

A fast Automatic and Robust Image Registration Algorithm

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Abstract—In this paper, a fast automatic and robust image registration algorithm is presented. First, we use the Fourier transform to calculate the relative position between the input images and sort the unordered image sequence. For two images with overlap region, we detect the feature points in the part of the region in one of the image with the robust method of SIFT. According to the coordinates of the feature points and the position relationship of two images, we can compute the space of the feature points in another image and detect the feature points in this region. Then, we use the geometric relation to reduce some mismatch points with structurally similar and achieve the robust image registration. We demonstrate illustrative results obtained by comparing and contrasting our output with other methods. This method can detect the effective feature points quickly for reducing the detection range of the feature points without human intervention and reduce the running time greatly in ensuring the feature points matching accuracy.

Keywords—Fourier transform; feature point; image registration

I. INTRODUCTION

Image mosaic technology is an important study in digital image processing areas. It has been widely used in virtual reality [1], medical image analysis [2], remote sensing, military [3], video compression, reconstruction and other various fields. Image registration as a key technology in image mosaic directly determines the result of image stitching.

Currently, the feature-based image registration methods are widely studied. These methods are not sensitive to image gray, rotation, deformation, noise and occlusion, and more stable and robust. Krystian Mikolajczyk has made the experiment to compare the performance of ten most representative operators [4]. The results show that, SIFT feature descriptor in the illumination, image rotation, scaling, geometric distortion, blurring and image compression has the best performance [5]. In recent years, many researchers have made many improvements from one performance or a specific application on the basis of these methods [6][7][8].

The image registration based feature points of SIFT method is often extracting the feature points in the entire image region as shown in Fig. 1, which are selected by Matier Date Set database.

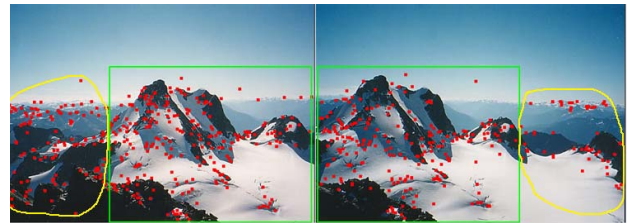


Figure 1. Feature points extraction

This method will extract a lot of invalid feature points which are not in the overlap region. We can see the points in the yellow line region in Fig. 1. These invalid feature points will occupy a lot of unnecessary time with the following feature points matching process. And there will be a lot of false matching points for matching such invalid feature points, which will be a huge impact to calculate the image transformation matrix.

The selected search region is the entire image region during the SIFT feature point extraction, so it will extract a large number of invalid feature points which is not in overlap regions and increase feature point extraction time.

To reduce the feature point extraction time, we propose to combine the Fourier transform and SIFT feature point extraction method to obtain the effective overlap region. Then, we extract the feature points in each effective overlap region of two images. Fourier transform method is often used in such image registration with only simple translation relationship. Generally, its robustness is not good when there are rotation, scaling and other complex relationship between images. However, its processing time is very short, so it can complete the video sequence registration when the camera is translational moving. So we choose to combine the Fourier transform and SIFT method to complete the image registration. Also we will use the geometric relation to reduce the invalid mismatching points and ensure the efficiency and accuracy of image registration. After the experimental verification, this method can reduce much time of feature point extraction and save the time of the following invalid points which participate in the point matching. So this method also improves the accuracy of feature point matching.

II. FOURIER TRANSFORM-BASED OPTIMIZATION ALGORITHM

A. Fourier Transform

According to the translation character of the Fourier transform, the translation relationship of the images has the performance of the corresponding phase transformation relationship. We assume that $f(x,y)$ and $F(\xi,\eta)$ for a pair of Fourier transform, the displacement is $(\Delta x, \Delta y)$. So we get the transformation:

$$f(x - \Delta x, y - \Delta y) \Leftrightarrow F(\xi, \eta) e^{-j2\pi(\xi\Delta x + \eta\Delta y)}. \quad (1)$$

The time domain $f(x,y)$ produces the displacement in frequency domain for the performance of the corresponding phase transformation, and the Fourier transform of the amplitude remain unchanged.

