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Optimized Adaptive Fuzzy based Image Enhancement Techniques

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Abstract

Image enhancement plays an important role in vision applications. Recently much work is performed in the field of images enhancement. Many techniques have already been proposed up to now for enhancing the digital images. The overall objective of this proposed work is to evaluate the performance of existing image enhancement techniques like Histogram equalization, adaptive histogram equalization and Fuzzy image enhancement technique. It has been found that the value of contrast parameter 'K' in fuzzy method was taken statically as 128. To overcome this, to make contrast dynamic a new optimized fuzzy method have been proposed. Here different optimization techniques ACO, PSO and ABC have been used to optimize the contrast and the technique with best optimized contrast value is selected. The newest approach has the ability to boost the contrast in digital images in efficient manner by utilizing the histogram based fuzzy image enhancement algorithm with optimized Contrast value. The proposed technique is designed and implemented in MATLAB using image processing toolbox.

***Keywords**: contrast enhancement; color image; optimization techniques; fuzzy method*

1. Introduction

Computer vision system enhancement is the method for improving the quality of image. It is relatively simple, that is modifying the image from light to dark or to enlarge or reduce contrast. The goal of image enhancement is to improve the quality of image in order to get more suitable results for a specific application than the original image. Contrast enhancement not only improves the visual quality of an image but also enhances image features for further processing. Contrast enhancement methods traditionally based on either spatial or Transform domain techniques. In case of spatial domain method, different procedures are directly applied on image pixels. On other hand transform domain works on modifying the frequency transform of an image. However, transformation for image into two dimensional is very time consuming task even with fast transformation which makes it less appropriate for real time processing. Further, spatial domain covers two popular methods histogram equalization and histogram specifications [1] and adaptive neighborhood histogram equalization.

2. Fuzzy Enhancement

In Fuzzy method for gray image enhancement and smoothing two merits have been considered. First approach is IF…. THEN ELSE rules for image enhancement, in this to enhance the pixels some directive fuzzy rules same as human-like reasoning are given and these rules are generated from the neighborhood pixel of the image. The second method relates to a rule-based smoothing. Here, on the basis of neighborhood compatibility different filter classes are devised. Further, for color images Enhancement three 2-D histograms (RG, GB, BR) technique is used and for color image enhancement using LHS color model [2] equalization method is used. In the fuzzy approach membership functions are used to structure fuzzy sets for utilizing the gray tone or color intensity property of the pixel. The image is taken as an array of fuzzy singletons whose membership value indicates the degree of some image property in the range [0-1]. For Gary scale images, different fuzzy membership functions improves the speed and quality of the enhancement and for color images histograms method are used which measure the quality of the enhancement on the basis of entropy[3]. In human visual system RGB color model for Histogram equalization is not feasible to use since it effects the original color composition of the image which produces color artifacts. For that reason RGB color image is converted to HSV (Hue, Saturation, and Intensity) where hue is the color content, saturation is bright light used to reduce the color content and V is the intensity of the color content. The H and S get preserved while V that is the intensity of the color is changing. Firstly to model the V , a Global type membership function is used which is suitable for under exposed images only and for over exposed and under plus over exposed images a global intensification operator (GINT) method[4] is used which stretch the contrast of V globally which changes the value of intensity parameter. For automatic image enhancement parameters of GINT on the basis of fuzzy entropy is calculated. For the enhancement of low contrast color images a Fast and efficient Fuzzy logic algorithm with histogram equalization is used. In digital image processing Histogram equalization (HE) method is simples [13] most effective technique but it has some limitation that it does not preserve the brightness and original look of images. To overcome this problem several Bi- and Multi-histogram equalization methods have been proposed. From which the Bi-HE methods significantly enhance the contrast and can preserve the brightness as well, but the natural look of the image get destroyed. To maintain the natural look of image, Multi-HE methods are proposed, in which the proposed method the histogram of an input image is decomposed into multiple segments and at each segment HE is applied independently [20]. It uses two parameters M and K, where M is the average intensity and K is the contrast intensification parameter. Only V parameter is stretched under the control of M and K. The value of control parameter M can be calculated form average histogram value. The value for K can be calculated on the basis of stretching required. From the experimental analysis, the value K is fixed as 128, which gives better results for the low contrast and low bright color images. The effectiveness of histogram and fuzzy based image enhancement method on various kinds of images like underwater, remote sensing images has been evaluated using MSE and PSNR parameter. The result has shown the effectiveness of the fuzzy based enhancement over the existing techniques [21].In this paper we have extended this fuzzy approach [20] and changed the value of contrast value 'K' dynamically using different optimization methods.

