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An improved method for eliminating ghosting in image stitching

Aiguo Li[1], Shuai Zhou[2], Rui Wang[3]
College of Computer Science and Technology
Xi'an University of Science and Technology
Xi'an, China
E-mail: Li_ag@sina.com, m18092971720@163.com, 2467203605@qq.com

***Abstract*—In the process of image stitching, Image stitching algorithms based on SIFT (Scale Invariant Feature Transform) feature have the robustness to the complex transformation between images. However, image stitching appears discontinuous and ghosting in the image registration. We proposed a fast image stitching algorithm to eliminate the seam line and ghosting. The algorithm through two cameras to capture images, and then combined with the OpenCV library to process image splicing using the improved fusion algorithm for the overlapping areas of two images. Firstly, the algorithm extracts the overlapping range of SIFT features of image mosaics. Secondly, the algorithm used the RANSAC algorithm to compute the homograph matrix H. Thirdly, an integral image without seam line was received by the combination of the improved image fusion algorithm which realizes seamless transition between the weight coefficients of images and changes in distance. The experimental results show that the algorithm not only eliminates the seam 1ine and ghosting effectively, but also improves the speed of image stitching.**

Keywords-SIFT features; image stitching; seam line; ghosting; Weight coefficients

I. Introduction

This Image stitching is an important part of computer vision and mathematical image processing. Image stitching technology has important applications in traffic video surveillance, remote sensing and so on. The most commonly used methods of image stitching on the main three: (1) Based on the transformation domain registration, intuitive, fast, easy to implement hardware, but for the situation of rotation and scaling, will produce obvious the seam line. (2) Based on gray-scale registration, this method requires a higher gray-scale attribute of the image, and only applies to images with smaller gradations. (3) Based on feature point matching, SIFT has strong robustness to brightness, rotation, scale, set deformation, blur and image compression, and provides good feature points. At present, the commonly used image stitching includes feature extraction, image registration and image fusion. Image fusion technology is an important part of the image splicing, is to be integrated within the image of the complementary information or significant information into an image which extract the two images useful information, and the image of the redundant information removed, and finally form a complete image of the image. Due to the difference of overlap between two images, there will be "ghosting" and "the seam 1ine" in the image after stitching directly. So after the registration of the image in the fusion process how to remove the "ghost" and the seam line is a very important part.

Over the years, for stitching has certain achievements at home and abroad. In 2004, Lowe proposed an image local feature description operator (SIFT), which is based on scale space, which is invariant to image scaling, rotation and even affine transformation[1]. The algorithm can solve the problem of image distortion, such as partial occlusion, rotation scaling and viewpoint change, but the high dimension of feature descriptor leads to the complexity of calculation and the matching time is too long. Yanke et al proposed to use the PCA-SIFT method to reduce the dimension of feature description[2], but that increased the amount of calculation without any prior knowledge, Grabner et al improves the computing speed of SIFT by integral image[3]. Can Ding et al proposed a descriptor to reduce the original 128 dimension to the 64 dimension[5-7], and the experimental results show that the matching speed is improved when the matching accuracy is guaranteed. C. M. Zou et al is used to gradually out of the algorithm for image fusion[8], thereby improving the efficiency of image stitching. But when there are moving objects, there will be the emergence of splicing gap. P. Liu et al firstly extract and match feature points[9], which used RANSAC algorithm to calculate the transformation matrix H , and finally use the improved weighted fusion algorithm which is at the basis of gray difference and edge detection to detect moving object and then fuse image. Z. Qu et al firstly extracted SIFT features in the given area of the full image[10]. After obtaining the corresponding feature, we used the RANSAC algorithm to compute the homograph matrix H. Then, an integral image without seam line was received by the combination of the best seam line and the improved image fusion algorithm. Based on SIFT feature matching and pixel weighting blending methods, an algorithm for robust and accurate image stitching was proposed by N. Cao[11], to solve the issues of image stitching in the larger scale, angle of view and illumination transformation. Q. B. Xu et al. In order to meet the needs of various visual simulation system for panorama[12], an algorithm based on SIFT operator is proposed, being able to mosaic multiple images to acquire the wide angle panorama, and verifies the validity of the algorithm. S. Q. Chen proposed an improved energy function [13] based on the Canny edge detection operator, which aims to minimize the gradient difference of overlapping regions. The result of optimal seam which were used energy function that put forward by experiment were compared to another result which were used error of brightness, gradient, gradient

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sum, weighting of gradient difference and gradient sum, Canny edge detection operator that were energy functions selection. Experiments showed that it can effectively reduce the gap of mosaic image. S. Wang is using the SURF algorithm to extract feature points[14], then to match the feature point and to transform image, finally to use nonlinear weighted fusion algorithm of overlapping boundary region, setting the weights of small changes, while the central part of a relatively large change, to achieve image quickly smooth transition effect. In this paper, we propose a method to adjust the brightness based on the optimal seams only in the brightness space. The experimental results show that the time efficiency of image registration can be improved effectively and the brightness adjustment effect can be improved. M. M. Zhao was used the phase correlation method to determine the position relation between the images in the process of image splicing[15], and then used SIFT feature points to register two images, and added the HIS to the traditional fade-and-fit fusion algorithm, finally achieved the Seamless stitching of the image that brightness is uniform.

