Accuracy Evaluation and Quality Control of Digital Orthomap-Sheets

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Key words: Digital aerial images, orthoimages, ground control point (GCP), spatial resolution, digital terrain model (DTM), simline, digital orthomap-sheets, spatial accuracy.

SUMMARY

With the evolution of digital photogrammetry, digital image processing is carried out more quickly and accurately. This makes digital images widely usable. Geometric accuracy and quality of orthoimages are very important characteristics. An orthoimage is an accurate representation of the Earth's surface. It gives complex information with high detail. The geometric accuracy of digital orthoimages is the same as the linear accuracy of a map. They can be used to digitize objects and features. The major advantage of orthoimages is their ability to be produced in a short time to provide up-to-date information for urgent planning. They are also produced at a less expensive production price than line or vector maps.[1] The aim of this paper is to evaluate the accuracy and quality of orthoimages, basis of a digital terrain model (DTM) approximated on the ground. The paper will show the measurements and results from a digital block aerial triangulation in Photogrammetry software, a crucial sign for a project quality, digital terrain extraction and editing. It also describes an orthophotogeneration process, tiling of digital orthomap-sheets and investigates the spatial accuracy and quality of digital orthoimap-sheets.

INTRODUCTION

The accuracy evaluation and quality control are very important for digital orthophotomap application. They are executed after the basic stages in the process of creation the digital orthophotomap. The quality and the spatial resolution of the digital images and the model of the terrain appear to have a great influence for producing an accurate planimetric digital color orthophotomap. The aim of this research is to assess the accuracy of the digital block triangulation and the digital model of the terrain, as crucial factors influencing the precision of the digital orthomap. The digital aerial images and the data are part of an European project on updating the digital orthomap serving the system of identifying agricultural areas in the country. In Bulgaria, the area is mainly mountainous, which is an obstacle during both: the process of taking aerial images and the balanced positioning of terrain markers. The main problem which occurred due to the terrain relief is distortion. The higher the flight the less inaccurate the images are with respect to distortion. The measurement, the assessment and the analysis are drawn by photogrammetric block covering flat and hilly terrain of 240 km^2. The block contains of 700 color digital images which were taken by a digital mapping camera DMC 01-0147 with focal length 120 mm., pixel size 12μм and virtual sensor size 13824x7680 [pixels]. The images are with end lap of 70% and side lap of 40-70%, grouped in 11 East – West orientated strips. The average flight height is 3600 meters, which determines spatial resolution of the 0.36 meters and scale factor 1:30 000.

This paper includes the complete stages of orthophotomap generating such as: digital block aerial triangulation, DTM extraction and editing, mosaicking, tiling into orthomap-sheets and the orthomap quality process.

1. **ORTHOMAP GENERATION PROCESS**.

The first and very important step of orthomap generation process is the measuring and automatically calculating of a digital block aerial triangulation.

1.1 Measuring of a digital block aerial triangulation.

A digital block triangulation is a process of establishing a mathematical relationship between the images contained in the project, the camera or sensor model, and the ground. The results of triangulation determine the image position and orientation, which are required for the purpose of DTM extraction, stereo feature collection and orthorectification.[2] A digital block triangulation is measured and automatically calculated in Photogrammetry ERDAS Imagine software. In the block project are defined a ground coordinate system (ellipsoid – WGS 84, with projection – UTM, zone – 35 North), the focal length of the camera – 120 mm, the pixel size – 12μм and are inputted exterior orientation parameters. The interior orientation defines the internal geometry of the camera or sensor as it is existed at the time of image capture. The exterior orientation defines the position and angular orientation of the camera that captured the image. The positional elements of exterior orientation include Cartesian coordinates of the camera position (Xo, Yo, Zo) and rotation angles at the moment of image capture . [2]

1.1.1. Point measurements and results.

The accuracy of automatic aerial triangulation depends on the quality and number of GCPs and tie points. There are 50 tie points between each stereopair generated in order to even distribution of connection between the images. A tie point is a point that has ground coordinates that are not known, but is visually recognizable in the overlap area between two or more images. The corresponding image positions of tie points appearing on the overlap areas of multiple images is identified and measured. Ground coordinates for tie points are computed during block triangulation. Tie points can be measured both manually and automatically.[2] During the automatically solution of triangulation, erroneous points are automatically identified and removed from the solution.
The next step of triangulation is measuring the image coordinates of GCPs in all images of the block. GCPs should be clearly visible points on the terrain with known coordinates in the terrain coordinate system, which are identified and measured in images. Both, the terrain coordinates and the measured photogrammetric image coordinates are used in block adjustment as observations.