3. Optimization Techniques

In optimization numerical function plays an important role for optimizing the objective function. The famous approach of Artificial Intelligence (AI) is Computational Intelligence (CI). Optimization is used to handle the complex problems and to find the best solution out of the solution space. For optimizing the numerical functions optimization algorithms can be categorized into two category that is evolutionary computing and meta heuristic methods. Various Optimization techniques like Ant Colony Optimization [6] (ACO), Particle Swarm Optimization [9] (PSO), and Artificial Bee Colony algorithm [8] (ABC). A graph representation based technique has been applied successfully to solve various hard combinatorial optimization problems. The main motive of ACO is to model the problem as to search minimum cost path in a graph. In this artificial ants walk through specific graph and find the good paths. In ACO ants working is parallel. First Ant finds a route between n nest (N) and Food source (F) and laid a Pheromone trail (τ). If the food is found, ant returns to nest laying down pheromone trail. Other ants randomly follow one of the path and lay pheromone trail. PSO provides the solutions to numerical and qualitative problems and is developed from swarm intelligence and is based on the research of bird and fish flock movement behavior. In these in the birds either scattered or fly together as to find the food. Among all there is always a bird that can smell a food resource. The bottom-up approach which behaves partially alike, and partially differently from bee colonies in nature. Artificial bees are the agents, which solves complex combinatorial optimization problem. Here every artificial bee computes one solution to the problem. There are two phases of algorithm forward pass and backward pass. Initially in each forward pass, every artificial bee is explore the search space. From predefined number of moves it constructs or improves the Solution and also forms a new solution. After obtaining the new partial solution, the bees again go to the nest and move the next phase that is backward pass. In this all artificial bees share information about their solutions. In nature, bees perform a dancing ceremony, and signaled other bees about the quantity of food they have collected and the distance of the area to the nest.

4. Proposed Methodology

The principle objective of the proposed algorithm is to supply better results than existing algorithms to improve the visibility of the digital images. In proposed method Input image is RGB image is converted into HSV. For calculating the value of intensification factor K different optimization techniques have been applied with fuzzy image enhancement. Further H and S are concatenated to V and obtained HSV is converted to RGB.

