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Improved SVD matching based on Delaunay triangulation and belief propagation

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ABSTRACT

Finding correspondences between pair of images of the same scene is a key problem in computer vision. When matching images undergo viewpoint change, partial occlusion, clutters and illumination change, there will be a lot of mismatches due to the limited repeatability and discriminative power of features. In this paper, we propose a robust matching algorithm that can remove false matches and propagate the correct ones to obtain more matches, thus improve the matching accuracy. First, extracts SURF (Speeded Up Robust Features) descriptors from the input two images, which can be used to build the proximity matrix. Then perform SVD (Singular Value Decomposition) on the proximity matrix to obtain the initial matches. Third, refine the initial matches by the unique property of Delaunay triangulation that can produce the maximum cliques of the two Delaunay graph. Finally, recover the lost matches with the constraint of dual graph of Voronoi. Experimental results on Oxford datasets indicate that our algorithm can improve the match performance compared to the RANSAC-based method.

1. Introduction

Automatically establishing of adequate and accurate correspondences between images in computer vision has been found with many applications, such as image retrieval, object recognition and tracking, autonomous robot navigation, image fusion and mosaic, stereo vision and so on [1].

The approaches of image matching can be classified as area-based and feature-based [2,3]. The feature-based approach is based on the extraction of salient structures–features – in the images. Significant regions (forests, lakes, fields), lines (region boundaries, coastlines, roads, rivers) or points (region corners, line intersections, points on curves with high curvature) are understood as features here, then do feature matching of to establish the correspondence between detected features of two images. They should be distinct, spread all over the image and efficiently detectable in both images. The features represent information on higher level. This property makes feature-based methods suitable for situations when illumination changes.

The feature extraction algorithms such as Scale Invariant Feature Transformation [4]. Lowe [4] presented SIFT for extracting distinctive invariant features from images that can be invariant to image scale and rotation. Bay and Tuytelaars [5] proposed speeded up robust features and used integral images for image convolutions and Fast-Hessian detector. Their experiments turned out that it was faster and it works well. The Speeded Up Robust Features (SURF) algorithm extracts salient points from image and computes descriptors of their surroundings that are invariant to scale, rotation and illumination changes.

Scott et al. [6] proposed SVD (Singular Value Decomposition)-based point pattern matching. The advantages of SVD-based methods are listed as follows: first, the SVD method can satisfy both the exclusion and proximity principles set and can be straight forward implemented founded on a well-conditioned eigenvector solution which involves no explicit iterations. In addition, it can cope nicely with image rotation, translation and deformation.

However, when matching images undergo viewpoint change, partial occlusion, clutters and illumination change, it will result in a correspondence set with a lot of mismatches due to the limited repeatability and discriminative power of features. The methods of remove outliers based on global spatial configuration assumes that all features undergo a rigid transformation, for example, such as RANSAC [7] (Random Sample Consensus). The RANSAC based method, have two major problems: (1) it cannot deal with non-rigid deformation; (2) it is sensitive to high number of outliers in the correspondence set; (3) it needs to adjust a certain number of parameters to adapt to the different applications.

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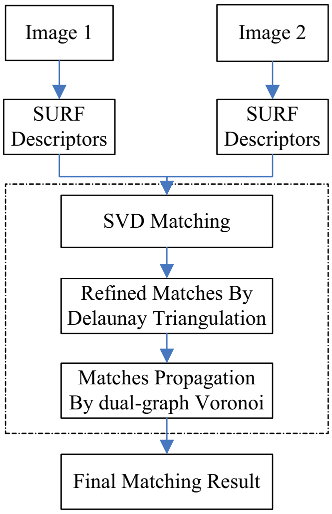

Fig. 1. Flowchart of the proposed matching method SVD_SURF_DELTRI.

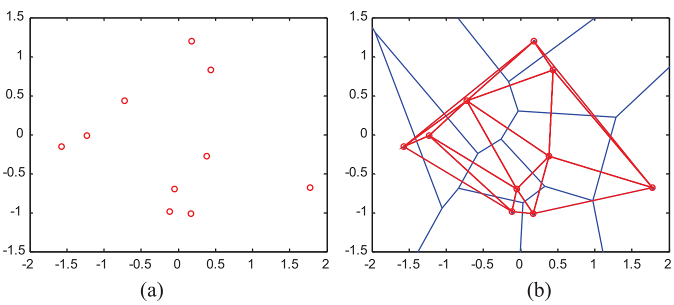

Fig. 2. Examples of (a) 2D points, (b) Voronoi diagram (blue line) and Delaunay triangulation net (red line). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

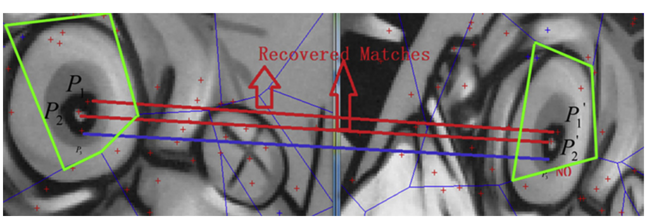

Fig. 3. recovered matches by dual graph Voronoi.

