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Image Mosaicing based on Adaptive Sample Consensus Method and a Data-Dependent Blending Algorithm

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Abstract

Image mosaicing refers to stitching two or more images that have regions overlapping with a larger and more comprehensive image. The Scale Invariant Feature Transform (SIFT) is one of the most common matching methods previously used in image mosaicing. The de-fects of SIFT are lots of mismatches, that reduce the efficiency of this algorithm. In this article, to solve this problem, a novel approach to image mosaicing is suggested. At first, the features of both images are matched based on SIFT to improve the mosaicing process. Then, the A-RANSAC algorithm suggested in [1] is employed to eliminate mismatches based on an adaptive threshold. This algorithm is used to delete incorrect matches and to improve the accuracy of images mosaicing. Image blending is the final step of mosaicing to blend the intensity of the pixels in the overlapped region to avoid the seams. The sug-gested approach of blending is based on the absolute Gaussian weighting function. The mean and variance of this function are considered as the average and variance of the data of the range of two images common to each other, respectively. The suggested blending method reduces border line in the combined images while preserving the information of the original images as much as possible, performing the mosaicing process better. The simula-tion results of the suggested image mosaicing technique, which includes the use of SIFT algorithm, A-RANSAC, and suggested image blending algorithm on the standard image databases and the created image database, show the superiority of the suggested approach according to median error criteria, precision.

Keywords: A-RANSAC, Blending Method, Image Mosaicing, Incorrect Matches, SIFT.

1. INTRODUCTION

Image mosaicing is a combination of two or more images of a scene taken at distinct angles[2]. The mosaicing process has various

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applications such as video compression, video matting, video conferencing, 3D image reconstruction, and applications in the medical field [3]. In general, image mosaicing consists of two stages: matching and image blending[4, 5]. Image matching is used to find the motion relationship between two or several images. Moreover, image blending is to create an image of stitching of several other images, so that their most important information is pre-served. Matching methods are generally parted into two classes: feature-based and direct methods[6, 7]. Feature-based methods are more accurate than the direct method and are widely used in practical applications[8, 9]. One of the applicable algorithms in the feature-based matching of image mosaicing is the SIFT algorithm[10, 11].

The SIFT algorithm was introduced by Lowe, which is resistant to scale changes and rotation. It is also stable against illumination shifts, Affine deviation, and noise[12], which makes SIFT important in many utilizations such as image mosaicing[13], object recognition [14], registration[15], and copy-move image forgery [16, 17]. Despite the applicability of SIFT, it has several incorrect matches, which decreases the precision. Much research has been done in the literature to delete incorrect matches in SIFT [15, 16, 18, 19].

The RANSAC algorithm is a resistant estimation method offered by Fischer [20]. This algorithm is widely used to eliminate incorrect matches in image mosaicing[21, 22]. In[23], the SIFT is used for extracting the features, and KD-tree algorithm and BBF search strategy for matching the features and the RANSAC for eliminating the incorrect matching and for improving the mosaicing process are used. This method has a high execution time for mosaicing more than two images. In[24], SIFT is used for image registration and the PROSAC algorithm is used to perform the mosaicing process; this method has good accuracy and performance. In[25], the SIFT is used to match the images and the RANSAC is used to improve the matching accuracy and improve the image mosaicing. In [13], the RKEM-SIFT algorithm and the improved RANSAC algorithm are used for image mosaicing. In the improved RANSAC, the threshold is considered based on the median, which enhances the image mosaicing process. Despite the widespread use of the RANSAC algorithm and improved versions of this algorithm in the image mosaicing process, there are still problems in the RANSAC that reduce the quality of the image mosaicing. One of these problems is with determining the appropriate threshold in RANSAC. If a small value is selected, it will reduce the rate of correct matches. If a large value is selected, it will increase the rate of incorrect matches, which ultimately affects the result of the mosaicing process seriously[26, 27].

Recently, a novel improvement has been applied to the RANSAC algorithm called A-RANSAC [1]. The efficiency of this method in retinal images registration has been investigated and confirmed. In this article, A-RANSAC method is used to eliminate incorrect matches and improve the image mosaicing. In this approach, the threshold value is chosen in a manner that the number of removed matches and the root mean square error are optimized simultaneously. One of the advantages of this method is determination of the adaptive threshold, which eliminates the maximum false matches and maintains the maximum correct matches. The proper performance of this algorithm motivates us to use it in the image mosaicing process. The second innovation is a novel method of blending images. Classic methods of image blending have the problem of creating boundaries between the blended images and loss of some information in the blended image. In the suggested blending method of this article, the absolute Gaussian weight function is used, the average and variance of which are considered based on the data of common areas of images.

