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Research on Visual Features-Based Method for Multi-Sensor Image Registration

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Abstract: Multi-sensor image registration is very important in the space image proceedings for its huge applying value. However, there are some difficulties from anisotropic multi-source spatial data. To consider the multi-resolution visual features in the image registration, we take the multi-resolution decomposition based on wavelet to direct the registration from the rough to the subtle, and then collect the contour which could meet the vision characteristics by use of extension of contour tracking algorithm to realize the multi-resolution shape feature matching based on Fourier transform on the basis of outline of the chain code of curvature functions. To compare with the existing image registration algorithm based on characteristics, the results shows that this method has better registration effect to heterogeneous images from multi-sensors. *Copyright © 2013 IFSA.*

Keywords: Vision characteristics, Image registration, Multi-sensor, Multi-resolution.

1. Introduction

Image registration means in different times, from different sensors or to different perspectives of images, two or more images of the same scene matching, the stacking process. With the development of image sensor and imaging technology, means more and more people can get different kinds of images. Under various applications demand, international scholars study of multi-sensor image fusion technique is becoming more and more attention. With the development of image sensor technology, multi-sensor image registration has become the image understanding and research hot-spot in the field of remote sensing, computer vision, and is widely used in automatic target recognition, intelligent robot, remote sensing, medical image processing and manufacturing, and other fields. Our proposed image registration method at home and abroad are compared and discussed the problems of multi-sensor image registration method, and then based on visual characteristics and multi-resolution multi-sensor image registration method of shape matching, are used to implement multi-sensor image registration.

2. Three Kinds of Image Registration Methods

Research of Multi-sensor image registration methods has developed more than 20 years, both in China and abroad, a variety of different methods have been put forward. The image registration algorithms can be roughly divided into the following three kinds [1].

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2.1. Registration Based on Gray Scale

This method makes use of the whole image gray scale directly measuring the similarity between two images, and then, using the search method to find the similarity degree of maximum or minimum value points, to determine the transformation model parameters between the two images. In order to further improve the operation speed, the literature presents a fast algorithm called sequential similarity detection algorithm. It take the comparison of the sum of absolute value of error as the basis, error and more than the front end of the minimum point of early, thus in this sequential detection of search strategy to improve the computation efficiency of the algorithm.

This similarity criterion is the traditional methods based on gray level directly related to operation or error operation method. Although these methods have respective advantages, but overall there is a common shortcoming, that is strongly influenced by different grayscale attributes or contrast difference, poor robustness. Literature mutual information as the similarity criterion is used to solve many imaging mode of medical image registration problem. Mutual information image registration method was proposed, and in the field of image registration, especially in the field of medical image registration has attracted great attention, many registration based on mutual information method is proposed. But mutual information is based on probability density estimation, the need to build a parameterized probability density model, a large amount of calculation, and require retain larger overlap between images [2]. In addition, this may also lead to pathological function, and the local minima problem. The image registration method based on gray level image gray level, the direct use of all available do not need to do to image feature extraction, improves the matching estimation accuracy and robustness of the algorithm [3]. However, due to the algorithm based on image intensity (such as cross-correlation algorithm) in the matching points in the surrounding area of gray level are involved in calculation, cause a large calculation for good service.

2.2. Image Registration Based on Fourier Transformation

Image translation does not affect the amplitude of Fourier transform, rotation of images can be used in image registration [4]. And, as a mature fast algorithm, Fourier transform can be implemented by special hardware, on the algorithm has more advantages. Phase correlation method are two translation mismatch image registration is the most basic method of Fourier transform and Fourier transform method is applied to the study of the image registration and many, such as literature, etc. Based on Fourier transform image registration algorithm is especially suitable for low frequency noise, such as images under different illumination conditions, etc. And, because it is not sensitive to changes in the frequency domain energy, thus can also be applied to many sensing image registration. In addition, the algorithm on the amount of calculation is better than the typical algorithms. In view of the amount of calculation, the following may proceed optimization: convert two-dimensional Fourier transform into a one-dimensional Fourier transform, the product type and the logarithmic processing. However, Fourier transform method also has certain limitation, this algorithm can be used to registration gray scale images of the attributes have a linear positive correlation, and require the images must meet the transformation of relationship defined, such as rotation, translation, etc.

