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COMPARATIVE ANALYSIS OF THE APPLICATION OF PIX 4D AND AGISOFT PHOTO SCAN SOFTWARE PACKAGES FOR PROCESSING DIGITAL IMAGES OBTAINED FROM UAVS

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Key words: unmanned aerial vehicle, aerial surveying, orthophotomap, Pix 4D, Agisoft Photo Scan.

Purpose: To study and compare Pix 4D and Agisoft Photo Scan software packages through the processing of digital images obtained from an unmanned aerial vehicle (UAV).

The novelty of the work is to make a comparative analysis of software packages in order to select the optimal software package for the creation of large-scale orthophotomaps based on aerial surveying material from the UAV.

Formulation of the problem

At present, modern technologies for the creation of topographical and cadastral plans are based on the use of digital aero-materials from UAVs. However, in order to qualitatively accomplish these tasks, it is necessary to explore and determine the benefits of software packages that can be used to process materials obtained as a result of aerial surveying from unmanned aerial vehicles.

Relationship with important scientific and practical tasks

Areas of application UAV are quite wide - from topographic large-scale plans, forecasting emergencies, conducting atmospheric and meteorological observations, operational or round-the-clock monitoring of the state of technological objects, road and railways, etc. The images obtained as a result of aerial surveying create large-scale plans of rural settlements, project generic plans, which in turn relates to land registration and the establishment of boundaries

Unresolved parts of the general problem

Creation of large-scale plans is an important task in the field of mapping of Ukraine, since existing topographic plans need to be updated over time, as they cease to meet the current state of the area. Therefore, an important task is to carry out renovation work and create topographical plans that will be used for the needs of the above. In order to choose the optimal software package for processing orthophotomaps, the authors tested the various software packages and identified the two most suitable. Therefore, in the article authors give a comparative description of only two: the software packages Pix 4D and Agisoft Photo Scan. As a result of the analysis, it is necessary to conclude which software package is best used for the processing of aerial photographs.

Setting objectives

1. To conduct a critical analysis of literary sources in order to identify the features of technological schemes for the creation of large-scale orthophotomaps.
2. Calculate the a priori estimate of the accuracy of the spatial coordinates of the points in relation to the scale of the orthophotomap that is created
3. From materials obtained as a result of aerial surveying from the UAV, to process orthophotomaps in scale 1: 2000 in the software packs Pix 4D and Agisoft Photo Scan.
4. Compare a priori and a posteriori estimates of the accuracy of created orthophotomaps in order to identify the optimal software package.
5. Carry out a comparative analysis of Pix 4D and Photo Scan software packages in order to identify the technological features of creating orthophotomaps.

Analysis of recent research and publications

The use of UAVs is promising for the removal of small in length of site facilities and the removal of linear objects. Their implementation is rapidly developing and they take a worthy place in aerosynamic processes. [4].

Image processing techniques are extremely important in modern science and production, and they are continuously evolving and improving. Forming images, improving quality and automating their processing is the subject of modern research and development.

Let's look at some literature on this topic.

The article [14] presents the following stages of collecting and processing images taken in various weather and light conditions: aerotriangulation, processing of the digital model of relief (DEM), creation of orthophotomap. The study used a Trimble UX-5 UAV-7 with a Sony NEX 5R digital camera (DC). The technical characteristics of UAV and DC are presented, the weather conditions at different stages of shooting are presented. The method of aerotriangulation, source of errors, advantages and disadvantages of this method of removal is given. The authors worked out orthophotomaps with the use of 16 reference and 5 control points, cloud points and digital terrain models in favorable and unfavorable weather conditions, and estimated the accuracy of the data received. The stages of creation of an orthophotomap with the help of automated software packages are presented. It is concluded that weather conditions significantly impair the quality of images, which in turn affects the quality of the orthophotomap and cloud points.

In our opinion, the article does not present the stages of image processing and does not specify with which software package the experiment was conducted.

