Универзитет у Бањој Луци I Архитектонско-грађевинско-геодетски факултет
University of Banja Luka I Faculty of architecture, civil engineering and geodesy
ISSN 2303-6036 **UDK** I UDC 72

АГ Г+

[7] 2019 7[1]

АГГ+ часопис за архитектуру, грађевинарство, геодезију и сродне научне области
ACEG+ Journal for Architecture, Civil Engineering, Geodesy and other related scientific fields

084-094 **Стручни рад** I Professional paper
UDK I UDC 528.7:623.746.2-519
DOI 10.7251/AGGPLUS1907084V
Рад примљен I Paper received 15/03/2019
Рад прихваћен I Paper accepted 22/07/2019

Miroslav Vujasinović
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka, vujasinovic.vm@gmail.com

Jelena Nedić
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka, jelena_n93@hotmail.com

Biljana Antunović
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka, biljana.antunovic@aggf.unibl.org

Miodrag Regodić
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka,, miodrag.regodic@aggf.unibl.org

ПРИМЈЕНА АМАТЕРСКИХ БЕСПИЛОТНИХ ЛЕТЈЕЛИЦА У ФОТОГРАМЕТРИЈИ

APPLICATION OF AMATEUR UAV IN PHOTOGRAMMETRY

Стручни рад
Professional paper
Рад прихваћен I Paper accepted
22/07/2019
UDK I UDC
528.7:623.746.2-519
DOI
10.7251/AGGPLUS1907084V

Miroslav Vujasinović
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka, vujasinovic.vm@gmail.com

Jelena Nedić
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka, jelena_n93@hotmail.com

Biljana Antunović
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka, biljana.antunovic@aggf.unibl.org

Miodrag Regodić
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Stepe Stepanovića 77/3, Banja Luka,, miodrag.regodic@aggf.unibl.org

APPLICATION OF AMATEUR UAV IN PHOTOGRAMMETRY

ABSTRACT

With the advancement of technology in the last ten years and the cheaper development of microchips, new technologies are available for everyone. In addition to high-performance computers, relatively low-cost drones have been developed. This paper presents the possibility of using unmanned aerial vehicles in geodesy as well as flight planning, flight execution, processing of collected data, describes the basic components of the quadcopter, data collection procedure, processing methods as well as accuracy of the obtained results.

Key words: *UAV, Photogrammetry, orthophoto, SfM*

ПРИМЈЕНА АМАТЕРСКИХ БЕСПИЛОТНИХ ЛЕТЈЕЛИЦА У ФОТОГРАМЕТРИЈИ

АПСТРАКТ

Напредовањем технологије у посљедњих десетак година и јефтинијим развојем микрочипова развијане су и нове технологије доступне свима. Поред рачунара са високим перформансама, развијене су и беспилотне летјелице са релативно ниском цијеном. У овом раду представљена је могућност примјене беспилотних летјелица у геодезији, планирање лета, извођење лета, обрада прикупљених података, те су описане и основне компоненте летјелица, поступак прикупљања података, методе обраде као и тачност добијених резултата.

Кључне ријечи: *УАВ, фотограметрија, ортофото, SfM*

1. INTRODUCTION

Photogrammetry is a scientific field that deals with the collection of reliable 3D information about physical objects and the environment through the process of capturing, measuring and interpreting images. The goal of photogrammetry is the faithful reconstruction of the captured 3D space. The reconstruction of 3D spaces from photographs gives the coordinates of the points that are closely connected with the captured objects, maps and plans, topographic maps, orthorectified photos, digital terrain models, digital 3D object models. The reconstructed points are determined without making actual contact with the measurement subject, and it is possible to determine their accuracy.

1.1. RELATED WORK

The problems and principles that photogrammetry deals with have been described in both domestic and international literature. New technologies such as the use of unmanned aerial vehicles in surveying have attracted particular interest and numerous scientific and professional papers have been written in this field. The paper from A. Žilić [6] defines a method for land surveying using SenseFly eBee drone and creating point cloud, digital terrain model and digital orthophoto map. Development of unmanned aerial vehicles and applications in engineering geodesy is a problem that has been addressed in the paper written by authors M. Gašparović and D. Gajski [7]. In the paper by the authors F. Chiabrando and L. Teppati Losè [8], used several UAVs to comparison of image quality, flight operations, flight planning and accuracy.

