

## Study on Mutual Information Medical Image Registration Based on Ant Algorithm

Luo Hong-yan

*Department of Electronics and Communication Engineering, Suzhou Institute  
Of Industrial Technology  
luohongyan1978@163.com*

### **Abstract**

*The mutual information has been combined with medical image registration widely, in order to improve the registration precision and speed of medical image, the application of ant algorithm on it is studied in depth. Firstly, the basic conception of mutual information is analyzed; secondly, the basic procedure of medical image registration is discussed; thirdly, the basic idea of ant algorithm is analyzed, and then the mutual information medical image registration based on FA is designed. Finally, simulation is carried out, and results show that this method can get better medical image registration effect.*

**Key Words:** *Mutual Information; Medical Image Registration; Ant Algorithm*

### **1. Introduction**

In recent years, the mutual information conception is introduced into the medical image registration, because this method cannot divide the image and process, and it has high precision and wide application range, then the registration precision of multimode image can get the sub pixel level, therefore it has been applied in the medical image registration widely. The mutual information application has been put into clinical application by years of development. In most cases, the mutual information can obtain better registration effect, however this method has some disadvantages, such as, the correctness, reliability, speed and other aspects should be improved further, that's because the mutual information function value is not convex function with good distribution, and the some local extremes exist. The medical image registration concludes two methods, which are method based on grey degree and method based on feature. The registration method based on grey can carry out registration through using the grey degree data of image directly. And the error brought because of division, it has the advantages of high precision, strong reliability and no pre-procession. For the registration method based on grey degree, the maximum mutual information has been applied in further. The mutual information is evaluated based on the generalized distance between the combined probability distribution and complete independent probability distribution of two images, which is used as measure of medical image registration. When two images based on common anatomic structures get the best registration, the corresponding mutual information of pixels is biggest. Because this method need not make any hypothesis for the different relations among figure grey degree under different imaging mode, and the figure needs not be divided, then it is used widely. This method is applied widely. But the interpolating procession make objective function based on mutual information has the local extreme, and then the traditional local optimization can converge at the local extreme and obtain the mistake registration parameter [1-2].

Ant algorithm is a heuristic algorithm that can solve complex combinatorial optimization problem, it has strong advantage, and it can obtain global optimization solution, the ant algorithm has many advantages, such as distributives, positive feedback

and robustness, it can be combined with many kinds of heuristic algorithms. Although the traditional ant algorithm has strong global optimization ability, however it need long searching time, and often happens stagnation behavior, therefore the traditional ant algorithm should be improved. The improved ant algorithm is used in the medical image registration can improve the speed of image registration, and the premature phenomenon can be avoided [3].

## 2. Basic Conception of Mutual Information

### (1) One order mutual information

The entropy can be used to measure the measure of information quantity included in the information source. The one order entropy of image is obtained based on the grey probability distribution of every pixel point. The corresponding expression is listed as follows [4]:

$$H(A) = - \sum_x P_A(i) \log_{g_A} P(i) \quad (1)$$

Combined entropy is the statistical quantity of inspect the relevance of two information sources  $A$  and  $B$ . The probability distributions of information sources  $A$  and  $B$  are defined by  $P_A(i)$  and  $P_B(j)$ , and the combined probability distribution of two information is defined by  $P_{AB}(i, j)$ .  $P_{AB}(i, j)$  denotes probability when  $A$  send  $i$  th information and  $B$  send  $j$  th information, and the combined entropy is expressed as follows:

$$H(A) = - \sum_{i,j} P_{AB}(i, j) \log_{g_{AB}} P(i, j) \quad (2)$$

The one order entropy is used to denote the one order mutual information, which is expressed as follows:

$$H(A) = - \sum_{i,j} P_{AB}(i, j) \log_{g_{AB}} P(i, j) \quad (3)$$

### (2) Two order mutual information

For a image  $A$ , the calculating expression of two order entropy is expressed as follows:

$$H_2(A) = - \sum_j - \sum_j P_A(i, j) \log_{g_A} P(i, j) \quad (4)$$

where  $P_A(i, j)$  denotes that combined probability distribution between grey degree  $i$  of a pixel point in  $A$  and the grey degree  $j$  of a relating pixel point. The combined probability distribution  $P_A(i, j)$  can be obtained through two order histogram of relating pixels.

$$H_2(A) = - \sum_j - \sum_j \sum_k - \sum_l P_{A,B}(i, j, k, l) \log_{g_{A,B}} P(i, j, k, l) \quad (5)$$

where  $P_{A,B}(i, j, k, l)$  denotes the combined probability distribution.

