GEOMETRIC AND MAPPING POTENTIAL OF WORLDVIEW-1 IMAGES

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ABSTRACT:

The geometric resolution of space images has been improved. With WorldView-1 and GeoEye-1 images taken from space with 0.5m ground sampling distance (GSD) are now available. The Bosphorus Engineering Consultancy Services Inc (BIMTAS), company of Istanbul Greater Municipality ordered a WorldView-1 image, covering large parts of Istanbul city. For the orientation and investigation of the scene accuracy, 29 ground control points (GCPs) could be used. Partially GCPs were handled as independent check points. Even with just one GCP a standard deviation of independent check points in the range of 1.0 GSD was reached. The limited accuracy of the point heights did not allow sub-pixel accuracy, which only was reached in the component direction across the view direction being independent upon the point height. Very similar results have been achieved with a scene in the area of Zonguldak. The information content of the very high resolution space image was tested by mapping all buildings in a sub-area. As reference a building layer of the same area, based on aerial images could be used. In city centres shadows of high buildings make the mapping difficult. Here a local Wallis-filter is helpful.
This investigation was supported by analysis of the WorldView-1 stereo pair Morrison, free of charge available in the WEB. An automatic image matching by least squares method was very successful in build up and open, not too mountainous areas, while in very steep parts, located in shadow and covered by forest, the matching result was limited. This is comparable with results achieved with QuickBird and IKONOS stereo scenes.

1. INTRODUCTION

In several countries classification of aerial images even for governmental organizations make the use of it complicate. As alternative solution we now have very high resolution space images. In the Greater Istanbul area IKONOS scenes have been used since years for change detection of buildings, especially in the water catchments areas (Büyüksalih, G., Jacobsen, K., 2008). The identification of the building height changes, being important for the area endangered by earthquakes, is difficult with 1m ground sampling distance (GSD). Now with WorldView-1 and GeoEye-1 optical satellite images, distributed with 0.5m GSD are available.
A GSD of 0.5m corresponds to the information contents of analogue aerial photos with the scale 1:25 000 (Jacobsen 2008) or to DMC-images taken from 5000m flying height. These are usual conditions for aerial mapping, demonstrating the competition between optical aerial and space images.
Also digital height models can be generated with a stereo configuration of space images.

2. USED DATA

A WorldView-1 scene over Istanbul and another over Zonguldak, both in Turkey, have been analyzed. The sample data set Morrison, available free of charge in the WEB, was used for the generation of a height model, but because of the limited control point definition it was not used of the analysis of the geometric potential.

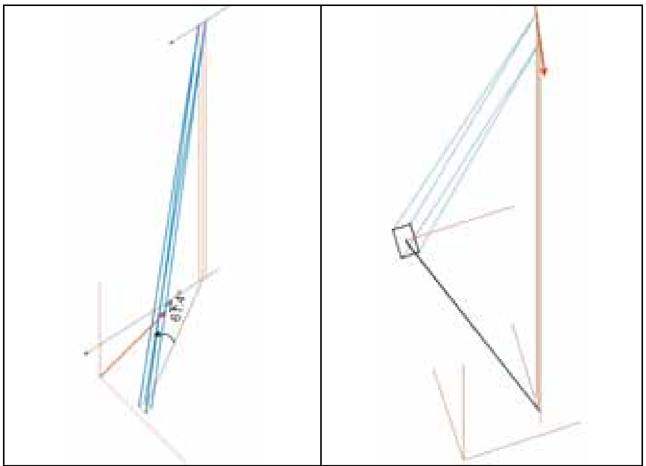

Fig. 1: imaging geometry of the WorldView-1 scenes
left: Zonguldak, right: Istanbul

WorldView-1 Istanbul:
Collection elevation: 60.7°, sun elevation: 25.8°
Acquisition date: November 11th, 2007

WorldView-1 Zonguldak:
Collection elevation: 61.4°, sun elevation: 49.5°
Acquisition date: September 16th, 2008

Table 1: technical data of used WorldView-1 scenes

Because of the elevation angles of 60.7° and 61.4° the projected pixel size on the ground exceeds the value of 46cm for the nadir view. Across the view direction the projected pixel size is 53cm and in the view direction 60cm. That means, the distributed images with 50cm GSD are over sampled.

