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Color Image Contrast Enhancement Using Modified Firefly Algorithm

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ABSTRACT

The image enhancement process is used for improving the standard of the image. It's inspired by the development of human perception pictorial information. Increasing the contrast of the image and removing the unwanted noise from the images is the picture enhancement process. A histogram of the low contrast images and depth image is employed to enhance image contrast. In the work, a color image is used as input and the authors extract the red, green, and blue pixel matrixes from it, then obtain the optimized histogram using the modified firefly algorithm, and then compare the performance matrices like PSNR and Entropy, etc. with other optimization techniques.

KEYWORDS

Firefly Algorithm, Image Enhancement, Image Processing, PSNR

1. INTRODUCTION

Image enhancement aims to contrast improvement of the original images. When the image display appropriately, a computer system or human can extract the required information. The image enhancement methods can be classified into four main parts: Pseudo coloring, transformation, unique domain, and point domain. The transformation of the histogram is used to improve the contrast of gray-level images. The histogram equalization method is popular, but the disadvantages are that output images have unnatural contrast and lighting. Image enhancement can be used in different applications for image processing, such as contrast enhancement, noise reduction, edge restoration, and edge enhancement (Singh, Kohli, and Diwakar 2013)(Maini and Aggarwal 2010). Global histogram equalization is the most common way of enhancing contrast in a picture. During the previous few decades, many approaches are used to enhance the contrast of image like Range Limited Bi-Histogram equalization (RLBHE), Brightness Preserving Bi-Histogram Equalization (BBHE), Brightness Error Bi-Histogram Equalization (MMBEBHE), Equal Area DSIHE(Dualistic Sub-Image Histogram Equalization) and rightness Preserving Bi-Histogram Equalization (BBHE) (Singh, Kohli, and Diwakar 2013).

The firefly algorithm is a simulated evolutionary algorithm used for parallel searching on local and global extremum. The firefly algorithm-based local enhancement algorithm has been used to optimize parameters search for better enhancement. The firefly algorithm is a modern heuristic algorithm applied to the non-continuous and non-linear optimization problem. The characteristics

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of the firefly algorithm are like minimum computation rate and higher converging to optimization problem solution. The greedy heuristic method is used to contrast enhancement of images (Majumder and Irani 2006). Hassanzadeh et al. (Hassanzadeh, Vojodi, and Mahmoudi 2011) developed a firefly algorithm-based adaptive local enhancement algorithm to improve the detail and grayscale of source images. Gopal et al. (Dhal et al. 2015) developed two algorithms to improve the contrast between low-contrast images using chaotic sequence and levy flight. All algorithms were applied to optimized Boost Filter parameters. Ye et al. (Ye, Zhao, and Ma 2015) developed an adaptive firefly algorithm to find optimal parameters and produce a gray level curve transformation to enhance images. This algorithm achieved the effective optimal parameters in an adaptive manner, which results better. Samanta et al. (Samanta et al. 2018) proposed the Mini Unmanned Aerial Vehicle (MUAV) system for capturing the low contrast /quality image. The firefly algorithm-based image enhancement method for gray level is used to enhance the image contrast. Xie et al. (Xie et al. 2019) developed two Types of Firefly algorithms like inward intensified exploration Firefly Algorithm and compound intensified exploration Firefly Algorithm. The first variant was found by the replacement of the attractiveness coefficient with a randomized control matrix. In the compound intensified exploration, firefly employs a dispensing mechanism. The Bat algorithm, firefly algorithm, and particle swarm optimization algorithm are used to solve the optimization problem.

Various image removal techniques are also used filters. Narendra et al. (Narendra Kumar, Dahiya, and Kumar 2020b), (Narendra Kumar et al. 2019), (N. Kumar, Dahiya, and Kumar 2020), (Narendra Kumar, Dahiya, and Kumar 2020a) Experimental results show that these more efficient for removing multilevel noise.

Here, we have modified the firefly optimization techniques to improve the image's contrast and compare the existing optimization techniques. The rest of the paper is organized as a section that discusses methodology, section 3 results, and discussion and rests above the paper's conclusion.

2. METHODOLOGY

2.1 Firefly Algorithm

The metaheuristic algorithm firefly is predicated on the behavior of fireflies and flashing patterns. Fireflies attract no matter their sex, thanks to the unisex nature of fireflies. The attractiveness of fireflies is proportional to fireflies' brightness, and attractiveness and brightness decrease, then distance increases. The less bright firefly move towards, the brighter firefly. If there's no brighter firefly, then a specific firefly moves randomly. The landscape of objective function is employed to work out the brightness of the firefly. Use the inverse square law when the sunshine intensity is out there at a specific distance (r) from the sunshine source. So, the sunshine intensity (I) decreases because the increasing the range (r) in terms of (I µ 1/ r^2).

In the algorithm of a firefly, there are three critical formulas, which are:

a) Attractiveness:

The function of attractiveness can be any decreasing monotonically functions such as following generalized form.

$$B\left(r\right) = B_0 e^{-\gamma r^m} \text{ (m}^3\text{1)} \quad (1)$$

Here γ is light retention coefficient, r is the distance of two fireflies, B_0 is the attractiveness at r = 0 and is a fixed light coefficient.

b) Distance:

The distance between any two fireflies i, j at x_i and x_j is the Cartesian distance

$$\boldsymbol{r}_{ij} = \boldsymbol{x}_i - \boldsymbol{x}_j = \sqrt{\sum_{k=1}^{d} \left(\boldsymbol{x}_{i,k} - \boldsymbol{x}_{j,k}\right)^2} \tag{2}$$

Here $x_{i,k}$ is the **(k)**th spatial coordinate component x_i of **(i)**th firefly and **d** is the number of dimensions.