To sum up, the similarity between an image and other images is matched, but when the scene is moving, it is easy to produce ghost, which brings great difficulty to the image matching. In order to solve this problem, this paper first through the registration of the original image by using SIFT algorithm, and then find out the overlapping part, to achieve a smooth transition between the weight coefficients of the image with the change of distance, and finally realize mosaic.

II. SIFT ALGORITHM PRINCIPLE

A. Feature Detection

The SIFT algorithm is an algorithm for extracting local feature. In the scale space, the extreme points are found, and the position, scale and rotation are not deformed. Gaussian convolution kernel is the only linear transformation kernel to achieve scale transformation. Lowe uses Gaussian kernel to construct the scale space of image that characteristic points are derived from the extreme points of differential Gaussian scale space. In the differential Gaussian image, the maximum and minimum values are obtained by comparing the 26 fields of each pixel with the current scale, upper scale, and lower scale. If it is an extreme point, it is determined as a key point.

The main principle: The input image is continuously filtered and sampled by Gauss function of different scales to form the image of the Gauss pyramid, we obtain the multi-scale spatial representation of Pyramid by subtracting the two Gauss images from the neighboring scales. It has the characteristics of simple calculation, which is the normalized DoG operator. Each point in DoG scale space was compared with the points of the adjacent scale and the adjacent position one by one, obtaining local extreme position which was the location of the key point and the corresponding scale. In order to improve the ability of anti-noise, the feature points of the contrast and the edge points were removed by fitting the position and scale of the two dimensional function. Therefore, the scale space of an image (x, y) is defined as L(x, y,σ) (where σ represents the variance of Gauss's function), which is obtained by image I(x, y) convolution with kernel G(x, y):

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y) \tag{1}$$

$$G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \tag{2}$$

The construction of the image of Pyramid: the image of a total of O group of Pyramid, each group has S layer, the next set of images from the previous set of images obtained by sampling.

The DoG operator is shown as follows:

$$\begin{aligned} D(x,y,\sigma) &= \left(G(x,y,\sigma) - G(x,y,\sigma) * I(x,y)\right) \\ &= L(x,y,k\sigma) - L(x,y,\sigma) \end{aligned} \tag{3}$$

B. Construction of Descriptor

Before constructing the SIFT descriptor, a main direction is given for each key point. The main direction is the direction corresponding to the gradient direction histogram of each point in the neighborhood of the critical point. The following descriptors are constructed in this direction, so that the constructed descriptor is invariant to rotation. The mode and direction of the gradient of each pixel is formula (4), (5):

$$\theta(x,y) = \tan^{-1}\frac{L(x,y+1)-L(x,y-1)}{L(x+1,y)-L(x-1,y)} \tag{4}$$

$$m(x,y) = \sqrt{\left(L(x+1,y) - L(x-1,y)\right)^2 + \left(L(x,y+1) - L(x,y-1)\right)^2} \tag{5}$$

The gradient direction of each key point is mainly determined by its neighborhood pixels in the direction of the gradient direction that statisticed by the gradient histogram statistics. The range of the gradient histogram is (2-2 PI).The peak value of the histogram represents the main direction of the key point. In the histogram, if there is another peak equivalent to 80% of the peak energy, the direction is defined as the auxiliary direction of the critical point.

The construction process descriptor: for any one of the key points in the scale space (where the Gauss Pyramid one layer), we can take a key point in the center of the pixel size of 16*16 in the region, then divide the neighborhood evenly into 4*4 sub regions, calculating the gradient direction histogram for each sub region. Then, the histogram of the 8 directions of the 4*4sub-region is sorted according to the position, so as to form a 4*4*8=128 dimensional vector, which is SIFT descriptor. Among them, the first dimension corresponds to the first gradient direction in the first sub region, the second dimension corresponds to the second gradient direction of the first sub region, and the ninth dimension corresponds to the first gradient direction in second sub regions, and so on. Then, the SIFT features are normalized to further reduce the influence of the illumination transformation.

