SENSORS OF HIGH AND VERY HIGH SPACE RESOLUTION APPLIED TO IMAGE MAPS: NEW CHALLENGES

Nilda Sánchez Martín*, Carlos Pérez**

Departamento de Ingeniería Cartográfica y del Terreno. Universidad de Salamanca
* Facultad de Ciencias Agrarias y Ambientales, C/ Filiberto Villalobos, 119 37007 Salamanca (SPAIN)
** Escuela Politécnica Superior de Ávila, C/ Santo Tomás, sn. 05003 Ávila (SPAIN)

E-mail: nilda@usal.es, carpegu@usal.es

ABSTRACT

The cartographic solutions are in continuous evolution with the new developments of space programs for high and very high space resolution sensors, such as QuickBird, Ikonos and secondarily Aster. The scene is instantaneous and faithful to the reality; these properties make it suitable in environment applications: risk forecast and analysis, natural resources evaluation, temporary evolution, etc. The powerful spatial resolution increases the interest of the new images to perform maps of great scale and detail.

This possibility outlines new cartographic challenges on cartographic design and end-product quality control. This study describes the problems and solutions found when working with images QuickBird and Aster in the district of Alba of Tormes, Salamanca. The object was to carry out basic cartography (image map scale 1:10,000) and agricultural and vegetation cartography scale 1:20,000 (forest masses, edaphology and litology, cultivations and uses, agronomics classes, etc.) Especially they will be two questions: 1) ortorectification process alternatives according to each image: Aster 1A and 1B, and Quick Bird "Standard Imagery" and "Basic Imagery" and 2) metric assessment for the final maps in geometric position and other associated precision terms.

1. INTRODUCTION

High and very high resolution spatial imagery, such as ASTER and QuickBird, have demostrated a great cartography utility for update tasks, overlays in GIS datasets and to build imagemaps. High resolution satellites became a way for cartography with a high geographical and thematic versatility: maps as a base for urban a cadastral use, thematic applications in agriculture, vegetation or soil. It is easy to find recent examples in Kristof et al. (2002) and McCarthy et al. (2001).

These applications make as a must the review of the traditional methods in Remote Sensing, especially in its metric aspect. It is obligatory to analize new process for orthorrectification and, later, the geometric assessment of the result in the warped image. It is also necesary to pay attention about the job in field: how to obtain the Ground Control Points (GCPs), the cartographic checking, the metric of the product and so.

This paper shows some potential approachs for the proccessing of six different images: ASTER 1A and 1B, QuickBird Standard 2A and Basic 1B (multispectral and pancromatic), moreover, derivated product and its integration in medium- and large-scaled cartography is considerated.

2. AIMS

The objetives to get in the part of the whole job which this paper is based were:

- To make a status of the question and a technical analisys on orthorectification methods and the metric assessment for ASTER and QuickBird imagery.

- To propose some of these methods as the very best result and valorate its errors and metric quality.

- To analize advantages and disadvantages for the cartography use of these images. Especially, under the relationship between airborne and spacecraft perspective. The traditional role of photogrammetry versus the new brand satellite resolution.

3. SOURCES OF INFORMATION

3.1. Area of study

The area of study is situated in Alba de Tormes, 25 kilometer east of Salamanca (Spain). This is a zone with a low relief (slopes up to 100 meters) The land cover is mainly agriculture with natural and artificial channels from the Tormes River.

3.2. Imagery sources

Four different products were taken from QuickBird satellite and ASTER sensor (on board of Terra satellite):

- QuickBird Standard 2A: two scenes (pancromatic; 0.7m spatial resolution and multispectral, 2.8 m). Standard format carries a previous orthorectification by the distributor, besides a sensor correction (focal distance, chip and distorsion of lens) and a previous radiometric correction.
- QuickBird Basic 1B: similar to the above products but without previous orthorectification.
- ASTER 1A: This product contains depacketized, demultiplexed, and realigned instrument image data with geometric correction coefficients and radiometric calibration coefficients appended but not applied. The VNIR telescopy has a spatial resolution of 15m.
- ASTER 1B: This product contains radiometrically calibrated and geometrically coregistered data for all ASTER channels. This product is created by applying the radiometric and geometric coefficients to the Level 1A data. So it has a previous warped when is adquired by the user.

