PROJECTS IN THE FIELD OF DAMAGE ASSESSMENT AND REDUCTION USING HIGH RESOLUTION REMOTELY SENSED IMAGES IN ITALY

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Abstract – In this last year, two huge National programmes have been launched in Italy; both programmes regard remotely sensed images used for disaster prevention, monitoring and assessment. These projects take into account all kind of remotely sensed data (both from geometric and spectral point of view), but particular attention should be paid to high geometric resolution satellite images, where evaluations that are aimed at the definition of the mapping scale, have to be strictly defined for. In this paper all problems connected to the use of satellite images for the production of orthophotos at a middle scale are investigated from a productive point of view. High resolution satellite images position accuracy tests carried out through orthoprojection procedures both using commercial softwares and homemade ones have been taken into account. Planimetric positioning errors and influence of GCPs number on the results will be shown, and moreover how the reference DEM could influence the final result. In detail the improving action of the utilization of an urban Dense DEM (altimetric information of terrain plus buildings) is shown. Finally future planned developments in the homemade orthoprojection algorithms are presented, when operational tasks are considered.

Keywords: Remote Sensing Programmes, Orthorectification, Rigorous, Orientation, High resolution, Accuracy, Rational Function Model

1. INTRODUCTION

The growing availability of digital data acquired both by satellite and aerial platforms, has lead Italian authorities to concentrate their efforts in the field of natural and *man-made* disaster prevention, monitoring and assessment, to these kind of data that, when correctly integrated to classic ones (digital maps, photogrammetric stereo pairs, GPS surveys, etc.) and managed by the use of GIS systems, could contribute to a more efficient and effective work flow. However, these data require some processes before their utilization, where geometric correction is one of the more sensible and difficult. After a brief description of Italian programmes, state of the art of geometric correction procedures will be taken into account when an operational task is considered.

2. THE ITALIAN ARMY "ENVIRONMENTAL PROTECTION INFORMATION SYSTEM"

This programme for environmental protection is devoted to the control and mapping of southern Italy area, where the main goal of the project is the support and improvement of the activities of all the public bodies involved in environmental crimes prevention and contrast. Financed by the Italian Government, this project finalize the different activities to crimes related to: toxic and dangerous waste, hydrologic and atmospheric pollution, building abuses, fires and damages to archaeological heritage.
Managed by part of the Italian Army (Arma dei Carabinieri), the GIS system is an operative tool where, apart from data already acquired in the context of different programmes (for example reference digital maps, statistical data concerning population, National DEM, land covers, 1:10.000 scale orthophotos, and Hyperspectral surveys), different others data should be collected, and in particular satellite ones.
In the technical specifications of the tender related to this project, different images acquired by satellite sensors, should be used, such as:

1. Landsat 5 and 7 TM and ETM+;
2. Spot 4 and 5 PAN and XS;
3. ERS 1 and 2 AMI,TSR,MWR,RA,GOME;
4. Envisat ASAR and AATSR;
5. NOAA 14, 15 and 16 AVHRR 2 and 3;
6. High geometric resolution satellites Ikonos, Quickbird and Eros.

The total cost of the project is approx. 32 millions euro, while for remotely sensed data is approx. 3.5 Million s Euro Taking particular attention to high resolution data, a 120.000 Km^2 coverage is requested for the 3 satellites, whereas Ikonos and Quickbird have to be considered in a bundle configuration (panchromatic and multi spectral). For Eros data, a possible stereo couple configuration should be considered. In the technical specifications the geometric correction for these high resolution data is a classical orthoprojection without any assessment in term of precision and accuracy of GCPs and final product nor for the DEM used. No procedures are defined for Eros data stereo orientation, neither for bundle (PAN + XS) data merge (pan-sharpened techniques).

3. THE ARTICLE 27 PROJECT

Financed by the Ministries of Environment, Defence and National Civil Protection, the so-called “Article 27” is an around 35 millions euro project devoted to high resolution remote sensing. The application field is primarily hydrogeologic vulnerability and in particular landslide risk. The principal goals of this project are:

1. identification of the main structural elements and surface drainage;
2. deformation survey;
3. identification of the main vulnerable anthropic features;
4. land cover;
5. dem/dsm updating on a national base.

