An Algorithm for Remote Sensing Image Mosaic Based on Valid Area

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Yuan Gao
City University of Hong Kong

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Yi Yang, Yuan Gao
Key Laboratory for Multi-spectral Information Processing Technologies, IPRAI,
Huazhong University of Science and Technology,
Wuhan 430074, China
young_yy519@126.com
kipykspy@gmail.com

Haitao Li, Yanshun Han
Key Laboratory of Geo-informatics of State Bureau of Surveying and Mapping,
Chinese Academy of Surveying and Mapping,
Beijing 100830, China
lhtao@casm.ac.cn
hys_han@casm.ac.cn

***Abstract*—In order to realize automatic image mosaic with HJ-1 satellite images, this paper proposes a bisector seamline algorithm which is based on the geometric characters of the remote sensing images valid areas. Firstly, the valid area is used to replace primitive rectangle image to participate in image mosaic, the feathering seamline is automatically generated on valid area. Then the seamline is effectively removed by an improved feathering algorithm. Finally, through the mosaic experiment on a group of 9 remote sensing images, the experimental result indicates that the new algorithm is applicable for complex polygon overlap, easy to realize and has a good visual effect.**

Keywords-seamless mosaicking; valid area; bisector seamline; feathering

I. INTRODUCTION

Remote sensing image mosaic is the process of combining multiple remote sensing images into a composite image. The image data sending by HJ-1 satellite, by reason of the sensor imaging modality, can only cover small area. Remote sensing image mosaic combining multiple images to a seamless complete image, not only providing strong protection for national or large-scale environmental and ecological monitoring, but also providing a wide range of image data for regional or national environmental change detection, classification and so on.

In the process of remote sensing image mosaic, it is inevitable to encounter multi-sensor images, image resolution change and color difference. It is necessary to make sure the mosaicking result is clear and smooth, so there are two key problems need to be solved: First, how to automatically generate robust seamline in overlap of multiple images; second, how to remove the seamline created by image gray scale (or color) difference.

For these two key problems, domestic and foreign scholars and institutions have begun many years of research, and form a series of sophisticated algorithms and techniques. Ref [1] proposed a concept of effective mosaic polygon (EMP), and used the image geometric characters to generate a bisector in the overlap, but the algorithm is only applicable to the situation of quadrangle. Ref [2] presents the hard correction method to remove the seamline in the mosaicked image. Every pixel along the seamline is well feathered, thus the mosaicking result effectively eliminates the seamline. As an improvement of these two methods, this paper proposes a bisector seamline algorithm which is based on the geometric characters of the remote sensing images valid areas, and uses an improved feathering algorithm to achieve seamless image mosaic.

II. DETECTION OF VALID AREA

After geometrically corrected of HJ-1 satellite image, the valid area of HJ-1 satellite image is not a rectangle, shown in Fig. 1: Due to geometric correction the image is rotated, and it is surrounded by invalid image area (black part), whereas the valid area is the middle section (gray part).

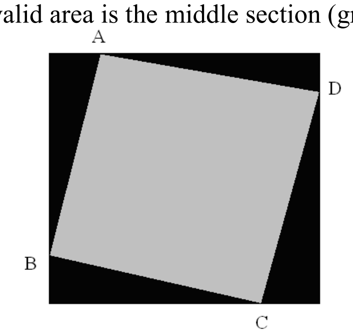
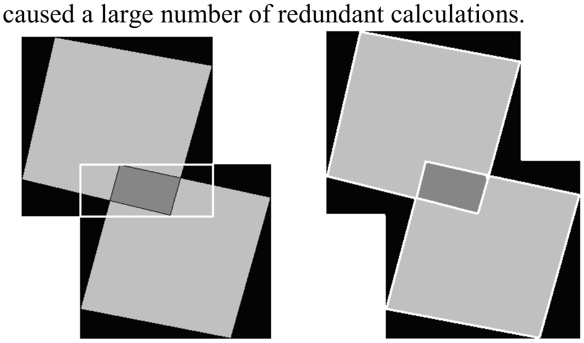


Figure 1. HJ-1 satellite image.

