FREE IMAGE REGISTRATION AND MOSAICING BASED ON TIN AND IMPROVED SZELISKI ALGORITHM

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ABSTRACT:

Based on colour images acquired from unmanned planes, we use projective transformation formula to eliminate the perspective distortion observed in overlapping area in two images and get big frame mosaic images through the arithmetic which is based on triangulated irregular network and improved SZELISKI. Confirming overlapping image areas are determined through computer graphics. TIN method is applied to image registering and mosaicing. SZELISKI mosaic algorithm is improved in this paper to control the scope of mosaic area, which is more favourable to human vision. Through researches on the above techniques, original images that acquired from unmanned planes can be processed sequentially by the method of image rectification, image registration, and image mosaic to get large frame images rapidly.

1. INTRODUCTION

In computer graphics, compositing multiple image streams together to create larger format images is discussed in (N.Green,1986). However, in this application, the relative position of the camera was known in advance. Compositing video into salient still based on affine transformation is discussed in (L.Teodosio,1993). In the computer vision filed, many techniques have been exploited to extract 2-D textures and 3-D models of the target scenes (R.Szeliski,1994). In the multimedia area, the same techniques have been used to create content overviews and visual indexes of digital video images (Y.Taniguchi, 1997).

In low altitude aerial photogrammetry, when the sensor gets large numbers of images, we need to ensure the quality of the images. The images must accord with the request of engineering. For example: longitudinal and lateral overlapping areas achieve the standard that we pre-established, the rotation declination is not too big. If there is aerial photographic gap or bad image, the aerial platform must flight to get the right images again. Traditional processing is very slow, so it needs a long time to know the global situation. If photographic interval is too long, the ground feature may change tempestuously, it may affect the whole effect of the image map.

The images that we get through aerial photogrammetry have intensity and geometrical distortion because the sensor platform is near to the ground, affected by wind, sunshine and the attitude of remote sensing platform. After we get small breadth images, we should use image mosaicing technology to acquire big breadth remote sensing image. If there are many control points on the ground or dependable GPS data, we can accomplish image mosaicing in many different ways. But in practical applications, most engineering need free image fast and sketchy mosaicing. So it is necessary to find a better method.

2. IMAGE REGISTRATION

The free image mosaicing is different from panoramic mosaicing which limited to cylindrical panoramas with camera rotating on levelled tripods, and in panoramic mosaicing, the first and last images should have little geometry distortion. But in aerial photogrammetry, the most important thing that we should do is to reduce intensity and geometrical distortion of two close images. In image registration, here analyze 8 parameters of perspective transformation.

2.1 Projective Transformation

A genuine projective transform (Shu Zhilong, 2000) is represented by the following equation:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} r_1 & r_2 & r_3 \\ r_4 & r_5 & r_6 \\ r_7 & r_8 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{1}$$

This method incorporates 3 interior orientation parameters, 6 exterior orientation parameters, and 3 parameters of different two planes transformation. So the 8 parameters can express the transformation between different planes. In this case, we need to know 4 pairs points at least (arbitrary 3 points not collinear), then the image registration will be done through translation, scaling, rotation, affine and perspective transformation. This

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kind of representation can be used in most image registration application. But when the strip is long, the accumulation of distortion is unacceptable.

Figure 1 is an example that five mosaicing images of a flight strip. The mosaic reference datum is the reference datum of the first image, the effect of error spread is obvious. So we need to determine an optimal reference datum.

Figure 1. Results of error spread

The most reasonable reference datum is the middle one of the two images. In order to prove it, we take the absolute orientation equation as an example.
The absolute orientation equation is as follow:

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} = \lambda R \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} = \lambda \begin{bmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} \quad (2)$$

Where

$$\begin{bmatrix} a1 & a2 & a3 \\ b1 & b2 & b3 \\ c1 & c2 & c3 \end{bmatrix} = \begin{bmatrix} \cos\varphi & 0 & -\sin\varphi \\ 0 & 1 & 0 \\ \sin\varphi & 0 & \cos\varphi \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{bmatrix} \begin{bmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R = M(\varphi, \omega, \kappa)$$

The orientation parameters are set median.

