Application of artificial fish swarm algorithm in image registration

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Abstract

As one of the fundamental tasks of image processing, image registration is the premise of image fusion and target recognition. This paper has discussed the principle and the detailed description of artificial fish swarm algorithm; analyzed the convergence performance of the algorithm and the effect various parameters of the algorithm play on convergence; applied artificial fish swarm algorithm in image registration; adopted normalized mutual information as the registration similarity principle with artificial fish swarm algorithm as the optimization search strategy and proposed an image registration method based on mutual information and artificial fish swarm algorithm. The experimental result shows that it has higher accuracy and reliability as well as rapid speed and that it can effectively perform image registration to apply artificial fish swarm algorithm in the image registration.

Keywords: artificial fish swarm algorithm (AFSA), image registration, optimization search strategy

1 Introduction

As the basic question in the field of image processing, image registration is the processing to match and superimpose two or more images of the same scene at different time, in different sensors or under different perspectives [1]. Image registration is an important step in such practical applications as image mosaic, target recognition, image fusion, target change detection and time-sequence image analysis and it has been extensively used in the fields like remote sensing data analysis [2], computer vision and medical image processing. After years' research, image registration technique has made many research achievements [3].

Artificial fish swarm algorithm (AFSA) is a new swarm intelligent stochastic global optimization technique and it has introduced the idea of artificial intelligence based on behaviors in solving optimization problems [4]. AFSA simulates the fish behaviors such as school, wander and forage in natural world and makes the swarm reach the optimal selection through collective collaboration of the fish. This algorithm mainly realizes the construction of artificial fish model and the description and implementation of such behaviors as forage, swarm and follow of the artificial fish [5, 6].

This paper has introduced the idea of artificial intelligence based on behaviors in solving optimization problems through the mode of autonomous animals; constructed a framework to solve problems, namely the fish-swarm model; generated a highly-efficient intelligent optimization, namely AFSA applied this algorithm in image registration and got satisfactory results. This paper first introduces the related theories and classification of image registration methods. Then it elaborates the basic principle and behavior description of AFSA as well as the main steps of AFSA in image registration. The final part is the experiment simulation and analysis.

2 The related theories of image registration

The images of the same scene surely have certain rotation, scale at different ratios and different grayscale properties due to the factors such as location, light, temperature, atmospheric refraction, topographic relief and the image displacement. When shooting the image and image registration is to search a transformation and make spatial matching of two or more images so as to eliminate various differences of the images. At present, image registration has been widely applied in image fusion, pattern recognition, data fusion, medical diagnosis and map correction [7].

2.1 BASIC REGISTRATION MODEL

Mathematically image registration can be expressed:

$$I_2(x,y) = g(I_1(f(x,y))), \tag{1}$$

where I_1 and I_2 are the two-dimensional matrixes of two images to be fused. $I_1(x,y)$ and $I_2(x,y)$ are the grayscale

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values of two images at (*x*,*y*); *g* is one-dimensional grayscale transformation and *f* is a two-dimensional coordinate transformation [8].

The process of registration is to search the optimal spatial transformation and grayscale transformation parameters to reach a matching between the images. In practice, we usually care about the coordinate transformation; therefore, the registration relationship can be simplified as Equation (2) without consideration of the transformation of grayscale factors [9].

$$I_2(x,y) = I_1(f_x(x,y), f_y(x,y)) . \tag{2}$$

2.2 CLASSIFICATION OF IMAGE REGISTRATIONMETHODS

So far, numerous researches and experiments have been made on image registration methods at home and abroad and different registration methods select different image elements. These methods are divided into the image registration method based on feature and the image registration method based on pixel.

2.2.1 Image registration method based on feature

This method mainly uses such obvious features of the image as the angular point, the cross point, the straight-line segment, the edge and the outline, according to which to estimate the transformation model between the images. This method greatly reduces the image information, resulting in few computation and high matching efficiency. However, these features should suffer little noise influence, have sufficient quantity and strong anti-jamming capability and it should also be easy to detect, which in fact, are very difficult to meet. The basic idea of registration based on image features is the same, as indicated in Figure 1, where feature extraction and feature matching are the key in registration [10].