3.3. Survey work

There were several field campaigns to take cartographical coordenates in the area of study. This job was made using a GPS navigator receiver (metrical accuracy with postproccessing) and a differencial correction GPS receiver (centimeter accuracy):

- 13 three-dimensional points taken with diferencial correction (DGPS) and centimeter accuracy.
- 30 three-dimensional points taken with DGPS navigator and submetric accuracy
- Different trajectories over roads and paths to metric assessment of the warping scenes.

3.4. Ancillary data

For the latter control we used previous cartography source:

- Vectorial maps (1:10.000) from Diputación of Salamanca and Junta de Castilla y León.
- Digital Elevation Model (DEM): Píxel 10m and interval of contours 10 m from the above maps.

4. METHODOLOGY

There were different ways to make the geometrical proccessing for the scenes.

The classic polinomial method, where threedimensional information is not proccesed, was rejected due its poor result in this kind of accuracy and imagery. Only in ASTER dataset that kind of mathematical transformation could be used but the results are not good enough to compare the methods we propose with. The reason is because of classic polinomial methods does not incorporate DEM to the rectification. So it is not possible to think the error from the relief of the zone will be corrected.

We analized deeply the three-dimensional methods from 'rigurous' or parametric method until 'empiric' or non-parametric ones. Both methods need a DEM so they make an real orthorectification, not only the rectification.

For the rigurous method is necesary to know the aptitud of the satellite and it is possible to use the colinear condition. For non-parametric method, the rational polynomials function, it is necesary to know several coefficients of these functions. These coefficients can be obtained from ground control points after a survey campaign or, in other case, it can be provided together the scene and its geometry. The most spreaded use of rational polynomials function is using the coefficient given by the distribuitor, so here that approach is used. But we have got our own coefficient using GCPs and this methodology is also analyzed. ASTER dataset does not include the coefficients for rational polynomials function, so it is impossible use this coefficients but it is possible calculate it.

However, ASTER has a header file containing coordinates latitude/longitude for several pixeles. Nowadays, the quality of this information is not valid for our aims. Some scenes have a huge error in the attitude GPS/INS system: there is an error up to 20 kilometers in longitude. We suppose new TERRA satellite (soon to lanch) will improve this attitude technology giving more estability within the orbit.

Our study is focused in Toutin's method for rigurous method (Toutin, 2002), and rational function (Toutin, 2004, Gurcan, 2004) for empiric methods. In all of the cases, we have used a collection of three-dimensional GCPs (in a different number depending on size of scene) and the DEM of the area.

4.1. Geometric proccessing

We have used the Root Mean Square error (RMS) as an inner value about the quality of our GCPs. We have tried several combinations of GCPs to find out what is the very best configuration according with a lower RMS error.

It was made with all of the products from QuickBird and ASTER and for both methods (rigurous and empirical).

Once the warped image is got, the quality of this product has been checked using two different methods:

1) Overlay between warping raster images and vectorial maps (1:10.000) (Figure 1)