3. IMAGE ORIENTATION AND ACCURACY OF OBJECT POINT DETERMINATION

Image orientation is the geometric base of any geo-referenced data acquisition. As dominating method of orientation the bias corrected sensor oriented rational polynomial coefficients (RPC) have been established (Jacobsen 2007). Together with the images and the header data, rational polynomial coefficients are distributed. They are expressing the relation between the image and the ground coordinates and are based on the direct sensor orientation of the satellite using a positioning system like GPS and gyros for getting the attitude data, supported by star sensors for compensation of the gyro drifts. The direct sensor orientations of WorldView-1 and GeoEye-1 are announced with a standard deviation of approximately 3m. In Turkey in addition to this we have an uncertain part for the Turkish datum, so an improvement by means of control points is required.
In the Istanbul area 29 and in Zonguldak 31 control points are given. For the orientation by sensor oriented RPC only few control points are required, so the remaining number of control points has been used as independent check points.

method of orientation	GCPs	at GCPs		at check points	
		SX	SY	SX	SY
RPC shift	1	0	0	0.57	0.51
RPC affine	4	0.15	0.01	0.54	0.52
RPC shift	4	0.29	0.30	0.56	0.53
RPC affine	8	0.19	0.12	0.56	0.58
RPC shift	8	0.33	0.23	0.58	0.54
RPC affine	29	0.42	0.47		
RPC shift	29	0.53	0.50		
3D affine	4	0	0	0.64	0.57
3D affine	8	0.15	0.11	0.70	0.69
3D affine +	8	0.10	0.11	0.49	0.62
3D affine ++	8	0.09	0.08	1.91	1.39
DLT	8	0.14	0.10	0.66	0.59

Table 2: results of scene orientation – WorldView-1, Istanbul [m], GCPs = ground control points

The bias corrected sensor oriented RPC orientation usually is done in two steps. At first the influence of the object point height is respected by the so called terrain relief correction, this is followed by a two-dimensional transformation to the control points. Here a simple shift or a two-dimensional affinity transformation can be used. Of course the two-dimensional affinity transformation requires at least 3 control points, so with just one control point only a shift is possible. A real accuracy analysis is only possible with independent check points, which are not used for the scene orientation. For 4 and 8 control points the improvement of the accuracy by a two-dimensional affinity transformation after terrain relief correction is negligible against a simple shift, confirming a very good inner accuracy of the WorldView-1 scenes. For comparison also a scene orientation by approximations has been tested. In general there is a loss of accuracy by the approximations, confirming results from other satellite images (Jacobsen 2007). The accuracy loss of the approximate orientation methods is depending upon the three-dimensional object point distribution. In the Istanbul scene 200m and in Zonguldak 350m height differences between the control and check points exist. For flat areas the orientation with 3D-affinity transformation as well as with the direct linear transformation (DLT) is difficult.

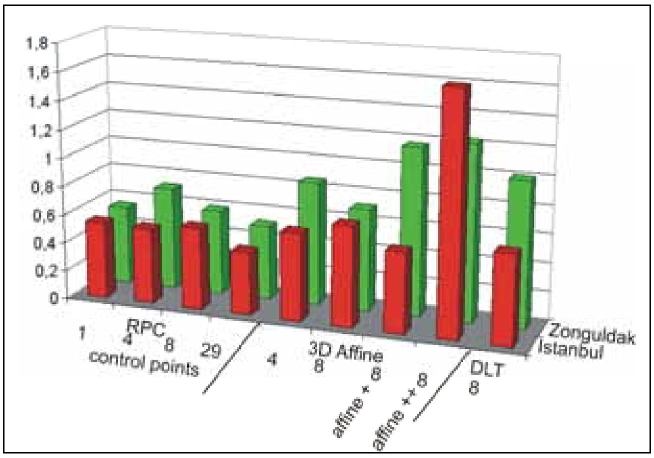

Fig. 2: graphical presentation of root mean square errors at check points – average of RMSX and RMSY [m]

As it can be seen in figure 2, the results at check points in the areas Istanbul and Zonguldak are quite similar; it is in the range of the projected pixel size. With a better point definition a higher accuracy would be possible, but a geometric quality close to 1.0 GSD is totally sufficient for topographic mapping.

