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Medical DR image enhancement based on AFSA

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ABSTRACT

During the process of imaging and digitization in DR system, due to the influence of electrical noise of electronic devices, optical scattering caused by imaging devices and light quantum scattering, vague imaging, low resolution and less obvious details are inevitable, bringing some difficulties in doctors' pathological diagnosis Therefore, it needs to enhance the images in the later stage of the DR system process and improve the image resolution, edges and other details. In order to present clear details while enhancing the contrast ratio, we introduce a medical DR image enhancing method based on hybrid optimization algorithm, which makes histogram equalization enhance in low frequency of the concerned range and piecewise linearity enhance in non-concerned range. This method combines the advantages of AFSA and membrane optimization algorithm. DR images enhanced with this method have better image effect and clearer details.

Keywords: Medical DR image, Image enhancement, Artificial Fish Swarm Algorithm

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INTRODUCTION

Digital radiography (DR) has advantages, such as high resolution ratio, wide dynamic range, fast speed of imaging and low-radiation to human body. It uses a flat plate detector to accept the X-ray and obtains the digital image signal directly. It has been the most advanced medical imaging method in the X-ray imaging field, and more and more widely used in the clinical diagnosis and the scientific research. However, during the imaging digitizing process of DR system, because of noise disturbance, excessively high or low exposure rate, great thickness of human tissue we take and other reasons, there are some unavoidable problems, such as fuzzy image, low resolution ratio and inconspicuous details, which make the quality of DR image unsatisfactory and influence the validity of medical diagnosis. Consequently, it brings certain difficulties in pathology diagnosis for doctors; therefore, the image visible quality should be improved by enhancing processing.

For this reason, in terms of the image enhancement algorithm for DR images, restraining the amplification of noise as much as possible is required while increasing dynamic range and enhancing contrast of the images. Based on the study of DR imaging principles, this paper analyses the causes of noises in DR images and the reasons for the blurring of image details. A method of image enhancement processing based on artificial fish school algorithm is then proposed, which achieves impressive results.

AFSA (Artificial Fish Swarm Algorithm)[1]is a swarm intelligent optimization algorithm based on animal behavior. To use swarm intelligent bionic algorithm, to achieve enhanced optimum parameters without manual intervention, so that the enhanced processing will have strong self-adaptability and versatility. The algorithm is simple and has strong global search ability and certain self-adaptability of the search space. What's more, the algorithm is not sensitive to the selection of parameters, which provides it with strong robustness and good performance of convergence.

This article intends to use AFSA in two-dimension Otsu method to identify dual threshold of the image automatically, and then identify the optimal segmentation curve self-adaptively using AFSA, realizing the goal of enhancing images self-adaptively[2].

EXPERIMENTAL SECTION

2.1.*DR Image Enhancement Principle*

DR image is a technology which transforms X-ray image directly into digital image signal in the control of a computer with image processing function with X-ray detector using one or two dimensions direct transform methods. Compared with traditional X-ray Imaging, DR system can transform the X-ray to electrical signals directly without the intermediate carrier of energy conversion, which greatly improves the conversion efficiency of the X-ray, decreases the noise that may be caused in the process of image and improves the final quality of the image[3].

Figure 1 represents the forming diagram of the hardware of DR system. The hardware of DR system mainly consists of X-ray tube, high-pressure producer, console for exposure, rack, hand brake, digital detector, control box and computer with operation. The operation platform software system mainly contains the operation and control software system, and special image processing software and relative network interfaces. The operator controls the RAD console through the handle switch, and the console controls the operation of the high voltage generator, enabling the X-ray tube to emit X-rays. The X-rays going through the human body are captured by the flat panel detector, and the obtained digital image signal is transmitted to the software workstation, which is connected to the physical image archiving communication systems(PACS) and available for tele-medicine. Figure 2 represents the DR schematic diagram of the imaging processing.

