Research of image registration algorithm based on template matching

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Abstract—*In order to provide support for image registration, the application of template matching in image registration is studied. This paper sums up four types, introduces the principle of each algorithm, and compares their advantages and disadvantages through simulation experiments: Based on the gray information of the algorithm is simple and real-time, but for complex image and low gray contrast images, cross matching results; mathematical transform based on the complex, large amount of calculation; mutual information does not require preprocessing, registration effect is good, is the research hotspot at present, but ignores the spatial relationship between pixels.*

Keywords—Image registration, Image matching, Template matching.

I. INTRODUCTION

Image matching is one of the traditional research directions in image processing. In practical application, It is often required by different sensors at different time, register the images of the same scene in the space position under different imaging conditions, or find the corresponding target in another picture according to the known template. Therefore, image matching [1-2] is the basis of image processing techniques such as image rectification and image fusion. In recent years, image registration [3-5] research has sprung up, especially in medical image [6-9] research. From the theoretical and conceptual point of view, it is the development of image matching technology, and some of the methods and ideas in image matching still play a special role. From this point of view, this paper sorts out the related research of image registration from the perspective of template matching, and analyzes their respective characteristics in combination with simulation.

II. METHODOLOGY

2.1 The method based on image gray information

2.1.1. MAD algorithm and its derivative algorithm

LeeSe proposed the Mean absolute difference algorithm in 1971, and its mathematical model is:

$$D(i,j)=\frac{1}{M\times N}\sum_{s=1}^{M}\sum_{t=1}^{N}\left|S(i+s-1,j+t-1)-T(s,t)\right| \tag{1}$$

where： $1\le i\le m-M+1$， $1\le j\le n-N+1$

S (x, y) is the detection image, and T (x, y) is the template. The algorithm calculates the average of L1 distance between the subgraph and the template, and the sub-graph with the lowest average absolute difference is the best matching object. In graph S, select the MxN size of the subgraph, at a certain point (i, j) for the upper left corner,. And calculate its similarity with the template and traverse the entire search map. The subgraph which is most similar with the template is the final result of the match, in all the sub-graphs which can be found.

The mean absolute difference algorithm [10-11] is a simple and stable algorithm with high matching degree. Different algorithms are derived along this line of thought. Sum of Absolute Differences algorithm is referred to SAD algorithm, and MAD algorithm is basically similar to the idea. But it is only simplified, which calculates the distance between the subgraph and the template.

$$D(i,j)=\sum_{s=1}^{M}\sum_{t=1}^{N}\left|S(i+s-1,j+t-1)-T(s,t)\right| \tag{2}$$

The Sum of Squared Differences algorithm (SSD), is also known as the error square sum algorithm, which calculates the L2 distance between the subgraph and the template.

$$D(i,j)=\sum_{s=1}^{M}\sum_{t=1}^{N}\left[S(i+s-1,j+t-1)-T(s,t)\right]^2 \tag{3}$$

The Mean Square Difference algorithm(MSD), is known as the mean square error algorithm, which calculates the average of the distance between the subgraph and the template.

$$D(i,j)=\frac{1}{M\times N}\sum_{s=1}^{M}\sum_{t=1}^{N}\left[S(i+s-1,j+t-1)-T(s,t)\right]^2 \tag{4}$$

2.2 NCC algorithm

Normalized Cross Correlation algorithm is mainly through the normalized formula to calculate the local part of the image and the gray value of the template. The following correlation measure to calculate the relationship of match between the two.

$$R(i,j)=\frac{\sum_{s=1}^{M}\sum_{t=1}^{N}\left|S^{i,j}(s,t)-E\left(S^{i,j}\right)\right|\bullet\left|T(s,t)-E(T)\right|}{\sqrt{\sum_{s=1}^{M}\sum_{t=1}^{N}\left[S^{i,j}(s,t)-E\left(S^{i,j}\right)\right]^2\bullet\sum_{s=1}^{M}\sum_{t=1}^{N}\left[T(s,t)-E(T)\right]^2}} \tag{5}$$

Where $E\left(S^{i,j}\right)$ and $E(T)$ denote the gray scale mean of subgraph and template graphs respectively in (*i, j*).

