

## THE SEAMLINE REMOVING IN THE GENERATION OF ORTHOPHOTO MAPS

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### ABSTRACT

Based on the analysis of the disadvantages of the existing methods for gray seamline removing, the algorithm based on the wavelet transform is presented and tested using real images, which is strict in theory and effective to remove gray seamlines in mosaicked image.

### 1 INTRODUCTION

Image mosaicking is one of the most important works in the generation of orthophoto maps which includes such main tasks as geometric mosaicking and gray seam-line removing. Geometric mosaicking can be strictly realized in computer according to the theory of Photogrammetry, whereas gray seam-line removing has almost not been well resolved. The focus of the paper is put on the removing of the gray seam-lines in the mosaicked image.

Generally, trivial gray differences in the two images to be mosaicked can cause obvious gray seam-lines in the mosaicked image, and in the process of image acquisition and processing, these trivial gray differences is almost inevitable. Therefore, there must be some techniques to remove these gray seam-lines so that the gray can transit smoothly on or near the position of geometric seam-lines. In the following sections, we firstly summarize some existing methods for gray seam-line removing, and then discuss how to use wavelet transform to resolve this difficult problem.

### 2 OVERLAPPING IMAGE BASED ALGORITHM

In this method, for every pixels at the two sides of the seam-line, its gray is corrected according to the gray difference between two pixels at the same position in a certain extent of overlapping areas, and the closer the pixel is to the seam-line, the larger correction value is, that is

$$I_i = I_i^A + (I_i^B - I_i^A) \times K \quad \square 1 \square$$

$$K = \frac{i}{W} \quad \varepsilon^{-1} \quad 0 \leq i \leq W - 1 \quad \square 2 \square$$

where  $I_i$  is gray value of the pixel after processed,  $I_i^A$  and  $I_i^B$  are respectively the original gray value of the pixels at the same position within a certain extent of overlapping areas,  $W$  is the smoothing width and less than the width of overlapping image areas,  $K$  is the weight.

This algorithm can acquire good results when two images are well registered, otherwise it probably doesn't. Additionally, this algorithm is not fit for the case that the overlapping degree of images to be mosaicked is small. Generally, aerial photographic images have adequate overlapping degree, but when only these images are used which are taken alternatively in the same line, they often don't satisfy the needs of overlapping degree.

### 3 ALGORITHM BASED ON THE AVERAGE DIFFERENCE BETWEEN TWO SIDES OF CUT-LINE

For regular aerial photos, adjacent two images within the same line are with the left-right relations, and those between the different lines are with the top-bottom relations, therefore the processing can be performed only in the left and right sides of cut-lines for the images in the same line and in the top and bottom sides of cut-lines for the images in the different lines. For every piece of cut-line in the whole mosaicked image, if it is the left-right one, the average gray difference between the pixels within a certain extent of the two sides of the cut-line is computed and then adjust the gray difference to the pixels at a certain extent of the two sides of the cut-line, if it is the top-bottom one, this operation is done in top-bottom sides of the cut-line. This processing is often called “feathering” intuitively.

Let  $\Delta g$  is the gray difference between two sides of the position  $i P_0 i$ : on cut-line,  $w$  is feathering width,  $d$  is the distance between  $i P_0 i$ : and the pixel  $i P i$ : to be corrected, and  $d$  is less than feathering width  $w$ , as shown in Figure 1, then the gray correction value  $\Delta g'$  of the pixel  $i P i$ : is

$$\Delta g' = \frac{w-d}{w} \cdot \Delta g \quad \square 3 \square$$

This algorithm (Zhu Shu-long, 2000) is also as approximate as described in section 2. If there are some pixels in one side of the cut-line as distinct from the others in lightness, it will cause the errors of gray difference  $\Delta g$  and then cause the errors of the gray correction value  $\Delta g'$ . Hence the cut-line should not traverse these positions in which these pixels with distinct lightness are located.

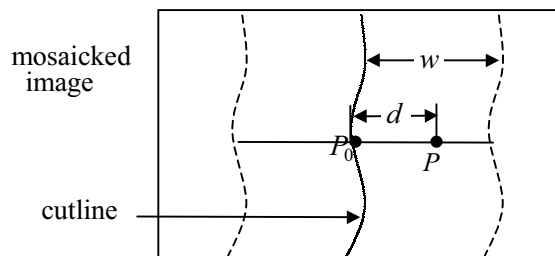


Figure 1. left-right processing of seamline on mosaicked image

#### 4 WAVELET BASED ALGORITHM

From the viewpoint of mathematics, gray seam-line removing corresponds to smooth connection of gray plane in the mosaicked image, but in fact, the image montage is different from the smooth connection of gray plane, because the former is to blur the image so that the image resolution decreases. The experiments show that, if the space resolution varies from  $W_{min}$  to  $W_{max}$  in the extent of montage and its corresponding wave-length is respectively  $T_l$  and  $T_s$ , in order that the gray seam-lines don't occur in the mosaicked image, the influence extent of gray correction must be not less than  $T_l$ , and in order to make the mosaicked image be clear, the influence extent of gray correction must be more than twice of  $T_l$ . When the space resolution near the cut-lines is larger, it is impossible to find correct the influence extent of gray correction.