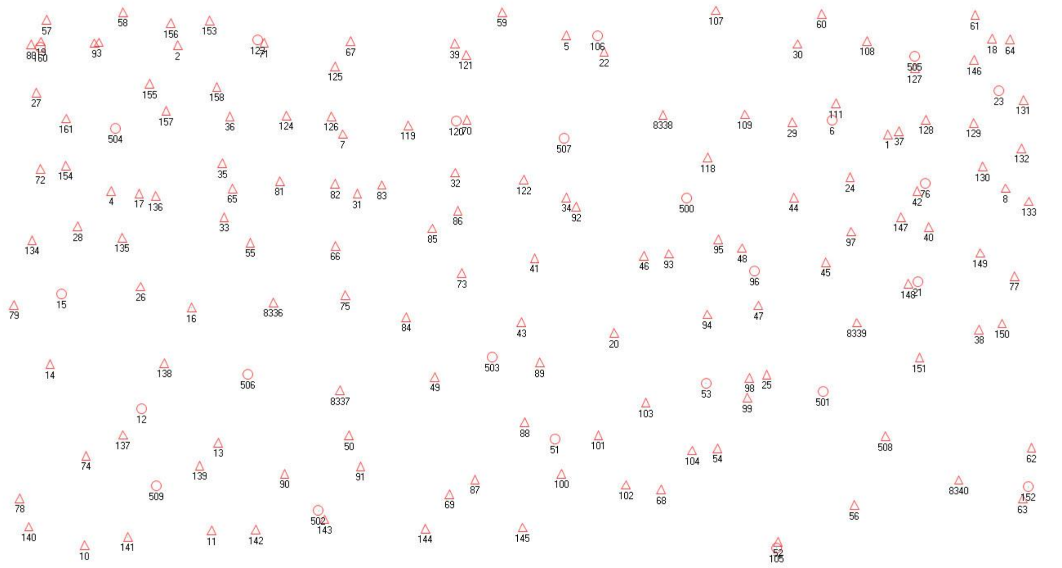

Figure 1. Scheme of GCPs

The GCPs are marked on the ground and have been measured in static mode with GNSS equipment. Then the GNSS data has been post-processed and the final GCPs coordinates have been calculated. The final coordinates' accuracy is better than ±2 cm in horizontal position and better than ±5 cm in height.
In the block file are measured image coordinates of 144 GCPs, 25 of which are measured vertically and 24 as a Check points. In this case, the GCPs form a strong geometric network of observations. (Figure 1) As a general rule, it is advantageous to have at least one GCP on every one third of each image in the block. After completing the bundle block adjustment process, new values for the control point coordinates are computed. Photogrammetry Project Manager computed the image coordinate residuals for each image measurement in the block. The RMSE of the 564 image points is m_x= 0.199, m_y= 0.175 pixels. The new control point coordinates are computed based on the estimated exterior orientation parameters and measured image coordinate values. The control point residuals reflect the difference between the original control point coordinates and newly estimated control point coordinates. The results are listed in (table 1) below.

Table 1. The residuals of control point in meters.

