X-Ray Image Enhancement using the Fruit Fly Optimization Algorithm

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***Abstract* — Medical images in the process of collection and transmission are susceptible to noise interference and become blurred. The parameters of traditional fuzzy enhancement algorithm are controlled by manual adjustment, often with poor efficiency and effect, which cannot be optimal. Because a fruit fly optimization algorithm has small number of parameters with global optimization capability, in this paper we combine it with fuzzy enhancement algorithm with the fruit fly optimization algorithm being used to optimize the parameters of fuzzy enhancement. The results of simulation show that fruit fly optimization algorithm can effectively make medical image clearer, highlight certain characteristics, and effectively improve the visual impact of medical images.**

Keywords - fruit fly optimization algorithm; fuzzy enhancement; image processing; fitness function.

I. INTRODUCTION

Medical images in the process of collection and transmission, susceptible to noise interference become blurred. Medical image enhancement can help to improve the quality of medical images, and highlight certain characteristics, so that the image becomes clear. Image enhancement methods could mainly be divided into three categories, namely fuzzy processing, frequency domain method and spatial domain method [1-3]. These methods require human to determine the transit point and the saturation point. Due to these shortcomings, the application of the traditional methods has been limited.

In 1981 SK Pal et al [4-6] proposed a new membership of functions and fuzzy enhancement operator to achieve enhancement of image contrast, and the algorithm steps are as follows:

Step1: According to the formula (2), for the purposes of different images and enhancement, the membership function of the parameter ($(F_e, F_d, g_{\max})$) should be adjusted, and consisting of all μ_{mn}, the fuzzy feature plane should be set, g_{mn} represents the maximum pixel value, F_e is exponential fuzzy factor, F_d refers to reciprocal fuzzy factor. By adjusting these parameters, vagueness size can be controlled.

So it's necessary to choose good fuzzy parameters of F_e and F_d, which can effectively enhance the image. The condition that $\mu_{mn} = G(g_c) = 0.5$ is referred to the transit point. Fuzzy parameters selection is close to the transit point, and the following conditions [7]:

$$g_{mn} = \begin{cases} < 0.5 & g_{mn} < g_c \\ = 0.5 & g_{mn} = g_c \\ > 0.5 & g_{mn} > g_c \end{cases} \tag{1}$$

So when the transit point g_c could be determined, and F_e through the formula (2), can be calculated to F_d.

Step2:Achieved by G, changing the spatial domain image to fuzzy domains.

$$\mu_{mn} = G(g_{mn}) = \left[1 + \frac{g_{\max} - g_{\min}}{F_d}\right]^{-F_e} \tag{2}$$

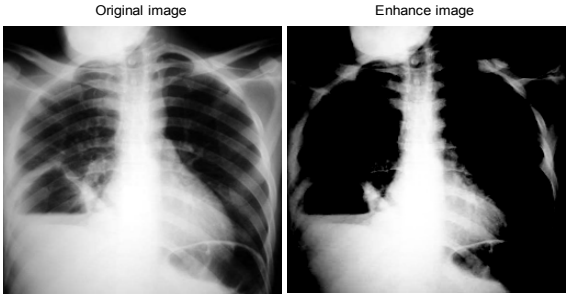
Through transformation by formula (3), which is fuzzy enhancement amended return called membership operator ($\mu_{mn} \to \mu'_{mn}$) [8]:

$$T(\mu_{mn}) = \begin{cases} 2 \cdot [\mu_{mn}]^2 & 0 \le \mu_{mn} \le 0.5 \\ 1 - 2 \cdot [\mu_{mn}]^2 & 0.5 \le \mu_{mn} \le 1 \end{cases} \tag{3}$$

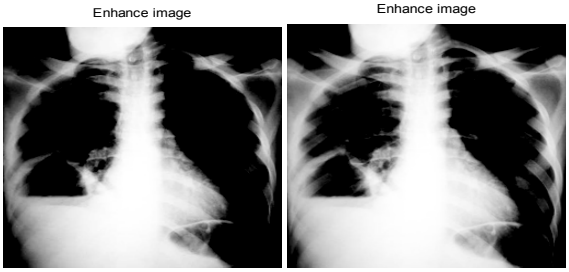
The key of fuzzy enhancement lies in fuzzy enhancement operator by increasing the membership value μ_{mn} greater than 0.5 and less than 0.5. Thereby ambiguity of G could be reduced. Fuzzy enhancement operator generated another fuzzy set on G.