c) Movement:

The firefly movement 'i' is attracted to the next brighter firefly 'j' is obtained by the following equation:

$$\boldsymbol{x}_i = \boldsymbol{x}_i + \boldsymbol{B}_0 \boldsymbol{e}^{-\boldsymbol{y}\boldsymbol{r}_{ij}^2} \left(\boldsymbol{x}_j - \boldsymbol{x}_j\right) + \pm\left(\boldsymbol{rand} - 0.5\right) \tag{3}$$

The second term of the equation is due to the attraction; the third term is randomization with α is a parameter for randomization, random number generator rand uniformly distributed in [0, 1]. For the many cases in the implementation $B_0 = 1$ and α Є [0, 1]

Pseudocode of the firefly algorithm:

```
Begin
f (x), x = (x_1,..., x_d)^T is the objective function
Produce starting populace x_i (i = 1, 2, …., n) of fireflies
I_i  is light intensity at x_i which is determined by f (x_i)
Characterize light retention coefficient γ
while (t <maxgeneration)
 for i = 1: n
      for j = 1: i all n fireflies (inner loop)
          if (I_j > I_i)
             Move firefly i towards j ;
           end if
          Varies attractiveness with range r via e^{-yr}
          Assess new arrangements and update with new light
intensity
      end for j
end for i
fireflies rank and locate the current best
end while
Post-process results and perception
end
```

2.2 Proposed Modified Firefly Algorithm:

1. Take a Colour input image and extract the red, green, and blue pixel matrixes.

2. Obtain the histograms $h_i[n]$, mass function(un-normalized discrete probability) of pixel intensities for each matrix.
3. Set the parameters, lambda, the quantity for positioning the amount of contrast on a scale of 0-20, and gamma, the amount of detail in the image to be retained, on a scale from $1 – 10^9$. Usually, lambda is around 4, and gamma is 50000.
4. Construct a Difference matrix, D, with backward-difference of histogram, i.e h[i]-h[i-1], required for histogram smoothening. The Difference matrix D € $R^{255*256}$ is bi-diagonal.
5. For each pixel matrix, obtain the optimized histogram, $h_o[n]$, from the firefly optimization algorithm.
6. Obtain the normalized histograms, p[n], from the optimized histograms. It gives an approximate probability distribution function of the pixel intensities.

$$p\left[i\right] = \frac{h_0\left[i\right]}{number\_of\_pixels} \tag{4}$$

7. Then, c[n], the Approximate CDF(Cumulative distribution Function), is obtained from p[n].

$$c\left[i\right] = sum\left(p\left[1:i\right]\right) \tag{5}$$

8. After the CDF is obtained, a modified discrete mapping function T[n] is used to map back to the spatial domain(pixels).

$$T\left(n\right) = \left(lambda + 1\right)x\{(2^\beta - 1)x(sum\left(p\left[1:n\right) + 0.5\right)\} \tag{6}$$

Where β is the number of bits used for representing pixel values and n € [0, 2^β-1] and p[n] is the probability density function.

The main steps of the proposed firefly method can be summarized as follow:

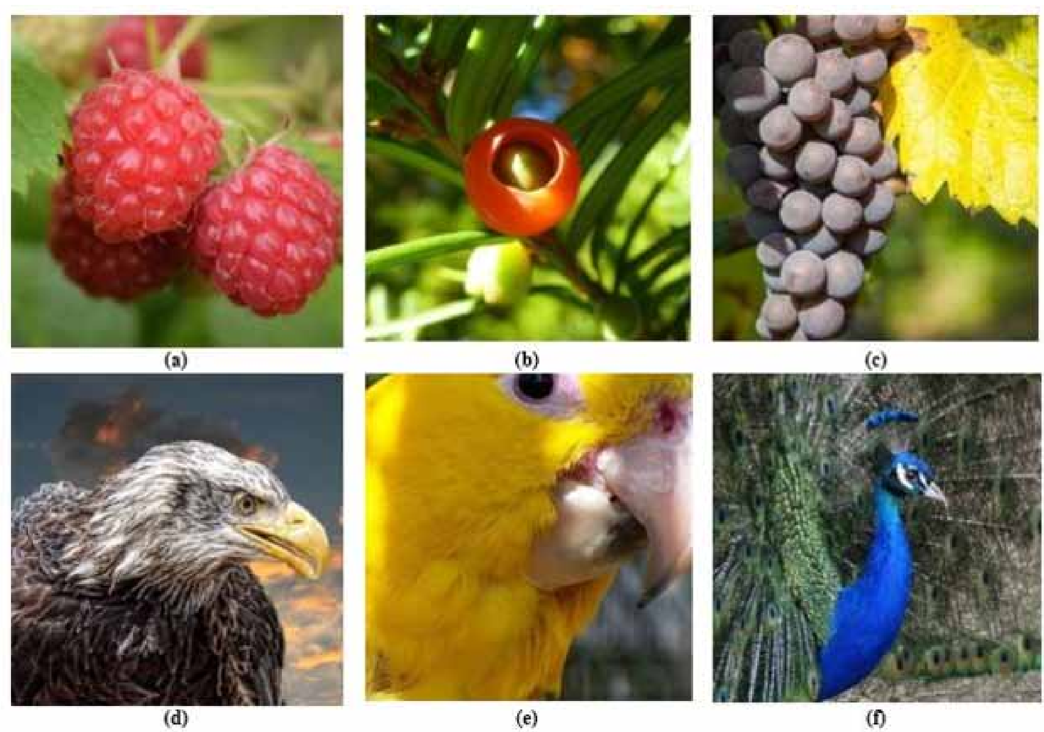
1) The firefly populations are initialized. The related parameters of firefly algorithm Initialize, such as initial attraction, medium absorption coefficient, phase factor, and the maximum number of iterations is 4000, randomly generate the initial location of firefly populations. To improve efficiency, alpha=num/N_iteration, betamin=alpha/N _iteration and gamma=betamin/N_iteration are modified to the constant value.
2) Get the luminosity of each firefly by measuring the objective function.
3) Recalculate the algorithm brightness of the modified position, then remove the first value and therefore the original position when the final value is increased, then retain the optimum value for the first value.
4) When the number of iterations exceeds the utmost value, populations sort of firefly by the brightness size and record the optimum location and, therefore, the maximum brightness returns to step 2 if the number of iterations fails to exceed the total value. They are taking the optimal solution for image enhancement into the simplified, incomplete beta function.

