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Innovative photogrammetric methods for monitoring agrolandscapes nanorelief

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Abstract. The object of the study is the materials of aerial photography obtained with the application of an unmanned aerial vehicle (UAV) DJI Phantom 3 Advanced and processed by Agisoft PhotoScan Professional Edition software. The objective of the present research is to study the feasibility of the data obtained by innovative photogrammetric methods for monitoring and analyzing the agrolandscapes nanorelief as well as for the design of agrolandscapes in adaptive landscape farming, to identify the possibilities of assessing the occurrence of erosion and make a forecast of their development in the study area using photographic plans. In the course of the work, methods and means of obtaining aerial photographs of a site in the Voronezh region were considered. The altitude map and orthophotomap resulting from image processing were analysed. It has been revealed that such digital models make it possible to study and analyze the state of the surface of agrolandscapes up to the smallest forms of nanorelief both visually and with the application of mathematical characteristics. However, deficiencies in the accuracy of the obtained plans along the edges of the shooting area were noted and the methods for solving the problem of inaccuracy were proposed.

1. Introduction

The shape of the earth's surface determines the use of territories in agricultural production. Areas having various agrolandscapes functions are used for various purposes. The main tasks for ensuring the process of territorial management are the tasks of territory cartography, terrain modeling, vector maps, many of which are used for environmental territory assessment [1].

The relief can undergo significant changes when studying the earth's crust geological structure, the underlying processes inside it as well as the interaction of many components of the natural environment, the effects of climate and human economic activity [2]. In this paper, we consider the changes that begin with the smallest forms, specifically, nanorelief characterised by a height difference from 10 cm to 1–2 m [3]. The laws governing the agrolandscapes nanorelief transformation enable to plan territories with regards to the conservation of the landscapes ecology and rational use of land. An adaptive landscape farming system and agrolanshaft design are used to preserve environmental functionality and prevent the degradation of agrolandscapes, [4]. Terrain monitoring enables to study the relief-forming factors and predict the development of its forms [5, 6]. Precise



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imagery of the nanorelief on maps and plans will help to objectively assess the condition of the fertile layer of farm field and agricultural land in general as well as the degree of soil erosion in different regions. Visualization will contribute to establishing the correct list of measures for organizing crop rotation, setting farm field boundaries taking into account the correct direction of cultivation relative to the linear forms of nanofiber, determining the distribution of crop rotation as well as timely planning the erosion control and land reclamation [7]. At present, innovative equipment, aerial photography methods and photogrammetric processing techniques are being used to create cartographic materials with increasing frequency.

The objective of the present paper is to assess the possibility of monitoring and analyzing nanorelief based on aerial photographs obtained with the application of innovative photogrammetric methods on the basis of the DJI Phantom 3 Advanced unmanned aerial vehicle (UAV) processed by Agisoft PhotoScan Professional Edition software, version 1.4.3. One of the stages of nanorelief research is processing the aerial photographs of field material. High-quality cartographic data will allow to identify and evaluate the possibility of erosion processes and to carry out a forecast of their development in the study area as well as to develop a selection of anti-erosion measures to reduce or slow down the processes of soil erosion basing on the study results [8, 9, 10]. Thus, it is possible to eliminate the erosion of a technological and environmental nature.

2. Materials and methods

The photographic survey of an 8.3 hectares area in the Kashira district of the Voronezh region was performed using the Phantom 3 Advanced UAV with the following parameters: scale of 1/2000, timespan of 9 minutes, height equal to 100 meters. Outer orientation, smoothness and stability of the device flight was carried out after calibrating the compass with an on-board GPS receiver and a set of navigation sensors (gyroscope, accelerometer, barometer, ultrasonic range finder) [11]. The camera shooting stability was ensured by a three-axis suspension stabilizer with a longitudinal, vertical and transverse axis from -90° to $+30^{\circ}$. The observation was performed with triple 80% overlap along the routes and 40% overlap between the routes with the objective to increase the accuracy of the photographic plan and to reduce contour gaps at the junctions of neighboring images caused by wind gusts, turbulence and other disturbing factors.