Step3:By G^{-1} inverse transform, a new gray level g'_{mn} is generated, in order to achieve an image fuzzy by the image domain to the spatial domain [9-10]:

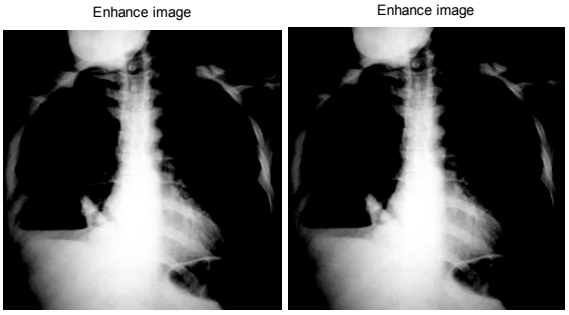
$$g'_{mn} = G^{-1}(\mu'_{mn}) = g_{mn} - F_d \left[(\mu'_{mn}) \frac{-1}{F_e} - 1 \right] \tag{4}$$



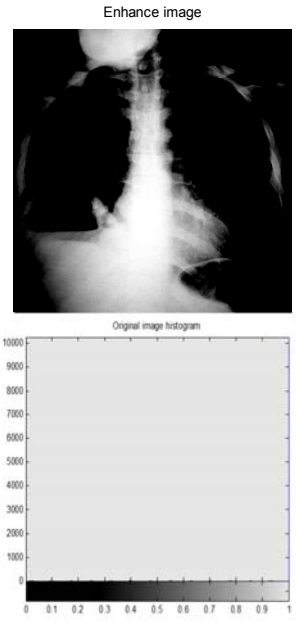
(a) Original image (b) Fe=1,Fd=32



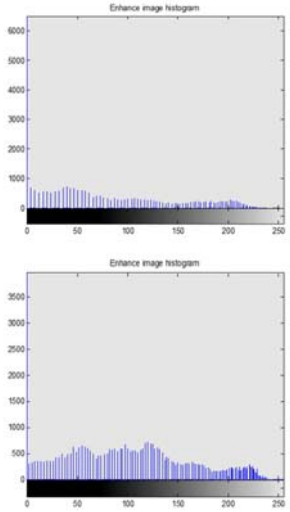
(c) F_e=1,F_d=64 (d) F_e=1,F_d=128



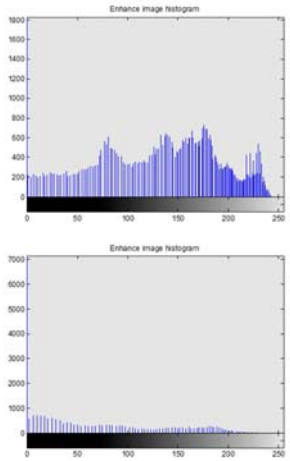
(e) F_e=3,F_d=64 (f) F_e=5,F_d=64



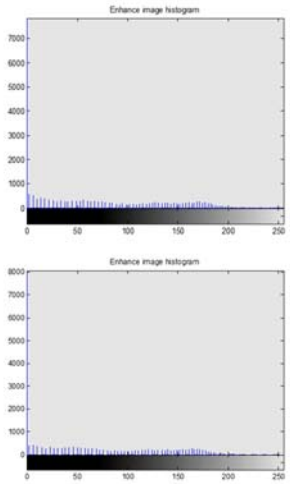
(g) F_e=7,F_d=64 (a') Original image



(b') F_e=1,F_d=32 (c') F_e=1,F_d=64



(d') F_e=1,F_d=128 (e') F_e=3,F_d=64



(f') F_e=5,F_d=64 (g') F_e=7,F_d=64

Figure. 1 Different Fe and Fd, different image enhancement effect and its corresponding histogram.

II. MATERIALS AND METHODS

A. Introduction of Fruit Fly Optimization Algorithm

Fruit fly optimization algorithm (Fruit Fly Optimization Algorithm, FOA) is a new evolutionary computing method proposed by Taiwan scholar WenChao Pan [5-8] in 2011.Global optimization by simulating the foraging behavior of fruit flies, which seek fresh process shown in Figure 2.