Also this project (whereas all Italian territory is considered) foresees to acquire similar data to the previous one. No technical specifications are available until now (April 2005), but, obviously the problem are absolutely similar to the above mentioned ones.

4. ORTHOPROJECTION MODELS

The geometric correction of high-resolution satellite images can be carried out using two different approaches: rigorous modelling or non-parametric modelling. Rigorous models are based on collinear equations (Toutin, 2004) that are adapted to *pushbroom* acquisition technique which is used by all high resolution satellites. In this case, the orientation parameters are modelled as time dependent polynomials of a higher degree than the first: the estimation of the unknowns requires approximated initial values which are extracted from the metadata files usually supplied together with the images.
However the Companies that distribute images are not always willing to supply detailed technical information to the final users concerning the platform that is used or about the characteristics of the sensor that are necessary to implement rigorous models. It was for this reason that non-parametric models, or rather generalised models (independent of both the type of sensor and of the acquisition method) were introduced. The most frequently used non-parametric methods are based on 3D rational polynomials, and which in literature are known as the Rational Function Model, RFM – Rational Polynomial Coefficients, Rational Polynomial Camera, RPC – Rational Function Coefficients, RFC *(*Dowman, Tao, 2002). Moreover a new prototype of a geometric correction procedure based on a Multy Layer Perceptron type (MLP) neural network, has been proposed in literature.

The rational function is the most commonly used non-parametric model, which is implemented in almost all software packages for the processing of satellite images. This type of approach is used by image resellers to allow the final user to obtain added value products, such as orthoprojection without the necessity of having a model of the sensor, but by only attaching the coefficients of the relation between the image coordinates and the ground coordinates.
The neural network consists of mathematical models whose operative philosophy is inspired by cerebral biological dynamics: the calculation process is schematized as a flow of distributed information whose elaboration occurs inside dedicated calculation units, which are known as “neurons” of the network. Some of these receive information from the external environment, others return answers to the environment and still others, if there are any, communicate with only the units inside the network: they are called input, output and hidden units, respectively.

5. GENERAL RESULTS OF THE TWO METHODS

The RFM and MLP non-parametric methods were tested with images acquired from different satellite platforms. The accuracy of the planimetric positioning was evaluated through the evaluation of the residuals on both the GCPs that was used for the estimation of the model parameters and on the CHKs (which were different from the previous ones). The mean values of the residuals were also calculated to show any systematic error. A geometrically homogeneous distribution of the GCPs on the entire image was maintained during all the tests, as the validity of the non-parametric methods decreased with an increase in the distance from the support points. Tables 1 and 2 report the results that were obtained using the polynomial relations and the neural networks.

Table A – Results obtained through the application of the RFM method

Satellite	N° GCPs	N° CHKs	$\Delta\xi$ mean CHK	$\Delta\eta$ mean CHK	RMSE CHK (pixel)	RMSE GCP (pixel)
Eros A1	51	6	0.00	0.00	3.19	0.83
QuickBird	60	30	-0.09	0.02	2.76	0.86
Spot5	50	5	-0.02	-0.09	2.09	1.01

Table B – Results obtained through the application of the MLP neural network method

Satellite	N° GCPs	N° CHKs	ΔE Mean CHK	ΔN Mean CHK	RMSE CHK (pixel)	RMSE GCP (pixel)
Eros A1	51	6	-0.23	-1.10	2.46	1.08
QuickBird	60	30	-0.23	-0.14	2.37	1.40
Spot5	50	5	-2.04	0.02	2.96	1.38

6. PLANIMETRIC POSITIONING ACCURACY TESTS

In order to proceed to a complete evaluation of the cartographic potentialities of high geometric resolution satellite images, QuickBird data have been orthoprojected, where two different approaches have been chosen: the

parametric and the not-parametric one. First operational way is based on the application of the rigorous sensor model (PCI OrthoEngine 8.2, Toutin's Model has been adopted); the second one is based on the self-developed Rational Function Model algorithm described above.
Different tests have been carried out to better understand the sensibility of such projecting model to the number of GCPs and to the DEM. The same image portion has been orthoprojected varying the number of GCPs taking care of maintaining a well distributed GCPs configuration. Accuracy tests based on the calculation of the X (Easting), Y (Northing) and total residuals (RMSE) have been done for each resulting orthoimage. The number of Check Points (CPs) has been increased while decreasing the number of the used GCPs (Table 3). In this section are presented the results obtained with the application of the rigorous model procedure with a 50x50 m DEM grid.
Figure 1 shows how the module of the X (dX) and Y (dY) residuals and the residuals RMSE $\left(\sqrt{\frac{dX^2+dY^2}{N}}\right)$ calculated on the CPs change versus the number of GCPs.