The two order mutual information based on two order entropy and combined two order entropy, which is expressed as follows [5]:

$$I_2(A, B) = H_2(A) + H_2(B) - H_2(A, B) \quad (6)$$

Normalization mutual information is defined by the following expression:

$$I_2(A, B) = \frac{H_2(A) + H_2(B)}{H_2(A, B)} \quad (7)$$

## 2. Basic Procedure of Medical Image Registration

The registration method is the combination of four aspects, which are feature space, searching space, searching algorithm and similar measure. The feature space can extract the feature information to be registered, searching space is the mapping mode and transformation range. The searching algorithm is the specific method of next transformation and the optimal transformation parameter obtained. The similar measure is a standard that can measure the similarity of images. The basic steps of general registration are listed as follows [6]:

(1) Extract the feature of divided image: the registration image generally concludes a certain feature quantity to reflect the similarity, therefore the proper feature quantity is chosen to confirm the geometry transformation of image, for example, boundary of registration image, anatomical feature point of image, outer signals of image, according to the specific situation, the proper feature quantity can improve the correctness of geometry transformation.

(2) Confirm the geometry transformation according the characteristics: the geometry transformation is transform the coordination point in a image to coordination image of another image, after the feature is extracted, the registration problem is transformed to the solution of transformation problem of two images. According to different deformation form, the transformation can be divided into linear transformation and nonlinear transformation. The linear transformation concludes rigid body transformation, affine transformation and projective transformation.

(3) Search optimization: after space transformation is carried out for floating image, a kind of similar measure function is defined through measuring the similar degree between the floating image and reference image. Similar measure function can achieve the optimization through changing the transformation parameters continuously. During the procession of optimization, the general similar measures conclude, root-mean-square distance, normalized correlation, gradient correlation, model gray, normalized mutual information. The common optimal algorithm concludes steepest descend method, simplex method, simulated annealing algorithm and genetic algorithm.

(4) Transformation: the transformation parameter is confirmed according to feature quantity, which is applied in the registration image, and the registration of every point in the image is achieved.

## 3. Basic Idea of Ant Algorithm

According to traveling salesman the basic theory of ant algorithm can be described, the ant algorithm is described as follows:

When  $t = 0$ , the original operation is applied, every ant is put in different city, and the pheromone concentration in different route  $edge(i, j)$  at this moment is set. The starting point of city for different ant is assigned to the first component in tabu table. Then the maximum probability of different ant from city  $i$  to city  $j$  is calculated, the corresponding calculating expression is listed as follows [7]:

$$p_{ij}^k(t) = \begin{cases} \frac{[\tau_{ij}(t)]^\alpha \cdot [\eta_{ij}]^\beta}{\sum_{k \in allowed_k} [\tau_{ij}(t)]^\alpha \cdot [\eta_{ij}]^\beta}, & \text{when } j \in allowed_k \\ 0, & \text{other} \end{cases} \quad (8)$$

where,  $allowed_k = \{n - tabu_k\}$ ,  $\alpha$  and  $\beta$  denote pheromone concentration and important degree of visibility to probability  $p_{ij}^k(t)$  respectively.

Through  $n$  times iteration, all ants can complete a whole journal, therefore tabu table corresponding to all ants is filled, and the  $L_k$  value of  $k$  th ant is calculated (the whole distance corresponding to  $k$  th ant complete every journal, then  $\Delta \tau_{ij}^k$  is amended, and the revised expression is listed as follows:

When  $k$  th ant pass the route  $edge(i, j)$  in  $[t, t + n]$  [8]:

$$\Delta \tau_{ij}^k = \frac{Q}{L_k} \quad (9)$$

Otherwise,

$$\Delta \tau_{ij}^k = 0 \quad (10)$$

where,  $\Delta \tau_{ij}^k$  denotes pheromone number per unit length released by  $k$  th ant on the route  $edge(i, j)$  in time interval  $[t, t + n]$ ,  $Q$  denotes constant.

Then the shortest route found out by all ants is saved, at the same time the tabu table of different ant is emptied.

The operation mentioned above is carried out continually, when the algorithm satisfies the convergence condition, the algorithm is over, at the moment, the ant group can find out a optimal traveling route satisfying the requirement.

#### 4. Mutual Information Medical Image Registration Based On FA

The normalization mutual information is used as similar measure in this algorithm; firstly the location of ant denotes the registration parameter. When 2D-2D rigid registration is carried out, the geometry transform parameters conclude horizontal displacement, vertical displacement and rotating quantity of the image around center point. When 2D-3D or 3D-3D rigid registration is carried out, the geometry transform parameters conclude displacement along  $X$ ,  $Y$ ,  $Z$  three axis and rotating measure around  $X$ ,  $Y$ ,  $Z$  three axis. Then according to the location of every ant the mutual information function value is calculated, which is used as pheromone concentration of the ant, the pheromone concentration can describe the good and bad of location of the ant and moving direction, through constant iteration the maximum value of mutual information can be found out, the maximum value of mutual information function is the optimal parameter of medical image registration.

