Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

The Use of Unmanned Aerial Vehicles (Drones) to Explore Areas of Hydrothermal Systems, South of Kamchatka Peninsula

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Keywords: thermal fields, drones, quadrocopter, orthophotoplans, digital terrain models

ABSTRACT

Unmanned aerial vehicles (drones) have been increasingly used in various industries and research works recently. They can perform a wide variety of tasks including the compilation of orthophotoplans and maps in urban planning, land registration, monitoring of the state of energy networks, etc. Moreover, methods of aerial photography utilizing drones have become essential in Earth sciences. Three-dimensional models of the terrains provided by drones during aerial photography are critical in ecological monitoring, river valleys and rivercoastlines`, forests` and geological processes` exploration, etc. The publication describes the experience in exploration of the thermal fields of hydrothermal systems in the south of the Kamchatka Peninsula utilizing the quadrocopter-type drone. Materials provided by the drone were processed, orthophotoplans and digital terrain models of the thermal fields were developed. The quadrocopter was extremely useful in obtaining the overview and panoramic photos, performing photo and video shooting of hard-to-reach places in the area, and creating orthophotoplans and digital terrain models. The derived orthophotoplans and the digital terrain models proved to be essential in solving a number of geothermal problems. They are being used in the processing of the field work materials: mapping of thermal sources and wells, creation of 3D geological and geophysical models of areas of thermal fields, etc.

1. INTRODUCTION

During the summer field work in 2017 and 2018, the authors participated in studies of the thermal fields of the Pauzhetsko-Kambalno-Koshelevsky geothermal region in the south of the Kamchatka Peninsula. Aerial photographs of the study area were obtained using a serial unmanned aerial vehicle such as the quadrocopter DJI Phantom 4 Pro (hereinafter referred to as the drone). This drone model was chosen for several reasons: ease of use and control; the presence of a high resolution camera; weight and dimensions should allow the use of the device in the field; flight on one battery for about 30 minutes. The selected drone model responded to all these conditions, with the exception of the flight time, which was 20-25 minutes of total flight time (depending on the direction and speed of the wind). To perform several flights away from electricity sources, an additional battery was used. The total weight of the drone, remote control and additional battery was about 4 kg. However, the need to recharge the batteries was limited by the time of aerial photography at a long distance from the 220 V outlet. Therefore, in 2018 a small-sized electric generator was additionally used.

2. CHARACTERISTICS OF DRONE

The drone is controlled using a radio remote control and a smartphone (or tablet) with a pre-installed manufacturer's application. The application allows you to: receive an image from the camera; monitor flight and battery parameters of the drone; choose a shooting mode; configure camera settings; select flight mode and other more detailed settings. Photographing is possible when the camera is tilted relative to the horizon from 0 ° to 90 °, in manual mode or in automatic mode at a given speed of photographing or video recording. The use of additional applications allows for automatic aerial photography over a given area, with a given frame overlap.

This drone model allows you to shoot at an altitude of 500 m from the take-off point. Overview areal survey was carried out at an altitude of 150-300 m. A detailed survey of the area, for example, the territory of thermal fields, was carried out at an altitude of 70-100 m. Flight altitude was selected depending on the ruggedness of the terrain and the specified final resolution of photographic materials.

To obtain a digital terrain model (DTM) of the thermal field region, it was necessary to perform from 5 to 25 flights (counting 1 flight is a flight on 1 battery). The number of flights depended on the area of the study area and the height of the shooting. During areal shooting, the camera was oriented perpendicular to the horizon line, the overlap with the following image was: front - 80%, side - 60%.

3. CREATE DIGITAL TERRAIN MODELS AND ORTHOPHOTOS

Photogrammetric processing of aerial photography materials was performed using the software Metashape Pro (AgiSoft).

All the processing steps were consistently performed (Agisoft Metashape User Manual ..., 2019): uploading photos and positions; aligning photos and building point clouds; loading and placement of markers with known geodetic coordinates; building points dense cloud; building a polygonal model; texture building; building digital elevation model and orthophoto.