Table C. Number of GCPs used for the tests

Test Number	Number of GCPs	Number of CPs
1	55	10
2	45	20
3	35	30
4	30	35
5	25	40
6	20	45
7	15	50
8	10	55

Such results demonstrate how increasing the number of GCPs, the general residuals trend lines tend to decrease, even if the best solution is reached with the 25 GCPs configuration. That could depend on the spatial distribution of the GCPs. Moreover, it can be noticed that the RMSE is always comparable to the geometric resolution of the QuickBird image (0.61 m).

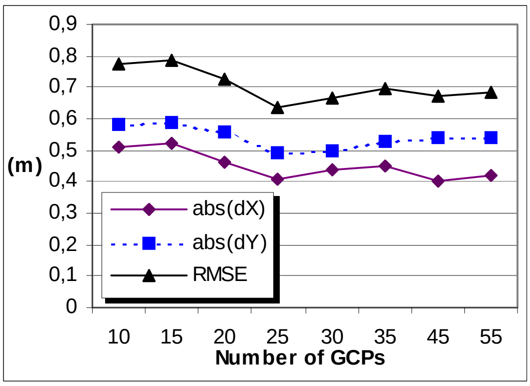

Figure 1. Residuals calculated on the CPs versus the number of GCPs used for the rigorous sensor model based orthoprojection

Table D. Means and Standard deviations of the DX and DY residuals statistical population.

n° GCPs	DX Mean (m)	DX STD (m)	DY Mean (m)	DY STD (m)
55	0,073	0,394	0,414	0,321
45	-0,057	0,376	0,289	0,446
35	-0,101	0,424	0,169	0,456
30	-0,142	0,420	0,030	0,469
25	-0,072	0,395	0,084	0,475
20	-0,115	0,411	0,180	0,506
15	0,115	0,483	0,203	0,559
10	0,145	0,485	-0,001	0,575

In order to evaluate which map scale this kind of orthoimages are suitable for, deeper statistical analysis have been carried out taking care of the map tolerance usually accepted. To do that residuals have been considered as statistical variables (one for each test) and their mean and standard deviation have been calculated (Table 4).
Results show that best accuracy is obtained with 25 and 30 GCPs. Fitting statistical test have been made on each residuals distribution in order to understand if they fit a normal statistical distribution or if they are affected by systematic or raw errors. In particular the χ^2 test has been performed. Residuals have successfully passed it. In such situations, according to the Tchebycheff theorem, at least the 95% of the residuals is comprised in the following ranges:

$-0.982 < DX_{30} < 0.698$ m; -0.908 m $< DY_{30} < 0.968$ m

$-0.862 < DX_{25} < 0.718$ m; -0.866 m $< DY_{25} < 1.034$ m

Such statistical data, for which the 95% of the residuals are lower than 1 m, suggest a potential use of Quickbird orthoimages for producing, or upgrading, 1:5000 scale maps (whose tolerance is 1 m).

6.1 RFM based orthoprojection

Preliminary tests have been done using the PCI OrthEngine procedure based on the Rational Function Coefficient supplied with the images. No GCPs has been collected. The obtained residuals on the same precedent CPs have been estimated to be about 10 m for all the situations. No further investigation needs to lead us to admit such method is not proper for our cartographic purposes.