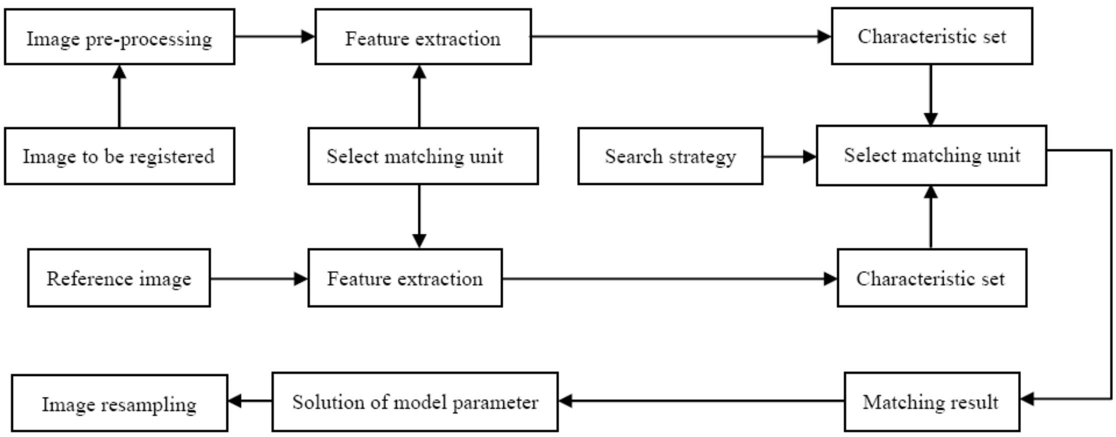


FIGURE 1 The basic steps about the registration method based on image feature

a) Feature Extraction: Generally, feature can be divided into point, line and plane and point feature includes: the thread cross point of line segment, the local breakpoint, the barycentre of closed region, the high point of curvature in the curve and the commonly-used angular point or the interest point in the custom zone. Align these identification points and reach the image registration.

b) Feature Matching: The reference and floating images are expressed with the obvious feature set selected from the step of feature extraction. Feature matching is to search the corresponding relationship between the feature sets with certain registration algorithm and the common reference and floating images usually judge whether to reach the purpose of registration by adopting the minimum distance and threshold restriction between the images. The features participating in feature matching usually use the property to keep unchanged in spatial transformation; otherwise, it is difficult to build the corresponding relationship between features.

2.2.2 Image Registration Method Based on Pixel

The registration method based on pixels has been studied the earliest and the most. It directly uses the grayscale information of the image without performing complicated pre-processing so as to avoid errors caused by feature extraction. It is easy to realize with high robustness and it can achieve sub pixel accuracy [11].

a) Correlation Method: correlation method is relatively suitable for mono-modal image registration and it is aimed for the small changes between the images. Mainly used in shift and rotation transformation of rigid body between the images, it can use variance, correlation coefficient and image interpolation to measure the effects of image registration so as to reach its maximum correlation; thus, realizing the image registration. The spatial transformation parameters at this time are those when reaching the registration. Correlation method is especially suitable for the tiny changes caused by certain illnesses found from a series of images.

b) Movement and Principal Axes Method: takin into account the principle of weight distribution in physical mechanics, this method searches the centroid and principal axis of the pixel points in the image and achieves the purpose of registration through spatial transformation. In general, it requires the images to be registered are complete and any missing data will cause mis-registration. This method is automatic and has high calculation efficiency; however, its registration accuracy is not high. Therefore, it can be only used in the coarse registration and primary registration of image.

c) Fourier Method: Fourier method is an effective registration method based on frequency domain with rapid registration speed. Phase correlation is to perform registration between the offsetting images by using the shift theory based on Fourier transformation. In essence, to conduct registration with Fourier method is to use certain properties such as shift, rotation and scale in Fourier transformation, which can be seen in the frequency domain of Fourier.

d) Maximum Mutual Information Method: currently, maximum mutual information registration method has drawn the attention of numerous scholars. It performs image registration on the overall gray information without imaging devices, image pre-processing, image segmentation and imaging mode and it has high registration accuracy. It is suitable for not only mono-modal image registration, but also multi-modal image registration. Besides, because the image registration based on mutual information also considers the edge entropy between the images, it balances a peak phenomenon in the overlapping of the image histogram background. Additionally, maximum mutual information registration method can also achieve the registration level of sub-pixel accuracy.

3 Artificial fish swarm algorithm (AFSA)

3.1 DESCRIPTION OF BASIC ARTIFICIAL FISH SWARM ALGORITHM

Assume that there are *N* artificial fish in a swarm and that the vector *X* is the individual state of the artificial fish, namely $X=(x_1,x_2,\cdots,x_n)$ where $x_i(i=1,\cdots,n)$ is the variable to be optimized of AFSA. *Y*=*f*(*X*) is the food concentration of the artificial fish at the current position and *Y* is the objective function of practical problems. $d_{i,j}=\|X_i-X_j\|$ is the distance between the individual artificial fish *i* and the individual artificial fish *j*. The other important parameters such as the visual field of the artificial fish, the maximum moving step, the congestion factor and the maximum number of tries in every forage are expressed as *Visual*, *Step*, *δ* and *Trynumber*. The congestion factor is to limit the fish swarm size of the artificial fish swarm so as to make more artificial fish individuals gather in the region with better state rather than the neighborhood with suboptimal state [12].