The rest of the article is organized as follows. In the second part, the suggested methods for image mosaicing are described. In the third and fourth sections, the results, experiments, and conclusions are discussed, respectively.

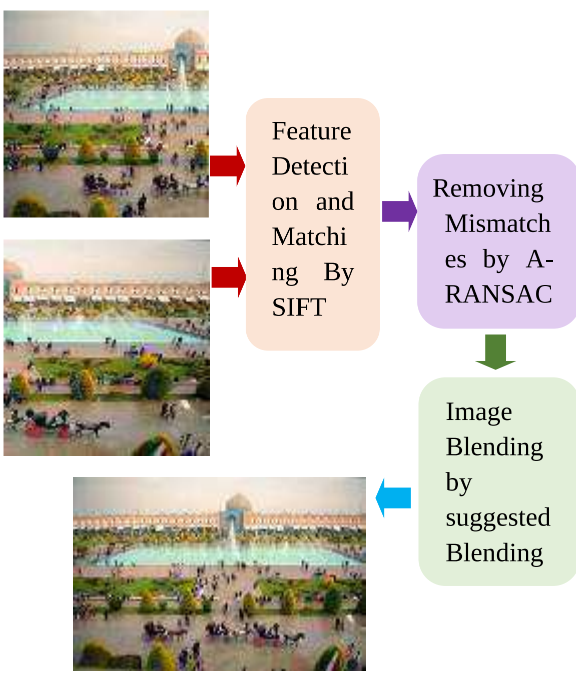


Fig.1. Folchwert of suggested image mosaicing method.

2. Method

In this section, the image mosaicing process is described in three steps, as shown in Fig.1. First, the features are identified and matched using the SIFT algorithm. Then, homograph is performed with the A-RANSAC algorithm to eliminate incorrect matches, and finally, the suggested Gaussian weight function method is used for image blending.

2.1. A-RANSAC

In this part, the A-RANSAC is used to increase precision and ultimately improve the function of the image mosaicing. The details of the method are explained below.

First step: A transformation model is constructed according to RANSAC and its parameters. See [20] for more details.

Second step: Different numbers of matched points based on the transformation type are randomly selected. For example, for affine transformation, three points are chosen.

Third step: In this step, an optimal threshold value is aimed to be found as the solution to a multi-objective optimization problem. Here, two goals of deleting incorrect matches and enhancing alignment accuracy are considered; combined into a single objective function by the weighted sum in accordance Eq. (1).

$$F = k \cdot RMSE + (1-k) \cdot number\{removedmatches\} \quad (1)$$

In (1), the value of is considered , meaning that the significances of RMSE and the number of deleted matched points are equal. Then the optimal threshold value is described as the argument of the minimization problem Eq. (2).

$$Thr._{opt.} = \arg\min_{Thr.}(F) \tag{2}$$

Fourth step: If the distance is less than the optimal threshold, keypoints have been correctly matched. Otherwise, both keypoints are removed.

2.2. Suggested Blending Method

Image blending is one of the most important steps in image mosaicing process, and improving this step will improve the image mosaicing process. Methods of image blending should be such that the edges of the image, artifact, and border of the images are not visible in overlapping areas [28]. So, we need a way to combine the transition from one image to another in a way that minimizes the problems of image blending. This process includes removing the border line in the combined images, while preserving the information of the original images as much as possible. A suitable method is suggested by blending two images according to Eq. (3), for which the amount of $\beta(x,y)$, is computed according to the next steps.

$$M(x,y) = \beta(x,y)M_1(x,y) + (1-\beta(x,y))M_2(x,y) \tag{3}$$

In (3), $M_1(x,y)$ and $M_2(x,y)$ are pixels in the first image and the target image at the same location of the overlapping region. $\beta(x,y)$ is the suggested absolute value of Gaussian weighted function which is computed in Eq. (4).