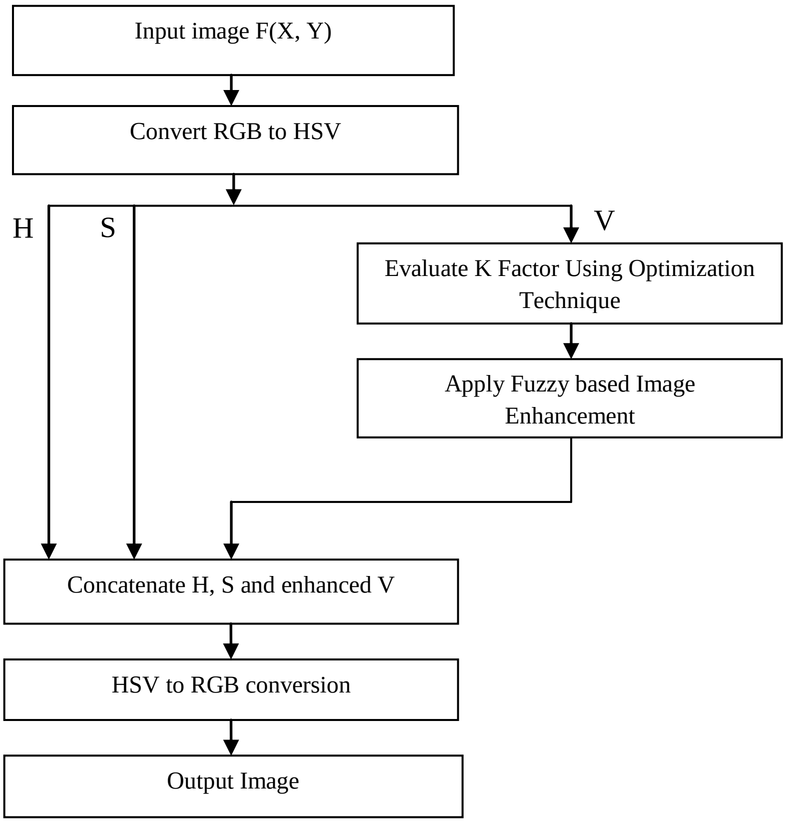


Figure 1. Flowchart Describes Working of Enhanced Fuzzy

5. Results & Discussions

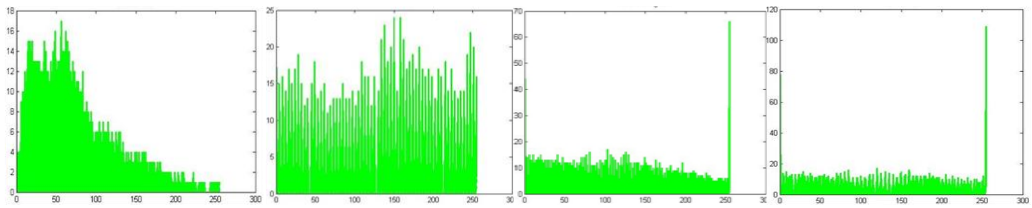
In this Experiment 10 images with low contrast and brightness have been taken and to analyze the performance of the fuzzy method various qualitative performance measures have been used.

5.1. Comparison of various Contrast Enhancement Techniques

Here, the basic techniques of contrast enhancements namely histogram equalization, adaptive histogram equalization, Fuzzy enhancement (K=128) and Fuzzy method with optimized value of K have been compared.

(a) (b) (c) (d)

Figure 2. (a) Input Image; (b) Histogram Equalized Image; (c) Adaptive Histogram Equalized Image; (d) Fuzzy Enhanced Image (K=128).

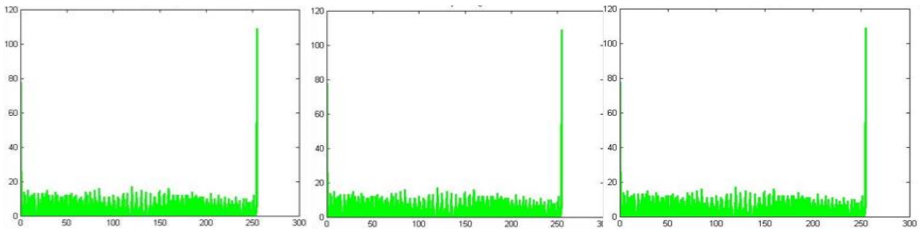


(a) (b) (c) (d)

Figure 3. Shows the Histograms of Above Image (a) Input Image; (b) Histogram Equalized Image; (c) Adaptive Histogram Equalized Image; (d) Fuzzy Enhanced Image (K=128).

(e) (f) (g)

Figure 4. (e) ACO Enhanced Image; (f) PSO Enhanced Image; (g) ABC Enhanced Image



(e) (f) (g)

Figure 5. Shows the Histograms of (e) ACO Enhanced Image; (f) PSO Enhanced Image; (g) ABC Enhanced Image

6. Performance Evaluation

Performance Evaluation table shows the analysis of optimization technique using different parameters that is MSE, PSNR, CII, SSIM, and execution time. The average values of parameters on conventional and new techniques have been calculated to analyze the performance.

6.1. Mean Square Error (MSE)

Mean Square Error [3] in image processing measures the average of squares of errors. In above equation *R* and *C* represent the number of rows and columns in the input images with index *i* and *j* respectively. *f(i,j)* represents the original image at location *(i, j)* and *f'(i,j)* represents the degraded image at location *(i,j)*.

$$MSE=\frac{1}{RC}\sum_{i=1}^{R}\sum_{j=1}^{C}\left(f(i,j)-f'(i,j)\right)^2 \quad (1)$$

Table 1 shows the MSE value obtained after applying different enhancement techniques on different images. Here the minimum value of MSE is obtained by PSO optimization technique and it shows the better results as compared to conventional, ACO and ABC.

