

Image Enhancement by using the intelligent optimization algorithm with a combination of bacteria and Particle Swarm Optimization

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Abstract

Improve the image contrast, plays an important role in the image processing system and it is used to improve image quality or to obtain precise details on the low quality pictures. In this article we have taken improving the image, an optimization problem and in order to optimize improve image function parameters that take advantage of distribution of local gray and global statistical information of original image we proposed a hybrid intelligent algorithm. The advantage of the bacteria and particle swarm optimization algorithm have been combined in Hybrid intelligent algorithms which is given in this article, in addition optimum fitness function is based on entropy information and image border information. The results of simulations and experiments have shown after applying this method in addition to increasing image contrast, detailed information of the target image is also significantly improved and noise reproduction is limited.

Keywords: Optimization algorithm bacteria, Particle Swarm Optimization, Intelligent optimization, Image enhancement

Introduction:

Contrast enhancement plays an important role in image processing system. Image enhancement techniques can be divided into four main categories: point operation, spatial operation, transformation, and pseudo coloring. The major limitations of various image enhancement schemes are difficulty in highlight the very finer details of the image and lack of means to adjust the parameters. The aim of our image enhancement algorithm is to get finer details of an image and highlight the useful information that is not clearly visible in the original image. Evolutionary algorithms have been previously used to perform image Enhancement. Evolutionary techniques used so far for the image enhancement problem, have several shortcomings, like: making use of a global method for image enhancement which is incapable of adapting to the local spatial content in the image, requirement for additional external parameters in the objective fitness criterion that make the automatic image enhancement technique parameter dependant . A hybrid intelligent algorithm was proposed to optimize image enhancement operator parameters in this paper. Enhancement operator was based on local gray level distribution and global image statistics. The advantages of bacterial foraging algorithm and particle swarm optimization algorithm was combined and the edge information of image and information of entropy could be used by the fitness function in Hybrid intelligent algorithm proposed in this paper.

II. HYBRID INTELLIGENT ALGORITHM

Bacterial foraging algorithm (BFO) is a kind of dynamic simulation of E. coli bacteria foraging behavior in human body which was derived by Kevin M.Passino [4].This has led scientists to model the activity of foraging as an optimization process. The foraging strategy can be explained by four processes namely: Chemotaxis, Swarming, Reproduction and Elimination/Dispersal

(a) Chemotaxis

Swimming and tumbling. It can swim for a period of time in the same direction or it may tumble, and alternate between these two modes of operation for the entire lifetime. To represent a tumble, a unit length random direction $\phi(j)$ say, is generated; this will be used to define the direction of movement after a tumble. Suppose $\theta^i(j, k, l)$ represents i-th bacterium at j-th chemotactic, k-th reproductive and l-the elimination dispersal steps. $c(i)$ is the size of the step taken in the random direction specified by the tumble (run length unit). Then in computational chemotaxis the movement of the bacterium may be represented by:

$$\theta^i(j+1, k, l) = \theta^i(j, k, l) + C(i)\phi(j) \quad (1)$$

(b) Swarming

It is always desired that the bacterium that has searched the optimum path of food should try to attract other bacteria so that they reach the desired place more rapidly. Swarming makes the bacteria congregate into groups and hence move as concentric patterns of groups with high bacterial density. This is represented by a timevarying cell-cell attractant function that is added to the cost function. But this step is neglected in the case of modified bacterial foraging for the sake of simplicity.

(c) Reproduction

The least healthy bacteria eventually die while each of the healthier bacteria (those yielding higher value of fitness function) asexually split into two bacteria, which are placed in the same location. This keeps the swarm size constant.

(d) Elimination/Dispersal

Gradual or sudden changes in the local environment where a bacterium population lives may occur due to various reasons e.g. a significant local rise of temperature may kill a group of bacteria that are currently in a region with a high concentration of nutrient gradients. Events can take place in such a fashion that all the bacteria in a region are killed or a group is dispersed into a new location. To simulate this phenomenon in BFO some bacteria are liquidated at random with a very small probability while the new replacements are randomly initialized over the search space.

