SEMIAUTOMATIC EXTRACTION OF 3D CURVES BASED ON SNAKES AND GENERALIZED POINT PHOTOGRAMMETRY FROM AERIAL IMAGERY

Yongjun Zhang,Quanye Du

School of Remote Sensing and Information Engineering, Wuhan University, 129 Luoyu Road,430079, China
- zhangyj@whu.edu.cn -duquanye@yahoo.com.cn

Commission III, ThS-7

KEY WORDS: Photogrammetry, Feature, Extraction, Building, Edge, Aerial, Imagery

ABSTRACT:

The Snakes or active contour models of feature extraction algorithm integrates both photometric and geometric constraints. It derives the feature of interest by minimizing the total energy of Snakes with an initial location of the feature. Linear features can be directly processed with either x or y collinearity equation under the model of generalized point photogrammetry. In this paper, a new approach of extracting 3D curves based on Snakes and generalized point photogrammetry is proposed. Firstly, curve feature is extracted based on parametric B-spline approximation and Snakes on a single image. The seed points of curve feature on other images are determined by matching corresponding points. Then the corresponding curves are extracted by Snakes. Finally, the 3D curve model can be achieved by generalized point photogrammetry. Experimental results show that the proposed approach is feasible for 3D curve extraction.

1. INTRODUCTION

Linear feature extraction is one of important parts of image processing. At present, reconstructed buildings are usually regular objects. There are no available algorithms to realize automatic and mass reconstruction for which including curve edges. Curve extraction and expression on images have been studied many years in computer vision field, and many available algorithms have been developed. Meanwhile, in photogrammetry field, some extraction and reconstruction algorithms of roads, contour, coastline are developed, but they most applied to a single image, without considering the case of big overlap imagery. This paper presents an approach to extract and reconstruct building curve edges from digital aerial images. However, it is semiautomatic. The identification task is performed manually, and some few seed points as approximation of curve feature should be provided manually but coarsely on a single image. Subsequently, with these seed points, the curve feature will be extracted precisely and automatically by Snakes. Furthermore, the corresponding curves on other images are extracted automatically using corresponding point matching and Snakes, and 3D curve model can be acquired by generalized point photogrammetry from multiple images.

2. SNAKES

Snakes, or active contour models was introduced firstly by Michael Kass et al. (Kass, et al., 1988). It is used widely in many image processing areas, such as image segmentation, image tracking, 3D reconstruction, etc. In the recent twenty years, it has been researched, and developed Greedy algorithm Snakes(Williams, Shah, 1990) , Dynamic Program Snakes (Amini, et al., 1990), LSB-Snakes (Grun, Haihong Li,1997), GVF Snakes (Chenyang Xu, Prince Jerry, 1998), FFA Snakes (Zhiqiang Hou, Chongzhao Han, 2005), etc.

A traditional snake is a curve:

$$v(s) = (x(s), y(s)) \tag{1}$$

which is under the influence of image forces and external constraint forces, while energy is minimum, namely internal and external force balance, curve arrives object edges. Energy function is:

$$E^*_{snake} = \int_0^1 E_{snake}(v(s))ds = \int_0^1 E_{\text{int}}(v(s)) + E_{image}(v(s)) + E_{con}(v(s))ds \tag{2}$$

Where E_{int} represent the internal energy of the spline due to bending，
E_{image} gives rise to the image force,
E_{con} gives rise to the external constraint force.

The internal energy can be：

$$E_{\text{int}} = \left(\alpha(s)|v_s(s)|^2 + \beta(s)|v_{ss}(s)|^2\right)/2 \tag{3}$$

Where $\alpha(s)$ and $\beta(s)$ are coefficients,

$$v_s(s) = \partial v / \partial s\,,$$
$$v_{ss}(s) = \partial^2 v / \partial s^2\,.$$

In fact, it becomes the following function during calculating.

$$E_{int}(v_i)=\left(\alpha_i\left|v_i-v_{i-1}\right|^2+\beta_i\left|v_{i-1}-2v_i+v_{i+1}\right|^2\right)/2 \qquad (4)$$

As external forces, E_{image} and E_{con} are determined by image information and user definition, typical external force is:

$$E_{ext}=-\left|\nabla I(x,y)\right|^2$$

or

$$E_{ext}=-\left|\nabla\left(G_\sigma(x,y)*I(x,y)\right)\right|^2 \qquad (5)$$

E_{snake} can be acquired after Snake initialization. Potential energy is transformed to kinetic energy, and consumed by next energy. Snake energy is minimized and drew to more stable status. That is to say, the key problem is to calculate the minimum energy.

