A METHOD FOR TRUE ORTHOPHOTO GENERATION BASED ON PROJECTION AND ITERATION STRATEGY

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ABSTRACT:

The conventional orthophotos always suffer from the problems of building lean and double mapping, due to the occluding of the buildings. This paper proposed a new occlusion detection method for true orthophoto generation. This method adopts the way of projecting roof and wall polygons to the ground horizontal planes, and obtains the occlusions by iteration strategy. Experiments with the color aerial image data of the city of Kunming shows that comparing to other two representative methods, this method can obtain more accurate results. Additionally, the neighboring images are used for occlusion compensation, and finally the true orthophoto is generated.

1. INTRODUCTION

1.1 General Instructions

Generally, the aerophotographs are captured when the sensor is tilt more or less. The orthophoto generation is processed by each pixel, through relief displacement correction using DEM of the district, and in other words, it is a progress of differential rectification. The orthophoto has plenty of benefits that combine the asset of a common map and an aerophotograph. It will be used as a map with its base functions such as measuring, searching destination, etc., what's more, the special map has abundant image characteristics, and it will propose more information than a general map.

The true orthophoto generation is distinguished with the conventional orthophoto. True orthophoto should express the interested object with correct locations and attribute. It needn't describe all the details correctly on the image, but the important features should be contained (Amhar.F, 1998). In the true orthophoto, building lean and double mapping is not permitted to appear, which are caused by occlusions, and it need to be harmonic in visual. As a result, the occlusion detection is vital important . In true orthophoto generation, most of the methods recover the relation of the ray between perspective center and objects, and find out which place can't be seen from the perspective center. If the object is occluded by other taller object, it was marked occluded. Finally, the occlusion status of each pixel composes a visibility map. The typical effective methods are Z-buffer, polygon-based method and angle-based method.

Z-buffer(Amhar, 1998; Rau et al., 2002)detects the occluded area by compare the distances of two orthophoto pixels of their corresponding DEM points to perspective center. In polygon-based method(Kuzmin et al., 2004), data is combined into polygons which are projected onto the image plane, and visible polygons are searched by comparing distances of overlapping polygons. The relationship of object points to the nadir points is brought up in angle-based and the off-nadir angles to the line of view are proposed to detect occlusions(Habib et al.,2007;Bang et al., 2007). Occlusion detection is the foremost and important step of true orthophoto generation.

2. REASONS OF OCCLUSION IN ORTHOPHOTO

The traditional approaches include two ways: direct and indirect orthophoto generation(Konecny,1979). Direct orthophoto generation is calculating the rectification pixels of the orthophoto by original image, as shown in formula (1)(Zhang & Zhang, 1996). There are obvious defects of the method, because on the orthophoto it leaves blank pixels sometimes, while other pixels may have multi values. The other way is indirect orthophoto generation. This process is adverse to the method above because it starts with the rectification photo, and calculates the corresponding pixels in original image. The pixel coordinates of points in original image is obtained by collinearity equation, and they will be transformed into scanning coordinates finally. The relationship of pixel coordinates with coordinates of orthophoto points as well as scanning coordinates is shown in formula (2) (Zhang & Zhang, 1996). X, Y, Z denote the coordinates of DSM points. x,y denote the image coordinates, and I, J denote the scanning coordinates. m_1, m_2, n_1, n_2 denote the rotation transformation of scanning coordinates to pixel coordinates. The nine elements in rotation matrix are denoted by (a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, c_3). The obtained value will be not in the center of the original image pixels, so the interpolation of pixel value is necessary.

