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Analysis of the accuracy of the orthophoto map building according to aerial photography results executed with UAV

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SUMMARY

Assess the accuracy of the orthophotomap, aerial survey was performed to create a plan on a scale of 1: 2000 of the territory of the Kachanivka National Historical and Cultural Reserve, located in the Ichnyansky district of the Chernihiv region.

Introduction

To assess the accuracy of the orthophotomap, aerial survey was performed to create a plan on a scale of 1: 2000 of the territory of the Kachanivka National Historical and Cultural Reserve, located in the Ichnyansky district of the Chernihiv region. For this 27 distinctive signs were marked on the reserve, most of which were cross-painted with white paint on the road surface, as well as underground hatchways and clear contours of the terrain. The coordinates of the markings were defined using a Leica Zeno GG04 GNSS receiver in Real Time Kinematic mode. Moreover, the coordinates of each distinguishing sign were determined 10 times with determination of the average value.

Method and/or Theory

Aerial photography was performed from a height of 250 m above the ground using an MAVIC 2 PRO unmanned aerial vehicle. The results of the aerial survey were processed using Agisoft PhotoScan program. An orthophotomap with a resolution of 6.02 cm / pix was obtained, which is a good result for a height of 250 m (Kotchenko, 2019). A fragment of the orthophotomap is shown in Figure 1.

To investigate the accuracy of the determination of the planned coordinates of points on the constructed orthophotomap, a comparison of their coordinates with the coordinates obtained by the results of GNSS observations in Real Time Kinematic mode using the Leica_Zeno_GG04 plus receiver was executed. For this purpose, the planned coordinates of the 10 control points on the plot were clearly identifiable on the orthophotomap (Figure 2) (Kotchenko, 2019).

Figure 1 *Fragment of orthophotomap with Tarnovsky palace*

Figure 2 *Location of checkpoints on the aerial object*

Examples

The coordinates were obtained in the coordinate system SK-63. The results of determining the planned position of control points and their errors are shown in Table 1 (Kotchenko, 2019).

Table 1

Results of determination of control coordinates of control points and their errors

# of point	Orthophotomap		GNSS-observations		Difference		In map
	X, м	Y, м	X, м	Y, м	ΔX, м	ΔY, м	ΔP, м
1	5624763,31	4311145,07	5624763,19	4311145,24	0,12	-0,17	0,21
2	5624757,30	4311086,87	5624757,15	4311087,00	0,15	-0,13	0,20
3	5624788,85	4311068,81	5624788,72	4311068,70	0,13	0,11	0,16
4	5624917,83	4311656,28	5624917,91	4311656,48	-0,08	-0,2	0,22
5	5625403,97	4311397,30	5625404,10	4311397,45	-0,13	-0,15	0,20
6	5625051,87	4311421,65	5625052,03	4311421,46	-0,16	0,19	0,25
7	5624681,27	4310541,83	5624681,16	4310541,96	0,11	-0,13	0,17
8	5624807,35	4310835,32	5624807,55	4310835,50	-0,2	-0,18	0,23
9	5625797,46	4311244,35	5625797,38	4311244,46	0,08	-0,11	0,14
10	5625437,89	4310481,90	5625437,79	4310481,75	0,1	0,15	0,18

The deviation of the planned coordinates of the control points was determined by the formulas

$$\Delta X = X_O - X_G,$$

$$\Delta Y = Y_O - Y_G, \qquad (1)$$

where X_O, Y_O – orthophotomap reference point coordinates, X_G, Y_G are reference point coordinates determined from GNSS observations.

The deviation of the planned position of the control points was determined by the formula

$$\Delta P = \sqrt{\Delta X^2 + \Delta Y^2}. \qquad (2)$$

To determine the coordinates of the checkpoint on the orthophotomap obtained from the aerial survey, the cursor was hovered over the image of these points on the computer screen. Hatch centers for underground communications and sidewalk angles were used as control points. Therefore, the following objects were taken to determine the accuracy of the pointing of the cursor at the centers of checkpoints. The results of calculations are given in the Table 2 and Table 3 (Kotchenko, 2019).

Table 2

The results of the pointing of the cursor at the center of underground hatchways

# of point	X, m	Y, m
1	5624763,29	4311145,05
2	5624763,33	4311145,09
3	5624763,29	4311145,11
4	5624763,28	4311145,12
5	5624763,30	4311145,06
6	5624763,25	4311145,08
7	5624763,23	4311145,10
8	5624763,24	4311145,09
9	5624763,26	4311145,10
10	5624763,24	4311145,10
11	5624763,24	4311145.12
12	5624763,23	4311145,06
13	5624763,28	4311145.07
14	5624763,30	4311145,07
15	5624763,28	4311145,14
m_x / m_y, cm	3,03	2,58

