SEMI-AUTOMATIC EXTRACTION OF HOUSES WITH MULTI RIGHT ANGLES FROM AERIAL IMAGES

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ABSTRACT:

The paper presents a general paradigm of semiautomatic house extraction from aerial stereo image pair. In the semiautomatic extraction system, the house model is defined as the one with multi right angles roof, then under the knowledge of the roof type, low-level and mid-level processing including edge detection, straight line segments extraction and obtaining initial house corners are used to establish the initial geometrical model of the roof-top. However, the initial geometric model is not so accurate in geometry. To attain accurate result, an improved Hough transform with constraints and a general least squares adjustment with geometric constraints in object space is applied to refine the geometrical model. As the adjustment model integrates the straight edge pattern and 3 dimensional constraints together, it is a well-studied optimal and anti-noise method. The experimental results show that it has given rise to a computational efficiency, high accuracy and robust.

1. INTRODUCTION

Automatic extraction of man-made object from space imagery is a hot-point problem in computer vision and digital photogrammetry. Up to now, many methods are presented for 3 dimensional building reconstruction, many technologies of image understanding and computer vision are widely used into this subject. At first, some researchers try to extract buildings automatically, but the bottleneck of the problem that is 'recognition' can't be resolved. Subsequently, Lang, Forstner and others offer semiautomatic extraction, and the accuracy is improved for reconstruction of buildings. At present, many commercial digital photogrammetric workstations have been developed and applied into practical production. Most of them can automatically generate digital terrain model (DTM), digital ortho-image (DOM) and so on, but there are not any systems can automatically extract and reconstruct buildings from space image (satellite or aerial image) to the level of practical production.

In this paper, we present an approach to semiautomatic house extraction from stereo image pair. Through the human-machine interface, an operator recognizes the type and rough position of the house, then the algorithm automatically extracts and accurately positions the vertexes of the house in object-space. The meaning of this strategy is to make full use of the advantage of Hough to extract lines, and remove the biggest obstacle of ambiguity of Hough transform and position initial corners in a wider range accurately. Under the constraints and clues of roof type and rough position, line segments extraction and optimization, and least squares adjustment with object-space are applied to output accurate 3-D model of the house. The human-machine corporation strategy fuses the advantages from both sides tone. One is the ability of human's vision and the other is the merit of fast and accurate evaluation of computer. It can raise the efficiency and accuracy of mapping from digital stereo image. On the other hand, once the function of automatic recognition of house comes into use, the algorithm of semiautomatic extraction can be directly used into the system to accomplish the 3-D reconstruction task. Following this part, main steps of the extraction algorithm, and some experimental results and conclusions are given.

2. INITIAL CONTOUR OF BUILDING

2.1 Hough Transform with Constraints to Extract Line

First step of semi-automatic house extraction is to offer initial value that means an operator chooses a position for the vertex of a house near the correct corner. The given position must be within a rectangle, the center of which is the actual corner, and the wide and high of which are given beforehand according with different situation. Being perpendicular to the line (l_1) that is an edge of the house generated by last Hough transform, an aslant rectangle (a) is determined centering about chosen current location. Then, the bit of image in the aslant rectangle (a) can be resampled and a horizontal bit (b) which is a polygon of the image is produced. Now, the original point of the coordinate system is set at the left-bottom of b. With this, ambiguity and time of calculation may be lessened, which is beneficial to Hough transform.

In this polygon, edges of the house are extracted by taking Sobel operator. The important thing is that the point only in the polygon can have a hand in the calculation. After convolution of pixel and Sobel masks, the value should divided out by 4, So, it can come to solution that the value of convolution may not be overflow (greater than the max or less than the min value of the gray image). At the same time, the gradient of each pixel ((g (x, y)/dy)/(g (x, y)/dx)) is calculated, which makes preparation for optimization for Hough transform.

Thinning the edges follows Sobel edge detection. Scanning from bottom to top, and from left to right of the house, if a pixel (pa) is in an edge obtained by Sobel edge extraction, its gradient is compared to the gradient of its adjacent two pixels in the direction of the gradient of pa, the pixel with maximum gradient value is edge pixel and reserved, accordingly, the other two pixels are not on the edge and deleted. This method is simple and efficient, because it makes full use of the value of gradient of each pixel. Then, after thinning, isolating point that contributes little to Hough transform must be deleted according with calculation the number of its connection, because many isolating points are noise or belong to another objects and their wrong gradients may lead to wrong Hough transform