$$X = Z \times \frac{a_1 x + a_2 y - a_3 f}{c_1 x + c_2 y - c_3 f} \qquad (1)$$
$$Y = Z \times \frac{b_1 x + b_2 y - b_3 f}{c_1 x + c_2 y - c_3 f}$$

$$\lambda_0 \begin{bmatrix} x - x_0 \\ y - y_0 \\ -f \end{bmatrix} = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix} \begin{bmatrix} X - X_S \\ Y - Y_S \\ Z - Z_S \end{bmatrix} \quad (2)$$

$$\lambda_0 \begin{bmatrix} x - x_0 \\ y - y_0 \\ -f \end{bmatrix} = \lambda \begin{bmatrix} m_1 & m_1 & 0 \\ n_2 & n_2 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I - I_0 \\ J - J_0 \\ -f \end{bmatrix}$$

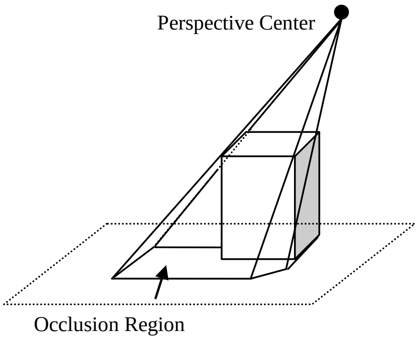


Figure 1. The occlusion region around the building

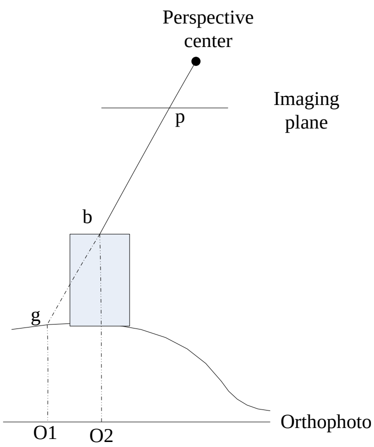


Figure 2. The principle of double mapping

The conventional orthophoto generation produces some problems such as building lean and double mapping. The tall buildings always occlude lower objects around them, but the differential rectification can't identify the occluded area, and this brings distortion. This distortion make buildings looking leaning and it occlude other objects. Double mapping is another immanent phenomenon. In figure 2, O1 and O2 are points of orthophoto. Examine the relation of projection, it can be found for point b on the DEM is recorded as p in the image plane, and g is corresponding to p as well, and on point O1 and O2 will be given the same gray value p, that lead to double mapping.

When the essential reasons of the two problems are discussed, we can find that traditional orthophoto generation can't detect the occlusion area. There are no corresponding gray values in the occluded area, so it's a good choice to find the occluded area first. Many researchers have made progress and they propose some effective method. In next section, we will discuss the typical occlusion detection method. Through analyzing the problems of the algorithms, we propose our improvement.

3. OCCLUSION DETECTION APPROACHES

3.1 The buildings occlude the terrain

Denote the projection area of the building wall and roof on the irregular ground as S_{bp}, and denote building occupy area as S_o, then the occluded region is $S_{bp} - S_o$, it's difficult to obtain the occlusion area directly due to the irregular terrain surface. This paper proposes a new occlusion detection method for the true orthophoto generation, which projects the roof and wall polygons to the ground horizontal planes, and obtains the occlusions by iteration strategy. In this algorithm, the projection ray is transferred to a quantity of projecting lines, and the occlusion region is composed of intersecting points of the projecting lines and ground. In this way, getting the projection area of the building wall and roof on the irregular ground is equivalent to obtaining the intersection points of the projecting line and terrain surface.

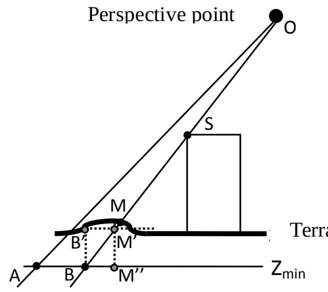


Figure 3. The buildings occlude the terrain

The corners of polygons describing roofs and walls are extracted, and these polygons are projected to a horizontal plane along the perspective direction, and these projected polygons are rasterized according to the accuracy. The projection light can be expressed as the line going through the projective centre and rasterized grid points. The lowest elevation of DTM is used as projecting horizontal plane. As the irregular terrain surface, the intersection points of the known projecting ray and the DTM can't be obtained directly. The points of intersecting the projecting line and horizontal plane are considered as the initial value, and the real intersection points of the projecting line and terrain surface are got by iteration method.

