

Efficient Digital Orthophotos Using Drones

Ajla Đideliija

Građevinski Fakultet, Univerzitet "Džemal Bijedić" Mostar, Mostar, Bosnia and Herzegovina

Abstract - In the last few years, a completely new method of surveying the Earth's surface has been developed for the purpose of surveying land and buildings. The use of drones to capture large areas in a very short period of time with a lot of great accuracy. It is believed that this method will represent the future in geodesy and all areas that surround it. This paper will present the efficient use of drones to create a digital orthophoto. Particular emphasis was placed on the practical application of drones with a detailed presentation of obtaining photogrammetric products based on photographs taken by the unmanned aerial vehicle. A practical example of the application of drones for digital orthophoto was conducted in Bosnia and Herzegovina for the city of Mostar.

Keywords— *Drones, Aerial Photogrammetry, Photogrammetric Products, Digital Orthophoto.*

I. INTRODUCTION

The past period is characterized by a very important developments in science, especially digital technology. All this has ensured the efficient application of new technological solutions for the development of a more advanced and modern society.

Geodesy as a science is experiencing an expansive development made possible by the application of new digital technologies. In the very beginnings of land measurement, the main means were ropes and chains, and the rate was used as a measure of length. The rapid development of appropriate instruments and technological discoveries has enabled us to have new instruments, information and communication technologies, GPS devices, at our disposal today. Thanks to the development of new technological solutions, a great shift has been provided compared to previous periods. One of the technological achievements are digital technologies and drones, which we deal with in this paper.

Unmanned Aerial Vehicle (UAV) or drone is an aircraft intended for unmanned flights, with which it can be remotely controlled or programmed to fly. It consists of the aircraft itself and other appropriate control or programming components necessary to control the aircraft. They can be managed or programmed by one or more people. They were initially used for military purposes to observe enemy units or movements, reconnaissance and espionage. The rapid development and cheaper production has enabled the use of drones for civilian purposes. They can be used to help locate and rescue, monitor certain areas, access dangerous areas without endangering human lives and other purposes.

Certain unmanned systems have also found application in geodesy. In the field of geodesy, Professor Wester-Ebbinghaus was the first to use a helicopter drone for photogrammetric purposes in 1980. [1]. Drones are not new in the field of innovation because they have been around for a long time, but their implementation in geodesy is relatively new and still evolving. The drone has its greatest application in geodesy in the field of aerial photogrammetry. By collecting data and subsequent photogrammetric processing, 3D point clouds, digital surface model, digital orthophoto and the like can be

created. From them, lengths can be measured, volumes calculated and profiles created. The geodetic profession effectively monitors the development of new technological solutions and increasingly uses them in its work.

The application of drones in geodesy is still an under-explored area. Their most common application in the field of geodesy is for photogrammetric purposes, for making 3D models of objects, digital terrain models and digital orthophoto plans. The application of drones in geodesy enables the production of geodetic bases that can be used effectively in a large number of areas.

II. USE OF UNMANNED AIRCRAFT FOR MAKING A DIGITAL ORTHOPHOT

Photogrammetric products that can be obtained on the basis of photographic images obtained with the help of cameras carried by drones are numerous. Appropriate single images can be used in almost all phases of spatial planning. Higher quality products are obtained by transforming the plane of projection into a plane parallel to the ground. If the observed soil we can see that it has different relief shapes, and the obtained photographs may contain errors. Only differentially rectified photographs geometrically clearly show the observed soil, so they can be considered as cartographic representations.

The overlaps of several such representations are called orthophoto maps and they are one of the most common photogrammetric products obtained using drones. In addition to orthophoto maps, it is possible to create numerous other cartographic representations from photogrammetric image data. The most common among them are planimetric, topographic and thematic maps.

III. EQUIPMENT AND SOFTWARE USED

The main backbone of all computer programs for processing digital camera photos is the SFM (Structure from Motion) algorithm. SFM is a relatively inexpensive way to reconstruct a high-resolution topography. This method eliminates the need for "a priori" known position and orientation of the camera as well as the need to use a network of control points of known coordinates determined by precise geodetic methods. The precondition for the successful application of this procedure is the high redundancy of the input data, more specifically the distinctive features that are automatically separated from a set of multiple overlapping photographs. This approach gives the best results when using a set of images with a large overlap area that encompasses the entire three-dimensional structure of the object of interest observed from a large number of different points of view.