1.2. TESTING AREA

The area where the experiment was conducted is part of the University of Banja Luka students' campus. The area is located on the banks of the river Vrbas, in the eastern part of the city. Campus is semi-built, with tall trees and lots of greenery, the area has been declared to be a monument of park architecture, with over a hundred plant species, with a Platanus alley over 100 years old.

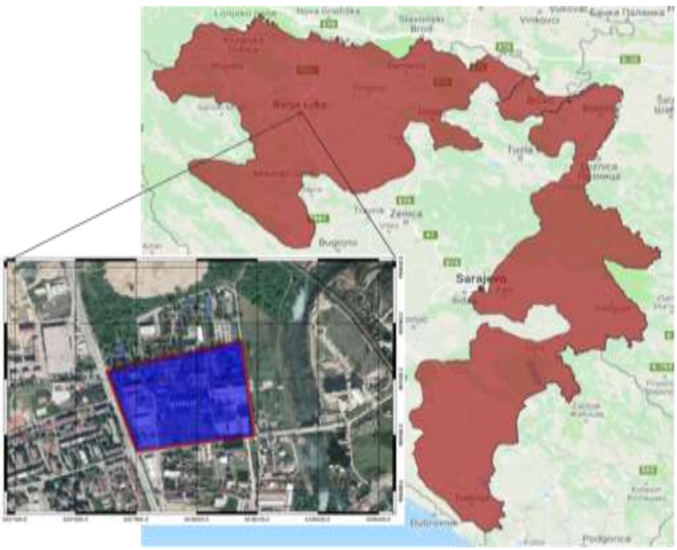


Figure 1. *Study area*

2. UAV TECHNOLOGY – QUADCOPTERS

Multirotor UAVs requires the least expertise and therefore are the most common choice for amateurs. Numerous benefits, most often reflected in the relationship between their capabilities and the required financial investments, make them popular in the professional field as well.

The control of multirotor drone is carried out by the pilot or operator, via radio transmitters. The operator gives the commands, the radio receiver receives them on the multirotor drone and executes them. The operation of the aircraft is governed by the navigation system, using the available sensors to monitor the operation of electric motors that move propellers. This whole system is powered by battery [1].

In order for the UAV to be used in geodesy, it is necessary to be equipped with appropriate measuring equipment, which can be a digital camera, LiDAR or other aerial photogrammetric system.

Unmanned aerial vehicle components with propellers are as follows:

- *The quadcopter frame*, which is the basic structural component of the aircraft, can be made of different materials (carbon fiber, aluminum, fiberglass, etc.)
- *The navigation system*, a major component of each aircraft, automatically controls the flight by using sensors to evaluate the current state of the aircraft.
- *The receiver and transmitter*, are the control units and enable the operator to operate the aircraft.
- *Telemetry*, enables the transmission of data between the unmanned aerial vehicle and the ground station. All measurements made on the flying platform are transmitted from the navigation system on the aircraft to the mission planning program on the laptop.
- *Real-time image transmission* equipment to operate the aircraft out of sight requires the application of real-time image transmission.
- *Ground stations* are an indispensable part of the system that enables the recording and measurement of drones. The ground station is the control segment, which manages the aircraft and monitors operations.
- *Battery*, high power density, or the ability to store large amounts of energy in a small package, has made it possible to use it widely, from mobile devices, computers, to drones.

DRIVE SYSTEM:

- *Propellers*, which convert the operation of electric motors into thrust and thus push the air back to propel the aircraft in the desired direction.
- *An electric motor*, is an electrical device that converts electrical energy and mechanical operation. In spacecraft this refers to rotation of the propeller.
- *The electronic speed controllers*, connected to the power supply, is a device that, based on the signal from the receiver, controls the speed of rotation of the electric motor and it enables the control of the aircraft.

Figure 2. *Quadcopter DJI Phatnom 3 [6]*

3. DATA AQUISITION

The main advantage of using unmanned aerial systems, as well as other modern technologies, is to save time and money. In order to maximize the savings of these resources, it is necessary to take precautionary measures, including: carefully determining the flight plan and checking the equipment needed so that the data collection could be done with a minimum number of field trips.

The necessary equipment for the task is: aircraft, remote control, aircraft and remote control batteries (charged), SD card, propellers, tablet / phone, USB cable.

