APPLICATION OF QUICKBIRD SATELLITE IMAGERY FOR UPDATING CADASTRAL INFORMATION

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ABSTRACT:

The high-resolution satellite images have recently attracted much attention in photogrammetry and GIS. In this paper the main approach for updating urban cadastral information using remote sensing and GIS data are being described.

Single panchromatic imagery from QuickBird, dated 27 March 2003, with 61 cm resolution in nadir is processed. The digital photogrammetric software PHOTOMOD 3.51 of RACURS Co. is used. The imagery covers about 270 km^2 of the territory of the Capital Sofia. The DTM from existing contours in *.SHP type with contour interval 5 m is generated. After Least Square adjustment the ground displacement for normally distributed check points is as follows: mean ± 0.82 m, maximal 1.64 m.

Geometrically correct orthoimagery at 1:5000 scale according to the local technical specifications is produced.

For a part of the territory a comparative analysis of accuracy between obtained orthoimagery and orthomosaic from aerial photographs dated 1 May 2001, is made. The aerial photography includes 18 pictures, taken by aerial survey camera RMK A 15/23 at 1:4500 scale. The accuracy obtained on X, Y, Z-axes for the check points is ± 0.048, ± 0.057, ± 0.205 m.

3D visualization of part of Sofia, which is based on two kinds of data – CAD and GIS is presented. The building heights have been taken from the available GIS information.

1. INTRODUCTION

GIS SOFIA Ltd. belongs to the Municipality of Sofia, which main activity is creation and maintenance of the information system and digital models of cadastre and revision of maps in digital format. It incorporates nine departments, one of them is the Photogrammetry Department.

One of the assigned to the company tasks is revision of the topographic map of Sofia at 1:5000 scale. For this purpose information from the following sources has been used:

- Existing topographic map at 1:5000 scale.
- Satellite image obtained from QickBird.
- Digital cadastral model of Sofia.

2. LARGE-SCALE TOPOGRAPHIC MAP

For the highly intensive activity regions of Bulgaria the large scale topographic map is produced at 1:5000 scale, and for the less intensive ones – high mountain and forest regions – at 1:10000 scale.

For production as well for revision of the large-scale topographic map aerial sterephotogrammetry is in use.

The aim of large-scale topographic map is to represent the location, form, dimensions and crops of the separate units. All situation details and objects visible within the map scale, all hydrographic and transport object and structure, as well as the terrain relief have also to be shown.

The large-scale topographic map is intended for the investigation, designing and planning of economic activities, for the solutions of research problems, as well as for defense purposes.

The content and scale of the topographic map is determined according to the purpose of its use in: agriculture, forestry, geological surveys, hydrographic and hydro-melioration activities, rural cadastre, etc.

The large-scale topographic maps for the territory of Bulgaria have been produced in 1970 Coordinate System and Baltic Sea Level Datum. Each map sheet with dimensions 50 x 50 cm of the map at 1:5000 scale covers 2.50 x 2.50 km = 6.25 km^2 from the Earth's surface. The graphical accuracy is not less than 0.4 mm in the scale of the map (1:5000) or 2 m on the terrain.

The large-scale topographic map is subject to periodic revisions depending on the respective needs. Due to the rapid change of the Capital Sofia infrastructure, it was necessary to revise the topographic map at 1:5000 scale for a part of the city.

Main source of information for revision of the map was the orthorectified QickBird satellite image.

3. ADVANTAGES OF THE SATELLITE IMAGES

Setting out in orbit of the new generation of satellites, providing images with high resolution, which are available for civil purposes, widens considerably the areas of application of the satellite images. In some respects they compete with the aerial pictures, especially for small-scale mapping.

The use of satellite images has certain advantages, such as:

- The process of photographing of the land surface is continuous lasting for a period of 4 days. Owing to this the most appropriate image was chosen.
- The formalities for aerial photography and flight arrangement are avoided here.
- The use of satellite images is considerably less expensive than the aerial pictures.

Due to the above mentioned reasons GIS SOFIA Ltd. decided to use satellite imagery for revision of the topographic map at 1:5000 scale for a part of the territory of the Capital Sofia.

4. MAIN CHARACTERISTICS OF QICKBIRD SATELLITE IMAGERY

4.1. Geometric resolution

Because of the large scale of the map an image, obtained by QuickBird is selected, which for the time being is with highest resolution – 61 cm in nadir for panchromatic image.

4.2. Radiometric resolution

Data obtained by QuickBird, have 11-bit dynamic range, which improves visualisation and makes them appropriate for use in urban territories.