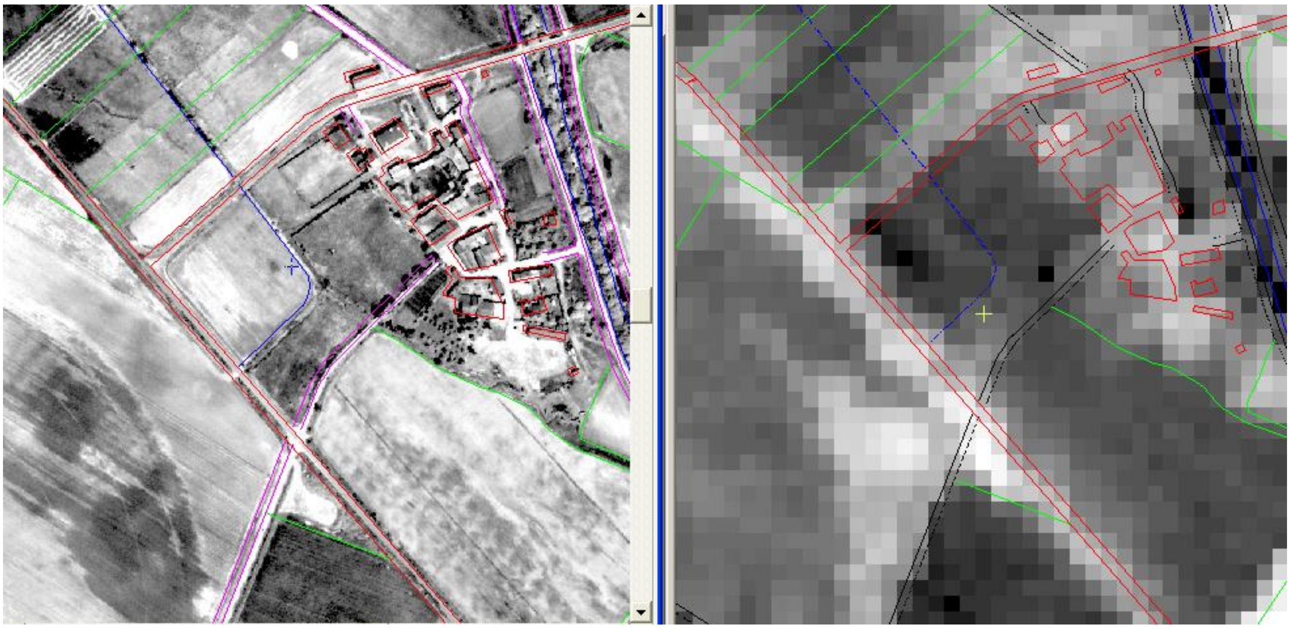

Figure 1. Overlay raster-vectorial QuickBird Basic 1B (size píxel 0.7 m; left) y ASTER 1B (size píxel 15 m, right)

2) Overlay between warping images and several trajectories of roads and paths taken with DGPS.

5. RESULTS AND DISCUSSION

5.1. Synopsis of the orthorectification process

Next table shows the errors for the different results of the orthorectification process. That is not the RMS error from the GCPs calculation. That is coming from a rigurous control in different zones of the image using ancillary information.

Overlay with 1:10.000 maps	Rigurous Model (Toutin)		RFPs using ancillary coefficients		RFCs computed with GCPs	
	Residual (m)	Residual (pix)	Residual (m)	Residual (pix)	Residual (m)	Residual (pix)
QB Standard 2A Mult.	10.10	3.6	---------------	----------------	8.66	3
QB Standard 2A Pan.	7.84	11.2	---------------	----------------	6.04	8,7
QB Basic 1B Mult.	2.03	0,7	3.12	1.1	3.90	1.4
QB Basic 1B Pan.	0.96	1.2	2.52	3.6	3.73	5.3
ASTER 1A	16.48	1.1	---------------	----------------	25.64	1.7
ASTER 1B	13.40	0.9	---------------	---------------	27.40	1.8

Table 1. Overview of result in the control a posteriori using check point and trajectories on the orthoimages.

Paying attention on Table 1, some explication and reflexions can be got from the different products and methods are:

- The very best method is using the rigurous method, what improve the result in all of the scenes.
- Rational coefficients are not embebed in the ASTER image, so it is not available this method for this kind of dataset.
- From the metric aspect, there is not a different enough between 1A and 1B ASTER levels. That is a rare phenomenon because of 1A is an almost raw level and 1B includes several preproccesing geometric corrections.

- Standard products from QuickBird include information about sensor and rational coefficients. So it is possible to warp an image what was previously warped by the distribuitor. However, this posibility does not get good results and the accuracy is too low (about 10m) for using in large scales.

- For QuickBird, there is homogeneity between pancromatic and multiespectral images. Of course, it is a better accuracy for the first ones (better spatial resolution), independetly of the warping method.

5.2. Some consideration for improving the process

We suggest some considerations to improve the orthorectification proccess:

- The collection of Ground Control Points and Check Point is very different according the spatial resolution of the scene. In QuickBird it is possible to choose several points which are highlighted by the context and the geometrical attributes. For ASTER, what has a bigger size of pixel, the election is according to radiometrical factors as edges in road or between land cover uses.

