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Research Article

Obtaining Photogrammetric Data by Using Non-Professional Uavs

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Abstract

This article covers the features of using non-professional UAVs to obtain photogrammetric information. The analysis of scientific articles on the use of UAVs in research was carried out. The algorithm of photogrammetric works was made, and also the task for aerial photography in the mobile software product DroneDeployv.4.1.0 was formed. Aerial photography was performed under the most favorable conditions using a UAV DJI Mavic 2 Zoom from an altitude of 70 meters and with a spatial resolution of 0.12 m. Reference ground points were created, the coordinates of which were determined using GNSS observations in RTK and static modes. The problematic aspects of aerial photography using non-professional UAVs are highlighted. Post-processing of aerial photography results in the software product AgisoftPhotoScanv.1.4 was made. A number of spatial models were formed: point clouds, 3-D surface, orthophoto plan, elevation map, etc. By comparing them with terrestrial geodetic surveys in the GIS package ArcGISv.10.5, the accuracy of the obtained materials was determined, which was 0.35 m in plan and 0.52 in height.

Keywords

UAVs, aircraft, cartography, orthophoto imaging, digital, GNSS survey, photogrammetric processing, aerial photography, 3-Dmodeling, gis-mapping

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Introduction

The prerequisites for using unmanned aerial vehicles (UAVs) as a new photogrammetric tool come from the drawbacks of two traditional ways of obtaining photogrammetric data: using space satellites and manned aerial vehicles. The main advantages of small UAVs are their efficiency in operation and compactness, but they are less stable in flight. This should be taken into account especially in large-scale mapping, which is subject to increased requirements to source materials, in particular, to the geometric parameters of the survey. Therefore, at first glance, highly detailed, saturated images obtained from UAVs may have a low photogrammetric quality in the context of traditional photogrammetric criteria. However, in general, UAV aerial photography technology has been largely perfected and meets all existing mapping requirements (Grayson, Penna, Mills, & Grant, 2018; Mikhaylov & Kukhtiaeva, 2017; Rylskiy, Paramonov, & Malevannaya, 2019).

General Regulations

Currently, the analysis of the possibilities of using aerial photography materials from unmanned aerial vehicles for large-scale mapping is outlined in the works of many domestic and foreign authors. Among the main researches on this topic are the works of many scholars. For the most part these works present the results of practical studies of the use of specialized geodetic UAVs of well-known world brands (Topcon, SenseFly, Delair), while the question of the use of modern non-professional vehicles has been little studied (Berteška & Ruzgienė, 2013; El-Ashmawy, 2018; Gotovac, Gotovac, & Papić, 2016).

The analysis of articles using UAVs in scientific research has shown that for the period of 2000-2019 over 9,900 articles were published with the keywords Unmanned aerial vehicles, Unmanned vehicles, UAV, Aircraft. These articles are found in journals included in the search platform with the bibliographic and reference database Scopus (Fig.1).

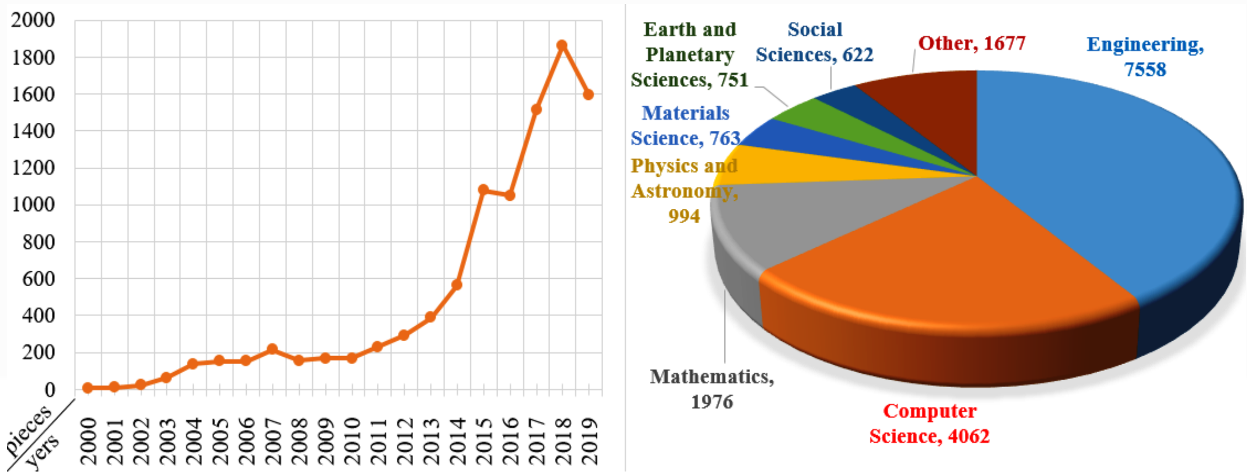


Fig. 1. The articles were published with the general keywords: a – years of publishing articles by keywords; b – including them in the relevant sections in the Scopus database

They have predominantly found their place in engineering, computer science and mathematics research. There are much less works linked to the mapping of the territory using UAVs, although there is a tendency for such studies to increase steadily.

Aim Of the Study

Assessment of the possibility of using unprofessional UAVs for the purpose of obtaining photogrammetric data, as a basis for drawing up a topographic plan and solving other applied problems.

The choice of the study area is caused by the necessity of drawing up basic topographic plans, of such territories, which are characterized by a considerable variety of engineering buildings, structures, vegetation and water bodies. Thus, aerial photography covers the territory of Chernivtsi school with an area of 23,500 m2, the absolute elevation ranges from 236.7 m (in the western part), to 230.2 meters (in the northern and eastern parts of the massif) with the concentration of high-rise residential buildings. The situation at the time of the survey is presented in **Fig. 2.**

Fig. 2. Situation on the territory of the facility at the time of survey (24.02.2019):

a – south-west corner; b –north corner; c – north-east corner; d – view from the height of aerial photography

It is determined that this area fully allowed the approbation of the proposed method of aerial photography of the territory using a UAV.

