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METHOD OF CREATION OF GEOINFORMATICS OF THE CARTOGRAPHIC BOARD OF BUILDING CONSTRUCTIONS BY MATERIALS OF THE GREAT AEROSPACE OF LOCATION OF UAV

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Formulation of the problem

The task of making a vector geoinformation layer of the contours of buildings from aerial photographs is relevant to all manufacturers of large-scale cartographic products. There is still no simple and effective solution that would take into account the features of merciless types of aerosols, in particular UAVs, and the availability of software modules for creating DSM high density terrain models, DTM terrain models and orthophotomaps directly into instrumental GIS. Therefore, it is logical to search for the inclusion of this information for geoinformation analysis in order to resolve the problem described.

Presentation of the main material of the problem

Analysis of research and unresolved parts of the general problem

One of the notable phenomena was the integration of methods of digital photogrammetry into the environment of geographic information systems [1] in the general tendency of geomatics development - the scientific and technical direction, which combines methods and means of technology for the collection, processing and use of spatial data. The programmatic photogrammetric instruments are introduced into the GIS program complexes, which provide the receipt of high-precision 3D information about the composition and geometric parameters of terrain objects from the images obtained by various types of shooting systems. Examples of such integration can be seen in up-to-date versions of both open and proprietary software GIS. For example, the ArcGIS GIS component includes the Drone2Map software module - a software product developed on the basis of Pix4D technology that allows the full cycle of automatic photogrammetric processing of aerial photographs [2,3]. Arrays of geoinformation - two- and three-dimensional models of objects and terrain, orthophotomaps, vector map data, etc. are obtained immediately in the structures and formats of a specific instrumental GIS. This advantageously distinguishes the integrated solutions from traditional import into GIS of this kind of data obtained by specialized photogrammetric software. Of course, the leading role as a data provider for digital photogrammetric stations is maintained by performing complex photogrammetric projects, for example, processing of received full-frame camera shots, ensuring data collection by photogrammetric operators in stereo, etc. In the end, the data received on the CFS, as a rule, are transmitted for further analysis and visualization in the geographic information systems.

Consequently, the integration of photogrammetric methods and geoinformation technologies provides geoinformation systems with the capabilities of operative acquisition of digital terrain models. The next stage of the technological chain is the transformation of these terrain models into a cartographic product.

For large-scale mapping, the main way of obtaining the contour of topographic plans is still the manual outline by the operator-operator of the objects along the orthophotoplane or the automatically created 3D model. This procedure is still not sufficiently automated. In some cases, there are significant limitations on the very possibility of obtaining reliable and accurate contours of objects. The above applies primarily to the objects of the area covered by crowns of plants and hanging parts of roofs of buildings [4]. Among such objects are the buildings and structures, the contours of which are shown on maps and plans in strict accordance with the requirements of national and industry standards. In Ukraine, current norms indicate that the contour of the building should be displayed on the projection of the cap with the display of the performances and other architectural details from the value of 0.5 mm on the scale of the plan [5, p.417-421]. Therefore, in large scale mapping, it is difficult to obtain the correct contour of the building as an orthophotoplaning and a 3D model DSM (digital model of the **visible surface)**

$$H_{DSM}=H_{рельєф}+H_{об'єкти\_місцевості}\ . \qquad (1)$$

This is prevented by the presence of projectors beyond the base of the building elements of the roof construction. Additional difficulties are caused by the presence of shaded areas (dead areas of removal) and the presence near the walls of buildings of high woody vegetation. To find out the method of outline of buildings, existing approaches are constructed based on the relative height of objects on the stage (excess of terrain objects above the relief). To obtain such information, it is necessary to complete the creation of a DSM terrain model in the polygonal structure or in the form of a cloud of 3 D points.

Methods for determining the points in 3D clouds that are related to the walls of buildings, are widely distributed in the processing of aerial laser scanning data (LIDAR). For example, in [11], in the case of LIDAR data, segmentation of points is provided based on their belonging to the vertical planes. In this analogy and in DIM (stereorekonstruktsiya on digital stereo), it is proposed to allocate the vertical parts of the walls, as in [9], for the received 3D cloud points. In order to select the contours of the building on DSM models, in particular, the way of using the altitude model gradient card as a hypothesis about the presence of a building [12] was investigated. The ineffectiveness of direct borrowing of LIDAR processing methods when processing the clouds of points obtained by the DIM technology is due to the peculiarities of obtaining and distributing points in a 3D cloud. One of these features appears in the works of Meixner P. and Leberl F. [13,14], when it is indicated by the difference in the size of the pixel on the horizontal plane (gsd on the ground) and the pixel size on the inclined (for walls of buildings - the vertical plane) . The calculations given by these authors for photos taken with different inclinations indicate that such a difference is significant for images with relatively small inclinations - up to 10 degrees. It should be added to our opinion that the projection size of the pixel of the picture on the wall of the building (as designated by the authors of the FSD, unlike the traditional GSD) will also depend on the spatial exposure (orientation) of the vertical plane relative to the sides of the aerial image. When creating a 3D cloud of points, this difference may be significant for stereo-design, especially when using various types of images. Most conventional stereoregulation programs do not ignore such cases of stereo discretion, rejecting points as mistakenly aware.

