Research and Analysis of Key Technologies in Image Mosaic

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Abstract

Considering the traditional image match optimization algorithm is low efficiency, and ghosting artifact in the field of image stitching is a common problem and the elimination of it is not an easy task. In this paper, we presents that through cluster analysis for different scales of feature points to obtain the global and better stable affine transformation, and the matched feature points are filtered consistency by affine transformation, so it can eliminate the false matching points. An improved dynamic programming (DP) method is presented to find the best stitching line. The improved weighted average method is used to achieve smooth stitching results and eliminate intensity seam effectively. Experimental results show that the proposed algorithm has good result of removing false matching and ghosting artifacts, it is robust.

Keywords: Image mosaic; clustering algorithm; dynamic programming ; Image fusion

1. Introduction

Image stitching is a process that combines several photographic images with overlapping field of view (FOV) to produce a panoramic format image or a high-resolution image. As shown in Fig 1. Image mosaic technology is widely used in military and civilian fields, such as satellite remote sensing, UAV surveillance and searching, robot vision, medical probe, electronic image stabilization and virtual reality, *etc.*, [1,2].
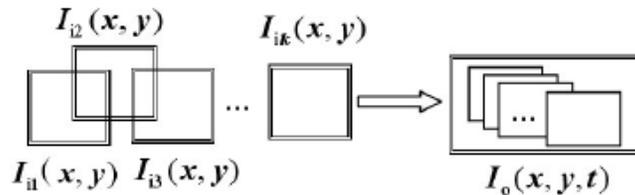

Figure 1. Sequential Images to be Mosaicked

Generally, image mosaic includes four steps: Geometric correction of images, Preprocessing of images, Image match and Image fusion. Image match and image fusion are the key of image mosaic. At present, the method that based on feature is simple and steady which is the hotspot in domestic and foreign. In 2006, Herbert Bay [3, 4] proposed Speed up Robust Features (SURF), which is a fast and robust features match algorithm. This algorithm has scale invariant feature and rotation invariant feature. Moreover, it is partially invariable for variant illumination, affine and perspective transformation. SURF surpasses or approaches

the similar methods in repeatability, distinctiveness and robustness, and this algorithm has obvious superiority in speed.

Although image mosaic has received a great deal of attention over the years, it remains a challenging problem. After the extraction of feature points, how to filter the false and unstable points from a large number of matching feature points in a set of mutually superimposed images, and to reduce poor effect of image mosaic which caused by a larger error affine transformation in the mosaic process is a problem. In order to get an accurate affine transformation, we need effectively filter mismatched and unstable matching feature points. But the efficiency of the traditional Ransac[5] algorithm is very low, which greatly affected the efficiency of mosaic algorithm. Meanwhile, image fusion is another key part of image mosaic, it is mainly used to eliminate seams and ghosting artifacts, the effect of that impact whether natural the mosaic images are. At presents, there are many smooth transition algorithms, but they still can be far from satisfactory in image fusion with moving objects.

In order to improve the efficiency of stitching algorithm and the quality of the fused image, this paper improves 2 key parts. The cluttering algorithm is used for different scales of feature point, and the parameters of global affine transformation are got by the clustering algorithm, which is used to filter the matched point. We propose a dynamic programming (DP) method to find the best stitching line. The improved weighted average method is used to achieve smooth stitching results.

2. Image Match Algorithm Based on Scale-Clustering Affine Filtering

Due to the shooting angle of the picture, and the difference of camera parameters and shooting conditions, affine transformation generated by local matching, it will lead to large stitching errors. How to build a method which can effectively eliminate the false matching points, and also can find the global optimum matching pairs, maintain the matching points by filter algorithm stability, it is the key to solve this problem. The edge points in matching feature points distribution area has double significance. First, it is importance sampling area which to build a global match pairs; second, it is area where high probability occurrence of false matching point. The false match points often appear at the edge of the feature point area and away from the dense feature point area. How to eliminate the false match points in the region, and retain the effective feature points become the key of algorithm design.

The most correct match points exist in the form of clusters, we can build corresponding global match pairs to filter false match point, through the center feature points of each cluster. In this paper, K-medoids algorithm is used to cluster [6] the feature points, because clustering algorithm can get central feature points of each cluster. While K-medoids clustering algorithm can ensure that the cluster centroids as effective feature points, that have the role of eliminating the outliers.

