Annals of the University of Oradea, Fascicle: Environmental Protection Vol. XXXIII, 2019
Analele Universităţii din Oradea, Fascicula: Protecţia Mediului Vol. XXXIII, 2019

PHOTOGRAMMETRIC PROCESSING APPLIED TO WATER MANAGEMENT FOR NH TOPOLOVĂȚU MIC, TIMIȘ COUNTY

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Abstract

Using aerial vehicles without pilot (UAV-unmanned aerial vehicle) or Drone has seen a rapid development, over the last decade, in order to obtain spatial information of the Earth's surface. This scientific paper was realized for the Hydrotechnical Node of Topolovățu Mic, from Timis County and has as purpose the processing of aerial images, obtained from a Phantom4 Pro device, which is capable to capture video at 4K resolution at 30 frames per second and Full HD 1080p at 120 frames per second for a slow motion with a Sony EXMOR camera that can take photos at 20 megapixel, with a maximum flight speed of 20m/s.

The device is equipped with positioning equipment, which connects to both GPS and GLONASS, allowing it to connect faster to satellites and position itself with high accuracy in the air. Phantom 4 automatically records the details of each flight made, so you can check your previous flights.In order to achieve the 3D model, were used oblique and vertical images with the highest accuracy. Nadir imaging was performed at an average height above ground (AGL–Above Ground Level) of approx. 113m. The imaging data was processed with the AgiSoft PhotoScan program using a number of 273 aerial images (total 287 aerial images). For image processing, the sotware proposes for each processing stage, different parameters that determine the precision and time of the final processing of the Topolovățu Mic Hydrotechnical Node.

The images were georeferenced using the control points from the ground. In the present paper, in order to achieve georeference, with very high precision, we have use of 18 control points (total 26 GCP) situated on the ground (GCP-Ground Control Points), which were determined in the field using a GNSS receiver in RTK mode (Leica GS08), obtaining coordinates in the Stereographic Projection System 1970. So, data exported from PhotoScan have provided textures, clouds of points, orthomosaics in red, green and blue spectral bands, obtaining a final precision of georeference by milliseconds order. The RMS error values being 0,029480 m on X; 0,041659 m on Y and 0,042573 m on Z, a resolution of 8,28 cm/pixel. From the 273 aerial images georeferenced on 18 GCP control points, were obtained 32.119.272 points.

The final stage of the data processing work includes the generation of orthophotomaps, mosaics, and raster images, in TIN and DEM formats as well as the generation of clouds of point (Point Cloud). Combining 2D and 3D, which allow classifying points and filter them for accurate objects modeling. At the end of aerial data post-processing UAV, were generated topographic models, was made data export in various formats, including Google Earth and LIDAR files (LAS), which then could be processed and viewed with other special programs such as: Global Mapper, Google Earth, Surfer, AutoCad, CloudCompare.

Key words: UAV, point cloud, ortofotoplan, AgiSoft PhotoScan, GCP, GNSS

INTRODUCTION

Use of UAVs is ideal to purchase research data at resolutions ranging from 0.5 to 2 cm. The programs used to process monitoring and reconstruction data may vary, as price, from the most expensive to the ones obtained as Open Source, obtaining data at high resolution (Rusnák, Miloš et al., 2017). Although UAVs have their origins in military contexts, they have also become valuable for scientific and commercial applications, especially during the previous decade (Nex and Remondino, 2014). The use field of UAVs is multiple, in civil applications, the reconstruction of high resolution surfaces (Anders. et al., 2013), the realization of cultural heritage and archeology sites, hydrology (Șmuleac, et al., 2017), in agriculture for monitoring the crops (Zhang. and Kovacs, 2012), in order to manage natural disasters, in topography (Șmuleac. et al., 2016) and mapping (Herbei. et al., 2016) and mapping (Barnes,. and Volkmann, 2015) and wildlife observation (Koh, and Wich, 2012), in engineering (Uysal, Toprak, 2015). In this context, Pajares offers a detailed review of the wide range of applications of remote sensing based on UAV (Pajares, 2015).