$$\begin{bmatrix} X_M \\ Y_M \\ Z_M \end{bmatrix} = \frac{1}{2} \lambda R' \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \frac{1}{2} \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} = \frac{1}{2} \lambda \begin{bmatrix} a_1' & a_2' & a_3' \\ b_1' & b_2' & b_3' \\ c_1' & c_2' & c_3' \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \frac{1}{2} \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix}$$

$$R' = M(\frac{1}{2}\varphi, \frac{1}{2}\omega, \frac{1}{2}\kappa)$$

Owing to that φ, ω, κ is small, take φ as an example:

$$\cos\frac{1}{2}\varphi = \cos\varphi \frac{\cos\frac{\varphi}{2}}{\cos\varphi} = \cos\varphi \frac{\cos\frac{\varphi}{2}}{2\cos^2\frac{\varphi}{2} - 1} \approx \cos\varphi$$

$$\sin\frac{1}{2}\varphi = \sin\varphi \frac{\sin\frac{\varphi}{2}}{\sin\varphi} = \sin\varphi \frac{1}{2\cos\frac{\varphi}{2}} \approx \frac{1}{2}\sin\varphi$$

$$\sin\frac{1}{2}\varphi \approx 0 \quad \frac{1}{2}\sin\varphi \approx 0 \quad \sin\frac{1}{2}\varphi \approx \sin\varphi$$

So $R \approx R'$.

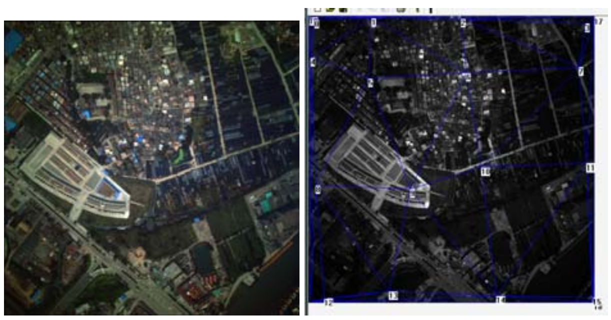
$$\begin{bmatrix} X_M \\ Y_M \\ Z_M \end{bmatrix} \approx \frac{1}{2} \begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} \quad (3)$$

This is the transformation between the image plane and the middle plane.

2.2 TIN Registration

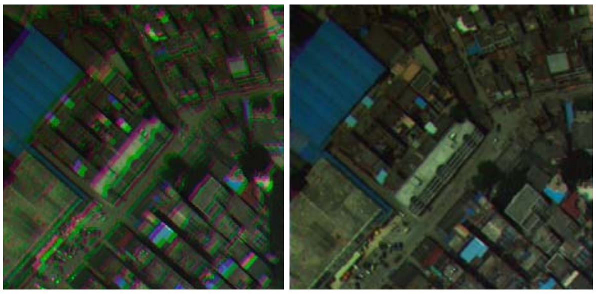
After global alignment, there still exists geometrical distortion because the CCD has local irregular distortion. It is difficult to remove completely, so we apply triangulated irregular network (TIN) registration (Xing Shuai, 2003) to solve this problem. We find enough corresponding image points and create TIN. Here we apply Delaunay triangulated network. Delaunay triangulated network is unique; there is not any point in the circumcircle of a triangle. It is a kind of triangulated network that most close to regularization. If the distributing of points is well-proportioned, there is not obtuse angle or acute angle triangle with very small angle. So the angle in Delaunay triangulated network should be acute angle triangle, or three edges approximately equal. Between triangles there is not any across or overlapping. If the image registration of some local areas is not well, in these areas we find more corresponding image points, and recreate TIN. Now the complex distortion decomposes to simple ones, here in each triangle the distortion is regarded as a simple affine distortion. The computer will calculate the result parameters quickly. The distortion of other types will be considered as well, the image registration completed soon.

If the images come from the same exposure station, a group of data often contain BRG multispectral images. Figure 2(a) is composite images of BGR wave band with TIN registration method. Figure 2(b) is the sketch map of TIN structure. There are 20 points in the image. If we select more point, the registr-ation effect will be better, but the calculating speed will be slow.



