Image Contrast Enhancement Approach Using Differential Evolution and Particle Swarm Optimization

Seema[1], Gaurav Bansal[2]

[1]M. Tech. Research Scholar, [2]Assistant Professor,
[1,2] A.I.M.T , Gorgarh, Indri , Karnal, India

Abstract -*Differential Evolution (DE) algorithm represent an adaptive search process for solving engineering and machine learning optimization problems. This paper presents an attempt to demonstrate its adaptability and effectiveness for searching global optimal solutions to enhance the contrast and detail in a gray scale image. In this paper contrast enhancement of an image is performed by gray level modification using parameterized intensity transformation function that is considered as an objective function. The task of DE is to adapt the parameters of the transformation function by maximizing the objective fitness criterion. Experimental results are compared with other enhancement techniques, viz. histogram equalization, contrast stretching and particle swarm optimization (PSO) based image enhancement techniques.*

Keywords: Image enhancement, histogram equalization, DWT, DE, PSO.

1. INTRODUCTION

The objective of image enhancement is to improve the quality of an image for subsequent analysis or for image display. Image enhancement refers to emphasis or sharpening, of an image features such as counters, boundaries, edges or contrast in order to facilitate further analysis and display. It is characterized as low level process includes noise reduction, contrast enhancement, and image sharpening operations to produce good quality image. Image enhancement techniques can be classified into two broad categories as spatial domain methods and frequency domain methods. Spatial domain image enhancement methods can be divided into four main categories: point operations, spatial operations, transformation operations, and pseudo coloring. The evaluation process of the quality of an image is subjective, needs human judgment. To define this process objective, it is essential to define an objective function which will provide a quantitative measure for enhancement quality. Automatic image enhancement is a method that produces enhanced images without human intervention. Majority of the image enhancement methods select a transformation function or mapping function to enhance contrast by gray-level modification of the output image in spatial domain. In this work, contrast enhancement operation is based on spatial operation. As image enhancement is an optimization problem that optimizes parameters of the transformation function in order to achieve an enhanced image by increasing fitness. The work done in this paper proposes an automatic image enhancement method which determine the parameter values of the transformation function automatically and objective evaluation is produced on the enhanced image which determine the effectiveness of the method. Recent years many evolutionary algorithms have been applied to image enhancement by several authors. A particle swarm optimization (PSO) algorithms used with intensity transformation function to local and global enhancement of the image. In this paper we have proposed gray-level image contrast enhancement by DE. DE is an evolutionary optimization algorithms produce better result in many applications. The results obtained by DE are compared with other automatic image contrast enhancement techniques and found better in many cases. Both objective and subjective evaluations are obtained on the output images which reveal our DE-based method outperforms others for a set of input images.

2. LITERATURE SURVEY

Sushma S J et al. in [1] discussed about the significance of image preprocessing in medical image processing. Consider the case of breast cancer detection, it was found that there are various schemes of optimization techniques which is either training based or leads to recursive iterations leading to computationally complex process. Hence, the proposed system implements a new optimization technique called Image Enhancement using Bio-inspired Algorithms. It is Different from existing bio-inspired algorithm because the proposed system doesn't use any training sequences or depends on single fitness function or performs recursive operation for exploring elite population. The algorithm performs automatic segmentation process followed by three level of enhancement operation for achieving local to global best optimization without using any forms of recursive functions. The outcomes are visually defined and well resolution to prove success factor.

Vani V et al. in [2] presents image enhancement on low contrast Wireless capsule endoscopy (WCE) images. The work focuses on enhancing the contrast of the capsule endoscopy image. WCE images are dark and difficult to visualize for diagnosis by physicians. Image enhancement methods to improve the contrast of the images may be used. Various image enhancement techniques such as histogram equalization, Multi Scale Retinex and Contrast limited Adaptive Histogram Equalization (CLAHE) techniques were being compared and analyzed. Image enhancements techniques were done for both on color image and gray scale image. CLAHE provides better contrast improvement of WCE images, while Multi Scale Retinex provides better human visualization.