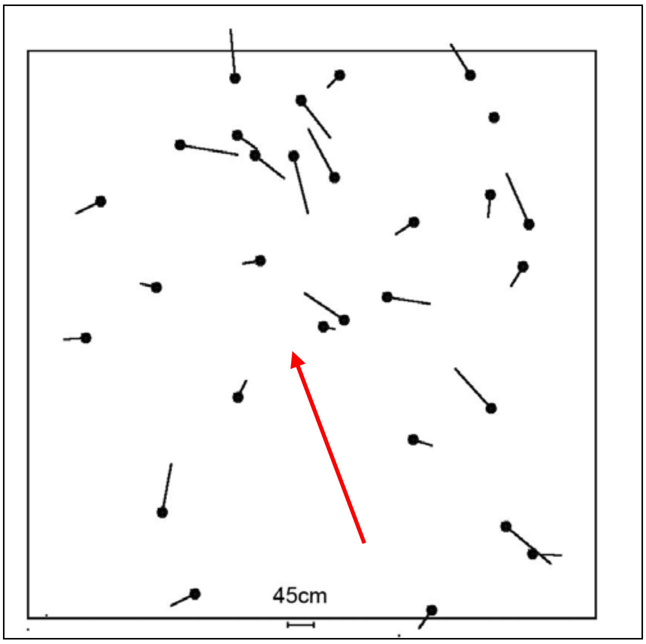

Fig. 3: discrepancies at control points, red arrow = view direction

Based on all control points in the Istanbul area the root mean square discrepancies are 52cm in the view direction and 36cm across the view direction (fig. 3). This is caused by a limited accuracy of the point heights. The component across view direction is independent upon the point height and indicates the pointing and scene accuracy. Corresponding to the error propagation the influence of the point heights to the horizontal coordinate components is 38cm. With the vertical view direction of 60.7°, the accuracy of the point heights is 63cm and this is a realistic figure for the used height values.

3. TOPOGRAPHIC MAPPING AND OBJECT RECOGNITION

Fig. 4: mapping of buildings – above based on WorldView-1, below map 1:5000 based on aerial images

Corresponding to the rule of thumb, that a GSD of 0.1mm is required in the map scale, with 50cm GSD a mapping in the scale 1:5000 should be possible. A part of the Istanbul scene has been used for the mapping of buildings - here reference data from the map 1:5000 are available (fig. 4). A detailed comparison shows, only few buildings have not been mapped in the WorldView-1 scene. A check in the satellite image made clear, also these buildings could be identified without problems; they only have been forgotten during mapping. Of course also new buildings have been mapped with the WorldView-1 scene. The building details are a little better in the map 1:5000 as by acquisition with the satellite image, but for the map scale 1:5000 it is totally satisfying.

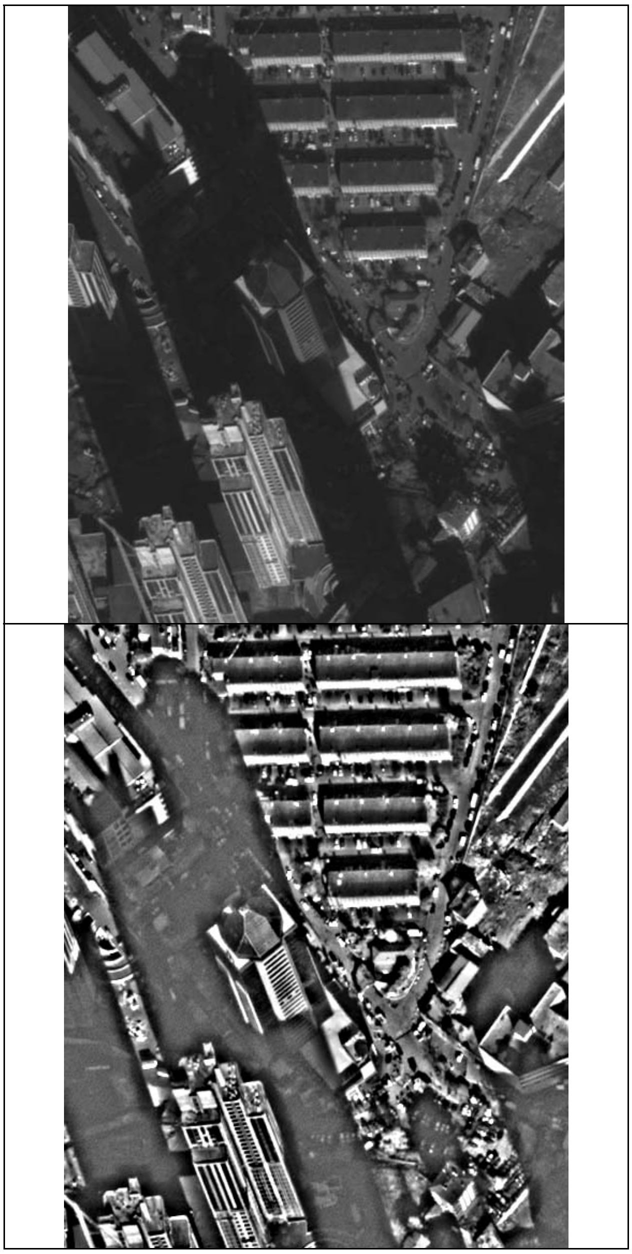

Fig. 5: above area influenced by building shadows, below enhancement of shadows by Wallis-filter

In the city area shadows from high buildings make the object recognition difficult. This has been improved by a Wallis-filter, enlarging the local contrast (fig. 5).