In the scientific work [4] the areas of use of UAV are given. An analysis of literary sources has been carried out, the main groups of civilian use of UAVs have been identified, the main advantages of the UAV to the traditional aerial and space removal are given. The

advantages and disadvantages of using cameras in four perspectives are defined and recommendations for their application are given. The tasks that can be solved by the UAV are given. On the basis of the analysis of literary sources, the authors proposed a global classification of UAVs.

The publication [2] considered the problem of creating cadastral plans and orthophotomaps of different scale for different tasks of land monitoring, and the advantages of aerial surveying use with the use of UAVs for solving these problems are presented. The authors conducted an analysis of research and publications devoted to solving this problem. A multi-line airing of the village of Kolonshchyna of the Kyiv region from the board of the UAV "Ptah" of the FAS NTUU-"KPI" construction project was performed and an analysis of the results was carried out. The Pegasus UAV was designed and built to continue the experiment. A second stage of experimental work was conducted which consisted of two parts and analyzed its results. For the correct orientation of the camera relative to the longitudinal axis of the aircraft, taking into account the angle of wear, a method for express-estimating velocity and wind direction at flight altitude has been developed and introduced. The estimation of accuracy showed unsatisfactory results, but the authors proposed methods for solving this problem.

From our point of view, the authors did not submit a software package with the help of which the processing of aerial surveying data was carried out.

The article [3] presents the advantages of using UAVs for manned airplanes and space shuttles. The authors of the article carried out an analysis of recent research and publications related to the solution of the problem. The multi-ray aerial plots of the Kolonshchyna village of the Kyiv region from the "Ptah" UAV have been fulfilled. A three-stage experiment with the use of the constructed UAV "Pegasus" was conducted. Sample stereopairs of different routes are processed to determine the quantitative parameters of the received images. The analysis of the results of the shooting is made, the problems which arise during the aerial surveying process and the possibilities of their solution are determined. The tendency of UAV development in two directions and advantages and disadvantages of these directions are described. The magnitude of image smear and irregular orthoscopy are calculated.

In our opinion, the authors did not describe the software package that was used to process materials.

The publication [1] shows the scope of the UAV and the benefits of the Trimble UX-5 UAV. Characterized by Trimble Business Center software package. Provided recommendations for reconnaissance of the work area. A study of the airplane on different sites was carried out at a wind speed not exceeding 5 m/s, and a brief analysis of the results was carried out. The a priori estimation of the accuracy of the determination of the spatial coordinates of the area is calculated. The coordinates of control points are measured using the Trimble R7 GPS receiver in RTK mode. The worked data confirmed the possibility of using UX-5 aircraft for large-scale orthophotomaps.

In our opinion, the view of the authors does not describe the software package which processed the removal materials: no specified technical requirements, not described functionality such as the creation of a textured model of the terrain.

The article [7] presents the advantages and uses of orthophotomaps. The orthophotomap of Neryungri (Russia) with an area of 72 km sq. Is created. The method of creation of orthophotomap with the help of DFS "Delta" is given. The accuracy assessment was performed in two groups of objects: stereomodels and orthophotomaps. Graphs of deviations of ortho objects from stereo objects are given. When conducting an assessment of accuracy, it is concluded that the created orthophotomap meets the requirements of a scale of 1: 1000.

In our opinion, the authors did not indicate the technical characteristics of the UAV and the digital camera, which was taken off.

In the paper [9], the advantages of aeronautics prior to topography are given. The possibilities of using UAVs for operational receipt of aerial photographs are considered. The stages of preparatory works are given before removal. The project of aerial surveying works and the parameters of aerosomy are calculated. A reconnaissance of the area was conducted to determine the place for the launch site. At camera processing it was checked: the quality of images, overlapping aerial photos.

From our point of view, the camera processing of materials was not completed, the authors had to draw an orthophotomap and draw conclusions based on the assessment of its accuracy.

The publication [10] highlights the prospects for using UAVs for aerial photography for mapping purposes. The concept of the UAV is revealed and the scheme of the priority of the UAV aircraft type before other types is given. Described methods of UAV control and their advantages. Characterized advantages of aerial surveying with the use of UAVs against traditional types of removal such as space taking and aerial use using a manned airplane. The authors mention the factors that hinder the rapid development of UAV use for civilian purposes. Some models of UAVs that can be used for aerosomnification are proposed.