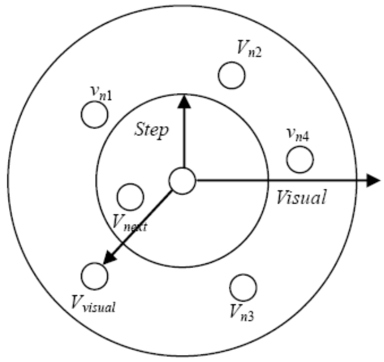


FIGURE 2 The visual and step of artificial fish

3.2 BEHAVIOR DESCRIPTION

The behaviors of artificial fish include: forage, swarm and follow.

3.2.1 Forage

Assume that the current state of artificial fish is. If this artificial fish per-performs forage, it will firstly select a state X_j randomly within its visual field. In seeking minimum, if $Y_i \ge Y_j$, then forage will be completed if moving one step towards this direction; if $Y_i \le Y_j$, re-select a state X_j randomly and judge whether it meets the condition to move forward. After repeating this for a *Trynumber* times, if it does not meet the forwarding condition, randomly move one step.

Express it mathematically:

$$\begin{cases} x_{inextk} = x_{ik} + Random(Step)\dfrac{x_{jk}-x_{ik}}{\|X_j - X_i\|} & Y_j > Y_i \\ x_{inextk} = x_{ik} + Random(Step) & Y_j \le Y_i \end{cases}, \quad (3)$$

where *k=1,2,…,n*.

x_{ik} – the *k*-th element of the current state vector X_i of artificial fish.

x_{jk} – the *k*-th element of the state vector X_j after random movement.

x_{inextk} – the *k*-th element of the next state vector X_{inext} of artificial fish.

Y_i – the objective function value of the current state.

Y_j – the objective function value after random movement.

Random(step) – a random number within [0,step].

The symbols in the following formulas are the same as they are here [13].

3.2.2 Swarm

Assume that the current state of the artificial fish is X_i and the number of companions in its visual domain is *n*.

If $n_f = 0$, it means that there is no companion in its visual domain and then implement forage.

If $n_f \geq 0$, it indicates that there are companions in its visual domain and then search the central position X_c of its companions according to:

$$X_{ck} = \frac{\left(\sum_{j=1}^{n_f} x_{jk}\right)}{n_f}, \tag{4}$$

X_c – the state vector of the central position;

x_{ck} – the *k*-th element of the state vector X_c of the central position;

x_{jk} – the *k*-th element of the $j(j=1,2,\cdots,n_f)$ the companion X_i;

Y_c – the objective function value of the central position.

Calculate the food concentration Y_c of this central position. Satisfying the following condition:

$$Y_c n_f / Y_i > \delta, \tag{5}$$

it indicates that the central position is not very congested and it is quite safe and then move towards this central position according to Equation (6); otherwise, implement forage [14].

$$x_{inextk} = x_{ik} + Random(Step)\frac{x_{ck} - x_{ik}}{\|X_c - X_i\|}. \tag{6}$$

3.2.3 Follow

Assume that the current state of the artificial fish is X_i and the number of companions in its visual domain as *n*.

If $n_f = 0$, it means that there is no companion in its visual domain and then implement forage.

If $n_f \geq 1$, it indicates that there are companions in its visual domain and then search the companion with the minimum corresponding function value $X_{\max}$ in its visual domain.

If it satisfies:

$$Y_{\min} n_f / Y_i > \delta, \tag{7}$$

it shows that the companion has small fitness value and that it is not very congested around here and then implement Equation (8); otherwise, implement forage.

$$x_{inextk} = x_{ik} + Random(Step)\frac{x_{\max k} - x_{ik}}{\|X_{\max} - X_i\|}, \tag{8}$$

$x_{\max k}$ – the *k*-th element of the state vector $X_{\max}$ [15].

3.2.4 Bulletin board

The bulletin board records the state of the optimal artificial fish. At the optimization iteration, every artificial fish individual checks and compares its own state with the current state on the bulletin board. If the state on the bulletin board is inferior to its own state, then replace the state on the board with its own state; in this way, the historical optimal state can always be recorded on the bulletin board and the final recorded optimal value is the optimal solution.