The image feature points have statistical description of different scales and directions. The feature points at different scales have different distribution and quantity. This paper selects the feature points with the description of position and scale in the image. So they have multiple attributes of the scale and coordinate, and obtain a more representative cluster centroid. The filter algorithm based on scale clustering is as follows.

Set image F1 and F2 for the image to be stitched, already they get extraction feature points through the surf operator and match characteristic points based on similar principles. The feature points in the F1 and F2, we get feature point set respectively, $f_1 = \{f_1^1, f_1^2, ..., f_1^m\}$ and $f_2 = \{f_2^1, f_2^2, ..., f_2^m\}$. Each feature point is described by 3 values: $f_p^q = (x, y, \sigma)$, (x, y) is the pixel coordinates of feature points in the image, R is the scale values of the feature point. Set the clustering number is 4, because building affine

transformation requires at least four match pairs of corresponding pixels, the algorithm steps are as follows:

Step 1 We get the surf feature points from F1 and F2, and match images with similar principles, eliminate unmatched feature points, then we get f_1 and f_2, build the description of feature points (x, y, σ). We use weighted Euclidean distance as distance formula.

Step 2 Set the number of clusters n = 4, it selects n objects as the cluster centroid randomly.

Step 3 Each point in the f_1 is assigned to the nearest centroid, which form n clustering clusters.

Step 4 Centroid of each cluster is recalculated.

Step 5 If the centroid change, jump to step 3, if not change, go to step 6.

Step 6 The quadrilateral outlined by four centroids is divided into two triangle, we use correspondence points of these four centroids to calculate affine formula as (1):

$$\begin{bmatrix} \varphi_x(x, y) \\ \varphi_y(x, y) \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} \tag{1}$$

Step 7 we use the affine equations from formula (1) to filter uniformly match pairs in the f_1 and f_2. If the affine error threshold is less than w, we reserved, If not, we eliminate it as the error matching points. The method can filter false match and larger error feature points effectively, though building the affine transformation of global description.

3. DP Method to Find the Best Stitching Line and Fusion Method

3.1. DP Method to Find the Best Stitching Line

In the process of image mosaic, sensing device offsets, the difference on the brightness of the image caused by imaging angle, registration method and geometric transformation method are imprecise, the difference of the colors and textures of image caused by physical factors etc, they all affect the image mosaic effect. If we fusion image directly, it will appears ghosting artifact in the overlapping areas of the image. Therefore, we need to find the best stitching line [7] in the overlapping area of the two images, which can not only avoid the ghost artifact, but also overcome the impact of seam as much as possible.

This paper uses the method of Dynamic Programming (DP) [8] to find the best stitching line. Firstly, the luminance between the two images to be adjusted, and it reduce the difference in the overlap area. Set the image A, B for the two images to be stitched with overlapping area, *M, N* is the length and width of overlap area, OV_A and OV_B are overlap areas of two images, brightness adjustment factor is set to σ, then

$$\sigma = \frac{\dfrac{1}{M \bullet N} \sum_{i=1}^{M} \sum_{j=1}^{N} OV_A(i, j)}{\dfrac{1}{M \bullet N} \sum_{i=1}^{M} \sum_{j=1}^{N} OV_B(i, j)} \tag{2}$$

When $\sigma > 1$, we adjust the luminance value of the image B, size is σ; when $\sigma < 1$, we adjust the luminance value of the image A, size is $1/\sigma$. After exposure difference correction, we can start to find the best stitching line, The calculated energy matrix is presented by *Sem*, direction matrix is *Dir*, energy matrix [9] is presented by *T* in the formula (3), the overlapping

area of the difference image size is set to m*n (If there are irregular overlap area, they can be extended to the rule area, which can be just involved in the irregular areas). Set the coordinates of the start point P is (μ, v) , When the overlap area is rule area, $\mu = 1$, $v = n/2$;when the overlap area is irregular area, P is the intersection, specific ideas:

$$T(i, j) = \alpha \bullet E_c(i, j) + \beta \bullet E_G(i, j) \tag{3}$$

Step 1 Initialization. According to the formula (3), we calculate the energy matrix T, and according start point of the best stitching line to initialize the first line of direction matrix Dir, and it changes the first line energy value of energy matrix Sem. The rule is: The point is located in the right of start point, they all point the left point in turn, the right point of P point in direction matrix Dir is set to 4. Similarly, the point in the left of start point, also point the right point in turn, the left point in direction matrix is set to 6, the direction value of P point is set to 0.