According to our opinion, the classification of the UAV, which is given by the authors is not complete, the model range of the UAVs is not a model of the world's leading firms.

The article [11] identifies the features of aerial surveying using the UAV. Suggested recommendations for designing aerial surveying. The sequence of processing aerial surveying data with the use of the software package Photo Mod is given. The sources of errors that arise when using an air gap with the use of a UAV are described in detail. The authors processed 595 images in two ways: without reference points and their application. The accuracy of the orthophotomap without reference points was 17 cm, with the reference - 8 cm. The authors draw conclusions about the prospects of using UAVs for aerial surveying and provide recommendations for the best results.

In our opinion, the authors of the article did not analyze the materials taken on the basis of processing data in several software packages.

In the paper [13], the authors outlined the advantages of using UAVs against manned planes. The technical characteristics of the DELTA-M UAV are given and the sources of errors that arise in the case of airplanes with the use of UAVs are investigated. An uncalibrated and calibrated camera was taken, which showed the benefits of a calibrated chamber. Precision control is carried out at 155 control points. The authors managed to achieve accuracy of 0.10 m and 0.15 m on X and Y, respectively.

From our point of view, the authors did not fully characterize the possibilities of using software packages; it was not indicated that with these packages, it is possible to create DEM and textured 3D models. The authors did not highlight the methodology for determining the accuracy of created orthophotomaps.

In the article [6] the authors investigated the scope and ways of creating DEM. For the study, shooting was performed on three routes. The given recommendations for working out of aerial surveying materials for creation of DEM. The process of gathering the reference points and the process of their subsequent application for processing are highlighted. Characterized sources of errors and major errors that arise during the processing.

The authors did not provide information about the software package, which allows the processing of aerial surveying data.

In the publication [12], the authors investigated the main problems with photogrammetric processing of aerial surveying materials. The basic stages of processing of aerial surveying materials for the creation of orthophotomaps are determined. Details of all data processing processes, requirements for snapshot files and reference points, camera calibration parameters and methods of their determination, and the technology behind which the Photo Scan software package is working out. The possible areas of application of the software package are indicated.

But the authors did not evaluate the accuracy of the work, the possibilities of the software package Photo Scan are not fully covered, the stages of processing the aerial surveying materials that are presented in this article are not complete.

In the article [8] the questions of performance of preliminary calculation of accuracy of determination of points coordinates on materials of aerial surveying with the use of unmanned aerial vehicles (UAVs) are considered. The mathematical model of determination of coordinates for a couple of photos is given. The mathematical model takes into account the use of GNSS data to determine the coordinates of the photographing and correction centers of the Inertial Navigation System (INS). The angular elements of external orientation in the above mathematical model are found using INS. Using the algorithm for converting the correlation matrices a strict expression is obtained to perform a preliminary calculation of accuracy. The method of variation received an expression to calculate the effect of systematic errors. Based on the obtained expressions, a priori precision determination of the coordinates for various conditions of aerial surveying was performed. Experimentally calculated the accuracy of airplanes for UAVs with typical characteristics, for the creation of topographic maps and plans.

In our opinion, authors should give an example of calculating the accuracy of aerial surveying for certain models of UAVs and DCs.

The scientific work [5] defines a range of tasks that are solved in digital image processing, solves current problems in image processing, analyzes the main research and publications on this topic, sets requirements for a digital model, considers the concept of image resolution, color depth and color model, pixel , identified the advantages and disadvantages of these models and recommendations for their application.

We believe that authors should have a description of image processing for various software packages: Pix 4D, Agisoft Photo Scan and Trimble Business Center.

As we see, the selected topics are relevant, which is confirmed by a large number of publications devoted to this topic, not only in Ukraine, but also abroad. As a result of the analysis of literary sources, we can conclude that the actual task is to investigate and determine the benefits of software packages that can be used to process digital images obtained from UAVs.