Topicality

The advent of unmanned aerial vehicles (UAVs) has breathed new life into the field of Earth's remote sensing. Due to the high resolution, the ability to perform periodic shots and the relatively low cost of shooting, aerial photography data has become available to the general consumers. But despite the general study of the use of ERS data in this area, the use of data obtained from UAVs has a certain specificity, somewhat different from the procedures of use of traditional space or aerial photographs. Therefore, in this study, an attempt is made to describe the specifics of obtaining UAV data, in particular from non-professional variations, with their subsequent photogrammetric processing (Moranduzzo & Melgani, 2014; Pajares, 2015; Yao, Qin, & Chen, 2019).

METHODOLOGY

UAV Performance and Technical Means

The process of aerial photography with the use of UAVs does not fundamentally differ from the use of large aircrafts, and consists of 3 stages: preparatory, flight survey and post-processing of the data.

The preparatory stage involves the selection and verification of the drone. Various types of UAVs can be used to complete the topographic plan on a 1: 1,000 scale. In the unmanned vehicle market, the Dji branded Phantom and Mavic quadcopter series recommended themselves rather well, with the main advantages, like a relatively low price, mobility and good technical characteristics.

Airplane and helicopter drones can be used to complete the M 1:1,000 topoplans. In the market of unmanned vehicles, the Mavic 2, Phantom 4 and Inspire 2 quadcopter models of Dji brand are quite popular. The Dji Mavic 2 Zoom model (**Fig. 3**) was chosen as the hardware basis, with such advantages as relatively moderate price (1 500 $), compactness and good technical characteristics.

Fig. 3. Dji Mavic 2 Zoom Quadcopter: *a – general view; b –standard specification*

The quadcopter is equipped with a 3 850 mAh battery that allows it to be in the air for about 31 minutes. For satellite navigation (GPS+GLONASS) flights, the horizontal and vertical positioning accuracy is 0.3 and 0.1 m, respectively. A special optical system will create a real-time flight map. With the SmartReturnHome feature, the drone is able to automatically return to the take-off location.

We chose a 12MPi (4,000x3,000 pixel) 1/2.3" matrix DJI stock camera as a survey device. The focal length of the lens can fluctuate within 24–48mm, but for our purposes it is fixed at the mark of 24 mm. A lamellar shutter allows operating at low temperatures (up to –20 °C).

Planned field examination. At the same stage, we made a draft of the works and calculated the parameters of aerial photography, considering the optimal altitude, lateral and longitudinal overlaps. In general, we chose a combined method in which aerial photography was performed using a drone and planned field examination (PVP) of aerial photography was obtained using GNSS survey. General flow diagram of the work performed is presented in Fig. 4.

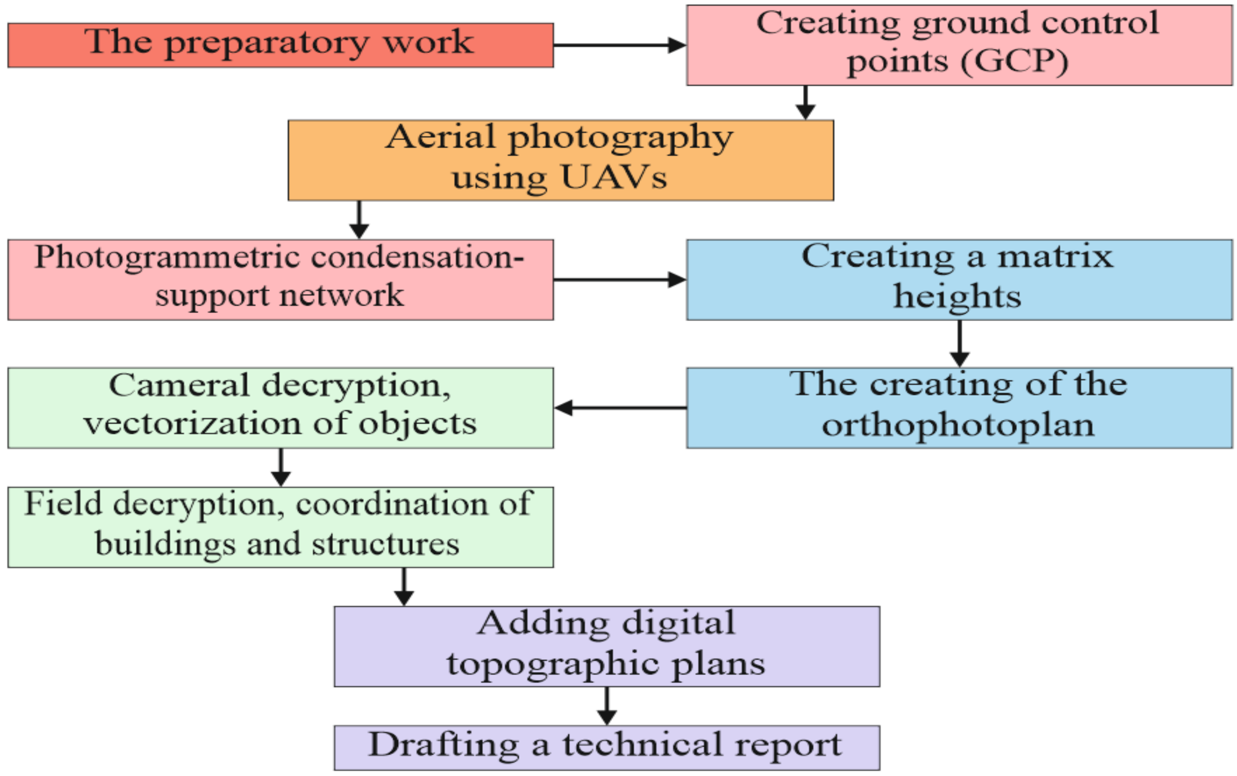


Fig. 4. Technological scheme of UAV aerial photography

To implement the combined approach, we have uniformly pre-designed the marking throughout the area, taking into account the terrain. Shady areas and those parts of the area that were covered with tree crowns were quite problematic. Also, in places where there are no natural contours, we have drawn up a layout of artificial signs – markers that should be clearly displayed in the photos, that is, we carry out a kind of marking of the territory. As a tool, we chose an aerosol paint of light and dark shades and made the markings on concrete, snow and soil surfaces. All the markings were displayed on a raster image, a space image in ArcMap v.10.5 (**Fig. 5**).

