de-hazing using improved dark channel prior based upon fast bilateral filtering instead of soft matting .however, the use of bilateral filtering had tried to show improvements over the previous techniques . Later, Shui et al. [7] had suggested Image Haze Removal of Wiener Filtering Based on Dark Channel Prior. However, this technique didn't perform better in some light bright area of the image. To remove the haze in efficient manner .Tripathi, et al. [8] had developed an algorithm which uses anisotropic diffusion for estimation of air light; It did not require user help and was also independent of the density of fog. , It could be applied on both color and gray images. Authors [9] had again suggested that fog formation was due to air light and attenuation and had observed that Air light increases the whiteness and attenuation increases the contrast in the scene. In comparative to this, Yuk et al. [10] had presented a novel Foreground decremented Preconditioned Conjugate Gradient (FDPCG) for adaptive background defogging of surveillance videos. Further, Ding et al.[11] had presented efficient directional based image de-hazing using quad trees; this technique was with different concept but did not remove the problems of artefacts in larger images. Then, Gujral et al [12] had formed Haziness Analysis to overcome the problems of previous techniques however; this technique was not suitable for objects which were opaque. Further, to reduce the reversal artefacts and preserving the edges, Singh [13] had developed Dark channel prior with gradient prior, the main feature of this technique was able to restore the detail information of image. In addition to this, for de-hazing the remote sensing images Li et al.[14] had utilized single image de-hazing using change of detail prior, this approach was able to remove the haze from an image by utilizing multiple scattering occurrences in dissemination of illumination.

However, this technique didn't preserve the edges of haze free images in efficient manner. To overcome the problems of existing DCP techniques. Singh et al. [16] had developed De-hazing of remote sensing images using FPDE based trilateral filter with adaptive histogram equalization technique to reduce the artefacts. However, this technique was not able to perform very well. To overcome the problems of DCP techniques, Kaur, et al [17] had implemented efficient image de-hazing using multi-objective differential evolution; this technique had optimized the parameters needed to enhance the visibility of image. This technique also suffers from halo and blocking artefacts. Singh, et al [18] had developed a novel de-hazing model for remote sensing images using gradient domain based weighted guided filter for removing the gradient reversal artefacts. As comparison to previous techniques it gives better and improved results but somewhere this technique was not able to remove the artifacts completely.

Our main contribution to this paper is to study the various haze removal techniques and to implement a Multi Objective Differential Evolution based Gradient Profile Prior Technique for Haze removal in Remote Sensing Images. Our technique has improved the results of existing technique by replacing the dark channel prior with gradient profile prior and multi objective differential evolution technique. The results of this paperhave been compared and analyzed with existing technique on the basis of parameters viz. Contrast Gain (CG), Percentage of Saturated Pixels(PSP), Mean Square Error(MSE), Bit Error Rate(BER) and Peak Signal to Noise Ratio (PSNR).

2. METHODOLOGY

The process of de-hazing the remote sensing hazy images using proposed technique starts with reading the input hazy image, processing it through two main phases i.e. Multi-Objective Differential Evolution and Gradient Profile Prior and ends with giving the restored haze free image.

2.1 OVERALL METHODOLOGY

The Overall methodology of proposed work has been divided into two phases.

a). Multi-Objective Differential Evolution (MODE): Firstly, the MODE has been applied on remote sensing hazy image, which generally optimize the parameters of image using fitness function to reduce the percentage of saturated pixels and increasing the contrast gain of input hazy image.

b) Gradient Profile Prior (GPP): Secondly, GPP has been applied on remote a sensing image which usually gives the detailed prior information about the gradients of input image.

And then after that other estimations like air light evaluation, transmission map evaluation, and atmospheric veil evaluation have been performed. After performing all aforesaid evaluations finally the restored image has been obtained by applying the restoration model. The overall process of de-hazing the remote sensing images using proposed technique is presented into Fig 1.