Presentation of the main material

Aerial surveying was conducted on the territory of the town of Vynnyky and was carried out with the use of the UAV FLIRT "Arrow" with the digital camera Sony ILCE-QX1 from a height of 520 m at an airplane speed of 80 km/h. The following settings were selected in camera settings: shooting mode set to priority shutter speed, focus infinity, aperture - F/4.5, ISO auto-exposure, shutter speed 1/1000 second. It is worth noting that the piloting process is conducted in fully automatic mode. The result is 132 photos of 7 routes.

The technical characteristics of the UAV and the digital camera are shown in Tables 1 and 2.

Table 1

Technical characteristics of the UAV FLIRT "Arrow"

Characteristics	**Parameters**
Take-off weight, kg	4,8
Battery capacity, A	16
Minimum flight speed, km / h	50
Cruising speed, km / h	60-80
Maximum flight time, min	100
Maximum flight range, km	100
Maximum controlled distance from the base, km	15
Maximum flight altitude, m	5000
Minimum working flight height, m	75
Maximum resolution of images, cm / pixel	2
Dimensions in the transport configuration, sm	120x25x25
Limit wind speed, m / s	12

Table 2

Main Specifications of SONY ILCE-QX Digital Camera 1

Characteristics	**Parameters**
Weight:	216 g

Dimensions:	74×70×53 mm
Matrix type:	CMOS
Focal distance	0,25 m
Effective resolution:	20.1
Matrix format:	APS-C
Matrix size:	357.28 mm^2 (23.20 mm×15.40 mm)
Matrix pixel size:	4.25 мкм
File format images	JPEG, RAW (12-bit ARW 2.3)
ISO settings:	Auto, 100, 200, 400, 800, 1600, 3200, 6400, 12800, 16000
Exposure Range:	30 - 1/4000

To confirm the possibility of applying images taken from UAVs to create orthophotomaps at a scale of 1: 2000, a priori estimate of the accuracy of determining the spatial coordinates of the area according to the formulas is calculated:

$$m_X = \frac{H}{f} * m * x + \frac{H^2 * x}{B * f^2} * m_p;$$
$$m_Y = \frac{H}{f} * m * y + \frac{H^2 * y}{B * f^2} * m_p;$$
$$m_Z = \frac{H^2}{B * f} * m_p;$$

where m – denominator of the scale of the survey (13300),
f – focal length ЦНЗК (f=28 mm),
x, y – abscissa and ordinate, respectively, frame frame of the CCD matrix CCDC,
$m_p = m_{x_1} = m_{y_1}$ =0.003 mm,
H – surveying height, (H =20 m).
B – the basis for taking pictures, respectively for 1: 2000 according to the specifications of the camera.

The results of a priori assessment of accuracy are given in Table 3:

Table 3

Apriori estimation of accuracy

Model of UAV	H (m)	Scale	Accuracy (m)		
			m_x	m_y	m_z
FLIRT «Arrow»	520	1:13000	0,26	0,19	0,48

At present, aerial surveying materials are increasingly being used to create orthophotomaps, which is becoming increasingly available every year. For the use of materials for removal during mapping of the earth's surface (for example, for the construction of orthophotomaps), it is necessary to perform orthotransformation of the images.

Technological scheme of creating an orthophotomap in Pix 4D is shown in Fig. 1

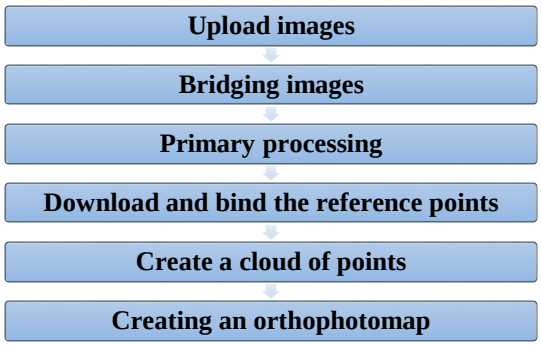

Fig. 1. Technological scheme of creating an orthophotomap in Pix 4D

The Agisoft Photo Scan software orthophotomap is built on the basis of data from the original images and a reconstructed model that allows you to create a high-resolution resultant image. Most often the orthophotomap export is carried out in the processing of aerial surveying data, in addition, the construction of an orthophotomap can be useful in case of need to create a detailed view of the object. Agisoft Photo Scan allows you to edit the orthopedic crop line for better visualization.