In BFO algorithm, bigger change to direction and bigger swimming step length could lead faster convergence and could easily jump out of local optimal point which also often led to surmount the global optimal point. On the contrary, smaller swimming step length would lead slower convergence and were easily to enter to local optimal area, unable to jump out. But, once the global optimal point was found, higher precision could be achieved in BFO algorithm. Particle swarm optimization (PSO) algorithm is a new kind of evolutionary computation method proposed by Kennedy and Eberhart.

In PSO algorithm, the target location was updated by particles through tracking their own local optimum and global optimal for all particles. Taken the idea in PSO, environment perception could be given to bacteria and iterate could be carried through bacteria by comparing their historical optimal and global optimal to all bacteria. So, based on bacterial foraging algorithm, the hybrid intelligent algorithm proposed in this paper could accelerate optimization ability and speed of bacteria foraging algorithm for providing directional guidance to bacterial chemotaxis operation by introducing the information sharing mechanism of particle swarm optimization. During the chemotaxis loop, the update of the tumble direction is determined by PSO evolution equation:

$$\phi(j+1) = w * \phi(j) + C1 * R1(P_{lbest} - P_{current}) + C2 * R2(P_{gbest} - P_{current}) \quad (2)$$

Where P_{lbest} is the best position of each bacterial and P_{gbest} is the global best bacterial. , $\phi(j)$ was used to define the random direction of movement after a tumble.

III. IMAGE ENHANCEMENT MODEL

A. Strengthen operator

On spatial domain image enhancement uses a fitness function which generates a new intensity value for each pixel of the $H \times V$ original image. The function used here is designed in such a way that takes both global as well as local information of the image to produce the enhanced image. We have chosen to use a less time consuming method similar to statistical scaling presented in literature. Expression for fitness functions are defined as:

$$g(x, y) = \left(k \frac{M}{\sigma(x, y) + b} \right) \cdot (f(x, y) - c \cdot m(x, y)) + m(x, y)^a \quad (3)$$

Where $m(x, y)$ and $\sigma(x, y)$ are the gray-level mean and standard deviation computed in a neighborhood centered at (x, y) and having $n \times n$ pixels. M is the global mean of the image, $f(x, y)$ is the gray-level intensity of input image pixel at location (x, y) while $g(x, y)$ is the pixel's output gray-level intensity value, at the same location.

By this transformation eq. (3), contrast of the image is stretched considering local mean as the center of stretch. Four parameters are introduced in the transformation function, namely a, b, c, k and to produce large variations in the processed image. To optimize the above four parameters with the proposed algorithm, then quality of images was presented by fitness function in the next section.

B. Evaluation Criterion and fitness function

The quality of an enhanced image is measured automatically by employing an efficient evaluation criterion. The fitness function is formed by combining three performance measures, namely entropy value, sum of edge intensities and number of edges (edge pixels). It can be observed that optimal enhanced image has more number of edge pixels and higher intensity value at the edges as compared with the original image. In addition, the entropy value used in the objective criterion reveals the finer details present in the image. The objective function is expressed as follows:

$$F(z) = \log(\log(E(I(Z)))) \cdot \frac{n\text{-edgels}(I(Z))}{H \times V} \cdot H(I(z)) \quad (4)$$

In equation (3) function $F(z)$ denotes the fitness function, $I(Z)$ is the gray-level enhanced image produced by the proposed enhancement algorithm.

$E(I(Z))$ is the sum of $H \times V$ pixel intensity of the edges detected with a Sobel edge detector, where the detector is applied to the transformed image $I(z)$. $n\text{-edgels}$ Denotes the number of edge pixels as detected with the Sobel edge detector. The term $H(I(z))$ is a measure of the entropy in the image $I(z)$. $E(I(z))$ and $H(I(z))$ is calculated on the enhanced image as given by Eqn. (6) and Eqn. (7) respectively:

$$E(I) = \sum_x \sum_y \sqrt{\left(\frac{\partial I}{\partial x}\right)^2 + \left(\frac{\partial I}{\partial y}\right)^2} \quad (5)$$

$$H(I) = - \sum_{i=0}^{255} e_i$$

$$e_i = \begin{cases} h_i \log_2 h_i & h_i \neq 0 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

Where h_i is the probability occurrence of i -th intensity value of enhanced gray image I .