Fig. 5. Look of objects chosen as points of GCP (ground control points) on the territory of school #6: *a – marking of the sewer hatch and its appearance on the ground; b – border marking and its appearance on the ground*

We determined the coordinates of the PVP points using ProMark-800 2-frequency GNSS receivers in RTK (Real Time Kinematic) mode. It's well-known, this mode allows us to obtain measurement corrections and determine location with centimeter precision in real-time mode in the network of permanent reference GNSS stations **(Fig. 6)**.

In **Table 1**, we have shown the objects that were used as identification marks for aerial photography of the school premises.

Table 1.
Information about identification marks on the premises of the secondary school # 6 obtained by GNSS-survey

№	**Description**	**Coordinate (Pulkovo-1942, Gauss Kruger, Zone 5)**		
		X	**Y**	**Z**
GCP 1	Sewer hatch in the western part of the school	5 420 993,911	5 347 917,970	236.265
GCP 2	Layout of the playground behind the school	5 421 086,516	5 347 946,743	233,682
GCP 3	Cross marked with paint near the east football gate	5 421 013,425	5 348 009,582	235,742
GCP 4	Pedestrian marking "Zebra" at the traffic light down the street	5 421 072,625	5 347 845,209	234,124
GCP 5	Curb corner in the western part	5 421 007,802	5 347 942,113	235,954
GCP 6	Northern corner of staircase to dining room	5 421 039,221	5 347 940,790	234,014
GCP 7	Plowed area near the northeast fence	5 421 055,427	5 348 070,767	232,244
GCP 8	Center of the circle in the marking near the sports equipment	5 421 082,878	5 347 997,345	233,451
GCP 9	Sewer hatch outside school premises, near the lake	5 421 133,479	5 347 994,699	229,541
GCP 10	Marking on the snow surface in the southern part of the area	5 420 999,186	5 347 820,35	236,355

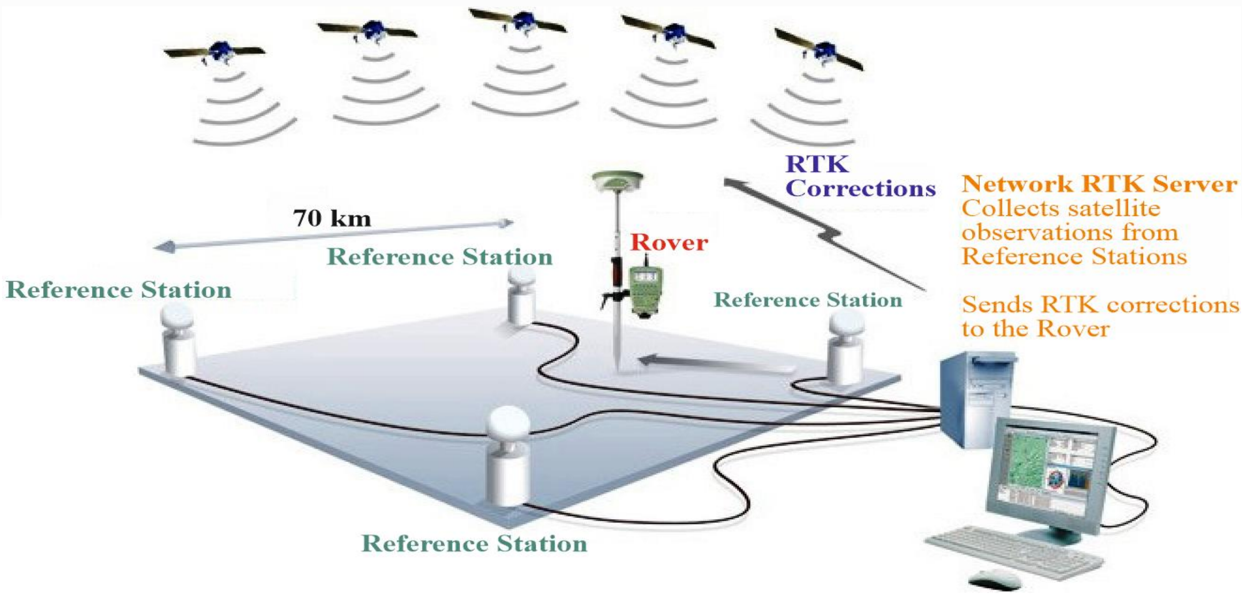


Fig. 6. Scheme of obtaining coordinates in RTK-mode

We plotted all the GCP-points designed and corrected in the course of filming works on a graphic basis. In this case, we used the GIS product ArcMap, which allowed in addition to visualization, to enter attribute information.

Image Data Acquisition

At the same stage, we formulated the flight task for the UAV. Generally, it was assembled in virtual mode on the Xiaomi Redmi 4 smartphone on Android v. 6.0.1 in the DroneDeploy application. It is worth noting that the software complex automatically calculates the tasks for aerial photography, based on the initial indicators that we introduced – the altitude and speed of flight. We also outlined the area of the survey and the starting and landing point positions on the interactive map (**Fig. 7**).

