EXTERIOR ORIENTATION FOR REMOTE SENSING IMAGE WITH HIGH RESOLUTION BY LINEAR FEATURE

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ABSTRACT:

An automatic approach to the exterior orientation by using linear primitives such as rivers and roads, which are extracted from the image and match to the existing vector data, is presented in this paper. Because the automatic identifying line features is much easier than point features, so that the observations are increased significantly and the exterior orientation can be improved. Proposed approach creates the possibilities for automatic exterior orientation in special data updating and the registration of multi-resolution remote sensing images. The exterior orientation is based on automatic linear object extraction and generalized point photogrammetry, so called generalized point it means that collinearity equation is still used for linear primitives, which is divided into three phases. In the first phase, by using three coarse conjugate point pairs defined manually a global affine transformation between remote sensing image and vector map is determined, which provide initial corresponding relation between image and map for automatic linear feature extraction. Based on the high accuracy extraction algorithm, the linear objects are optimized automatically in the second phase. In the third phase, the exterior parameters of remote sensing image with high resolution are computed based on the linear object segments by the generalized point photogrammetry. Proposed method can used for both affine transformation and second order polynomial for remote sensing image. Within the study, some experiments are carried out for a number of images with high resolution. All of the results of the experiments show that the approach mentioned above is feasible and very efficient.

1. INTRODUCTION

It is now widely accepted that photogrammetry has reached the digital age and that many processes can be carried out more efficiently using digital data than with hard copy images. It is by no means yet accepted that digital methods can offer savings in time and cost across the board and it is likely that the development of more robust automatic techniques will be needed before this can happen. The automatic exterior orientation of remote sensing imagery is a promising task in photogrammetry and remote sense, which is usually completely performed by a human operator in the Digital Photogrammetric Systems existing today.

The need of making map revision arises due to the addition or removal of terrain features. The rapid changes in the map contents and the need for up-to-date maps have compelled surveyors to focus their attention to the development of faster and more economical map revision processes. Photogrammetric techniques and satellite techniques are main means for the map revision, in which remote sensing imagery are effective and economical data source. In the processing the captured image, the first step is calculating the parameters of image position and orientation.

Exterior orientation for remote sensing image is a prerequisite for its geo-reference, which was solved using a number of well-defined ground control points (GCPs) traditionally. It is a time consuming operation because the GCPs were measured manually and the recognition of control points was very difficult. Generations of researchers have worked hard to improve this process.

It is essential that the same feature is identified from the image and the reference data. In view of these issues, other researchers have investigated the use of higher-level geometric features such as lines or curves as observed geometric entities to improve the automation for estimating exterior parameters, which also improve robustness and accuracy. With the recent trend towards automatic extraction and recognition of features from digital imagery, it is becoming advantageous to utilize features in photogrammetric applications. Those features can be used to increase the redundancy and improve the geometric strength of photogrammetric adjustments. In addition, it is easier to automatically extract features than distinct points from imagery. In the literature many advantages of using line observations instead of points can be found. The most prominent advantage is the better automation potential for extraction and measurement of lines in digital imagery (Burns, 1986). From the geometrical point of view lines have the advantage that they only have to be partly visible in the image, and this does not have to be the same part for image and corresponding map.

An automatic approach to the exterior orientation by using linear primitives such as rivers and roads, which are extracted from the image and match to the existing vector data, is presented in this paper. Because the automatic identifying line features is much easier than point features, so that the observations are increased significantly and the exterior orientation can be improved. Proposed approach creates the possibilities for automatic exterior orientation in special data updating and the registration of multi-resolution remote sensing images.

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This paper is organized as follows: Section 2 briefly summarizes the automatic river feature extraction based on old vector river map by profile matching. The mathematical model and its solution of generalized point photogrammetry are presented in Sections 3. In section 4, based presented method above, some tests are carried out and the precision proved the method is manipulable. Conclusion is drawn in section 5.

2. AUTOMATIC FEATURE EXTRACT

Extraction of curvilinear features such as rivers and roads has been one of popular research topics in computer vision, photogrammetry, remote sensing and GIS communities. Automation of such extraction has been key research issue, although full and reliable automation is yet to be achieved. Various methods proposed for this theme include perceptual grouping, (Trinder and Wang, 1998; Katartzis et al., 2001), scale-space approaches (Mayer and Steger, 1998), neural network and classification (Doucette et al., 2001), "snakes" or energy minimization (Gruen and Li, 1997), and template matching (Vosselman and Knecht, 1995; Gruen at al., 1995; Hu et al., 2000). Those methods were always proposed for road extraction from aerial imagery or remote sensing imagery, which were not always fit for river extraction from remote sensing imagery.