The use of DJI Phantom 4 Pro drone allows you to quickly and easily load camera positions into the program. Data loading occurs automatically when adding photos to the project. During the alignment of photos, the position and orientation of all cameras (photos) in the project are determined and building points cloud (**Figure 1**).

Figure 1: Cloud point. Project of 3000 photos of the Pauzhetsky hydrothermal deposit area.

For a high-precision geodetic reference of the resulting digital model, it is necessary to arrange the marking points on the earth's surface with known geodetic coordinates. Refinement of the position of markers in the model is carried out automatically or manually. Markers should be evenly distributed across the survey area.

The program calculates depth maps for each image based on the calculated camera positions. After this, a dense point cloud is built (**Figure 2**). A dense point cloud can be edited or exported for further work. Points of dense clouds can be classified, for example: highlight points of the earth's surface or low points.

Figure 2: Dense point cloud. Project of 3000 photos of the Pauzhetsky hydrothermal deposit area.

Agisoft Metashape supports several methods for creating a three-dimensional polygonal model and provides a number of settings that allow you to perform an optimal reconstruction for a specific set of photos. If in the process of shooting the lighting conditions varied widely, then the program can use the color correction function. This feature helps to align the brightness and white balance in frames. Combining a polygonal model and the resulting texture of colors allows you to get a realistic digital terrain model (**Figure 3**), which can be viewed in the program and exported for further work.

The building of the orthophotomap in the program is carried out on the basis of the data of the initial images and the reconstructed model, which allows you to create the resulting high-resolution image. Metashape allows you to edit the cut lines of the orthophotomap for better visualization. **Figure 4** shows a fragment of the orthophoto of the Verhne-Pauzhetsky thermal field (resolution 8 cm/pix).

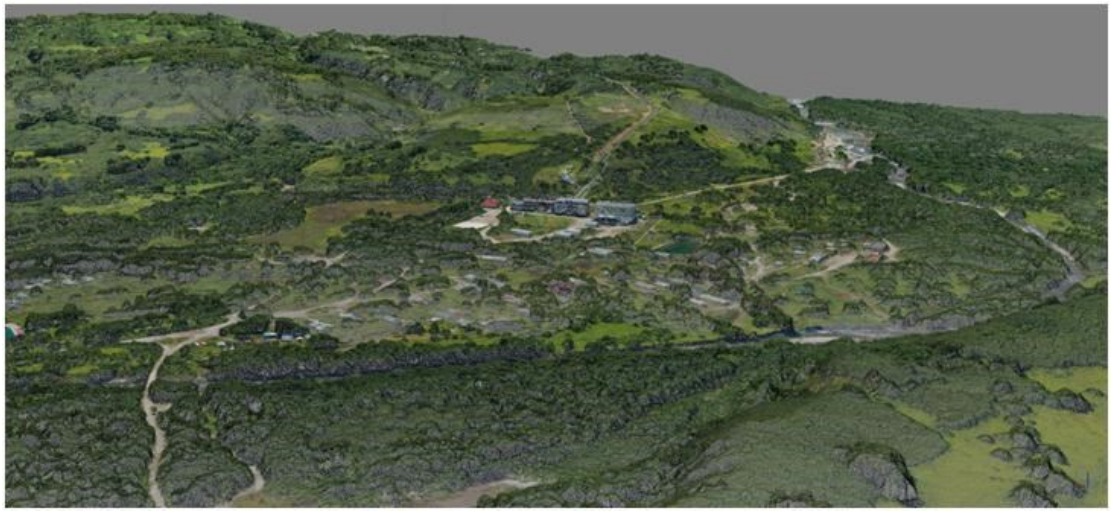

Figure 3: Digital terrain model. A project of 3000 photos of the Pauzhetsky hydrothermal deposit area.

Figure 4: Orthophoto fragment of the Verhne-Pauzhetsky thermal field.

Metashape allows you to create and display a digital elevation model, which is a surface model in the form of a regular grid of absolute elevation values. The most accurate results of building a digital elevation model can be obtained on the basis of a dense point cloud. The digital elevation model can be used to measure the coordinates of points, distances, areas and volumes, as well as display profiles of sections along a given line. According to the data obtained, it is possible to create contour lines and display them on a digital elevation model or an orthophotomap.