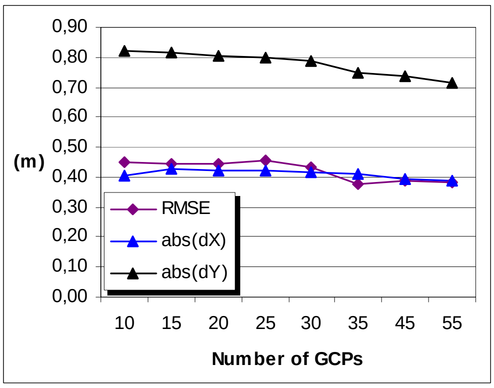

Figure 2. Residuals calculated on the CPs versus the number of GCPs used for the RFM based orthoprojection

Figure 2 shows how the module of the X (dX) and Y (dY) residuals and the residuals RMSE calculated on the CPs change versus the number of GCPs. This time again results show how growing up the number of GCPs the general residuals trend lines tend to get lower. It can be noticed that the RMSE is comparable to that obtained through a rigorous sensor model approach.

7. INFLUENCE OF THE REFERENCE DEM IN THE ORTHOPROJECTING PROCEDURE

In order to proceed to an evaluation of the influence of the DEM on the final result a RFM based orthoprojection has been carried out on Eros A1 panchromatic image. The goal was to investigate how for urban areas cartographic purposes the orthoimages quality is improved by using a Dense DEM (terrain height plus buildings height).
In the left image, orthoprojected with a usual DEM, 50x50m grid and accuracy of 15m, it can be noticed how the overlaid cartography is not good fitting over the bridge. In this case relief displacement due to the bridge has not been corrected because simple DEM is not completed with buildings height information. Right image instead has been orthocorrected with a Dense DEM (accuracy of 0.8m) derived from the available 3D numeric map. In this case it is possible to notice the correct fitting of the map on the bridge. Due to a limitation of the present release of our self-developed software the duplication of the radiometric information of the hidden area can be observed: we are working for further developments of the software directed to a multi image approach which takes care of such problem by a dynamic search of the right digital number for the hidden areas on different-view-angle images of the same area.

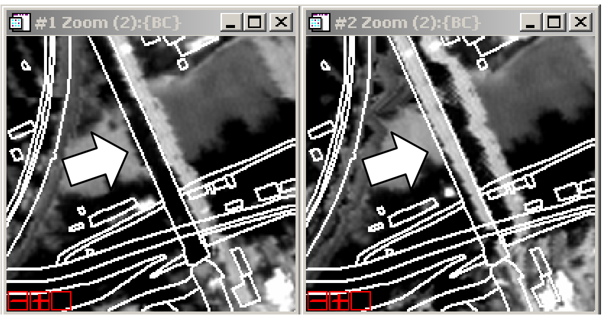

Figure 3. Orthoprojection with a DEM (left) and with a Dense DEM (right)

Taking into account processing time, it is quite obvious that using a RFM approach, the collimation of numerous points requires more time (at least four hours for image) while using rigorous models less points have to be taken into account. Considering that the complete coverage of the Army project is approx. 120.000 Km^2, approx. 1000 images should be acquired. The main problem is the real availability of these data; the acquisition of these images in short time spans represents infact a problem for synchronous sensors, while could be less important for Eros platform. In addition, as reported in the literature, different accuracies gainable with different data, could produce discrepancies when mosaicking, considering also different data spectral range (Pan for Eros, XS for Ikonos and Quickbird). Moreover, the costs to acquire high geometric resolution satellite images is considerable high, being approx. 25 $ per Km^2. Nowadays, at the same cost one can get photogrammetric digital images suitable for at least 1:5000 scale map, in a XS mode (visible and near IR) and fully stereoscopic. Being orientation and steroplotting algorithms well known and fully operational, a “aerial digital” approach, should be still considered the first best.

8. CONCLUSIONS

General expectations from high resolution satellite images seem to be confirmed. Commercial softwares can really be thought as producing tools in cartographic field. Moreover it has been demonstrated that: a) rigorous models and Rational Function Models lead to comparable results. b) in cartographic application of orthoimages is necessary to pay attention to the third spatial dimension (buildings or discontinuities when landslide are considered). That means that for such areas orthoimages cannot be considered a good map tool for large scale mapping if no Dense DEM is used. In addition, when such huge projects are concerned, particular attention should paid to the real availability of such images and to the availability of a dense grid of GCPs suitable, in terms of precision and distribution, for the georeferencing phase. Technical specifications are absolutely necessary, when satellite images are concerned; these specifications should determine what kind of geometric approach one must use, based on the type of GCPs available, the possible off-nadir taken, the type of area to ortoproject.

6. REFERENCES

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