3.3 ALGORITHM FLOWCHART

Based on the behavior description of the above-mentioned artificial fish, every artificial fish searches its environmental conditions and its companions to choose an appropriate behavior to move at the fastest towards to optimal direction. Finally, the artificial fish gathers around several local extremum.

The algorithm implementation flow includes:

1) Initialization: define the population size as *N*; generate *N* individuals randomly within the definition domain of the variable and assign the maximum generation Gen_{max}, the generation *Gen*, the visual field of the artificial fish Visual, the moving step of the artificial fish Step, the congestion facto δ and the trials *Trynumber*.

2) Assign the value on the bulletin board: calculate and compare the corresponding fitness value to every individual fish; choose the optimal state of the artificial fish and assign its value to the bulletin board.

3) Choose implementation behavior: every artificial fish simulates swarm and follow; implement the optimal behavior by comparing the fitness value; the default behavior is forage and *Gen*=*Gen* +l.

4) Update the bulletin board: compare the fitness value of every artificial fish and the value on the bulletin board, replace it if it is better than the value on the bulletin board; otherwise, keep the value on the bulletin board unchanged.

5) Judge end condition: when $Gen > Gen_{max}$, end the algorithm and output the optimal value; otherwise, turn to Step (3).

4 Image registration based on artificial fish swarm algorithm

The image registration is mainly to realize registration on image with affine transformation. The image affine transformation usually includes horizontal shift, vertical shift, rotation and scale and its solution parameter space is four-dimensional. Apply fish swarm algorithm in the image registration with similarity measure function as food concentration; perform iteration optimization on the fish individuals with fish swarm algorithm as the search strategy and find out the optimal registration transformation parameter of the image. This method searches with normalized mutual information (*NMI*) as similarity measure criterion, namely FC of the algorithm and AFSA as the search strategy and its specific steps are as follows:

1) Input the size of artificial fish swarm (*N*), the maximum iterations (number), the visual field of artificial fish (Visual) and the congestion factor (δ).

2) Set the initial iteration number=0， generate *N* artificial fish individuals in the feasible domain of control variable and form initial fish swarm.

3) Calculate the food concentration FC of the current position of every fish individual in the initial fish swarm. Compare their FCs; record the maximum FC in the bulletin board and assign this fish to the bulletin board.

4) Every artificial fish simulates and implements follow and swarm respectively. The artificial fish with bigger FC implements the behavior in practice and the default behavior is forage.

5) After every artificial fish acts once, compare its FC with that on the bulletin board and if it is better than that on the bulletin board, replace it.

6) End condition judgment: judge whether num has reached the set-top maximum iterations number. If it is, output the optimal registration parameter set; otherwise, make number+=1 and turn to Step (4).

The specific flowchart of the algorithm is indicated in Figure 3.

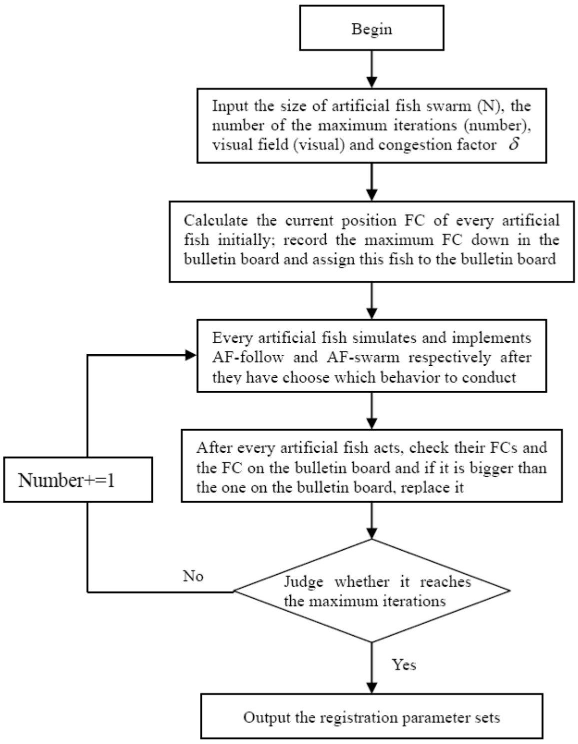


FIGURE 3 Image registration based on AFSA

5 Experiment simulation and analysis

5.1 OBJECTIVE EVALUATION PARAMETERS

There are four parameters to be used in objective evaluation.