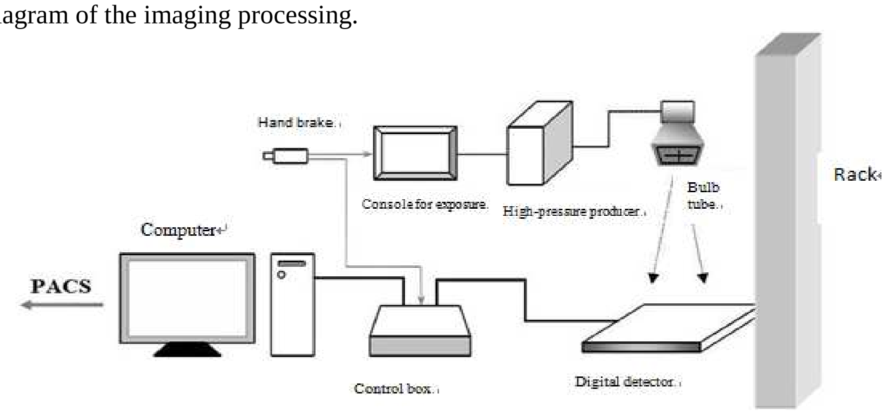


Figure 1. DR System Hardware components

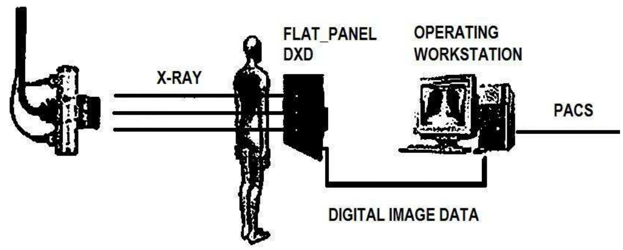


Figure 2. DR Imaging Schematic Diagram

2. 2.*The Method of Medical DR Image Enhancement Based on AFSA*

2.2.1. Basic Principle of AFSA

Artificial Fish (AF) is an intelligent unit that encapsulates its own data parameters and all kinds of behaviours[4]. It can sense Y the density change of food in the visual range and choose different behaviour model with its own behaviour evaluation function to change its current location X, and move to the global optimum location through constant behaviour selection.

2.2.1.1. Parameter Definition

Assume that there are fish-number AFs in a certain water area, and the location status of any AF is shown with vector $X=(x_1,x_2,\cdots x_n)^T$, $x_i(i=1,2,\cdots,n)$ is the required variable and n is the variable dimension X; $Y=f(x)$ represents the food concentration at the current position of the AF; the distance of AF is marked with the 2-norm of the vector X, namely $d_{i,j} = \|x_i - x_j\|$; visual is the sensing range of an AF, and in this range, AF can sense the food concentration of the center position Y_c and the number of companions n_f ; step is the largest mobile step length, which can be constant or variable; δ is the crowding factor which describes the degree of crowding of companions in the sensing range[5].

2.2.1.2 Behavior Descriptions

1. Foraging Behavior

Assumethe present position of the ith AF is X_i, to visual randomly select the jth artificial fish X_j as per formula (1) within the sensing range. During seeking the minimum value questions $Y_j < Y_i$, AF moves one step forward as per formula(2), otherwise, to reselect other artificial fish within the sensing range, and then compare the food concentration to determine whether to move or not, thus repeating Try-number times, if no move is observed, a random step shall be made as per formula (1).

$$X_j = X_i + (2 \times rand(\ ) - 1) \times \text{visual} \tag{1}$$

$$X_{next} = X_i + rand(\ ) - 1 \times \frac{X_i - X_j}{\|X_j - X_i\|} \times step \tag{2}$$

Therein, rand( ) is the random number between 0 and 1.

2.Swarming Behaviour

Assume the number of partners in the sensing or interference range visual of the ith AF is n_f, the food concentration is Y_c in central place is X_c. If $Y_c n_f < \delta Y_i$, then the swarm in this area is considered to be not very crowded, AF should adopt swarming behavior and move a step forward as formula (3); otherwise, it is considered to be overcrowded, and foraging behaviors should be performed.

$$X_{next} = X_i + rand(\ ) \times \frac{X_c - X_i}{\|X_c - X_i\|} \times step \tag{3}$$

3. Rear-end Behavior

If the searched maximum food concentration by the ith AF in its sensing range visual is $Y_{\max}$ and the location is $X_{\max}$ .If $Y_{\max} n_f < \delta Y_i$, the food concentration at $X_{\max}$ will be considered as the highest while the fish swarm is not too crowded, and the rear-end behavior should be implemented, the swarm moves forward as formula(4). Otherwise the foraging behavior should be implemented.

$$X_{next} = X_i + rand(\ ) \times \frac{X_{\max} - X_i}{\|X_{\max} - X_i\|} \times step \tag{4}$$

4. Random Behavior

Random behavior is the default state of foraging behavior. When implementing the foraging behavior, if AF still cannot go forward after attempting the Try-number repeatedly, then the strategy of moving one step randomly should be implemented according to formula (1). And the AF can escape from local minimum to reach the goal of overall optimization. So the setting of Try-number is very important for escaping from the local extremum[6].

2.2.1.3 Implementation Process

(1) Set initial parameter $fish-number, try-number, visual, delta, step$ and maximum iterations $MAXGEN$.

