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Improvement of SURF Feature Image Registration Algorithm Based on Cluster Analysis

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Abstract: The present study concentrating about image registration based on feature. With the shortcomings of low precision and limited applicability in the traditional registration algorithm by using random sample consensus method, an improved registration algorithm is proposed in this paper. Cluster analysis based on shared nearest neighbor is used to eliminate mismatching pairs. Initial matching pairs are used to construct two-dimensional vectors. These vectors are divided into different groups according to SNN similarity, and then the appropriate groups are selected as the final matching pairs to calculate parameters of the transform model. Experimental results show that this algorithm improves the accuracy, applicability and robustness of registration, and satisfies the need of image mosaic. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Image registration, Clustering analysis, Shared nearest neighbor, Image mosaic.

1. Introduction

Image mosaic is a technology that carries on the spatial matching to a series of images which are overlapped with each other, and finally builds a seamless and high quality image which has high resolution and big eyeshot compared with each single image [1]. Image mosaic has been widely used in virtual reality, remote sensing image processing, robot vision, medical image processing and other fields. The quality of the mosaic image mainly depends on image registration accuracy. Registration algorithm needs to ensure the accuracy of matching, however, its calculation complexity should not be too large. The core problem is looking for a mapping to align the overlap part between images. Then the images are fused to get a mosaic image [2].

Currently, there are two types of widely used image matching algorithms: Area-based matching and Feature-based matching. In recent years, as the matching algorithms based on local invariant features have smaller calculation, better robustness, they draw more and more attention. Aiming at the problems of large data volume, high time complexity, poor timeliness existing in the Scale-invariant feature transform algorithm which was proposed by D. G. Lowe [3], H. Bay, et. al proposed speeded up robust features (SURF) algorithm which is an image registration method based on feature information [4]. SURF algorithm has been widely used in real-time

image mosaic areas because it ensures the robustness of the algorithm and it improves the efficiency and reduces the time complexity [5]. But the low correct rate of matching and other shortcomings still limit its application [6].

As is shown in Fig. 1, the registration algorithm based on SURF consists of five steps: feature detection, feature point description, feature point matching, mapping relation establishment and image fusion [7]. The nearest neighbor matching method is used to find the initial corresponding matching points (as shown in Fig. 2) after using SURF algorithm to extract feature points. For more mismatch pairs exist in the set of initial matches, random sample consensus (RANSAC) method is used to eliminate false matching pairs in traditional algorithm. Parameters of the transform model are estimated by using matching pairs. Then the corresponding mapping relationship is established [8]. Finally, the overlapping regions of images are fused to get a panoramic image.

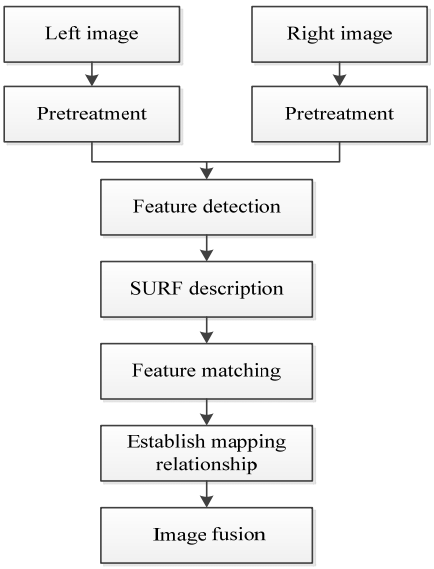


Fig. 1. Flow chart of image registration.

Fig. 2. Initial matching point pairs obtained by nearest neighbor method.

The research shows that a lot of mistaken matches still exist in the final matching pairs obtained by using RANSAC method as shown in Fig. 3 and matching accuracy is not satisfactory. Using this algorithm to mosaic two images with larger rotation is not effective enough and sometimes even can't complete mosaic. To make the algorithm more precisely and stably, an improved registration algorithm based on cluster analysis is proposed to further exclude mismatching point pairs in this paper.