A DJI Phantom 3 Professional drone was used for aerial photogrammetric survey. It is a multicopter, more precisely a quadcopter. The frame of the spacecraft is made of carbon fiber to keep its weight as low as possible. The aircraft is powered by a LiPo battery with a capacity of 4480 mAh and a voltage of 15.2 V. The battery weighs 365 g. The sensor of the used device belongs to the CMOS group of sensors, which is standard today in commercial digital cameras of professional quality. [2]. The camera has a maximum resolution of 4000 x 3000, or 12.76 megapixels. An ISO value of 166 was used, and

an aperture value ranging from $F / 2.8$ to $F / 3.61$. The shutter speed was set to $1/1000$ second. The quality of the displayed data can be seen in Figure 1.



Figure 1. Example of a photograph taken (source: Institute for Physical Planning of the City of Mostar)

The use of control points during photogrammetric recording is necessary for the needs of precise engineering works. The reasons for this are multiple. The control points serve so that the obtained photogrammetric products can be adequately georeferenced [7]. According to them, objects are formed, ie characteristics, which are clearly recognizable on the ground. Care must be taken that the markings are of appropriate dimensions, ie that they are clearly recognizable in photographs at the desired flight altitude. Care should be taken that its colors are in contrast with the surrounding terrain and that it is placed in a visible position, ie that it is not obscured in any direction of flight by higher vertical objects, vegetation or their shadows [3]. In this work, white rectangular plates were used, and black circles were marked on the front. An example of the label used is shown in Figure 2.



Figure 2. Used checkpoint markings (source: Institute for Physical Planning of the City of Mostar)

IV. PLACE OF USE AND QUALITY OF PHOTOGRAPHY

The area covered by the analysis, ie where certain photogrammetric products were formed, is Vododerina (Blagaj). The input data consisted of a set of 112 photographs and 8 control points. Prior to the processing, it is necessary to pre-process the collected data. Photo preprocessing includes a process supported by the processing software used - Agisoft Photoscan. It is a process of assessing the quality of the collected photographs. This procedure examines the sharpness, ie the level of detail, (Figure 4) of the part of the photo that is most in focus, and the procedure is repeated for each photo separately. Since aerial photogrammetry focuses on all elements of photography, this function is ideal for working with such collected photographs. Based on the assessment, the function assigns a numeric value between 0 and 1 to each photo. It is recommended to eliminate photos with a value less than 0.5

from the processing process because they are considered bad. This feature is useful to automatically eliminate blurry photos whose quality is significantly impaired by the vibrations of the propulsion system and the movement of the aircraft. The conducted testing concluded that all collected photographs were of satisfactory quality for further processing.

For the purposes of data processing, the computer program Agisoft Photoscan version 1.4.5 was used. It is a commercial program owned by Agisoft, and a trial version of the 30-day program was used. The program is primarily intended for the creation of various three-dimensional models from two-dimensional data, or photographs. Photo scan also enables the adjustment of the procedure precisely for the needs of geodetic activities. In addition to 3D models, it is also possible to create digital orthophoto cartographic representations as well as digital height models. The basis of the program used is the SFM algorithm. During the pairing of photos, the algorithm searches for and recognizes the points, ie the characteristics, which are common to individual photographs and connects or pairs them. At the same time, the relative positions of the camera in relation to the observed object are determined at the time of shooting for each photograph, and the camera calibration parameters are corrected. The result is a sparse dot cloud and the sum of all camera positions. Everyone the estimated data are defined in a relative coordinate system and are required subsequently georeferenced. The result of this step is shown in Figure 3.



Figure 3: Sparse dot cloud and the sum of all camera positions

V. OPTIMIZATION OF RESULTS

Optimizing the results obtained in the previous step is the most demanding step, and probably has the greatest impact on the final quality of the display geometry. After the iterative procedure in the previous step has been used to estimate the camera positions at the time of shooting, they need to be refined to obtain the highest quality results. Camera position optimization begins with correcting a sparse point cloud. The available tools need to manually remove all points in the point cloud whose position is visibly misjudged [4]. This is followed by manually placing the markers as shown in Figure 4 and defining the coordinate system.



