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An efficient registration method for partially overlapping images

Shu-qing Chen[a,b], Hua-wen Chang[a], Hua Yang[c,a]*

[a]College of computer science, Sichuan University, Chengdu 610065, China
[b]Department of Electronics and Information Engineering, Putian University, Putian 351100, China
[c]School of Computer, China West Normal University, Nanchong 637009, China

Abstract

In this paper, a method for accelerating registration of partially overlapping images is presented. Image registration is a fundamental problem in image processing and computer vision. Numerous studies have been done on this subject and can satisfy most of engineering application requirements. However, the registration processing is very time-consuming when the images are very large. So, time-saving methods are desirable.

The proposed method, which is based on a feature-based method, concerns the computational cost of registration of partially overlapping images. The feature-based method generally contains four steps--features detecting, features matching, estimation of the homography and image warping and blending. The new method includes two stages. In the first stage, overlapping areas are rapidly estimated from the low-resolution correspondences of candidate images by a SIFT-based method. In the second stage, a homography between the image pairs is calculated by the same SIFT-based method, which involves only the overlapping areas between a target image and a reference image. Then the target image is warped and blended with the reference image. The experimental results demonstrated that our proposed method can reduce the computational cost to 10%~30% of that of the SIFT-based homographic estimation (SHE) methods with little compromise in accuracy.

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* Corresponding author.
E-mail address:talk2csq@hotmail.com.

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1. Introduction

Image registration is a fundamental problem in image processing and computer vision. Many techniques for image registration have been proposed in literature. Surveys of image registration methods can be found in [1, 2]. Generally, these techniques can be separated into two categories. One is area-based image registration, which directly uses image intensity to estimate the geometric transformation between a target image and a reference image. In last century, most of the publications concerning image registration belong to area-based method, such as [3]. Another is feature-based image registration. The breakthrough of image feature detection around 2000 has greatly promoted the development of feature-based image registration. Brown and Lowe used invariant feature in their great work of automatic panoramic image stitching [4]. Other feature-based image registration methods can be found in [5, 6].

Scale invariant feature transform (SIFT), which is proposed by Lowe in [7], includes both feature detector and feature descriptor. SIFT has an extensive application in image registration, matching and pattern recognition because of its invariance in rotation, scale and illumination. However, the computational cost increases sharply when source images are very large. Therefore, several methods have been designed to reduce the computational cost of SIFT-based algorithms. For example, the method proposed in [4] used k-d tree [8] to find approximate nearest neighbors in order to accelerate the SIFT descriptors' matching. It is a way of saving the computational cost at a price of reducing precision in essence. No algorithms are known that can identify the exact nearest neighbors of points in high dimensional spaces that are any more efficient than exhaustive search [7]. Literature [9] enhanced the computational efficiency by using only four seed points to estimate the parameters of the geometric transformation. In principle, it is a method aiming to avoid the iterative computation involved in the process.

In this study, a new method is proposed to improve the computational performance. This method is based on SIFT and nearest neighbor algorithm with linear search. It includes two stages. In the first stage, the overlapping areas are rapidly estimated by a SIFT-based method on low-resolution correspondences of the candidate images. In the second stage, the transformation is calculated by the same SIFT-based method, which involves only the overlapping areas of the target image and the reference image. Then the target image is warped and blended according to the reference image.

2. SIFT-based image registration

Image registration is a process for overlaying images (two or more) of the same scene taken at different times, from different view points, and /or by different sensors [1]. It is well understood that the geometric relationship between two adjacent images can be formulate as a 3×3 homography in homogenous coordinate [10]. SIFT-based image registration can be achieved by two steps. Firstly the homography between the two images is calculated. Then the target image is warped to the reference image according to the homography. This paper focuses on the homographic estimation rather than the warping or blending.

The SIFT-based homographic estimation (SHE) is described here and we refer to it as SHE for convenience. Firstly, SIFT features are extracted from both the target image and the reference image. Secondly, the features in the image pairs are matched by nearest neighbor algorithm with linear search. Thirdly, RANSAC (random sample consensus) [11] is used to exclude the outliers of the feature pairs which are inconsistent with a homography. The homography of the image pairs is calculated by least square solution with those consistent feature pairs. In the step of feature matching the k-d tree algorithm is used in [3]. However, as has been shown in [8], its performance obviously declines when the dimension of space is higher than ten. Therefore, we doesn't use k-d tree algorithm in the feature matching.

3. The proposed method

The improved method based on SHE is described in this section. The new method includes two stages. In the first stage, the overlapping areas are rapidly estimated. Firstly, both the target image and the reference image are scaled down with anti-aliasing and get low-resolution correspondences of the candidate image pairs. Then, the overlapping areas are roughly estimated from the low-resolution images by a SHE method. In the second stage, only the overlapping areas of image pairs are used to estimate the homography between them, which is achieved by the same SHE method. The homography is used to warp the target image to the reference image.