Finally, the image is obtained from this mapping. We have compared the results with existing optimization techniques, on various performance metrics are calculated like PSNR, entropy, MSE, MAE, UQI, Average difference, Structural content, Normalized Absolute error, and Normalized cross-correlation.

3. RESULTS AND DISCUSSION

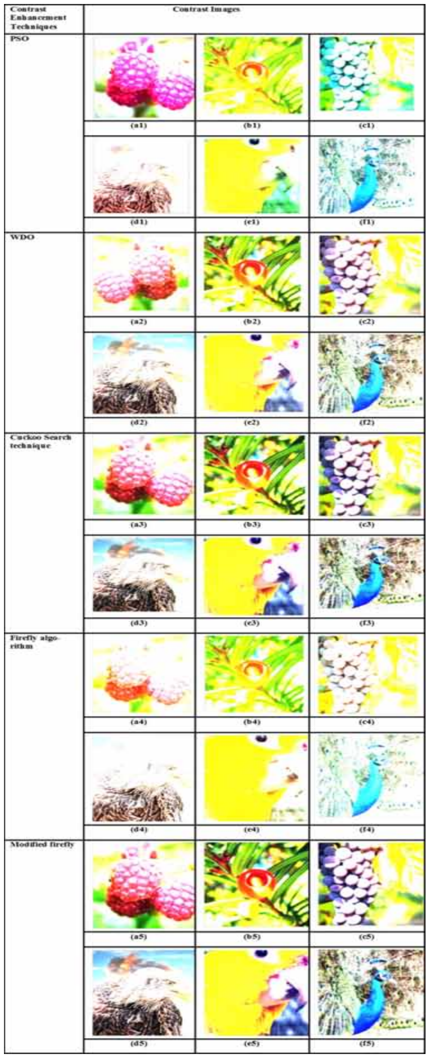
The measurement tests were carried out to evaluate the performance of the proposed technique in 256x256 pixel image resolutions in these input images. In this paper, 6 images (shown in figure 1) are tested compared to PSO (particle swarm optimization), WDO (Wind Driven Optimization), CST (Cuckoo Search Technique), and FA (Firefly Algorithm) performance of the proposed technique. These results reflect that the output image is more precise and smoother than the other conventional approaches, contrast-enhanced by the proposed technique. We used different measurement measures of image quality to determine the consistency of the contrast images.

Figure 1. Original Images



After applying various contrast enhancement techniques and our proposed technique, the contrast-enhanced images are given below in Fig. 2.

Figure 2. Contrast Images after applying methods like PSO, WDO, CST, FA, and MF.



3.1 Image Quality Measurement:

Various image quality measurement metrics like PSNR (Peak_Signal_to_Noise_Ratio), Root Mean Square Error (RMSE), Universal_Quality_Index (UQI), Mean Absolute Error (MAE), and Mean Square Error(MSE) in Table-1. Table 1 showing that our proposed technique is better than other contrast enhancement techniques.

Table 1. Image quality measurement results PSNR, RMSE, UQI, MAE, and MSE

Image quality measurement	Image	Contrast enhancement techniques				
		PSO	WDO	Cuckoo Search Techniques	Firefly	Proposed technique
PSNR	a	24.9881761	24.53175867	24.80980154	24.24383464	24.89998545
	b	24.55564833	25.17236533	25.43784338	24.59737435	25.57194463
	c	24.54760284	24.62581159	24.88675405	24.22740269	24.96250278
	d	24.72240271	25.00915929	25.16096966	24.65195924	25.27898848
	e	24.43203628	24.54586809	24.72570376	24.21416782	24.76497026
	f	24.63273131	24.86306976	25.21129196	24.25358751	25.30224185
RMSE	a	26.6672	27.4831	27.2935	27.5155	27.0316
	b	27.273	27.273	27.0446	26.9684	26.7114
	c	26.0283	26.9021	26.6239	26.8219	26.416
	d	27.2741	27.2996	27.1589	27.2783	26.9364
	e	27.3329	27.346	26.9144	27.0048	27.0207
	f	27.49	27.5936	27.11	27.623	26.8812
UQI	a	0.563186331	0.509336924	0.562463598	0.473588863	0.583581816
	b	0.335784186	0.37699197	0.418433466	0.330452848	0.443520317
	c	0.592271173	0.578756355	0.624447373	0.527530098	0.636916247
	d	0.446798221	0.502624264	0.543415395	0.438530634	0.561351492
	e	0.531664655	0.516034577	0.548716884	0.491361407	0.555833375
	f	0.39566567	0.4253437	0.478465999	0.347277234	0.488856043
Mean absolute error	a	327.2654572	347.204483	308.4660645	390.6735687	297.8182526
	b	330.4471283	281.2168427	253.672287	331.190506	240.1844025
	c	293.9021606	281.6362762	249.7732697	337.1946564	244.2194977
	d	384.1290283	326.8092194	298.6529846	392.9012604	288.562439
	e	270.9181671	283.8328705	261.2786865	298.6360931	259.0487518
	f	406.4295959	372.4773865	332.4949341	463.6839142	322.3859558
MSE	a	711.1385	755.3223	744.9365	757.1035	730.7049
	b	743.8176	743.8167	731.4117	727.2968	713.4972
	c	677.4701	723.7205	708.831	719.4164	697.8034
	d	743.8764	745.2704	737.6051	744.1058	725.5682
	e	747.0884	747.8028	724.3863	729.2608	730.1204
	f	755.6986	761.4049	734.9512	763.0314	722.5983

Figure 3. Performance(Noise removal) of our proposed technique and existing techniques for images a, b, c, d, e, and f.