The residuals of the control points				
Point ID	rX	rY	rZ	Total RMSE
1	-0.0722	0.0465	-0.0012	0.125094
2	-0.0207	0.025	-0.0007	0.035824
3	-0.0087	-0.0075	-0.0055	0.015052
4	0.0198	-0.0078	0.0058	0.03428
7	-0.0634	0.0134	0.006	0.109877
8	0.0086	0.0495	-0.014	0.014851
9	0.0285	-0.0054	-0.0025	0.049305
10	0.008	0.0036	-0.0021	0.013842
11	0.0039	0.0326	0.003	0.006751
13	-0.0411	0.0153	-0.0142	0.071191
14	-0.0428	0.0405	-0.0051	0.074159
16	0.0443	-0.052	0.0129	0.076734
17	0.0344	-0.0213	0.0061	0.059554
18	-0.0066	0.0055	0.0023	0.011506
19	0.0096	0.016	0.0028	0.016668
20	-0.0805	-0.0683	0.0026	0.139376
22	0.0266	0.0217	-0.0022	0.046089
24	-0.0042	0.0357	0.0003	0.007349
25	-0.0545	0.0254	0.0305	0.094467
26	0.0491	-0.0141	-0.0101	0.085122
27	-0.0202	-0.01	0.0022	0.035045
29	0.0076	0.0115	-0.0046	0.013236
30	-0.0127	0.0472	0.0066	0.022035
31	-0.0585	0.0457	-0.014	0.101283
32	0.0061	-0.0133	-0.0025	0.010621
33	0.0012	-0.0417	-0.0065	0.002053
34	-0.0303	-0.0194	0.0063	0.052506
35	-0.0337	0.0068	-0.0089	0.058353
36	-0.0032	0.0712	-0.0083	0.005607
37	-0.039	0.0384	-0.0235	0.067636
38	0.018	0.0078	0.007	0.03124
39	-0.0113	-0.0094	-0.002	0.01964
40	0.0185	0.0341	-0.0034	0.031997
43	-0.0063	0.0096	-0.0001	0.010967
44	-0.0029	0.0757	0.0122	0.004977
45	-0.0044	0.0398	-0.0155	0.007543
46	-0.0296	-0.0214	-0.0251	0.05122
47	-0.0169	-0.0044	-0.0203	0.029346
48	-0.02	0.0048	-0.0093	0.034611
50	-0.0217	0.0523	-0.0276	0.037591
52	-0.0286	0.0168	-0.0069	0.049567
54	-0.0487	-0.0429	0.0065	0.084271
55	-0.044	0.0231	0.0061	0.076285
56	-0.0792	0.0937	0.0072	0.137166
57	-0.0303	0.0096	0.0057	0.052541
58	-0.0299	-0.0094	-0.007	0.051768
59	0.0017	-0.0027	-0.0069	0.002954
60	-0.0005	-0.0244	-0.0115	0.000918
61	-0.0041	-0.0107	-0.0063	0.007078
62	0.0332	-0.025	0.0005	0.057473
63	0.0015	0.0615	-0.0001	0.002675
64	-0.0117	0.0186	0.003	0.02022
65	-0.0263	0.0186	-0.0059	0.045581
68	0.0428	0.0053	0.0055	0.074186
69	0.0108	0.0726	-0.0208	0.018752
70	-0.0219	0.059	-0.0049	0.037869
72	-0.0298	-0.002	-0.0143	0.051592
508	-0.0186	0.0743	-0.0218	0.032172

The residuals of the control points				
Point ID	rX	rY	rZ	Total RMSE
92	0.0543	0.0299	-0.007	0.093969
94	0.0487	-0.1221	0.0229	0.084303
95	0.009	0.0167	-0.0019	0.015615
97	0.0014	-0.0479	0.006	0.002474
98	-0.0393	-0.1139	0.0246	0.068032
99	0.0068	-0.0206	-0.0244	0.011823
100	0.0361	0.0215	-0.007	0.062477
101	-0.0187	-0.0401	0.0144	0.032388
102	0.0217	-0.0788	0.012	0.037521
104	0.0165	-0.0187	-0.0039	0.028609
111	-0.0226	-0.0253	0.0169	0.039098
118	0.0585	-0.02	0.0032	0.101367
119	-0.0951	0.0214	-0.008	0.164763
121	0.0194	-0.051	-0.0011	0.033584
122	0.0844	-0.0375	0.0096	0.14618
124	-0.0345	0.0298	-0.0029	0.05973
125	0.0201	-0.0234	0.0101	0.034808
126	0.0355	0.0245	0.006	0.061569
127	0.0931	0.0112	0.0212	0.161313
128	0.011	-0.0157	-0.0008	0.019068
130	-0.0195	-0.0376	-0.0104	0.033798
131	-0.0081	0.0059	0.0055	0.013983
132	0.0299	-0.0327	0.009	0.051847
133	-0.0248	0.0064	-0.0085	0.043016
135	-0.1995	-0.0254	-0.0112	0.345556
138	-0.0123	-0.0303	-0.0164	0.021285
139	-0.0032	-0.0115	-0.0024	0.005477
142	0.0556	-0.0094	0.0034	0.096293
144	0.0175	0.0196	-0.0004	0.030336
145	0.041	0.0362	-0.0032	0.07102
146	0.0004	-0.0005	-0.0083	0.000696
148	-0.0106	-0.0295	-0.0257	0.018282
149	0.0437	-0.0133	0.0503	0.075655
150	0.0138	-0.0416	-0.0061	0.023854
153	0.0185	-0.0296	-0.0118	0.032068
154	-0.0182	-0.0571	-0.0026	0.031477
155	0.0524	0.0128	0.0056	0.090813
158	0.0022	-0.0146	0.0352	0.003753
161	0.1369	0.054	-0.0119	0.237184
8336	0.0053	0.0414	-0.0134	0.009191
8337	-0.0795	-0.0141	0.0179	0.13776
8338	-0.0253	0.017	-0.007	0.043786
140	0.029	0.0178		0.050219
141	0.0305	0.026		0.052899
151	0.0404	-0.0335		0.070045
5	0.0217	0.0205		0.037546
8339	0.0091	-0.0333		0.015779
66			0.0089	
136			0.0063	
137			0.056	
103			-0.0299	
67			-0.0061	
49			0.0024	
143			-0.0017	
107			0.0014	
108			-0.0039	
109			0.0033	
147			-0.003	

