DSM GENERATION FROM VERY HIGH RESOLUTION OPTICAL AND RADAR SENSORS: PROBLEMS AND POTENTIALITIES ALONG THE ROAD FROM THE 3D GEOMETRIC MODELING TO THE SURFACE MODEL

Mattia Crespi, Paola Capaldo, Francesca Fratarcangeli, Andrea Nascetti, Francesca Pieralice

DITS - Area di Geodesia e Geomatica – Università di Roma "La Sapienza"
via Eudossiana, 18 - 00184 Rome, Italy

1. INTRODUCTION

Digital Surface Models (DSMs) have large relevance in many engineering, land planning and environmental applications for a long time. At present the data required for the generation of DSMs can be acquired by several sensors/techniques, among which airborne LiDAR, aerial photogrammetry, optical and radar spaceborne sensors play the major role.

In this respect, the availability of new high resolution optical and radar spaceborne sensors offers new interesting potentialities, provided a proper concern is taken at each stage of the long road from data acquisition to DSM generation.

In this paper some topics related to image orientation and matching are investigated with respect both to optical and radar sensors; possible solutions are proposed and discussed on the basis of original algorithms and models applied to some examples and still open problems are highlighted.

2. OPTICAL IMAGERY

As concerns optical very high resolution imagery, QuickBird, WorldView-1 and GeoEye-1 are presently available, with a Ground Sample Distance (GSD) for panchromatic acquisitions of 0.61 m, 0.50 m and 0.41 m respectively.

2.1. Image quality

At first it has to be recalled that their potentialities for DSM generation are strictly related to image quality, which affect both the image coordinate measurements for orientation estimation and the matching process. Therefore, apart from the standard quality evaluation performed during the so-called in-orbit test period, from which general quality indexes are retrieved [1], it is useful to have tools to evaluate image quality also at the final user level. Image quality is quantified by some parameters, such as the radiometric resolution and its accuracy (represented by the noise level), and the geometric resolution and sharpness (described by the Modulation

Transfer Function). A procedure to evaluate the image quality parameters was implemented in a suitable software and tested on high resolution imagery acquired by the QuickBird, WorldView-1 and Cartosat-1 satellites [2].

2.2. Image orientation

A second important issue concerns the orientation of the stereo pairs from which a DSM has to be generated. Two different kinds of orientation models may be used: the so-called rigorous models and the terrain independent generalized sensor models [3]. The rigorous models are based on a standard photogrammetric approach where the image and the ground coordinates are linked through collinearity equations. On the contrary, in the terrain independent generalized models this link is represented by Rational Polynomial Functions (RPFs), whose coefficients (so-called Rational Polynomial Coefficients – RPCs) are usually supplied into the imagery metadata. Original rigorous models were developed and implemented for QuickBird, WorldView-1 and GeoEye-1 sensors and the results related to several examples are compared to those derived from other software. Moreover, a new procedure for RPCs generation starting from the mentioned rigorous models was also implemented and tested; the novelty of this procedure is the adoption of the modeling "parsimony principle", according to which only the (few) statistically significant RPCs are estimated through a numerically stable SVD-QR factorization least squares solution. The user RPCs generation may be useful, for example, in case of non standard size imagery (long strip images), for which vendor RPCs are not usually supplied, or when standard size imagery are divided in different tiles, each with its proper RPCs but without RPCs for the whole image. Several examples with QuickBird, WorldView-1 and GeoEye-1 were carried out, and the results were compared with those stemming from vendors RPCs.

2.3. Image matching

The third step to generate a DSM is the image matching, that establishes an automatic correspondence between a huge amount of homologous points. This process has a great relevance and is a crucial step for the generation of a product with good completeness and accuracy.

As concerns the optical imagery, many different matching approaches have been developed in photogrammetry and computer vision. In all methods, the fundamental step is to define the matching entity, that is a primitive of the master which has to be compared with a primitive in other slave image(s) in order to identify correspondences among different images. According to the kind of primitives to be matched, we can distinguish two basic techniques, the Area Based Matching (ABM) and the Feature Based Matching (FBM) [4],[5]. In the ABM methods, a small window, composed of grey values, represents the matching primitive and the principal methods to assess similarity are cross-correlation and Least Squares Matching (LSM). The FBM techniques use basic image features as main class of matching primitives, that are typically the easily distinguishable primitives in the images like line, corners, edges, etc.