2.3. Vision-based Method for Image Registration

Because in multi-source image fusion, multi-sensor the captured image is often inconsistent value, therefore, it is difficult to use the method based on image gray scale. In addition, the method based on image gray scale also very sensitive to zoom, rotate and distortion. And based on the characteristics of the image registration method can effectively avoid the above shortcomings. First of all, the image characteristics compared with pixels, much less in number, which makes the relatively small amount of calculation and speed; Secondly, feature matching between the measurement will change as location and sharp, as a result, this method is easy to find accurate matching position; Finally, due to the feature extraction has the strong ability to adapt to changes in gray scale, so the method can process images between large misalignment. But on the other hand, it is only a small part of the image gray level information can be used, this method of feature extraction and feature matching error are also more sensitive, requiring reliably extract features and keep the robustness and consistency. To this, can use commonly used image characteristics, including some features, including angular point, high curvature points, etc. in a straight line segment, edge, outline, closed area, and statistical characteristics such as moment invariants, center of gravity, etc.

It can be seen that for significant edge, outline feature in image registration, between based on edge, outline and closed area registration method has stronger robustness. However, this kind of method of image edge detection and segmentation on the technology of complete dependence makes them also has limitations, which require the use of a good image, the image segmentation result, enough closed area contour segmentation and so on. In addition, if the image size is large, the image segmentation and edge extraction are also need to spend a lot of time [5].

3. Visual-based Image Registration

For matching two images, the image must be found between the transformations. In most of the space of multi-sensor images, the camera to the distance of the object relative to the object size is close to infinity, so the transformation between the obtained images can be as a planar rigid body transformation. Planar rigid body transformation is composed of scaling, rotation and translation transformation. According to the transformation in formula 1, mapping the point (x_1, y_1) in the image I_1 to the point (x_2, y_2) in the reference image I_2.

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = sR\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + D = S\begin{bmatrix} \cos(\alpha) & \sin(\alpha) \\ -\sin(\alpha) & \cos(\alpha) \end{bmatrix}\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + \begin{bmatrix} d_x \\ d_y \end{bmatrix}, \quad (1)$$

where, are respectively the position of the corresponding points on two images, 's' for scaling coefficient, 'α' as the rotation angle, 'D' for the size of the translation.

If consider from different locations of the 3D scene image deformation may occur, or the registration from any position in the same plane of the scene, many images at the same time assume the relative distance between the camera to the objects in the scene and it's smaller than the depth of field, the projection transformation model is a better approximation, projection transformation model design to eight parameters, there is the following relationship, as shown in equation 2.

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \frac{\begin{bmatrix} m_0 & m_1 \\ m_3 & m_4 \end{bmatrix}\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + \begin{bmatrix} m_2 \\ m_5 \end{bmatrix}}{\begin{bmatrix} m_6 & m_7 \end{bmatrix}\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + 1} \quad (2)$$

$$k = 0,1,2,3...7$$

If we can find several pairs of the corresponding feature points 'P' in the two images of, as shown in formula 3.

$$P = \{[x_{1i} y_{1i}], [x_{2i} y_{2i}]\} \quad (3)$$

Then we can estimate the parameters in the above transformation formula. Here the feature matching technology based on visual characteristics, implementation is suitable for multiple sensors, based on the multi-resolution image registration, the so-called visual characteristics, is refers to the people for registration procedures, see images often used from coarse to fine, from global to local method; For heterogeneous multi-sensor image matching method based on shape feature is usually adopted. Therefore, based on visual feature registration consists of two steps multi-resolution feature matching. Step 1 is set up based on wavelet image pyramid, the original image is decomposed into has main outline of the image and the detailed features of images, mainly under the different resolution contour extraction [6]; Step 2 is based on the extraction of contour, implement outline of multi-resolution matching, finally determine the control points of image registration.