Fig. 3. Registration result by using RANSAC method.

2. Registration Algorithm Based on Single-class Clustering

Vectors are constructed by using initial matching point pairs obtained using nearest neighbor method. Two splicing images which have extracted feature points are aligned in the same plane coordinates as shown in Fig. 4, supposing the set of initial matching pairs obtained by the nearest neighbor algorithm is expressed as

$$P = \{(p_{1i}, p_{2i})\} \quad i = 1, 2, \ldots, N \ . \tag{1}$$

One of the feature point pairs (p_{1i}, p_{2i}) is selected to construct two-dimensional vector as

$$s_i(x, y) = (p_{2ix} - p_{1ix}, p_{2iy} - p_{1iy}) . \tag{2}$$

The corresponding point set of initial matching pairs is described as

$$S = \{s_1, s_2, \ldots, s_N\} . \tag{3}$$

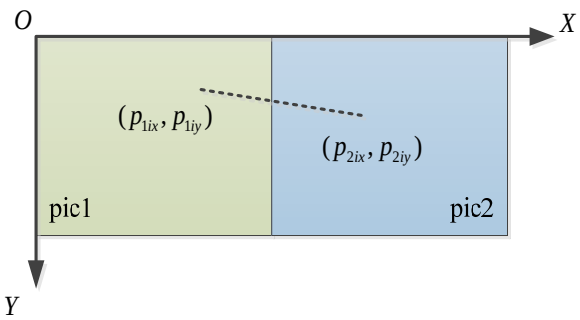


Fig. 4. A matching pair in a plane coordinates.

The research shows that the corresponding vectors constituted by correct matching pairs should be substantially the same in length and angle, showing a certain cluster-feature. It can be found out that the mosaic effect is better when the most densely concentrated sub-set extracted by artificial observation method from point set is used in mosaic [9]. So one clustering method based on density of each point is used to extract correct matching pairs. The method steps are as follows:

1) With s_i as the center and a, b as the side length, draw a rectangle. Compute the number of points within the rectangle. This number is the density of the point;

2) Select the point with the maximum density, and then select all of the points that fall within the rectangle of maximum density point;

3) The corresponding matching pairs of the points obtained by step 2) can be treated as the correct matches. Get the collection S' of the final matches.

The construction of the rectangular area is very important. An adaptive method of random sampling is adopted to determine the sides. The method consists of the following steps:

1) Take out N points from point set S randomly, and point set S_{sample} is got.

2) Find the difference in the abscissa and ordinate between any two points of these N points.

3) Compute the arithmetic mean of the n smallest values in abscissa differences as a'. Similarly, compute the arithmetic mean of the n smallest values in Ordinate differences to get b'. Make $a = 2*a', b = 2*b'$.

In the experiments, N takes 100 and n takes 5. This algorithm can be applied in images with certain shooting angle offset and a certain rotation, and it also can automatically adjust some parameters depending on the images. By using the method to match, the mistaken matches are eliminated and the accuracy of matching is higher. The mosaic image can accurately restore the panoramic image as shown in Fig. 5.

(a) registration result

(b) mosaic result

Fig. 5. Experimental results by single-class clustering method.

3. Registration Algorithm Based on Multi-class Clustering

In practical applications, because two images to be spliced generally present small shooting angle offset, the vectors constructed by feature point pairs are consistent. The final matching pairs obtained by single-class clustering method are distributed uniformly and dispersedly in the images, and then the parameters of the transform model can be calculated reliably by using the least squares method. However, when the images with larger shooting angle offset and a larger rotation, the vectors constructed by feature point pairs are not entirely consistent. The matching pairs obtained by above method fall close to a local area. Using these matching pairs to calculate parameters of the transform model is likely to cause morbid equation problem, which has a negative effect on the mosaic effect. Aiming at these problems, this paper presents an improved registration algorithm based on multi-class clustering.