- The high resolution for QuickBird lets to locate several targets in field previous to the observation which is going to improve the orthorectification proccess (Figure 2). ASTER's spatial resolution does not let this kind of targets.

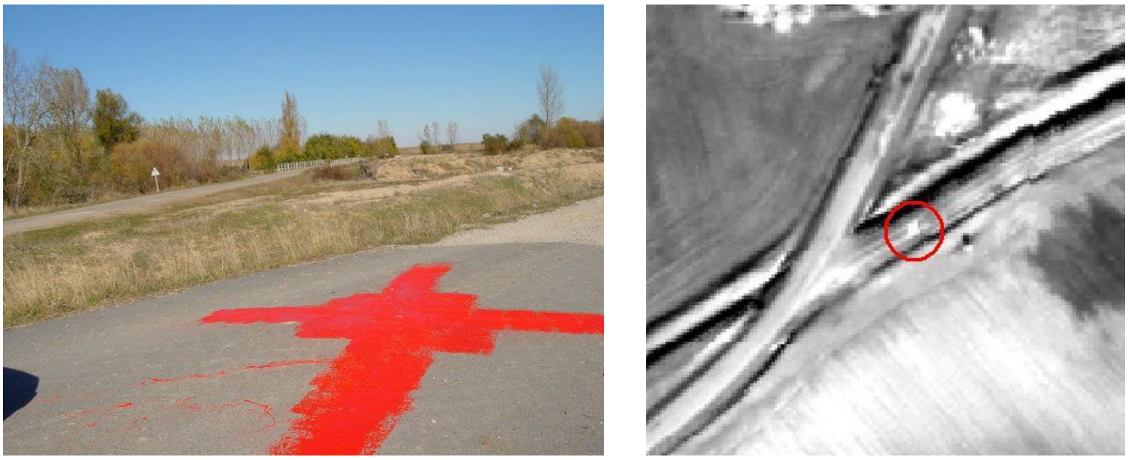

Figure 2. Handmade Target used as GCPs. Real location (left) and imagery location (right).

- The survey work is different from one and other kind of image. ASTER lets to use information digitize from an adequate cartography or to use a navegator GPS receiver (like used by mountainers or in orientation raids). Meanwhile, QuickBird needs a diferencial GPS receiver to get submetric accuracy. As bigger is the spatial resolution (smaller pixel) more difficult is the survey campaign.

- In the same way, the control for warped images depends on the resolution. Our solution was to use 1:10.000 maps as overlay, what is an easy solution for both very different size of pixel in ASTER and QuickBird.

- The final accuray of the process depends on the quality and resolution of Digital Elevation Model (Palà and Pons, 1995). It is necessary a DEM grid with a resolution similar to the original scene. It results more important when size of pixel is smaller. So for high resolution satellite it is a bottleneck to get an adequate DEM, because it is not easy to find submetric grid.

- The number of GCPs depends on several factors: size of scene, spatial resolution, relief, attitude of the satellite. There are some studies about the geometric configuration of GCPs within QuickBird scenes (Kurczynski, 2005) and a lot of studies for other satellites (Landsat, Spot, IRS,…). Anyway, we think these factors are very related with each scene so it is very hard to give some guidelines which were valid for every job.

5.3. Critical analysis of the images from the point of view of the orthorectification

- The image QuickBird BASIC 1B is adapted to make cartography on the propose scales: 1:10.000 (pancromatic) and 1:20.000 (multispectral), agreed with the prescriptions of European Commission ISPRA in 2004.

- Being QuickBird Standard a product previously warped by distributor, how is possible that it includes orbital parameters for the rigorous method? The original product has an error considered by the distributor about 23m. Therefore, Standard format does not throw satisfactory results for cartographic uses: neither the original product nor the warped one.

- The errors obtained for the images ASTER are not permissible in any case to integrate cartography on the scale 1:10.000. Nevertheless, it is a utility for scales of territorial planning etc.

- Level 1A and 1B for ASTER got a similar accuracy. We think a bigger size of pixel inhibits the previous corrections. It diminishes the pre-corrections and lets to mask the final error inside the size of pixel itself. This phenomenon has been studied with several ASTER scenes from different area and time and all of the time got a similar accuracy 1A and 1B level.