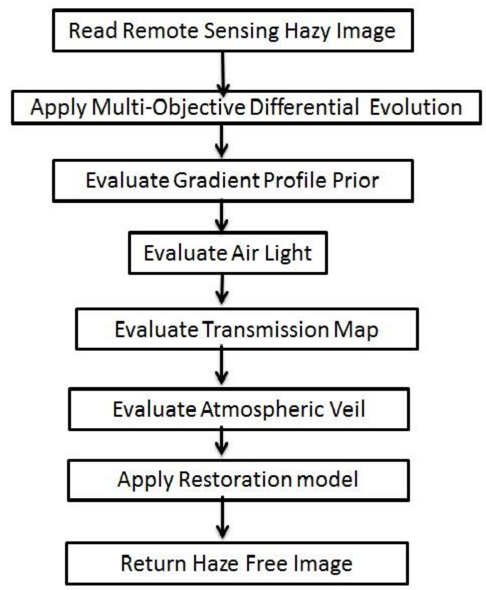

Fig 1: Flow chart of de-hazing using proposed technique

2.2 PROPOSED ALGORITHM:

It is proposed that Multi-Objective differential Evolution and gradient profile prior has been combined to perform the better than all previous techniques. The proposed algorithm works into 13 steps.

These 13 various steps through which we can get the clear haze free image are as:

Step 1: To start the whole process we have to take remote sensing hazy image.

Step 2: Generate random population for differential evolution. Here, differential evolution is used to optimize the image parameters on which the clarity of image mostly depends.

Step 3: Differential evolution works according to multi-objective fitness function.In proposed work, there is multi-objective function in which two parameters are used to select an optimal generation.

MOF=w1*CG+w2*(1/PSP) (1)

Step 4: Repeat the steps 5 to 7 until stopping criteria not met.

Step 5: For each population, r=1, 2, 3…N, where r is iteration index, a new mutant vector $D_{i,G+1}$will be created follows:

$$D_{i,G+1} = x_{c1,G} + F(x_{c2,G-}x_{c3,G}) \quad (2)$$

$where\ c_1, c_2, c_3$ are distinct. F is mutation Factor, the value of F is taken as 0.5. $D_{i,G+1}$is also called donor vector, which is responsible for further generation.
Step 6: Apply cross over operation, which often combine productive solutions coming from earlier generation with current donors.

$$T_{i,G+1} = \{D_{i,G+1} \text{if } rand_{j,i} \le CR\} \quad (3)$$

Else $D_{i,G+1} = x_{i,G}$
Where is $T_v$trial vector, CR is cross over ratio taken as 0.4 and $x_{i,G}$ is target vector.
Step 7: Apply selection operator to select the optimum parameter. The greedy scheme is crucial for fast convergence of DE.

$$x_{i,G+1} = T_{i,G+1} \text{ If } T_{i,G+1} \le f(x_i, \text{j}) \quad (4)$$

Otherwise, $x_{i,G+1} = x_{i,G}$
Here, $x_{i,G+1}$is the best individual.
Step 8: Once the stopping condition met means when there is optimal population is available, then apply gradient profile prior.
Step 9: Gradient profile prior all about the prior information about the gradients of hazy image. The gradients of image are obtained as:

$$\nabla A^c_{mg} = \text{m.N} \quad (5)$$

where m is magnitude and N is direction.
Haze Formation model is defined as:

$$F_{mg}(j) = A^c_{mg}(j)T_{mp}(j)+1 - T_{mp}(j) \quad (6)$$

Step 10: Atmospheric light estimation A_{tl} plays a significant role for removing the haze from a hazy image. The pixel with highest gradient in $F_{mg}$is called global atmospheric light.
The atmospheric light can be evaluated as:

$$A_{tl}(j) = F_{mg}(max_j(A^c_{mg})) \quad (7)$$

$where, A^c_{mg}$, Shows actual image radiance of each color channel and F_{mg} is called hazy image.
Step 11: The Third step of proposed approach is transmission map estimation. To evaluate the transmission map$T_{mp}(j)$, we have to normalize the haze image F_{mg} byA_{tl}. Let us assume that $A_{vl}$is known. Hence, (6) can be rewritten as follows:

$$\frac{F_{mg}(j)}{A_{tl}} = \frac{A_{mg}(j)}{A_{tl}} T_{mp}(j) + A_{vl}(j) \quad (8)$$