2D curve on images can be represented in parametric form as

$$x(s)=\sum_{i=0}^{n}N_i(s)X_i$$
$$y(s)=\sum_{i=0}^{n}N_i(s)Y_i \qquad (6)$$

where X_i and Y_i are the coefficients of the B-spline curve in x and y direction repectively. $N_i(s)$ is the normalized 3th B-spline between knots S_i and S_{i+4} (Hongwei zhagn,2004).

3. GENERALIZED POINT PHOTOGRAMMETRY

Traditional photogrammetry is based on feature points, and points in photogrammetry means only physical or visible points, such as dots, crosses and corners (Zuxun Zhang, Jianqing Zhang, 2005). According to camera model, the collinearity equations are:

$$x=x_0-f\frac{a_1(X-X_S)+b_1(Y-Y_S)+c_1(Z-Z_S)}{a_3(X-X_S)+b_3(Y-Y_S)+c_3(Z-Z_S)} \qquad (7)$$

$$y=y_0-f\frac{a_2(X-X_S)+b_2(Y-Y_S)+c_2(Z-Z_S)}{a_3(X-X_S)+b_3(Y-Y_S)+c_3(Z-Z_S)} \qquad (8)$$

where x and y are the observations,
X, Y and Z are the coordinates of ground point,
a_i, b_i, c_i $(i=1,2,3)$ are the orientation matrix composed of rotation angles φ, ω and κ, where Y-axis is taken as the primary axis.
X_s, Y_s, Z_s, φ, ω, κ, f, x_0, y_0 are the exterior and interior parameters.

In fact, the equations need to be linearized during calculating.

Usually, a space curve can be parameterized as

$$\begin{cases} X=f(t) \\ Y=g(t) \\ Z=h(t) \end{cases} \qquad (a\le t\le b) \qquad (9)$$

where $f(t)$, $g(t)$ and $h(t)$ are the locus of points on the space curve as a function of curve parameter t, ranging from a to b. Incorporating equation (9) into equation (7) and (8) leads to:

$$x=x_0-f\frac{a_1(f(t)-X_S)+b_1(g(t)-Y_S)+c_1(h(t)-Z_S)}{a_3(f(t)-X_S)+b_3(g(t)-Y_S)+c_3(h(t)-Z_S)} \qquad (10)$$

$$y=y_0-f\frac{a_2(f(t)-X_S)+b_2(g(t)-Y_S)+c_2(h(t)-Z_S)}{a_3(f(t)-X_S)+b_3(g(t)-Y_S)+c_3(h(t)-Z_S)} \qquad (11)$$