The digital camera has rectangular images. Thus, it is placed in such a way that the long side of the image is located across the flight, which enables to shoot a large area with the same length of the route. The images slur at an UAV flight speed of 10 m/s was eliminated by a low shutter speed of 1/1800 s [12, 13].

Cartographic materials were obtained by processing 82 images with the use of Agisoft PhotoScan for two hours in a semi-automatic mode. The program automatically finds the common points of photographs and determines the position, orientation and internal geometry of the camera. Then, the preliminary compilation is made with regards to the sparse number of these image points. Figure 1 shows the obtained automatic preliminary compilation.

Afterwards, a sparse coordinate reference for three signs with known coordinates and heights shown in white in Figure 1 was made manually. Further, PhotoScan constructed a dense cloud of points pointing the shape of the object. It was made in automatic mode basing on the calculated parameters of the photos. This point cloud was used for building a three-dimensional surface being a polygonal 3D model and an altitude map (Figure 2) [14]. At the final stage, an orthophotomap was built. Its fragment is presented in Figure 3. The comparison of the obtained orthophotomap with the materials of a previously completed tacheometric survey at a 1:2000 scale revealed that the accuracy of the model obtained corresponds to the requirements for creating topographic maps almost throughout the entire territory [15]. The necessary accuracy is maintained in the center of the survey area, in the area where the signs and the largest longitudinal and transverse overlap of the images are located. At the edges of the territory there are distortions and gaps.

The program functionality and the photographs quality enables to increase the orthophotomap and study the image of the earth's surface in great detail (Figure 3).