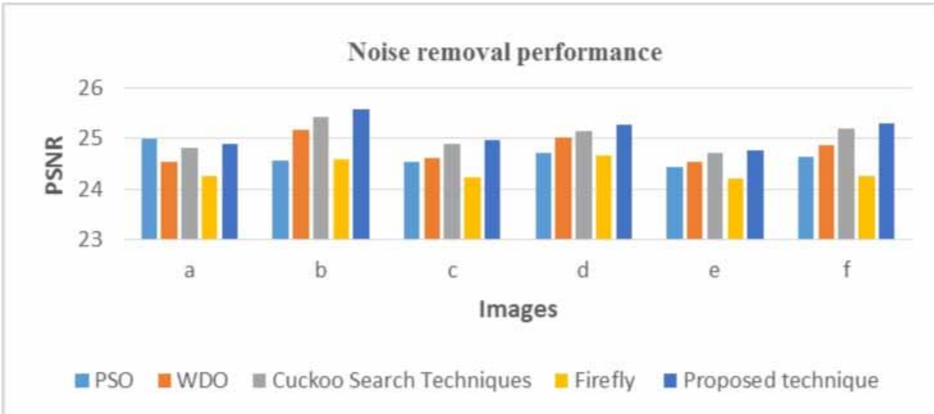


Figure 4. The RMSE performance of our proposed technique and existing techniques for images a, b, c, d, e, and f.

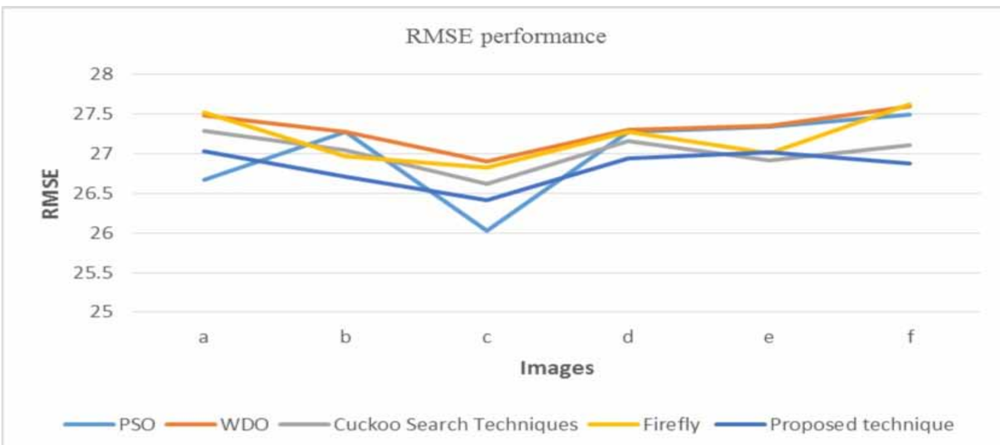


Figure 5. UQI performance of our proposed technique and existing techniques for images a, b, c, d, e, and f.

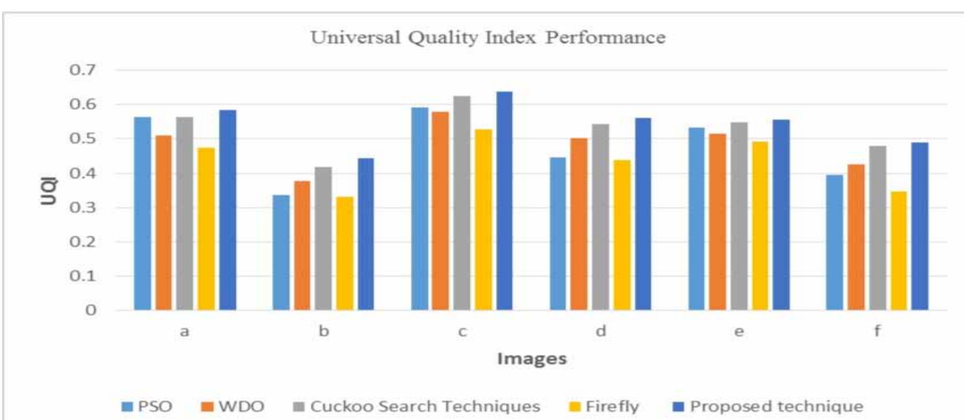


Figure 6. Mean absolute error values of our proposed technique and existing techniques for images a, b, c, d, e, and f.