We assume that image $f_1(x,y)$ and $f_2(x,y)$ have the relationship in time domain is:

$$f_1(x, y) = f_2(x - \Delta x, y - \Delta y). \quad (2)$$

According to the translation character of the Fourier transform, the Fourier transform of each image is:

$$F_1(\xi, \eta) = |F_2(\xi, \eta)| e^{-j2\pi(\xi\Delta x + \eta\Delta y)}. \quad (3)$$

So we can obtain the phase correlation function expression through the cross-power spectrum of the inverse Fourier transform:

$$h_{ql}(x, y) = \delta(x - \Delta x, y - \Delta y). \quad (4)$$

The phase correlation function is a pulse function from the above equation. It is almost zero in other position but not in the position of $(\Delta x, \Delta y)$. This position is the displacement what we want to calculate. By calculating the amount of translation of the images we get the position relationship of the images. Then we use the position relationship between the images to segment the image's overlap region.

When there are rotation and scaling relations and some other complex transformations in the images, Fourier transform of the spectrum will be distributed form a single peak to the other small peaks, as shown in Fig. 2.

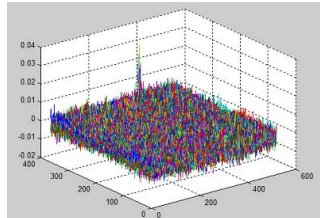


Figure 2. The spectrum peak chart

B. Robust feature points extraction method

SIFT algorithm extracts the local feature in the image. It searches the feature points in scale space and extracts the position, scale and rotation invariant of feature point. SIFT feature is the local feature of the image. It is invariant in rotation, scale, brightness variations. It is also stable in perspective changers, affine transformation, noisy and so on. SIFT algorithm obtained the spatial location, the scale and descriptors of the feature points by establishing an image scale space.

The time complexity of the fast Fourier transform is $O(n \log n)$, while for SIFT detecting feature point is $O(n^2)$. We assume that the scale factor is k ($k < 1$) for the image overlap region of the entire image region. So the computation time of the fast Fourier transform combined with SIFT algorithm used to extract the feature points is recorded as $n \log n + (k * n)^2$. While the computation time of the SIFT algorithm used to extract the feature points is recorded as n^2 . If $n \log n + (k * n)^2 < n^2$, we can calculate the range of k is less than 0.63. That means, when k is less than 0.63, the computation time of the fast Fourier transform combined with SIFT algorithm used to extract the feature points is less than SIFT algorithm. Usually the overlap region in entire image region is from 30% to 50% will be able to complete image registration well. So this method satisfies the general requirement of image registration. Through the calculation above concluded, the improvement method increases the fast Fourier transform time, but by reducing the feature points detecting region to reduce the running time is feasible.

III. GEOMETRIC TOPOLOGICAL STRUCTURE OF FEATURE POINTS

The feature points which are extracted with above method may have structurally similar content in different images. So the descriptors of those feature points are also similar. These feature points will appear mismatch points in matching process.

This paper presents the use of geometric topological relationship of feature points to distinguish the feature points which have the similar descriptors but different space location.

We see the matching feature points above in Fig. 3. Assumed Fig. 3(a) and Fig. 3(b) are matching points, the same as Fig. 3(c) and Fig. 3(d). According to the image geometric transformation, no matter how the triangle changes that the points which are in the triangle internal remaining in the triangle internal. So the matching feature points will not appear the situation from Fig. 3(a) to Fig. 3(d) after the image geometric transformation.

We extract the feature points according to the coordinate information of them and put these points to Delaunay triangulation to record the geometric relationship of each feature point. So we can remove the mismatching feature points which are having similar descriptors but different space location using the geometric relationship of feature points.

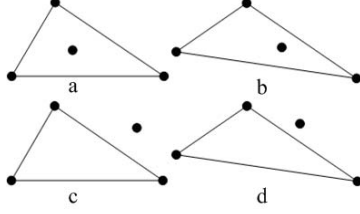


Figure 3. Geometric topological structure of feature points

We obtain the relative position relationship of the images through the Fourier transform method, it can be concluded that the right region of the image which relative position in left or the left region of the image which relative position in right must include the overlap region of two images, and the up and down relationship is also applied.

