Neurocomputing 151 (2015) 1430–1438

Contents lists available at ScienceDirect

Neurocomputing

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

A fast affine-invariant features for image stitching under large viewpoint changes

Xiaomin Ma [a,*], Ding Liu [a], Jian Zhang [b], Jing Xin [a]

[a] The Faculty of Automation and Information Engineering, Xi'an University of Technology, Xi'an 710048, China
[b] Faculty of Engineering and Information Technology, University of Technology (UTS), Sydney, Australia

ARTICLE INFO

Article history:
Received 29 May 2014
Received in revised form
19 September 2014
Accepted 13 October 2014
Communicated by Haowei Liu
Available online 28 October 2014

Keywords:
Image stitching
Image alignment
Affine-invariant features
ASIFT
FREAK

ABSTRACT

Image alignment and stitching is a popular application on many smart phones, but it is time consuming and creates a critical bottle neck in the course of implementation. In this paper, a fast and high-quality image stitching method is proposed. First, a series of simulated images is obtained by simulating the latitude and longitude angles of a raw image; second, FAST detector is used to detect the features of all the simulated images and described by Fast Retina Key-point (FREAK) before all the feature information is projected to the raw image; third, Hamming distance is used as a feature similarity metric and all the features are matched directly instead of using the repetitive projection in Affine-SIFT (ASIFT). RANSAC is then used to achieve the optimal affine-transformations, and lastly, a weighted average bending algorithm is used to smooth the intensities of the overlapping regions. The experimental results demonstrate that the proposed image stitching method greatly increases the speed of the image alignment process and produces a satisfactory result.

1. Introduction

As the customer's demand of enjoying a panorama increases, image stitching attracts more and more attention on smart phones [1]. A panoramic image has a wide field of view and is constructed from a series of images taking one by one and having overlapping areas. To generate a visually natural panorama, image alignment and image blending [2], are necessary. Image alignment is the premise of image blending and used for finding a transformation to make different images totally correspondent in space domain. Hence, the quality of image alignment directly influences the accuracy and efficiency of image stitching [3]. In general, image alignment can be divided into three main categories: first, transformation domain-based method [4]; second, intensity-based method [5]; third, feature-based method [6]. Among them, the feature-based method mainly uses the distinctive features between images, such as contour, edge, statistic features. It has been widely used since the early days of stereo matching [7] and has more lately received popularity for image stitching applications [8]. However, the images to be stitched are often derived from different views, different time or different sensors, this requires image alignment algorithm has good ability to resist affine transformation. Meanwhile the construction of panorama needs a lot of computational power and memory, but smart phones only have limited resources compared to desktop computers. In this paper, we propose a fast and fully affine-invariant image alignment algorithm called Affine-Freak (AFREAK) to fit the efficient stitching on smart phones.

The contributions in this paper are summarized below. (1) A new image alignment algorithm is proposed to realize the fast feature extraction and feature matching, especially when the image views are too different. The proposed algorithm combines the idea of simulating affine transformation in Affine-SIFT (ASIFT) [9] with the rapidity of FAST [10] detector and FREAK [11], so the time efficiency is compatible with fully affine-invariance in AFREAK. (2) Considering that FREAK is a binary descriptor, Hamming distance is used to instead of Euclidean distance, meanwhile, a new matching strategy is proposed which simplifies the redundancy steps in ASIFT. These changes further improve the rapidity of AFREAK.

The paper is organized as follows. In Section 2 related image alignment algorithms are compared from two aspects: rapidity and affine-invariance. In Sections 3 and 4, stitching process based on AFREAK is first systematically introduced, then the contributions are explained in detail. In Section 5 the rapidity of AFREAK and effectiveness of image stitching are verified through three groups of experiments. Finally a conclusion is drawn in Section 6.

2. Related works

Lowe et al. [12] proposed a scale invariant feature transformation (SIFT), the algorithm has good distinctiveness and robustness.

* Corresponding author.
E-mail address: xunjiatong@163.com (X. Ma).