4. DETERMINATION OF HEIGHT MODELS

With the WorldView-1 test data Morrison, which Digital Globe makes available via internet, a height model has been generated. With a height to base relation (h/b) of 1.6 the Morrison stereo model follows the most often used angle of convergence; it corresponds to the relation of analogue wide angle cameras. The relation h/b=1.6 is optimal for open areas, but it has some disadvantages for city areas with large occlusions and partially not stereoscopically visible ground areas.

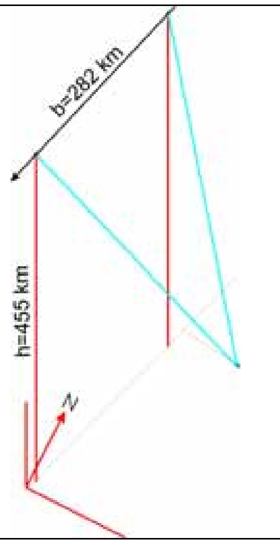

Fig. 6: imaging geometry of WorldView-1 model Morrison

height to base relation h/b=1.6

The automatic matching by least squares with region growing by the Hannover program DPCOR embedded in program DPLX has had no general problems in the build up areas, while in the mountainous shadow areas the matching was difficult. With the sun elevation of 27.6° long shadows exist.

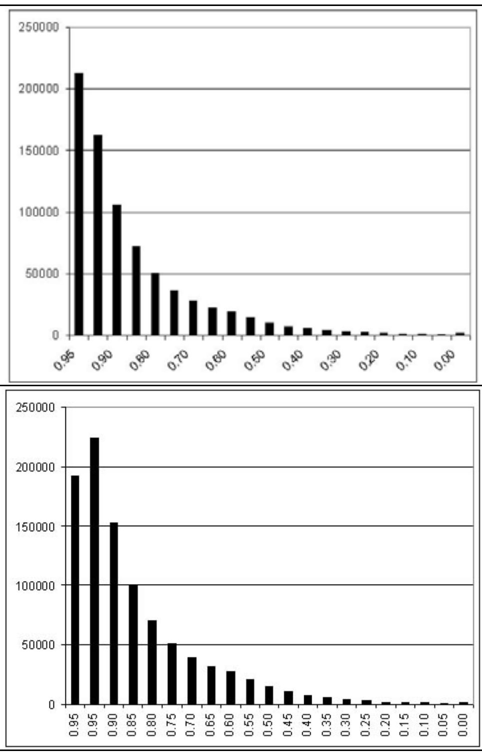

Fig. 7: histogram of correlation coefficients – above build up areas, below mountainous area

The histogram of the correlation coefficients (fig. 7) is optimal for build up areas, but also good for the mountainous parts, where the correlation coefficient group 0.90 up to 0.95 has the largest frequency.

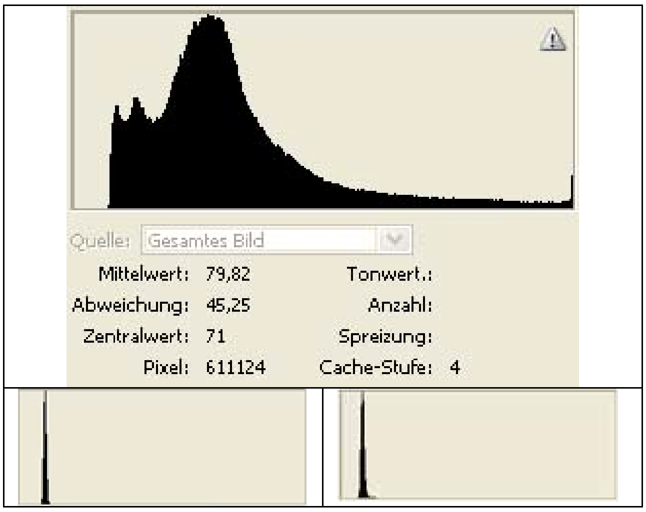

Fig. 8: histograms of grey values – above whole scene, below left: not matched build up areas, below right: not matched mountainous areas

The overall grey value distribution of the whole scene is good (fig. 8, above), while in the not matched areas (fig. 8, below) the variation of grey values is very limited.

