Development of a digital surface model and a digital terrain model based on ERS data

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Abstract. The paper considers the development methods of a digital surface model and a digital terrain model of the Dead City territory. The work utilizes the Phantom 4 PRO UAV with high flight stability and excellent shooting quality (camera 20Mg/px) with 4K resolution that allows creating qualitative DSM, DTM with a possibility of storage, processing, transfer on various platforms in different formats.

1. Introduction
The development of a digital surface model and a digital terrain model of the Dead City territory began with the collection of photographic material.

Before the beginning of aerial photography, the determining factor is correct selection of the required type, mode of aerial photography as well as competent preparation of the flight mission. There are many varieties of aerial photography. The type of aerial photography is chosen depending on the final objective and the software that will be used for further processing of the material.

We used high-altitude (height more than 40 m) general coverage photography, since the Dead City represents a mountainous terrain with frequent wind changes. The use of UAVs in conditions of variable winds and variable relief is safe at such altitudes.

Leveling survey (90°) makes it possible to choose the objects: their adjacent sides, inclination angles, vegetation, forms of relief, to minimize deviations of UAV from the selected flight trajectory.

The flight mission was to compile the general scheme of UAV flight, in which all factors of future flight are taken into account with high accuracy. Competent flight mission is one of the most important factors of aerial photography, which is directly related to the quality of thus obtained material.

The next step is to select the pilot mode. This work is based on “autonomous” mode of UAV flight, it provides accurate and high-quality shooting, as well as a sufficient percentage of overlap between photographs of the area.

2. Methods and materials
Flight mission and flight mode was compiled in SKYCATCH program. When you start the program, the “NEW MISSION” window appears. Here we define a new flight mission plan and select the flight mode, additional parameters are specified later.
After selecting the “NEW MISSION”, the program should give access to your geodatabase, i.e. to the operator’s location. This is done to more accurately link the model to the orthophotomap, and to allow the UAV navigating space based on the geographic coordinates of the terrain in real time. Orthophotomap is a photographic terrain plan derived from the processing of remote sensing data of the Earth’s surface using UAVs.

The second step is to “Find Yourself on the Map”. After we clicked “NEW MISSION”, a satellite map pops up, and the access to mobile device geodatabase allows the satellite to find your location automatically.

![Software Dialog Box](image1)

**Figure 1.** Software Dialog Box

After you start the map, the blue dot automatically detects and displays your location in the spatial coordinate system.

Next, it is necessary to set the flight parameters and the mode of UAV take-off and landing. We click on the pencil icon in the main window of the program and the “Settings Window” appears. With a finger we highlight the terrain section that we want to shoot on the map, and the program automatically lays out the optimal route of shooting, which will require the minimum flight time, will allow covering the required objects as much as possible and creating the required viewing angle during aerial photography.

![Software Dialog Box](image2)

**Figure 2.** Software Dialog Box
After the route is laid, we proceed to add the main parameters of the survey: UAV flight altitude, descent angle, camera rotation angle. On the main window of the program interface press the icon “Flight Settings” and in the program window the settings window appears, where we mechanically enter the required flight altitude and survey angles.

After setting the flight mode and entry of precise parameters of UAV flight, press “READY TO FLY”. Then the UAV starts the flight, it will move along the trajectory determined by the flight mission, collect photographic material with the specified shooting resolution and with the optimal percentage of overlap between photos. For safety, we can set the UAV flight to a manual mode at any moment and start control from the console. The landing accuracy makes ± 1 meter from the start point.

**Figure 3. Software Dialog Box**

After the completion of the UAV flight and the collection of the necessary data of remote sensing of the Earth’s surface (based on aerial photography), the stage of processing of the obtained data begins, on the platform of which a digital surface model and a digital terrain model will be built.

Agisoft Photoscan Pro was used to process the resulting material. It is a modern automated GIS platform designed to collect, store, process and transmit remote sensing data of the Earth’s surface.

The interface of the program includes hundreds of functions in the sphere of creation of digital models of a relief, an area, processing of space pictures, creations of orthophotomaps, georeferencing of maps and creation of relief maps.

**Figure 4. Agisoft Photoscan Pro interface**
When you start the program, a “blue ball” immediately pops up in the center of the program window. It is an auxiliary element, if you move the cursor and scroll the “blue ball”, you immediately get the impression of a three-dimensional space.

The processing of received data begins with the fact that we load the filtered data into the program itself. This is done to run the program itself. Next, in the “Processing” section, click “Download Photos”, then the program window appears and the “Desktop” opens. After that, we select the folder we want and upload all the photos to the program.

After a short processing, the program loads the material we want. At the stage of loading the material into the program and before processing, it is important to keep track of what we upload into the program. Next, we check whether there are any photos with unsatisfactory quality in the general array.

After loading, all selected material is displayed in the program itself. This is done to make it easier for the user to adjust image quality and edit material as data processing proceeds.

![Figure 5. Loading data into Agisoft Photoscan Pro](image)

After downloading the data, the next step is “Processing”, which includes “Photo Alignment”. This is the first stage in the algorithm for building a digital surface model or a digital terrain model.

In the “Photo Alignment” step, the program begins to calculate snapshot points using algebraic and mathematical algorithms.

Depending on the area of the snapshot and the number of pixels on its area, the program calculates the places from where the UAV produced the snapshot and begins to collect and align the points from which subsequent snapshots were taken into one flat plane. This process is called photo alignment.

The program principle is inextricably linked to the PC control point, namely the processor. As we know the PC has two control points: basic and mathematical.