C. Algorithm for the image enhancement

The image processing effect depends on parameters ($a, b, c,$ and k) after dealing with eq. (3) and the larger the value of the fitness function which was determined by eq. (4) as image quality criteria, the better contrast enhancement effect. So image enhancement processing was transformed into the process of looking for ($a, b, c,$ and k) optimal value.

Assuming that bacteria position on behalf of ($a, b, c,$ and k) of a certain value, then the brief pseudo-code of the hybrid intelligent algorithm has been provided below:

Step1: initialize parameters of hybrid algorithm.

Step2: Input image.

Step3: Elimination/Dispersal loop variables.

Step4: Reproduction cycle variables.

Step5: Chemotaxis loop variables.

[5.1]Take a chemotactic step for every bacterium

[5.2]Process the input image by eq. (3) and calculate fitness function value of the bacteria by eq. (4)

[5.3] Determine tumble direction of the bacteria by eq. (2)

[5.4] swimming: find best swimming step length

[5.5] go to Step5 until all bacteria is counted

Step 6: evaluate each bacterium global optimal (Pgbest) and local optimal (Plbest), each bacterial direction is given.

Step 7: next Chemotaxis, go to Step 5.

Step 8:reproduction, calculate fitness function of all bacteria and arrange them in an ascending order; half of the bacteria with small value of fitness function die and the remaining reproduce unceasingly so that total number of bacteria remains the same.

Step 9: next Reproduction, go to Step 3.

Step10: Elimination, eliminate each bacterium according to certain probability, go to Step 2.

Step 11: output enhanced image.

IV. A LGORITHM COMPARISON AND ANALYSIS

A. Results of implementation

In order to test the effect after image enhancement processing using the algorithm proposed in this paper, Lena and Building image was adopted as experiment object. Then, we compared image enhancement effect of algorithm proposed in this paper with Histogram equalization Genetic algorithm and PSO algorithm. Results are shown in figure 1 and figure 2 respectively. (a) is Original image, (b)is image dealing with Histogram equalization(HE), (c) is image dealing with Genetic algorithm(GA), (d) is image dealing with PSO algorithm(PSO), and (e)is image dealing with Algorithm proposed in this paper (HIA). Because of their common use, quality evaluation parameters of information entropy, mean square error, peak signal to noise ratio were chosen by us for quantitative description of the enhanced image thereby to get objective and qualitative evaluation to the algorithm proposed in this paper.