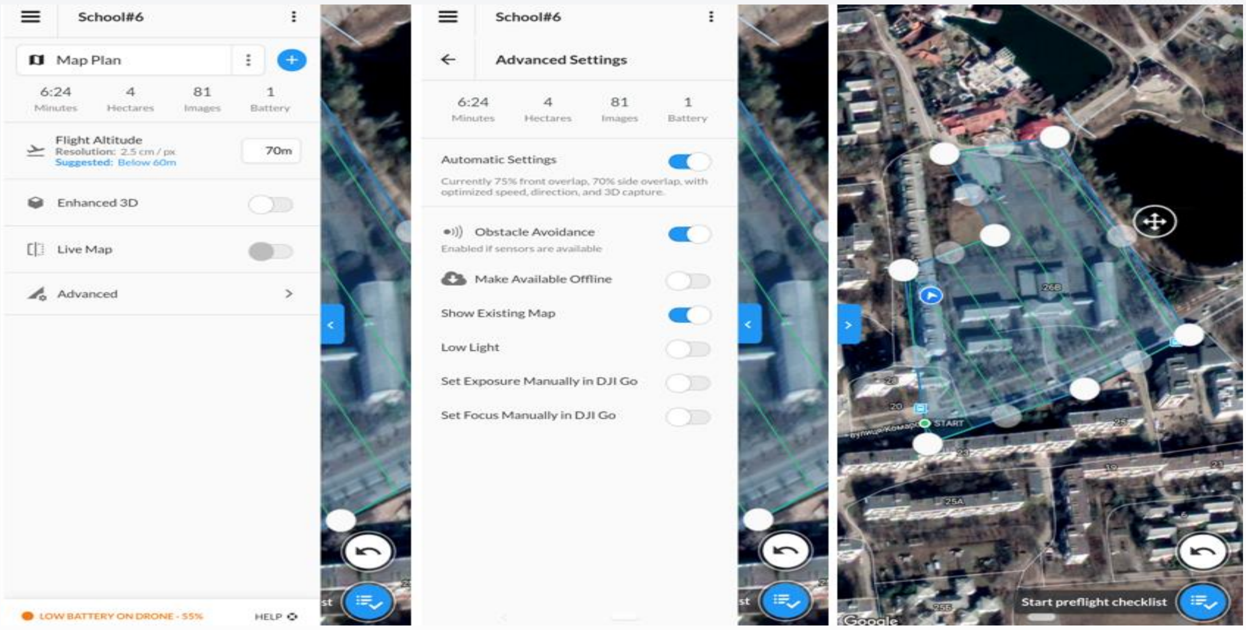


Fig. 7. Forming a flight task in DroneDeploy: a – making the removal height; b – setting additional parameters; c – interactive map

That is, a minimum of action is required by the operator. However, it should be remembered that the specifications of the camera, including the short lens focus, requires a clear altitude. The original spatial resolution of the images will depend on this setting. Yes, according to aerial photography instruction and recommendations for using the Mavic 2 Zoom, at a survey altitude of 200 m, the spatial resolution will be 28 cm / pixel, at an altitude of 70 meters, it will be 7 cm / pixel, and when reduced to the 35 m mark – 5 cm / pixel (**Table 2**).

Table 2.
Dependency of the survey altitude of the UAV Dji Mavic 2 Zoom to the spatial resolution

Scale compliance:	**1:5 000**	**1:2 000**	**1:1 000**	**1:500**
Spatial resolution of orthophoto plan, cm:	28	14	7	5
Altitude of survey, m	200	140	70	35

These indicators are key when choosing the scale of the topographic plan, as due to high-rise building the flight altitude is limited by the lower mark of 30–35 meters (the height of the adjacent 5 and 9-storey buildings is 18 and 30 meters, respectively). Therefore, when using this drone, we cannot fall below that mark, which makes it impossible to plan at a scale of 1:500.

Each of the scenes covers an area of about 17,000 m2 (1.7 ha), with lateral and longitudinal overlaps of 70 % and 75 %, respectively. The great importance of overlaps, especially the longitudinal one, is one of the basic requirements for the use of light and ultra-light aircrafts. This will minimize the errors of the carenage and yawing of the UAV by further processing of the results of the survey.

In general, when you press the "Start" button, the whole process is performed by the virtual system in semi-automatic mode, but the operator has to constantly monitor the process of survey on the interactive map (**Fig. 8**).

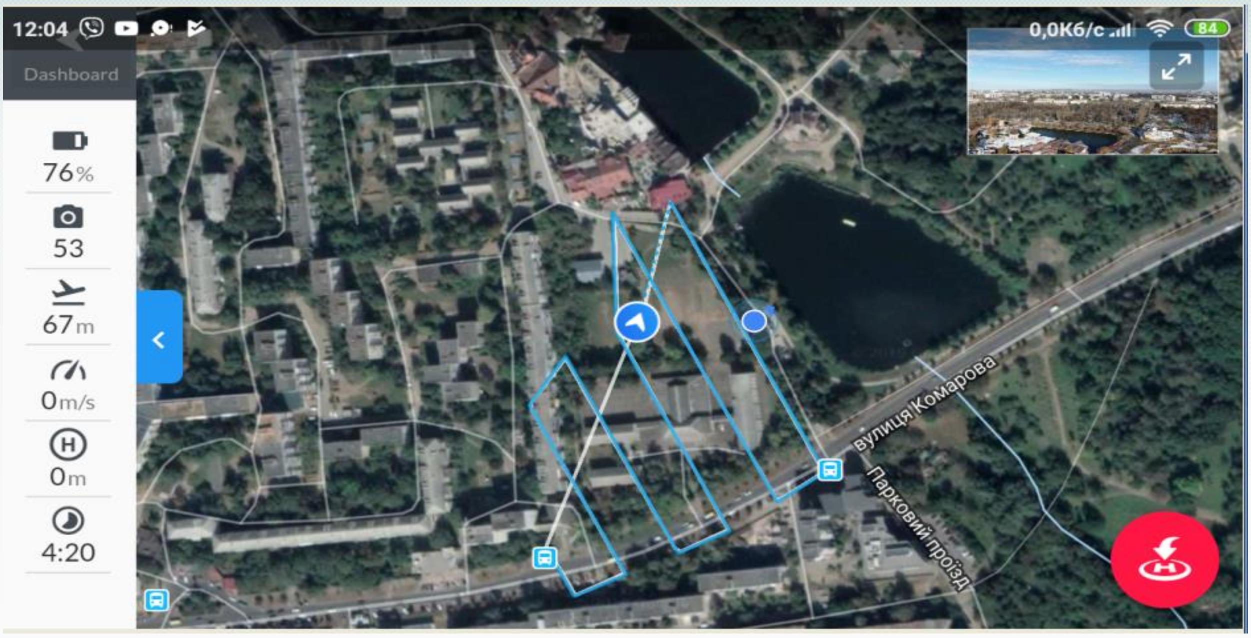
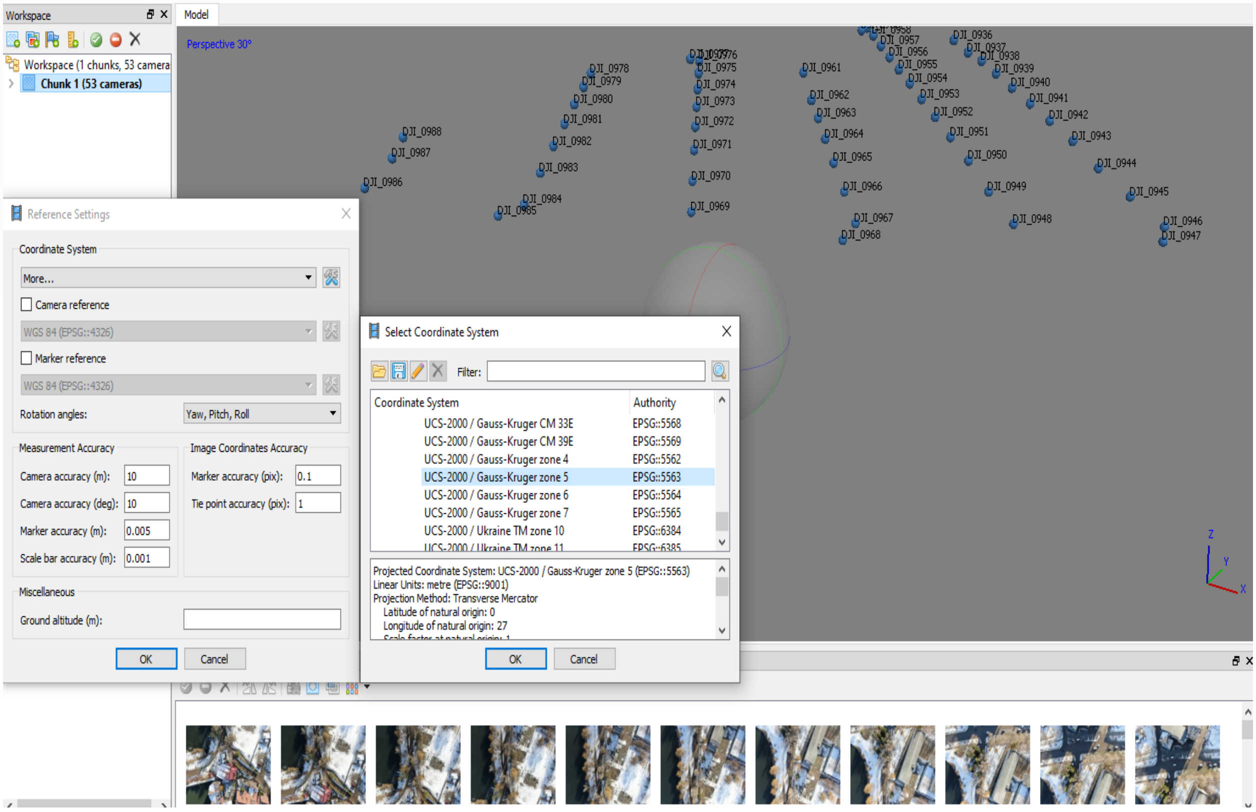