With low density DSM model for the qualitative perception of the walls of buildings a part of the authors suggest to perform additional removals. This approach is used in particular [6]. The authors propose to complement the main block of aerial photographs with perspective images taken from a multicopter with a deflection of the optical axis of the camera from a vertical angle of 45 degrees and ground images taken by a high-resolution camera. The volumes of additional information are very significant, and its receipt makes it much more difficult and makes the project more expensive. The ineffectiveness of the described approach is that not all additional information can be used to solve the problem in real terms. When setting the corresponding points of various types of images, the operator can not be overcome without introducing new mistakes and reducing the level of automation of the common technology. Obviously, the output may relate to more thorough planning of additional shots, sending them not to receive information about all facades, but first of all on specific elements such as the corners of buildings.

The work [15], as described by us in [4], uses the effect of compaction on the plan XY points of a three-dimensional cloud of points in the locations belonging to the facades. The authors propose to build an index card that takes into account the local excess of the color information about the point of the facade, and the other pixels that do not belong to the facade are ignored. Next, this image is segmented with the average for each color segment. The method shows good results in the selection of facades with the use of perspective images. One disadvantage is the suggestion to employ only one stereopair - obviously, the effect of the densification of the point clouds manifests itself to a small extent, in the data structure there are possible omissions due to the presence of shading zones.

Next, note the presence of a large number of publications, which in advance, as a goal of photogrammetric technology, the acquisition of not the actual contours of houses as a contour of the topographical plan, and the receipt of the topographical layer "buildings footprints", that is, the construction track. This term is spreading to refer to the total contour of all parts of the building and is the contour of the projection on the plane of the plan not only the walls of the building, but also all its other parts - roofs, verandas, balconies, sometimes scumbags around the house, and so on [7,8]. This is explained by the interest of consumers not only in topographical products in the classical sense, but in cadastral documentation. For example, in India, this information is needed to calculate the property tax. However, the main proposed methods for extracting information from images are identical to those described above for the outline of the building itself, with the addition of techniques for segmentation of spectral information.

In general, summing we will indicate that solving the problem of precise mapping of buildings is possible by integrating photogrammetry methods as a method of information gathering and analytical methods of geoinformatics.

Presentation of the main research material

As noted above, for GIS users there is no technological difficulty in obtaining directly in the GIS environment of digital terrain models such as DSM, DTM, orthopedic. Establish a procedure for obtaining, according to the aerial data from the UAV, a vector cartographic layer of the contours of buildings in accordance with the requirements of standards [5]. As the input data, we use a cloud of 3D dots, which is a DSM model. This cloud of points is obtained by the technology of dense stereo-construction, provided that its density is set equal to the difference in input aerial photographs. For large-scale aerosomnia we consider the distinction of gsd = 0.075m typical. The contours of buildings for topographic plans scale from 1: 500 should be displayed on the projection of the base with the display of the projections and other architectural details in size from 0.25 m and larger [5].

Solution to the task

Let's proceed from the known prerequisites for the formation and processing of clouds of 3D points in order to get the planned contour of the house, namely:

• Under the photogrammetric treatment of UAV images, the practical accuracy of determining the coordinates of the points of the DSM model is m_{XYZ} = 2gsd, that is, under the conditions described above, the removal from the UAV m_{XYZ} = 0.15cm. On vertical planes, the points are fixed unevenly, the reason is the peculiarities of the texture of each wall, the presence of the image of concrete walls at different angles of removal and other causes (Fig. 1);

• Exceeding the surface of the relief of points belonging to the walls of buildings should be taken into account in the range from 1 to 2.5 meters. This will cut off the points belonging to objects close to the surface of the earth and the points of the upper floors, balconies, roofs, crowns of trees hanging over the houses, etc. (Fig. 1, on the right).

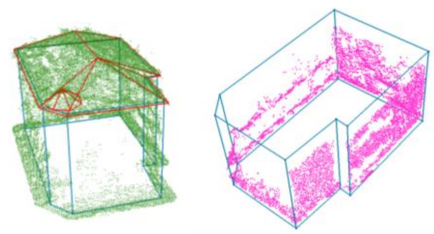

Fig.1 DSM surface dot model obtained by airplanes from UAV

The condition for selecting points from a common cloud of points that potentially belong to the walls of buildings, we write the expression:

$$B_k = \begin{cases} TRUE, & 1m \leq \Delta H(i,j) \leq 2.5m \\ FALSE, & 2.5m \leq \Delta H(i,j) \leq 1m \end{cases} \quad (2)$$

where: B_k - a sign of the probable affiliation of point k to the wall of the building; ΔH (i, j) is the coordinate range Z of the cloud points projected onto the pixel of the orthophoto with coordinates (i, j); k is the point index that is part of the cloud of 3D points.

