3-D map production using an Orbview-3 stereo pair

F. Giulio Tonolo & F. Perez
ITHACA, Torino, ITALY

F. Nex & M. Piras
Politecnico diTorino - DITAG, Torino, ITALY

Keywords: high resolution, satellite, mapping, accuracy, stereo pair, rigorous model, stereo plotting, semantic

ABSTRACT: This paper concerns map updating and production using high resolution satellite images, and it is aimed at the evaluation of the achievable planimetric and height accuracies paying attention to the correct identification of all the required map features. Tests concerning orientation and stereoplotting of an OrbView-3 stereo pair are shown. This approach allows 3D maps to be produced (or updated) using traditional stereoplotting operations. The chosen test site is the one indicated by the ISPRS Commission VIII/ WG 2, is the Susa Valley (2006 Olympic Winter Games area). A GPS survey has been planned in order to obtain a suitable database of Ground Control Points and Check Points. In order to evaluate which map scale the generated 3D features are suitable for, a statistical analysis of the 3-D residuals was performed with respect to oriented ADS40 panchromatic imagery. Italian Technical Specifications for Map Production allow to relate the previous statistical results to the defined thresholds stated for different map scales. Particular attention was paid to the content information, with the aim of defining the map entities (prescribed for that map scale) that can be easily recognised.

1 INTRODUCTION

Geometric processing of high resolution satellite images allows map products such as orthoimages and vector maps to be generated. Papers dealing with geometric correction generally show tests based on rigorous or generalized models: planimetric accuracy is then estimated through statistical analysis on Check Point (CP) residuals. Comparison of the Root Mean Square error (RMSE) value and map precision show that high resolution satellite images are suitable for map scales varying from 1:5,000 to 1:10,000 (depending on geometric resolution, off-nadir angle, Ground Control Point accuracy, etc.). These studies generally only refer to the geometry of these kinds of data, neglecting both semantic and radiometric issues. This paper concerns map updating and production using an Orbview-3 in-track stereo pair (GSD = 1.2 m), and it is aimed at the evaluation of the achievable 3-D accuracy paying particular attention to of the correct identification of all the required map features.

2 GPS SURVEY

In order to achieve the goal of evaluating 3-D mapping accuracy using an OrbView-3 stereo pair, it is necessary to perform the orientation using Ground Control Points (GCP) characterised by high accuracy. A GPS survey in the previous mentioned test area was therefore planned. The 3-D coordinates of 30 points, to be used both as GCP and Check Points (CP) were estimated using relative GPS positioning. The selection of these points was precisely planned, considering only points which were visible in both images and homogeneously distributed all over the test site. The presence of large woods and grass areas in the mountainsides made very difficult to select the points. Nevertheless, a very good distribution was obtained (Fig.2). Those points were chosen at altitudes that varies from 1100 m to 2400 m in order to improve the orientation accuracy.

The chosen approach, known as “fast-static occupation”, is based on double frequency receivers and the short baselines allow to have short occupation times for each surveyed point. Two different networks were planned. The first network is made up of four existing permanent GPS stations in Piedmont close to the test site: a new vertex CES1 was instead specifically created for this research. The first network scheme is shown in the left side of Figure 1. The described network is intrinsically adjusted and allows the coordinates of the CES1 vertex to be estimated with respect to the global reference system WGS84-IGM95 (that is the national reference system currently in use). The second network is made of two master stations (GRAV and CES1) and the thirty points to be surveyed. Thanks to the short length of the baselines (a few kilometres) and the low accuracy requested (< 30cm), it was possible to use a fast-static approach. Each surveyed point was connected, during data processing, to both the GRAV and CES1 master stations, allowing a relative positioning to be obtained. The scheme of the secondary network is shown in the right part of Figure 1.