2.3 SSDA algorithm

Sequential Similarity Detection Algorithm is put forward by Barnea and Sliverman in 1972. The algorithm is mainly through the error to determine the pros and cons, to find the best match. The specific process is as follows:

Define the absolute error, which actually describes the pixel value of a certain pixel value minus the pixel mean value of the image, and The absolute value of sub-map minus template map corresponding to the location of the pixel poin:

$$\begin{cases} e(i,j,s,t)=\left|S_{i,j}(s,t)-\overline{S}-T(s,t)+\overline{T}\right| \\ 1\le i\le m-M-1, 1\le j\le n-N-1 \end{cases} \tag{6}$$

Where, the ones with the crossed lines represent the mean of the subgraph and template respectively:

$$\overline{S_{i,j}}=E\left(S_{i,j}\right)=\frac{1}{M\times N}\sum_{s=1}^{M}\sum_{t=1}^{N}S_{i,j}(s,t) \tag{7}$$

$$\overline{T}=E(T)=\frac{1}{M\times N}\sum_{s=1}^{M}\sum_{t=1}^{N}T(s,t) \tag{8}$$

In the template map, randomly selecte non-repetitive pixels, and calculate the absolute error with the current subgraph. With the error accumulation, write down the cumulative number of times H, when the error accumulated value exceeds the threshold. The cumulative times of all subgraphs H is represented by a table R (I, j). SSDA detection is defined as:

$$R(i,j)=\left(H\left|\begin{matrix}\min\\ 1\le H\le M\times N\end{matrix}\left[\sum_{h=1}^{H}e(i,j,s,t)\ge Th\right]\right|\right\} \tag{9}$$

The threshold of the valve is the interruption condition of the program. It is also a measure, which increases slowly by comparing the cumulative growth rate of the error, which is likely to be the matching point.

2.4 PIU algorithm

In 1992, Woods found that in the medical image, the same tissue structure was different in different modes of gray values, thus suggesting an image registration based on the uniform intensity of MR PET. The basic idea of PIU measurement is that the pixel of a certain grayscale value in a mode is the distribution of a different grayscale value in the other mode. The expression of PIU measure is defined as:

$$PIU(R,F)=\sum_r \frac{n_r\sigma_{F_\tau}(r)}{N\mu_{F_\tau}(r)}+\sum_f \frac{n_f\sigma_R(f)}{N\mu_R(f)} \tag{10}$$

Among them, N is the total number of pixels in the template, which is the product of the number of template rows. n_r and n_f respectively represent the number of pixels in the template and the subgraph with the grayscale of r and f, and it should be noted that although the gray values of the two are different, there is a certain corresponding relationship. F_τ represents a subgraph in the search diagram. Where:

$$\begin{cases} \mu_{F_\tau}(r)=\dfrac{1}{n_r}\sum_{\omega_r} F_\tau(X_R) \\ \mu_R(f)=\dfrac{1}{n_f}\sum_{\omega_f} R(X_{F_\tau}) \\ \sigma_{F_\tau}(r)=\dfrac{1}{n_r}\sum_{\omega_r}\left[F_\tau(X_R)-\mu_{F_\tau}(r)\right]^2 \\ \sigma_R(r)=\dfrac{1}{n_f}\sum_{\omega_f}\left[R(X_{F_\tau})-\mu_R(f)\right]^2 \end{cases} \tag{11}$$

$\sum_{\omega_r} F_\tau(X_R)$ indicates that the gray value of r pixels in template R is the sum of pixel gray values in the corresponding position in subgraph F_τ.

III. THE METHOD OF MATHEMATICAL TRANSFORMATION

3.1 Fourier-Mellin invariant

Reddy et al. proposed the Fourier-Mellin invariant based on the translational property of Fourier transform.