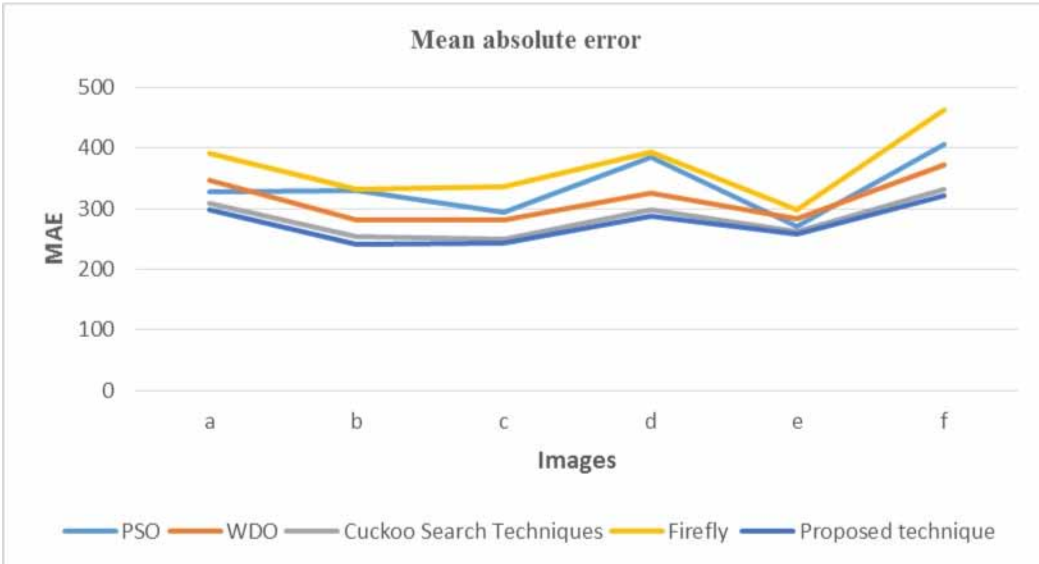
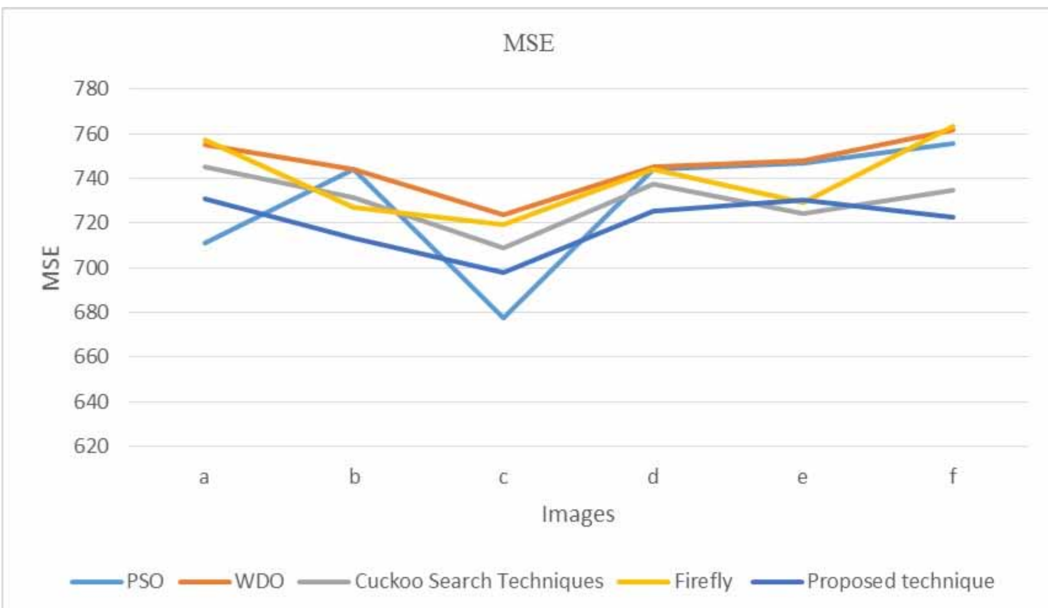


Figure 7. MSE values of our proposed technique and existing techniques for images a, b, c, d, e, and f.



3.2 Image Error Measurement

We have evaluated the Average Difference, Structural Content, Normalized Absolute Error, Normalized Cross-Correlation of our proposed and existing techniques for the images a, b, c, d, e, and f.

Table 2. Image error measurement of our proposed technique and existing techniques for images a, b, c, d, e, and f.

Image error measurement	Image	Contrast enhancement techniques				
		PSO	WDO	Cuckoo Search Techniques	Firefly	Proposed technique
Average Difference	**a**	92.06652832	107.4785767	98.08900452	120.6197357	95.21647644
	b	102.5136719	85.9833374	79.32380676	101.8190308	75.90180969
	c	107.2675934	103.5390472	96.79129028	119.7168579	95.19555664
	d	112.0076599	99.61355591	92.44923401	114.5398102	89.55895996
	e	111.8907623	111.2514648	106.7682037	117.1077423	105.9883118
	f	101.1876068	94.88568115	85.51078796	118.6170654	83.31756592
Structural Content	**a**	1.031439001	1.031439001	1.031439001	1.031439001	1.031439001
	b	1.031439001	1.031439001	1.031439001	1.031439001	1.031415609
	c	1.031408018	1.03143536	1.030825508	1.031426287	1.027927955
	d	1.030686885	1.029745167	1.026911803	1.031207491	1.017822474
	e	1.031043872	1.031303588	1.030729102	1.031437149	1.030049507
	f	1.031439001	1.031439001	1.031090162	1.031439001	1.030015499
Normalized Absolute Error	**a**	0.454773059	0.482044125	0.46561967	0.505960235	0.460796321
	b	0.468092696	0.444333981	0.434972416	0.466202933	0.430903249
	c	0.481349896	0.47791435	0.469060336	0.505107495	0.467826441
	d	0.507093263	0.490751253	0.478140233	0.510356979	0.473522881
	e	0.491348979	0.495685698	0.494363384	0.498870407	0.49478827
	f	0.469708265	0.460302153	0.44532045	0.502353739	0.441904237
Normalized Cross-Correlation	**a**	0.9999927	0.994996799	0.999980852	1	0.999930767
	b	0.999999102	0.999997307	0.999995811	0.99999982	1.000016815
	c	0.999864821	0.999793018	0.999855464	0.999929031	1.001870453
	d	1.000412408	1.001166311	1.003749836	1.000038305	1.01236385
	e	1.000382753	1.000131303	1.000688735	1.000001795	1.001348959
	f	0.999996051	0.999980912	1.000236023	0.99999994	1.00119213

Figure 8. Average Differences of our proposed technique and existing techniques for images a, b, c, d, e, and f.