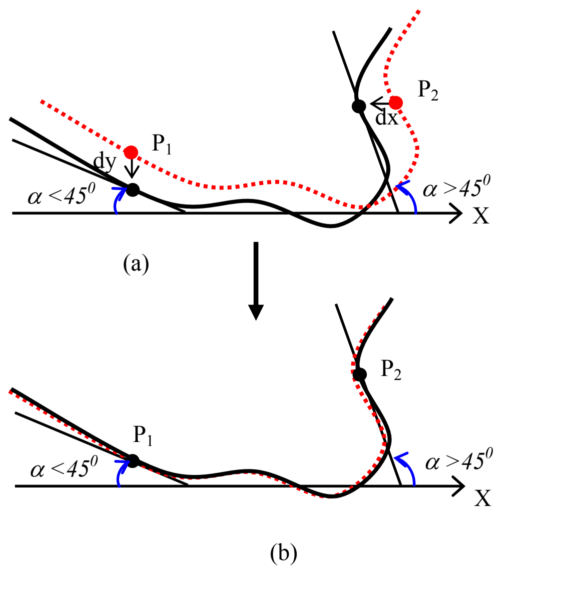


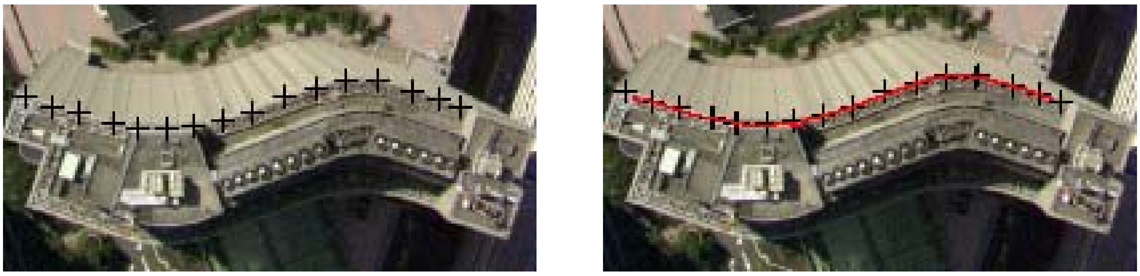
Figure1. curve reconstruction with generalized point photogrammetry

Suppose the tangential vector of a point on the observed image curve is α (as shown in figure1a), equation (10) is used for exterior orientation and 3D reconstruction if $45^0 \leqslant \alpha \leqslant 135^0$ or $225^0 \leqslant \alpha \leqslant 315^0$, otherwise equation (11) is used. The above model can be used for reconstruction of space curves.

For a space curve, its disparity between the observed image feature and the projected space feature is shown in figure 1a. The disparity becomes smaller and smaller during iterations, and usually converges within several iterations (as shown in figure1b). A space curve is photographed in at least two stereo images, the image parameters and the model of the curve may be solved by an iterative bundle adjustment with equation (10) and (11) simultaneously. To ensure the stability of adjustment, more than two overlapping images are expected. However, one should be careful that the parameter a and b in equation (9) have to be known for opening curves, while it is not necessary to be known for closed curves, such as circles and ellipses. Degenerate cases must be avoided to reconstruct the curves. For example, the perspective center falls in the plane where a 3D planar curve lies. In this case, the image feature will be an edge instead of a curved feature.