4.3. Spectral range

According to the spectral range, the delivered images are grouped as follows:
- Panchromatic – with range of 450-900 nm.
- Multispectral – four channels with different spectral range:
  - Blue (450-520 nm).
  - Green (520-600 nm).
  - Red (630-690 nm).
  - Near-Infrared (760-900 nm).

4.4. Main products

QuickBird offers satellite images in three basic products depending on the level of processing of the rough image: Basic, Standard and Orthorectified.
- Basic Imagery appears to be the product with least additional processing. Just corrections for elimination of the radiometric and sensor distortion are made, and no other geometric corrections. It is delivered with additional files with information for efemerides, sensor position, etc. These data are needed for setting up of an rigorous sensor model. Basic Imagery is considered as most appropriate for further photogrammetric processing. Minimum order is a full scene 270-300 km^2.
- Standard Imagery is an image, which is corrected with respect to the radiometric, sensor, and platform-induced distortions and the topographic distortion, using the GTOPO30 digital elevation model. The image is georeferenced and is made in a pre-set cartographic projection. It is possible to order parts of the scene (minimum area of 25 km^2). A variety of this product is Ortho Ready Standard Imagery. It is appropriate for orthorectifying when using a ready digital elevation model.

- Orthorectified Imagery is a product, corrected for radiometric, sensor and topographic distortion. Usually for its orthorectification, digital elevation model and geodetic points are used, provided by the user. It is georeferenced and transformed into pre-defined cartographic projection.

4.5. Basic data about the selected image

The image is panchromatic Basic Imagery, which covers the central part of Sofia. It is an archive image, taken on 27 March 2003 at 09:17 hours GMT. The period, when the image was made, was very appropriate in view of vegetation of plants – hardly any leaves, which could stand in the way of important features. Although that early spring is characterized by unstable weather conditions, in this case they are extremely appropriate – 0 % clouds. The time interval between acquisition of the image and the time of its purchase and start of further processing for orthorectification and deriving the vector information is within a period of four months, which is completely satisfactory.

5. GEOMETRIC CORRECTIONS

5.1. Use of 3D polynomial transformation in the range of entire image

The digital photogrammetric software PHOTOMOD 3.51 of RACURS Co. is used for processing of the image. However, the software package does not contain QuickBird sensor model. Hence transformation of the image is performed by 3D – polynomial transformations, derived on the basis of geodetically defined points.

A special feature of such transformations is that the polynomial coefficients have no physical meaning, in other words do not correspond to any geometric model. They are empirically obtained relations, which makes the result very much influenced by the number, location and accuracy of the ground control points in use.

Because of the nature of activity of GIS SOFIA Ltd. sufficient number of geodetically determined points is provided. Specific elements from the terrain, which are clearly visible on the image and defined at earlier geodetic surveys, are used.

Despite of the large number of ground control points the achieved accuracy is insufficient in the range of the entire image. In some areas the deviations are up to 4 – 5 m.

5.2. Use of 3D polynomial transformation in the range of a part of the image

The central part of the image, where the terrain is relatively flat (high differences of less than 250 m) is selected. There are 16 control and 19 check points used. The obtained maximum and RMS errors in position of the check points are 1.64 and 0.82 m respectively. The residuals in X and Y directions, as well as the location of points are given in Table 1 and Figure 1.

Orthorectification by use of DEM, which is generated from contours at 5 m is performed. The obtained maximal displacement and RMS error in position of the check points are 1.74 and 0.91 m respectively.

— Residuals in control points				Residuals in check points			
№	Point	dx Pixels	dy Pixels	№	Point	dx Pixels	dy Pixels
1.	11	-0.456	-0.755	1.	14	-0.287	-0.813
2.	5	-0.104	0.306	2.	15	1.043	-1.081
3.	60	-0.003	-2.708	3.	152	0.297	1.405
4.	1132	0.102	1.918	4.	32	0.442	-0.771
5.	99	0.722	2.741	5.	33	1.992	0.209
6.	114	-0.268	-1.301	6.	154	2.035	-0.519
7.	46	0.466	0.322	7.	92	0.808	-0.548
8.	501	0.443	-0.164	8.	500	0.250	-1.612
9.	509	-0.855	0.750	9.	502	0.175	-0.743
10.	159	0.007	-0.849	10.	508	0.767	-0.296
11.	160	0.598	-0.126	11.	156	0.706	0.848
12.	85	0.044	-1.580	12.	162	1.044	-1.451
13.	100	-0.495	-0.641	13.	163	0.981	1.375
14.	106	0.681	-0.774	14.	165	-0.019	0.947
15.	107	-0.016	2.337	15.	103	-0.012	0.918
16.	133	-0.863	0.525	16.	111	0.318	1.005
				17.	115	0.177	1.700
				18.	116	-0.898	-0.404
				19.	117	-0.087	-0.825
RMS:		0.49	1.40	RMS:		0.80	1.01
MAX:		0.86	2.74	MAX:		2.04	1.70
Approximate ground displacement [m]				Approximate ground displacement [m]			
RMS:		0.92		RMS:		0.82	
MAX:		1.78		MAX:		1.64	

