RPC MODELING FOR SPACEBORNE SAR AND ITS APLICATION IN RADARGRAMMETRY

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1. INTRODUCTION

There are two main methods for modeling satellite imaging geometry: the rigorous physical sensor model and the mathematical replacement sensor model. The rigorous physical sensor model has a high accuracy, but it is quite complex and costs too much time for positioning each pixel. By relating image coordinates and object coordinates through mathematical functions, the replacement sensor model can avoid the time-consuming iterative procedure. The rational function model is a typical type of a replacement sensor model which takes the form of a rational function [1]. Due to its capability of maintaining the accuracy of the rigorous sensor model, the rational function model is considered to be able to replace the rigorous physical sensor models [2].

The RPC (Rational Polynomial Coefficient) model is a rational function model which relates image 2D coordinates and the corresponding object 3D coordinates by rational polynomial [3]. It has been successfully applied in geo-location of high-resolution optical imagery, such as IKONOS, QuickBird, GeoEye-1, etc., and has become a standard component for processing optical data. However, the applicability of the RPC model to spaceborne SAR data has not been systematically studied until recently. In our proposed paper, we investigate the approach for building RPC models for stripmap TerraSAR-X data and applying it to radargrammetry for DEM generation.

2. GEOLOCATION USING RPC METHOD

There are two methods for RPC modeling. One is the inverse method in which the planimetric object coordinates are represented as rational polynomials functions of the image coordinates and the ground elevation [4], as shown in Eq. (1) and (2):

$$X = \frac{p1(r,c,Z)}{p2(r,c,Z)} \quad (1)$$

$$Y = \frac{p3(r,c,Z)}{p4(r,c,Z)} \quad (2)$$

The other method is known as the forward method, in which the image coordinates in line/pixel are expressed as rational functions of the 3D object coordinates [5]-[7], as shown in Eq. (3) and (4):

$$r = \frac{p5(X,Y,Z)}{p6(X,Y,Z)} \quad (3)$$

$$c = \frac{p7(X,Y,Z)}{p8(X,Y,Z)} \quad (4)$$

In RPC-based geo-location, the rational polynomial coefficients need to be solved in the first place. A regular object grid covering the full extent of the image with several height layers can be established. The corresponding image coordinates of every grid point in object space will be calculated using the rigorous sensor model and the known satellite ephemeris data [8]. In our study, the Range-Doppler model is used as the rigorous sensor model for spaceborne SAR data. RPC coefficients can be estimated using a least-squares solution with an input of the object grid points(X, Y, Z) and the corresponding image grid points (r, c).

Solving ill-conditioned linear equations is the key point of solving the RPC coefficients. Since ill-conditioning causes a huge amplification of errors, the normalization of the image 2D coordinates and corresponding object 3D coordinates need to be done in the first place. Biased methods like ridge trace, L-curve and unbiased method like the iteration method by correcting characteristic value (IMCCV) have all been tested [9]-[11]. Experimental results show that the ridge trace method is quite time-consuming with a low accuracy. The L-curve method is fast but the accuracy is lower than IMCCV, while IMCCV takes much more time in iterative calculations due to its strong dependence on the initial values for the solution. Therefore, a hybrid approach is proposed to combine the L-curve and the IMCCV methods for RPC modeling.

3. RPC APPLICATION IN RADARGRAMMETRY

RPC models can be used in many applications in which geo-locations of remote sensing data are required. In our proposed paper, we will analyze the potential of RPC models for spaceborne SAR data radargrammetry.

In radargrammetry, a SAR stereo pair is acquired with different incidence angles. The data is processed to reconstruct the 3D geometry in object space. The classical radargrammetric method is the parallax-based method which uses the difference of homologous point coordinates on reference and match image to calculate the corresponding object's height.

Dealing with a stereo pair calculation, the inverse RPC method is adapted to iterative calculate the object coordinates [4], [7]. The stereo pair needs to be matched and the RPC coefficients of the reference and match image are calculated by the above mentioned method. For a pixel on the reference image, setting an initial approximate value for elevation Z, the corresponding object coordinates can be calculated using the RPC model of the reference image. This pixel's homologous point in the match image can also calculate another corresponding object coordinates. Since the two pixels are homologous points, the corresponding object coordinates should be identical. According to the difference of the two object coordinates, the initial value of elevation Z can be corrected. This process is repeated until the specific maximum number of iterations has been reached or Z converges. Based on our experiments, the algorithm does always converge fast when the two image points are indeed a pair of homologous points.

Based on an exampled from Malaysia, the capability of rapid 3D reconstruction via RPC with TerraSAR-X data will be shown.

4. PRELIMINARY CONCLUSIONS

RPC Model accuracy is evaluated in TerraSAR-X images. In the final paper we will evaluate the model also for ASAR, Radarsat, COSMO-SkyMed and ALOS images. The experimental results show that high accuracy can be obtained by the hybrid approach at a low cost in computation time.

REFERENCES

[1] C.V. Tao and Y. Hu, "A comprehensive study of the rational function model for photogrammetric processing," *Photogrammetric Engineering & Remote Sensing,* vol. 67, pp. 1347-1357, 2001.

[2] F.C. Paderes, E.M. Mikhail, and J.A. Fagerman, "Batch and on-line evaluation of stereo SPOT imagery," in *Proc. ASPRS-ACSM Convention*, Baltimore, Maryland, pp. 31-40, 1989.

[3] F. Volpe, "RPC based processing of QuickBird high resolution satellite data," in *Proc. Polish Remote Sensing and GIS Conference*, Bialobrzegi, Poland, 2004.

[4] X.Yang, "Accuracy of rational function approximation in photogrammetry," in *Proc. ASPRS 2000 Annual Conference*, pp. 23-27, 2000.

[5] C.W. Greve, C.W. Molander, and D.K. Gordon, "Image processing on open systems," *Photogrammetric Engineering & Remote Sensing*, vol. 58, pp.85-89, 1992.

[6] OpenGIS Consortium. "The OpenGIS Abstract Specification-Topic 7: Earth Imagery," in URL:http://www.opengis.org/techno/abstract/99-107.pdf [online], 1999.

[7] C.V. Tao and Y. Hu, "3D reconstruction methods based on the rational function model," *Photogrammetric Engineering & Remote Sensing*, vol. 68, pp. 705-714, 2002.

[8] C.S. Fraser, G. Dial, and J.Grodecki, "Sensor orientation via RPCs," *ISPRS Journal of Photogrammetry & Remote Sensing*, vol. 60, pp. 182-194, 2006.

[9] X. X. Yuan and X. Y. Lin, "A method for solving rational polynomial coefficients based on ridge estimation [in Chinese]," *Geomatics and Information Science of Wuhan University*, vol. 33, pp. 1130-1133, 2008.

[10] G. Rodriguez and D. Theis, "An algorithm for estimating the optimal regularization parameter by the L-curve," *Rendiconti di Matematica, Serie VII*, vol. 25, pp. 69-84, 2005.

[11] X. Z. Wang, D. Y. Liu, Q. Y. Zhang, and H. L. Huang, "The iteration by correcting characteristic value and its application in surveying data processing [in Chinese]," *Journal of Heilongjiang Institute of Technology*, vol. 15, pp. 3-6, 2001.