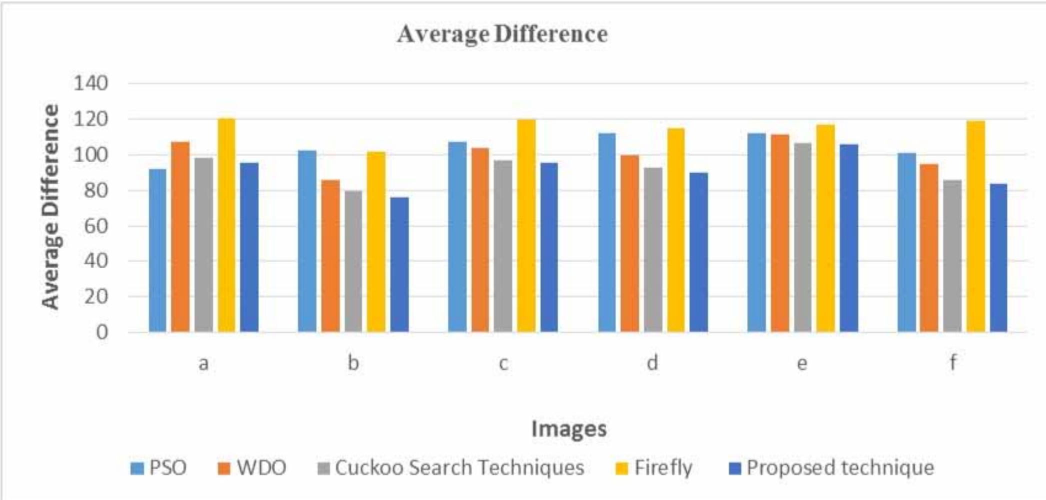
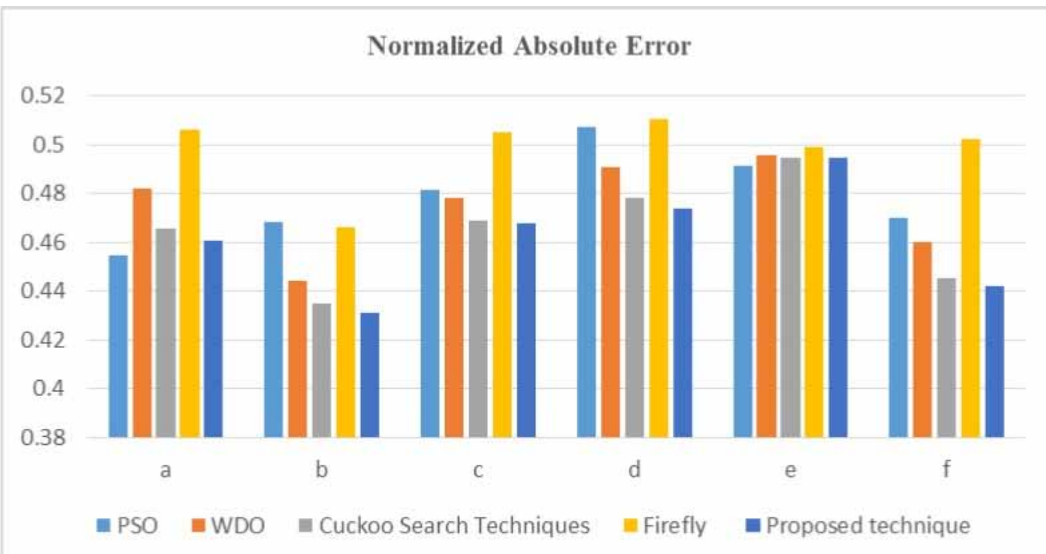


Figure 9. Normalized Absolute Error value of our proposed technique and existing techniques for images a, b, c, d, e, and f.



3.3 Image Entropy Measurement

The average information of images is a measure of the degree of randomness is also called entropy. We have used entropy to evaluate the entropy of original images as well as contrast images. Conditional entropy, joint entropy Normalized mutual information, Mutual information is used for evaluating the contrast images, that is, the output images of various existing techniques and the proposed technique.

Table 3. Image entropy measurement of our proposed technique and existing techniques for images a, b, c, d, e, and f.

Image	The entropy of the original image	The entropy of the contrast image				
		PSO	WDO	Cuckoo Search	Firefly	Proposed Technique
(a)	7.800219894	2.909818813	3.199495802	3.738809325	2.046679556	3.908575114
(b)	7.248845875	3.603027097	4.583274236	4.91876065	3.68981472	5.012412094
(c)	7.902213008	3.086097633	3.680402539	4.0301438	2.466449336	4.157944443
(d)	7.711000601	2.479520008	3.975540335	4.316623336	2.536013181	4.536387278
(e)	7.588589584	2.780000569	3.128772188	3.42958601	2.299688264	3.519495885
(f)	7.362636835	3.430574406	4.08128896	4.602275552	2.377511337	4.78073566

Figure 10. The entropy of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.