$$\beta(x,y) = \left| 2 \times \sqrt{2\pi\sigma} \times N(x;\mu,\sigma) - \frac{1}{2} \right| \tag{4}$$

In Eq. (4), $N(x;\mu,\sigma)$ is computed in Eq. (5).

$$N(x;\mu,\sigma) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(x-\mu)^2 / 2\sigma^2} \tag{5}$$

In the absolute Gaussian weighted function, the suggested variance is computed according to Eq. (6) and the suggested mean is computed according to Eq. (7).

$$m = mean(\{x_i \mid i = 1,\dots,n\}) \tag{6}$$

$$\sigma^2 = \mathrm{var}(\{x_i \mid i = 1,\dots,n\}) \tag{7}$$

In these equations, x_i is the data in overlapping areas and n is the number of pixels in overlapping areas.

3. IMPLEMENTATION AND EXAMINATION OF RESULTS

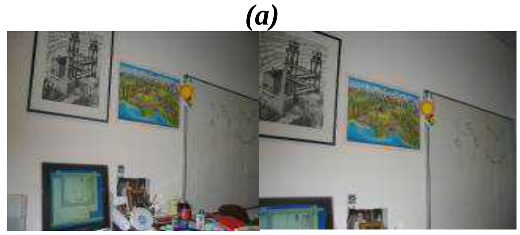
To evaluate the capability of the suggested approach and its efficiency in image mosaicing, two experiments were performed. In the first experiment, the performance of the A-RANSAC method in eliminating incorrect matches is investigated and in the second experiment, the suggested approach for image mosaicing is investigated. The database of the images used in this article includes two sets. The database of the first images includes images that have been taken from historical and natural places from different angles. In the second database, standard images have been used in reputable sources (images from the first and second databases have been shown in Fig. (2) [29]. To evaluate the efficiency of the suggested approach from the matching precision criterion Eq. (8), the SITMMR Eq. (9) [26].The SITMMC Eq. (10) [26], median error [30].

$$\text{Precision}=\frac{NB_{CM}}{NB_{TM}} \quad (8)$$

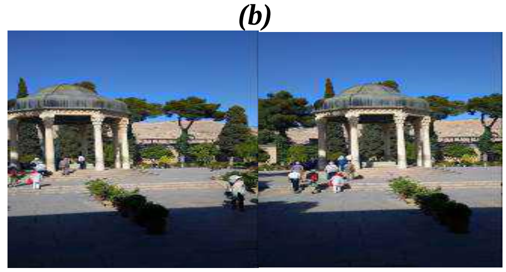
$$\text{SITMMR}=\frac{NB_{FM}+1}{NB_{TM}} \quad (9)$$

$$\text{SITMMC}=\frac{NB_{CM}-1}{NB_{TM}} \quad (10)$$

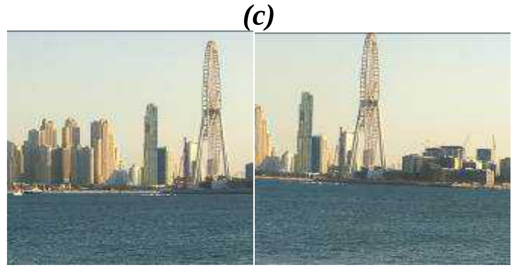
(a)



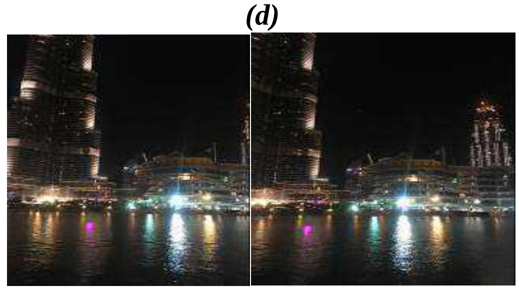
(b)



(c)

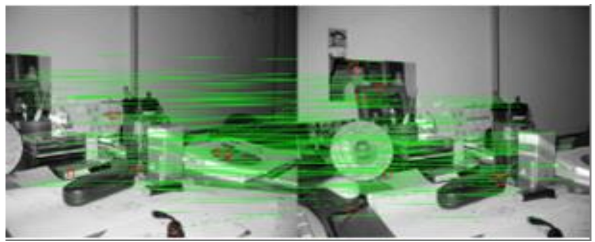


(d)



