Mosaic Method for Insulator Images Based on Region Characteristics

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Abstract. Based on the analysis of image registration methods based on region and feature, an image mosaic method based on edge statistical features is proposed. By using the mean and mean square deviation of RGB parameters of edge region pixels as matching criteria, this method improves the shortcomings of general region registration algorithm, such as large computational complexity, sensitivity to brightness and scale changes, poor real-time performance and adaptability, and simplifies the calculation of global region features of images to that of local region features. This method makes full use of the relevant information of the RGB parameters of the pixels. Compared with the registration calculation based on gray level, it has the characteristics of abundant optional features and high practicability.

1. Introduction
Image mosaic refers to the technology of forming a high resolution panorama with a wide angle of view (360° of view) from a group of overlapping images through various image transformations, image registration and image fusion. It involves computer graphics, computer vision, image processing and pattern recognition, and it is widely used in space exploration, medical images, video retrieval, virtual reality and other fields[1-2]. Panoramas formed by image mosaic technology can produce high quality virtual scenes, and have the advantages of strong sense of reality, fast image production, good real-time, low hardware requirements[3]. Panoramic image can help the observer to observe the key parts and their surroundings comprehensively and intuitively. If necessary, panoramic plane or stereo image can be obtained by image mosaic technology, which is an effective solution.

The basic process of image mosaic includes image preprocessing, image registration, image fusion and so on. The purpose of image preprocessing is to enhance the details of the image, suppress noise and improve image quality. Image registration is the key to the success of image mosaic[6]. It is the process of matching and aligning two or more images of the same scene acquired by different sensors in different time, different orientation and different working conditions. The image registration method used directly determines the merits and demerits of image mosaic.[7].

Image mosaic registration methods are mainly divided into region-based image mosaic method and feature-based image mosaic method.

The feature-based registration method estimates the transformation matrix between images by extracting obvious blocks, lines and points as features. The general steps of image registration are: 1) extracting the features of the image to be registered; 2) matching the features of the image; 3) estimating the transformation matrix between the images by matching features; 4) aligning the images by using the transformation matrix. The advantage of this method is that it is insensitive to brightness...
and noise, and can deal with large misalignment between images. Therefore, feature-based image registration method is widely used at present.

In feature-based registration methods, feature detection is the basis of image registration. Different feature detection methods are selected according to the scene characteristics of images to be stitched. The common edge detection methods are Roberts operator, Sobel operator[11], Prewitt operator[12], Canny operator[13]. The common corner detection method is Harris corner detection algorithm.

Roberts operator highlights the region of high spatial frequency, which often corresponds to the edge. When used, the input image and the output image are usually gray-scale images. The pixel value of each point of the output image represents the absolute magnitude of the spatial gradient of the input image at that point. Its characteristic is to perform a simple, fast and two-dimensional spatial gradient measurement on the image. Sobel operator is a two-dimensional spatial gradient measure on the image, which highlights the edges corresponding to the high spatial frequency region. It is usually used to find the approximate absolute gradient of each point in the input gray image. The operator consists of a pair of 3×3 convolution masks. Prewitt operator is an approximation method for estimating the size and direction of edges. Compared with Prewitt operator, Sobel operator weights the position of pixels, which can reduce the degree of edge ambiguity. Therefore, the effect is better than Prewitt operator. Differential gradient edge detection is a time-consuming calculation to estimate the direction of training edge from the magnitude of X and Y directions. However, compass edge detection obtains the direction directly from the maximum response of the core, and the Prewitt operator is limited to eight possible directions. Experience shows that most direct direction estimates are not very accurate[14].