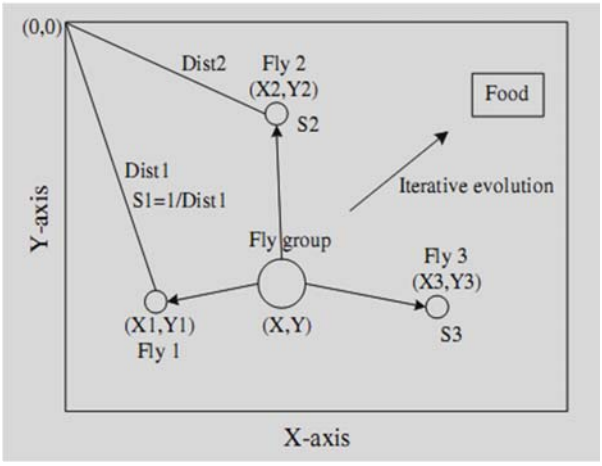


Figure. 2 Group of fruit fly iterative search food

B. Algorithm Steps

Fruit fly optimization algorithm can be divided into seven steps, and concrete steps are as follows [9]:

(1)The initialization position of fruit fly groups are shown in Figure 2, and the result is initialized In its X axis; In its Y axis.

(2) When the search direction RV_x and RV_y are settled, search distance of individual fruit fly random can be obtained by the following formula:

$$\begin{aligned} X_i &= initX\_axis + RV_x \\ Y_i &= initY\_axis + RV_y \end{aligned} \tag{5}$$

(3) Since the position of the unknown food has been settled, the individuals need to estimate the distance Distil between the current location and the origin. Flavor concentration is calculated after determining the value of Si. Flavor concentration value is equal to the reciprocal of the distance.

$$\begin{aligned} Disti &= \sqrt{X_i^2 + Y_i^2} \\ S_i &= 1/Disti \end{aligned} \tag{6}$$

(4) The flavor concentration determination values are put into concentration determination function to calculate the concentration of the flavor of the current position of the individual in fruit fly.

$$Smelli = Function(S_i) \tag{7}$$

(5) The optimum flavor concentration of Fruit fly Groups, can be obtained by the following formula:

$$\left[bestSmell\ bestIndex\right] = \max(Smelli) \tag{8}$$

(6) The best flavor concentration and the population corresponding x and y coordinates of fruit fly groups should be retained, through its own visual positioning of the food source, toward the position of the food.

$$\begin{aligned} bestSmell &= bestIndex \\ X\_axis &= X(bestIndex) \\ Y\_axis &= Y(bestIndex) \end{aligned} \tag{9}$$

(7) The iterative optimization, iterative steps (2) - (5) could be used to determine whether the favor concentration is better than the previous iteration flavor concentration. If satisfied, than go into step (6).

C. Fuzzy Enhancement Measure

Image fuzzy enhancement effect is mainly about the decreases toward the direction of information entropy, and therefore to measure the effect of fuzzy enhancement by comparing the information entropy before and after image enhancement.

Definition of information entropy:

$$H = -\sum_{i=1}^{256} p_i \log(p_i) \tag{10}$$

Where: p_i represents the normalized histogram.

Definition of fuzzy entropy:

$$SH = \frac{1}{MN \ln 2} \sum_{i=1}^{M} \sum_{j=1}^{N} \left[S_n\left(\mu_{ij}\right) \right] \tag{11}$$

Where: *MN* represents the size of image. S_n represents *shannon* formula. Where

$$S_n = -\mu_A(x_i)\ln\left(\mu_A(x_i)\right) - \left(1-\mu_A(x_i)\right)\ln\left(1-\mu_A(x_i)\right) \tag{12}$$

D. The Fitness Function

Fuzzy entropy is a image evaluation parameter used to enhance the effect. Due to the fact that the fuzzy entropy mainly reflects the brightness of the image, while the contrast sensitivity is low, so the fuzzy entropy needs to be improved. Its improved fitness function is:

$$\text{Fintness}\left(\mu\right) = \frac{\max(\mu_{ij}) - \min\left(\mu_{ij}\right)}{1 + \frac{1}{MN \ln 2} \sum_{i=1}^{M} \sum_{j=1}^{N} \left[S_n\left(\mu_{ij}\right) \right]} \tag{13}$$

In formula (11), $\max(\mu_{ij})-\min\left(\mu_{ij}\right)$ represents the fuzzy contrast, $\max(\mu_{ij}),\min\left(\mu_{ij}\right)$ represents the maximum and minimum fuzzy feature plane. The larger the result of $\max(\mu_{ij})-\min\left(\mu_{ij}\right)$ is, more clear the image is. The smaller $SH=\frac{1}{MN\ln 2}\sum_{i=1}^{M}\sum_{j=1}^{N}\left[S_n\left(\mu_{ij}\right)\right]$ the fuzzy entropy is, the clearer the picture becomes .Therefore the greater the fitness function $\text{Fintness}\left(\mu\right)$, more significant the image blur enhancement effect is, which would also make quality higher.