Fig. 8. Aerial photography routes and the process of survey on an interactive map

Photogrammetric processing of images.

Further steps were to process the results and assemble an aerial mosaic. Drawing of the basics of photographing and constructing a phototriangulation model were done in the AgisoftPhotoscan software. This software is a versatile tool for generating orthophoto plans and 3D models of the surface of the survey objects by their photo images. We select the coordinate system inherent for Chernivtsi, that is, the SK-42 and the Baltic Height System, and download the anchoring data of the centers of photographing, together with that we display the images themselves (**Fig. 9**).



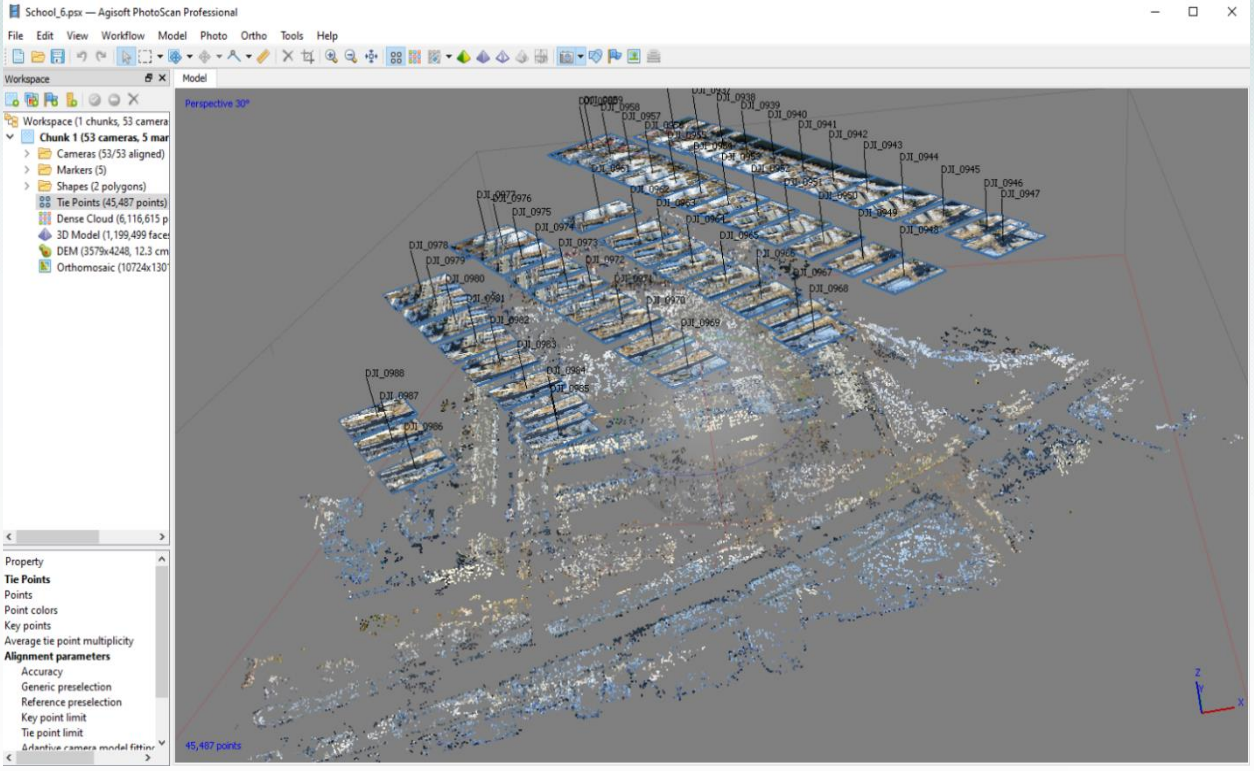


Fig. 9. Initial actions with shooting results: *a – choice of the SK; b – downloading photo centers*

We form a point model of the Earth's surface, that is, we create a sparse and dense cloud of points that describe the territory and a set of parameters of mutual orientation of the photos (**Fig. 10**). Also, since we have a terrestrial plan-altitude base, we set markers (marks) of anchor points in the photos and download their rectangular coordinates (**Fig. 11**).