P. Bidwai et al. [3]. The idea behind image enhancement is to bring out the detail in the image that are obscured. Resolution and contrast are the two important attributes of an image. Resolution is a key feature of all kind of images. Resolution and contrast enhancement have many applications such as image compression, medical application, feature extraction satellite imagery, astronomy, geo-scientific studies. In this author developed a method to enhance the quality of image. The enhancement is done with respect to both resolution and contrast. The proposed technique uses discrete wavelet transform (DWT) and singular value decomposition (SVD). The technique decomposes the input image into four sub-bands by using DWT and estimates singular value matrix of low frequency sub-band image, then it reconstructs enhanced image by applying inverse DWT. The technique is applied to grey level, color image and satellite image and their comparative analysis is done. The experimental results show the superiority of the proposed method over conventional techniques.

P. Kale et al. [4] Due to aging factor and variations in the atmospheric conditions, old historic images start degrading. To preserve them effectively convert them in digital format and apply image enhancement algorithms. In this author compare two image enhancement algorithms i.e. Hybrid Binarisation and Histogram Equalization method. By analysis made by visual appearance on the enhanced images we can conclude that hybrid Binarisation method outperforms the histogram equalization algorithm. But some background noises existing in the enhanced images are finding. The enhanced images will remain in binary format only. The time taken by global thresholding is comparatively less than, local thresholding. Weiner filter gives better results for removal of noises from the old image. Qualities of the enhanced images are being measured by image statistics like PSNR, Mean, and Standard deviation. Results show that Hybrid Binarisation method performs better than Histogram Equalization both in visual perception and image metrics values.

3. PROPOSED WORK

3.1 Local enhancement method

Local enhancement method uses transformation function that based on the gray-level distribution in the neighbourhood window of size (n x n) centered at each pixel in the input image. The transformation function [11] applied to each pixel at coordinates (x, y) using following equation

$$g(x, y) = A(x, y).[f(x, y) - m(x, y)] \quad (1)$$

With

$$A(x, y) = \frac{M}{\sigma(x,y)} \text{with} 0 < k < 1 \quad (2)$$

In equation (1) and (2), m(x, y) the local mean and $\sigma(x, y)$ local standard deviation are computed in an n x n neighbourhood centered at (x, y) pixel of the input image. Thus, the values of m and σ depend on the intensity value of the pixels in the neighbourhood of (x, y). M is the global mean of the input image.

3.2 Proposed enhancement method

The proposed enhancement method is derived from (1) and is applied to each pixel of the input image using the following transformation:

$$g(x,y) = \frac{K.M}{\sigma(x,y)+b}[f(x,y) - c.m(x,y)] + m(x,y)^a \quad (3)$$

In equation (3) a, b, c, and k are the parameters defined as real positive numbers and these values are same for the whole image. Comparing equation (2) and (3), it is shown that if the values of the parameters b = 0, c = 1, k = 1and the last term $m(x,y)^a$ is absent, then both equations same. The eq.(1) has extended the value of the transformation output range by modifying the local enhancement method as shown in eq.(3). Four parameters are introduced in transformation function namely a, b, c, and k to improve the brightness and contrast of the processed image. The task of the DE is to evolve the best combination of these four parameters according to an objective criterion that describes the contrast of the image.

3.3 Fitness function

In order to achieve an automatic image enhancement technique and no objective parameters adjustment by the human intervention, a criterion to evaluate the quality of the enhanced image should be chosen. This criterion is considered as fitness function of the DE. To describe the criterion, it is required to mention that the enhanced image has more number of edges and also it has high intensity of edges. But these two are not sufficient to describe the fitness function for a good enhanced image. Another one measure has been added i.e. entropy value of the image. Entropy value indicates the average information content in the image. For enhanced image the histogram of the gray-levels are uniformly distributed that increase the entropy of the image. These three measures together describe the following objective criterion and in this study it is used as fitness function to be maximized.

$$F(Ie) = \log(\log(E(Is)))\frac{nedgels(Is)}{MxN}.H(Ie) \quad (4)$$

In the eq. (4), *Ie* is the enhanced image of the original image produced by the transformation function mentioned in eq.(3).The edges or edgels can be detected by using many efficient edge detector algorithms. In this paper Sobel edge detector is used as automatic threshold detector [Rosin]. Other edge detector algorithms such as Laplacian and Canny can be used to find edges or edgels of the enhanced image. The sobel edge operator produce an output image Is from the input enhanced image *Ie* as:

$$Is(i,j) = \sqrt{\delta hIe^2 + \delta vIe^2} \quad (5)$$

$$\delta hIe(i,j) = gIe(i+1,j-1) + 2gIe(i+1,j) + gIe(i+1,j+1) + gIe(i-1,j-1) - 2gIe(i-1,j) - gIe(i-1,j+1)$$

and

$$\delta vIe(i,j) = gIe(i-1,j+1) + 2gIe(i,j+1) + gIe(i+1,j+1) + gIe(i-1,j-1) - 2gIe(i,j-1)gIe(i+1,j-1)$$