73	-0.0216	-0.0249	-0.005	0.037478
74	-0.0264	-0.0086	-0.0384	0.045785
75	-0.014	-0.0054	-0.004	0.02419
77	-0.0169	0.0106	-0.0136	0.02928
78	-0.024	0.0228	0.0035	0.041523
79	0.0298	0.0018	-0.0146	0.051594
80	0.0124	-0.0333	-0.003	0.021412
82	0.1044	0.0598	-0.0069	0.180803
83	0.0787	-0.0634	0.0133	0.136284
84	0.0476	-0.055	0.0039	0.082511
86	0.0136	-0.0412	0.0116	0.023597
87	0.0264	-0.0777	0.0212	0.045805
89	-0.009	0.0208	0.0055	0.015536
91	0.0504	-0.0057	0.0164	0.087241

88			0.004	
90			0.0039	
28			-0.011	
41			0.0027	
42			0.0141	
93			0.0112	
156			0.0081	
157			-0.0115	
85			-0.003	
71			0.0033	
81			-0.0007	
129			0.0063	
134			0.0603	
8340			0.0053	

It is highly recommended a greater number of GCPs to be available than those actually used in the block triangulation. Additional GCPs can be used as check points to verify independently the overall quality and accuracy of the block triangulation solution.

1.1.2. Accuracy assessment of digital aerial triangulation.

A check point analysis compares the photogrammetrically computed ground coordinates of the check points to the original values. The result of the analysis is an RMSE that defines the degree of correspondence between the computed values and the original values. Lower RMSE values indicate better results.[2] Check points are used to verify independently the quality of the bundle block adjustment. Once the exterior orientation parameters have been solved, the image coordinate values of the check points are used to compute the Cartesian X, Y, and Z coordinates. The computed coordinates are subtracted from the original input coordinates to compute the check point residuals. Check points are used as the best source for determining the accuracy of the bundle block adjustment. The results are listed in table (2) below.

Table 2. The residuals of check points.

The residuals of the check points			
Point ID	rX	rY	rZ
6	0.0263	0.2059	-0.2344
500	-0.1192	-0.0182	-0.0722
15	0.0243	-0.0281	0.0432
501	-0.1074	-0.0207	0.1356
502	0.197	0.3698	0.3773
21	-0.053	0.051	-0.0994
23	-0.0795	-0.08	0.3099
503	-0.0795	0.2628	-0.1762
504	-0.0681	0.0535	-0.2304
505	-0.1214	0.0382	-0.2447
506	-0.193	-0.0052	0.6172
51			-0.0791

The residuals of the check points			
Point ID	rX	rY	rZ
53	-0.3201	-0.1361	-0.541
507	0.0248	0.0711	0.0445
509	-0.1665	0.1144	0.0915
105	-0.0056	-0.1437	-0.1136
120	0.0823	-0.1011	0.6476
123	0.1627	0.0047	-0.4075
160	0.0927	-0.0677	-0.7616
96	0.0061	0.0291	-0.0949
152	-0.0297	0.1326	-0.2627
76	0.0558	0.1405	-0.0937
12	0.1057	0.1524	-0.5285
106	-0.113	-0.0048	0.7093

A bundled solution is computed including the exterior orientation parameters of each image in a block and the Cartesian X, Y, and Z coordinates of the tie points and adjusted GCPs. The block of images in the project is simultaneously processed in the solution. A statistical technique known as least squares adjustment is used to estimate the bundled solution for the entire block while also minimizing and distributing error. Triangulation summary is shown in figure below (2).