In this paper, a new algorithm for river extraction was proposed with two steps, which provide the observations for the exterior orientation in the next section. First a global affine transformation between remote sensing image and vector map is determined by using three coarse conjugate point pairs defined manually, which provide initial corresponding relation between image and map for automatic linear feature extraction. In the second steps, profiles matching is preferred for precise extraction of river feature points based on the radiological characteristic of river on the remote sensing imagery and the initial position proposed in the first step.
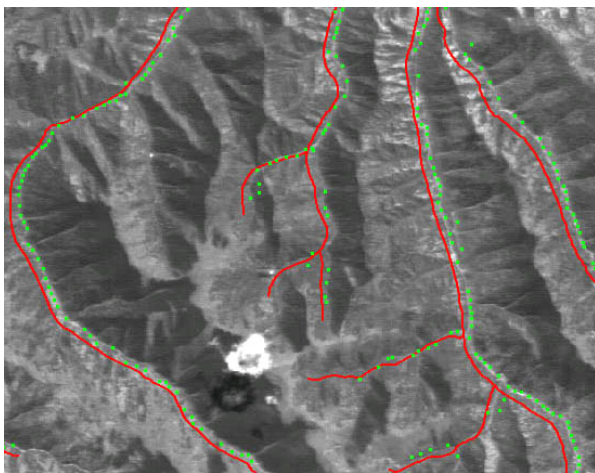

Figure 1: river feature points extraction by profile matching, the red lines are initial value provided by vector road map; the green points are feature points extraction by profile matching
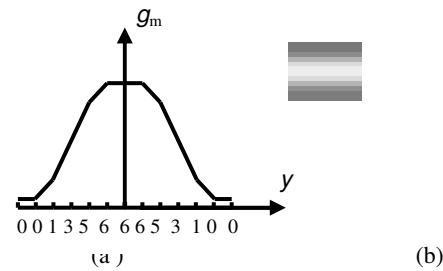

Figure 2: Stand Ridgelike Template (a) and the Generated Model Profile over Maximising Cross Correlation (b)

On the remote sensing imagery, the characteristic of rivers are not distinct like the roads, which are geometrically elongated, have a maximum curvature, and radiologically have a homogeneous surface and a good contrast to adjacent areas. In this paper, the whole rivers net were not extracted whereas the feature points of the rivers were extracted corresponding to the projected river line segments beside the initial position transformed through three coarse conjugate point pairs (Figure 1). The profile matching compares the model profile with the river profile at the position on the normal orientation of the initial river line segments. The model profile was generated with a stand ridgelike template over maximising cross correlation (Figure 2). The differences between the two profiles are modelled by two geometric (shift and width) and two radiometric (brightness and contrast) parameters. These parameters are estimated by minimising the square sum of the grey value differences between the profiles (Ackermann (1984)). Least squares matching are preferred over maximising cross correlation because least squares matching can estimate the precision of the profile shift. This precision can be used to evaluate the success of the matching algorithm and moreover is required as weight for the exterior orientation. Another advantage of least squares matching is the possibility to model the geometric (and radiometric) transformation between the two profiles. Not only the river position, but also the river width can be estimated. Thus, when the road width is changing, least squares matching can obtain good results while cross correlation will fail (Figure 1).

3. MATHEMATICAL MODEL

Traditional photogrammetric exterior orientation procedures are point based. The exterior orientation of a single image can be determined by means of several control points. Their image coordinates and ground coordinates are the observations in the collinear equations, and the exterior orientation parameters are computed in a least squares adjustment. In this research, the exterior orientation is based on automatic linear objects extraction and generalized point photogrammetry, so called generalized point it means that collinear equation is still used for linear primitives.

Some literature proposed line photogrammetry, which used linear primitives to calculate the exterior orientation parameters based on the principle that the object space point P lies on the plane defined by the perspective center S and the two image space points defining the image line (a and b) (Figure 3). The collinear error function was adopted with the observational values of extracted linear primitives and their corresponding object space linear primitives (Zuxun Zhang 2003). In this

paper, a more simple error function is proposed based on the generalized point photogrammetry, which unifies the point primitives and linear primitives.

From mathematical all lines or curves are consists of points (figure 4) and the collinear equation is commonly used the all mathematical points. In this research, the affine transformation mathematical model based on parallel ray projection was adopted (equation 1), which is the strict in theory and the parameter computation of remote sensing image with high resolution based on it is very stable, namely the problem of the relativity of image parameter calculation is solved completely by the strict geometric model (Jianqing Zhang 2002). For every pair of image space line segment and object space point, only one equation, depending on the direction of the line segment, is used. When θ is more than $45°$ dx can be served as the error, otherwise when θ is less than $45°$ dy can be served as the error. The underlying principle in this mathematical model is that the projected point of the object space line by the mathematical model (green point) lies on the line segment extracted from the image (Figure 4). If we have little GCPs the hybrid adjustment can be done without any modification of the error conditional equation, which can solve the problem of too little GCPs or improper distributing and improve robustness and accuracy of adjustment.
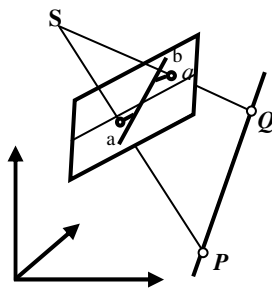