Step 12: Next step is to find out the coarse atmospheric veilA_{vl} as:

$$A_{vl}(j) = 1 - T_{mp}(j) \quad (9)$$

Step 13: Last step is to evaluate the restoration model. The restoration model gives the restored image or haze free image.

$$A_{mg}(j) = \frac{F_{mg}(j) - A_{tl}}{\max(T_{mp}(\text{j}), \gamma)} + A_{tl} \quad (10)$$

The resorted image suffers from noise when transmission map $T_{mp}(j)$ reaches towards the zero.$T_{mp}(j)$is constrained as lower bound which is denoted by γ.according to literature review, γ is experimentally set to 0.1.

2.3 DATASETS

In order to enhance the visibility of remote sensing images ,Eight remote sensing images have been taken from QUICKBIRD[34],IKONOS[34],GEOEYE1[34],TRIPLESAT[34] and KOMPSAT[34] sensors.

2.4 ANALYSIS PARAMETERS

To compare and analyze the results of proposed technique with existing technique number of parameters viz. Mean square error, Percentage of saturated pixels, Peak signal to noise ratio, Contrast gain, and Bit error rate has been taken.

1. Mean Square of Error (MSE): MSE means to measure the mean of squares of the problems or perhaps deviations which are, the real difference between foggy in addition to fog-free graphic here [24]. MSE can be evaluated as:

$$\text{MSE} = \frac{1}{\text{MN}} \sum_{\text{i}=1}^{\text{M}} \sum_{\text{j}=1}^{\text{N}} (\text{x(i, j)} - \text{x(i, j)})^2 \quad (11)$$

2. Percentage of Saturated Pixels (PSP): The contrast gain of haze free image should not be so high that the pixels of restored image become saturated. Saturated pixels are basically from the category of salt and pepper noise. It can be denoted as:

$$\text{P}_{\text{sp}} = \frac{\text{o}_\text{s}}{\text{M} \times \text{N}} \quad (12)$$

Where, o_s is Number of saturated pixels in image Is.

The minimum Percentage of saturated pixels depicts that given de-hazing technique provides better result than others [16].

3. Peak Signal to Noise Ratio (PSNR): The peak signal to noise ratio is used as a quality measurement between original and reconstructed image. The higher the value of PSNR, better the quality of the reconstructed image. An improvement in the PSNR magnitude will increase the visual appearance of the image. It can be calculated as

$$\text{PSNR=10log10 [R2/MSE]} \quad (13)$$

Where, R is the maximum possible pixel value of the image and MSE is the Mean Square Error.

4. Contrast Gain(CG): Contrast Gain is defined as the average contrast difference between hazy and haze free images .Higher the value of contrast gain indicates that given haze removal technique is more efficient and others.[13]

$$\text{C}_{\text{gain}} = \text{C}_{\text{Idehz}} - \text{C}_{\text{1haze}} \quad (14)$$

Where, $C_{Idehz}$and $C_{1haze}$are mean contrast of dehazy and hazy image respectively.
Contrast gain should be high to get the clear picture. [17].

5. Bit Error Rate (BER): Bit Error Rate that immediately becomes the number of errors occurs inside of a chain of any pointed out the number of bits. Bit error rate can be described by the following equation:

$$BER = \frac{\text{Number of errors}}{\text{total number of bits sent}} \quad (15)$$

However,the BER should be minimized.

3. RESULTS

To analyze the performance of proposed method, an experimental platform has been designed and implemented. The hardware used for experimentation is Intel core i5@2.40GHz with 8 GB RAM and testing software is MATLAB 2013a.

3.1 VISUAL ANALYSIS

To demonstrate the effectiveness of the proposed method, eight remote sensing hazy images have been taken.