Canny operator is an approximate implementation of the optimal edge detection operator, that is, the boundary points are located at the maximum of gradient amplitude after the image is smoothed by a Gauss function. Canny operator first smoothes the image with a Gauss filter, calculates the magnitude and direction of the gradient, then processes the image with non-extremum suppression technology, and finally obtains the required edge image. Therefore, Canny operator has been widely used because of its good anti-noise performance and edge detection accuracy. The disadvantage of Canny operator is that the operator needs to set threshold artificially, does not have adaptive ability, needs some experience and many experiments to find the appropriate threshold. Harris operator is improved on the basis of Moravec operator[16]. It is a feature detection operator based on local autocorrelation function proposed by Harris C and Mike Stephen, which combines corner and edge. The main difference from Moravec operator is that the first-order partial derivative is used to describe the change of brightness. The advantage of Harris operator is that the calculation is simple and only the first-order difference of gray level and filtering are used. Experiments show that in regions rich in texture information, Harris operator can extract a large number of useful feature points, while in regions with less texture information, fewer feature points can be extracted. Because the calculation process only involves first derivative of the image, the extraction of diagonal points is relatively stable even if there are image rotation, gray level change, noise influence and viewpoint transformation.

The feature-based registration method can effectively reduce the computational complexity by extracting some features of the image for matching. This method has robustness when brightness and scale change. The disadvantage is that it is easy to produce non-linear distortion, which is not suitable for the image mosaic of insulators in this paper. The reason is that the surface of insulators used online tends to be uniform and smooth due to dust, stain, dressing or cleaning, which leads to more similar feature points in insulator images and leads to image registration failure.

The region-based registration method aligns the intensity of correlation between image pixels. Firstly, the interest points are selected in one image, and then the corresponding pixels are searched by cross-correlation in another image. The advantage of region-based method is that it can provide very accurate registration using all available image data, but the disadvantage is that it needs a complex initialization[8]. Relevance method is a traditional registration method, which calculates the similarity of images directly by using the gray information of images. It is necessary to select the corresponding measurement function according to the characteristics of the images to be registered, and find an optimal spatial transformation through one or several optimization algorithms. The advantage of this
method is that it does not need complex image preprocessing, and its implementation is simple. The disadvantage of this method is that it has a narrow application range and a large amount of computation. Kuglin C D and Hine proposed a phase correlation method[9]. The image was transformed from spatial domain to frequency domain by Fourier transform, and the phase information in cross power spectrum was used for image registration. The method is insensitive to brightness change and can be used to obtain images from different sensors, but the registration results depend on the signal's superiority and noise. If the image is contaminated by noise in a very narrow band (low-frequency noise or sharp noise), whitening process can effectively eliminate the influence of noise in these areas. However, if the SNR of some areas in the image is very low, the whitening process will worsen the result. De Castr and Morandi C propose an extended phase correlation method [10], which is used to register images with both rotation and translation transformations. Although the rotation transformation does not include translation, rotation and translation usually occur simultaneously, which constitutes a more complex transformation. De Castro and Morandi C use the method of determining the rotation angle first and then the translation transformation for calculation.

Region-based registration method has the advantages of high accuracy and full use of all image data, but it needs a large amount of computation and is sensitive to brightness and scale changes. It can not meet the real-time and adaptive requirements in practical applications. In view of the shortcomings of region-based registration method, this paper discusses an image mosaic method based on region features and RGB parameters.

2. Computing based on regional features

Figure 1 shows an insulator image of eight stations, and its photographing station is shown in figure 2. s1-s8 in figure 2 constitutes eight working stations for photography. The images taken by each working station correspond one by one with the local images of 8 insulators in figure 1. It can be seen that the difference of each working station is 45°.

The task of image mosaic is to match and mosaic the 8 insulator images shown in figure 1 to form a complete insulator image shown in the circumference part of figure 2. The splicing process of s1 and s2 is discussed below. Assuming that the binary images of insulators at workstations s1 and s2 as shown in figure 3 have been obtained by image preprocessing, registration and clipping of s1 and s2 are necessary in order to obtain the stitching images of s1 and s2. The position relationship between s1 and s2 is shown in figure 4.
Figure 3. Binary diagram of s1 and s2 stations after pretreatment.

Figure 4. Photo overlap of s1 and s2 stations.

If the insulator images of positions s1 and s2 in figure 3 are mosaic, the edges of insulators in positions s1 and s2 need to be extracted. Then the center corresponding to the insulator edge is determined, and then s2 is translated to coincide the center of the arc edge with the center of s1. Then s2 is rotated counterclockwise by 45° (under ideal conditions), the joint of the non-overlapping parts of s1 and s2 can be completed, and the overlapping parts of s1 and s2 can be calculated. The overlapping part of the image takes one of s1 and s2. Then the stitching of image s1 and s2 is completed.