In the image registration algorithm based on contour, as a result of the influence of image noise, often can't extract the outline of more representatives. Therefore, we use wavelet transform to image decomposition into a large outline of low frequency which is part of the image and details the characteristics of the high frequency image, then we took the LoG operator to pick up main contours of different resolution images, so the extracted contour retained the image in the salient features under different resolutions. To extract the closed contour, using multi-resolution based on Fourier transform shape feature matching algorithm, to get the corresponding outline two images, and their center of mass as a registration control points. Set according to the control points, least square method is used to calculate transform parameters, after consistency check and image resampling, after registration of images. As shown in Fig. 1.

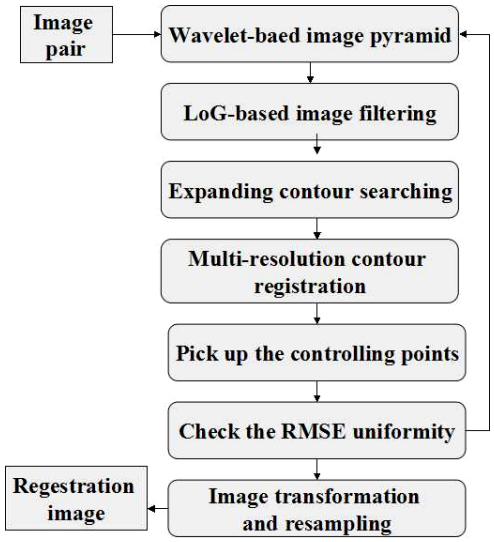

Fig. 1. The registration processing.

4. Expanding Contour Searching Algorithm

Image filter after the intensity of the figure can search the zero points or symbol changes to determine the edge, but the resulting edge point is affected by the noise, is discontinuous. Another kind of get the continuous contour line method is to adopt double threshold method to search the contour. Two preset threshold T_1 and T_2, the convolution is greater than the T_1 and less than T_2 pixels as the candidate profile. Double threshold method in the practical use, however, not well to keep the population distribution of original strength figure shape. Here we used a

contour searching algorithm based on single threshold of improvement.

Because of the LoG operator to filter the image in a zero has the nature of the single width, and the concern is on the vision characteristic, so here take majority in statistical sense do zero as a silhouette. In the experiment, makes the histogram function $H_{(I)}$ the first minimum as a threshold, as shown in the equation 4.

$$\frac{dH(i)}{di} = 0 \quad (0 < i < 256), \tag{4}$$

where 'H' is the histogram function, 'i' presents gray scale. First the bottom as a threshold, the threshold of strength figure make contour map, on the basis of the outline of the search. Usually the outline of the search algorithm according to the eight adjacent tracks in turn, get the contour of eight adjacent chains code said [6]. Eight adjacent chain codes begin with the current pixel, east to the starting point, according to the coding counterclockwise to represent the contour. Outline the upper left corner of the image tracking algorithms start search, until meet the first contour points.

And then the contour points as the starting point, search counter-clockwise 3 × 3 neighborhood of the current pixel, take the first non zero for the next contour point, and continue to search from the contour points, until the neighborhood does not exist in the zero point. Because of the noise, the above search algorithm can't get the continuous on the vision, but the outline of the discontinuity in the contour map, especially those who has the remarkable characteristics of closed contours. So we need to extension of tracking algorithms, within the 3×3 neighborhood does not exist under the condition of the outline, the algorithms to search neighborhood 4 * 4. If there are any starting point, then connect the starting point of a closed contour (closed contours). If there are any other than zero, the connection that point, and continue to search from that point. So we can get as much as possible closed contours, and has a long length of open contour (open contours), to improve the efficiency of matching algorithm.

5. Multi-resolution Shape Feature Matching

Shape feature is an important expression of image content, from each of the contour search contours express the shape and distribution characteristics of the image [7]. Shape characteristics according to the form of expression can be divided into based on boundary and area of the two types. Shape feature expression is important criterion of displacement, rotation and scaling invariance. Based on the visual feature, people always compare roughly the shape of contour, and then the details of the comparison between the outline of roughly similar characteristics. Here, will be represented by chain code into a closed contour curvature function expression, and then use a closed contour of periodic on the Fourier transform, the Fourier transform in frequency domain expression of shape features. The low frequency part represent the shape of the overall outline, the high frequency part represent the profile details.