The flight is preceded by a trip to the field to check if there are any obstacles that could make it impossible to work. The determined ground situation is followed by the definition of the flight plan, which in this case was done in the *Pix4DCapture* application. It is also advised that the first connection of *Pix4DCapture* or *DJI Go* to the aircraft be made before leaving the field because a stable connection to the wireless internet is required.

3.1. FLIGHT REALIZATION

The flight time of 0.164km^2 test area was approximately 17 minutes. The flight was performed at the height of 50m with a transverse overlap of 75% and a longitudinal overlap of 70%. 313 photos were taken with a spatial resolution of 2.19cm/px.

The basic steps in flight execution were:

- Determining location on a map;
- Connecting phone and remote controle with USB cable;
- Removing gimbal holder;
- Placing the aircraft at the take-off point;
- Activating the remote control;
- Turning on a drone;
- Launching the *DJI Go* application, determining whether the application is connected to the aircraft;
- Setting up the camera in the *DJI Go* application;

- Launching *Pix4Dcapture* App and
- Selecting the START option in the application.

After completing the above steps, the application takes over control of the aircraft and the flight is performed automatically according to the defined plan shown in Figure 3.

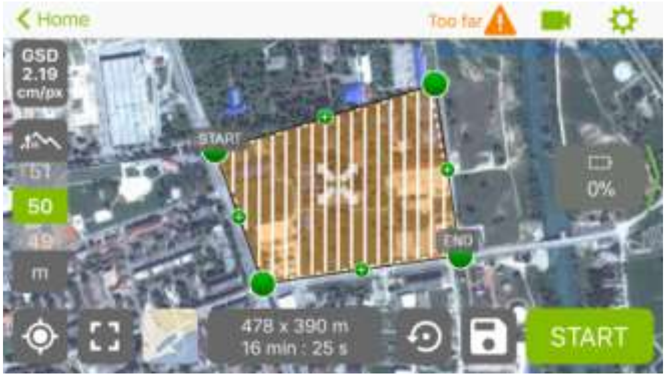


Figure 3. *Selected area at the Pix4Dcapture App*

4. DATA PROCESSING

4.1. PRINCIPLE OF PHOTOGRAMETRY

Photos are two-dimensional and the location of any point in the image can be represented with only two coordinates: *x, y* - latitude, longitude.

The real world is three-dimensional and the location of any point in the real world can be described by three coordinates: *x, y, z* - latitude, longitude, altitude.

Photogrammetry is the science of using 2D photographs for accurate measurements in 3D space. In order to do this, it is necessary to reconstruct in some way the information lost in the recording process.

Problem: A ray of light falling on a given pixel of an image could have come from any point along the direction of the ray (Figure 4A).

Solution: Adding another photo taken from another location can determine the cross-section of the beam, and thus the 3D location of the point from which the rays arrived (Figure 4B).

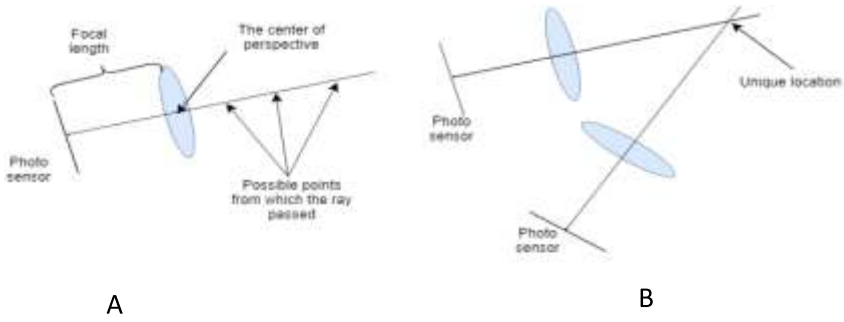


Figure 4. *Principle of position determination from images [9]*

4.2. STRUCTURE FROM MOTION (SFM)

Structure from Motion (SfM) is a low-cost photogrammetric method for obtaining high-resolution 3D geometry information from 2D images, with reduced need for user supervision, ideally suited for low-budget research and application in remote areas. SfM is laying on the same basic principles as stereoscopic photogrammetry, which provides the possibility to reconstruct 3D structure from a series of overlapping images, acquired from different observation points. The advantage of SfM over conventional photogrammetry is that reconstruction is possible using a cheap consumer-grade camera. However, the main difference is that SfM determines camera positions and orientation is solved automatically and without need to predefine a set of visible, ground control points with known 3D positions [2] [3].