Because of errors, when s2 and s1 are joined together, the angle of s2 rotating counterclockwise is an undetermined angle, and its value is within 45°±5°. Therefore, it is necessary to accurately calculate the counterclockwise rotation angle of s2. In order to obtain a more accurate counterclockwise rotation angle of s2, a calculation method of rotation angle based on regional features is designed. The processing procedure is as follows.

After extracting the insulator edge in s2, the arc p1p2 shown in figure 4 of the overlapping part of s2 and s1 is calculated by rotating s2 counterclockwise from 40°~50°. It is easy to find that the overlapping arc p1p2 is the longest when s2 needs to rotate 40° to splice with s1, and the corresponding center angle is more than 25°. When s2 needs to rotate 50° to splice with s1, the overlapping arc p1p2 is the shortest, and the corresponding center angle is equal to 20°. That is to say, the central angle of overlapping arc p1p2 is not less than 20°. For the sake of simplicity and generality, the arc corresponding to the center angle of 10°is intercepted as the characteristic point of the arc p1p2.

Firstly, the horizontal axis angle 15° is taken as the radius op1. The intersection point between the radius and the insulator edge is p1. Then the horizontal axis angle 25° is taken as the radius op2. The intersection point between the radius and the insulator edge is p2, and the edge arc s1_p1p2 is the characteristic arc on s1. The method of obtaining arc s2_p1p2 on s2 is similar to that on s1.

Then the RGB parameters of all the pixels of the arc are extracted along the edge arc s1_p1p2. Within the range of 40°~50°, the RGB parameters of all the pixels of arc s2_p1p2 are extracted on s2 by rotating s2 in an increment of 1°. Then compared with the RGB parameters extracted from arc s1_p1p2, the mean and mean square deviation of the difference were calculated, and the minimum is the initial stitching rotation angle α of s2.

Taking the initial stitching rotation angle,α, as the reference point, the RGB parameters are extracted by rotating s2 +0.5°and -0.5° respectively. Compared with the circular arc s1_p1p2, the mean and mean square deviation of the difference between them are calculated, and the smallest one is the new stitching rotation angle α of s2.

Based on the new stitching rotation angle,α, the RGB parameters are extracted by rotating s2 at +0.25°and -0.25°, respectively. Compared with the circular s1_p1p2, the mean and mean square deviation of the difference are calculated, and the smallest one is the new stitching rotation angle α of s2.

Repeat the above steps until the stitching accuracy of s2 meets the requirements and the calculation of stitching rotation angle is completed.

So far, the stitching position and rotation angle parameters of s1 and s2 can be obtained completely. It is easy to stitch s1 and s2 together according to these parameters.
3. Mosaic Algorithms Based on Region Features

Region-based registration method has high accuracy and can use all image data. However, this method has the disadvantages of large amount of computation, sensitivity to brightness and scale changes, and can not meet the real-time and adaptive requirements in practical applications. In order to enhance the advantages and avoid disadvantages, an image mosaic algorithm based on RGB color space is designed.

The algorithm is summarized as follows.

a. Pre-processing of mosaic image, segmentation of object (insulator) in image, edge extraction, arc extraction and arc parameter calculation;

b. Centroid registration of s2 and s1 on the basis of s1;

c. Calculate the RGB parameters of the pixels in which the arc s1_p1p2 and the arc s2_p1p2 respectively. For the convenience of calculation, a rectangle is established, with p1 (x11, y11) and p2 (x12, y12) as diagonal vertices. The coordinates of the four vertices of the rectangle are [(x11, y11), (x11, y12), (x12, y11)].

d. For different incremental angles, the difference of RGB parameters between the pixels of arc s2_p1 P2 and arc s1_p1p2 is calculated, and the mean value E and mean square value σ of the difference are obtained. The minimum is taken as the initial rotation angle α of s2. For convenience of calculation, a rectangle is established with the points of P1 (x21, y21) and P2 (x22, y22) as the diagonal vertices of the rectangle. The four vertex coordinates are [(x21, y21), (x21, y22), (x22, y22), (x22, y21)]. The mean E and the mean square value of RGB spatial difference are calculated by formulas (1) and (2), respectively.