Commento [F1]: Anzichè primary

Commento [F2]: Anzichè secondary

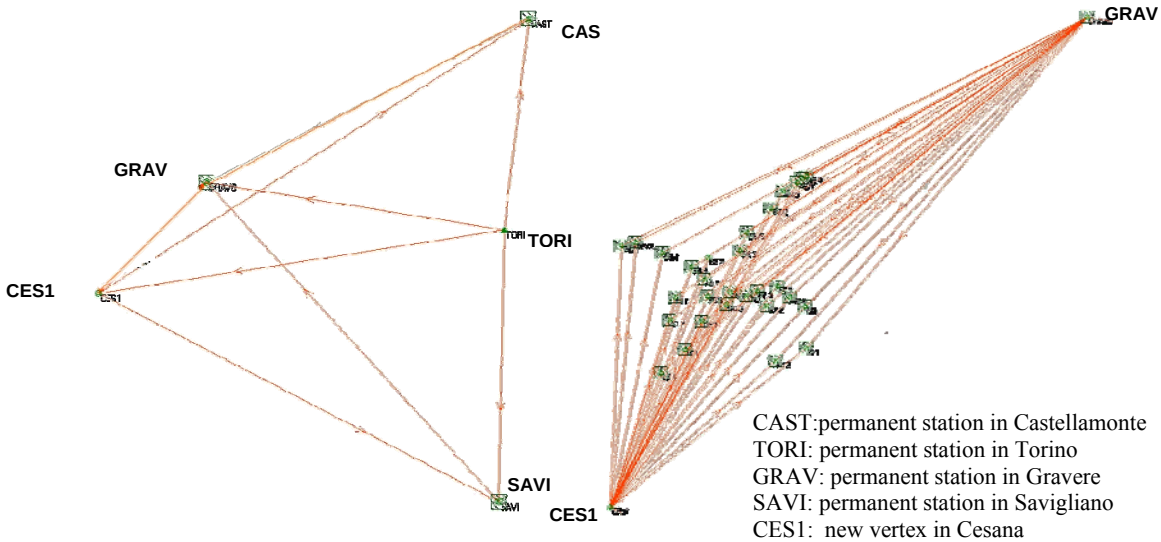


Figure 1: Primary network (left) and Secondary network (right)

The Raw GPS data were processed in order to remove any possible outliers. All the baselines was calculated independently and the final coordinates were evaluated through a least constrains adjustment. Using the Gravere permanent station as a control point, it was possible to state that the average planimetric and height accuracies are respectively about ±1 cm and ±1.5 cm.

3 STEREO PAIR ORIENTATION

The Orbview-3 rigorous model available in the LPS software was used for the orientation procedure. OrbView-3 stereo pair was oriented using the 30 points surveyed utilizing the afore described GPS fast-static approach. 11 points were considered as GCPs while the others were used as CPs. Several GCP distribution were tested but, as expected, the best results were obtained choosing a pattern covering the whole images, as shown in Fig. 2 a). The use of automatically generated tie points (TP) did not improve the results of the orientation or the stereoscopic view. The orientation residuals are shown in Table 1 and in Figure 2 b). The figures show that different planimetric and altimetric precisions were obtained. This event is probably due to the base to height ratio of Orbview-3.

Nevertheless, the obtained RMSE values make it possible to assume that Orbiew-3 stereo images are suitable for 1:10,000 mapping.

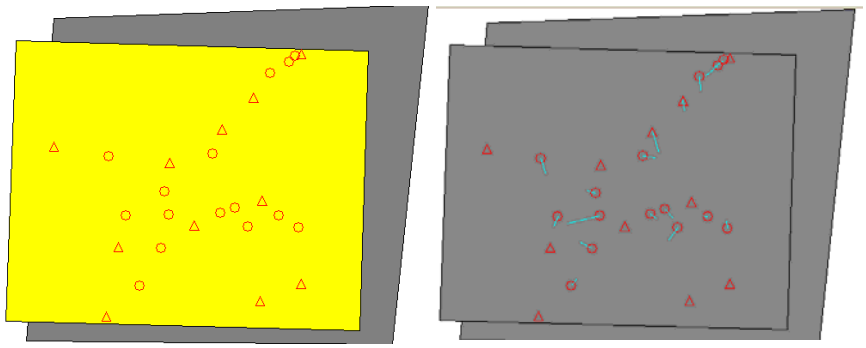


Figure 2 – Orbview-3 stereo pair. a) GCP (triangles) and CP (circles) distribuition b) CP residuals

Table 1 – RMSE and maximum absolute value in the GCP and CP residuals

	EAST (m)		**NORTH (m)**		**H (m)**		**X (Pixel)**	**Y (Pixel)**
	RMSE	Abs Value MAX	RMSE	Abs Value MAX	RMSE	Abs Value MAX	RMSE	RMSE
GCP	1.03	2.9	1.01	1.85	2.76	4.79	0.85	0.99
CP	1.04	1.80	0.74	1.00	2.93	4.44	0.80	0.94

4 STEREOPLOTTING

According to several papers dealing with the same topic of this work, it is expected that the Orbview-3 imagery quality could allow the generation of 1:10,000 maps. For this reason, a traditional stereoplotting was generated of the map entities which are prescribed by Italian Technical Specifications for 1:10000 Map Production (see Fig. 3).