The principle is showed as figure 3. Denote point O as the perspective center, and denote point B as the intersection point of the line going through roof corner and the projection plane.

$$\begin{cases} x = x_o + (x_o - x_B)t \\ y = y_o + (y_o - y_B)t \\ z = z_o + (z_o - z_B)t \end{cases} \quad (3)$$

Denote point B′ as the point on the DTM, that has the same horizontal coordinates as B. According to the coordinates values, the elevation value of point B′ is obtained by interpolating the DTM grids. Denote (x_o, y_o, z_o) as the coordinates of perspective center, and denote (x_B, y_B, z_B) as the coordinates of point B, Substitute ZB′ into the equation (1), and the coordinates of intersection point M of plane Z=ZB′ and the line OB is obtained, then the elevation value is calculated by the horizontal coordinates of point M, and so on. When the differential of the current calculated elevation and previous value is within the threshold, the iteration ends, and the current DTM point is the point M.

In this way, the actual intersections of each line that go through the buildings and the DTM can be calculated. An index grid in accordance with the scale of the orthophoto can be constructed, and the occlusion area is recorded. Finally, the indirect rectification is adopted, and the occlusion area is filled with black.

3.2 The buildings occlude other surroundings

In the city region, there are always dense buildings, and it is necessary to consider the occluding between the buildings.

The perspective ray which goes through the higher buildings may has intersections with the lower buildings and terrain. In this paper, the buildings and terrain will be combined to an entire DSM, and the occlusion region will be obtained by calculating the intersection points of the lines and the entire DSM.

As shown in picture 4, The line OB intersects the higher buildings at point S, and intersects the lower buildings at N, and intersects the terrain at M. it can only obtain the point M which is the intersection point of line OB and the terrain when adopt the method in 3.1.

A moving elevation plane Z_{move} is chosen and moved between the lowest plane and the highest plane. The elevation plane move from the lowest plane Z_{min} and the highest plane Z_{max} according to certain intervals, and the intersection points of the perspective lines and the plane are obtained. As shown in figure 4, the perspective line OB and the plane Z_{move} intersect at P, and the actual occlusion point N can be calculated by iteration strategy.

The entire intersection points of the perspective lines and DSM can be obtained by recording the intersection points when moving the Z_{move} plane. Similarly, the whole intersection points of the lines going through the buildings and DSM, and the collection of intersection points is the occlusion by the buildings.

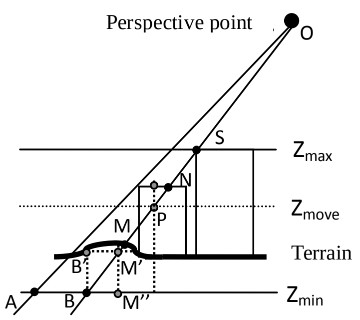


Figure 4. The buildings occlude other surroundings

3.3 Occlusion compensation

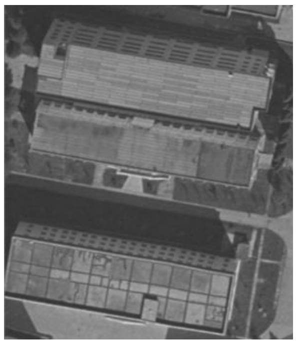
When the occlusion region is detected, it's necessary to refill the region from neighbour slave images. If the occluded point is visual in more than one slave images, it needs to choose the image that has less relief displacement(Zhou, 2005). Generally, the near to the nadir, the less of the relief displacement. As a result, the compensation principle is choosing the pixel that according to the distance to the nadir point.

4. EXPERIMENT AND RESULT

Real data is used for testing our methods. The image data is captured over the city of kunming, China. The elements of interior orientation and exterior orientation are all available. DBM(Digital Building Model) and DTM are extracted with stereo measurement by VirtuoZo.