E(*Is*) is the sum of M x N pixel intensity of sobel edge image *Is*. *N edgels* is the number of pixels, whose intensity value is above a threshold in the sobel edge image. The entropy of the enhanced image *Ie* is calculated as follows:

$$H(Ie) = -\sum_{i=0}^{255} ei \quad (6)$$

where ei = hi log2(hi) if hi≠ 0, otherwise
ei = 0and hi is the probability of occurrence of ith intensity value of enhanced image.

Code

```
Set NP, F, and CR parameters of the DE
Set Gmax and gen = 1
Initialize a population of size NP of D dimensional target vectors
Evaluate fitness values of each individual vector of the population using eq. (5)
Set best = best solution with maximum fitness value
while gen ≤ Gmax do do
for each target vector xi i =1 to NP do do
Generate enhanced image using eq. (4) for xi
Evaluate fitness value using eq. (5) for xi
If Fitness(xi)>Fitness(best) then
best = xi
end if
Randomly select index of three different
individuals such that r1 ≠r2≠r3≠i
The mutation operation produces donor vector
vi = xr1 + F.(xr2 − xr3)
The crossover operation produces trail vector ui using target xi and donor vi vectors
for each parameter j = 1 to D do do
if rand ≤ CR then uij = vij then
uij = vij
else
uij = xij
end if
end for
The selection operation produces new target
vector xi as follows
if Fitness(ui) >Fitness(xi) then
xi = ui
else
old target vector xi will be retained as
parent for next generation
end if
end for
gen = gen + 1
end while
```

4. EXPERIMENTS AND RESULTS

In this paper, many gray-level images are used to perform Image enhancement (IE) experiment; here we presented results of only eight images. Results of the proposed differential evolution based image enhancement (DE-IE) are compared with other techniques namely linear contrast stretching (LCS), histogram equalization (HE) and PSO based image enhancement (PSO-IE). Table 1 contains description of base value of input images such as fitness value, entropy, edgels, detail variance (DV) and background variance (BV). Table 2 contains the description of proposed value of input images. Chart 1 gives the comparison of fitness value of base and proposed value of images. Chart 2 gives the comparison of entropy of base and proposed value of images. Chart 3 gives the comparison of no. of edgels of base and proposed value of images. Chart 4 gives the comparison of Dv values of base and proposed value of images. Chart 5 gives the comparison of Bv values of base and proposed value of images.

Table 1: Base value of input images

Base Image	Fitness	Entropy	Edgels	Dv	Bv
rice.png	1.3182	7.3079	5697	0.008	0.0013
pout.tif	1.404	7.0453	6632	0.006	0.0034
tire.tif	1.3577	6.0991	4928	0.014	0.0021

Table 2: Proposed value of input images

Image	Fitness	Entropy	Edgels	DV	BV
rice.png	1.3406	7.7977	5765	0.0095	0.0015
pout.tif	1.4762	7.1594	6825	0.0108	0.0031
tire.tif	1.3671	6.0561	4992	0.0136	0.0021