Table 1. MSE Values

MSE Evaluation						
IMAGES	**HE**	**AHE**	**Fuzzy**	**ACO**	**PSO**	**ABC**
IMG1	7198	4806	33.266	40.360	30.038	36.6795
IMG2	6533	1441	2.3899	12.0017	1.6134	4.2084
IMG3	4253	1887	11.0720	12.7860	10.2340	11.8800
IMG4	5386	4346	6.7550	13.0622	6.2490	7.7189
IMG5	3262	2922	53.1340	45.5340	53.2040	52.1580
IMG6	7768	6817	21.483	59.883	12.558	58.639
IMG7	4015	3048	18.5801	21.7910	16.2656	19.7168
IMG8	3710	2021	12.8838	10.7402	12.8838	10.3477
IMG9	861	1335	25.1479	28.7275	22.9750	24.5721
IMG10	2652	3606	8.8606	10.2120	8.3840	9.5160
Average	**4563**	**3222.9**	**19.3572**	**25.50976**	**17.4408**	**23.5436**

6.2. Peak Signal to Noise Ratio (PSNR)

PSNR [3] refers to the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the quality of image. Higher value of PSNR indicates that the reconstruction is of higher quality.

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20.\log_{10}\left(\frac{MAX_I}{MSE}\right) = 20\log_{10}(MAX_I) - 10.\log_{10}(MSE) \dots .(2)$$

Table 2 shows the PSNR value obtained after applying different enhancement techniques on different images. From the table values it is evident that the value obtained by PSO optimization technique is higher as compared to conventional, ACO and ABC.

Table 2. PSNR Values

PSNR Evaluation						
IMAGES	**HE**	**AHE**	**Fuzzy**	**ACO**	**PSO**	**ABC**
IMG1	9.5587	11.3130	32.9107	32.0712	33.4030	32.4866
IMG2	9.9797	16.5442	44.3470	37.3384	46.3239	41.8896
IMG3	11.8225	15.5134	35.3963	34.5756	35.9316	34.1237
IMG4	10.8181	11.479	39.3450	36.9706	40.1727	39.2553
IMG5	13.0347	13.4282	33.2302	34.1692	33.2302	33.9073
IMG6	9.2277	9.7949	34.8097	30.3577	37.6757	30.5000
IMG7	12.0939	13.2907	35.4403	34.7480	36.0181	35.1829
IMG8	12.4371	15.0751	37.0304	37.8207	37.0304	37.9824
IMG9	18.7808	16.8760	34.1528	33.5478	34.518	34.2264
IMG10	13.8951	12.5605	38.6830	38.0397	38.896	38.3463
Average	**12.16481**	**13.5875**	**36.53454**	**34.9638**	**37.3199**	**35.7900**

6.3. Contrast Improvement Index (CII)

The parameter is used to compare the results of contrast enhancement methods. Contrast improvement can be measured using CII [20] as a ratio. Contrast improvement index is defined as:

$$\mathbf{CII = C_{proposed} / C_{original}} \dots \qquad (3)$$

Where C is the average value of the local contrast measured with 3*3 windows.

Table 3 shows the CII value obtained after applying different enhancement techniques on different images. From the average table values it is evident that the contrast value obtained by PSO optimization technique is higher as compared to conventional, ACO and ABC.

Table 3. CII Values

CII Evaluation						
IMAGES	**HE**	**AHE**	**Fuzzy**	**ACO**	**PSO**	**ABC**
IMG1	3.0170	3.0240	3.0386	3.0327	3.0438	3.0360
IMG2	3.0197	3.0460	3.3521	3.0712	3.8140	3.1500
IMG3	2.9765	2.8163	3.0709	3.0524	3.0883	3.0465
IMG4	2.8502	3.0274	3.0683	3.1098	3.0773	3.0681
IMG5	3.1552	3.1393	3.0996	3.2454	3.1009	3.1009

IMG6	3.0169	3.0207	3.0435	3.0247	3.0738	3.0257
IMG7	3.0179	3.0248	3.0481	3.0464	3.0534	3.0449
IMG8	2.8454	3.1658	1.3663	1.9316	6.3663	6.1568
IMG9	3.1939	3.1343	1.5160	3.3269	4.7310	1.6342
IMG10	3.1384	3.0501	2.3369	3.1683	0.8600	3.2950
Average	**3.02311**	**3.04487**	**2.6940**	**3.0009**	**3.4208**	**3.2558**