E. FOA Fuzzy Enhancement Algorithm Flow.

During initialization, a number of randomly generated populations, corresponding $\text{Fintness}\left(\mu\right)$ to each population are calculated. It's necessary to find the maximum value of the fitness $\text{Fintness}\left(\mu\right)$ of the population, and then update the velocity and position according to the fruit fly algorithm rules. Until calculated after a given algebra, with maximum fitness, a value F_e , F_d that corresponds to fuzzy enhancement parameters to enhance medical image fuzzy, could be found.

The algorithm is as follows:

Step1: the position of initialization fruit fly and parameters of algorithm.

Step2: The calculation for each population corresponding to $\text{Fintness}\left(\mu\right)$, comparison to the optimal value of individual history to optimum population history are necessary. If the optimal value is better than the individual or population history, the current value of the reserved locations and the best history values of individuals or groups should be updated. On the contrary, history is retained on an optimal value.

Step3: In accordance with the updated rules fruit fly position moving particles to a new location.

Step4: Determine whether the maximum algebra. If $Iteration < Maxgen$, then optimizing end. Conversely, return to Step2.

Step5:Fuzzy enhancement parameters to finally find a maximum fitness value $\text{Fintness}\left(\mu\right)$ of the corresponding F_e , F_d to enhance medical image fuzzy.

III. Results and Discussion

In order to verify the effectiveness of the proposed algorithm, the population size is set to 20, and the number of iterations is 50.With two standard test images as the test object, research on fruit fly optimization algorithms to enhance image fuzzy effect, which enhances effect shown in Figures 3, 4 and 5 below.

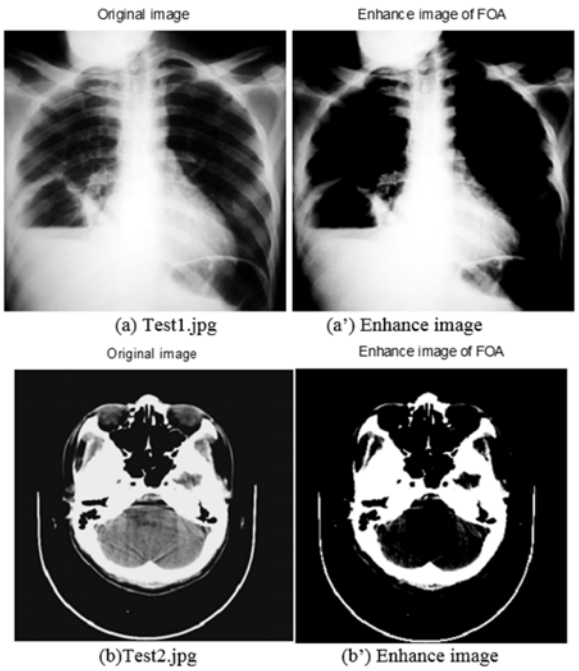
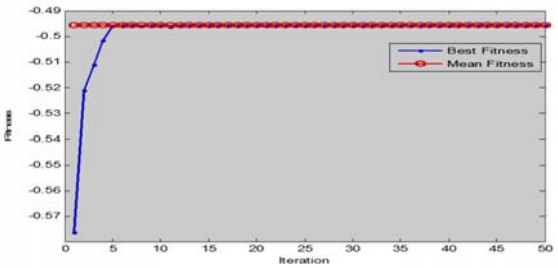
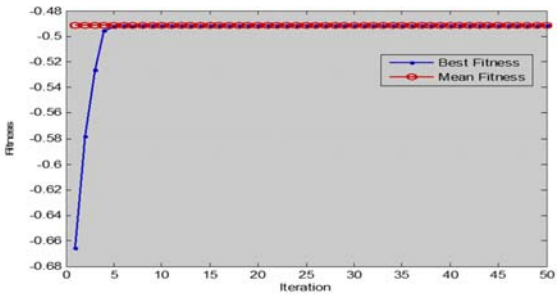


Figure. 3 FOA fuzzy enhancement effect.