The main is set by default, and when processing data, the program starts to recognize only it, and when using the program, it is recommended to use the mathematical processor of the PC. This approach greatly accelerates PC operations and processes.

When we do high quality ERS processing, it takes a lot of computer time, and the mathematical processor accelerates material processing. To do this, the program has its own algorithm. The mathematical processor of PC control in the program includes the following actions:

- “tools”;
- “settings”;
- “these models”;
- “GPU” (we tick off).

After the “Photo Alignment” stage, a weak dot sketch for the future model is created in the additional control window, i.e. the program begins to find common areas of “overlap” between paired photos at this stage and prepares the frame for their further bonding.

Aerial photography in autonomous mode with the help of the flight mission is the main step that provides for qualitative observation of the percentage of overlap required for model creation.
Figure 6. Alignment of photos

Figure 7. Enabling GPU for data processing

Figure 8. Creation of a point cloud
After the point cloud is built, the second stage of material processing begins to create a digital surface model and a digital terrain model. The second stage of processing in Agisoft Photoscan Pro is called “Building a Dense Point Cloud”. It is based on the principle of “mosaic”. As in the first case, the PC recognizes all algorithms that the user sets as mathematical operations, so it is not recommended to turn off the graphics (mathematical processor).

To create a dense point cloud, click “Processing” – “Create Dense Point Cloud”.

Figure 9. Creation of a dense point cloud

Building a dense point cloud is the process of the program binding common points on various images obtained from the UAV. After completing the “Create Dense Point Cloud” process, the model gets a pronounced contour and gray color.

In general, during the whole processing process, we can view the model on different spectra by switching modes on the panel window. This is done so that each download and processing step can be monitored.

After completing the “Create Dense Point Cloud”, we proceed to the next processing step. It is called “Build Model”.

The “Build Model” phase is the main step of processing. That is why it takes a long time. To start building a model, you must refer to the “Processing” menu and click “Build Model”, where we specify the required quality.

Depending on the specified quality, the download time will vary following the principle of “higher quality – more time”.

At the stage of model construction, the future digital surface model or the digital terrain model becomes complete.

To do this, you must create a texture and specify the geometric dimensions and shape. Immediately we indicate in the program whether we want to get a further map of heights.

After the “Build Model” phase, the texture phase begins.

Texture is necessary to give the digital surface model or the digital terrain model the greatest possible real appearance. The texture also provides an opportunity to express contours and outlines that allow you to better see small areas and contours. They, in turn, give detail and contrast.

To begin the texture process, open the “Processing” window and click “Draw Texture”. It does not take a long time to build a texture, as we do the main steps with the PZU graphics processor.

Texture construction is the final step of processing remote sensing data using UAVs in Agisoft Photoscan PRO.
In the program itself, you can view the results of any stage of model creation. To do this, the program interface offers very fast and convenient switches that allow you to instantly turn on the “View Model” in different spectra and layers. Next, we can start doing additional operations and actions on models depending on what we want to get.

Figure 11. Creation of texture

The most common use is to “Create a Height Map”, which allows obtaining the elevation of any section of the model. The accuracy of elevations depends on the accuracy with which previous actions were carried out on the Earth’s remote sensing data. Building a height map is a long process that is divided into several stages. Each stage has its own meaning and duration within a time frame. The first stage – the model shall be saved in STL format. It is done so that we can make a model leader and create a backup (for security reasons) for external media.
Figure 12. Height mapping

3. Results
The software provides a wide range of functions for exporting and importing data. After building a height map, we can export the acquired data in different formats and to different media regarding the fact where we want to use them and what we want to get from these exported data.

A height map is a platform target map that provides a characteristic of the excess of a certain territory or relative to the elevation of an object.

As mentioned above, you can export spot elevations after you create a map. To do this, open the “File” window and click “Export Height Map”. Next, a dialog box appears in which you need to specify the format in which we want to store our data. Without a height map, it is impossible to obtain orthophotomap in the software.

One of the most important and irreplaceable features of the AGISOFT PFOTOSCAN PRO is that it enables the creation of high-quality orthophotomaps based on created digital surface models or digital terrain models.

The most important high-precision engineering tasks in the field of geodesy, photogrammetry, mine surveying, digital modeling and construction are solved on the basis of orthophotomaps.

The creation of orthophotomaps is the main platform for further geodetic justification, as georeferencing is done on the map using accurate and qualitative orthophotomap.

The AGISOFT PFOTOSCAN PRO creates the orthophotomap based on the built digital surface model or digital terrain model, which, in turn, are created on the basis of aerial photography.

To start the creation of the orthophotomap, you must access the “File” menu in the program window and the “Build Orthophotomap” dialog box. After clicking “Build Orthophotomap” the data processing begins in a green loading format that does not take long.

The created orthophotomap can be unloaded in the formats we need. We recommend using the STL format, which allows taking the file to external sources. Then the orthophotomap can be opened without the initial remote sensing data of the Earth’s surface.
4. Conclusion

This paper explores the processes of creating a digital surface model and a digital terrain model. The analysis of the crowdsourcing technology in the creation of digital maps was carried out.
The functional model is the basis for building a data model. In fact, without data about what kind of information is involved in creating a digital terrain model, it is pointless to build a data model. Based on the analysis, a model of processes for a digital terrain model was created, which is the source for the data model. The collaborative modeling method linked entities and attributes in process and data models.

Digital modeling technologies make revolutionary changes in almost all spheres of human activity: construction, medicine, geodesy and mine surveying, etc.

Thus, the use of the latest digital technologies in engineering geodesy, construction and monitoring of buildings, structures and the Earth’s surface seems quite relevant.

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