The procedure of mutual information medical image registration based on FA is listed as follows:

- Step 1 two medical images to be registered are input, that are reference image and floating image.
- Step 2 the pixel data of reference and floating images are obtained.
- Step 3 the ant algorithm is used to carry out optimization for registration procession, set the scale of ant group as  $m$ , according to different ant  $k$  a

vector  $Path_k$  concluding 15 components is defined, the vertical coordination of 15 nodes that the ant need to pass are assigned to different component in vector  $Path_k$ , it can describe the route of  $k$  th ant.

Step 4 set time counter  $t = 0$ , the cycling times  $N = 0$ , when the maximum cycling times  $N_{max}$  and  $t = 0$ , pheromone concentration  $c$  in different node is chosen, define  $\Delta \tau(x_i, y_{i,j}) = 0$ , and all ants locates on the stating point  $O$ .

Step 5 define  $i = 1$ .

Step 6 Calculate the transition probability of ant to different node in line segment  $L_i$ .the roulette wheel method is used to choose a node in the line segment  $L_i$  for different ant, at the same time  $k$  th ant is moved to this node, and the veridical coordination of this node is saved on the location of  $Path_k$ .

Step 7 let  $i = i + 1$ , if  $i \leq 15$ , return to step 6; if  $i > 15$ , return to step 8.

Step 8 According to  $Path_k$ , the space transformation is carried out for floating figure.

Step 9 The normalization mutual information function value is calculated for the reference image and floating image after transformation, and the normalization mutual information function value is used as the pheromone concentration of ant.

Step 10 sorting is carried out for  $n$  ants, and the maximum value of mutual information is considered as the current global optimization solution.

Step 11 the pheromone concentration comparison is carried out for every ant  $i$  and other ants in the group, when the pheromone concentration of ant  $i$  is less, the location of ant should be update, the ant should move to the location that has higher pheromone concentration, through multiple comparisons mentioned above, the location update of the ant can be completed.

Step 12 set  $i \leftarrow i + 1$ ,  $N \leftarrow N + 1$ , the pheromone concentration of different node is calculated, and all components of  $Path_k$  fall to zero.

Step 13 Check and search the boundary of searching space.

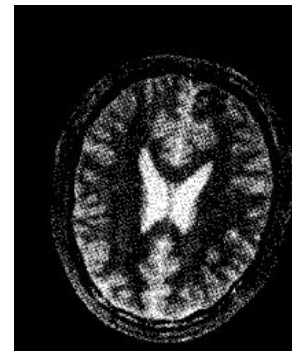
Step 14 When  $N > N_{max}$ , the cycling operation is over, and the optimal registration parameter is output.

## 5. Experimental Analysis

In order to verify the correctness and reliability of the medical image based on ant algorithm, an experiment is carried out. A MR image is chosen as the floating figure, which is shown in figure 1. Through translation and rotation the reference image can be obtained, which is shown in figure 2.



**Figure 1: Floating Image**



**Figure 2: Reference Image**

During the procession of translation, the normalization mutual information value can generate mange local extremes, while for the rotation there is good robustness. The registration based on maximum mutual information is carried out for the floating and reference image, the interpolating method applies PV method, the objective function optimization applies ant algorithm and traditional algorithm, then the transformation parameters are found out, and the results can be analyzed.

Ant algorithm has the following parameters: the scale of ant group  $m$  is set as 8, the maximum iteration times  $N_{max}$  is set as 110,  $\alpha = 0.5$  and  $\beta = 1.5$ .

The simulation results are shown in table 1.

**Table 1: Simulation Results of Medical Image Registration**

Algorithm		Traditional algorithm	Ant algorithm
Convergence iteration steps		57	28
Normalized mutual information		1.2832	1.3561
Registrati on results	Displacement in x direction/mm	11.4395	11.6792
	Displacement in y direction/mm	-15.4488	-15.6830
	Direction angle/ $^{\circ}$	11.4736	10.8862
Error	Error of displacement in x direction/mm	0.4328	0.2105
	Error of displacement in y direction/mm	0.4206	0.1946
	Error of direction angle/ $^{\circ}$	0.1284	0.0058

As seen from table 1, the registration precision based on ant algorithm is higher than that based on traditional algorithm, the ant algorithm has strong global searching ability, it has strong ability in jumping out of local extreme on searching global optimization solution, and the convergence of ant algorithm improved relative to the traditional algorithm.

## 6. Conclusions

The mutual information registration has the advantages of high precision, strong robustness and no pre procession. But the mutual information function exists many extremes, which can make optimization procession enter the local optimization, and can not obtain the global optimization. The ant algorithm can obtain global optimization solution, and jump out of the local extremes, simulation results show that the ant algorithm can improve the registration precision of medical image, and improve the searching procession.

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## Author

**Luo Hong-yan**, she is a lecturer in Zhejiang Financial College. His research direction is Electronics and Communications.