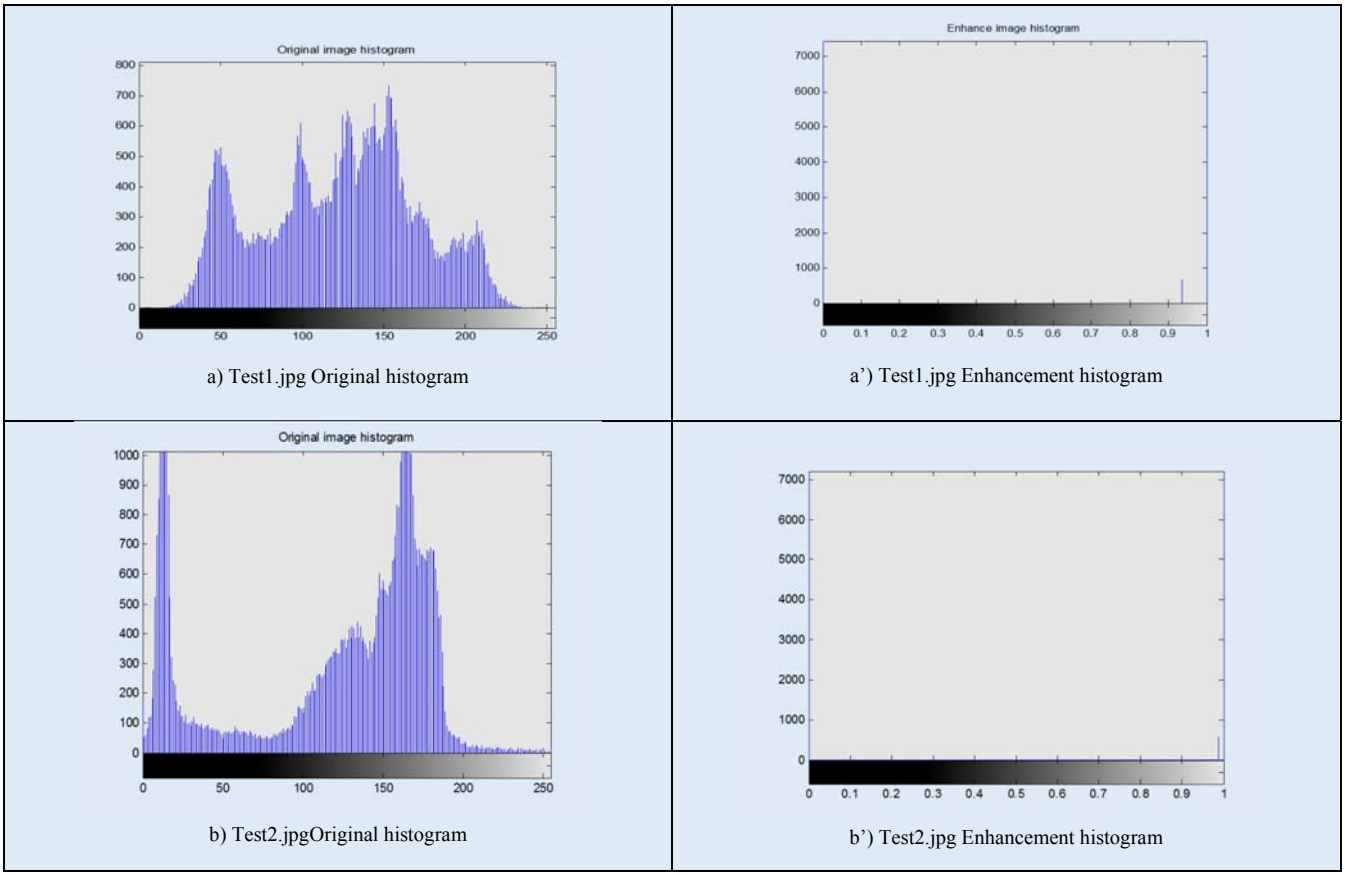


(a) Test1.jpg FOA convergence curve of fuzzy enhancement.



(b) Test2.jpg FOA convergence curve of fuzzy enhancement.

Figure. 4 FOA fuzzy enhancement curve.



a) Test1.jpg Original histogram

a') Test1.jpg Enhancement histogram

b) Test2.jpgOriginal histogram

b') Test2.jpg Enhancement histogram

Figure. 5 FOA histogram contrast before and after the fuzzy enhancement.

By fruit fly optimization algorithm, the image fuzzy enhancement results could be optimized and comparison shows that this algorithm can effectively highlight the characteristics of image, improve image visual effect and efficiency. It also can avoid manually adjusting the parameter, which could guarantee the quality of the best image and configure the best fuzzy enhancement parameters.

By fruit fly optimization algorithm combined with the image fuzzy enhancement algorithm, fruit fly excellent search performance optimization algorithm could be used for image enhancement fuzzy enhancement of two fuzzy optimization parameters F_e , F_d .By constructing appropriate fitness function, fuzzy medical image enhancement could be realized. Simulation results show that fruit fly optimization algorithm for image fuzzy enhancement is better than traditional algorithms, and it has some practical value. It also can enhance adaptive fuzzy parameters, which could improve the efficiency significantly.

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