Given two images $f_1(x,y)$ and $f_2(x,y)$, the following geometric transformations are met:

$$f_2(x,y)=f_1(\alpha(x\cos\theta_0+y\sin\theta_0)-dx,\alpha(-x\sin\theta_0+y\cos\theta_0)-dy) \tag{12}$$

Where dx and dy are the translations, α 3 represents the scale factor for the two image sizes, and θ_0 is the rotation angle. The Fourier transform can be used to obtain their relationship in the frequency domain:

$$F_2(x,y)=\alpha^{-2}\left|F_1\left[\alpha^{-1}(\mu\cos\theta_0+\nu\sin\theta_0),\alpha^{-1}(\nu\cos\theta_0-\mu\sin\theta_0)\right]\right|\exp\{-j\phi_{f2}(\mu,\nu)\} \tag{13}$$

Where, $\phi_{f2}(\mu,\nu)$ is the spectral phase of image $f_2(x,y)$, and the shift property of Fourier transform can have its power spectrum relation as:

$$|F_2(\mu,\nu)|=\alpha^{-2}\left|F_1\left[\alpha^{-1}(\mu\cos\theta_0+\nu\sin\theta_0),\alpha^{-1}(\nu\cos\theta_0-\mu\sin\theta_0)\right]\right| \tag{14}$$

Let's rewrite this in terms of polar coordinates:

$$\begin{cases} \alpha^{-1}(-\mu\cos\theta_0+\nu\sin\theta_0)=\dfrac{\rho}{\alpha}\cos(\theta-\theta_0) \\ \alpha^{-1}(-\mu\sin\theta_0+\nu\cos\theta_0)=\dfrac{\rho}{\alpha}\sin(\theta-\theta_0) \end{cases} \tag{15}$$

$$\text{then}\begin{cases} S(\rho,\theta)=\left|F_2(\rho\cos\theta,\rho\sin\theta)\right| \\ R(\rho,\theta)=\left|F_1(\rho\cos\theta,\rho\sin\theta)\right| \end{cases} \tag{16}$$

Thus, the above power spectrum relation can be rewritten as

$$S(\rho,\theta)=\alpha^{-2}R\left(\theta-\theta_0,{}^{\rho}\!/_{\alpha}\right) \tag{17}$$

The logarithm $\begin{cases}\lambda=\log\rho \\ k=\log\alpha\end{cases}$ is introduced to further rewrite.

$$S(\rho,\theta)=\alpha^{-2}R(\theta-\theta_0,\lambda-k) \tag{18}$$

By Fourier transform:

$$S(\mu,\nu)=\alpha^{-2}R(\mu,\nu)\exp\{-j2\pi(\mu\theta_0+\nu k)\} \tag{19}$$

$S(\mu,\nu)$ and $R(\mu,\nu)$ are pairs of matching images pairs, and the upper formula transforms the rotation and scaling of the two into the translational change of the Fourier domain.

3.2 SATD algorithm

The Sum of Absolute transformation Difference (SATD algorithm) is a summation algorithm of the Absolute value of adama transformation. The Hadamard transform, or the walshe-adama transformation, is a generalized Fourier transform, which is an orthogonal square matrix composed of the +1 and -1 elements. The so-called orthogonal square matrix means that any two rows (or two columns) of it are orthogonal. The hadamard transform is equivalent to multiplying the original image S matrix by one hadamard transformation matrix, H, which is HQH. The sum of the absolute value of the elements obtained after transformation is the value of SATD, which is the basis for the discrimination of similarity. Go through all of the subgraphs above and find the smallest subgraph of the SATD value, which is the best match.