Mean value is

\[ E_i = \frac{1}{x_{12} - x_{11}} \sum_{n=1}^{y_{12} - y_{11}} (x_{2n} - x_{1n}), \quad E_i = \frac{1}{y_{12} - y_{11}} \sum_{n=1}^{y_{12} - y_{11}} (y_{2n} - y_{1n}), \quad i = R, G, B \]  

(1)

The mean square deviation is

\[ \sigma_i = \sum_{n=1}^{y_{12} - y_{11}} (x_{2n} - E_i)^2, \quad \sigma_i = \sum_{n=1}^{y_{12} - y_{11}} (y_{2n} - E_i)^2, \quad i = R, G, B \]  

(2)

e. The mean and mean square values of RGB parameters of new arcs s2_p1p2 and s1_p1p2 are calculated by rotating s2 + 0.5° and -0.5° on the basis of initial rotation angle α, and the minimum is taken as the new rotation angle α of s2;

f. Change the rotation increment to 0.25 and repeat step e to get a new registration rotation angle α until the registration accuracy meets the requirements;

g. s2 and s1 are spliced according to the new registration rotation angle alpha, and attention is paid to the processing of overlapping parts;

h. Read in the new diagram and go back to step a. Exit if all splicing has been completed.

In step a, two methods can be used to obtain the radius of the arc and the coordinate parameters of the center of the circle. One is extracted by Hough transform, the other is calculated by geometric method. As shown in figure 5, the coordinates of the arc endpoints (in pixels) are q1(x1, y1) and q3(x3, y3). The right-most point of the arc is q2(x2, y2). The radius passing through the point is the horizontal radius.

The slope of line q1q2 is

\[ k = \frac{y_2 - y_1}{x_2 - x_1} \]  

(3)

The slope of the vertical line l1 passing the midpoint of q1q2 connection is
The equation of $l_1$ is

$$y = k_1 x + b_1$$ \hspace{1cm} (5)

The slope of line $q_2q_3$ is

$$k = \frac{y_3 - y_2}{x_3 - x_2}$$ \hspace{1cm} (6)

The slope of the vertical line $l_2$ passing the midpoint of $q_2q_3$ connection is

$$k_2 = -\frac{x_3 - x_2}{y_3 - y_2}$$ \hspace{1cm} (7)

The equation of $l_2$ is

$$y = k_2 x + b_2$$ \hspace{1cm} (8)

By substituting the midpoint of $q_1q_2$ and $q_2q_3$ connections, $0.5[(x_1+x_2), (y_1+y_2)]$ and $0.5[(x_3+x_2), (y_3+y_2)]$, into the formulas (5) and (8) respectively, we can obtain $b_1$ and $b_2$. The intersection point of line $l_1$ and $l_2$ is the center of arc($x_0$, $y_0$).

$$x_0 = \frac{b_2 - b_1}{k_1 - k_2}, \hspace{0.5cm} y_0 = k_1 \frac{b_2 - b_1}{k_1 - k_2} + b_1$$ \hspace{1cm} (9)

The radius $r$ of the circle is

$$r = x_2 - x_0$$ \hspace{1cm} (10)

Using the above method to process the eight-station insulator image shown in figure 1, the stitching effect of eight partial insulator images is shown in figure 5. It shows that the target has been achieved.

Figure 5. Mosaic effect of eight-station insulator image in figure 1.

4. Conclusion

Based on the analysis of the advantages and disadvantages of two kinds of image registration methods, this paper focuses on a method of image mosaic based on regional features. The method uses the mean and mean square deviation of the RGB parameters of the local edge of the matched image as the matching criterion. The calculation of global region feature of image is simplified to that of local region feature. For the shortcomings of the general region feature registration algorithm, such as large computational load, sensitivity to brightness and scale changes, poor real-time performance and self-adaptability, the improvement is made. Secondly, the registration feature calculation in this paper
is carried out directly in RGB space, making full use of the relevant information of pixels, and other features besides mean and mean square deviation can also be selected as matching criteria. Therefore, compared with the gray-based method, the number of optional features is abundant and the practicability is greatly improved.

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