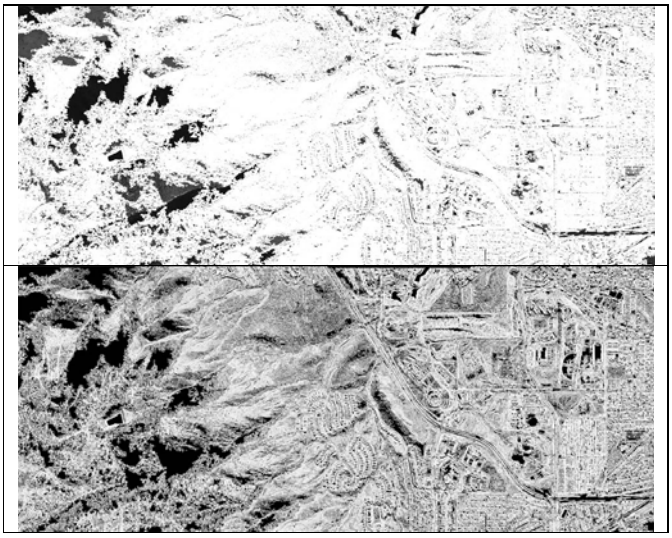

Fig. 9: above: white = matched points, not white = back ground
below: quality image – correlation coefficients shown as grey values: c=1.0 = grey value 255 (white)
c=0.6 = grey values 41 (grey)

As visible in figure 9, the matching quality in the build up areas on the right hand side in general is good, while in the mountainous part on left hand side the correlation coefficients are smaller and larger matching gaps exist. The main problem is caused by the shadow regions – here a higher sun elevation and hazy conditions have advantages. Haze leads to better light conditions in shadows, especially for shorter wavelength (blue spectral range).

As usual, the matching has been made with a point spacing of 3 pixels. This for area based matching is a usual point distance; a smaller spacing leads to higher correlation of neighbored points.

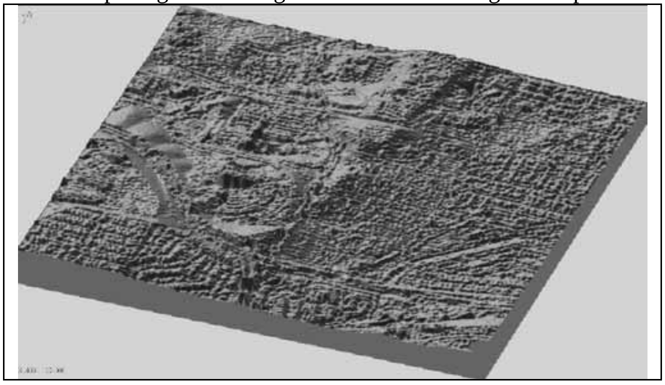

Fig. 10: 3D-view to generated height model in build up areas

The area based matching by least squares is optimal for open areas, but in build up areas it is rounding the building shape to hill-structures. If sharp building contours are required, a semi-global matching and mutual information should be used (Hirschmüller 2008).
It was not possible to analyze the accuracy of the height model because of missing accurate reference data.

5. CONCLUSION

The panchromatic WorldView-1 scenes have a ground resolution in the range of usual aerial images. Also the geometric accuracy can be compared. Even the automatic image matching leads to similar results as aerial images. The selection of very high resolution optical space images or aerial images is just depending upon the availability and access to the images together with the financial conditions and not depending upon the technical facts.

REFERENCES

Büyüksalih, G., Jacobsen, K., 2008: Determination of the build up area development in the Greater Municipality of Istanbul by space images, EARSel Workshop Remote Sensing - New Challenges of High Resolution, Bochum 2008, http://www.ipi.uni-hannover.de/ (access April 2009)

Hirschmüller, H., 2008: Stereo Processing by Semi-Global Matching and Mutual Information, IEEE Transactions on Pattern Analysis and Machine Intelligence 2/2008

Jacobsen, K., 2007: Geometry of Digital Frame Cameras, ASPRS annual conference, Tampa 2007 (on CD) + http://www.ipi.uni-hannover.de/ (access April 2009)

Jacobsen, K.:, 2008: Geometrisches Potential und Informationsgehalt von großformatigen digitalen Luftbildkameras. PFG (2008), Nr. 5, S. 325-336 + http://www.ipi.uni-hannover.de/ (access April 2009)