The overlap of two images is shown as the white rectangle in Fig. 2(a) below, which contains invalid data fields(black part) and the non-valid data overlap(gray part). When generating the seamline, it will take into account these invalid regions, affected the generation of seamline, and caused a large number of redundant calculations.



(a) (b)

Figure 2. (a) Original image overlap, (b)Valid area overlap

In this paper, we detect the valid area of image first, the valid area is used to replace primitive rectangle image to participate in image mosaic. Quadrangle is an effective geometric method to record the original image valid area. To determine the valid area in a given image, we can record the maximum pixel with valid data in four directions (up, down, left and right) of the image, as shown in Fig. 1: A, B, C, D are the four maximum points, and quadrangle ABCD is the external boundary of the valid area. The valid area overlap of two images is shown in Fig. 2(b). The white rectangle is the external boundary of image valid area, and the dark part is the valid area overlap, which only contains valid area. It not only ensures the accuracy of the generation of seamline, but also reduces the computation in overlap and improves efficiency.

III. GENERATION OF BISECTOR SEAMLINE

After detecting the valid area of the images, it is time to find an optimal seamline in the valid area overlap, aiming at combining the images seamlessly. The optimal seamline should have the following characteristics:

1) Always through the intersection points of two images, to ensure that all parts of the overlap is feathered;
2) Evenly divide the overlap area, to ensure that both sides of the seamline have enough transition area;
3) According to various special shape of overlap, seamline can also be generated robustly.

Ref [1] proposed a bisector generation algorithm. It assumes that the overlap of any two images is a quadrangle. The steps for generating a bisector in quadrilateral overlap are shown in Fig. 3 and described as follows.

Step 1) Calculate the intersection points of two images. Quadrangle ABCD is the overlap of the adjacent images. There A and C are the intersection points.

Step 2) Calculate the middle points in the quadrilateral overlap.AE, DE, BF and CF are the angle bisectors of the four internal angles. There E and F are the middle points. Then the polyline AEFC is the bisector of the two images.

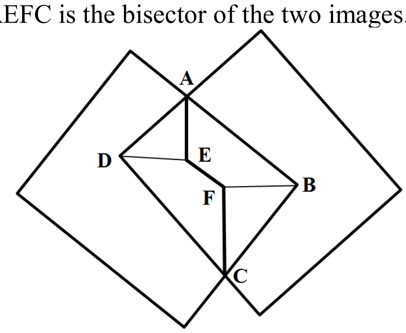


Figure 3. Generation of bisector in quadrangle

When dealing with multiple images, the mosaicking is done by the image sequence, so the new overlap maybe is not a quadrangle. The algorithm in [1] is applicable to the case of quadrilateral overlap, but it is not fit for complex polygon situations. In this paper, we improved the algorithm to adapt for complex polygon overlap.

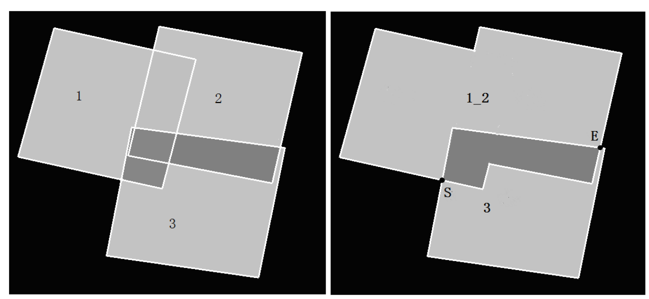
As shown in Fig. 4(a), it is using the algorithm to make a mosaic of three images, named images 1, 2 and 3. Image 1 and image 2 do a mosaicking, form the mosaicking result 1_2, which would mosaic with image 3. There the overlap of image 1_2 and image 3 is a complex polygon. The steps for generating the bisectors between 1_2 and 3 are shown in Fig. 4 and described as follows.

Step 1) Calculate the intersection points of two images. Let them be the start point and end point of the seamline (S and E in Fig. 4(b)).