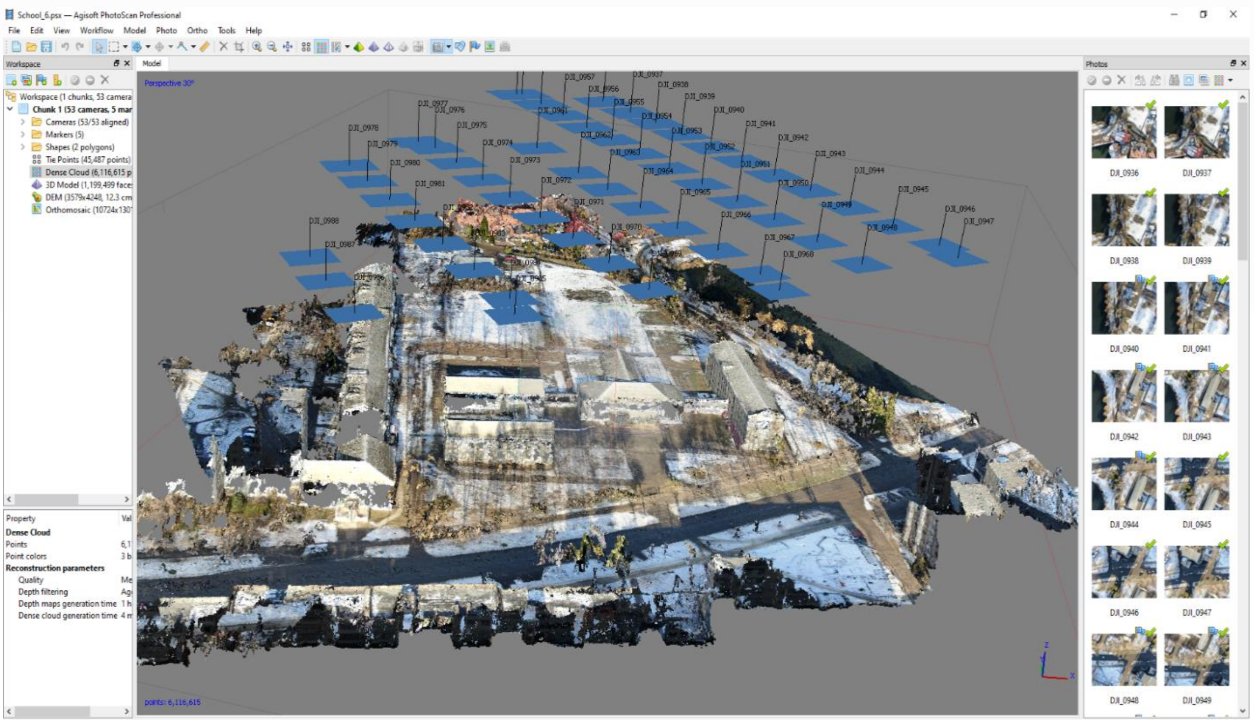


Fig. 10. Creating a dense cloud of aerial photography points

Fig. 11. Setting of markers on the model

It should be noted that it is not always sufficient to have an orthophoto plan to obtain accurate cartographic products. You have to see the obtained photogrammetric model in 3-D format. In particular, you have to see the points that can be used for the contour. You should be able to make metric measurements in the absolute coordinates of the project and to perform various vectoring and clustering operations of topographic information. Therefore, in the first place, we form a 3-D terrain model after a dense cloud of points (**Fig. 12**).