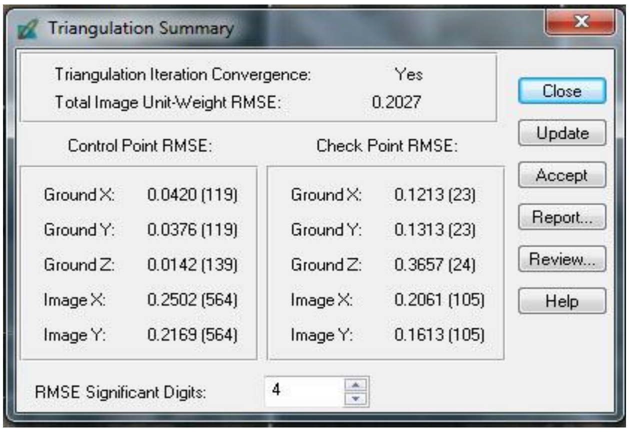

Figure 2. Triangulation summary

The total image RMSE from all observations in the block project is 0.20 pixels. All values under 0.33 pixels are correct. According to specification the RMSE of the observations should be no more than 0.5 pixels. The RMSE in the Cartesian X, Y and Z coordinates of control points are determined to be 0.042, 0.037 and 0.014 meters respectively. And the RMSE in the X, Y and Z of check points are determined to be 0.121, 0.131 and 0.366 meters respectively. From these results the planimetric accuracy of check points is equal to:

$$\sqrt{0,121^2 + 0,131^2} = 0,178 \text{ м.}$$

On the other hand the linear accuracy can be estimated as:

$$\sqrt{0,121 + 0,131 + 0,366} = 0,786 \text{ м.}$$

Linear accuracy is approximately equal to triple the initial ground resolution. [4]

1.2. DTM extraction and editing.

The next step of orthophoto map production is a digital terrain extraction and editing. Automatic DTM extraction involves the automatic extraction of elevation information from imagery and the subsequent creation of a 3D digital representation of the surface of the Earth. A DTM represents the elevation associated with the topography of the Earth and not necessarily the human-made (such as buildings) or natural (such as trees) features located on the surface of the Earth. A normal orthophoto is made on basis of a model of the terrain. The terrain model does not include buildings, vegetation etc. This result in the image where buildings are leaning away from the image center, so their positions are not corrected, and only objects that are in level with the terrain are represented correctly. Roads running over bridges will look like they “bend down” to follow the terrain below it.[5] In this case, after bundle block adjustment, the DTM is generated from Photogrametry in Automatic Terrain Extraction (ATE) in .LTF format with cell size of 4 m. In order to automatically extract topography only, specific parameters governing the elevation extraction process must be specified. However, typically additional editing outside of the DTM extraction process is required to obtain a 3D topographic representation only. This process is referred to as DTM editing. DTM editing techniques are used to remove invalid elevation points in order to create an accurate representation of the topography and surface of the Earth. Theoretically DTM generated by correlation method has an accuracy of about 0.3 to 1 pixel which corresponds from 0.1 % to 0.2% of flight height. Flight height of digital aerial images is H = 3600 m, therefore theoretical accuracy of DTM could be from 36 cm to 72 cm.[6]

The DTM accuracy has been improved by editing in stereo mode. Editing consists in drawing break lines of all artificial objects, roads, ditches and embankments, bridges and all characteristic landforms. Where the model is generated by visible surface level of the objects, all points of the array are edited on the ground. Figure (3) shows the edited terrain break lines drawn on infrastructure elements at different height levels, bridges, subways, streets, etc. After completion of the editing process, the terrain has been converted to raster format .IMG with cell size of 2 m. The DEM has been checked before used into the orthophoto generation.