Table 1. The residuals in control and check points
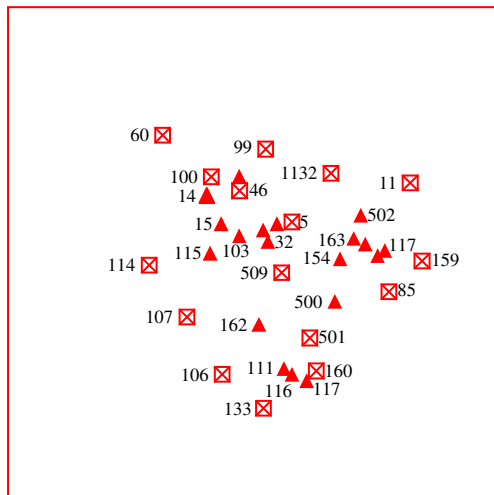

☒ Control point   ▲ Check point

Figure 1. Points location within the imagery

The accuracy is verified also by superimposition of vector objects from the available cadastral information over the orthorectified image. The differences are within the obtained maximal displacement and RMS error.

The results show that, the use of 3D polynomial transformations, obtained on the basis of ground survey points, appears to be an unreliable approach, especially when applied for large territories. Its use for smaller regions with insignificant relief variations, when having sufficient number of control and check points, gives considerably better results.

5.3. Use of Rational Polynomial Coefficients (RPC), supplied by QuickBird, with further polynomial transformations

With the cooperation by RACURS Co. relatively good results are obtained in the range of the entire image. The software was upgraded, which gives the opportunity to include RPC, submitted together with the satellite image. They are such an empirical coefficients that, the obtained functions represent approximation of the rigorous sensor model. Their use is an alternative to application of accurate physical model of the sensor, especially for relatively flat terrain.

The following approach is used:
- Transformation by use of the RPC is made.
- The precision of the obtained result is increased by means of 3D polynomial transformations of the basis of points, measured by GPS.

For the experiment 8 control and 15 check points, normally distributed within the range of the image, are used. The obtained obtained maximal displacement and RMS error in position of the check points are 2.56 and 1.40 m, respectively. The errors in X and Y directions, as well as the location of points are given in Table 2 and Figure 2.

Residuals in control points				Residuals in check points			
№	Point	dx Pixels	dy Pixels	№	Point	dx Pixels	dy Pixels
1.	01	-0.030	-1.464	1.	04	-1.205	-2.700
2.	02	0.086	0.835	2.	07	-0.555	-0.598
3.	03	0.044	-1.555	3.	08	0.040	-1.328
4.	05	0.014	-0.561	4.	09	-0.559	-0.402
5.	06	-0.065	1.323	5.	13	0.772	0979
6.	11	-0.028	1.025	6.	14	-0.258	-2.342
7.	15	-0.181	0.072	7.	16	-1.101	-0.369
8.	22	0.160	0.325	8.	17	1.350	-3.238
				9.	19	0.542	-0.820
				10.	20	-2.052	1.334
				11.	21	2.316	-1.521
				12.	23	0.290	-2.606
				13.	24	-2.605	2.388
				14.	25	-0.389	2.010
				15.	26	0.997	-2.387
RMS:		0.10	1.03	RMS:		1.26	1.89
MAX:		0.18	1.56	MAX:		2.61	3.24
Approximate ground displacement [m]				Approximate ground displacement [m]			
RMS:		0.64		RMS:		1.40	
MAX:		0.97		MAX:		2.56	

Table 2. The residuals in control and check points

After the orthorectification the obtained maximal displacement and RMS error in position of the check points are 2.30 and 1.54 m, respectively.