III. FEATURE POINTS MATCHING

Corresponding to the same view of the scene image, the transformation relationship between adjacent images can be described by the following 8 parameters of the projection transform model:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} m_0 & m_1 & m_2 \\ m_3 & m_4 & m_5 \\ m_6 & m_7 & 1 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{6}$$

(x', y') and (x, y) are points to be matched for the two images, $m_0 \sim m_4$ is the scale and the amount of rotation, m_2, m_5, show the horizontal and vertical translation of the amount respectively, m_6, m_7 represent the horizontal and vertical direction of the shape variables. To transforms equation (6) into the 8 parameter linear equations and find the eight parameters that requiring at least 4 pairs of matching points. Usually in the registration of the two images over-lapping area, there are also individual gray values close to the point[4]. By using the RANSAC algorithm to eliminate the false matching, we can get a set of basic matching points. The number of the points is much larger than 4 pairs, and the images to be registered are fused by H projection in the same coordinate system. We can match with SIFT algorithm to calculate the conversion matrix M which shows that:

$$M = \begin{bmatrix} 1.1193 & -0.1364 & 502.6568 \\ 0.0367 & 0.9984 & -10.5523 \\ 8.9491 & -0.0001 & 1.0000 \end{bmatrix} \tag{7}$$

We can draw conclusions from the above data, that the vertical shape variable m_7 is very small and negligible. According to the actual situation, you can make m_7=0, and use a 7 parameter matrix instead of 8 parameters.

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} m_0 & m_1 & m_2 \\ m_3 & m_4 & m_5 \\ m_6 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{8}$$

IV. IMAGE FUSION

After obtaining the transformation relation between the images, the overlapping positions of the images can be determined. But in the actual image acquisition process, the offset of acquisition devices, difference of images caused different angle, registration method and geometric transformation method that is not accurate, changes in object position, different color and texture caused by physical factors in the image acquisition equipment and other objective factors, which will affect the image mosaic effect, but what is more important is that if there is an object in motion, there will be a clear ghost, when the moving object is easy to produce ghost in the overlapping region of the image mosaic process. As shown in figure 1:

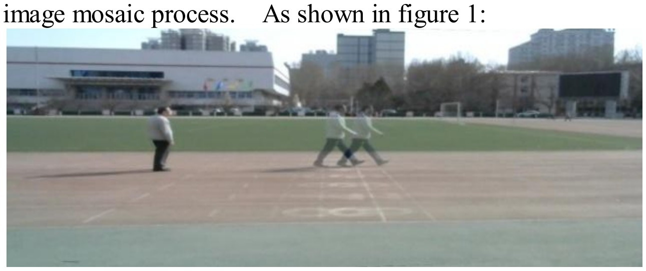

Figure 1. As shown in the figure.

A. Weighted Average Fusion

In practical applications, the most common is the weighted average fusion, fusion formula is as follows:

$$f(x,y) = \begin{cases} f_1(x,y), & (x,y) \in f_1 \\ \omega_1 f_1(x,y) + \omega_2 f_2(x,y), & (x,y) \in (f_1 \cap f_2) \\ f_1(x,y), & (x,y) \in f_1 \end{cases} \tag{9}$$

Among them, f is the fused image, f_1 and f_2 are overlapping parts of the image, ω_1 and ω_2 are f_1 and f_2 in the overlap region corresponding to the weight of the pixel, and to meet the $\omega_1 + \omega_2 = 1$, $\omega_1 < 1$, $\omega_2 < 1$.. When $\omega_1 = 0.5$ and $\omega_2 = 0.5$, the equivalent of two image pixel averaging.

B. Improved Weighted Average Fusion

If the method of fusion is adopted directly, the ghost will appear in the overlapping area of the image which caused by moving object. When the adjacent images are sliced, we needs to be integrated into the overlapping area of adjacent image information in order to achieve a smooth transition between images, In other words, a point pixel value in overlapping pixel region of the image mosaic is derived from the corresponding point value of adjacent images. In this paper, based on the accurate registration of SIFT, using only one image information in moving objects area of image mosaic, and based on determining the moving object region, we used the improved weighted average method. In the images of f1 (x, y), If the pixel is closer to the central area of the image, then the weight value of the pixel point will be greater, on the contrary, if the pixel is closer to the edge area, the weight value of the pixel points will be smaller. The whole process is realized by C++, the experimental results verify the effectiveness of the algorithm. The algorithm of weighted fusion image is shown as follows: the width of the reference image is L_x:

$$\omega_1 = \left(1 - \left|\frac{x}{L_x}\right|\right), \omega_2 = \left|\frac{x}{L_x}\right| \tag{10}$$

$$f(x,y) = \left(1 - \left|\frac{x}{L_x}\right|\right) f_1(x,y) + \left|\frac{x}{L_x}\right| f_2(x,y), (x,y) \in (f_1 \cap f_2) \tag{11}$$

Among them, f is the fused image, f_1 and f_2 are overlapping parts of the image, ω_1 and ω_2 are f_1 and f_2 in the overlap region corresponding to the weight of the pixel, and to meet the $\omega_1 + \omega_2 = 1$, $\omega_1 < 1$, $\omega_2 < 1$.