When processing multispectral images, Agisoft Photo Scan allows you to calculate the Vegetation Index (NDVI) and other indices that can then be used to evaluate the vegetation state using the Raster Calculator tool available on the orto tab.

The technological scheme of creating an orthophotomap is shown in Fig. 2

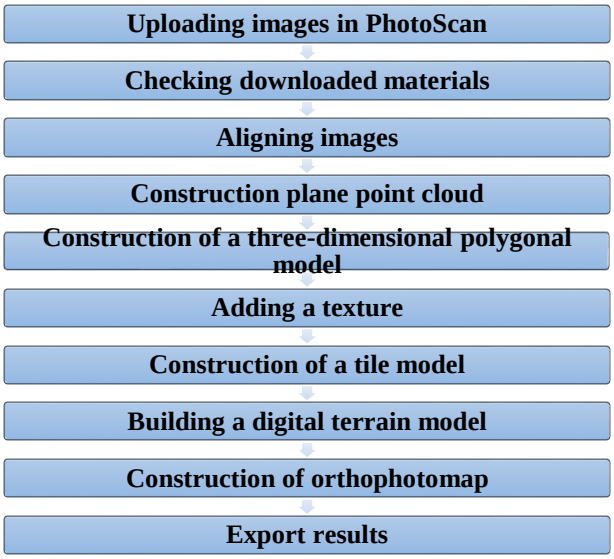

Fig. 2 Technological scheme of creating an orthophotomap in Agisoft Photo Scan.

To conduct an assessment of the accuracy of determining the coordinates of the points of the area, 57 test points were marked on the research site. The coordinates of control points were determined when conducting PVP GPS-receivers Trimble R7 in RTK mode. After the creation of orthophotomaps in the Digitals software environment, the coordinates of the above-mentioned checkpoints and defined UPCs were removed from these materials. After downloading the finished orthophotomap in the Digitals program, a checkpoint is searched for and its coordinates are measured, then the obtained coordinates with the

coordinates of the reference point from the coordinate tables are compared. The results of the assessment of accuracy are given in Table 4.

Table 4

Порівняльний аналіз Pix 4D та Agisoft Photo Scan

	Pix 4D	**Agisoft Photo Scan**
Language	English	Russian
Accessibility	Free trial license for 15 days	Free Trial License for 30 Days
Input files	Images, file coordinates of aerial surveying images, coordinate file of reference points	
Bind	Coordinate file	
Processing	3 steps	4 steps
Processing time	3-5 hours	6-8 hours
Accuracy	m_x =0,19 m m_y =0,11 m	m_x = 0,19 m m_y = 0,13 m

Comparing the values of the a priori estimation of the accuracy and significance of the GCP by control points, we can conclude that the values of GCPs by control points do not exceed the value of the a priori estimation of the accuracy of spatial coordinates for the software product Pix 4D.

Conclusions

1. Orthophotomap parts of the city of Vinniki were created using the Pix 4D and Agisoft Photo Scan software packages.

2. Based on the experimental work, a comparative analysis of Pix 4D and Agisoft Photo Scan software packages was made. As a result, we conclude that the use of the Pix 4D software package allows you to reduce processing time and achieve better accuracy.

3. Determination of coordinates of control points by orthophotomap does not exceed the value of a priori assessment of accuracy, which confirms the ability to create plans in scale 1: 2000.

4. The prospect of further research is to increase the accuracy of the processing of digital images obtained with the use of UAV.

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Comparative analysis of the application of Pix 4D and Agisoft Photo Scan software packages for processing digital images obtained from UAVs

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The article estimates the a priori estimation of the accuracy of determining the spatial coordinates of the area. The results of experimental work are presented and a comparative analysis of Pix 4D and Agisoft Photo Scan software packages is made.