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Adaptive Image Enhancement based on Gravitational Search Algorithm

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Abstract

To improve the adaptability and effect of image enhancement, this paper has proposed an image enhancement method based on Gravitational Search Algorithm (GSA), which is used for optimizing the parameters of the normalized incomplete Beta function using the characteristics of the original image, the acquired function is employed to enhance the degraded image. The simulation results show the method can effectively enhance the global contrast of the image and vision. So this method is practical in the field of gray level image adaptive enhancement.

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Keywords: Gravitational Search Algorithm, image enhancement, grey image

1. Introduction

Image enhancement is one of the most important issues in degraded image processing, its purpose is to make obscure image clear or draw out what we are interested in [1]. So a lot of methods have been developed and they can mainly be divided into two classes: local and global methods, image enhancement technique can be roughly divided into three categories including the frequency domain method, the Space domain method and fuzzy processing [2]. Among them, the frequency domain method is the convention of original image in a kind of transform domain, in which some transformation is processed to achieve the

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enhancement purpose; The space domain directly processes the original image, the main methods consist of histogram equalization, straight party edge extraction and so on, Fuzzy enhancement method is that the original image data is mapped through airspace, the various properties of characteristic plane image information are processed, finally the information data of inverse image mapped into space domain and then we can get the enhanced image. These traditional image enhancement methods have poor availability and the weakness of huge calculation so how to establish a method which can automatically adjust image grey level accord to the characteristics of the image is very significant. The nonlinear convention of gray level is an efficient method in the field of image enhancement which uses four kinds of transform functions according to different states for the gray level images. In this paper, the author proposes an adaptive image enhancement method which can improve the degraded image according to the image characteristics, using the Gravitational Search Algorithm for optimizing the parameters of Beta function. The simulation results show the proposed method can obviously improve the quality of degraded image.

2. Gravitational Search Algorithm

GSA [3] is a novel optimization algorithm which obeys the law of gravity and simulates Newton's gravitational force behaviors, which was introduced by Rashedi [4]. In the algorithm, agents are regarded as objects which performance is determined using their masses, all these objects attract each other by the gravity force, and this force causes a global movement of all objects towards the objects with heavier masses. Hence, masses cooperate using a direct form of communication, through gravitational force. The heavy masses–which correspond to good solutions – move more slowly than lighter ones, this guarantees the exploitation step of the algorithm. The position of the mass corresponds to a solution of the problem, and its gravitational and inertial masses are determined using a fitness function.

Now, consider a system with N agents. the position of the ith agent is defined as follows::

$$X_i = (x_i^1, \cdots, x_i^d, \cdots, x_i^n) \text{ for } i = 1, 2, \cdots, N \tag{1}$$

where x_i^d presents the position of *i*th agent in the *d*th dimension.

In the time t a force acts on mass j from mass i. This force is given as follows:

$$F_{ij}^d = G(t)\frac{M_{pj}(t) \times M_{aj}(t)}{R_{ij}(t) + \varepsilon}(x_j^d(t) - x_i^d(t)) \tag{2}$$

where M_{aj} is the active gravitational mass related to agent *j*, M_{pi} is the passive gravitational mass related to agent i, $G(t)$ is gravitational constant at time *t*, ε is a small constant, and $R_{ij}(t)$ is the Euclidian distance between two agents *i* and *j*:

$$R_{ij}(t) = \| X_i(t), X_j(t) \|_2 \tag{3}$$

The total force acting on mass *i* in the *d*th dimension in time *t* is given as follows:

$$F_i^d(t) = \sum_{j \in Kbest, j \neq i}^{N} rand_j F_{ij}^d \tag{4}$$

where $rand_j$ is a random number in the interval [0, 1], *Kbest* is the set of first *K* agents with the best fitness value and biggest mass.

In term of the Newton's second law, the acceleration related to mass i in time t in the dth dimension is given as follows:

$$a_i^d = \frac{F_i^d(t)}{M_{ii}(t)} \tag{5}$$

where M_{ii} is the inertial mass of ith mass.

So, the next velocity of an agent is considered as a fraction of its current velocity added to its acceleration, its position and its velocity could be calculated as follows:

$$v_i^d(t+1) = rand_i v_i^d(t) + a_i^d(t) \tag{6}$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \tag{7}$$

gravitational constant will take an initial value at the beginning and it will be reduced by time to control the search accuracy as follows:

$$G(t) = G_0 e^{-\alpha \frac{t}{T}} \tag{8}$$

where T is the number of iteration, G_0 and α are given constant.

The gravitational mass and the inertial mass are updated by following equations:

$$M_{ai} = M_{pi} = M_{ii} = M_i, \ i = 1, 2, \cdots, N \tag{9}$$

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \tag{10}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \tag{11}$$

where $fit_i(t)$ represent the fitness value of the agent i at time t, and, $worst(t)$ and $best(t)$ are defined as follows for a minimization problem:

$$best(t) = \min_{j \in \{1, \cdots, N\}} fit_j(t) \tag{12}$$

$$worst(t) = \max_{j \in \{1, \cdots, N\}} fit_j(t) \tag{13}$$

3. Incomplete Beta Function for Nonlinear Convention

For visual characteristic of eye, may images present a brighter, darker or more concentrated grey in a specific region, which correspond to four classes as follows in Fig. 1 [5]:.