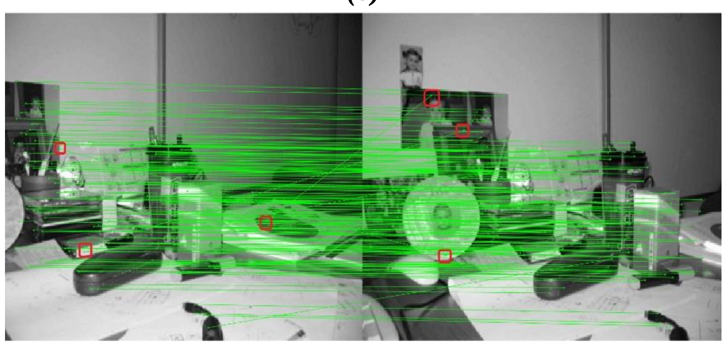
(e)

Fig.2. Database Images,(a)(b) ,images from database [29], (c)images of Hafiz from Shiraz, Iran (d) (e) images from Dubai.



(a)

(b)



(c)

Fig.3. Image matching. (a) matching by SIFT-CAR [26], (b) matching by SIFT-SRSRANSAC [31] ,(c) matching by SIFT-A-RANSAC [1].

3.1. Evaluation of the Performance of the A-RANSAC Algorithm on the Image Mosaicing Process

In this section, two images with changing angles are used to evaluate the A-RANSAC performance in removing incorrect matches. Fig. 2 shows the results of the deleted matches. The correct matches that were mistakenly deleted by the RANSAC algorithm are marked with a square.

The total number of matches in A-RANSAC [1] is more than that in SIFT-CAR and SRS-RANSAC methods. On the other hand, the number of incorrect matches in A-RANSAC method [1] is less than that in SIFT-CAR and SRS-RANSAC [31] methods, which shows the effective performance of SIFT-A-RANSAC method [1] in eliminating incorrect matches.

As seen in Table.1, the A-RANSAC function is better than other methods.

3.2. Evaluation of the Performance of the Suggested Blending Method in Image Mosaicing

In this experiment, the function of the suggested blending method is used over two images with changing angles, the results are shown in Fig. 4.

As seen in Fig.4, in the base Gaussian weighted function method and the suggested approach, the blending process is better than the weighted average method because the yellow rectangle shows the parts that are seen in the base Gaussian weighted function method and the suggested approach, but not in the base Gaussian weighted function method. The black parts in the suggested approach are less than the base Gaussian weighted function method, which indicates the effective performance of the suggested approach. Fig. 5 shows the boundary line of the blending method. As it seems, the boundary line in the suggested approach is insignificant and has been able to overlap well.

Table 1. ***Experiment Results Of Methods*****.**

Method	Image type	SITMMC	SITMMR	precision
SIFT-CAR [26]	DATA1	0.936	0.063	0.945
SIFT-SRS [31]		0.60	0.4	0.70
A-RANSAC [1]		**0.96**	**0.04**	**0.97**
SIFT-CAR [26]	DATA2	0.853	0.146	0.864
SIFT-SRS-R [31]		0.763	0.236	0.774
A-RANSAC [1]		**0.930**	**0.06**	**0.935**
SIFT-CAR [26]	DATA3	0.80	0.2	0.813
SIFT-SRS-R [31]		0.831	0.168	0.842
A-RANSAC [1]		**0.878**	**0.121**	**0.882**
SIFT-CAR [26]	DATA4	0.848	0.151	0.855
SIFT-SRS-R [31]		0.834	0.165	0.842
A-RANSAC [1]		**0.851**	**0.148**	**0.857**
SIFT-CAR [26]	DATA5	0.839	0.160	0.844
SIFT-SRS-R [31]		0.807	0.192	0.819
A-RANSAC [1]		**0.933**	**0.066**	**0.941**