6	6	P	4	4
A	C			
B				

Figure 2. Initialization

When it modifies the first line direction matrix gradually, the corresponding energy value of pixel point in accumulated energy matrix increase from the point p to the two sides, as in formula (4)(5)

$$\text{If } \boldsymbol{j} > \boldsymbol{v} , \quad Sem(m, j) = Sem(m, j-1) + T(m, j) \tag{4}$$

$$\text{If } \boldsymbol{j} < \boldsymbol{v} , \quad Sem(m, j-1) = Sem(m, j) + T(m, j-1) \tag{5}$$

Step2 We take i line as an example, to illustrate executive process of the algorithm in other lines, it set point A is located on the i line, j column in the Figure 2.

First of all, the energy accumulated value and direction update from left to right, the accumulative energy value is calculated as follows:

$$\begin{cases} M = Min\{Sem(i-1, j-1), Sem(i-1, j), Sem(i-1, j+1), Sem(i, j-1)\} \\ Sem(i, j) = T(i, j) + M \end{cases} \tag{6}$$

It can be seen from the above formula, when the energy accumulated value update from left to right, due to the energy accumulated value of pixel point on the right side is not updated, so there is no comparison. After find the minimum value points, $Dir(i, j)$ is set to the direction value of the point, $Sem(i, j)$ is set to the current calculation sum value. Also we need note in this process that it is special case of edge points.

Secondly, it scan from right to left, the energy accumulated value is calculated as follows

$$\begin{cases} M = Min\{Sem(i-1, j-1), Sem(i-1, j), Sem(i-1, j+1), Sem(i, j-1), Sem(i, j+1)\} \\ Sem(i, j) = T(i, j) + M \end{cases} \tag{7}$$

The steps is similar with "left to right scan", the difference is when it scan reversely, the point of comparison for 5, respectively is direction of 1, 2, 3, 4, 6. In this process, if energy accumulated value of the current point is smaller than from left to right the energy

accumulation value, it need replace the energy accumulated matrix values again, and it modify the direction value of direction matrix, and avoid the coreference phenomenon, it is shown as Figure 2, if A point C, then C cannot point A. Instead, it selects another point. When it executes to the left, this line end, jump to the next line, and it continue to execute from right to left scan.

Step 3 When it scans to the last line, the scanning complete, we obtain the final orientation matrix and the energy accumulated matrix. We count energy value of the e last line, which is in the energy accumulate matrix, and obtain the coordinates of the minimum energy point, which point is set to termination point.

Step 4 According to the termination point of direction matrix *Dir*, we search reversely, it is shown as Figure 2, B point A, so the value of B in direction matrix is 2.If B is the current point of stitching line, then the next point in stitching line is A point. It continues to search the next point, which point A point to, and mark the found point. When the found point is start point, and the search end, the best stitching line is formed by the mark point along the way.

3.2. The Improved Fusion Method

During the experiment we found that the sequence image mosaic directly, when the brightness of the adjacent gray image overlapping area is much difference, even if exposure correction method corrected, the best stitching line cannot overcome the emergence of the seam completely. Therefore, after stitching line optimization, how to eliminate the stitching seam, and fusion of image mosaic, is also very important. In order to utilize the stitching line fully, and to eliminate the seam and to retain overlapping image information of seam-line on both sides, so that the image gray value of the stitching line evenly on both sides of the transition, this paper adopt the weighted average method [10,11]to realize image fusion.