Line positioning comes after points in the edges having been determined. In this scheme, the two parameters in the polar coordinate system are ρ and θ, ρ is the geometric distance, θ can not locate in the third quadrant as a consequent of the transform of coordinate systems and the position of the bit of this image. When Hough transform is done, an accumulator is constructed. At the same time, the slope of this line is put down. The direction of the line that is perpendicular to an edge of a house is the gradient(θ)of the pixel in the edge theoretically, but the calculated gradient of a point is inaccurate. According as polygon approximation, the calculation of accumulator is done not only to the parameter unit of θ, but also to the parameter units of $\theta \pm \Delta\theta$.Here, $\Delta\theta$ is limited.

$$\min\{|\theta - \theta_g|, |\theta - \theta_g + \pi|\} < 3\sigma_\theta$$
$$\Delta\theta = \min\{|\theta - \theta_g|, |\theta - \theta_g + \pi|\}$$

where θ =angle component in the polar coordinate system
θ_g =gradient of a pixel
σ_θ =contrast

After each point finishes accumulation, repeat segments must be deleted to obtain the accurate edge. Because part of pixels in one edge may be in another one by being calculated. First, local maximum value should be obtained. So, approximate thresholds of dρ and dθ (where: dρ denotes the span of ρ, and dθ is the span of θ for two iterate segments of two lines) are given by experiment. Second, repeat segments are deleted preliminarily. Line l_1 intersects line l_2 in a local region, and their decalage is less than Δθ (generally, it is less than 10 degree) ,and at the same time, the diversity of polar length of the two lines are less than Δρ, then, the shorter line is deleted. To obtain as good result of Hough transform as possible, more work must be done. If some points in Line l_1 are in Line l_2 at the same time, two constraints have to be considered. The first is their decalage Δα. In the Figure 2.1-1, P is a point in l_1, PP' is orthogonal of l_2, and point P' is in l_2.

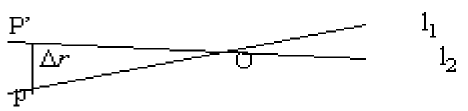

Figure 2.1-1

$$\Delta\alpha = \Delta r / t \qquad (1)$$
$$\Delta r = \rho_1 - \rho_2$$
$$\rho_1 = x\cos\theta_1 + y\sin\theta_1$$
$$\rho_2 = x\cos\theta_2 + y\sin\theta_2$$

where Δα=decalage of l_1 and l_2
Δr=distance of PP'
θ_1=angle component of l_1 in polar coordinate system
θ_2=angle component of l_2 in polar coordinate system
t= length of a valid segment

The second one is the length constrain. In the Figure 2.1-2, l_2' is the parallel line of l_2, and segment BE is one part of line l_1 (r_1, θ_1) . P is the intersection of BE and l_2. EE', BB' and PP' are perpendicular to l_2' , and B', P', E' are in l_2'.

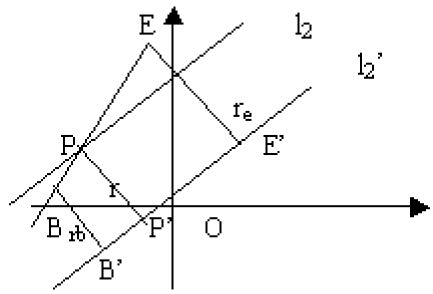

Figure 2.1-2

$$\min\{r_b, r_e\} \le r \le \max\{r_b, r_e\} \qquad (2)$$

where r_b =the distance of BB'
r_e =the distance of EE'.
r=the distance of PP'

The constraint (1) (2) must be valid when the segment BE is a repeat part of l_2. If all points in one line (l_1) are all in line(l_2), line l_1 is deleted, and if part of l_1 is in l_2 and the contrast radio of l_1 and l_2 is larger than a value that is predestined, and l_2 is longer than l_1, l_1 should be deleted.

2.2 Initial Value of Corners

Initial position of a corner is the intersection of two perpendicular edges. When edge information of one corner of a house are too ambiguity to extract good lines, the extracted lines of its two neighbour corners can determine that corner. If this is failed, it must determine artificially. After candidate corners are extracted, candidate intersections of each corner are put down for further procession in turn according to the area of a polygon that consists of candidate corners. The same work must done in the other epipolar image to obtain the candidate corners of the same house. So far, the initial contour of a house is extracted.