(a) (b)

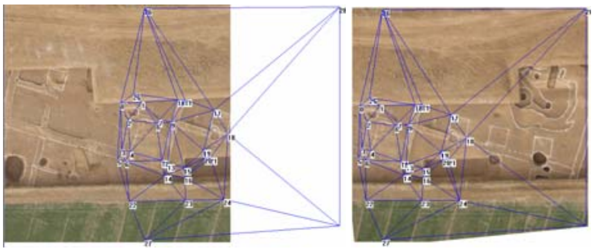
Figure 2. Multi-Band image and TIN sketch map



(a) (b)

Figure 3. Top left corner image

Figure 3 is the top left corner of the image, (a) is synthesized directly and (b) is synthesized after TIN registration. Figure 3(b) is better than (a) obviously.
If the images come from sequential exposure station, it usually has one colour image at each station. The following is Luoyang archaeological data. Figure 3 are two images of a long strip.



(a) (b)

Figure 3. An air photo pair

Figure 3 is an air photo pair. Through TIN registration, the two images may be connected together.

TIN also can deal with geometrical distortion during mosaicing. In overlapping areas we should find several corresponding point pairs, and through adjustment acquire the coordinates with minimal error of corresponding image points, then two images create TIN and resampling respectively. Now the two images have little difference, and then put up an appropriate seam.

Figure 4.Result of image mosaicing

Figure 4 is the mosaic result of two images. We can see the ground is flat. In the overlapping area, if there exit tall features, the mosaic calculation will be more complex. We must decrease relief displacement first.
The calculation formula (Lui Jingyu,1995) is:

$$\delta h_a = \frac{\Delta h}{H} r_n \left[\frac{1 - \frac{r_n}{2f} \sin\varphi \sin 2\alpha}{1 - \frac{\Delta h}{2Hf} r_n \sin\varphi \sin 2\alpha} \right] \tag{4}$$

If $\alpha = 0$, namely level image， we can get:

$$\delta h = \frac{\Delta h}{H} r \tag{5}$$

Where r is the principal-point radial distance, assume that the flight altitudes of the images are consistent, Δh of the same feature is also unique. We can get:

$$\frac{\delta h_1}{\delta h_2} = \frac{r_1}{r_2} \tag{6}$$

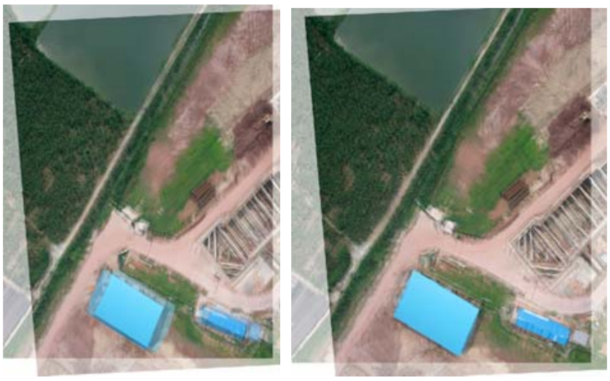
Where

$$r_1 = \sqrt{(x_1 - X_{T1})^2 - (y_1 - Y_{T1})^2}$$
$$r_2 = \sqrt{(x_2 - X_{T2})^2 - (y_2 - Y_{T2})^2}$$

(X_{T1}, Y_{T1}) is the central point coordinate of left image，(X_{T2}, Y_{T2}) is the central point coordinate of right image. In a strip, we may use the following formula to compute the coordinate of (x,y).

$$x = x_{\min} + | x_1 - x_2 | \frac{r_{\min}}{r_{\min} + r_{\max}}$$
$$y = y_{\min} + \frac{1}{2} | y_1 - y_2 |$$

r_{min} is the correspond radial distance of x_{min}.
Figure 5(b) is the image that after correction by TIN, and the relief displacement is less than that in Figure 5(a). It can improve the effect of mosaicing which is more favourable to human vision.