Figure 4: Placing markers in the appropriate places in the photos

Depending on the needs and possibilities, the available time and the amount of clearly recognizable characteristics, it is necessary to manually connect the photos with markers, ie. they need to be marked on the appropriate pairs of photos. The accuracy of the model is the difference between the calculated 3D coordinates (from the cross section of the beam) and the actual coordinates (measured by the GNSS receptor). In order to obtain an objective measure of accuracy, it is necessary to use Check points whos coordinates are known, but are not used when calculating the model. The quality control procedure consists of the following: it is necessary to turn off marker B1, run the Optimize cameras command and write the obtained value in the table and repeat the procedure with other markers. Table 1 shows the values obtained for each marker.

Table 1. Values for each marker after quality control

| Kontrolne tačke | Vrijednosti (cm) |
|-----------------|------------------|
| B1 | 9,9545 |
| B2 | 5,8173 |
| B3 | 15,8434 |
| B4 | 11,8769 |
| B5 | 3,7908 |
| B6 | 0,7684 |
| B7 | 7,874 |
| B8 | 4,7397 |

The highest value of those shown in the table is the accuracy of the model.

The next step is to create a dense cloud of dots. The point cloud is obtained based on the estimated positions of the cameras and photographs. The new view is significantly denser than a sparse point cloud. When starting the procedure, it is possible to select the desired quality level and filter the output point cloud. Each higher level of quality brings four times more points and twice the positional accuracy of each point. This consequently slows down and complicates the further process. The average level of quality was used in this paper. The result of this step is shown in Figure 5.



Figure 5: Dense point cloud

The next phase is the development of a three-dimensional model of the so-called. mesh. In this step, the points of the dense point cloud are interconnected into small triangular elements. Hence the other name of this model, which is an irregular network of triangles. This creates a network of polygons, ie triangles that represent the surface of the observed scene. Software usually contains two partially different algorithms for creating a grid 3D model. One is adapted to work with flat, planar surfaces, and the other is used for all other types of buildings. For the purposes of aerial photogrammetry, the first mentioned algorithm is used. Defining the total number of triangles is left to the program,

since in this way the optimal value for displaying the desired area is selected. The method of interpolation is also accepted, which closes the holes in the dense cloud of points created due to insufficient data. Texture can be added to the described 3D model. This procedure significantly improves the visual impression and is necessary in order to create an adequate orthophoto representation based on the model. There are several ways to assign texture to the resulting model [5]. For the needs of aerial photogrammetric products, it is recommended to choose a mosaic display, so it was used. Figure 6 shows the obtained 3D model and a sample of the 3D model.



Figure 6. 3D model and sample 3D model

When the 3D model is completed, it is possible to create an orthophoto view and a digital height model based on its data. The process of making the mentioned photogrammetric products is fully automated. It is necessary, as with each step so far, to determine the desired parameters. When creating an orthophoto view, it is necessary to select the desired coordinate system in which it will be georeferenced. You need to choose how to create the texture. Also, it is necessary to define the desired pixel dimension, or the desired spatial resolution. The program itself calculates the maximum spatial resolution it can offer and which makes sense to choose [6]. In this case, the spatial resolution is 2 cm. The process of making a digital height model is analogous to the process of making an orthophoto with one difference. Since it is an evenly distributed grid of points with corresponding three-dimensional coordinates, there is no need to select the desired texture. The resolution for the digital model height in this case is 10.2 cm. Figure 7 shows a digital orthophoto, an enlarged orthophoto detail, and a digital elevation Model



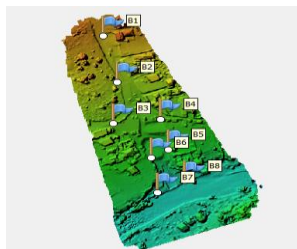


Figure 7: Digital orthophoto, enlarged orthophoto detail and digital elevation model

CONCLUSION

Drones are not new in the field of innovation, but their application in certain areas is relatively new. They are now finding application in all spheres of life, and here we have presented their application in geodesy. Their use has numerous advantages such as economy, speed, obtaining accurate and quality recording results, recording inaccessible surfaces, and protection of people who are exposed to danger in their work.

Our aim in this paper was to present the application of drones and to show the production of photogrammetric products using Agisoft Photoscan software, and the appropriate digital altitude model for the observed area.

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