Fig 2(a), Fig 3(a), Fig 4(a) and 5(a) shows the input hazy images, and it has reduced visibility. Therefore the existing methods[16] has been applied to these hazy images to obtain the haze free images as shown in Fig 2(b), Fig 3(b),Fig 4(b) and 5(b)respectively. Then the proposed method has been applied on input hazy images that perform better than existing method as shown in fig 2(c), Fig 3(c), Fig 4(c) and 5(c).

Figure 2: Results of Haze Removal Techniques for GEOEYE-1[34] Hazy Image (a) Input Image (b) Existing method (c) Proposed Method.

Figure 3: Results of Haze Removal Techniques for TRIPLESAT [34] Hazy Image (a) Input Image (b) Existing method (c) Proposed Method.

Figure 4: Results of Haze Removal Techniques for IKONOS [34] Hazy Image (a) Input Image (b) Existing method (c) Proposed Method.

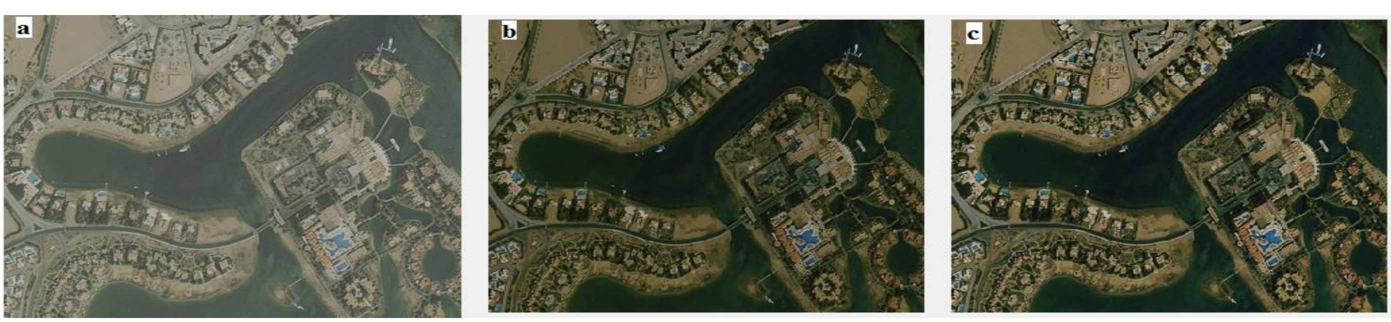

Figure 5: Results of Haze Removal Techniques for QUICKBIRD [34] Hazy Image (a) Input image (b) Existing method (c) Proposed Method.

3.2 QUANTITATIVE ANALYSIS

Table 1: Comparative Analysis for Mean Square Error (MSE) of Eight Remote Sensing images using Existing and Proposed Method.

Input Images	Existing Method[16]	Proposed Method
Hazy Image 1	0.053186	0.039036
Hazy Image 2	0.068481	0.056500
Hazy Image 3	0.060034	0.045970
Hazy Image 4	0.089179	0.070583
Hazy Image 5	0.027440	0.020680
Hazy Image 6	0.067627	0.054979
Hazy Image 7	0.035941	0.026698
Hazy Image 8	0.055427	0.040907
Mean	0.05716	0.04441

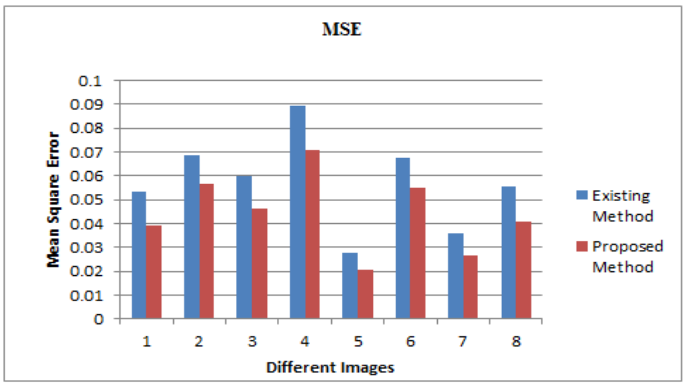

Figure 6: Comparative Analysis of MSE for different images using Existing and Proposed Method.