The analysis of the results shows that this approach ensures the needed accuracy for scale 1:5000 in the range of the entire image.
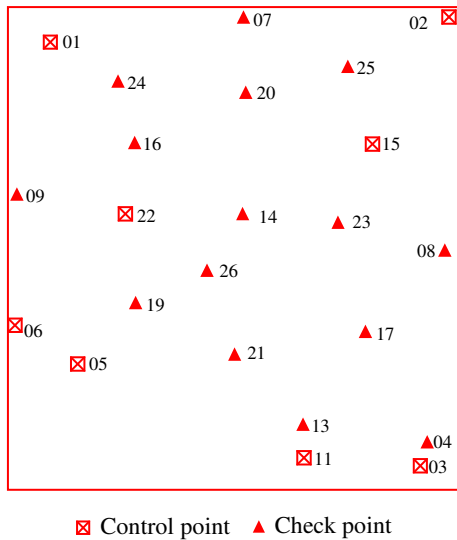

Figure 2. Points location within the imagery

Since these models do not correspond to the geometric relations it is better to be applied in cases, when sufficient additional information is available (points and vector objects), which information could be used for control of the orthorectified image.

6. REVISION OF THE TOPOGRAPHIC MAP

The obtained orthoimage is used for revision of the map at 1:5000 scale.

Due to the limitation, imposed by the resolution of the satellite image, not all objects can be identified with sufficient accuracy and clearness.

- The boundaries between separate properties are clearly visible, but hardly classified. The basic information about them is taken from the available digital model.
- Large residential and industrial buildings of a similar type are clearly visible on the image and can be plotted in accordance with the required accuracy.
- The small buildings and buildings with complex outline are not well recognised. In order to secure their accurate and proper representation, information from the digital model of cadastre and additional check (interpretation) and field surveys, are made.
- The streets, roads and separation strips are easy to be identified.
- Single train and tram rails are not clearly recognisable. The stations, however, are clearly visible.
- Water areas – lakes, swimming pools, dams, as well as their facilities are easily and accurately identifiable.
- Some of the water flows can be identified indirectly, while corrected river beds are clearly visible.

- It is impossible to identify the terrain elevation by a single scene (without a stereo-pair). In order to depict the relief contours, spot heights and break lines from the cadastre are used.

When object boundaries are unclear and can not be identified properly, other sources of information are used:
- Data from the cadastral information.
- Field interpretation of the image.
- Field survey.

7. COMPARATIVE ANALYSIS OF ACCURACY OF ORTHOPHOTO IMAGES, OBTAINED FROM AEROPHOTO AND SATELLITE IMAGES

The rapid development of sensor technologies and decrease of the pixel size on the earth's surface lead to the following questions:
- Up to what scales and for what purposes the use of aerial photographs or satellite images is justified?
- Is it justifiable to involve more expensive activities for the topographic maps at 1:5000 scale?

In respect to this a comparative analysis of accuracy of an orthophotoimage obtained from satellite image and one from aerial photographs is performed.

An aerial photography of a part of Sofia with area 4.5 km^2 is used. This is a region, having relatively high buildings and rapidly changing infrastructure. It is covered by 3 strips with 18 aerial photographs in total.

Data about the photography:
- Aerial survey camera RMK A 15/23.
- Approximate image scale 1:4500.
- Average flight height above the terrain 690 m.

The aerial triangulation is based on 8 control points, pre-marked on the terrain. The achieved accuracy is established by 9 check points. The results are compared in Tables 3 and 4, where Xm, Ym, Zm are average coordinates calculated from all models, and Xg, Yg, Zg are geodetically determinated coordinates, as well as dXY is the ground displacement of the points. Unacceptable residuals are marked with an asterisk (*).

№	Xm-Xg [m]	Ym-Yg [m]	Zm-Zg [m]	dXY [m]
11	-0.06	-0.06	-0.26*	0.08
13	-0.01	0.07	0.14	0.07
24	0.02	0.03	0.19	0.04
16	-0.08	-0.07	-0.22*	0.10
31	0.09	0.05	-0.22*	0.11
26	-0.01	0.01	-0.19	0.02
44	0.00	-0.06	0.18	0.06
46	-0.02	-0.07	-0.22*	0.08
RMS:	0.05	0.06	0.20*	0.08
MAX:	0.09	0.07	0.26*	0.11

Table 3. Ground control points residuals

An orthophotomosaic is produced on the basis of the DEM, generated from 3D vector objects and points, for the entire territory.

The maximum deviation with linear objects is 1.20 m, which is within the graphical accuracy for the corresponding map scale.