The first stage of SfM is the processing of acquired images by Scale Invariant Feature Transform (SIFT) object recognition system to identify most prominent common feature points, often called keypoints or points of interest, across the entire image set [4]. Those keypoints are invariant to the image scaling and rotation and partially invariant to changes in illumination and orientation, while their number mainly depends on the resolution and texture of the image [2].

After identification of the feature points, a sparse bundle adjustment is applied to determine camera pose (camera model parameters and camera orientation) and to triangulate a sparse point cloud in a relative local 3D coordinate system. The main reason for the use of bundle adjustment is to minimize possible errors in the estimation of camera poses. [5] Each feature point must be identified on at least 3 images to be used for the point cloud generation. The following step is densification of the sparse point cloud using Multi-View Stereo algorithms, e.g. Clustering Views for Multi-View Stereo (CMVS) and Patch-based Multi-View Stereo (PMVS2), which generates high-resolution 3D models, while isolating and removing gross errors.

To be able to use such generated point cloud in the real-world project it is necessary to transform it into an absolute coordinate system. This can be achieved through manual identification of GCPs in the point cloud and calculation of appropriate transformation parameters [2].

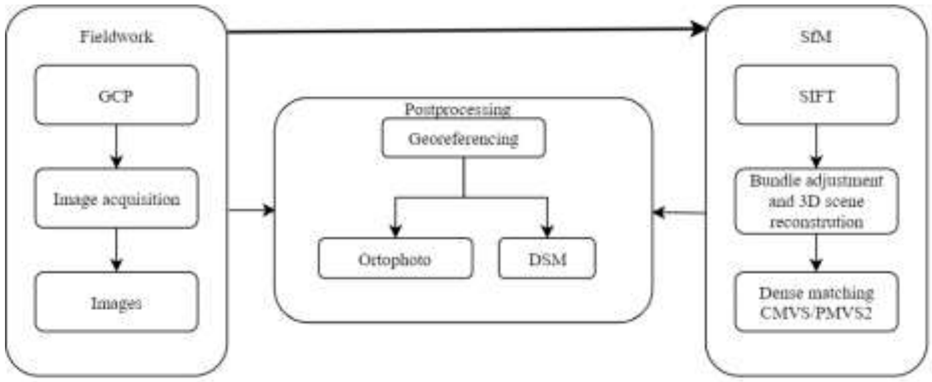


Figure 5. *From image to orthophoto and DSM*

4.3. PROCESSING PROCEDURE

In addition to the detailed preparation and execution of the flight, the most important thing for digital orthorectified imaging is image processing, which is fully automated. It is done in three steps:

1. Initial processing – photos and additional input data, such as control points, are used to:

- Definition of key points: identifying specific characteristics as key points of images;
- Key point matching: finding images that have the same key points and linking them;
- Optimization of the camera model: calibration camera parameters;
- Geolocation: determining the location of the model if geolocation information is provided.

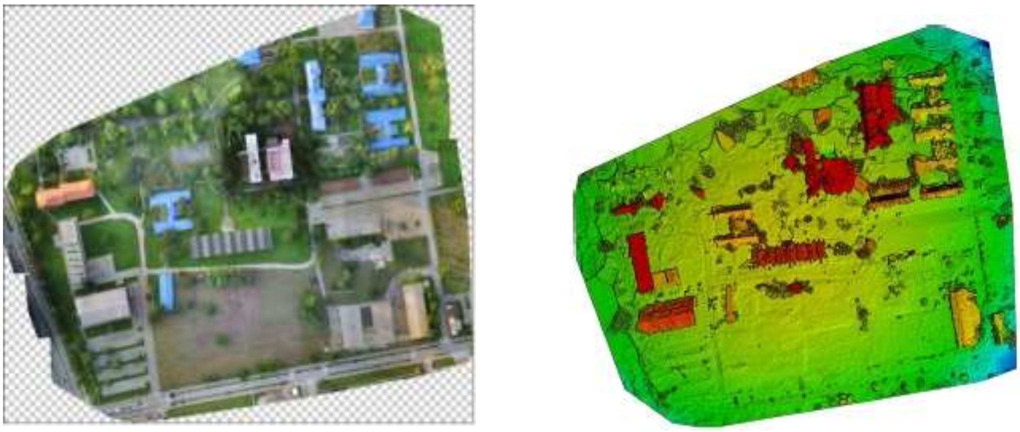
During this phase, automatic tie points are created, which form the basis for the next steps.