3. GENERAL ADJUSTMENT WITH GEOMETRIC CONSTRAINTS IN OBJECT SPACE

3.1 Error Equation

With the help of full digital photogrammetry system Virtuozo, two epipolar images and their positions in object space can be gotten. In the Figure 3-1, two epipolar images are given at the top. Four corners of the roof of this house are represented by a, b, c, d distinguishingly. In object space, corners are A, B, C, D accordingly. According with forward intersection, the coordinates of corners are calculated ($\hat{X}$, $\hat{Y}$, $\hat{Z}$) in object space. As the observation values, these candidate corners (x, y) in images are inaccurate, and shift along x and y is dx and dy distinguishingly, which causes inaccurate coordinates of object in object space, and it is same on the contrary. The shift of a point in object space is signified with dX, dY, dZ. Then, having the coordinates of object in object space as the parameters, the error equations of indirect adjustment can be listed based on resection.

$$
\begin{aligned}
dx_{lxi} &= f_{lxi}(dX_i, dY_i, dZ_i) \\
dy_{lyi} &= f_{lyi}(dX_i, dY_i, dZ_i) \\
dx_{rxi} &= f_{rxi}(dX_i, dY_i, dZ_i) \\
dy_{ryi} &= f_{ryi}(dX_i, dY_i, dZ_i)
\end{aligned}
\qquad (3)
$$

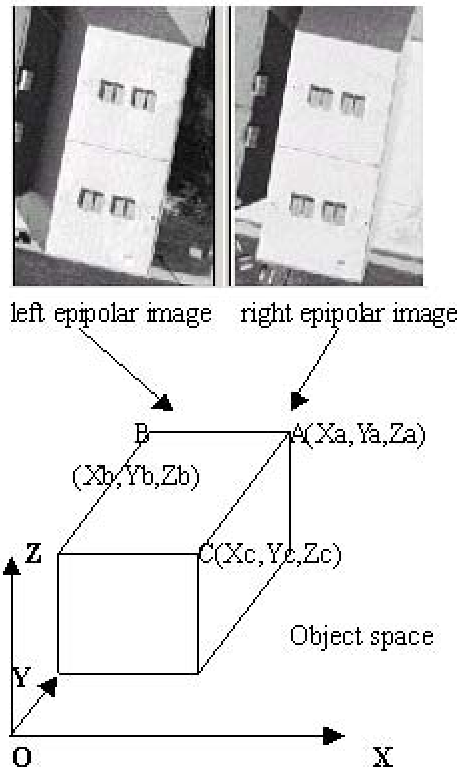

Figure 3-1

3.2 Constraint Equations

3.2.1 Zero Parallax of Vertical Orientation

In epipolar image pair, homonymous points are in the same horizontal line. As a result, there is not parallax in vertical orientation for the two homonymous points in an epipolar image pair, and the parallax in horizontal orientation decides the altitude of the homologous point in object space. Then, the constraint equation is produced.

$$
\begin{aligned}
dy_{ri} - dy_{li} - (y_{ri} - y_{li}) &= 0 \\
dy_{ri} &= f_{lyi}(dX_i, dY_i, dZ_i) \\
dy_{li} &= f_{ryi}(dX_i, dY_i, dZ_i)
\end{aligned}
\qquad (4)
$$

3.2.2 Straight Angle Constraint

In an image, two line consisting of a straight angle may be not vertical for geometric distortion because of projection. So, the constraint must be given based on object space.

$$
\begin{aligned}
&(X_a - X_C)dX_b + (X_c + X_b - 2X_a)dX_a \\
&+ (X_a - X_b)dX_c + (Y_a - Y_C)dY_b \\
&+ (Y_b + Y_c - Y_a)dY_a + (Y_a - Y_b)dY_c - L = 0
\end{aligned}
\qquad (5)
$$

where X_i=coordinate of corner I in object space along X axle
Y_i=coordinate of corner I in object space along Y axle
Z_i=coordinate of corner I in object space along Z axle
i= sequence number of a, b, c
I= sequence number of A,B,C

3.2.3 Equal Altitude

For a house with multi straight angles, altitudes of its corners are equal.

$$
\Delta Z_i - \Delta Z_{i-1} + Z_i - Z_{i-1} = 0 \qquad (6)
$$

where ΔZ_i=altitude of corner i
i-1,i,i+1=three serial corners in object space

Together with the error equations (3) and Constraints (4) (5) (6), the function model of indirect adjustment with constraints can be created, and the corners of the house can be positioned accurately by calculation of least square adjustment.