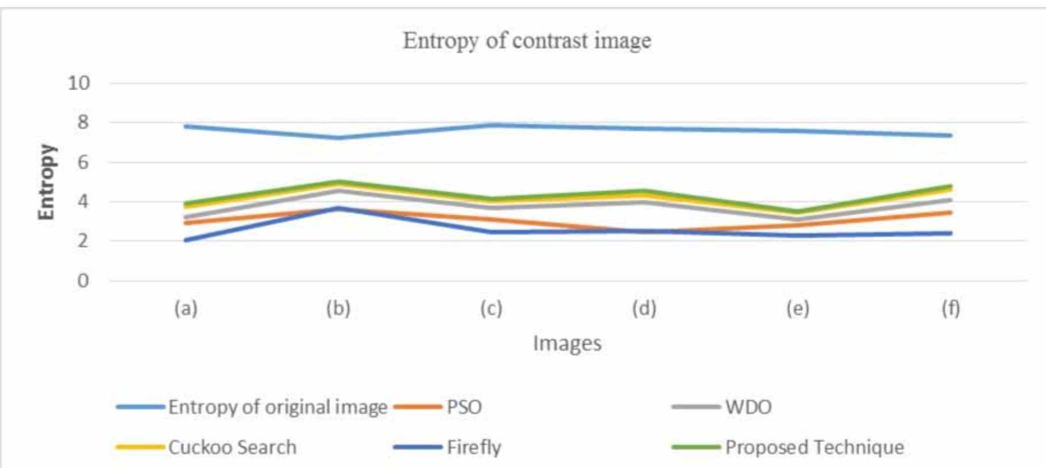


Table 4. Entropy values of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.

Image entropy measurement	Image	Contrast enhancement techniques				
		PSO	WDO	Cuckoo Search Techniques	Firefly	Proposed technique
joint entropy	a	8.424693039	8.289470607	8.386772005	8.029729548	8.416742755
	b	7.698920737	7.74169932	7.779818301	7.643614671	7.803094462
	c	8.416916553	8.432784503	8.467181793	8.198599061	8.505117943
	d	8.141175149	8.348183444	8.413352226	8.101437619	8.46002838
	e	7.978364841	7.882072423	7.930470203	7.725315158	7.934191194
	f	8.018980726	8.060488665	8.160548944	7.723440515	8.183551087
Conditional entropy	a	5.514874226	5.089974805	4.647962679	5.983049991	4.508167641
	b	4.09589364	3.158425085	2.861057651	3.953799951	2.790682368
	c	5.330818919	4.752381965	4.437037994	5.732149725	4.3471735
	d	5.661655141	4.372643109	4.096728889	5.565424438	3.923641101
	e	5.198364272	4.753300235	4.500884194	5.425626894	4.414695309
	f	4.58840632	3.979199705	3.558273392	5.345929177	3.402815427
Mutual information	a	2.285345668	2.71024509	3.152257215	1.817169903	3.292052253
	b	3.152952234	4.09042079	4.387788224	3.295045924	4.458163507
	c	2.571394089	3.149831043	3.465175015	2.170063283	3.555039509
	d	2.049345459	3.338357491	3.614271711	2.145576163	3.787359499
	e	2.390225311	2.835289349	3.08770539	2.16296269	3.173894275
	f	2.774230516	3.38343713	3.804363443	2.016707658	3.959821408
Normalized mutual information	a	0.479695342	0.542518273	0.583715957	0.454796576	0.596216603
	b	0.6169489	0.709652329	0.734824081	0.637125165	0.739602167
	c	0.520702238	0.584070447	0.614031339	0.491543473	0.620198518
	d	0.468679542	0.602947351	0.62646001	0.485191087	0.640362808
	e	0.520398296	0.581875247	0.605249548	0.517766575	0.614146092
	f	0.552004265	0.617223921	0.653550274	0.48201989	0.667438945

Figure 11. Mutual information of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.

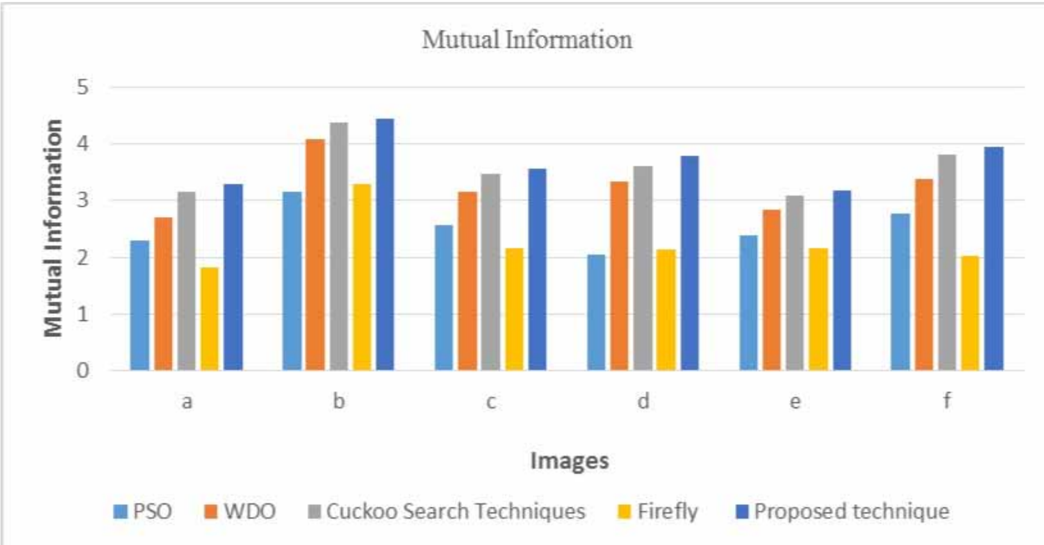
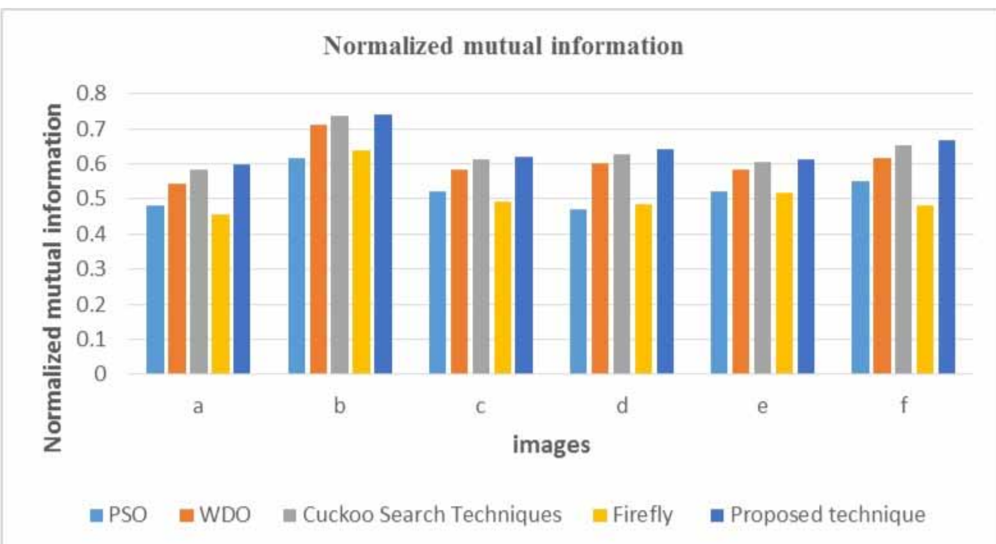