(a) (b)

Figure 5. Contrast of before and after correction

3. IMAGE MOSICING

The key problem in automating the process lies in developing a good algorithm to optimally determine the seam between images of neighbouring regions. Because of the distortion of the lens and other unknown factors, the overlapping areas of two images can not be coincided completely. In the case when there is a large overlap between the images, Szeliski (Szeliski,1996) has proposed a method for image registration by directly minimizing the discrepancy in intensities between pairs of images. The seam of Szeliski algorithm is a vertical line.

$$I = \beta I_1(x,y) + (1-\beta) I_2(x,y) \quad (7)$$

Where

$$\beta = (x_{\max} - x)/(x_{\max} - x_{\min}) \quad (8)$$

The formula (7) is calculating formula of Szeliski algorithm.

3.1 Overlapping Region

The main problem of this part is to find the overlapping region between two neighbouring images. It often uses computer graphics knowledge to confirm overlap area. This part is not the emphasis of this paper, so here we regard the overlap region as known.

3.2 Improved SZELISKI Algorithm

Human's vision is sensitive to vertical and horizontal line. The improved SZELISKI algorithm changes the direction of the seam. In Figure 6, the rectangle represents overlapping area, and the line drill through (x_2, y_2) and (x_4, y_4) represents the seam.

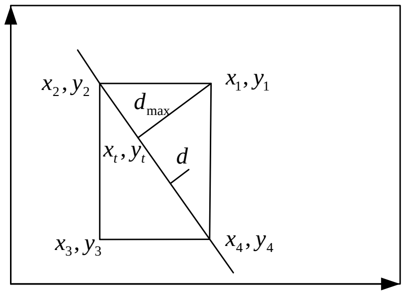


Figure 6. Sketch map of overlap area

d is the distance of a point that in overlapping area to the seam, d_{max} is the farthest distance that in overlap area pass through d to the seam. Here equation (8) changes into (9).

$$\beta = 1/2 - d/2d_{\max} \quad (9)$$

If image registration is not very well, SZELISKI algorithm will appear ghosting phenomena while mosaicing. In order to improve the mosaic effect, we replace linear function with nonlinear S function. Figure 7 is the curve of S function.

$$y = \frac{1}{1+e^{-a(x-b)}} \quad (10)$$

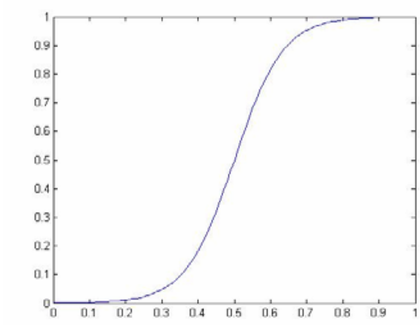


Figure 7. S function curve

Where *a* denotes the change trend, *b* is an offset. When *a* is small, it is close to linear change. In contrast while *a* is big, it is close to direct mosaicing. So we usually specify *a* between 5 and 35, and *b* is set to 0.5.

4. RESULTS AND DISCUSSIONS

Through TIN and improved ZELISKI algorithm, we can mosaic images well. Figure 8 is Luoyang archaeological mosaic images that apply TIN mosaic method. The ground of Figure 8 is flat, TIN algorithm is suitable to deal with flat ground mosaicing, and at the same time the error spread is limited. The lens distortion can be neglected.

Figure 8. Luoyang archaeological image

Figure 9. Image mosaicing based on improved ZELISKI algorithm

Figure 9 is mosaic images of a small region that apply improved ZELISKI method. We usually decrease relief display-cement first because there are many tall features. Then we use improved ZELISKI algorithm. The colour transition changes naturally, and the ghosting phenomena is reduced to the minimal.

5. CONCLUSIONS

This paper that use TIN registration and mosaicing may correct local irregular distortion that the global process can not achieve. TIN will change the added image points, and the number of image points lies on the complexity of the distortion of the image. This process will not affect other areas during image registration. During image mosaicing TIN is created in overlapping areas, and the distortion in overlapping areas will be corrected. Out of overlapping areas will be little affected, this will not propagate error. Furthermore the speed of calculation is very fast; these techniques are appropriate for fast processing after acquiring images, preview the whole data, and then make decision for the next step.
Improved ZELISKI algorithm can mosaic images automatically; it is suitable to deal with several kinds of area with tall features.

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