Wang Jian-zhong (1993) proposed a method to resolve this problem based on the wavelet theory. Because the wavelet function is, in fact, a band-pass filter, the wavelet components in different resolutions corresponds to a certain frequency width, the larger the scale parameter  $j$  is, the larger the resolution of this component is. Therefore the frequency width of every wavelet component is not large. In this method, two images to be mosaicked are firstly decomposed into a series of high-frequency sub-images and a low-frequency one, the corresponding two sub-images with the same resolution at every levels are then respectively mosaicked in the domain of wavelet transform, these mosaicked sub-images are finally reconstructed into an image in which the gray seam-lines have been removed. The smoothness and clarity of the image are all considered in this algorithm.

Let  $s$  the image A and image B are the one to be mosaicked—its data are respectively  $C_A^0 = C_A^0(n, m)$  and  $C_B^0 = C_B^0(n, m)$ —After orthonormal wavelet transform, their wavelet components are as follows

$$\begin{aligned} &(d_A^{11}, d_A^{12}, d_A^{13}), \dots, (d_A^{N1}, d_A^{N2}, d_A^{N3}), C_A^N \\ &(d_B^{11}, d_B^{12}, d_B^{13}), \dots, (d_B^{N1}, d_B^{N2}, d_B^{N3}), C_B^N \end{aligned}$$

if a part  $\Omega_B$  of image B shall be mosaicked into image A (as shown in Fig.2)—then let

$$K(x, y) = \chi_{\Omega_A}(x, y) = \begin{cases} 1 & \text{if } (x, y) \in \Omega_A \\ 0 & \text{if } (x, y) \in \Omega_B \end{cases} \quad \square 4 \square$$

if we let  $K(x, y)$   $s$  samples be  $C_\Omega^0$ —its low-frequency components at every resolutions be  $C_\Omega^1; \dots; C_\Omega^N$ —set

$$d^{ij}(k, l) = C_\Omega^j(k, l) d_A^{ij}(k, l) + [1 - C_\Omega^j(k, l)] d_B^{ij}(k, l) \quad \square 5 \square$$

$$C^N(k, l) = C_\Omega^N(k, l) C_A^N(k, l) + [1 - C_\Omega^N(k, l)] C_B^N(k, l) \quad \square 6 \square$$

where  $i = 1 \square 2 \square \dots \square N \square j = 1 \square 2 \square 3$ . Let  $\{(d^{11}, d^{12}, d^{13}), \dots, (d^{N1}, d^{N2}, d^{N3}), C^N\}$  be components of wavelet transform of mosaicked image, then we can acquire the mosaicked image using the inverse algorithm of wavelet transform. To be cautious that the image edges must be processed when using wavelet transform, otherwise some information will be lost in this operation.

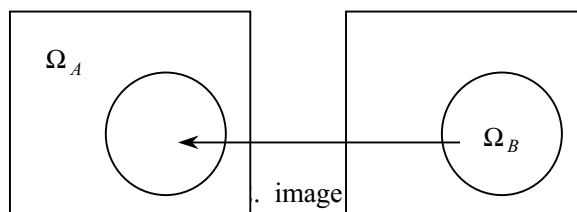
Assuming that the low-pass filter and the corresponding high-pass filter are  $H = (h_0, h_1, h_2, h_3)$  and  $G = (g_{-2}, g_{-1}, g_0, g_1)$  respectively, the samples of the original discrete signal are  $C^0 = (c_0^0, c_1^0, \dots, c_{M-1}^0)$ , then the image edges are processed according the following precise formulas in our experiments:

For left image edges, we have—

$$\begin{cases} c_{-1}^0 = c_{-2}^0 = 0 \\ c_{-1}^1 = \frac{h_2}{h_1} d_0^1 \end{cases} \quad \square 7 \square$$

For right image edges, we have—

$$\begin{cases} c_M^0 = 0, \quad d_{M/2}^1 = 0 \\ c_{M+1}^0 = -\frac{h_2}{h_0} c_{M-1}^0 + \frac{h_3}{h_0} c_{M-2}^0 \end{cases} \quad \square 8 \square$$



This algorithm is strict theoretically in removing gray seam-lines. Its disadvantages are that is complex and needs more time and memory consumption in the process of operation. In the following section, we will find its good effect in removing gray seam-lines.

## 5 Experiments

In order to verify the real effect of wavelet based algorithm, two images of the same ground areas with different lightness and contrast are used in our experiments. Figure 3 and Figure 4 are the original images to be mosaicked, the former is darker and with lower contrast, the latter is brighter and with higher contrast. Figure 5 is the result that hasn't been processed using wavelet based algorithm, in which the gray seamlines occur obviously. Figure 6 is the result that has been processed using wavelet based algorithm, in which there are no gray seamlines. This experiment indicates that wavelet based algorithm is very effective and can acquire satisfactory results in gray seamline removing.



Figure 3. one of two image to be mosaicked



Figure 4. the other of two image to be mosaicked



Figure 5. the mosaicked image without seamline removing



Figure 6. the mosaicked image after seamlines removed

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