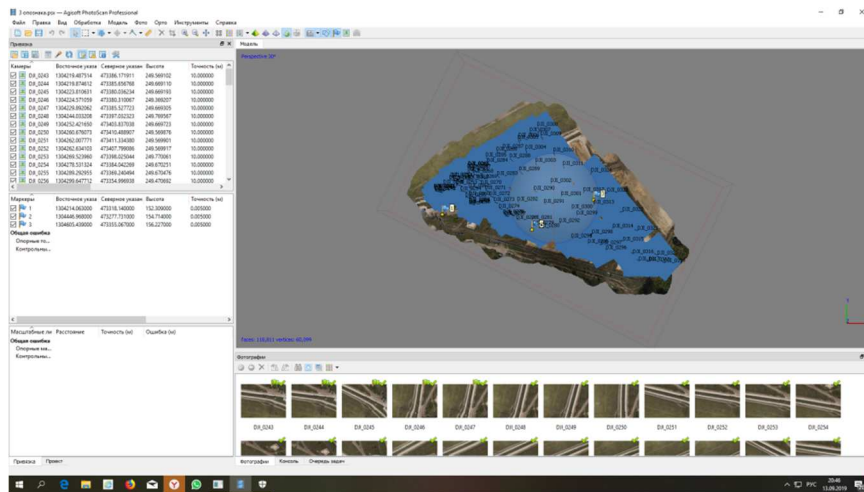


Figure 1. Preliminary compilation on a sparse cloud of common points

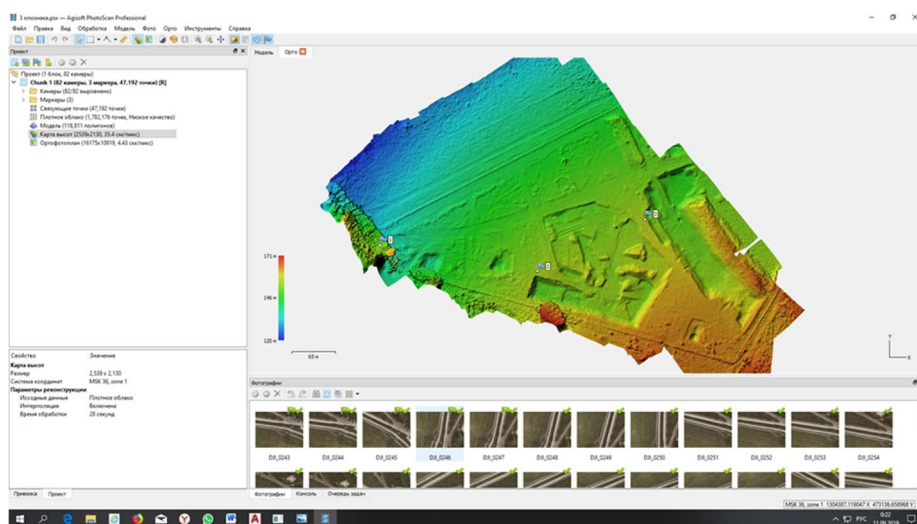


Figure 2. Altitude map



Figure 3. Orthophoto a shooting fragment

Figure 4 shows a relief fragment represented by an altitude map of a dense point cloud. The points heights deviation is presented in colors and tone range. When placing the cursor on any point of this digital terrain model, the information on the plan and elevation coordinates of a point is displayed with an accuracy of up to 1 mm.

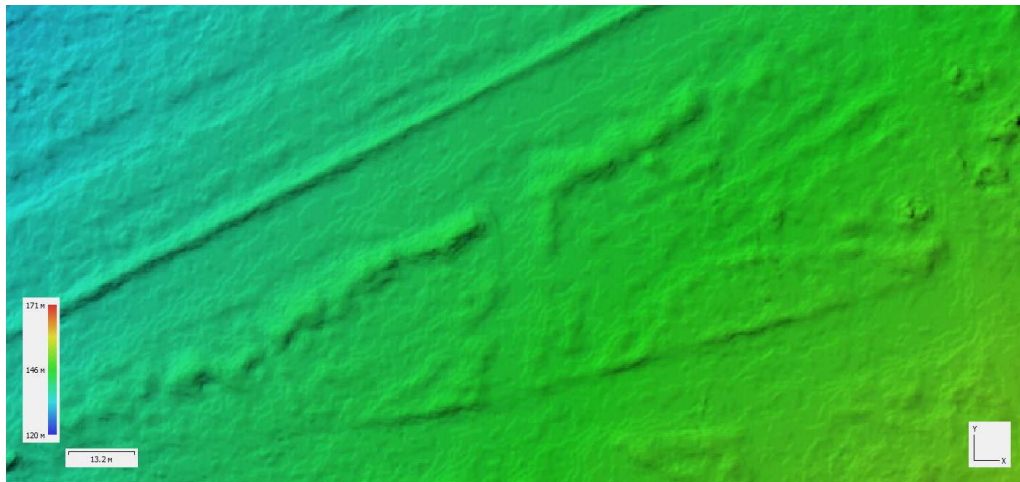


Figure 4. Altitude map of a terrain segment

Thus, after decoding the landforms on the orthomosaic, the heights of the selected points are determined on the altitude map.

It is possible to build terrain profiles on the basis of the selected areas. A detailed image provides a means of studying and analyzing the state of the chosen agrolandscapes surface up to the smallest forms of nanorelief both visually and mathematically. Accordingly, tubercles and furrows with relative height variations equal to 10-15 cm have been revealed in the considered area.



Figure 5. Orthophoto a shooting fragment

However, gaps and outlines displacements are observed at the shooting edges in spite of the triple images overlapping and fixing by ground control points (Figure 5). Similar problems arise due to inaccurate UAV positioning with an application of an on-board GPS receiver with a 1m to 5m inaccuracy as well as an insufficient number of ground control points for images linking.

The problem of the objects location inaccuracy can be solved in two ways. The first method

implies increasing the number of ground control points in the shooting area by developing an additional supporting geodetic thickening network. The second one requires an additional mini GPS receiver with an antenna for UAVs, which makes it possible to determine the points coordinates in the mode of real time kinematic (RTK) with centimetric positioning accuracy essential for creating large-scale 1:500 and 1:1000 plans without additional ground control points [14, 15]. However, the second method can increase the cost of equipment by 2-6 times.

3. Conclusion

Thus, the necessity to create cartographic materials for monitoring and studying the state of the nanorelief for the spatial organization of agrolandscapes requires the application of the operational geospatial data obtained promptly by means of innovative photogrammetric technologies. Geodetic data obtained by photographic survey build a necessary information base for performing cadastral works [16]. However, it is essential to use either the required number of identifications when processing images or more expensive equipment with additional functions in order to increase the accuracy of shooting.

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