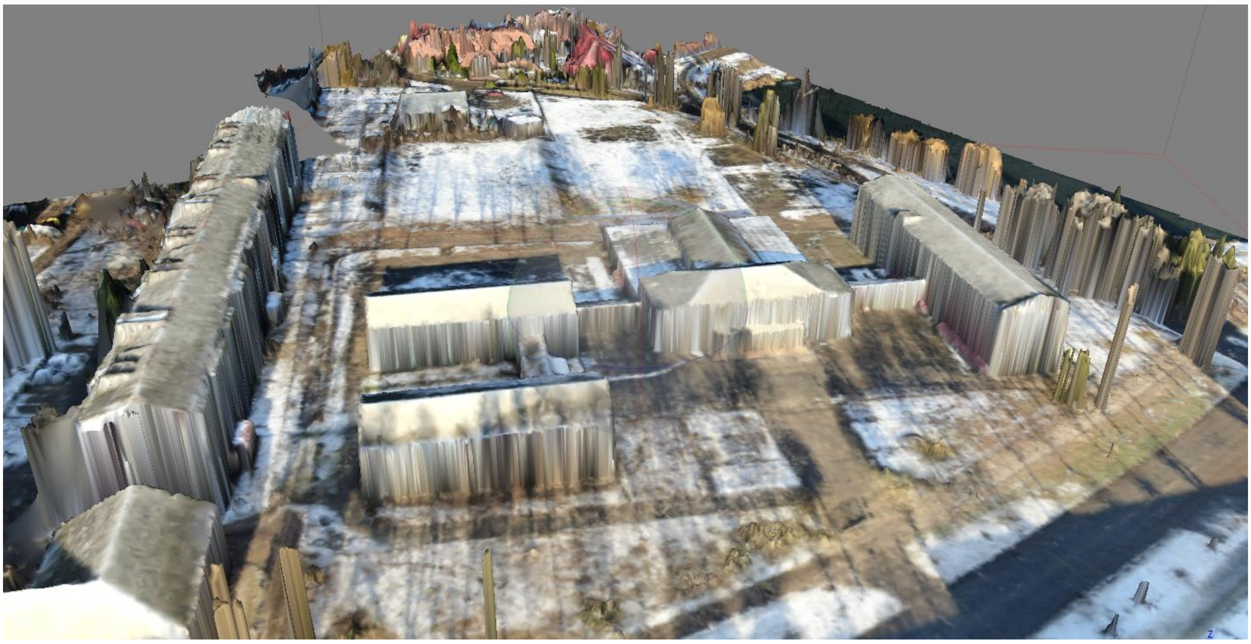


Fig. 12. Creating a 3-D territory model

According to the data above, we create a map of heights, i.e. a digital model of the terrain. This work allows determining absolute heights of objects to the nearest millimeter. Generalized values are reflected by the color spectrum, where blue is the lowest (lake) mark and red is the highest (9-storey residential buildings) **(Fig. 13)**

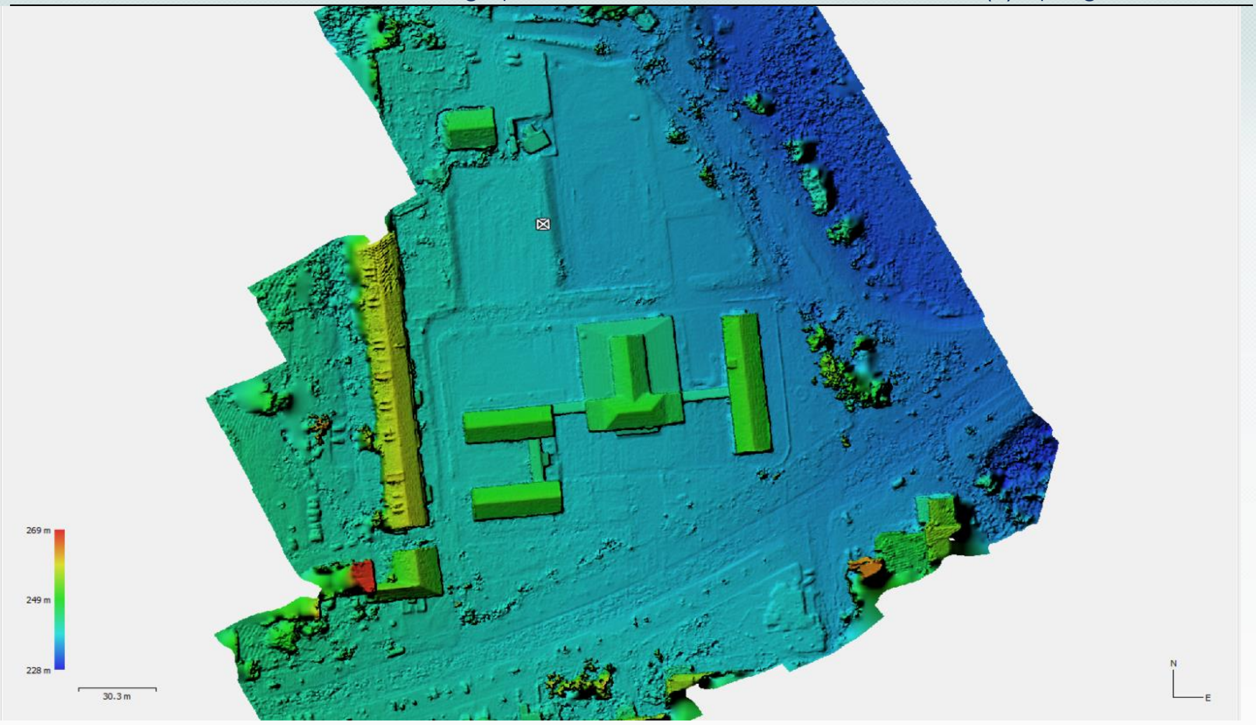


Fig. 13. Height map view

The creating of the orthophotoplan by aerial photography is important. While doing it, the previous parameters and models are taken into account. It is worth noting that the result completely satisfied us, and in **Fig. 14** we can perform further analytical and decryption work, despite the presence of long shadows of objects.

Fig. 14. View of the created orthophoto plan

Dem Evaluation

The coordinates of 10 reference and 5 control marker points created in the survey area were used to assess the accuracy of the generated orthophoto plan. The results of comparing the accuracy of construction of the photogrammetric model showed the following. The inconsistencies of the planned position of the reference points does not exceed 7–14 cm, the control points – 7–16 cm. This corresponds to the accuracy of the survey scale of 1:1,000. The average values of inconsistencies of height position of the reference points in the photogrammetric networks did not exceed 12–15 cm, control 15-20 cm. The networks were obtained with the use of projection centers and markings. The average values correspond to the accuracy of survey with a contour interval of 1 m.

To carry out a detailed assessment of the accuracy of the orthophoto plan, ground topographic survey of the surveyed area was performed. The survey was performed using a SOKKIA CX-55 electronic tacheometer, using the polar survey method. Control points and survey pegs were obtained from different stations. Topographic survey data were processed in Digital's software **(Fig.15)**.

