Pattern Recognition 81 (2018) 471–483

Contents lists available at ScienceDirect

Pattern Recognition

journal homepage: www.elsevier.com/locate/patcog

Line matching based on line-points invariant and local homography

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ARTICLE INFO

Article history:
Received 14 July 2017
Revised 9 March 2018
Accepted 27 March 2018
Available online 16 May 2018

Keywords:
Line matching
Characteristic number
Line-points projective invariant

ABSTRACT

Line matching across views is a fundamental task in many applications. Existing methods are hardly applicable to across view scenarios due to the limitation of line descriptors and matching strategy. In this paper, we present a novel line-points invariant based on a new projective invariant named characteristic number. The invariant is able to reflect the intrinsic geometry of line and points, which keeps invariant across views. The construction of this invariant uses intersections of coplanar lines instead of endpoints, rendering more robust matching across views. Accurate homography recovered from the invariant allows all lines, even those without interest points around them, a chance to be matched. Extensive comparisons with the state-of-the-art validate the matching accuracy and robustness of the proposed method to projective transformations. The method also performs well for image pairs with similar textures and those of low textures.

1. Introduction

Feature matching is a basic method for many computer vision problems [1,2]. Points and lines are two kinds of the most basic features, and both are prone to be mismatched due to illumination and sudden viewpoint changes. Robust point feature descriptors and matching methods have been well studied and widely used [3,4] during the years, while line matching methods are less successful due to the complex changes in different views and higher geometric complexity. However, lines can incorporate more semantic and structural information than points, thus it is indispensable to match lines in many manmade scenes where lines are abundant, applications including 3D modeling, pose estimation and robot navigation [5–7].

Line matching across views is a challenging work, as both texture and geometry information might be changed. For example, one object in across view images may has different deformations. Some parts of the object may be stretched in one view but compressed in the other view, and some parts may even disappear out of the view. In order to obtain robust relative position between lines, some methods resort to epipolar constraints [8][1] or geometric invariants [9,10]. However, these kinds of methods highly depend on the accuracy of interest points and end points of lines. Some methods leverage the distance between lines and interest points to construct projective invariants [11,12]. However, the lines without interest points around have little chance to be matched, and the number of matched lines are limit. In fact, the number of matching lines is also a vital factor to evaluate line matching methods, which are widely used in 3D reconstruction [13]. Motivated by above problems, we propose a novel line matching method based on a newly developed projective invariant, named *characteristic number* (CN) [14]. The main contributions are:

(1) A new line-points projective invariant is constructed base on the intersections of coplanar lines, which are more robust than those interest points matched upon textural information;
(2) A similarity metric between line neighborhoods given by a series of line-points invariant values less affected by mis-matched interest points;
(3) Homographies between matched line neighborhoods and homography recovered from the intersections of matched lines make it possible to exploit more potential matching lines including short lines and line pairs without interest points around them.

The projective invariance of CN was introduced in [15] acting as geometric constraints for fiducial point localization under face pose changes. Later, Jia et al. employed this invariant property to construct a shape descriptor robust to perspective deformations [16]. Here, we make an extension to [17], which took the advan-

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[1] Epipolar constraint is about the geometric relations between the 3D points and their projections onto the 2D images that lead to constraints between the image points.

https://doi.org/10.1016/j.patcog.2018.03.031
0031-3203/

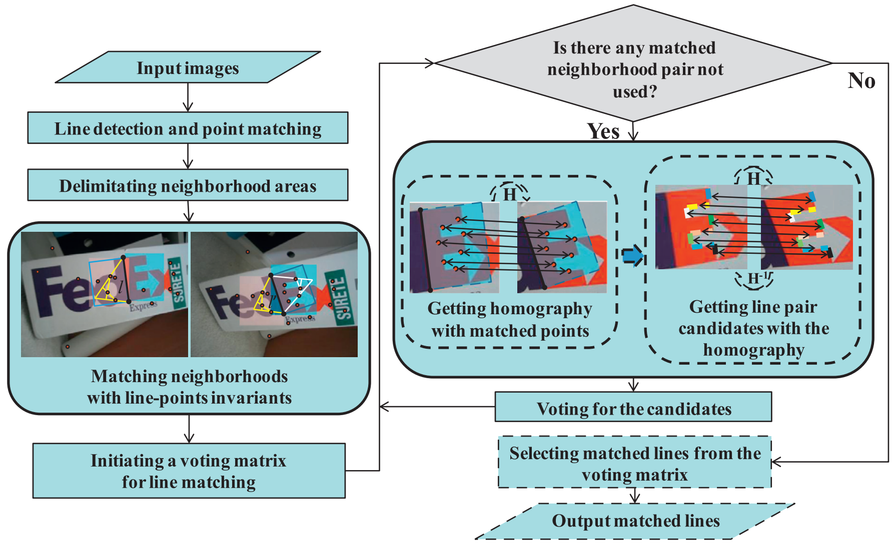

Fig. 1. Overview of the proposed method.