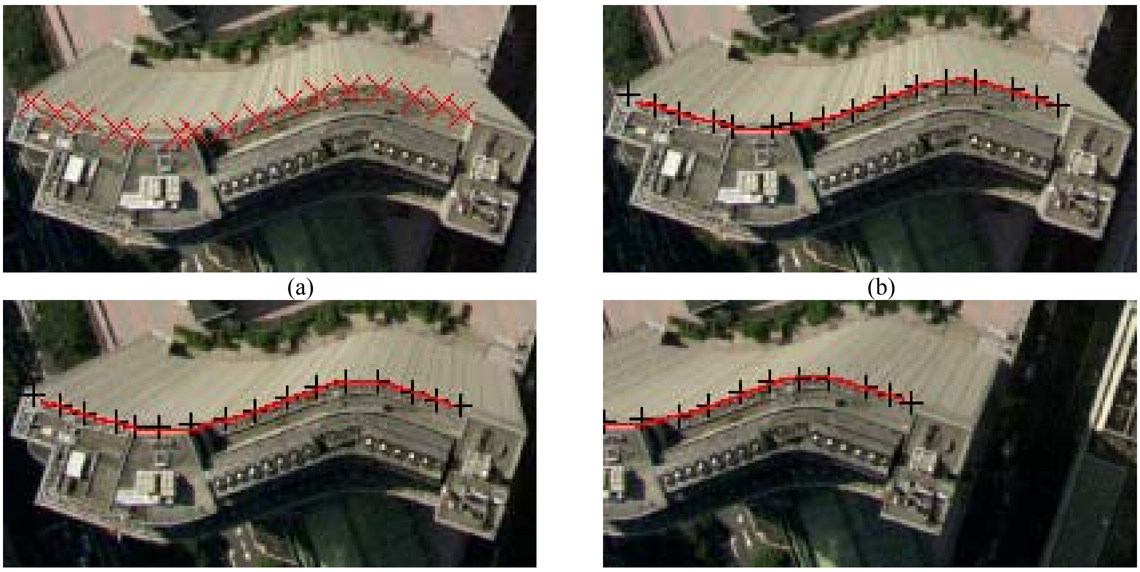
4. EXPERIMENT

Our test data is a set of big overlap aerial imagery, and the curve features of interest are building curve edges. Snakes algorithm requires that the seed points of object curve must be near to the true edge. Otherwise, it can not converge to the ideal contour. In the first place, one image with a good object imaging is selected, and some seed points are located manually (as shown in figure 1a, the black cross points), then object curves are extracted automatically by snakes (as shown in figure 1b, the red curve), and curve is expressed by B-splines. Secondly, the seed points are transferred to other images by corresponding points matching. The maximum correlation algorithm is adopted in our experiment (Zuxun Zhang, Jianqing Zhang, 2005). The result of corresponding seed points on another images are shown in Figure 2a (the red cross points). In this way all seed points are determined, and the corresponding curves can be extracted automatically on other images (as shown in figure 2b, 2c and 2d, the red curves. The black cross points are corresponding seed points by matching.). In addition, the interior and exterior orientation elements can be acquired by triangulation or other methods. Furthermore, the space 3D curve model can be achieved by traditional photogrammetry adjustment and generalized point photogrammetry adjustment.



(a) (b)

Figure2. Semiautomatic curve extraction on a signal image. (a) Initial seed points of curve feature. (b) Curve extraction result.



(a) (b)

(c) (d)

Figure3. Multiple images corresponding curve extraction result. (a) The corresponding points of seed points on another image. (b)(c)(d) Automatic curve extraction result on other images.

5. CONCLUSION

In this paper we have presented a new approach for curve feature extraction. The method of active contour models (Snakes) constrained by both photometric and geometric conditions extracts curve feature accurately on a single image. Through corresponding point matching, corresponding curve extraction by Snakes is implemented automatically on other images. Instead of a set of points on the feature, a B-spline representation of the curve feature is estimated. Furthermore, the 3D curve model can be achieved by generalized point photogrammetry effectively. The precision and reliability of the estimated 3D curve feature are determined by covariance matrix. This approach is not restricted to building curve edge extraction. Other similar curve features, especially in close-range photogrammetry, also can be extracted and reconstructed. Further studies will make use of more extensive constrained conditions, and improve automatization of processing.

REFERENCES

Amini, A., Weymouth, T., and Jain, R., 1990. Using Dynamic Programming for Solving Variational Problems in Vision. *IEEE Trans. Pattern Analysis and Machine Intelligence*.

Chenyang Xu, Prince Jerry L., 1998. Snakes, shapes, and gradient vector flow. *IEEE Transactions on Image Processing* , 7 (3),pp.359 -369.

Grun A, Haihong Li, 1997. Semiautomatic linear feature extraction by dynamic programming and LSB-Snakes. *Photogrammetric Engineering & Remote Sensing*, 63(8),pp. 985-995.

Hongwei Zhang, 2004. Automatic registration between remote sensing image and vector map (PhD Dissertation), pp. 40-43.

Kass, M., Witkin, A., and Terzopoulos, D., 1988. Snakes: Active Contour Models., *Int'l J. Computer Vision*, vol. 1, pp. 321-331.

Williams, D.J., Shah, M., 1990. A fast algorithm for active contours. *Third Int'l Conf. Computer Vision*, pp. 592-595.

Zhiqiang Hou, Chongzhao Han, 2005. Force field analysis snake: an improved parametric active contour model. *Pattern Recognition Letters,* 26(5), pp. 513-526.

Zuxun Zhang, Jianqing Zhang, 1996. *Digital Photogrammetry*. Publishing House of Wuhan Surveying and Mapping University, Wuhan, pp. 159-169.

Zuxun Zhang, Jianqing Zhang, 2005， Generalized point photogrammetry and its application. *Geomatics and Information Science of Wuhan University,* 30(1), pp. 1-4.

ACKNOWLEDGEMENTS

This work is supported by the National Natural Science Foundation of China (NSFC) with Project No. 40671157 and National Hi-tech Research and Development Program (863 Program) of China with Project No. 2006AA12Z136.