Figure (1) : Processed Lena images by different algorithms

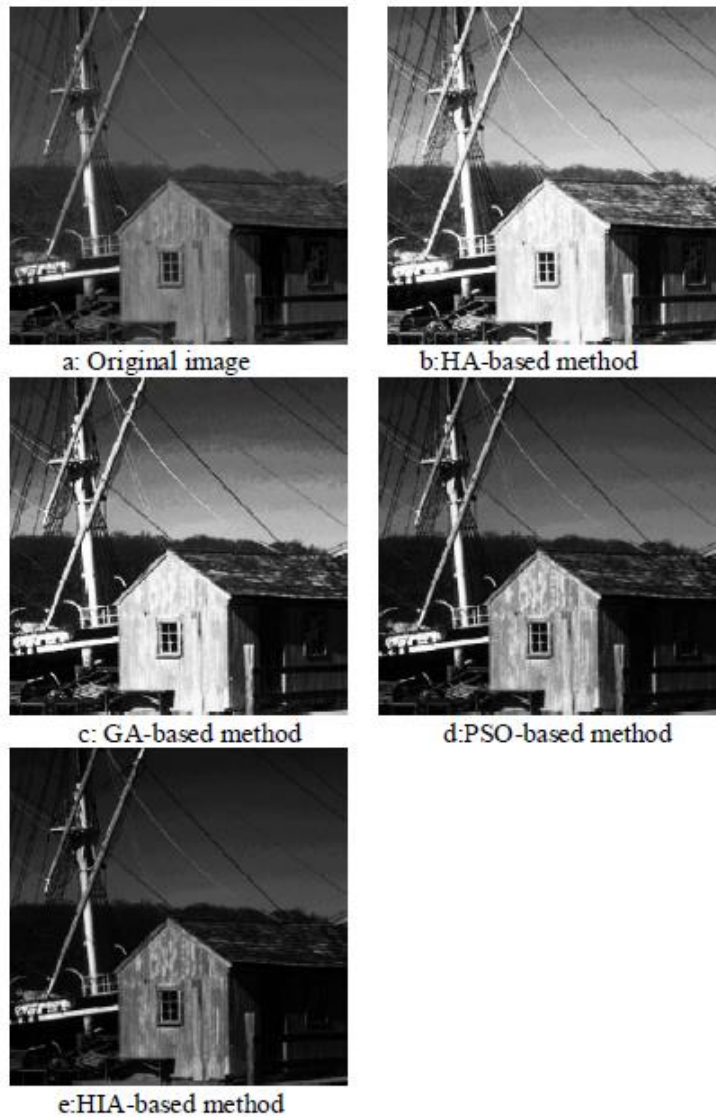


Figure (2) Processed Building images by different algorithms

As shown in figure 1 were obviously enhanced than the other two algorithm ,brighter images, much more outstanding details, good visual effect were got in the image proceeded by the algorithm proposed in this paper.

Table 1 lists the image quality assessment parameters of algorithm proposed in this paper and the other algorithms. From table 1, it could be discovered that image entropy of Histogram equalization algorithm is larger than the other three kinds of intelligent algorithm. Minimum mean square error, maximum peak signal to noise ratio and information entropy were gotten in the algorithm proposed in this paper which means that image quality and average amount of information were better in this algorithm, so it could enhance image detailed characteristics and restrain noise preferably.

Table 1 : Different image quality assessment parameters of each algorithm used

Algorithm		RMSE	PSNR	Image entropy
HA-Based Method	Lena	6.938	62.37	5.07
	Building	7.025	66.23	6.63
GA –based Method	Lena	4.928	65.37	5.19
	Building	6.061	67.87	6.72
PSO – based Method	Lena	4.857	68.87	5.24
	Building	6.429	69.31	6.89
HIA – based Method	Lena	4.948	68.84	5.29
	Building	6.841	70.24	7.10

B. Robustness

Robustness of the Algorithm proposed in this paper (HIA) is related with the repeatability of the results. To evaluate the robustness of HIA, 5 independent runs were performed for each image. Figure 3 gives results for each run. In order to evaluate the repeatability of the experiments we should see that all the curves, for each image, have the same shape and be clustered together. The plots in figure 3 indicate a good behavior of HIA, also in terms of the repeatability of this method.

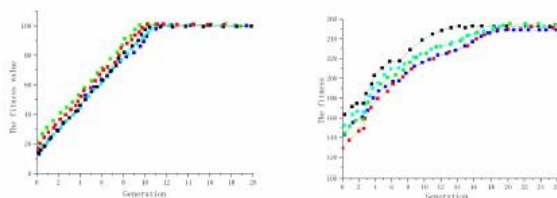
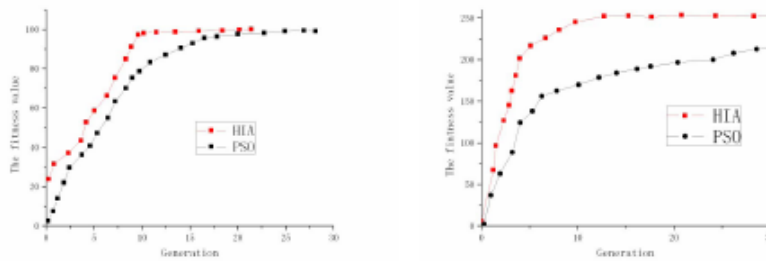


Figure (3) Convergence process of HIA after 5 times running



**Figure (4) Comparison of convergence process of HIA and PSO
(Average after 10 times running)**

It was showed that the 10 times average convergence situation after processed with algorithm proposed in this paper and PSO. As shown in figure 4, convergence precision and convergence speed of algorithm proposed in this paper were better than PSO.

V. C ONCLUSIONS

Contrast enhancement has an important position in the image processing. In this paper, Hybrid intelligent optimization was used to enhance image contrast, so to parameterize the image enhancement operator and then to optimize it using hybrid intelligent algorithm. Because the optimized fitness function was based on entropy and edge information of image, so the algorithm could enhance edges and detail of the image and restrain noise amplification. The experimental results showed that the enhanced image disposed by the algorithm proposed in this paper was clearer and easier to observe. This method has very great help to the further study of image processing.

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