According to the relationship of distance between the pixels within the overlap area and the boundary of the overlapping area, If I_1, I_2 is two registered images, we stitch and fuse the images I_1, I_2, the fused image can be expressed as:

$$(x, y) \in (I_1 - (I_1 \cap I_2))$$
$$(x, y) \in (I_1 \cap I_2) \tag{8}$$
$$(x, y) \in (I_2 - (I_1 \cap I_2))$$

Parameter d_1, d_2 have concern with the width of overlapping area, and $d_1 + d_2 = 1$, $0 < d_1$, $d_2 < 1$。 In the overlapping area, d_1 from 1 to 0, d_2 from 0 to 1, it is shown as Figure 3 (a) (solid line is expressed d_1, broken line is expressed d_2). Thereby it achieves the slow smooth transition, which from I_1 to I_2 in the overlap region. In this method, overlapping area of the mosaic image sequence in the image spatial position is not consistent, especially the moving objects will be unable to avoid ghosting and ghosting artifact which is very obvious.
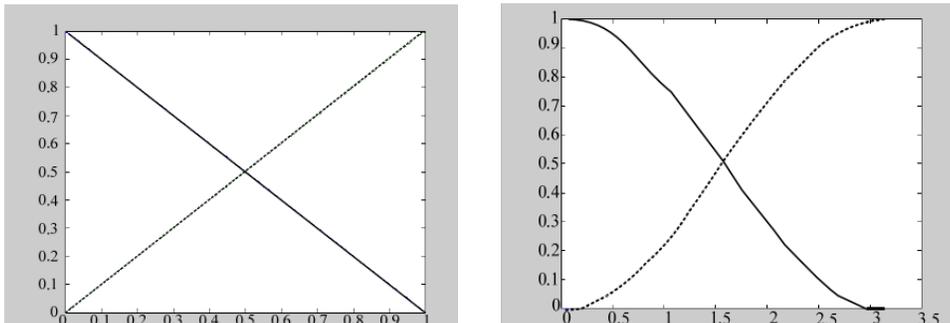
(a) 0-1gradient weighting function   (b) Cosine gradient weighting function

Figure 3. The Weight Function of d_1, d_2

This paper improved the algorithm, the weights of d_1、d_2 introduce the function with cosine transform, where $d_1 = \frac{1}{2}(1+\cos\theta)$, $d_2 = \frac{1}{2}(1-\cos\theta)$, $0 < \theta < \pi$, the value of θ is determined by the width of each line in the overlap region, the initial value is 0. If the width of overlap region in some line is w, then $\theta_i = \pi / w$, the overlapping area of this line from left to right with the pixel position increment. As the Figure 3(b) shown, (solid line is expressed d_1, broken line is expressed d_2), weights d_1, d_2 decreases in the overlap region and increased velocity gradient all easer than 0-1, this will ensure that the weights of reference image I_1 is greater, which overlapping area in the left side of the middle line, and the weights of reference image I_2 is greater, which overlapping area in the right side of the middle line, thereby it effectively reduces the ghosting and ghosting artifact near left and right edges of the overlapping area. The fused images as image I_1 and image I_2 again weighted fusion using this method, so it can increase weight of I_2 in the mosaic image, thereby eliminating ghosting phenomenon of overlapping areas around the midline. Thereby it eliminates ghosting artifact of overlapping areas around the midline.

4. Experiment Result and Analysis

We select 4 images, and do the comparative experiment between the feature clustering filter algorithm and traditional Ransac algorithm which eliminates false matching point, we can get the number of matching pairs, the mean and variance of feature point offset. The Ransac algorithm experimental results show that there is a big fluctuation on the number of eliminating match points and feature points offset. The algorithm in this paper is better than Ransac algorithm to eliminate the mismatching points and feature points offset. It is shown as Table 1.

Table 1. The Comparisons of Two Algorithms

Algorithm	Offset mean of feature point	Variance of the offset	Number of reserved match pairs	Variance of the number of reserved match pairs
Ransac Algorithm	106.958	3319.678	215.2	12318.9
Algorithm of this paper	9.454	0	288.7	0

Where Offset of feature point is the sum of offset, that generated by affine transformation of each feature point. Set offset degree is s, the feature points to be transformed is (x_i, y_i), i = 1, …n, then it stitches after affine transformation φ, the new location is $(\varphi_x(x_i, y_i), \varphi_y(x_i, y_i))$, the calculation of stitching offset degree is:

$$s = \sum_{i=1}^{n} \sqrt{(\varphi_x(x_i, y_i) - x_i)^2 + (\varphi_y(x_i, y_i) - y_i)^2} \tag{9}$$