Table 2: Comparative Analysis for Percentage of Saturated Pixel (PSP) of Eight Remote Sensing images using Existing and Proposed Method.

Input Images	Existing Method[16]	Proposed Method
Hazy Image 1	0.23062	0.19758
Hazy Image 2	0.26169	0.23770
Hazy Image 3	0.24502	0.21441
Hazy Image 4	0.29863	0.26567
Hazy Image 5	0.16565	0.14381
Hazy Image 6	0.26005	0.23448
Hazy Image 7	0.18958	0.16339
Hazy Image 8	0.23543	0.20226
Mean	0.23583	0.20741

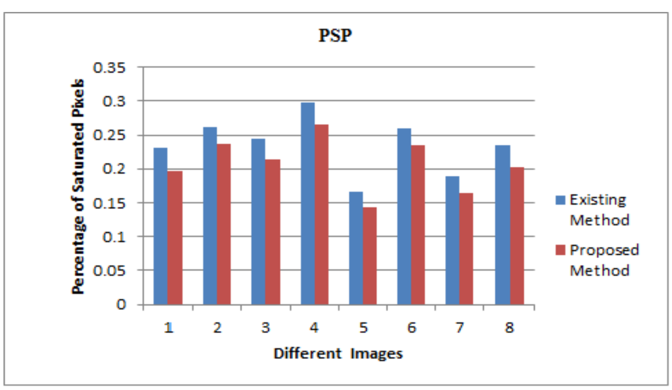

Figure 7: Comparative Analysis of PSP for different images using Existing and Proposed Method

Table 3: Comparative Analysis for Peak Signal to Noise Ratio (PSNR) of Eight Remote Sensing images using Existing and Proposed Method.

Input Images	Existing Method[16]	Proposed Method
Hazy Image 1	60.8728	62.2162
Hazy Image 2	59.7751	60.6102
Hazy Image 3	60.3468	61.506
Hazy Image 4	58.6282	59.6438
Hazy Image 5	63.7469	64.9753
Hazy Image 6	59.8296	60.7288
Hazy Image 7	62.5749	63.8661
Hazy Image 8	60.6936	62.0128
Mean	60.80884	62.19490

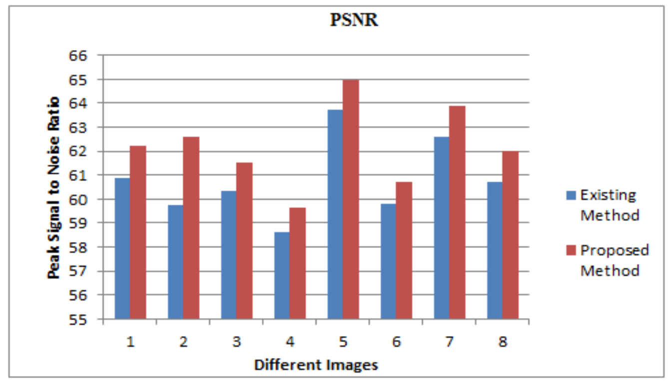

Figure 8: Comparative Analysis of PSNR for different images using Existing and Proposed Method.

Table 4: Comparative Analysis for Contrast Gain (CG) of Eight Remote Sensing images using Existing and Proposed Method.