http://dx.doi.org/10.1016/j.neucom.2014.10.045
0925-2312/

It is invariant to the change of the illumination, image noise, rotation, scaling, and small changes of the viewpoint. A family of SIFT-like and SIFT-extension algorithms, including principal components analysis (PCA)-SIFT [13], gradient location-orientation histogram (GLOH) [14], DAISY [15] and speed-up robust feature (SURF) [16] are developed. But all of them do not have affine-invariance and cannot favor the applications when there is a large view changes. Morel et al. improved SIFT and proposed a fully affine-invariant image alignment algorithm (ASIFT). It enhances not only the affine-invariance of SIFT, but also has good robustness for viewpoint changes. However, the time consuming caused by SIFT detector and SIFT descriptor has extremely restricted its applications in some fields which has higher requirements for rapidity. Pang et al. [17] proposed a fully affine invariant SURF (FAIR-SURF) algorithm, it is faster than ASIFT. Despite all of these promising algorithms, the rapid computation with low memory and computation complexity is far from being a solved problem. Therefore, the binary robust independent elementary feature (BRIEF) [18], the oriented fast and rotated brief (ORB) [19], the binary robust invariant scalable key-points [20] (BRISK) and the fast retina key-point (FREAK) are presented. Among them, FREAK is the best one [11], which is inspired by Human Visual System (more exactly retina), and proposed in Conference on Computer Vision and Pattern Recognition (CVPR) [11]. It is more compact while remaining robust to scale, rotation and noise, and faster to compute with lower memory load than SIFT or SURF, for example, the computing speed of FREAK descriptor is 77 times faster than SURF descriptor. FREAK descriptor is formed by comparing the image intensities of pairs of symmetrical receptive fields over circular sampling grid pattern, the pattern is similar to the distribution of retina which has higher density of points near the center and the density of points drop exponentially. Rosten et al. presented features from accelerated segment test (FAST), it is a sort of simple and fast feature detector which has repeatability and the capability of noise immunity, in particular, it is faster than SURF detector. The process of feature detection is as follows: considering a circle with the radius $r=3$ pixels around the feature candidate P and comparing the intensity of P with other pixels in the circle. If there exists n pixels which are all brighter than P and n is greater or equal to a threshold ($n=9$), the feature candidate P is defined as a FAST feature. As we know, either FREAK descriptor or FAST detector alone is not enough to realize image alignment, meanwhile, in order to make image alignment algorithm can be adapted to the applications which require both affine-invariance and rapidity.

We herein propose a new image alignment algorithm called Affine-Freak (AFREAK). It not only inherited the rapidity of FAST detector and FREAK descriptor, but also the fully affine-invariant of ASIFT. The method firstly makes use of the idea of stimulating longitude and latitude to ensure the affine-invariant feature extraction and description; secondly, FAST and FREAK are used for feature extraction and description; then an improved matching strategy is used for features matching which accelerates the rapidity further; finally, AFREAK is applied to image stitching and realize the rapid and seamless image stitching.

3. The image stitching principle based on AFREAK

The key enabling idea in the method is extracting features and matches through image alignment algorithm from series of images, then computing the optimal transformation between images using a large number of correct matches, finally realizing the stitching of a panoramic image.

3.1. Framework

The proposed image stitching method based on AFREAK algorithm contains two sections: (1) image alignment (including AFREAK feature extraction and description, coarse matching and precise matching); (2) image blending (including transformation estimation and weighted average blending). Among them, AFREAK feature extraction and description, matching are the two improvements, they can realize the fast and accurate extraction of affine-invariant features even when there is a large change of views. Fig. 1 gives an overview of the method.

The specific process can be divided into five steps:

(1) Take series of images captured from different viewpoints as reference images and images to be stitched (a pair of image for example in Fig. 1).
(2) Quickly extract the affine-invariant features and describe them using AFREAK.
(3) Obtain precise matches using Hamming distance [21] and random sample consensus (RANSAC) [22] (coarse matches and precise matches are shown in Fig. 1).
(4) Estimate the accuracy affine-transformation H between the images according to numerous accurate matches, and project the image to be stitched to the coordinates of the reference image using matrix H.
(5) Use weighted average algorithm to cope with unsmoothed transition in overlapping region and realize the seamless image stitching (the stitching result is displayed in Fig. 1).

3.2. AFREAK detection and description

Considering that FAST and FREAK not only have invariance in rotation, transformation and brightness, but also are stable in noise and views changes to some degree. Especially, they are faster than SIFT, SURF and BRISK, We proposed a new image alignment algorithm AFREAK. It has fully affine-invariance while keeping the rapidity advantage. If we assume that the camera is located in front of the object, affine transitions of image occur as the camera moves

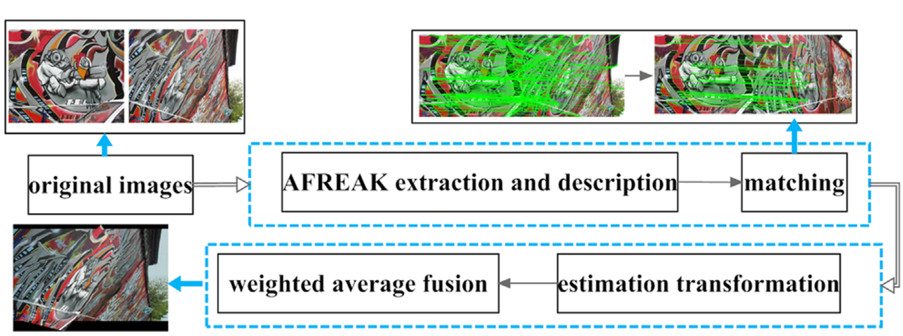

Fig. 1. System framework of image stitching.