3. Methods based on mutual information

The registration of mutual information is a hot topic in the field of medical image registration in recent years. In 1995, collignon and viola were first used for medical image registration. Mutual Information (MI) describes the correlation between the two systems. In the registration of two images, the mutual information is to reflect the degree of mutual information between them through their entropy and combined entropy. For an image, its entropy represents the information contained in the image. Its mathematical form is as follows:

$$\begin{cases} p_i=\dfrac{h_i}{\sum_{i=1}^{N-1}h_i} \\ H(R)=-\sum_{i=0}^{N-1}p_i\log p_i \end{cases} \tag{20}$$

p_i represents the probability of grey degree i. h_i represents the total number of pixels of i pixels in image R, and N represents the grayscale series of image R.The combined entropy reflects the correlation between the two images, R and S. The joint information entropy of R and S is expressed as:

$$H(R,S)=-\sum_{r,s}P_{RS}(r,s)\log P_{RS}(r,s) \tag{21}$$

For images R and S, the mutual information is expressed as:

$$MI(R,S)=H(R)+H(S)-H(R,S) \tag{22}$$

According to the definition of MI, when the similarity of two images is higher or the greater the overlap, the mutual information between them is larger, but the overlap part of the meeting causes misregistration. Subsequent researchers point out that the reduction of overlapped areas means less sampling points, thereby reducing the statistical index of probability distributions; At the same time, with MI as the correlation measure, the overlap between the two images decreases, which can lead to misregistration. Mismatch usually occurs when the gray value gap between image and background is smaller, while the increase in marginal entropy is much faster than that of combined entropy. To this end, Studholme et al introduced the concept of NMI (normalized Mutual Information). Maes et al. introduced the concept of ECC (Entropy Correlation Coefficient,). The formula is as follows

$$NMI(R,S)=\frac{H(R)+H(S)}{H(R,S)} \quad ECC(R,S)=\frac{2MI(R,S)}{H(R)+H(S)} \tag{23}$$

The greater the similarity between the two images, the greater the correlation and the smaller the joint entropy, the greater the mutual information.

IV. EXPERIMENTAL RESULTS

Several representative algorithms are selected from the three methods. For the Fourier-Mellin method, it was tested in four cases, such as rotary translation, and found that its registration effect was good.

Template SAD search figure SAD registration

FIG. 1. SAD REGISTRATION

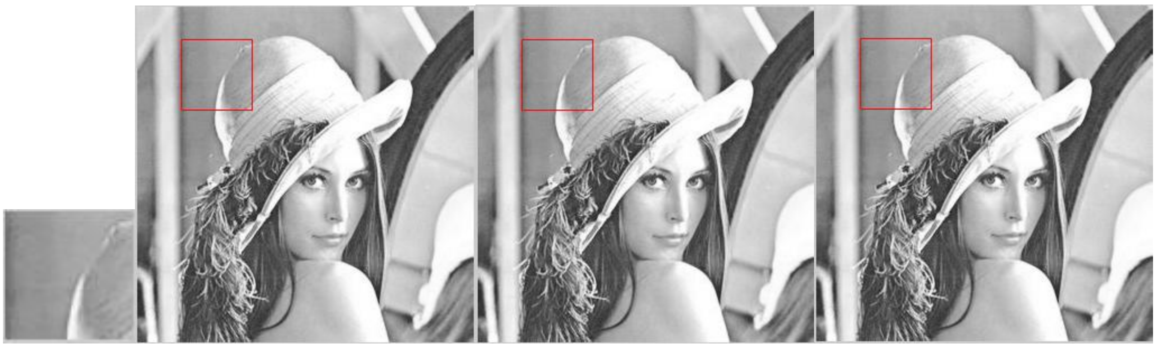
Template SATD search figure SATD registration

FIG. 2. SATD REGISTRATION

Template (crop) Template (rotation) Template ((rotation +translation) Template (translation)

Fourier-Mellin search figure **Fourier-Mellin registration figure**

FIG. 3. FOURIER-MELLIN REGISTRATION RESULTS



Template MI registration figure NMI registration figure ECC registration figure

FIG. 4. MUTUAL INFORMATION REGISTRATION RESULTS

V. CONCLUSION

The results show that the algorithm based on gray-level information is simple and real-time, and it is sensitive to noise. The calculated amount is proportional to the size of the input image. For the image with complex image and low gray contrast, the matching result is cross- The Fourier-Mellin method is still correct for the picture after the rotation translation. The mutual information does not need to be preprocessed and the registration effect is good. It is the current research hotspot, but ignores the spatial position between the pixels relationship.

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