№	Xm-Xg [m]	Ym-Yg [m]	Zm-Zg [m]	dXY [m]
12	-0.06	-0.00	0.25*	0.06
23	-0.01	-0.06	0.17	0.06
14	0.07	0.02	0.18	0.08
15	0.01	-0.05	0.17	0.05
25	0.03	0.08	0.07	0.09
32	0.00	-0.00	0.11	0.01
35	0.05	0.03	0.34*	0.05
36	-0.02	0.06	0.15	0.06
45	0.04	-0.07	0.12	0.08
RMS:	0.04	0.05	0.19	0.06
MAX:	0.07	0.08	0.34*	0.09

Table 4. Check points residuals

An orthophotomosaic on the basis of the DEM, generated from 3D vector objects and points, for the entire territory is produced. The situation including roads and buildings over the orthoimages were digitized and superimposed. The result is well done coincidence of outlines and completeness of visible information. The maximum deviation with linear objects is 1.20 m, which is within the graphical accuracy for the corresponding map scale.

For topographic and cadastral maps at 1:5000 scale the satellite imagery meets the requirements for accuracy of information.

8. 3D VISUALISATION OF A PART OF SOFIA

The advance of computer technology in Digital Photogrammetry, Remote Sensing, Geographical Information Systems, Real Time 3D Digital Model and Visualization Systems have enhanced undoubtedly in recent years.

Three-dimensional visualisation gives information directly perceptible to human brains in such a detailed way that conventional plannar way of presentations are not capable. The applications of this realistic method of real time visualization could be seen in many fields (engineering, urban and city planning, architecture, design, science and art). Such a visualization can be obtained using DEM, high resolution orthophotos, satellite images and another data needed for the used software product.

The research in this field is started with collecting all accessible data from our GIS data using ArcView software. Easily from plannar visualization we obtained 3D buildings. Various colors are used according to their proper floor illustration (Figure 3).

The experimental buildings are visualized on the panchromatic satellite image stretched over the surface (Figure 4) and on the Figure 5. They are situated on DEM for a better surface visualization. Other experiments are made also for various

applications. The aim is to reach the most geometrically correct and real looking tree-dimensional model. For this reason several software products are tested, and a 3D model is generated.
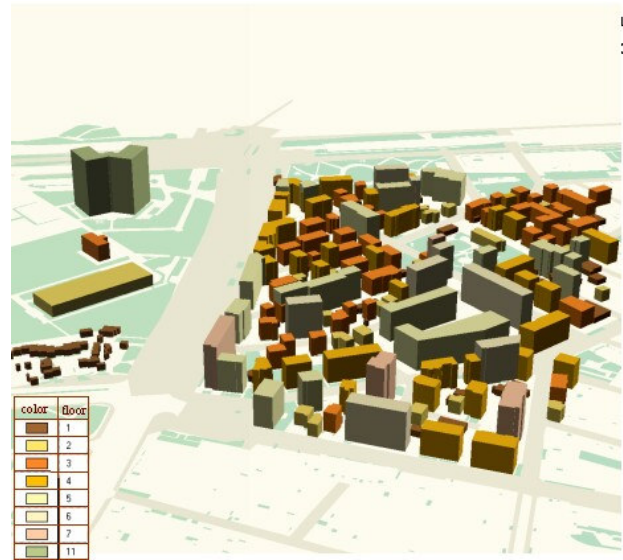

Figure 3. 3D visualization of buildings according to their floors

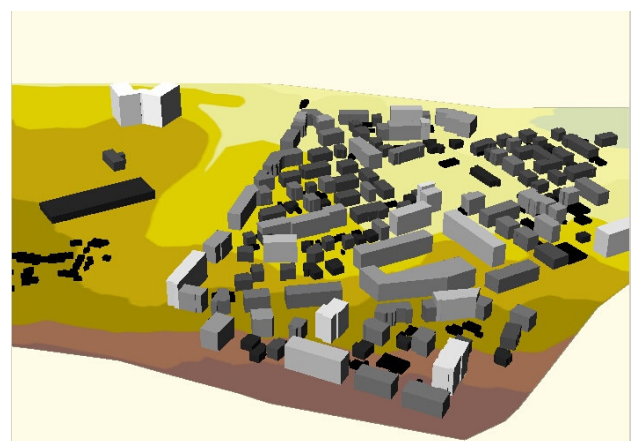Figure 4. Buildings situated on the panchromatic satellite image

Figure 5. The basis on this figure is DEM

9. CONCLUSIONS

The geometrical accuracy of the orthorectification of high resolution satellite images meets the requirements for topographic map at scale of 1:5000.

The outlines of a part of the objects can not be defined within the accuracy requirement of the scale. In this case it is necessary to use other sources of information. The use of aeral pictures provides higher completeness of information, but is considerably more expensive.

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