tage of the CN property giving the characterization of the intrinsic geometry between line and points. In this paper, we prove the projective invariance of the line-points invariant. Analysis on low-textured image and short lines are demonstrated. A new matching strategy for short lines (less than 20 pixels), which are removed in [11,12,17] is proposed. Furthermore, we provide explicit analysis and experiments on the effects and selection of parameters. In order to validate the robustness of the proposed method on mis-matched points, two different strategies of matching interest points are employed, and the performance under different number of mis-matched interest points are demonstrated. Finally, we enlarged the dataset including image pairs under a large varieties of transformations with various textures and geometrical structures [18]. Thus, the enlarged dataset covers abundant situations to validate both our methods and the state-of-the-art.

Fig. 1 sketches the work flow of the proposed method. The line-points geometries in the neighborhood of each line construct our new line-points invariant upon CN robust to projective transformations. Hence, we are able to obtain well-matched neighborhoods as well as the homography between these neighborhoods. Finally, we incorporate more matched line pairs using this homography for line matching.

The rest of this paper is organized as follows. Section 2 gives some overview of the related works. Section 3 introduce a projective invariant namely characteristic number and the way we construct the line-points invariant. The details of the proposed method is deliberated in Section 3. Extensive experiments and comparisons are reported in Section 4. We finally summarize and conclude the paper in Section 5.

2. Related work

The existing line matching methods can be classified into three main groups: line matching based on texture information, line matching with relative relationship between lines and line matching with epipolar constraints or geometric invariants.

The texture based method is derived from feature descriptors of points. Inspired by SIFT, Wang et al. [19] proposed a SIFT-like texture descriptor for line matching, the mean-standard deviation line descriptor (MSLD). MSLD is generated from the textures around each line, which can even be used to match some simple curves. However, in many man made objects, the textures around many lines are quite similar, which makes descriptors of this kind less distinguishable. Kim and Lee [20] leverage textures around the intersections of lines instead of the vicinity of lines. However, both methods are sensitive to scale changes, which is quite common in feature matching, as the descriptors are taken from the original image with fixed patch size. Thus, texture based methods are typically sensitive to various image transformations, and may fail on images with similar textures and/or those of “low textures” that have relatively fewer feature points with prominent local intensity gradients.

To avoid the shortcomings of texture based descriptors, some methods use the relative relationship of a group of lines to achieve better performance in low texture images. In [21], lines are clustered into many groups and a feature named *line signature* (LS) is calculated for each group. Unfortunately, a complicated multi-scale scheme is used to enhance the performance under scale changes, which makes LS computationally expensive. López et al. [22] proposed an iterative process that uses structural information calculated from different local appearance and geometric properties of line groups. Both methods perform well in low texture images. Nevertheless, both methods highly rely on the endpoints of line segments. These endpoints are prone to be mismatched when their locations are not accurate due to various image transformations and partial occlusions. Thus, Zhang and Koch [23] combined both local texture information and geometric attributes to match lines and achieved better performance than the methods using only texture or geometric information.

Epipolar constraints [24] and geometric invariants are also widely used in line matching methods. Similar textures and inaccurate endpoints have less effects on these constraints or invariants. Lourakis et al. [9] introduced a projective invariant [25] based on two lines and two points to match lines. However, this method can only work on plane scene. Al-Shahri and Yilmaz [10] exploited the epipolar geometry [24] and coplanarity constraints between pairs of lines. This method performs well in wide-baseline images, but the performance highly depends on the accuracy of the matched interest points. Fan *et al.* [11,12] provided two kinds of invariants based on the distance between matched feature points and lines. This method is robust under various image transformations. Again, it highly depends on the accuracy of the matched interest points. Ramalingam et al. [6] proposed a simple strategy based on cross ratio for line matching and 3D reconstruction, they took the intersections of lines and virtual lines constructed using pairs of interest points to calculate the cross ratios. The idea of