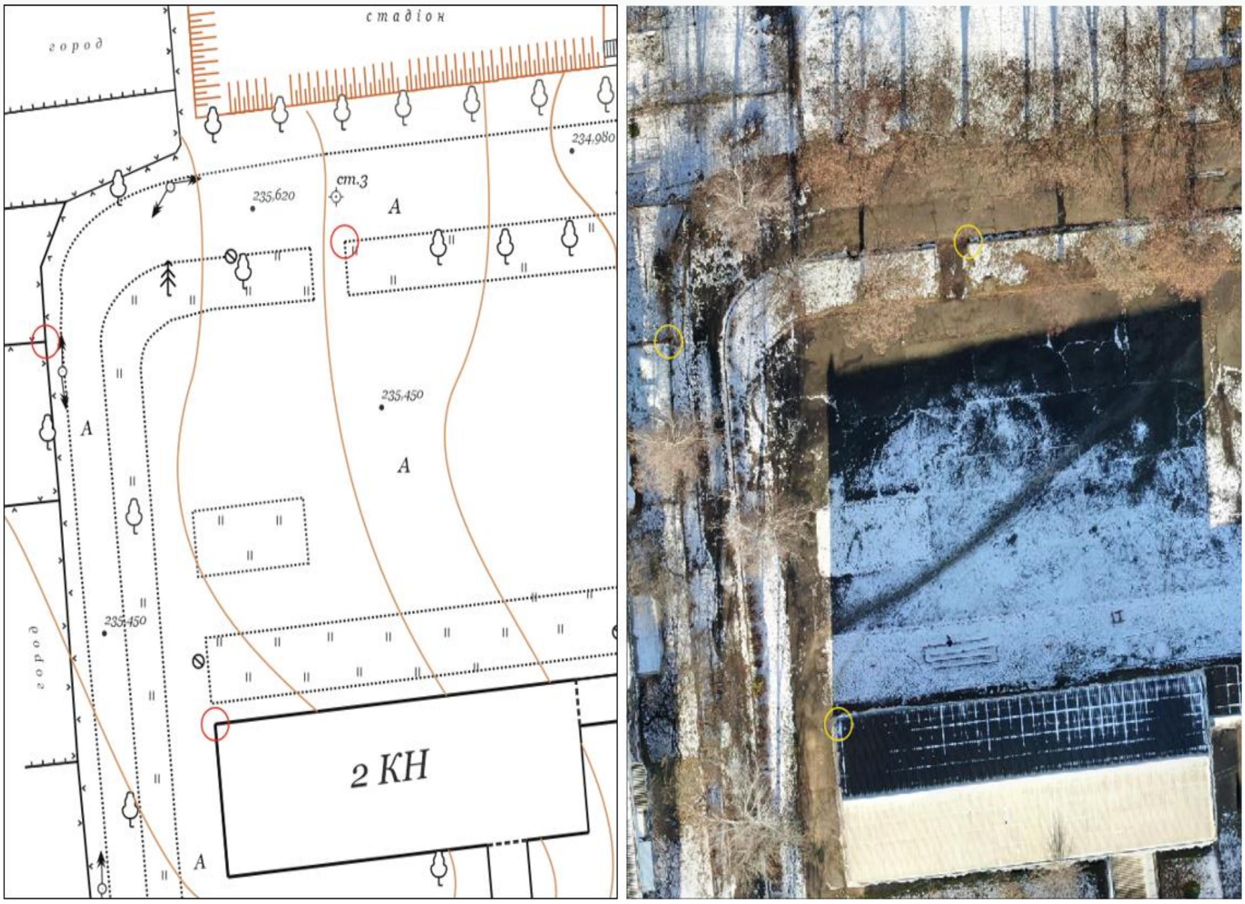


Fig. 15. *Comparison of aerial photography results:*a – topographic plan; b –orthophoto plan

Table 3 shows the results of the relative assessment of the accuracy by the reference points and in table 4 – by the control points. In total, the same number of reference and control points was used as in the formation of the photogrammetric network.

Visual analysis showed that the DEM areas near fences and filtered objects, especially near tall buildings, significantly distort the model.

The assessment of height accuracy shows that the points of the digital terrain model have the DEM accuracy required for the survey with a contour interval of 1 m. The points were obtained by photogrammetric processing of images adjoining the earth surface and away from the height objects at a certain distance.

Table 3.
Relative assessment of the accuracy by the reference points

Types of errors	X, м	Y, м	Z, м
Mean error	0,02	0,2	0,02
Root mean square error	0,06	0,07	0,03
Maximum error	0,09	0,11	0,08

Table 4.
Relative assessment of the accuracy of balancing topographic survey data by control points

Types of errors	X, м	Y, м	Z, м
Mean error	0,04	0,5	0,03
Root mean square error	0,12	0,11	0,04
Maximum error	0,08	0,09	0,05

Discussion

Despite the positive results and the general suitability of the formed models for solving mapping problems, it is important to remember that the results of aerial photography from non-professional UAVs have significant limitations. First of all, they are inferior to similar images obtained from professional UAVs, both in terms of metric characteristics of cameras and mutual placement of photography centers, which are calculated by inertial GPS. In turn, the use of non-professional UAVs allows photography to a wider range of consumers that is important in low-budget research. Also, by reducing the photography height and increasing the values of the overlaps to the optimal values, it is possible to approach the reference values (Colomina & Molina, 2014; Du et al., 2016; Korchenko & Illyash, 2013; Valavanis & Vachtsevanos, 2015; Woodcock & Strahler, 1987).

One of the problems that arose during the study was related to obtaining accurate plan-altitude coordinates of terrain points, which is solved by mounting the RTK system directly on the copter. However, this increases the cost of the kit by 1.5-2 times. Also, you should take into account the natural conditions of aerial photography, in particular the influence of light, season, temperature and wind speed. Thus, for the study area with significant vegetation, the use of aerial photography in the summer is impossible. The height of the survey is separate parameter, especially when using small aircrafts with non-metric, stock cameras installed on them. Therefore, further research should be based on assessing the impact of these indicators on the final result.

Therefore, by reducing the height of the survey and increasing the values of the overlaps of the images, as well as with the involvement of terrestrial surveying instruments, we obtained positive results.

Conclusions

The use of non-professional UAVs to obtain photogrammetric data can significantly reduce the overall cost of aerial photography. The flight assignment, as well as its operational correction, can be easily accomplished in real time by a qualified geotechnician. Besides, it can be stated that the UAV data are suitable for the creation of 3D terrain models and they meet the requirements for topographic mapping and solving various economic problems (Crommelinck et al., 2017; Feng, Liu, & Gong, 2015; Fernandez Galarreta, Kerle, & Gerke, 2015; Gevaert, Persello, Sliuzas, & Vosselman, 2017; Ma, Wu, Yu, Xu, & Wang, 2016; Tamouridou et al., 2017). The terrestrial markings, the coordinates of which are obtained through GNSS observations, should be a prerequisite for this. The problematic issues include the loss of radio signal, with the inability to observe telemetry information on the display of a mobile device. Also, a significant problem when performing aerial photography can be created by the actions of aggressive birds, which increases the accident rate of use of small UAVs.

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