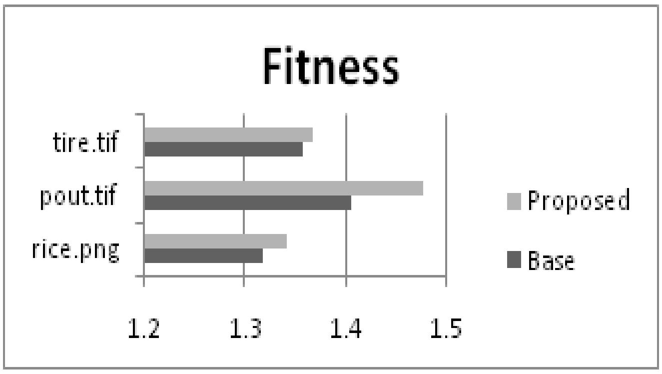

Chart- 1: Comparison of fitness value of base and proposed value of images

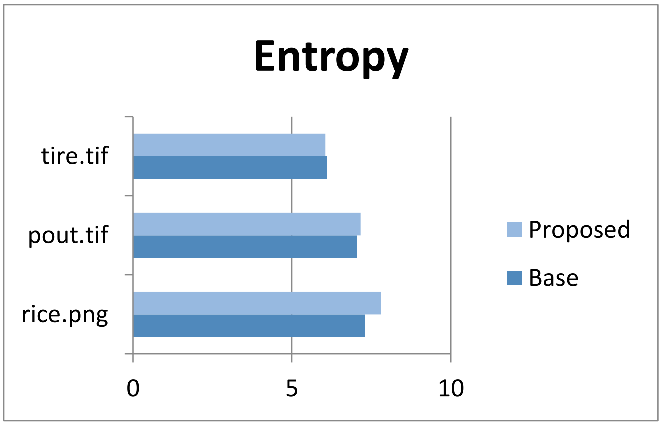

Chart- 2: Comparison of entropy of base and proposed value of images

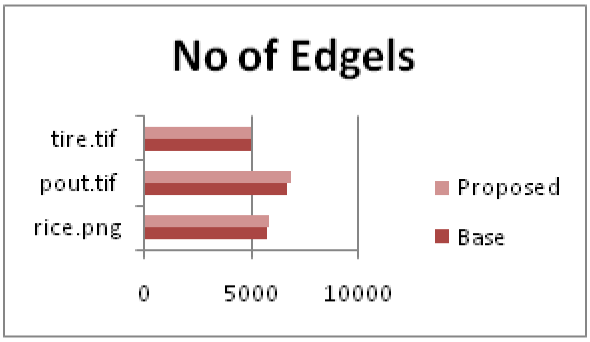

Chart- 3: Comparison of no. of edgels of base and proposed value of images.

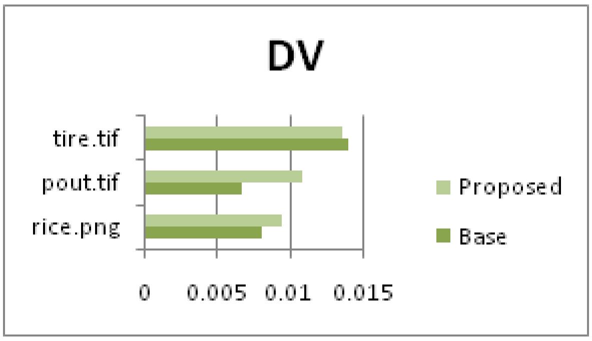

Chart -4: Comparison of Dv values of base and proposed value of images

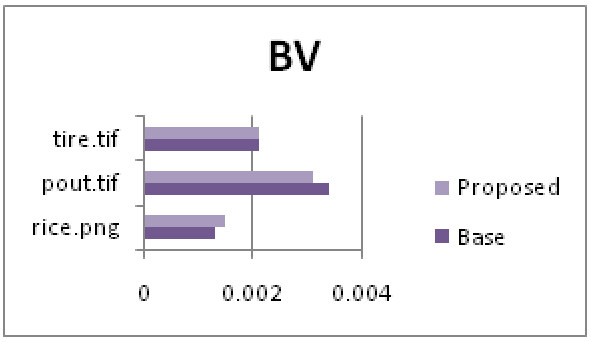

Chart -5: Comparison of Bv values of base and proposed value of images**.**

5. CONCLUSION

In this paper we have proposed an automatic contrast enhancement technique using differential evolution for grayscale images. The resulted images obtained by the base images are compared with proposed images.

The performance of PSO algorithm is very much parameter dependent and fine tuning of the parameters provide better result. However, DE has few parameters need to be set and simple to use with greater robustness than PSO. We compared the results by considering the DV and the BV used for objective evaluation of the enhanced images. However, the DV is not always reflecting precisely the detail content level in the image. Another precise objective computation can be possible by considering the number of edgels. Image contains the higher number of edgels can be considered as having more detail content.

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