4. EXPERIMENT AND CONCLUSION

4.1 Experiments

4.1.1 Experiment No.1

A aerial gray image and the extraction results appear in Figure 4.1.1-1, 4.1.1-2. In the Figure 4.1.1-1, there is a house with multi straight angles. It can be seen that the contour of house is extracted correctly. In the Fig 4.1.1-2, it displays a corner that is sextuple than that of 4.1.1-1. The initial position of the corner is given artificially that is represented by a red cross, and a green cross represents the extracted corner. From the figure, it is clear that the corner is extracted accurately even if the diversity of the initial point and the genuine one is close to 10 pixels. As a result, when an operator mapping, he can fell much more relaxed and easy for decreasing work., at the same time, it is more accurately than man does so.

4.1.2 Experiment No.2

In the Figure 4.1.2-1, it is an original aerial gray image. After edge extraction, points in edges are extracted and displayed as pixels with 256 gray in the Figure 4.1.2-2. The edge information is not bountiful, and there are so much noise. The Figure 4.1.2-3 is an original image. It is clear that edge with a little fringe points and much noise is extracted correctly, and the contour of this house that is drawn with red lines is peripheral. In Figure 4.1.2-4, the image is sextuple than original image. The green cross is initial inputting position of a corner, and the red cross means the extracted corner.

4.2 Conclusion

The application indicates that the algorithm is one algorithm with good interactivity, a measure of interference immunity, good accuracy, high speed and more efficiency. Aiming at extracting multi straight angles house, the advantage of Hough transform enables it to prevent the noise, and the geometrical conditions decide the alone and superior initial position of a corner. The least square adjustment with constraints of object space positions the house accurately last.

However, this approach is appropriate for a house with multi straight angles only. There is a great potential for generating an efficient scheme to extract other kind of complicated houses. For complicated house, different method may be applied for corner and edge with different character.

Figure 4.1.1-1

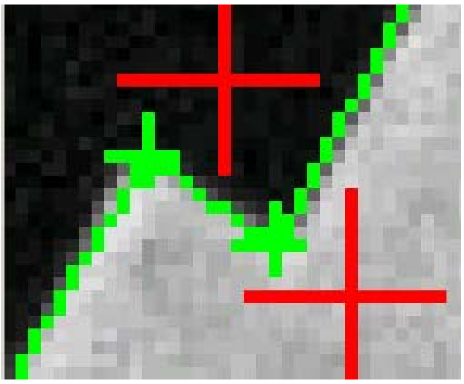

Figure 4.1.1-2

Figure 4.1.2-1

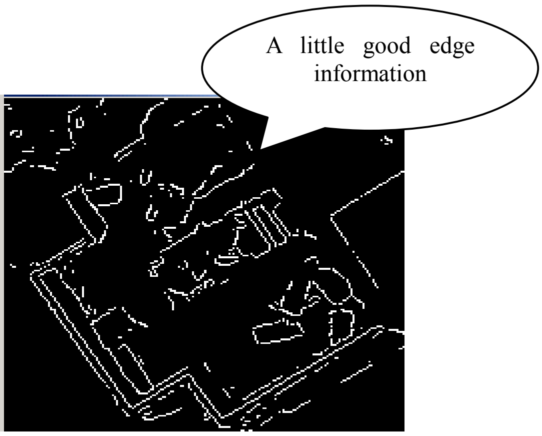

Figure 4.1.2-2

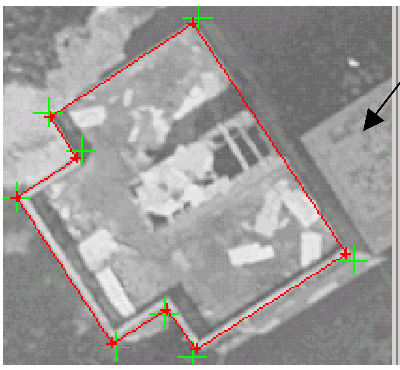

Figure 4.1.2-3

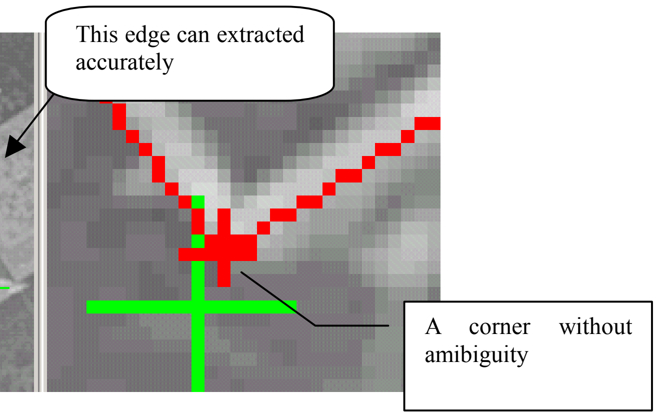

Figure 4.1.2-4

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