



A survey on image mosaicing techniques [☆]



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ABSTRACT

Image mosaicing, the process of obtaining a wider field-of-view of a scene from a sequence of partial views, has been an attractive research area because of its wide range of applications, including motion detection, resolution enhancement, monitoring global land usage, and medical imaging. A number of image mosaicing algorithms have been proposed over the last two decades. This paper provides an in-depth survey of the existing image mosaicing algorithms by classifying them into several groups. For each group, the fundamental concepts are first explained and then the modifications made to the basic concepts by different researchers are explained. Furthermore, this paper also discusses the advantages and disadvantages of all the mosaicing groups.

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1. Introduction

Nowadays, image mosaicing is gaining a lot of interests in the research community for both its scientific significance and potential derivatives in real world applications. Image mosaicing is the alignment of multiple overlapping images into a large composition which represents a part of a 3D scene [1]. Mosaicing could be regarded as a special case of scene reconstruction where the images are related by planar homography only [2]. This is a reasonable assumption if the images exhibit no parallax effects, i.e. when the scene is approximately planar or the camera purely rotates about its optical center [3]. Using mosaicing it is possible to extend the field of view (FOV) of a camera by preserving the original resolution and without introducing undesirable lens deformation [4]. There have been a variety of new additions to the classic applications of image mosaicing that primarily aim to augment the FOV. Mosaic construction is finding its practices in many computer vision and computer graphics applications, such as motion detection and tracking [5–7], mosaic-based localization [8,9], resolution enhancement [10–12], and augmented reality [13,14]. Furthermore, video compression [15], video indexing [16], and image stabilization [17] are some of the prominent areas where mosaicing is creating significant impacts.

As shown in Fig. 1, mosaicing involves various steps of image processing: registration, reprojection, stitching, and blending.

Registration refers to the establishment of geometric correspondence between a pair of images depicting the same scene. In order to register a set of images, it is required to estimate the geometric transformations which align the images with respect to a reference image within that set. The set may consist of two or more images taken of a single scene at different times, from different viewpoints, and/or by different sensors. The most general case of the transformation is the 8 degree of freedom planar homography [1]. The next step, following the registration, is reprojection which refers to the alignment of the images into a common coordinate system using the computed geometric transformations. The goal of the stitching step is to overlay the aligned images on a larger canvas by merging pixel values of the overlapping portions and retaining pixels where no overlap occurs. Errors propagated via geometric and photometric misalignments often result in undesirable object discontinuities and seam visibility in the vicinity of the boundary between two images. Thus, a blending algorithm needs to be used during or after the stitching step in order to minimize the discontinuities in the global appearance of the mosaic. The aforementioned registration step has been conceived to work with images with a single color band. Different techniques have been used by different mosaicing algorithms to deal with multiple color bands. For example, in [18–21] one of the color bands of the input RGB images are taken into consideration while obtaining the transformation parameters. In [22–24] on the other hand, the RGB images are first converted to grayscale and then transformation parameters are obtained. In either case, after finding the optimal transformation parameters, all the color bands are processed and

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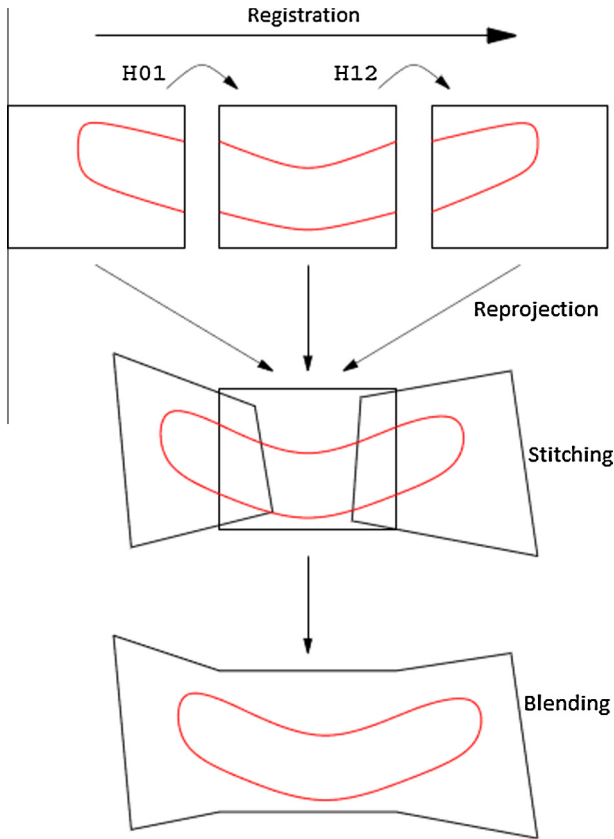


Fig. 1. Different steps of image mosaicing. Here H are the homography matrices between source images. Adapted from [1].

combined together during the reprojection step in order to produce color mosaic.