Input Images	Existing Method[16]	Proposed Method
Hazy Image 1	1.9873	1.9912
Hazy Image 2	1.9819	1.9862
Hazy Image 3	1.985	1.9894
Hazy Image 4	1.9714	1.9799
Hazy Image 5	1.9952	1.9963
Hazy Image 6	1.9822	1.9866
Hazy Image 7	1.99	1.9952
Hazy Image 8	1.9864	1.9968
Mean	1.98492	1.9902

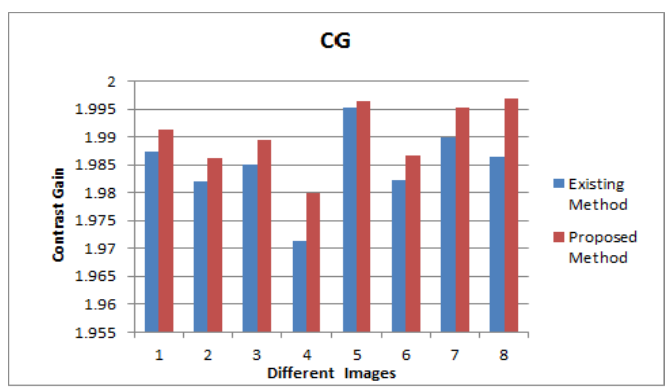

Figure 9: Comparative Analysis of CG for different images using Existing and Proposed Method.

Table 5: Comparative Analysis for Bit Error Rate (BER) of Eight Remote Sensing images using Existing and Proposed Method.

Input Images	Existing Method[16]	Proposed Method
Hazy Image 1	0.016428	0.016073
Hazy Image 2	0.016729	0.016499
Hazy Image 3	0.016571	0.016259
Hazy Image 4	0.017057	0.016766
Hazy Image 5	0.015687	0.016467
Hazy Image 6	0.016714	0.016175
Hazy Image 7	0.015981	0.015658
Hazy Image 8	0.016476	0.016126
Mean	0.01645	0.01615

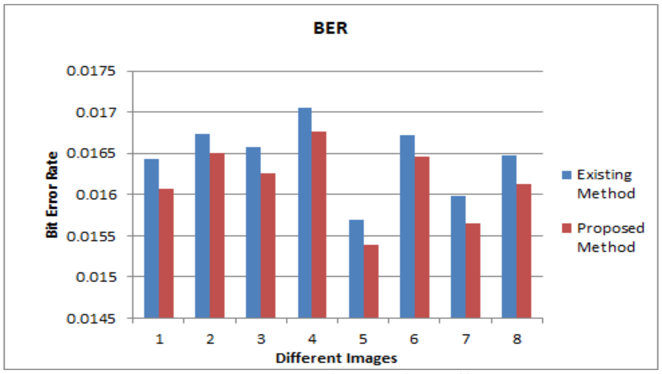

Figure 10: Comparative Analysis of BER for different images using Existing and Proposed Method.

4. DISCUSSIONS

The performance of MODEGPP method has been compared with FPDE method [16] using remote sensing hazy images taken from sources such as QUICKBIRD [34], TRIPLESAT [34], IKONOS [34], GEOEYE-1 [34] and KOMPSAT [34] sensors.

Table 1 to 5 shows the MSE, PSP, PSNR, CG, BER values of haze free images using proposed method and existing method. The tables 1,2 and 5 clearly depicts that in proposed method the mean value of MSE ,PSP,BER has been reduced/improved from 0.05716 to 0.04441 ,0.23583 to 0.26741,and 0.01645 to 0.016155 respectively. Whereastable 3 and 4 clearly depicts that in proposed method the mean value of PSNR and CG has been increased/improved from 60.8084 to 62.1949 and 1.984 to 1.990 respectively.

5. CONCLUSION

In this thesis work, we have designed Multi-Objective Differential Evolution based Gradient Profile Prior Technique for image de-hazing .The proposed technique using gradient profile prior and multi objective differential evolution can reduces image haze effectively and improve the vision quality of image. This technique ensures the preservation of edges and minimal vision artefacts. The proposed method raises the PSNR and CG values of images, as well as decreases the values of PSP, BER and MSE. It has been observed that the proposed schemes provides better results than the existing schemes both in terms of visibility and retention of original image properties to implementation and performance assessment.

6. FUTURE SCOPE

The work can further be extended by including various evolutionary techniques like Ant colony optimization, Negative selection algorithm or fuzzy logic kind of techniques along with gradient profile prior to improve the quality of the Haze removal algorithms.

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