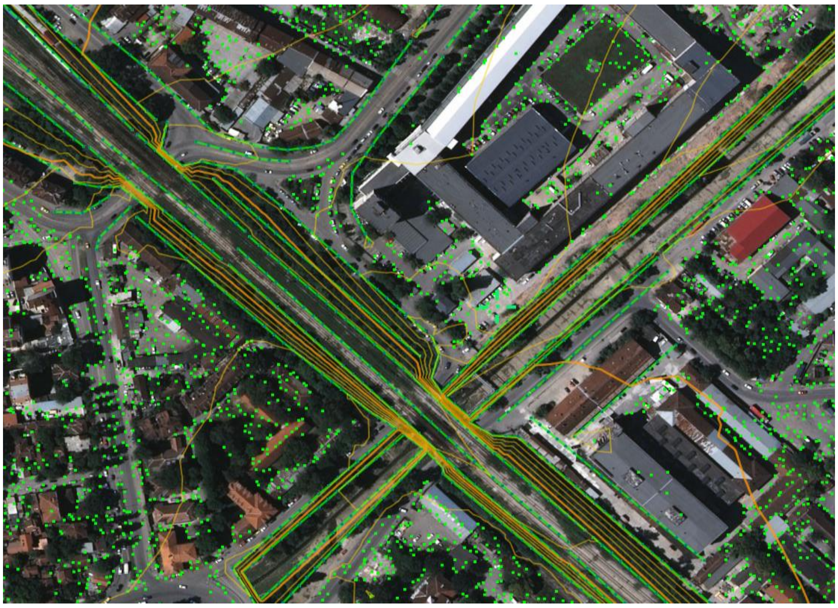

Figure 3. DTM editing

1.3. Orthoimage generation, mosaicking and tiling into orthomap-sheets.

The orthorectification process requires highly accurate digital elevation model (DEM) for the creation of map-accurate orthoimagery. Using DEM reduces the effect of topographic relief displacement on raw imagery. Errors in DEM have a great influence on the accuracy of digital orthoimages. Orthorectification generates planimetrically true orthoimages in which the displacement of objects due to sensor or camera orientation, terrain relief, and other errors associated with image acquisition and processing has been removed. The orthoimage has the geometric characteristics of a map and the qualities of a image. The objects on an orthoimage are in their true orthographic positions. Therefore, orthoimages are geometrically equivalent to conventional line and symbol planimetric maps. Any measurement taken on an orthoimage reflects a measurement taken on the ground. Orthoimages allow to extract georefered information easier and faster than conventional cartography. Multiple orthoimages can be joined together seamlessly to create an orthoimage mosaic. The mosaic is created in Mosaic-pro. The simlines are generated with a good strategy. All simlines are checked and edited. The editing process of simlines inherently represent relative control of the geometric accuracy of orthoimages by comparing the location of the same object in overlapping orthographic images. According to the specification, the differences between the same object in images should be no more than two or three pixels. The differences between images are not larger than one pixel, which meets the requirements for first class accuracy of orthographic images (Figure 4). The next essential element in the process of mosaic is radiometric balance of images made by image dodging. Image dodging uses an algorithm to correct radiometric irregularities (such as hotspots and vignetting) in an image or group of images. Image dodging corrects brightness and contrast imbalances due to several image inconsistencies. [7]

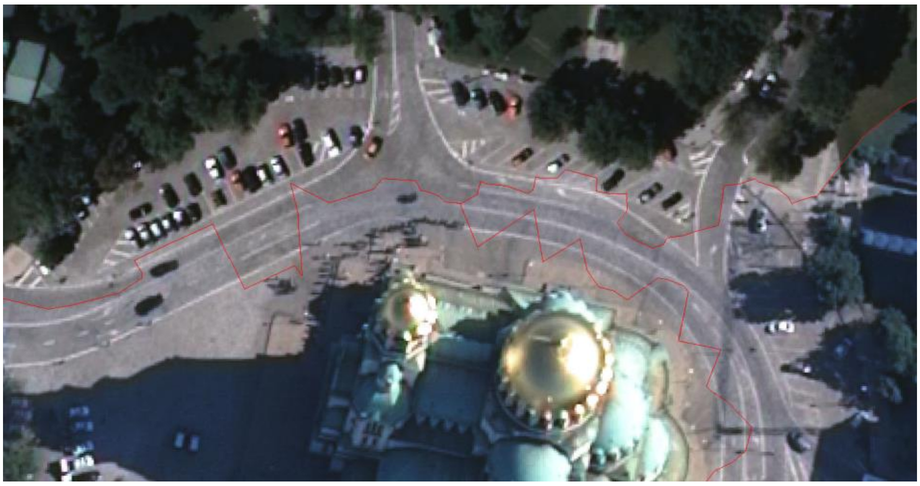

Figure 4. Sim line generation and editing.

The last step of orthomap production is tiling into orthomap-sheets. Orthoimages are usually delivered as individual orthomap-sheets. According to specification for aerial photography and photogrammetric services, the spatial resolution after orthorectification should not be lower than 0.36 meters. All generated orthoimages are tiled into 4 kilometers orhomap-sheets with 0.40 m. ground simple distance, 8 bits radiometric resolution, RGB in GEOtiff format.(Figure 5)