2. Point Clouds – Dense Point Clouds with 3D Texture are added to automatic tie points:

3. Digital surface model, orthomosaic and index map creation:

- Digital surface model: enables volume computation, orthomosaic design and reflection map;
- Orthomosaic: created by orthorectification, a procedure that removes perspective distortions from recordings;
- Reflection map: the goal is to create a map where the value of each pixel faithfully represents the reflection of the object;
- Index map: creating a map where the color of each pixel is determined based on a mathematical expression that combines different reflection ranges.

After completing the above three steps, a digital orthophoto image was obtained in TIFF format. The most important product that can be further used for various purposes as described above. Figure 6(A) shows a digital orthophoto, and Figure 6(B) shows the corresponding digital surface model.



A B

Figure 6. *Ortophoto (A) and Digital Surface Model (B)*

5. RESULT AND DISCUSSION

Data acquisition can be considered as successfully performed since the recommended criteria for the quality of the produced digital orthophoto are satisfied, in terms of horizontal (xy) accuracy while vertical (z) accuracy exceeds the interval. Lower accuracy in the z axis was expected, because control points were used as 2D points. The following table presents the criteria and values obtained for this project.

Table 1. *Accuracy parameters of the executed project*

	Max value	Obtained
Camera optimization	5%	4,37%
Spatial resolution		2,2 cm
Relative accuracy (95%)	Horizontal: 1-3 x GSD=2,2-6,6 cm Vertical: 1-3 x GSD=2,2-6,6 cm	Horizontal : 3,9 cm Vertical : 8,2 cm
Absolute accuracy (95%)	Horizontal : 1-2 x GSD=2,2-4,4 cm Vertical : 1-3 x GSD=2,2-6,6 cm	Horizontal : 3,9 cm Vertical : 8,2 cm

Figure 7 shows the deviation of the theoretical (blue points) and calculated values (green points) of the position of the image, as well as the control points. Situations such as XY plane, XZ plane and YZ plane are given. The ellipses indicate the absolute position of the points.

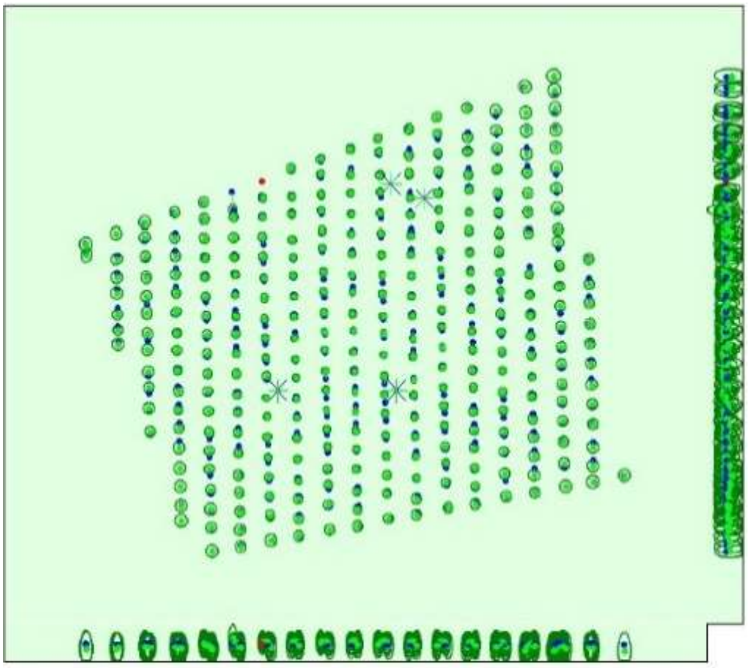


Figure 7. *Uncertainty Ellipse*

Figure 8 shows the overlapping images. According to legend, red and yellow represent poor overlap, while green indicates excellent overlap – over 5 images for each pixel.