(2) Use initialization function $AF-init(\ )$ to initialize artificial fish swarm.

(3) Initialize the food concentration in the environment around the artificial fish swarm with target function $Y = f(X)$.

(4) Implement behavior evaluating function $value(\ )$, and select the behavior.
(5) If it meets the maximum number of iterations or the precision of adaptive fitness function, the algorithms will stop and return to the optimal individual X_{best} and the optimal function value Y_{best}.

2.2.2 Two-dimensional Otsu Threshold Segmentation
Japanese scholar Yukio proposed Otsu first[7], which is also called the maximum interclass variance method. Otsu algorithm, based on one-dimensional histogram, takes the maximum interclass variance of background and target as the screening criteria of threshold value. The gray level cannot fully reflect the spatial information of image. Especially when the image contains noise, background and foreground won't be distinguished and thus cause incorrect segmentation. On the basis of this[8], the one-dimensional Otsu threshold segmentation method was extended to two-dimensional by Liu Jianzhuang and others. The appearance probability of defined target and background was $\omega_0(t,s)$ and $\omega_1(t,s)$,respectively:

$$\omega_0(t,s) = \sum_{i=1}^{t}\sum_{j=1}^{s} p_{ij} \qquad \omega_1(t,s) = \sum_{i=s+1}^{t}\sum_{j=t+1}^{s} p_{ij} = 1 - \omega_0(t,s) \tag{5}$$

Where, p_{ij} represents the joint probability of the appearance of (gray level, local average gray level) in the image. The vector of the mean values μ_0 and μ_1 corresponding with the two types is:

$$\mu_0 = (\mu_{0i}, \mu_{0j})^T = [\sum_{i=1}^{t}\sum_{j=1}^{s} ip_{ij} / \omega_0(t,s), \sum_{i=1}^{t}\sum_{j=1}^{s} jp_{ij} / \omega_0(t,s)]^T =$$
$$[\mu_i(t,s)/\omega_0(t,s), \mu_{j(t,s)}/\omega_{0(t,s)}]^T \tag{6}$$

$$\mu_1 = (\mu_{1i}, \mu_{1j})^T = [\sum_{i=s+1}^{t}\sum_{j=t+1}^{s} ip_{ij} / \omega_1(t,s), \sum_{i=s+1}^{t}\sum_{j=t+1}^{s} jp_{ij} / \omega_1(t,s)]^T \tag{7}$$

$$\mu_1 = (\mu T_i, \mu T_j)^T = (\sum_{i=1}^{t}\sum_{j=1}^{s} ip_{ij}, \sum_{i=1}^{t}\sum_{j=1}^{s} jp_{ij}]^T \approx \omega_0(t,s)\mu_0 + \omega_1(\mathrm{t,s})\mu_1 \tag{8}$$

Use the trace of inter-class dispersion matrix $t_r S_B(t,s)$ as dispersion measures:

$$t_r S_B(t,s) = \omega_0(t,s)[(\mu_{0i} - \mu_{Ti})^2 + (\mu_{0j} - \mu_{Tj})^2] + \omega_1(t,s)[(\mu_{1i} - \mu_{Ti})^2 + (\mu_{1j} - \mu_{Tj})^2] =$$

$$\frac{[\mu_{Ti}\omega_0(t,s) - \mu_i(t,s)]^2 + [\mu_{Tj}\omega_0(t,s) - \mu_j(t,s)]^2}{\omega_0(t,s)[1 - \omega_0(t,s)]} \tag{9}$$

Obtain the best threshold when the inter-class dispersion matrix trace reaches the maximum value, namely $(T,S) = \arg\max_{1\le s,t\le L}\{t_r S_B(t,s)\}$.

In order to improve the anti-noise performance, this paper utilizes the dividing discriminant method proposed in document [9]:

$$b(m,n) = \begin{cases} 1 & 0 \le f(m,n) + g(m,n) \le T + S \\ 0 & f(m,n) + g(m,n) > T + S \end{cases} \tag{10}$$

2.2.3.Grey Level Transformation

Grey level transformation is to transform the gray level function $f(x,y)$ of the original picture using a transform function T into a new image function $g(x,y)$, namely $g(x,y)=T(f(x,y))$. People often use segmentation linear transformation method to highlight the target or gray range they are interested in and restrain the grey range they are not. Segmentation linear transformation is to divide the graphical gray interval into two sections and even multi-sections to conduct linear transformation respectively[10]. The linear transformation of this paper is shown as Ffigure 1, and its mathematical expression is:

$$g(x,y)=\begin{cases} f(x,y)\times\dfrac{H_1}{T_1},\ f(x,y)<\mathrm{T}_1 \\ H_1+(f(x,y)-T_1)\times\dfrac{H_2-H_1}{T_2-T_1},T_1\le f(x,y)\le T_2\ (1) \\ H_2+(f(x,y)-T_2)\times\dfrac{255-H_2}{255-T_2},\ f(x,y)>T_2 \end{cases} \qquad (11)$$

Among which (T_1,H_1) and (T_2,H_2) are the coordinates of two turning points in Figure l. It is easy to know from formula (11) and Figure.l that, by adjusting the location of the inflection point of the polyline and the slope of the segmentation line[11], which means the value of controlling parameter T_1,T_2,H_1,H_2, extension and compression of any gray level range can be realized.