From the global observation, direction vectors are consistent in local area; from a local point of view, the vectors in different regions still have some difference. In this paper, shared nearest neighbor (SNN) clustering method [10] is used to divide S into different groups. The correct groups which have the top m maximum density are selected. The corresponding pairs in the selected groups are regarded as the final matches to estimate the transform model. The method steps are as follows:

1) Calculate Euclidean distance of any two points in set S to get adjacency matrix.

2) Find K-Nearest Neighbor of each point.

3) Compute Shared Nearest Neighbor similarity (SNN similarity) between any two points.

4) Classify the collection S with a clustering rule.

5) Calculate the density of each group and sort them according to the density.

6) Select the top m highest density groups. The corresponding matching pairs can be treated as the final matches.

It has been found that the nearest neighbor number K can be set at about 2 % of the number of initial matching pairs which participate in the cluster analysis, or K is taken to a value between 40 and 60. If K value is too large, the algorithm will have large calculation. If K is too small, S will be divided into too much groups, affecting the effect of clustering. When SNN similarity between two points is greater than c_T, the two points are put in the same group. The choice of c_T has an important influence on the clustering effect. Experiments show that when $c_T = (0.4 \sim 0.6) * K$, the clustering effect is well. This paper takes $c_T = 0.5 * K$.

In the classification process, the traversal sequence of the points is important for the classification result. When finding K-Nearest Neighbor of each point, the sum of the Euclidean distance between this point and its nearest neighbors is calculated. The points are sorted according to the sum value of each point in ascending order, thus the point at the top has a relatively high gathering degree. Select the first point as the first group, traversal its neighbors to compute SNN similarity between the point and each of its neighbors. When SNN similarity between two points is greater than c_T, the two points are put in the same group. At the same time, this neighbor is regarded as the next candidate traverse point. Breadth-first search algorithm is used to classify S in proper order. Algorithm pseudo-code is as follows:

```
PRODUCE_CLASS(i,color,group)
  s ← d[i]
  PUSH(group, s)
  Q ← ∅
  ENQUEUE(Q,s)
  while Q ≠ ∅
    do u ← DEQUEUE(Q)
      for each v ∈ Adj[u]
        do if color[v]=WHITE and CommonNeighborNum(u,v) ≥ c_T
          then color[v] ← GRAY
            ENQUEUE(Q,v)
            PUSH(group,v)
```

After S was automatically divided into several groups, the density of each group is computed by the following formula:

$$\rho = \frac{n}{(x_{\max} - x_{\min})(y_{\max} - y_{\min})}, \tag{4}$$

where n is the number of points in the group, $x_{\max}$ is the maximum abscissa value of all points in the group, $x_{\min}$ is the minimum abscissa value, $y_{\max}$ is the maximum ordinates value and $y_{\min}$ is the minimum ordinates value. The groups are sorted according to their density, and then the top m highest density groups are selected to calculate parameters of transformation model. Reference value of m satisfies the following formula:

$$\frac{\rho(m+1)}{\rho(m)} < 0.5. \tag{5}$$

Generally, m can't be more than 5.

4. Experimental Results

The algorithm based on SNN similarity is used to match feature points for multi-group of the actual shooting images, and then to complete image mosaic.

For the two images shown in Fig. 5, the point pairs are divided into several groups. Five most concentrated groups are selected to complete mosaic task, the results are shown in Fig. 6. It is clear that the matching pairs obtained by multi-class clustering algorithm are more dispersed, the accuracy of matching is higher, and the mosaic effect is better.

In order to illustrate the advantages of multi-class clustering algorithm, single-class clustering method and multi-class clustering method are respectively used to deal with two images with a larger change in angle of view and with larger rotation. The experimental results are shown in Fig. 7 and Fig. 8, the distribution of matching pairs is shown in Fig. 9. It is clear that the distribution of the matching pairs obtained by multi-class clustering method is more uniform, which is conducive to calculate the parameters of the transform model by the least squares method. The experimental results show that present registration algorithm is more reliable, robust and feasible.