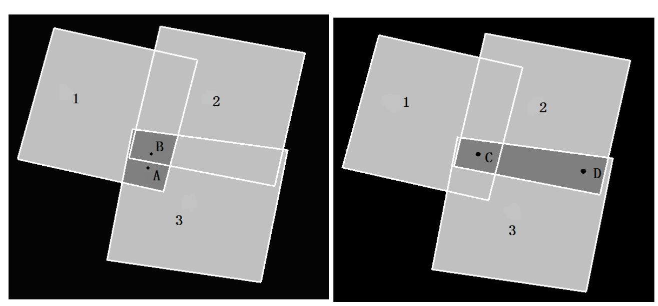
Step 2) Calculate the middle point of the image with each pre-mosaic image respectively. For example, calculate the middle point in the overlap of image 1 and image 3 (A and B in Fig. 4(c)), then calculate the middle point in the overlap of image 2 and image 3 (C and D in Fig. 4(d)).

Step 3) According to the nearest method, connect all the middle point from the start point to the end point. As shown in Fig. 4 (e), the polyline SABCDE is the primary seamline.

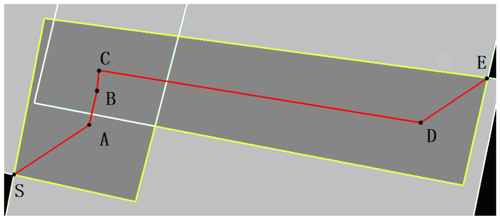
Step 4) Repair the seamline, to remove some large angle and small angle (nearly on the same line). There A、B、C is approximate on the same line, we can delete B point, and thus the polyline SACDE is the final seamline (Fig. 4(f)).



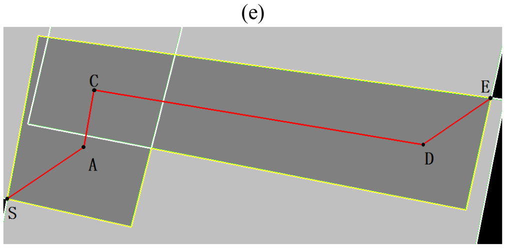
(a) (b)



(c) (d)



(e)



(f)

Figure 4. Generation of bisector in complex polygon

The whole process of the algorithm is fully automatic, without human intervention, and the generated seamline meets the three characteristics of the optimal seamline.

IV. SEAMLINE REMOVAL

Due to gray scale (or color) difference of the two images, there inevitably exists a seamline on the overlap in the mosaicking result. It needs a method to remove the seamline in the mosaicking result.

Ref [2] presents the hard correction method. It computes the average gray difference between the pixels along the seamline, and then adjusts the gray difference to the pixels. We usually called this process feathering. The one-dimensional feathering is shown in Fig. 5. After feathering, the gray difference Δg is not centralized at a point, but evenly distributed in the overlap, thus the mosaicking result effectively eliminates the seamline.

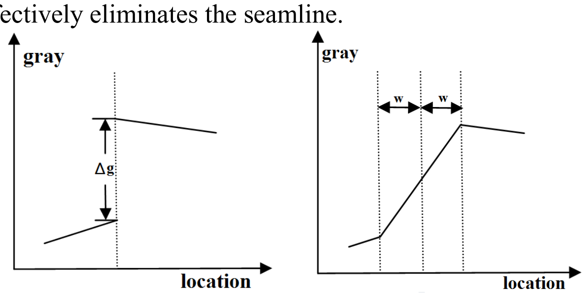


Figure 5. One-dimensional feathering

The points on both sides of the seamline are feathered by the following formula:

$$\begin{cases} I_i = IA_i + (IB_i - IA_i) \times K \\ K = \dfrac{i}{W} (0 \le i \le W) \end{cases} \quad (1)$$

In the formula, I_i is the pixel value after feathering. IA_i and IB_i are the pixel value of the two pre-mosaic images. K is a weight. W is the feathering radius, whicih is less than the maximum distance between the seamline and the overlap boundaries

We extended the algorithm to the two-dimensional case in this paper. Let $I_1(x, y)$, $I_2(x, y)$ respectively be the pixel value of the pre-mosaic image. The pixel value of the final mosaicking result $I(x, y)$ is defined as

$$I(x, y) = w(x, y) \times I_1(x, y) + (1 - w(x, y)) \times I_2(x, y) \quad (2)$$

Where $w(x, y)$ is the feathering weight function,

$$w(x, y) = \frac{W \pm d(x, y)}{2W} (d(x, y) \le W) \quad (3)$$

In (3), W is the feathering radius, similar to (1), *d(x, y)* is the Euclidean distance between pixel (x, y) and the seamline, the symbol depends on the point position relationship with the seamline.