The four images are the building of my university, they are shown in Figure 4, and we use the algorithm in this paper to stitch and fuse these images. The effect of image matching and

filtering is shown as Figure 5, and the effect of image fusion and eliminating seam is shown as Figure 6.
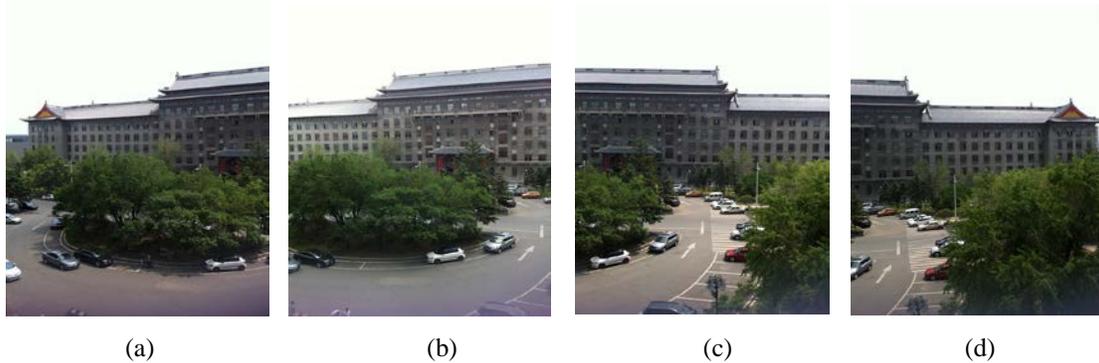

| (a) | (b) | (c) | (d) |

Figure 4. The Building of University

Figure 5. Effect of Image Mosaic

Figure 6. Effect of Image Fusion

5. Conclusion

In this paper, feature points are extracted by the basis of SURF algorithm, cluttering algorithm is used for different scales of feature points. The parameters of global affine transformation are got by the clustering algorithm, which improve the accuracy of image stitching, and has good stability. We propose an improved dynamic programming method to find the best stitching line. The improved weighted average method is used to achieve smooth stitching results and eliminate intensity seam effectively. The algorithm is better than traditional fusion algorithm to reduce the probability of ghosting artifact, and the quality of fusion is higher. The experimental results show that the proposed algorithm has good result of removing false matching and ghosting artifacts, it is robust. But the calculation time is a little longer, so it is not suit real-time image mosaic, we need to improve the computational efficiency further.

Acknowledgements

References

[1] X. Kai, G. Hengye and Z. Tianwen, "A survey of image mosaics technology", Acta Electronica Sinica, vol. 4, no. 32, **(2004)**.

[2] J. Tie, Z. Guibin and S. Ao, "Review of Research Status of Panoramic Image Mosaic Technology", Journal of Chongqing Technology and Business University(Natural Science Edition), vol. 12, no. 29, **(2012)**.

[3] H. Bay, "From wide-baseline point and line correspondences to 3D", Zurich: ETH Zurich, **(2006)**.

[4] H. Bay, T. Tuytelaars and L. Van Gool, "SURF: speeded up robust features", Proceedings of the European Conference on Computer Vision, Austria, **(2006)** May 7-13.

[5] C. Fuxing and W. Runsheng, "Fast RANSAC with preview model parameters evaluation", Journal of Software, vol. 8, no. 16, **(2006)**.

[6] J. W. Han and M. Kamber, "Data mining concept s and techniques", San Fransisco: Morgan Kaufmann, **(2009)**.

[7] J. Davis, "Mosaics of scenes with moving objects", Pro of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Santa Barbara, CA, USA, **(1998)** June 23-25.

[8] Y. Tang and H. yan Jiang, "Highly Effieient Image Stitehing Based on Energy Mav", Image and Signal Proeessing, **(2009)**.

[9] J. Shin and Y. Tang, "De-ghosting for Image Stitching with Automatic Content-Awareness", Pattern Recognition, vol. 23, **(2010)**.

[10] R. Szeliski, "Video mosaics for virtual environments", Computer Graphics and Applications, vol. 2, no. 16, **(1996)**.

[11] W. Jianning, G. Baolong and F. Zongzhe, "An image mosaic method based on interest points matching", Journal of Computer Applications, vol. 3, no. 26, **(2006)**.