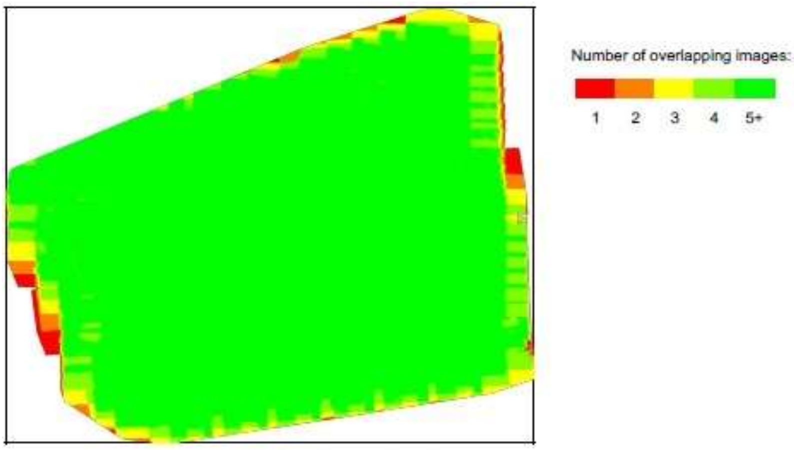


Figure 8. *Overlapping of images*

The survey methods developed over time, which resulted in a reduced amount of time, people and financial assets needed to acquire data, while at the same time they increased the accuracy and precision. In Table 1 the time needed to conduct the survey with different work methods are presented. This statistic is based on the measurement with only one work team.

Significant difference in time and human resources required to collect data in the same area by traditional geodetic methods. The criteria are taken from the Geodetic Standards of the Republic of Serbia.

Table 2. *Comparison of different methods for mapping*

Method	Number of workers needed	The area that can be surveyed in one work day	Number of days needed for a survey of 17ha
Orthogonal method	2+4	1,7 ha	10
Polar surveying	2+3	2,2 ha	8
GNSS method	2+3	2,2 ha	8
Satellite images	-	-	1
UAV	2	25ha	1

6. CONCLUSION

The benefits of using this technology have been validated through numerous scientific papers. The process of planning, executing and processing the photos can be completed in just a few hours with brief preparations. Due to the disadvantages of conventional survey methods, which is primarily related to the high cost, the use of drones has a greater advantage. The data set obtained by processing the images collected by UAV technology is richer in content than the data collected by conventional methods. The disadvantage of this technology is the short flight duration due to the low battery capacity. The solution to this problem would be to have a higher capacity battery or to plan more flights for larger areas and process it in a unique model, which is a recommendation for further research.

7. LITERATURE

[1] Medić, T.(2015). „Izmjera nepristupačnih područja pomoću bespilotnih letjelica“, Diplomski rad, Zagreb: Geodetski fakultet

[2] M. J. Westoby, J. Brasington, N. F. Glasser and M. J. Hambrey, (2012). “Structure-from-Motion photogrammetry: A low-cost, effective tool forgeoscience applications,” Geomorphology, vol. 179, pp. 300-314

[3] N. Micheletti, J. M. Chandler and S. N. Lane, (2015). “Structure from motion (SFM) photogrammetry,” in Geomorphological Techniques, S. Cook, L. Clarke and J. Nield, Eds., London, British Society for Geomorphology

[4] M. James and S. Robson, (2012). “Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application,” Journal of Geophysical Research, vol. 117, no. F3

[5] S. Bianco, G. Ciocca and D. Marelli, (2018). “Evaluating the Performance of Structure from Motion Pipelines,” Journal of Imaging, vol. 4, no. 8

[6] A. Žilić, (2015). „APPLICATION OF UNMANNED AERIAL VEHICLES IN GEODESY ON THE EXAMPLE OF AERIAL PHOTOGRAMMETRIC SYSTEM SENSEFLY EBEE“, Geodetski Glasnik, vol. 49, no. 46

[7] M. Gašparović, D. Gajski (2016) „Unmanned Aerial Photogrammetric Systems in the Service of Engineering Geodesy", International Symposium on Engineering Geodesy – SIG

[8] F. Chiabrando, L. Teppati Losè, (2017)"PERFORMANCE EVALUATION OF COTS UAV FOR ARCHITECTURAL HERITAGE DOCUMENTATION. A TEST ON S.GIULIANO CHAPEL IN SAVIGLIANO (CN) – ITALY", Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W6, 77-84

[9] K. Kraus (1993). „Photogrammetry, Vol. 1: Fundamentals and Standard Processes", Dunler, Bonn

[10] DJI Phatnom 3(september 2019). Internet: https://www.dji.com/phantom-3-standard