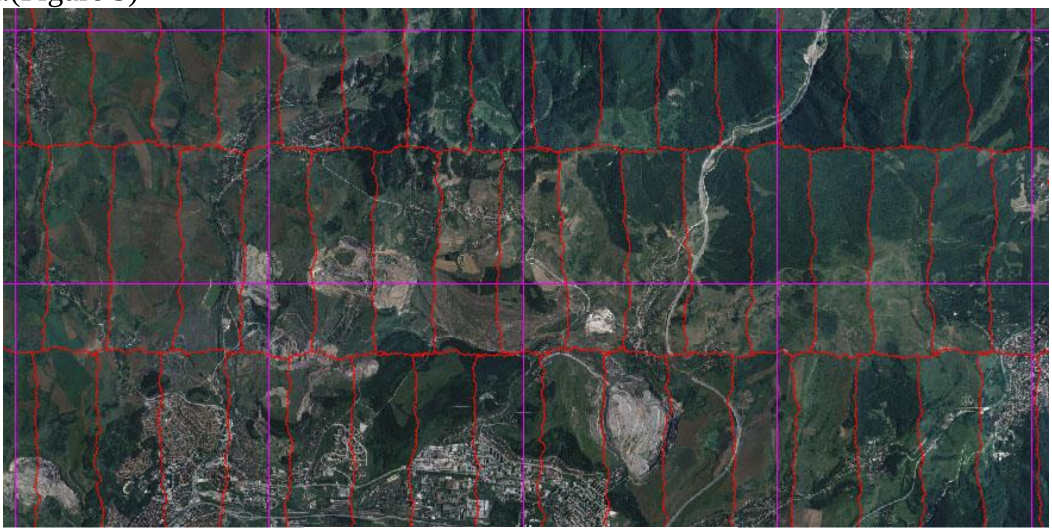

Figure 5. orthomap-sheets generation.

2. QUALITY AND ACCURACY ASSESSMENT OF DIGITAL ORTHOMAP-SHEETS.

The quality and accuracy of a digital orthophoto map are very important especially when it is used in the creation or updating of GIS data base by digitizing. Quality issues fall into two general categories. The first is spatial accuracy and the second is image quality (Smith, 1995). Spatial accuracy refers to the location of pixel elements with respect to their true location on the face of the Earth. Image quality considers pictorial defects and tonal differences, both within and across the orthomap-sheets. Checking orthoimages requires reference objects or image details from which the accuracy can be determined.[8]

2.1. Spatial accuracy.

Accuracy assessment of digital orthophoto map is performed with absolute control of geometric accuracy, through comparison the ground coordinates of check points with this from orthophoto map. A total of 20 check points are selected from the one orthomap-sheet (Figure 6) The check points are clear visible points from images and the ground. The ground coordinates of check points are determined from GNSS observation with the same accuracy as the control points. The check points used for accuracy assessment are not included in digital aerial triangulation.

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.

$$RMSEx=\sqrt{\frac{\sum(Xdata,i-Xcheck,i)^2}{n}} \quad (1), \qquad RMSEy=\sqrt{\frac{\sum(Ydata,i-Ycheck,i)^2}{n}} \quad (2),$$

where:

$Xdata,i$, $Ydata,i$ are the coordinates of the i-th check point in the dataset;

$Xcheck,i$, $Ycheck,i$ are the coordinates of the i-th check point in the independent source of higher accuracy;

n is the number of check points tested;

i is an integer ranging from 1 to n;

Horizontal RMSEr is defined as

$$RMSEr=sqrt[RMSEx^2 + RMSEy^2] =0,319 \text{ m.} \quad (4),$$

The results of accuracy assessment are shown below in table 3.

Table 3. Accuracy assessment.

point	GPS observation (meters)		orthomap-sheet (meters)		difference		squared difference		sum of squared differences
	X	Y	X	Y	X	Y	X	Y	
1	4735619.487	196427.046	4735619.792	196426.690	-0.305	0.356	0.093	0.127	0.220
2	4735620.607	197673.769	4735620.622	197673.994	-0.015	-0.225	0.000	0.051	0.051
3	4735301.641	198685.318	4735301.796	198685.010	-0.155	0.308	0.024	0.095	0.119
4	4734881.572	197127.194	4734881.881	197127.301	-0.309	-0.107	0.095	0.011	0.107
5	4734371.537	198718.493	4734371.657	198718.740	-0.120	-0.247	0.014	0.061	0.075
6	4734023.530	196333.140	4734023.841	196332.992	-0.311	0.148	0.097	0.022	0.119
7	4734354.532	197649.733	4734354.831	197649.958	-0.299	-0.225	0.089	0.051	0.140
8	4734192.810	199682.842	4734192.800	199683.098	0.010	-0.256	0.000	0.066	0.066
9	4733347.251	196686.690	4733347.245	196686.547	0.006	0.143	0.000	0.020	0.020
10	4733253.899	197745.880	4733253.998	197746.228	-0.099	-0.348	0.010	0.121	0.131
11	4733874.844	198559.887	4733874.610	198559.998	0.234	-0.111	0.055	0.012	0.067
12	4733600.403	199501.858	4733600.380	199502.029	0.023	-0.171	0.001	0.029	0.030
13	4733306.856	199564.062	4733307.188	199564.025	-0.332	0.037	0.110	0.001	0.112
14	4732293.834	196384.265	4732293.549	196384.281	0.285	-0.016	0.081	0.000	0.081
15	4732840.119	198143.668	4732840.440	198143.986	-0.321	-0.318	0.103	0.101	0.204
16	4732266.300	198513.627	4732266.413	198513.794	-0.113	-0.167	0.013	0.028	0.041
17	4732522.713	199488.455	4732522.636	199488.590	0.077	-0.135	0.006	0.018	0.024
18	4732971.035	199922.951	4732971.218	199922.613	-0.183	0.338	0.033	0.114	0.148
19	4735379.774	199694.295	4735379.963	199694.521	-0.189	-0.226	0.036	0.051	0.087
20	4732528.918	197345.494	4732528.582	197345.198	0.336	0.296	0.113	0.088	0.201
						sum	0.974	1.068	2.041