6.4. Structural Similarity Index Measure (SSIM)

It is based on three computations of three terms, named as luminance, contrast and structural. The basic equation of SSIM is:

$$SSIM(x,y) = [l(x,y)^{\alpha}].[c(x,y)^{\beta}].\,[s(x,y)^{\gamma}] \quad \ldots \qquad (4)$$

Table 4 shows the results of SSIM value obtained after applying different enhancement techniques on different images. It is vivid from the average analysis that the value obtained by PSO optimization technique is higher as compared to conventional, ACO and ABC.

Table 4. SSIM Values

SSIM Evaluation						
IMAGES	**HE**	**AHE**	**Fuzzy**	**ACO**	**PSO**	**ABC**
IMG1	0.5071	0.5539	0.9753	0.9692	0.9783	0.9724
IMG2	0.4745	0.7817	0.9993	0.9935	0.9996	0.9985
IMG3	0.5662	0.7751	0.9961	0.9949	0.9968	0.9941
IMG4	0.3232	0.6727	0.9955	0.9895	0.9959	0.9947
IMG5	0.6190	0.6251	0.9582	0.9693	0.9582	0.9582
IMG6	0.4832	0.4681	0.9861	0.9570	0.9934	0.9584
IMG7	0.7227	0.6786	0.9851	0.9820	0.9873	0.9840
IMG8	0.7251	0.7749	0.9977	0.9982	0.9977	0.9984
IMG9	0.8181	0.7325	0.9955	0.9946	0.9961	0.9957
IMG10	0.4323	0.5813	0.9961	0.9951	0.9965	0.9956
Average	**0.5671**	**0.6643**	**0.9884**	**0.9843**	**0.9899**	**0.985**

6.5. Execution Time

It is the time taken by the algorithm to process the image.

Table 5 shows the Execution time taken by different enhancement techniques on different images. From the table values, it is evident that the value obtained by ABC enhanced is faster as compared to conventional, ACO and ABC.

Table 5. Execution Time

Execution Time						
IMAGES	**HE**	**AHE**	**Fuzzy**	**ACO**	**PSO**	**ABC**
IMG1	1.1325	1.4133	0.0826	47.9940	4.4811	0.6311
IMG2	1.0663	1.5305	0.1148	47.8868	3.9386	0.6645
IMG3	1.6216	1.5577	0.1781	85.8634	4.3285	1.0583

IMG4	0.5971	0.8683	0.0655	25.7670	3.9302	0.4613
IMG5	0.4912	0.5319	0.0470	16.3780	4.3123	0.3703
IMG6	0.8139	0.5707	0.1039	34.0873	4.2018	0.5707
IMG7	0.8205	1.0614	0.0640	25.6325	3.7901	0.5002
IMG8	1.5064	1.6346	0.2418	82.3673	4.5918	1.2443
IMG9	0.8738	0.8652	0.0646	29.169	3.8133	0.5510
IMG10	0.6715	0.7891	0.0700	25.9973	3.9166	0.4712
Average	**0.95948**	**1.08022**	**0.10323**	**42.1142**	**4.13043**	**0.6522**

7. Conclusion

The fuzzy based image enhancement approach has the ability to boost the contrast in digital images in efficient manner by utilizing the histogram based fuzzy image enhancement algorithm. The overall objective of this work is to evaluate the effectiveness of histogram and fuzzy based image enhancement for various kinds of images. The fuzzy and histogram based enhancement has been designed and implemented in MATLAB using image processing toolbox. Firstly, the results have shown the effectiveness of the fuzzy based enhancement over other conventional basic methods. It has been found that the value of contrast intensity 'K' in fuzzy method has been taken as static as 128. To overcome make contrast dynamic we have introduced a modified approach. Here different optimization techniques ACO, PSO and ABC have been used to optimize the contrast. It is concluded that different optimization techniques (ACO, PSO and ABC) have shown optimized values for contrast parameter 'K'. From optimistic values it is clear that there is a difference between the values obtained from different techniques however, from quality measures it has been analyzed that the value obtained by PSO technique is more efficient than ACO and ABC.

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