Standard square error (deviation) in map m_p = 4,0 cm

Standard square error (SSE) on axes m_X, m_y is determined by known Bessel formula (Voitenko, 2003), and SSE in map is calculated according to formula

$$m_K = \sqrt{m_X^2 + m_Y^2}. \qquad (3)$$

Table 3

The results of cursor pointing on the pavement angle

# of point	X, m	Y, m
1	5624788,85	4311068,81
2	5624788,85	4311068,81
3	5624788,83	4311068,84
4	5624788,83	4311068,85
5	5624788,81	4311068,78
6	5624788,94	4311068,82

7	5624788,93	4311068,83
8	5624788,92	4311068,76
9	5624788,90	4311068,88
10	5624788,94	4311068,80
11	5624788,92	4311068,82
12	5624788,96	4311068,83
13	5624788,91	4311068,92
14	5624788,89	4311068,83
15	5624788,97	4311068,79
m_x / m_y, cm	5,09	3,93

To analyze the accuracy of the relative location of the terrain points on the orthophotomap, calculations were performed to establish that the ΔP distribution of deviations (Table 1) is normal. For this purpose, the Kolmogorov criterion was applied (Table 4) (Voitenko, 2003).

Table 4

Application of Kolmogorov criterion vs deviations ΔP

#	*ΔP*	*z*	*F'(z)*	*F(z)*	*D*	№	*ΔP*	*z*	*F'(z)*	*F(z)*	*D*
1	0,14	-1,6	0,05	0,055	-0,005	6	0,2	0	0,55	0,724	-0,174
2	0,17	-0,8	0,15	0,212	-0,062	7	0,21	0,2	0,65	0,724	-0,074
3	0,17	-0,7	0,25	0,0825	0,1675	8	0,22	0,4	0,75	0,724	0,026
4	0,18	-0,5	0,35	0,604	-0,254	9	0,25	1,3	0,85	0,877	-0,027
5	0,2	0	0,45	0,724	-0,274	10	0,27	1,8	0,95	0,877	0,073

$|Dmax| = 0{,}274;\ Dq = 0{,}41;\ (q = 1 - 0{,}95 = 0{,}05);\ |D\max| < Dq$

The Table 2 shows that the distribution of ΔP values is not contrary to normal. In addition, the variation series of ΔP values given in table 4, has a median $\Delta P_M = 0{,}2$ m, which is the standard error (Voitenko, 2003). Therefore, the formula (Voitenko, 2003) is applied for the transition from standard error to standard square error (SSE) given the normal distribution of ΔP values (Voitenko, 2003)

$$m = 1{,}48 \cdot \Delta P_M \,. \tag{4}$$

According to formula (4) $m = 29{,}6$ cm.

The deviations of the planned coordinates of the control points and, as a result, the deviation of their planned position, are defined by formulas (1) and (2). They shall have: errors of planned position of the orthophotomap points relative to the markings; errors of removal of the planned coordinates from the orthophotomap by pointing at the centers of control points; GNSS receiver centering errors over control points; errors in determining the planned coordinates of control points with the GNSS receiver Leica Zeno GG04. Therefore, you can write:

$$m = \sqrt{m_{ORT}^2 + m_K^2 + m_C^2 + m_G^2}\,, \tag{5}$$

where m_{ORT} – SSE of objects planned position on orthophotomap relative to markings;

m_K – SSE of obtaining of planned coordinates from orthophotomap with cursor pointing;

m_C – SSE of centering of GNSS-receiver over control points;

m_G – SSE of determining of planned coordinates of control points with the help of Leica Zeno GG04 GNSS-receiver.

The base station was selected the one located in Priluky (Kotchenko, 2019), with a distance of 34 km from the district of control points location. Thus according to accuracy characteristics of Leica Zeno GG04 GNSS-receiver in Real Time Kinematic mode (Leica Zeno GG04. User Manual, 2019)

$m_G = 10$ mm + $(2 \cdot 34)$ mm = 78 mm = 7,8 cm. The error of centering the GNSS-receiver over control points can be taken as apriori ± 1 cm, which for a confidence probability 0,95 allows to move to SSE which equals $\pm 0{,}5$ cm. Then, from formula (5) it is possible to determine SSE m_{ORT},

$$m_{ORT} = \sqrt{m^2 - (m_K^2 + m_C^2 + m_G^2)}\,, \qquad (6)$$

Which for above mentioned values will be 28,31 cm.

Conclusions

SSE of the location of objects on the orthophotomap relative to markings and according to formula (3) will be $\Delta P'_M = m/1{,}48 = 28{,}31/1{,}48$ = 19,1 cm. At a scale 1:2000 the value $\Delta P'_M = 19$ cm will be displayed as value 0,095 mm on the orthophotomap. The standard error in relative position of closest contours on the orthophotomap will not exceed 0,095 mm ×2 = 0,19 mm. According to paragraph 1.1. 16 (Main department of geodesy, cartography and cadastre under the Cabinet of Ministers of Ukraine, 1998) « …. In the territories with capital and multi-faced construction the standard errors in relative position on the map of the closest contours points (capital buildings, houses as well) should not exceed 0,4 mm». Therefore, the constructed orthophotomap meets the regulatory requirements for the accuracy of the planned position of contour points.

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