6. FUTURE JOBS

QuickBird scenes have a handicap if we wish use this dataset for non-metric product:

- It has a low spectral resolution (3 bands in visible and one more in infrared wavelength) so its interest in cartography for forest or agricultural task is a doubt. It is hard to derivate adequate products in relation with its low spectral resolution.

- There is not a direct way to get stereoscopical views. They are from scenes taken in different dates and the cost of this product is high.

In this way, it results a good idea to fuse the high spatial resolution from QuickBird with the high spectral resolution from ASTER. This would be a product with a potential caracteristic to use in forest and agriculture: vegetation, humid and arid index, thermical state of the vegetation and soil and a huge number of potential applications.

In the other hand, we think the cost of high resolution images is too high for several applications. Sometimes aerial photogrammetry is a better option than satellite dataset:

- Photogrammetry is cheaper for imagemaps. Depending on the size of area but about one third for regional zone (100x100km). This ratio improves when size of zone arises.

- Analogic and digital aerial digital cameras for photogrammetry give the same spectral resolution that high satellites (visible and near infrared) and a better spatial resolution (pixel about 6, 10, 25, 50cm in aerial pictures depending on hight of flight).

- Stereoscopy is cheaper, easier and accuracy with photogrammetry than high resolution satellites.

7. CONCLUSIONS

After the verification of the warped images, we think it is better to make all of the process from the raw scenes (the lowest level of proccessing is better than higher one) without a previous proccesing by the distributor. So, it is not valid to use QuickBird Standard product if we wish to make a metric large-scaled map.

The rigurous model (Toutin's algorithm) is better than the rest, as much for ASTER as for QuickBird. We bet to use the rigurous methods better than the empirical methods, and far better that the classic bidimensional polynomial method.

Orthoimages derived from ASTER, since the metric results, seems useful for cartographic applications to scales over 1:100.000 or use as management tools: ground uses, irrigated land, territorial planning, updating, etc.

Fusion of the cheap ASTER dataset with high resolution will improve the final result for agriculture and forest applications.

8. REFERENCES

European Commission, JRC-ISPRA (2004), Guidelines for Best Practice and Quality Checking of Ortho Imagery. ver. 2.3 (07/04/04) http://marsunit.jrc.it/Mapping/GuidelinesfororthoQA/OrthoBPGuidelinesv2-3doc2402.pdf

Gurcan, B., Murat, O., Karsten, J., 2004. Precise georeferencing of rectified high-resolution space images. Papers of ISPRS 2004. http://www.isprs.org/istanbul2004/comm1/papers/34.pdf

Kristóf, D., Csató, E., Ritter, D., 2002. Application of high resolution satellite image in forestry and habitat mapping-evaluation of IKONOS images through a Hungarian case study. Papers of ISPRS 2002. http://www.isprs.org/commission4/proceedings/pdfpapers/349.pdf

Kurczynski, Z., Wolniewicz, W., 2005. Assessment of Very High Resolution Satellite Images (VHR) for the developement of topographic database., Papers of VI Setmana de Geomatica, Barcelona, 2005

McCarthy, F., Cheng, Ph. and Toutin, Th., 2001. Case Study of Using IKONOS Imagery in Small Municipalities, Earth Observation Magazine, 10 (11):13-16, Novemver 2001.

Palà, V. and Pons, X., 1995. Incorporation of Relief in Polynomial-Based Geometric Corrections. Photogammetric Engineering &Remote Sensing, 61 (7), pp. 935-944

Toutin, Th., Chénier, R., Carbonneau, Y., 2002. 3D models for high-resolution images: examples with EROS, IKONOS and QuickBird. Papers of ISPRS 2002. http://www.isprs.org/commission4/proceedings/pdfpapers/156.pdf

Toutin, Th 2004. Geometric Processing of Remote Sensing Images: Models, Algorithms and Methods (review paper). International Journal of Remote Sensing, 25 (10), pp. 1893-1924

BIOGRAPHY

Nilda Sánchez Martín is a professor in the University of Salamanca since 1992. Her working area is the Cartographic, Geodesy and Photogrammetry Engineering. Hers interests are the Remote Sensing applications in Environment and Agriculture, Photogrammetry applied at Artistic and Historic Heritage and Cartography.