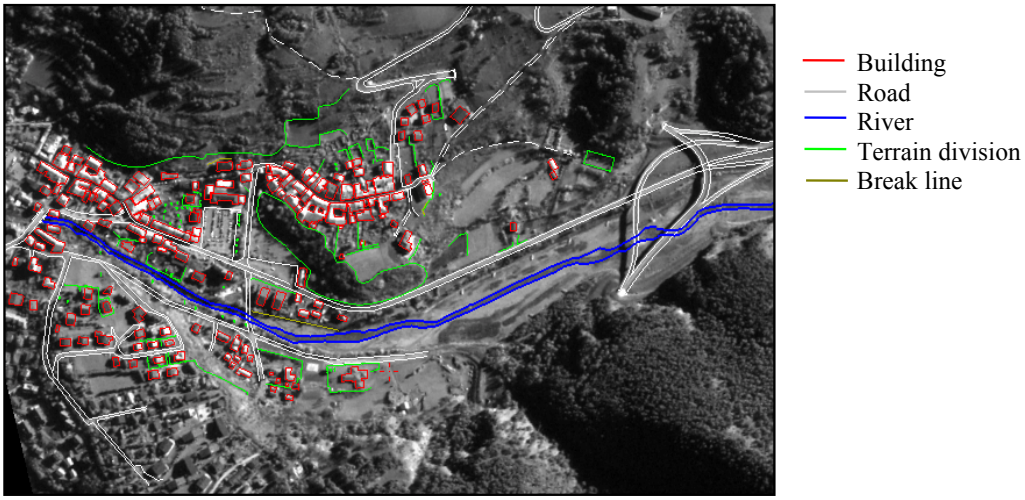


Fig. 3 – Features extracted from the Orbview-3 images (the Oulx Village)

The chosen test site is the one indicated by ISPRS Commission VIII/ WG 2, in the Susa Valley (2006 Olympic Winter Games area). In particular, a part of the Oulx village which is located in the lower of Susa Valley was considered. The processed Orbview-3 images were acquired at about 9.30 AM; consequently there are quite long shadows which cover up the narrow roads and the terrain sloping to the North. The results of the stereoplotting were analyzed from two different point of view. Firstly the geometric accuracy of the plotted features was considered. This procedure was performed through the comparison between the Orbview-3 images and an oriented ADS40 photogrammetric flight. ADS40 strips were acquired at a 6000 m flight altitude that allowed 3D coordinates to be extracted with a higher accuracy than the available 1:5,000 scale map, as was demonstrated by the comparison with the GPS surveyed points (less than 0.5 m for easting, northing and height). In particular, the same map features were stereo plotted by the same operator using both the oriented ADS40 imagery and the oriented Orbview-3 images. The coordinates of these details were then compared in order to calculate the residuals of the planimetric and height coordinates. Particular attention was paid to the content information, considering the map entities (prescribed for that map scale) that could be easily recognized. The goal of this semantic analysis was to verify whether it is possible to recognize and plot all the entities that are prescribed by Italian Technical Specifications, in order to verify the potential suitability of Orbview-3 images for the generation of 1:10,000 maps.

4.1 *Geometric Analysis*

In order to investigate whether the plotted features are suitable for mapping purposes at a certain map scale, it is necessary to evaluate the 3-D accuracy. According to the expected accuracy, which depends on GSD values, it was decided to use the Italian Technical Specification for 1:10,000 Map Production. The previously mentioned technical specifications state that the threshold values for coordinates, distances and heights measured on the map should be the following:

Commento [F3]: Anzichè planimetric and height

$$\sqrt{(E'_P - E_P)^2 + (N'_P - N_P)^2} \leq 4.00 \text{ m} \quad (1)$$

$$|Q' - Q| \leq 2.5 \text{ m} \quad (2)$$

$$|d' - d| \leq \left(4.00 + \frac{d'}{1000}\right) \text{m} \quad \text{while d'} \leq 2000 \text{ m} \quad (3)$$

$$|d' - d| \leq 6.00 \text{ m} \quad \text{while d'} > 2000 \text{ m} \quad (4)$$

where:

- (E'_P, N'_P) represents the planimetric coordinates of a stereo plotted point P and (E_P, N_P) the coordinates of the same point measured on the reference map;
- d' is the horizontal distance between two plotted points and d is the measured distance of the same points on the reference map;
- *Q'* is the height of a stereo plotted point and *Q* is the measured height of the same point on the reference map.