V. EXPERIMENTAL RESULTS

In order to verify the feasibility and effectiveness of the algorithm, we choose 9 HJ-1 satellite images which are covering a study area in Qinghai, Gansu and Inner Mongolia, China. The images used in this paper are 4 bands, the resolution is 30m, and the image size is approximately 2400 by 2200 pixels. Fig. 6 shows the 9 original remote sensing images. Each image is denoted by a white rectangle. The generation of seamline is shown in Fig. 7. Each overlap between two adjacent images successfully generates the seamline (the thick polyline in Fig. 7).

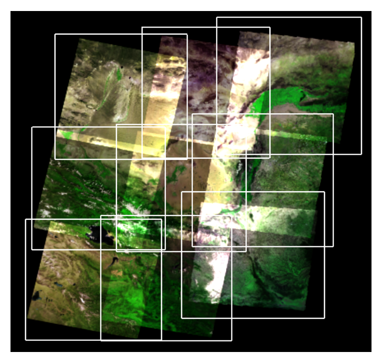


Figure 6. Original images

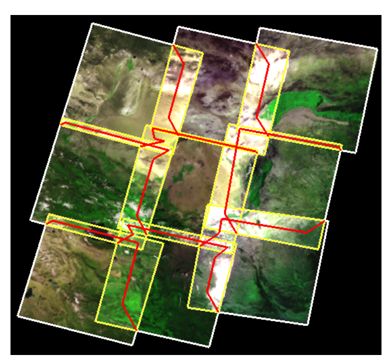
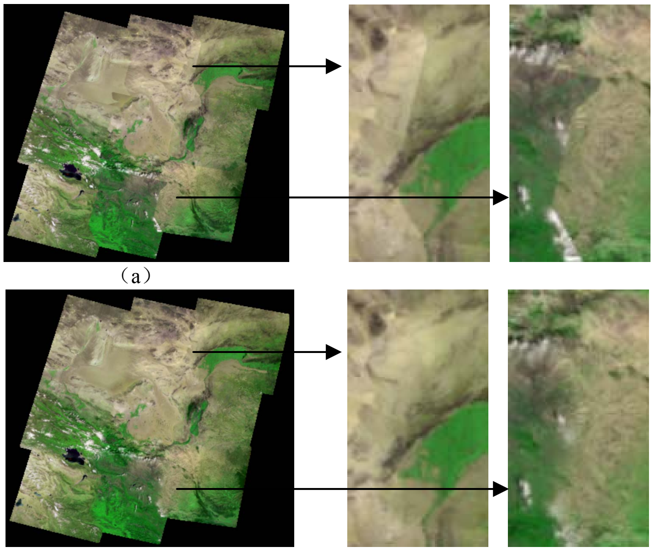


Figure 7. Generation of seamlines



(a) (b)

Figure 8. Mosaicking result by 9 HJ-1 satellite images: (a)mosaicking result without featherin, (b) mosaicking result with feathering

Fig. 8 shows the final mosaicking result. Fig. 8(a) shows the mosaicking result without feathering, there exists visible seamlines on the overlap of two adjacent images. Fig. 8(b) shows the mosaicking result after feathering, the result effectively removes the seamlines, and has a good visual effect.

VI. CONCLUSIONS

In order to realize automatic image mosaic with HJ-1 satellite images, this paper proposes a bisector seamline algorithm which is based on the geometric characters of the remote sensing images valid areas, uses an improved feathering algorithm to achieve seamless mosaic of remote sensing images. Through the mosaic experiment on a group of 9 remote sensing images, the experimental result indicates that the new algorithm is applicable for complex polygon overlap, easy to realize and has a good visual effect. The algorithm takes advantage of the geometric characters of the images, but ignores the gray information of the images. How to combining the geometric characters and gray information of the images is the further problem.

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