Delaunay triangulations [8] pervade computer vision. They not only provide a convenient and robust neighborhood representation for Voronoi tessellations of the image plane, but also provide a powerful geometric representation for volumetric information.

In this paper, we propose a robust matching algorithm that can remove false matches and propagate the correct ones to obtain more matches, thus improve the matching accuracy. First, extracts SURF (Speeded Up Robust Features) descriptors from the input two images, which can be used to build the proximity matrix. Then perform SVD (Singular Value Decomposition) on the proximity matrix to obtain the initial matches. Third, refine the initial matches by the unique property of Delaunay triangulation that can produce the maximum cliques of the two Delaunay graph. Finally, recover the lost matches with the constraint of dual graph of Voronoi. Experimental results on Oxford datasets indicate that our algorithm can improve the match performance compared to the RANSAC-based method.

The rest of this paper is organized as follows. Section 2 gives and overview the related works for the image matching based on SVD.

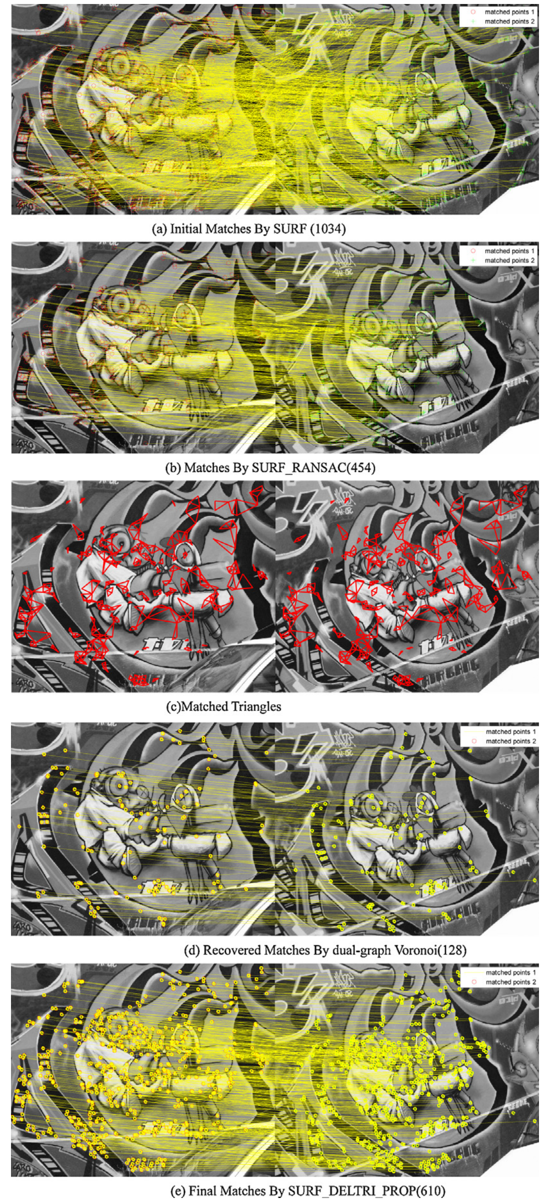

Fig. 4. Matching results of SURF_RANSAC and Proposed method on Image pairs of graf. (a) Initial Matches By SURF (1034); (b) Matches By SURF_RANSAC (454); (c) Matched Triangles; (d) Recovered Matches By dual-graph Voronoi (128); (e) Final Matches By SURF_DELTRI_PROP(610).

Section 3 presents the proposed method in detail. Section 4 gives the experimental results. Section 5 concludes our work.

2. Related work

This SVD based image matching methods have been exploited by different authors in the past. Scott and Longuet-Higgins [6] proposed a method that is based on computing a proximity matrix that depends on the distance between points belonging to the two images. In [9], the authors used this algorithm for stereo correspondence and showed that it has good performance and deals nicely with translation, shearing and scaling deformation. In [10], the authors used this algorithm for matching two uncorrected real images and proved that this algorithm is effective for matching image pairs under different imaging conditions and does not require a correlation threshold for a candidate point match to be accepted. In [11], the authors presented a method based on the