Let T and R denote a target image and a reference image, respectively. Then the proposed method can be described as follows:

- Step 1. Low-pass filtering is applied to T and R for anti-aliasing. Then the low-resolution correspondences, t and r, are obtained by down-sampling T and R to a specified scale, respectively.
- Step 2. Estimate the rough homography (RH) between T and R from t and r by SHE. Firstly, the SIFT features, which have been extracted from t and r, are matched by nearest neighbor algorithm with linear search to get the feature pairs. Then we exclude the outliers of the feature pairs by RANSAC before back-projecting the coordinates of these consistent feature pairs to T and R. Finally, the RH between T and R is calculated by least square solution with the new coordinates of those consistent feature pairs.
- Step 3. The overlapping areas (OT and OR) of T and R are extracted by warping T to R by RH.
- Step 4. Estimate the precise homography (PH) between T and R from OT and OR by SHE. This process is similar to the estimation of RH.
- Step 5. T is warped to R by PH, and the overlapping areas of them are blended by weighted averaging.

One may find that the proposed method is very simple, since it just executes image reducing once and SHE method twice. This method is based on two facts. One is that the time cost of SIFT feature detection increases with the rise of resolution for any given image. Another is that the time cost of matching SIFT features grows significantly with the rise of quantity of the participated features. So, we try to reduce both the size of image and the number of features which are involved in the SHE method. For partially overlapping image pairs, it is a waste of time to detect all features in the image pairs because a large number of features, which are out of the overlapping areas, are impossible to find correct matches between them. So, it is desirable to rapidly extract the overlapping areas of an image pair. Then, on one hand, in order to improve the computational performance, the low-resolution images are used in the estimation of overlapping areas. On the other hand, in order to keep the accuracy of the proposed method, the overlapping areas of the original high-resolution image pairs are used to estimate the homography between them.

4. Experiment

We evaluated the performance of our proposed method by the following experiments. The experiment was conducted on a personal computer with a 2.6 GHz CPU of Intel Celeron and 2 GB RAM. The coding platform was matlab with version 7.6. Two synthetic image sets are used to demonstrate the performance of the proposed method. The size of each image is 1420-by-1480. Textures in the two image sets are different. The scale of image down-sampling is set to 0.25 for both width and height in our experiment. Each image set includes three different characteristic image pairs. For the first pair, the target image is rotated by 30^{o} and overlaps with the reference image of less than 10% area. For the other two pairs, the target image is further contaminated with the impulse noise of density 0.06, and Gaussian white noise of mean 0 and variance 0.1, respectively. For every image pair, the proposed method is compared with the SHE method by both the accuracy and computational cost of the homographic estimation. For every image set, only the registration result of one image pair with the impulse noise is presented in Fig. 1 and Fig. 2. The accuracy and computational cost of the two image sets by the proposed method and the SHE method are illustrated in Table 1 and Table 2, respectively.

Fig. 1. Result of first image set: (a) by proposed method; (b) by SHE

Fig. 2. Result of second image set: (a) by proposed method; (b) by SHE

The results of the two methods are very similar and the differences are very hard to be perceived visually. We can see that the computational cost varies from image to image due to the difference in textures. But the proposed method is faster than SHE method in total. The running time of the new method is reduced to 10%~30% of that of corresponding SHE method.

Table 1. Registration accuracy

	Proposed method	SHE
First image set, rotation	30.0077^{o}	30.0014^{o}
First image set, rotation, impulse noise	29.9919^{o}	30.0264^{o}
First image set, rotation, Gaussian noise	29.9303^{o}	29.9364^{o}
Second image set, rotation	29.9987^{o}	30.0008^{o}
Second image set, rotation, impulse noise	30.0057^{o}	30.0036^{o}
Second image set, rotation, Gaussian noise	29.8006^{o}	30.0115^{o}

Table 2. Computational cost of homography estimation

	Proposed method(seconds)	SHE method (seconds)
First image set, rotation	25.125	96.657
First image set, rotation, impulse noise	35.515	105.468
First image set, rotation, Gaussian noise	35.360	117.750
Second image set, rotation	121.2665	1175.297
Second image set, rotation, impulse noise	127.578	790.406
Second image set, rotation, Gaussian noise	97.640	572.015

5. Conclusion

In this paper, a new method, which is based on SIFT and nearest neighbor algorithm with linear search, was proposed for accelerating the registration of partially overlapping images. Experiments demonstrated that our proposed method can reduce the computational cost to 10%~30% of that of the SHE method with little compromise in accuracy.

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