A proposed methodology to perform image matching is based on corner detection and LSM refinement, combining the advantages of ABM to those of FBM. To unify the two techniques, a FBM was first used to search homologous points in the two images (using the few points collimated manually entered as input) and then a LSM was used, governed by one or more affine transformations calculated with points obtained by the FBM. Moreover a pyramidal approach has been investigated in order to optimize the management of very large size images and to improve the reliability of matching process. The methodology performs quite well if the texture is not so complex; otherwise, also this combined approach often fails with high complex textures, as urban areas, which are of great relevance for city modeling. A different approach based on dynamic programming appears more promising for such context [6] and it is now under implementation and testing,.

3. SAR IMAGERY

3.1. Radargrammetric approach

As regards the DSM generation from SAR data, it is well known that usually the interferometric approach has been used, due to the low resolution amplitude available until now. Nevertheless, the alternative radargrammetric approach is available, whose importance is now rapidly growing due to the new high resolution imagery (up to 1 m) which can be acquired by COSMO-SkyMed, TerraSAR-X and RADARSAT-2 in SpotLight mode. Similar to the optical satellite stereo pair orientation, the radargrammetry technique performs a 3D reconstruction based on the determination of the sensor-object stereo model, in which the object position is computed by the intersection of two radar rays with two different look angles [7]. The fundamental equations of the model are two range equations and two zero-Doppler equations; some parameters in the model have to be refined in a least squares estimation, in particular those related to satellite positions and velocities. Moreover, the radargrammetric approach does not suffer for the coherence problem, so that may be complementary to the standard interferometric one: the two approaches should be integrated in order to exploit at best SAR data for DSM generation [8].

In this respect, an original radargrammetric model for the orientation of high resolution SAR imagery was implemented for COSMO-Skymed and tested.

3.2. Image matching

Finally, it is still an open problem the matching algorithm for radargrammetric DSM generation with COSMO-Skymed imagery; some investigations starting from the matching algorithm implemented for the optical imagery were performed and the first results are presented and discussed.

4. REFERENCES

[1] Helder, D., Choi, J., "On-orbit Modulation Transfer Function (MTF) measurements on QuickBird", *Proc. of the 2003 High Spatial Resolution Commercial Imagery Workshop*, NASA/NIMA/USGS Joint Agency Commercial Imagery Evaluation Team, Reston, VA, USA, 2003.

[2] M. Crespi, L. De Vendictis, "A Procedure for High Resolution Satellite Imagery Quality Assessment", *Sensors,* MDPI, 3289-3313, 2009; doi:10.3390/s90503289.

[3] M. Crespi, F. Fratarcangeli, F. Giannone, F. Pieralice, "Overview on models for high resolution satellites imagery orientation", *Geospatial Technology for Earth Observation Data (*Li D., Shan J., Gong J. Editors), Springer, Heidelberg (Germany), pp. 63-104, 2009.

[4] K. Jacobsen, "Digital Surface Models of city areas by very high resolution space imagery", *Proc. of the 1st EARSeL Workshop of the SIG Urban Remote Sensing*, Humboldt-Universität zu Berlin, Berlin (Germany), 2006.

[5] Zhang, L., *Automatic Digital Surface Model (DSM) generation from linear array images*. PhD Dissertation, Institute of Geodesy and Photogrammetry, Zurich (Switzerland), 2005.

[6] Sun, C., "Fast Stereo Matching Using rectangular Subregioning and 3D Maximum-Surface Techniques". *Int. J. Computer Vision*, pp. 99-117, 2002.

[7] Leberl, F. W., *Radargrammetric image processing*, Artech House, Norwood (UK), 1990.

[8] M. Crosetto, F. Pérez Aragues, "Radargrammetry and SAR interferometry for DEM generation: validation and data fusion", *Proc. of CEOS SAR Workshop*, ESA-CNES, Toulouse (France), 1999.