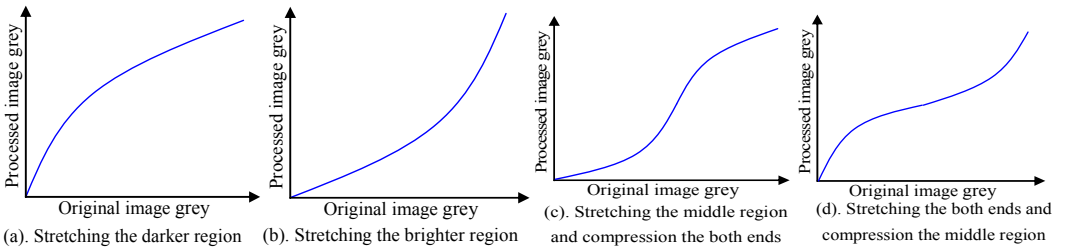


Fig. 1. Nonlinear convention of grey image

To achieve enhancement of different types of degraded image, Tubbs [6] has presented a normalized incomplete Beta function for image enhancement which is defined as:

$$F(u) = B^{-1}(\alpha, \beta) \int_0^u t^{\alpha-1}(1-t)^{\beta-1} dt, \quad (0 < \alpha, \beta < 10) \tag{14}$$

In the formula, $B(\alpha, \beta)$ is the Beta function, which is defined as:

$$B(\alpha,\beta)=\int_0^1 t^{\alpha-1}(1-t)^{\beta-1}dt \tag{15}$$

4. Adaptive Enhancement for Grey Image based on GSA

Based on the above section, the normalized incomplete Beta function is used as grey image generalized convention [6], which is as follows:

$$f(i_{xy},\alpha,\beta)=\frac{\int_0^{i_{xy}} t^{\alpha-1}(1-t)^{\beta-1}dt}{B(\alpha,\beta)} \tag{16}$$

The fitness function used is defined as:

$$Fintness(f)=\frac{1}{n}\sum_{x=1}^{M}\sum_{y=1}^{N}f^2(x,y)-(\frac{1}{n}\sum_{x=1}^{M}\sum_{y=1}^{N}f(x,y))^2 \tag{17}$$

Where M and N present respectively the length and width of the image to be enhanced, and $n=M\times N$, $f(x,y)$ represents the enhanced pixel value of the original image. The bigger the value of the fitness function, the better the enhance effect of the image.Based on the above analysis, the flow chart for adaptive enhancement for grey image based on GSA is depicted in Fig. 2.

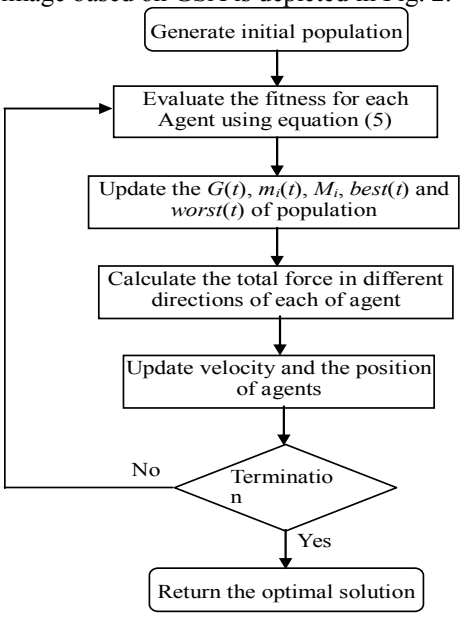
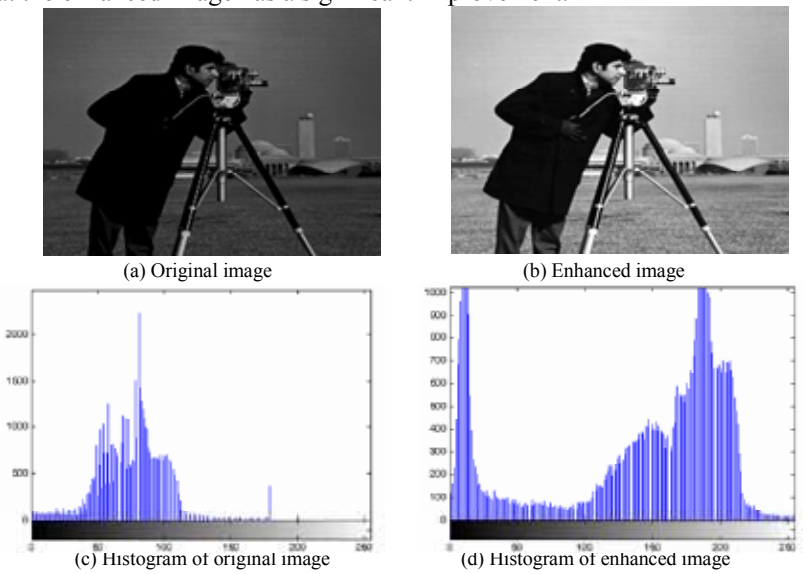


Fig. 2. Flowchart diagram of GSA for grey image enhancement

5. Experiment and Result

In our experiments, a degraded images with the grayscale size 256×256 is used which gray range value is [0, 255]. The parameters for GSA are as follows: the population N is set to 50, the maximum iteration is set to 100, the initial gravitational constant G0 is set to 100, and α is set to 20.It can be seen that in Fig .3 that he original image of "cameraman" the grey scale is in a low contrast and the grey level is gathered together a region, the grey levels are well distributed which can present a clear detail, and both the bright

and dark regions are balanced, the gray scale has been greatly stretching after the image enhancement. It is obviously that the enhanced image has a significant improvement.



(a) Original image (b) Enhanced image

(c) Histogram of original image (d) Histogram of enhanced image

Fig. 3. Enhancement effect of 'cameraman'

6. Conclusion

This paper uses GSA to optimize the parameters of the normalized incomplete Beta function, which is applied to enhance the degraded image. It can be seen from the experimental results that, the image enhancement method based on GSA has an adaptive ability; it can adjust the grey level of image according to the original image, the proposed method has a good enhancement effect.

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