Figure 12. Normalized mutual information of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.



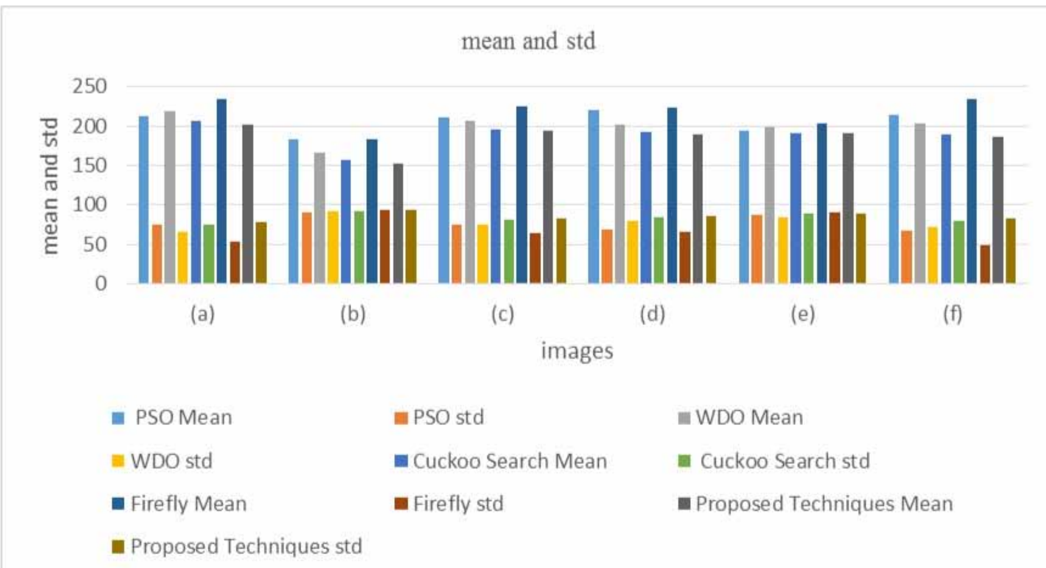
3.4 Mean and Standard Deviation (std) Measurement:

We have compared the mean and standard deviation(std) of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.

Table 5. Mean and standard deviation (std) of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.

image	Contrast Enhancement techniques									
	PSO		WDO		Cuckoo Search		Firefly		Proposed techniques	
	Mean	std	Mean	std	Mean	std	Mean	std	Mean	std
(a)	211.8722	75.00691	218.7938	65.63951	205.8809	75.45692	233.2834	53.92929	202.32	78.08405
(b)	182.4191	91.10644	166.009	92.12754	156.8275	92.92203	182.6669	93.80659	152.3095	93.48186
(c)	210.2689	75.30389	206.3887	74.57871	195.7677	81.41881	224.9082	63.69727	193.9067	82.56218
(d)	220.8313	69.15147	201.7247	79.32311	192.3393	83.83582	223.7554	65.50917	188.9758	85.59515
(e)	194.6508	88.16084	198.9557	85.17548	191.4376	89.17471	203.8901	90.66043	190.6747	88.81086
(f)	214.3019	67.00858	202.9845	71.7123	189.657	80.35929	233.3866	49.15038	186.2668	82.23127

Figure 13. The mean and Std of our proposed technique and existing techniques for contrast images of original images a, b, c, d, e, and f.



3.5 Discussion:

We have taken six images for result analysis and compared the results with the existing optimization techniques; it is found that our proposed techniques' results and image quality are giving better than existing optimization techniques. We are not able to implement the result in video signals. This paper has not also calculated the time complexity because we have given more priority to enhancement.

4. CONCLUSION:

This article introduces the modified firefly algorithm; the histogram method is used from image enhancement and compared the proposed model (i.e., modified firefly algorithm) with existing optimization algorithms. The test is performed on 6 images. From the comparison tables, we can conclude that our proposed model gives better image enhancement quality than others, as the PSNR of our proposed algorithm is better than other existing techniques. In the future, we will use various modified optimization techniques and implement the video and compare the time taken.

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