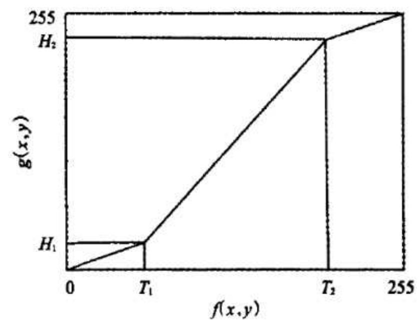


Figure 3. Three-section linear transformation

This paper applies AFSA (artificial fish swarm algorithm) in two-dimensional Otsu method, which identifies the dual threshold and of an image T_1 and T_2 automatically, and then identifies H_1 and H_2 using AFSA with certain evaluation standard of image equality, and eventually identifies the coordinates of segment point[12].

2.3 *Recursive Otsu segmentation preset correction*

This paper uses recursion Otsu segmentation preset correction algorithm to realize self-adaptive obtain of optimum control parameters and thus reaches the optimum enhancing result. To divide image by threshold method, the key is to select threshold value r. If the selected threshold value is too high, it will divide the target point into background point by mistake, losing useful messages of the image; if the threshold value is too low, the background point will be divided into target point, bringing errors in the follow-up work of image segmentation. Thus, only by choosing the right threshold value better can the best result of image segmentation be reached.

Otsu method requires that the distance between target mean value and background mean value should be as long as possible in the two divided parts of the image by the threshold value we calculated[13].Meanwhile, the algorithm requires that the pixel cohesiveness of the two classes should be as good as possible, that is to say, the distance between the pixel and the centre of the two classes should be as short as possible. Specific steps are described as follows:
(1) Read the image needed to be enhanced.
(2) Construct the two-dimensional histogram of the original image and the mean value image.
(3) Selecting the trace of inter-class dispersion matrix in the two-dimensional histogram as the fitness function of AFSA.
(4) Separate the background region and the target region by using the threshold value r which is searched from

the AFSA.
(5) Conduct another threshold value segmentation on the background region and the target region (repeat (2)-(4)), and record the threshold value as T_1 and T_2.
(6) On the basis of confirming the T_1 and T_2, continue to search the parameter H_1 and H_2 by AFSA. Based on the measuring functions of image contrast ratio quality evaluation that comes from literature [14], design the fitness function of AFSA:

$$Fitness(i) = \frac{1}{n}\sum_{x=1}^{M}\sum_{y=1}^{N} f^2(x,y) - [\frac{1}{n}\sum_{x=1}^{M}\sum_{y=1}^{N} f(x,y)]^2 \qquad (12)$$

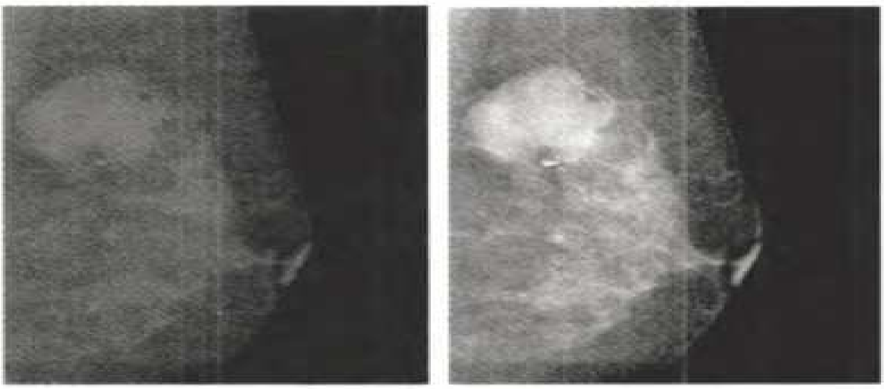
Among them, f represents a certain kind of artificial fish, M and N respectively represent the width and height of the image, $n = M \times N$, and the bigger the value of $Fitness(i)$ is, the more evenly the image grey scale will be distributed and the better the quality of the image will be.