Table 2 - Differences between the Orbview-3 and ADS40 3-D coordinates

	ΔE (m)	**ΔN (m)**	**ΔZ (m)**
Mean	-0.4	-1.1	4.3
Sqm	2.2	2.1	3.4
RMSE		3.3	

The map used as a reference was a vector map generated by the same operator using ADS40 oriented strips (panchromatic forward and backwards bands were used). About 400 points and 400 distances were compared, in order to perform a rigorous statistical analysis. It was decided to con-

sider only points relative to Buildings features, which can be more easily identified on the reference map. The results of the statistical analysis (Table 2) show that the standard deviations and RMSE values seem to respect the 1:10,000 2D accuracy. Unfortunately only 81% of the considered points respect the coordinate test, while 89% f the calculated distances respects the threshold values. It can be noticed that in order to reach the 95% requested in the Technical Specification it is necessary to set the acceptability planimetric threshold at 6.0 m (which means an approximately 1:15,000 map scale). The worst results were obtained for the elevation test.

Commento [F4]: Anzichè planimetric

Table 3. Percentage of points and distances that respect the 1:10,000 map scale thresholds.

	Passed		Not Passed	
	Number	**%**	**Number**	**%**
Distances	412	89	0	11
Coordinates	333	81	80	19
Heights	85	21	328	79

4.2 *Semantic Analysis*

This kind of analysis is aimed at evaluating the image quality and the information content of the Orbview-3 stereo-pair. In particular, it was tried to vectorize all the details which are requested in the Italian Technical Specifications for 1:10,000 Map Production. The handiness of interpretation for each detail was evaluated, with the aim of studying whether a map feature can be easily recognized and subsequently plotted. All this work is summarized in Table 4 where the map entities are subdivided into seven different categories, according to Italian Technical Specifications. Each category is further divided in subcategories (i.e. the road and railway category is divided into paved roads, foot roads, track, etc.) whose number is written in brackets. Each subcategory was classified as "Vectorizable" or "Only recognizable".

Table 4 –Map features classification

MAP FEATURE		**Vectorizable**	**Only Recognizable**	**Problems**
Roads, Railways (10)		90%	10%	The exact railway position not precise
Buildings, urban furniture, technical buildings (8)		88%	12%	Technical buildings not vectorizable; edges of houses not always well defined
Water, water works, etc. (4)		100%	0%	Use of coloured images preferable

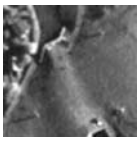
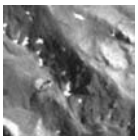
Energy, material, fluid pipelines and lines (6)		50%	50%	Aerial transport (sky lifts) not vectorizable
Man-made Territorial divisions (5)		100%	0%	Building material not recognizable (coloured images)
Break lines (4)		100%	0%	Use of coloured images preferable
Vegetation (5)		100%	0%	Use of false colour images preferable
TOTAL		88%	12%	

Table 4 shows that there are problems in stereoplotting some map features, such as railway, pylons or cables in pipelines which are easy to detect but not to stereo plot.

Previous tests of the researching group show that visible colour or false colour images help to identify and plot some map features which are difficult to detect from only the panchromatic band, such as dividing walls, brooks or rocky areas. Nevertheless, from a semantic point of view, Orbview-3 images can be used for the generation of 1:10,000 maps.

Commento [F5]: Al posto di vectorize

5 CONCLUSION

The performed tests allow the authors to state that:

- according to the orientation results and RMSE value obtained on more than 400 CP, Orbview-3 stereo images seem to be suitable for 1:10,000 planimetric mapping. A more rigorous approach based on statistical analysis shows that 95% of the CPs are consistent with 1:15,000 2D mapping;
- the height accuracy is not suitable for 1:10,000 mapping, furthermore it is present a systematic overestimation (about +4 m) of the elevation using the Orbview-3 oriented stereo pair;
- from a semantic point of view, Orbview-3 imagery is suitable for 1:10,000 mapping, although it should be advisable to use the multispectral information.

REFERENCES

De Valencia ; K.J., Paredes jr, F., 2006. *Rigorous sensor modelling and triangulation for Orbview-3*, ASPRS 2006 Annual Conference, Reno, Nevada, USA

Topan, H., Buyuksalih, G., Jacobsen, K., 2006. *Information contents of OrbView-3 for topographic mapping*

Various Authors. 1994. *Capitolato d'oneri per la formazione della carta tecnica regionale numerica alla scala 1:10000 della Regione Piemonte*, Italy

Büyüksalih, G., Akcin, H., Jacobsen, K., 2006, *Geometry of Orbview-3 Images*