4. CONCLUSION

As a result of the aerial photography and subsequent processing, digital terrain models and high-precision orthophotomaps of the Verhne-Pauzhetsky (**Figure 5**), Vostochno-Pauzhetsky, Nizhne-Koshelevsky, Uzhno-Kambalny Central thermal fields areas were calculated with an estimated orthophoto 4-6 cm/pixel resolution. The obtained data, after additional processing, can be the basis for the construction of high-precision topographic plans of the studied areas.

The work carried out has shown that the development of technologies, technical means in the field of creating unmanned aerial vehicles and software for photogrammetric processing of aerial photography data makes it possible to obtain a result for creating a digital terrain model previously available only to professionals at relatively small costs.

The derived orthophotoplans and the digital terrain models proved to be essential in solving a number of geothermal problems. They are being used in the processing of the field work materials: mapping of thermal sources and wells (**Figure 6**), creation of 3D geological and geophysical models of areas of thermal fields, etc.

5. ACKNOWLEDGMENTS

The authors are deeply grateful to their colleagues who participated in field works for their all-inclusive assistance. This work was supported by the Russian Foundation for Basic Research (Project No. 19-05-00102).

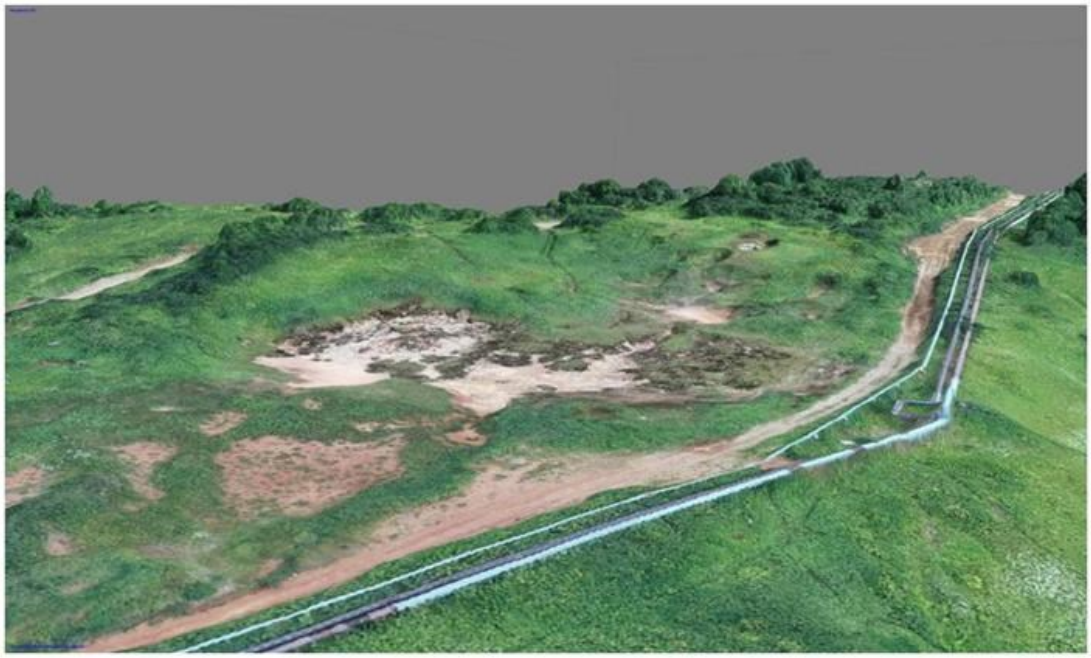

Figure 5: Digital terrain model of the Verhne-Pauzhetsky thermal field.

Figure 6: The Verhne-Pauzhetsky thermal field with location of boreholes and open pit: 1 - shallow boreholes; 2 - deep exploration boreholes; 3 - open pit; 4 - isolines of relief; 5 - isolines of temperature of clay at depth 0.5 m.

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