5. Conclusion

Aiming at the shortcomings of the traditional registration algorithm based on SURF, this paper introduces a registration algorithm using single-class clustering method to exclude false matching pairs. And then the paper proposes an improved algorithm using multi-class method based on SNN to reject false matching pairs. The algorithm can effectively remove mismatch pairs, get accurate matches. Experimental results show that the algorithm can be used well in most image mosaic cases. It improves the accuracy, applicability and robustness of matching and further improves the effect of image mosaic.

This algorithm is especially applicable to the images with a larger shooting angle offset and a large rotation as well as images whose height greater than width. It enhances the ability of algorithm to solve

complex splicing problems. For the time complexity of finding K-Nearest Neighbor is larger, future research would focus on improving the efficiency and optimizing the parameters setting.

(a) registration result (b) mosaic result

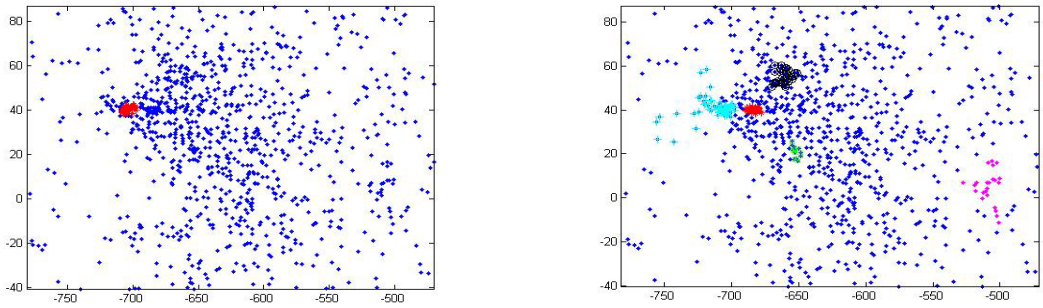
Fig. 6. Experimental results by multi-class clustering method.

(a) registration result (b) mosaic result

Fig. 7. Using single-class clustering method.

(a) registration result (b) mosaic result

Fig. 8. Using multi-class clustering method.



(a) single-class method (b) multi-class method

Fig. 9. The distribution of matching pairs.

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References

[1]. W. Wang, P. Z. Lu, An overview of digital image mosaic, *Journal of Chinese Computer Systems*, Vol. 27, No. 7 2006, 1347-1352.
[2]. Ruan Qin, Peng Gang, Li Rui, Study on image registration and mosaic technology based on surf feature, *Computer & Digital Engineering*, Vol. 39, Issue 2, 2011, pp. 141-144, 183.
[3]. D. G. Lowe, Distinctive image features from scale-invariant keypoints, *International Journal of Computer Vision*, Vol. 60, Issue 2, 2004, pp. 91-110.
[4]. H. Bay, T. Tuytelaars, L. Van Gool, Surf: Speeded up robust features, Computer Vision–ECCV 2006. *Springer*, Berlin Heidelberg, 2006, pp. 404-417.
[5]. R. Zhang, J Zhang, C. Yang, Image registration approach based on SURF, *Infrared and Laser Engineering*, Vol. 38, Issue 1, 2009, pp. 160-165.
[6]. L. Zhao, G. Gen, K. Li, A. He, Images matching algorithm based on SURF and fast approximate nearest neighbor search, *Application Research of Computers*, Vol. 30, Issue 3, 2013, pp. 921-923.
[7]. B. Zitova, J. Flusser, Image registration methods: a survey, *Image and Vision Computing*, Vol. 21, Issue 11, 2003, pp. 977-1000.
[8]. R. Szeliski, Video mosaics for virtual environments, *IEEE Computer Graphics and Applications*, Vol. 16, Issue 2, 1996, pp. 22-30.
[9]. X. L. Long, Q. Chen, J. W. Bao, Improvement of image mosaic algorithm based on SURF, *Applied Mechanics and Materials*, Vol. 2748, No. 427, 2013, pp. 1625-1630.
[10]. R. O. Duda, P. E. Hart, D. G. Stork, Pattern Classification, *John Wiley & Sons*, 2012.