average	0.049	0.053	0.102
RMSE	**0.221**	**0.231**	**0.319**

Computing Accuracy According to the NSSDA:

Accuracy =2,4477*0,5*(RMSEx+RMSEy)= **0,553 m**. (5). [9]

For full control of the geometric accuracy of research ortho quadrangle, a comparison is committed with existing vector map created by field measurements. Through comparative analysis of raster and vector data it has been found that the maximum mismatch is equal to 1.5 pixels, which in this case is less than the linear accuracy of triangulation 0.79 m. (Figure 7)

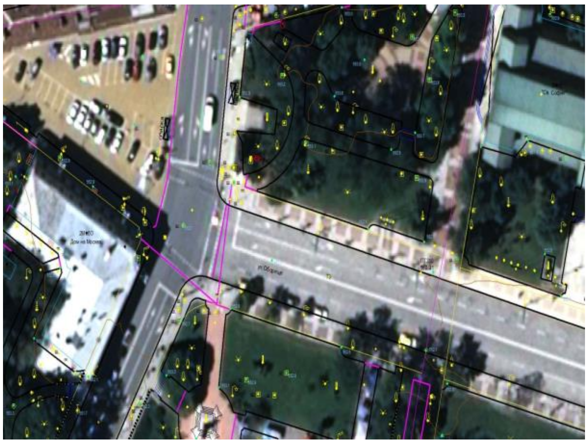

Figure 7. Comparison assessment.

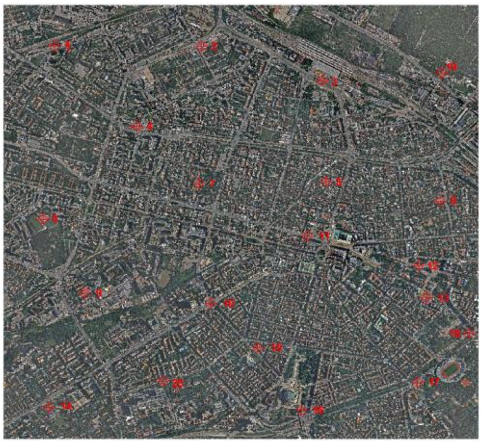

Figure 6. Comparison assessment.

2.2. Image quality assessment

Image quality assessment of digital orthomaps is done visually by comparing the shape and colour characteristics of the same object in different orthographic images. In generating orthomaps of large regions the main problem is radiometric leveling of the orthoimages in the process of mosaic. The images used in this paper have similar radiometric parameters allowing their colour leveling to be done automatically by image dodging.

Another major problem in generating normal orthophoto are shaded or invisible spots resulting from high objects such as buildings, bridges and other facilities, which are not designed in their true positions. When for these reasons digitization of invisible objects is impossible, it is performed digitally Stereo (stereo feature collection) in 3D mode.

3. CONCLUSION.

All measurements, analyzes and evaluations in this paper aim to demonstrate the quality of orthorectified digital images. The accuracy of the block aero triangulation has major impact on the accuracy of stereomodel, DTM, orthoimages and stereo feature collection. As final result is achieved linear accuracy of 0.79 m, which meets the specifications for horizontal accuracy of first-class topographic maps in scale 1: 2 500. If the achieved accuracy is not sufficient, then the only way to improve it is to increase the number of GCPs.

With regard to DEM, good aerial triangulation is a prerequisite for the proper generation of the model without distortions, defects and blunders. During editing the terrain has been found several inaccuracies. The most common ones are unfiltered high objects, buildings and forests and inaccurate generated model in specific landforms. The generation of normal orthophoto with high accuracy requires high accurate DEM.

Based on the presented results from the accuracy evaluation of the digital orthophotomap created with the data and technology described in details in this paper, the following conclusion is to be drawn:
Digital orthophoto map covers the geometric accuracy of 0.55 m, therefore the generated orthomap-sheets are suitable for mapping and processing of geospatial products in scale 1: 2000 and smaller.

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