A number of mosaicing algorithms have been proposed in the literature [10,19,23–36]. Even though the state of the art indicates advancements in this research area in recent years, image mosaicing still remains a challenge because of several factors like registration and blending. Since pose and acquisition systems vary, the set of possible observations of a scene is immense [37]. Thus the task of determining the correspondences between observed images is complicated. Similarly, reducing the visible inconsistencies near the boundaries of the overlapping images is also challenging. While the majority of the recent works focus specifically on dealing with the aforementioned challenges, a comprehensive review of the existing algorithms remain mostly overlooked. Literature review shows that only a few review papers [38–42] on the existing image mosaicing techniques have been carried out. In [38,41,42], the authors review the existing mosaicing techniques based on a specific image registration method. [39] gives an overview of the different steps of image mosaicing techniques. However, the authors did not categorize the existing methods. [40] presents a review work in the field of document image mosaicing and retina image mosaicing only. Thus, none of the existing survey discuss the major categories of image mosaicing algorithms and ultimately fail to classify the most recent image mosaicing techniques. The continuous emergence of new image mosaicing algorithms in recent years necessitates such a review, which will be valuable guide to researchers and developers for selecting a suitable image mosaicing method for a specific application. In this paper, we classify the past and current mosaicing techniques based on image registration as well as image blending. For each of these classifications, we provide a comprehensive review of the major categories of the image mosaicing methods. The basics of these

categories are first described. Then, for each of these basic categories, the evolving paths are discussed by providing the modifications that have been applied to the basic methods by different researchers. Since the current state-of-the-art is very large, only those works, which we think contributed significantly to the mosaicing literature, are discussed in this manuscript.

The rest of the paper is organized as follows: Section 2 provides the taxonomies of the existing mosaicing algorithms. Section 3 explains the classification of mosaicing methods based on image registration. Section 4 reviews the classification of mosaicing algorithms based on image blending. Finally, the paper comes to a conclusion in Section 5.

2. Classification of image mosaicing algorithms

Image registration and blending are the two significant research areas which directly influence the image mosaicing performance. Being the first and last step of image mosaicing, it is almost impossible to build a successful mosaicing algorithm without correctly implementing registration and blending algorithms. Though attempts have been made to overcome the registration errors by utilizing sophisticated blending algorithms, the significance of accurate registration in image mosaicing still remains unquestionable. In this paper, we focus on classification of the existing image mosaicing algorithms based on their registration methods, as well as based on their blending methods.

As shown in Fig. 2, based on image registration methods, image mosaicing algorithms can be spatial domain-based or frequency domain-based. Spatial domain-based image mosaicing can further be grouped into area-based image mosaicing and feature-based image mosaicing. Feature-based image mosaicing can again be subdivided into low level feature-based image mosaicing and contour-based image mosaicing. Low level feature-based mosaicing can be divided into four classes: Harris corner detector-based mosaicing, FAST corner detector-based mosaicing, SIFT feature detector-based mosaicing, and SURF detector-based mosaicing. As shown in Fig. 3, based on the image blending techniques, mosaicing algorithms can be transition smoothing-based and optimal seam-based. Transition smoothing-based mosaicing can further be grouped into feathering-based, pyramid-based, and gradient-based mosaicing.

3. Classification of image mosaicing based on registration

Image registration is not only an important step of image mosaicing, but also the foundation of it. Registration of multi-source images, which are focused on the same target but produced from different sensors, different perspective, and different times, computes the optimal geometric transformation by looking into the correspondences between each pair of images. This process makes the multi-source images aligned into a common reference frame using the estimated geometric transformations. To the extent that corresponding points from multi-source images are aligned together, the registration is successful [43]. The aforementioned correspondences can be established either by matching templates between images, or by matching features extracted from images, or by utilizing the phase correlation property in the frequency domain. Different classes of image mosaicing algorithms based on the image registration are discussed in the following two subsections.

3.1. Spatial domain image mosaicing algorithms

Algorithms in this category use properties of pixels to perform registration, and, thus they are the most direct methods of image

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