RESULTS AND DISCUSSION

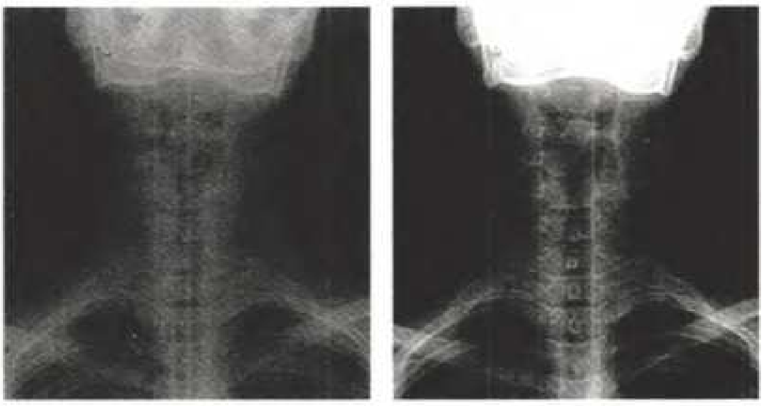
Simulation experiments are realized by programming with MATLAB 7.0 software. To verify the versatility and self-adaptivity of the enhancement approach in this paper, the experiment will choose 3 sets of DR images that are: breast DR image, spine DR image, and chest DR image. The images after using the enhancement approach in this paper are shown in Figure 4.

3.1. *Human visual subjective evaluation*

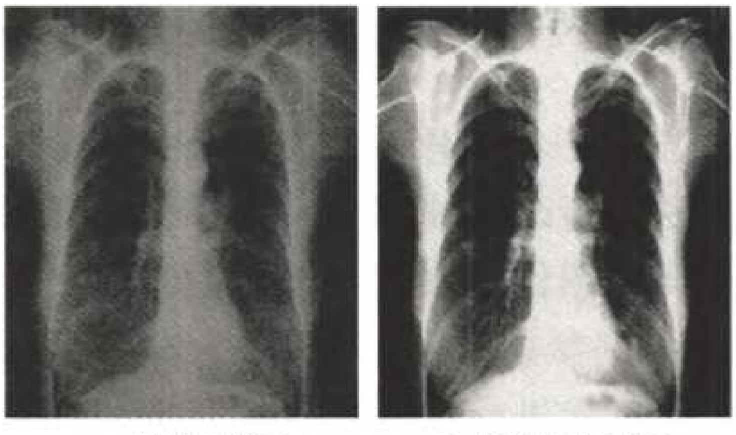
As shown in Figure 4, the detailed information of the patients' original image is vague and of low contrast. The enhancing method in this paper not only eliminates the noise and enhances the contrast, but also makes the detailed information clearer. Simulation experiments make contrasts in the following several aspects.



(a) Original image 1 **(b) Enhanced image 1**



(c) Original image 2 **(d) Enhanced image 2**



(e) Original image 3 (f) Enhanced image 3

Figure 4. Enhancement contrast of DR image

3. 2.*The Fuzzy Index Eevaluation*

The sharpness of the image is measured by the index of fuzziness, which the formula is:

$$F_B = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\min[\mathrm{P(i, j)},1] - p(i, j)] \tag{13}$$

Where , $P(i, j) = \sin[0.5\pi(1 - f(i, j) / f_{\max}]$, $f(i, j)$ is the gray value which located at (i, j) in the image and $f_{\max}$ is the maximum grey value in the image. Image sharpness increases as the index of fuzziness decreases. Table 3 shows the contrast result of the image's index of fuzziness before and after enhancement.

Table 3. Comparison results of the fuzziness index

Parameter	Comparison result					
	Fig. 3a	Fig. 3b	Fig. 3c	Fig. 3d	Fig. 3e	Fig. 3f
the fuzzy index	0.253 8	0.100 5	0.300 7	0.120 8	0.298 1	0.098 9

Table 3 illustrates that the fuzziness index of the enhanced image has been significantly decreased, which proves that the enhanced image has much higher sharpness.

CONCLUSION

A kind of medical DR image enhancement method has been put forward in this paper. First, apply the optimized AFSA into 2-D Otsu algorithm, and automatically determine the dual threshold of the image so as to divide the image into three sections of background, objective and transition zone. Then based on a certain image quality assessment standard, confirm the changes of slopes for each section by using AFSA algorithm to self-adaptively in order to achieve the purpose of image enhancement.

The experiment result demonstrates that the method introduced in this paper can improve the medicine DR image contrast, and the algorithm mentioned can facilitates enhanced image to be subsequently analyzed and processed.

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