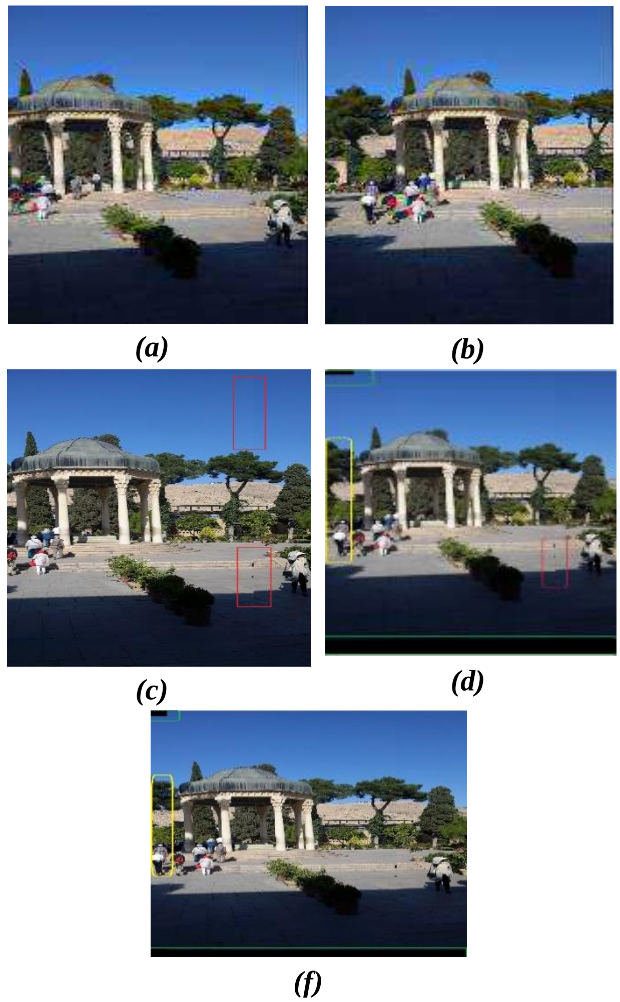


Fig.4. Image mosaicing, (a) reference image, (b) sensed image, (c) image mosaicing by weighted average method [32], (d) image mosaicing by base Gaussian weighted function [33], (f) image mosaicing by the suggested approach.

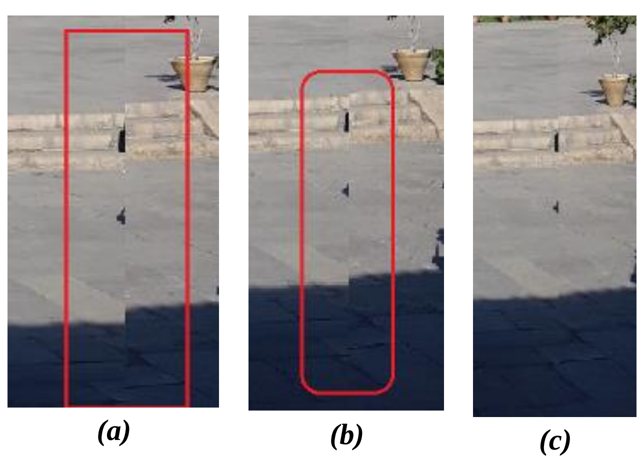


Fig.5. Image Mosaicing, (a) Blending By Weighted Average Method [32], (a) Blending By Base Gaussian Weighted Function [33], (c) Blending By The Suggested Approach .

Table 2. Average median error of methods.

Method	median error
weighted average method [32]	6.318
Gaussian weighted function [33]	5.430
Suggested blending method	3.629

Table 3. *Nomenclature.*

SIFT	Scale Invariant Feature Transform
RANSAC	RANdom Sample Consensus
A-RANSAC	Adaptive RANSAC
RKEM-SIFT	Redundant Keypoint Elimination method-SIFT
PROSAC	Progressive Sample Consensus
RMSE	Root-Mean-Square Error
SITMMR	sum of inverse total number of matching and mismatch ratio
SITMMC	subtraction of inverse total number of matching and matching correctness

As is shown in Table. 2, the suggested blending function is better than other methods.

4. CONCLUSION

In this article, a novel approach to image mosaicing process was introduced using a combination of the SIFT method, the A-RANSAC method, and the suggested blending method. Initially, using the SIFT algorithm, features were extracted from images. Then, to reduce the incorrect matches, the threshold value was selected in the A-RANSAC algorithm in a manner that, the number of removed matches and the root mean square error be optimized simultaneously. Finally, the proposed Gaussian weighted function was used to combine the images. The proposed approach improves the image mosaicing accuracy. In the future, we will try to remove the border lines by proposing a new method for image blending.

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