Figure 3: perspective geometry model between the image space line segment and the object space feature point on line segment
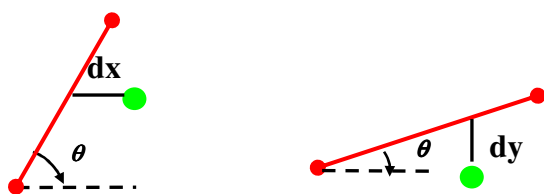

Figure 4: geometry condition between the image space line segment and the object space feature point on line segment, green point is projected from corresponding 3D line, the red point is extracted feature point corresponding to 3D line

$$x = (a_0 + a_1 X + a_2 Y + a_3 Z)\frac{f - x tg\alpha}{f - \dfrac{Z}{m\cos\alpha}} \quad when \quad |\theta| \ge 45°$$

$$y = b_0 + b_1 X + b_2 Y + b_3 Z \quad\quad when \quad |\theta| < 45°$$

(1)

Where x and y are image space coordinate in pixel

X and Y are object space coordinate in meter

In term of least squares estimation, equation (1) can be considered as a nonlinear observation equation. Applying Taylor's series to equation (1), dropping second and higher order terms, the linearized form of the observation equation becomes

$$A_1 \cdot dx + A_2 \cdot da_0 + A_3 \cdot da_1 + A_4 \cdot da_2$$
$$+ A_5 \cdot da_3 + A_6 \cdot d\alpha + F_x = 0$$

(2)

$$A_1 \cdot dy + A_7 \cdot db_0 + A_8 \cdot db_1 + A_9 \cdot db_2$$
$$+ A_{10} \cdot db_3 + F_y = 0$$

4. RESULT

In this section, results of the approach proposed in this paper are presented. We select three SPOT3 PAN images with 10 m pixel ground resolution at south of Gansu province of China, which belong to mountainous area. The topographic database of river net is vectored from map with the scale of 1:50000. The DEM data is obtained with the precision of 25m-grid space. Because of the non-linearity of the system, the final solution is obtained iteratively. The result indicated that the iteration converges very fast. After each iteration of the adjustment the weight of each observation is recomputed with the weight function of Helmert method. Then the weights of the observations containing gross errors will become smaller and smaller until finally approach zero. Therefore, the result of adjustment will not be affected by the blunders. Based on the exterior orientation parameter, SPOT3 PAN Images are superposed by the georeferenced Map with the scale of 1:50000 (figure 5). To quantitatively assess the accuracy of the exterior orientation parameters computed above, 50 check points for every image (ground object points and their corresponding points on image) was tested (table 2). The three test area are all belong to mountainous area with the elevation interval of 1000m above and slope grade of $20°$ above. The conclusion can be drawn that the exterior orientation can satisfy the requirement of map revision with the scale of 1:50000 based on the criterion in table 2 (Remote sensing institute of Sichuan province,2002).

Model name	RMSE	X-RMSE	Y-RMSE	Max X-err	Max Y-err
257281	1.266	0.978	1.500	-1.929	3.471
256282	1.309	1.300	1.318	3.124	-3.036
258282	1.485	1.461	1.508	2.608	-2.651

Table 1: Experiment Results Of Exterior Orientation with Check Points (Unit: Pixel)

Type of region	Characteristic	RMSE	Max Error
Plain or Hill	elevation interval 600m grade 6°	20m	2 times of RMSE
Mountain	elevation interval ≥600m grade ≥ 6°	30m	2 times of RMSE

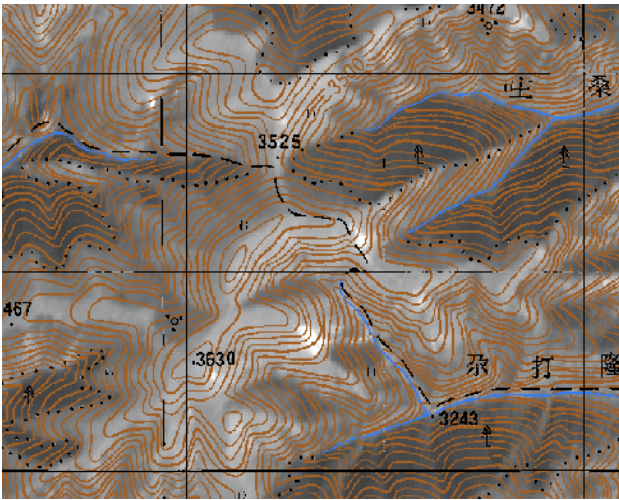Table 2: Precision of Check Points for Map Revision with Scale of 1:50000

Figure 5: SPOT PAN Image superposed by Map with Georeference based on the exterior orientation parameter

5. CONCLUSION

This paper introduces a fully automatic approach for the exterior orientation of remote sensing imagery with high resolution by matching extracted river feature points from the image against the corresponding objects of an existing vector river map or a GIS database. The implemented approach is based on automatic curvilinear features extraction from remote sensing imagery and generalized point photogrammetry. The result shows that the exterior orientation can satisfy the requirement of map revision with the scale of 1:50000. The presented procedure does not need much manual interaction and therefore has the potential to be integrated into an automatic workflow. Proposed approach creates the possibilities for automatic exterior orientation in special data updating and the registration of multi-resolution remote sensing images.

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