V. EXPERIMENTAL SIMULATION AND ANALYSIS

The general image mosaic method has high time complexity and low precision. The image is discontinuous and ghost when registering. With the continuous improvement of the algorithm, the image fusion algorithm based on SIFT algorithm and the improved fusion weighted fusion algorithm can effectively improve the image registration rate and stability, in addition to commendable robustness and security, the matching time has been shortened, but also effectively eliminate ghosting. The size of two original images is 640*480. The experimental results are shown in figure 2. From the following picture we know that in the overlap region with the object movement situation, in the incremental weighted average fusion algorithm, the ghost will be generated, as shown in figure 3, the improved weighted average fusion algorithm effectively removes ghosting. As shown in figure 4. In order to better compare the fusion effect, and compared with the method described in article[8], this paper uses time and clarity as the standard. Similarly, the experimental results of the static image stitching is also very good.

Definition: this gradient value can reflect the clarity of the image, with the ability to express the characteristics of small details and texture changes.

$$g=\frac{1}{(M-1)(N-1)}\times\sum_{i=1}^{(M-1)}\sum_{j=1}^{(N-1)}\sqrt{\left(\frac{\partial f(x_i,y_i)}{4\,\partial x_i}\right)^2+\left(\frac{\partial f(x_i,y_i)}{4\,\partial y_i}\right)^2} \tag{12}$$

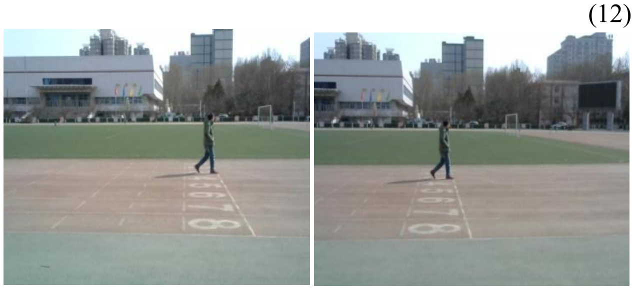

Figure 2. Original image

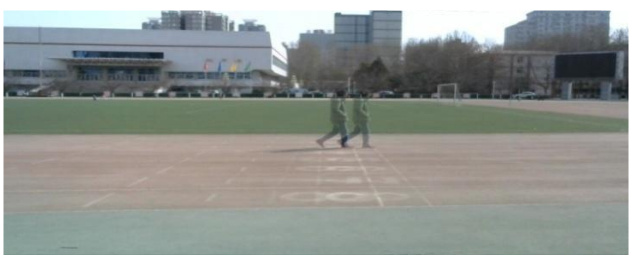

Figure 3. Article fusion.

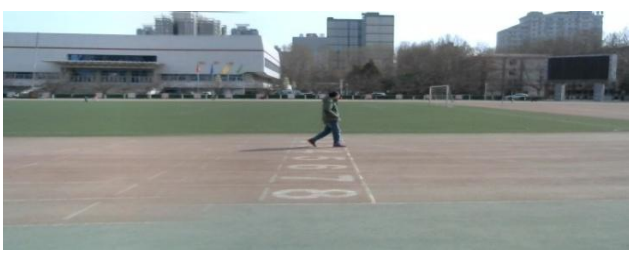

Figure 4. Improved weighted average fusion.

TABLE I. Comparison between the proposed method and the previous method for image stitching.

	Time	***Clarity***
The fade in fade out method（object motion）	***2.3s***	***1.24625***
Proposed method（object motion）	***1.4s***	***1.29131***
The fade in fade out method（no object motion）	***1.8s***	***1.46143***
Proposed method（no object motion）	***0.8s***	***1.53232***

CONCLUSION

Image stitching is an important technology in the field of computer vision. In this paper, a new method of moving scene image mosaic based on SIFT feature and improved weighted fusion algorithm is proposed, which extracts the feature transform matrix, then obtains the overlapping region of the output image, and finally uses the improved weighted average fusion algorithm for image fusion. The experimental results show that the improved weighted fusion algorithm for image fusion is able to eliminate ghosting and get better image mosaic effect. However, there are also shortcomings in this paper, that is, the speed of the video fusion is relatively slow, so in the future research and improvement is how to improve the speed of the algorithm.

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