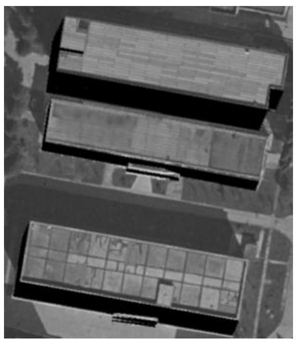
The lowest elevation is 1905.40m ,and the highest elevation is 1930.66m.The moving interval of the elevation plane is set to 2.7m, and the iteration threshold is 0.05m.

Based on the experiment data , the angle and ray traced method, Z-buffer method are compared with the algorithm proposed in this paper.

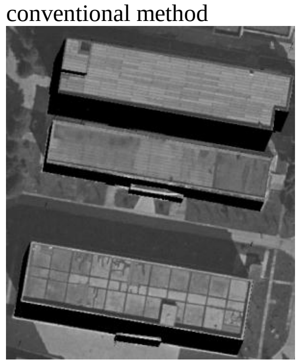


a. Original image

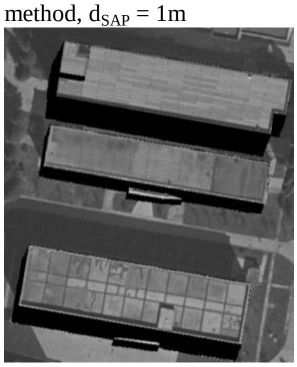
b. Rectification by conventional method



c. Angle and based ray tracing method, d_{SAP} = 1m

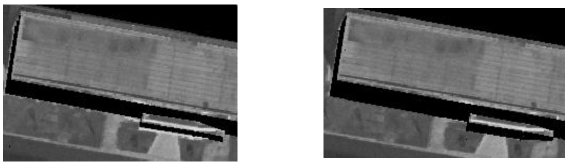


d. Angle and based ray tracing method, d_{SAP} = 0.5m



e. Z-buffer method

f. Our method



g. details of Angle and based ray tracing method   h. details of our method

Figure 5. Comparison of 3 algorithms.

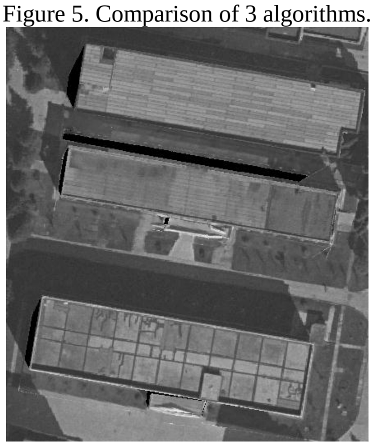


Figure 6 True orthophoto generation

In figure 5, a is the original image. Figure b shows the result of the conventional rectification method, and it leads to the problem of double mapping. Figure c and d show the results of the angle and based ray tracing method. When The search interval d_{SAP} is set to 1m, the occlusion detection result shows in c, and the d shows the result when the search interval d_{SAP} isset to 0.5m. The precision of the details improve obviously, but still not precise enough on the edges of the building. Figure e shows the result of Z-buffer method, and it has good result while it appears some inaccurate detection points. The result of our method is revealed in figure d, and it's more accurate especially in details. Picture g and h give the detail results of Angle and based ray tracing and our method. Finally, the occlusion detection image is additionally compensated by neighbour image, and the true orthophoto is generated as shown in figure 6.

5. CONLUSIONS

Occlusion detection is the first and most vital step of the true orthophoto generation. Whether double mapping or building lean is solved depends on this process directly. This paper proposed a new occlusion detection method for true orthophoto generation. This method adopts the way of projecting roof and wall polygons to the ground horizontal planes, and obtains the occlusions by iteration strategy. Experiments show that the algorithm is effective for the true orthophoto occlusion detection. In addition, occlusion compensation is completed and true orthophoto is generated.

6. REFERENCES

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