5.1. Feature Vectors' Pickup for Shapes

Assume that 'C' is the closing of the border on the complex plane, using its sealing ability and cyclical, with a fixed point on the boundary b as a starting point, moving at a constant speed in a counterclockwise direction along the curve, the function, 't' for the time variable [8]. Take 'z (t)' cycle to 2π is 'z (t)' can be expressed in Fourier coefficient as in equation (5):

$$z(t) = \int C_n e^{i \cdot n \cdot l}, \tag{5}$$

where 'C_n' is the Fourier descriptor of 'C'. 'L' for the length of the curve, 'L' arc length along the curve, then we get the formula 6.

$$t = \frac{2\pi l}{L} \tag{6}$$

We can obtain Fourier coefficient from equation 7.

$$\begin{aligned} C_n &= \frac{1}{N}\int_0^N z(t) e^{-i \cdot n \cdot l} dt \\ &= \frac{2\pi}{L}\int_0^L z(s) e^{-i \cdot (2\pi / t) \cdot n \cdot l} Dl \\ &0 \le l \le N - 1. \end{aligned} \tag{7}$$

where 'z(t)' is the curve rate function. Set contour 'C' composed of N points, its sequence is (x_l, y_l), then on the contour curvature is defined as a point of the tangent point on the arc length of differential, namely expression 8:

$$z(l) = \frac{d}{dl}\theta(l), \tag{8}$$

where θ is the edge tangential Angle function, as shown in equation 9.

$$\begin{aligned} \theta(l) &= \arctan\left(\frac{dx}{dy}\right) \\ &= \arctan\left(\frac{dx/dl}{dy/dl}\right) = \arctan\left(\frac{x_l'}{y_l'}\right) \end{aligned} \tag{9}$$

By the curvature of the nature of the function of the shape feature of translation invariant. In order to

keep the shape feature of rotation invariance, use only the Fourier coefficient of the mould and ignore the phase information. In order to make the feature scaling invariance, each mode of Fourier coefficient divided by direct current (DC) component. So, with only a few low coefficient of 'F_i' (take 5 in the experiment), can obtain high quality closed contour shape representation. Each contour shape descriptor for:

$$f_k = \left\{ |F_1| \quad |F_2| \quad |F_3| \quad |F_4| \quad |F_5| \right\} \tag{10}$$

5.2. Shape Feature Matching Based on the Minimum Distance Classifier

Take each closed contour shape descriptor to the shape characteristic vector and the outline of the similarity between problems can be converted into the correlation of multidimensional eigenvector problem. A reference image to extract the m a closed contour, stay n the registration image to extract a closed contour, the relative distance between any two shape characteristic vector is defined as in formula 11:

$$dij = \sum_k \left| F_{ik} - F_{jk} \right|^2 \quad 1 \le i \le m, 1 \le j \le m \tag{11}$$

By calculating the shape features related to the distance, can get the characteristics of the distance between two images contour collection matrix '$|d_{ij}|$'. According to the principle of minimum distance classification, the two contours '(C_i, C_j)' that satisfy the following conditions expressed in formula 12 and 13, can be credited that they have similarity.

$$\min_i \left| d_{ij} \right| = \min \left| d_{ij} \right| \tag{12}$$

$$m = \min_i \left| d_{ij} \right| < T \tag{13}$$

'T' is the threshold. According to the feature matching algorithm to get the contours of the above, calculate contour center of gravity, as image registration control points.

6. Experiment Results

Choose remote sensing images, and the experimental results are compared. Using extended contour tracking algorithm for contour map, to keep the shape of the contour and distribution of original image. Based on this algorithm to extract the closing of the contour, the use of shape matching algorithm can get better effect and more controlling points, and better registration results have been obtained.

7. Conclusions

In this paper, we have submitted a kind of registration method of vision characteristics based on multi-resolution. According to the vision rules, improve the contour searching algorithm to realize the image registration suitable to multi-sensors. In the visual-based image registration algorithm, local salient feature of non-closed contour means very much to pick up the characteristics points. When people do further research in the future, people should pay much more attention to the non-closed contour and multi-resolution shape registration so that better registration effect can be obtained.

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