To calculate the simple, we choose to extract the feature points in the right region of the image which relative position in left or the left region of the image which relative position in right. We can see this region which is framed in red lines in the left image in Fig. 4. The black irregular region is the feature point distribution which extracted in the red rectangle region. Then we obtain the feature points distribution in the other image (the green rectangular region in right image) with the feature points coordinates range extracted in black irregular (the green rectangular region in left image) and the position relationship of two images. The feature points are being extracted in this green rectangular region in the second image (see the extracted feature points in the green rectangular region in the right image). With the above method we complete the feature point extraction process in the overlap region of two images. Then all the matching feature points are obtained through the feature descriptors of the feature points in two images in Fig. 4. Moreover we use the geometric topology of the feature points to remove those mismatching points. Then the transform relationship of two images is being obtained with the RANSAC algorithm. The blue irregular region is the overlap region of two images in Fig. 4. Finally, through the projective transform that the image registration result can be obtained in the same coordinate.

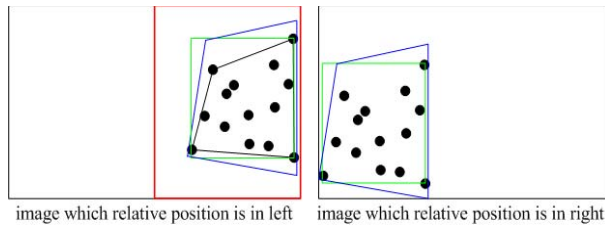


Figure 4. The overlap region segmentation

IV. EXPERIMENTAL RESULTS

The hardware configuration of the experimental machine has the CPU InterCore2 T6400 2.00GHz, and the memory is 2.00GB. The software development environment is MatlabR2009b. The experiment images are being selected by Abbey Date Set database images and two digital images.

We compare the improved method which is proposed in this paper with the classical SIFT method. The following two experimental results are shown in Fig. 5 and Fig. 6 at the bottom of this column.

Comparing with the above two groups of experimental results, it can be seen that the quality of the image registration using the improved method is as same as using classical SIFT method. While it greatly reduces the image registration running time (see the data comparison in Table 1). In this paper, we do the same experiments in same experimental condition in above two group images using two different methods. The two Abbey images size are same 300×384 pixels. The two Lake images size are same 512×384 pixels. The major steps running time of the two group image registration are listed in Table 1 which is at the top of the next column.

It can be seen in Table 1, the efficiency of image registration running time is improved 30%~40% using this paper's method (depending on the size of the image). Therefore, the improved method proposed in this paper has been greatly improved the efficiency of the algorithm.



Figure 5. The results using two methods in Abbey images: (a) original images; (b) the results of classical SIFT method and the improved method

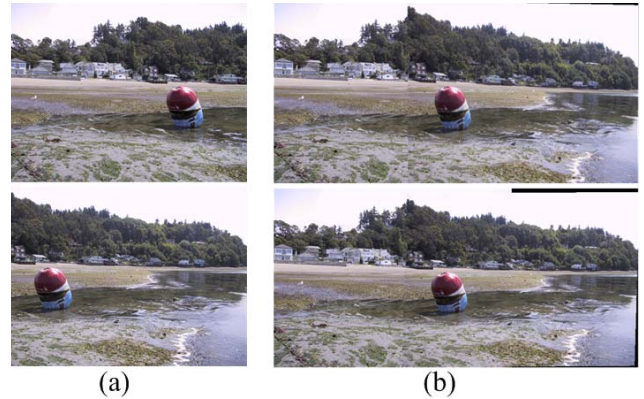


Figure 6. The results using two methods in Lake images: (a) original images; (b) the results of SIFT method and the improved method

TABLE I. THE COMPARISON RESULTS OF TWO METHOD

Image	method	Feature Points extraction time	image registration time	the improved efficiency of image registration
Abbey	SIFT	2.199s	3.816s	37.6%
	the improved method	1.138s	2.380s	
Lake	SIFT	3.979s	9.177	35.9%
	the improved method	1.954s	5.879	

V. CONCLUSION

In this paper, the experiments which we have done are all using two images to do the image registration. This method can also be using for more than two images to make the image registration. Just to add the global image registration in more than two images.

And we propose a fast automatic and robust image registration algorithm, which is based the fast Fourier transform and SIFT method. The main idea of this method is to use Fourier transform to calculate the relative position between images. Combined with SIFT method to calculate the overlap region of each image. It is also using the geometric relation of the feature points to remove the mismatching feature points which are having similar descriptors. Because the complexity of feature point extraction is more than the Fourier transform. Therefore, the improved method increases the fast Fourier transform time, but reduce the running time of some mismatching feature points. It also reduces much running time for the subsequent matching process. So the image registration

efficiency has been greatly improved. Also, we use the structural characteristics of the feature points to remove many mismatching points and improve the accuracy of the image registration.

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