The indicator of the wall contour of the building is the compaction of the DSM model points. The document, which confirms this effect, is a point density map created by standard GIS analysis tools (Fig. 2).

Fig.2 The DSM model dashboard map shows the model densification in the walls of the house (polylines)

DSM Dot Density Raster Map is used by us to investigate the method of establishing the contour of building walls. Justifications for rasterization of data obtained by photogrammetric processing can be found, for example, in [10]. For example, the classification of raster data instead of the input cloud of points led to a decrease of accuracy of 5%, which can be considered rather insignificant negative effect. In our case, the differentiation of the raster map of density is set equal to the spatial separation of aerial photographs.

Apply density value as surface attribute. Then, from Figure 2, it is easy to see that such a surface has an edge in the places of the highest density, that is, in places corresponding to the outer contours of the walls. Because the conditions for removing different walls are different (take-off angle, niceness of shading zones (occlusion), texture properties of the surface of the walls, etc.), the bending is difficult to reproduce with 3D polynomials. As an option, we suggest using raster geoinformation analysis tools. In particular, consider the software tools for hydrological analysis, such as the automatic allocation of the catchment basin (Fig. 3).

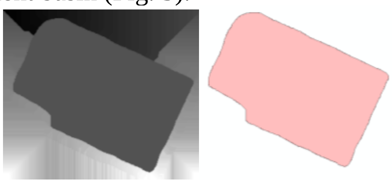

Fig. 3 Raster (left) and vector (right) model of the basin of the catchment, constructed behind the density surface of the DSM model

Fig. 3 shows a fragment of a raster and vector contour map obtained by the use of an instrument for the allocation of basins of the catchment. These maps are constructed over the surface, where the height attribute is the density value of the DSM point model filtered by condition (2). This example is given for the model of the building depicted in Fig. 1, 2.

For the selection of polygons that do not belong to the image of buildings, you can use a binary raster mask [9], formed in our case on the condition:

$$g(i,j) = \begin{cases} 0, & \text{якщо } Dens(i,j) < T \\ 1, & \text{якщо } Dens(i,j) \geq T \end{cases} \quad (3)$$

where: g (i, j) - image - a mask of buildings, which is built on the entire territory of the study with a given distinction; Dens (i, j) - the density of the cloud of points in a specific pixel of the mask; T is the a priori set threshold value of the density of the cloud of points, the achievement of which is the hypothesis that the pixel belongs to the wall of the building.

The next step in geoinformation analysis is to normalize the contours of buildings by eliminating unwanted artifacts in their geometry. Fully-functional instrumental GIS have sufficient means to simplify contours, smooth out polylines, orthogonalize polygons. A part of such instruments is specially designed for processing orthonormal paths of buildings [17]. The specific selection of tools, the order of their application and the parameters of each of them should be chosen for a specific instrumental GIS and parameters of the DSM model of each photogrammetric project.

We have proposed the proposed method for performing large-scale topographical shots of several settlements. The object of one of these projects (the clinic's home in the village of Davydov, Pustomyty district) was used by us to construct illustrations in this article. Aerial images of UAV had typical parameters of mutual overlap and scaling. Photogrammetric blocks are processed in software packs of Pix4D and built on a similar methodological basis Drone2Map. All processes of geoinformation modeling and analysis are executed in instrumental GIS ArcGIS 10.5. The methodology has significantly reduced the timing of creating topographical plans. In its application, the work of the operator-man is reduced to visual inspection and editing, if necessary, of the contours of buildings and structures. Obviously, the reliability of the results of the outline of houses, the quality of reproduction of geometric shapes depends on factors such as the spatial dispersion of images, the lack of close proximity to houses of high vegetation, other structures, etc.

The main problem detected during the testing of the technique is that the outline of the building usually has missing points in the corners. Since the house usually has the right shape with right angles, the corner points can be added by the operator. Automation of this procedure can be the subject of further research.

Conclusions

The conducted researches demonstrate the possibility of automated construction of the vector layer of the contours of buildings in the environment of GIS according to the data obtained by photogrammetric processing of aerial photographs. And the last process can be performed directly in the environment of instrumental GIS. The technique, which allows to eliminate the influence of such undesirable factors for contouring the presence of hanging parts of roofs of buildings, crown trees near the walls and others, is proposed. The method has been tested on several real projects of large-scale topographical removal of villages in the Lviv region.

The prospect of further research is to improve the technique of simplifying and orthogonalizing the contours of buildings and automating the procedure for selecting artifacts in a DSM model that can distort results.

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Method of creating geoinformatics of cartographic layer of building contours on materials of large-scale aerial survey of UAVs

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The methodology for treating clouds of 3D points, obtained by photogrammetric processing of large-scale UAV aerial photographs for the automated acquisition of building contours, is disclosed.