5.1.1 Correlation coefficient

The registration effect is evaluated by measuring the correlation coefficient of two images, as follows:

$$R_{cc}=\frac{\frac{1}{M-1}\sum_{i=1}^{M-1}(r_i-\bar{r})(c_i-\bar{c})}{\sqrt{\frac{1}{M-1}\sum_{i=1}^{M-1}(r_i-\bar{r})^2}\sqrt{\frac{1}{M-1}\sum_{i=1}^{M-1}(c_i-\bar{c})^2}}, \quad (9)$$

where $\bar{r},\bar{c}$ are the averages of pixels of two images and M is the number of pixel points The bigger correlation coefficient is, the better registration effect is. The registration effect is the best when R_{cc}=1 and it is worst when R_{cc} =0.

5.2.2 Minimum mean square error MSE

The registration effect is evaluation by measuring the minimum mean square error, which can be found with Equation (10). The smaller *MSE* is, the better registration effect is:

$$MSE=\sqrt{\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[R(r,c)-O(r,c)\right]^2}, \quad (10)$$

where $R(r,c)$ and $O(r,c)$ are the registered and source images.

5.3.3 Signal to noise ratio SNR

Signal to noise ratio is usually an evaluation parameter for image quality and the image effect can be evaluation by calculating the signal to noise ratio with the definition of the minimum mean square errors of the source and the registered images, as follows:

$$SNR=\sqrt{\frac{\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[R(r,c)\right]^2}{\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[R(r,c)-O(r,c)\right]^2}}, \quad (11)$$

where $R(r,c)$ and $O(r,c)$ are the registered and source image respectively.

5.3.4 Normalized mutual information NMI

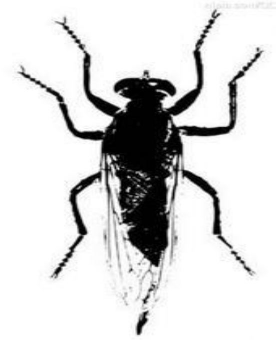
Normalized mutual information can also be a parameter function to evaluation the registration effect and the calculation method of normalized mutual information is:

$$NMI(A,B)=\frac{H(A)+H(B)}{H(A,B)}, \quad (12)$$

where $H(A)$ and $H(B)$ are the information entropies of two images and $H(A,B)$ is the joint information entropy of two images.

5.2 EXPERIMENTAL ANALYSIS

Compare the registration result by using AFSA with those by using Powell algorithm and particle swarm optimization and Figure 4 are the experimental and registered images. This experiment adopt MRI as the experimental images.



a) Target image

b) Image to be registered

c) PSO

d) Powell algorithm

e) AFSA

FIGURE 4 Images of matching experiment and matching results

Table 1 are the transformation parameters of image registration by using artificial fish swarm algorithm, the traditional Powell algorithm and particle swarm optimization. In this table, *x* and *y* are the movement distances of pixel in horizontal direction and vertical direction; *r* is the rotation angle of the image and *s* is the scaling.

TABLE 1 Transformation parameters of image registration

	PowellAlgorithm	**PSO**	**AFSA**
x	-2.4221	-2.7627	-2.8928
y	0.9823	1.0193	1.6127
r(°)	36.7163	38.4118	40.3671
s	1	1	1

Table 2 indicate the evaluation parameters of the three algorithms: the algorithm with feature point only, the algorithm with grayscale information only and the algorithm of this paper and these parameters include: R_{cc} (correlation coefficient), *MSE* (mean square error), *SNR* (signal to noise ratio), *NMI* (normalized mutual information) and T (registration time).

TABLE 2 Evaluation parameters of image registration

	Powell Algorithm	**PSO**	**AFSA**
R_{cc}	0.8441	0.8461	0.8507
MSE	14128.827	14113.278	14100.231
SNR	2.0374	2.0936	2.1163
NMI	0.53361	0.60748	0.66846
T(s)	62.263	50.362	45.738

It can be seen easily from the above experimental result that the algorithm proposed in this paper has the maximum R_{cc} and *NMI* as well as the minimum *MSE*, suggesting that this algorithm has better accuracy. The maximum *SNR* indicates that this algorithm has better robustness and the minimum matching time demonstrates its effectiveness.

6 Conclusion

This paper takes normalized mutual information as the similarity principle of image registration; applies artificial fish swarm algorithm in image registration to conduct optimization processing algorithm and gives specific process description and flow chart of the algorithm. It can be seen through experimental result and evaluation parameters that the algorithm of this paper has better accuracy, efficiency and robustness.

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