Turner and his colleagues in 2015 highlighted the fact that it is the latest technology to realize digital photogrammetry in real time, as well as to obtain a land elevation model (DEM), but with the inconvenience of not realizing images under dense vegetation (Turner et al., 2015). UAV photogrammetry generates high resolution topographic data essential for 3D terrain modeling. Operations approached for UAV imaging and data processing consist of several essential steps: preparation of UAV equipment, calibration, establishing control points (GCP), point cloud processing and analysis as well as obtaining orthophotomaps. Indeed, remote sensing methodologies and techniques for 3D modeling of a cultural patrimony allow the generation of very realistic 3D results that can be used for a variety of purposes, such as the development of historical documentation (El-Hakim et al., 2007), and the realization of digital preservation, monitoring in time of objectives with UAV technologies (Bruno et al., 2010) and viewing 3D data.

With regard to photogrammetric data analysis, software programs uses different approaches, both with commercial solutions and with open source solutions (Remondino F. et al., 2014; Agisoft PhotoScan, 2014).

MATERIAL AND METHOD

In order to obtain the aerial data required for this study, the research was divided into 4 stages, namely: stage 1 refers to the preliminary study, stage 2 to the positioning of the GCP control points, stage 3 to obtaining the aerial data, stage 4 refers to processing of aerial data. At the same time for the acquisition of data for mapping with UAV equipment, the following steps will be taken: land recognition and identification of possible hazards in order to make the flights, identification of take-off and landing points, placement of control points at the ground (GCP), aerial imaging of the area of study, quality assurance and data processing, data precision assessment, image processing with **Agisoft PhotoScan Professional Version**: 1.4.0 build 5650 (64 bit), 3D mapping and 3D extraction operations, cloud point grading and orthophotomaps.

RESULTS AND DISCUSSION

This research was carried out on the Topolovățu Mic Hydrotechnical Node, located in Timis County at approx. 60 km from the city of Timisoara and approx. 10 km from the city of Lugoj, which is located strategically at the Timis-Bega discharge channel on the Timis River. The purpose of this Hydrotechnical Node, built in 1758 by engineer Maximilian Fremaut (an engineer who carried out essential water management works in the 18th century in Banat) being one of the oldest arrangements from Romania, is to deviate in drought weather the waters of the Timiș River in the Bega Channel, in order to balance the flow or otherwise to divert the water from the Timis River to the Bega River.

Land Recognition and setting **Ground Control Point (GCP)** was **the first step** in the aerial image collection process. In order to complete the data processing operations including georeferencing, a number of **18** control points (**GCP**) were used, points that were determined with the **Leica GPS** model, **GS08**, using the **RTK** method (Table 1, Figure 2). Managing control points (GCP) and the correction of those locations are particularly important for carrying out accurate mapping with UAVs. Three or more control points (GCPs) are required in order to achieve the georeferencing of the obtained orthophotoplane, but the more the number of them will increase, the better the precision and the quality of the data acquisition will be of high precision. After the AgiSoft PhotoScan user manual, at least 10 control points (GCPs) are required to referencing the model, and they will need to be distributed in lines or create regular patterns, such as equilateral triangles. Another relevant condition for distributing control points is their arrangement at different vertical heights (at different altitudes, if this is possible), including their positioning on riverside, canals, terraces, as well as the parameters for making the flight plan.

To achieve the 3D model and get the point cloud (**Point Cloud)**, were used oblique and vertical images for the best accuracy. Nadir imaging was performed with an AGL (**AGL** Above Ground Level) of 13. The aerial images were processed with the AgiSoft PhotoScan program using for processing **273 aerial images**.

The set of 273 images from the shooting flights were uploaded to **AgiSoft PhotoScan**, and the control points from the ground determined with the **GPS** equipment were identified and positioned manually (Figure 3). In PhotoScan, the tagging algorithm is a priority and requires considerable verification and adjustment by the human operator for placement of the marker point. Marking centers have been carefully checked and manually adjusted where it was necessary. Coordinates for those **18 GCP** points were loaded and an initial alignment was performed (Table 2)

Table 1

Presentation of coordinates of GCP soil control points in Stereographic 1970 Projection System, NH Topolovățu mic

GPS point No.	**X (m)**	**Y (m)**	**Z (m)**	**GPS point No.**	**X (m)**	**Y (m)**	**Z (m)**
GPS1	478944,7491	238505,967	102,9181	GPS14	478846,8925	238491,049	102,3714
GPS2	478891,8496	238420,72	102,3054	GPS15	478825,2726	238443,122	102,2533
GPS3	478897,9112	238467,129	102,0203	GPS16	478823,3087	238490,39	105,3035
GPS4	478892,0439	238387,666	105,7409	GPS17	478990,9908	238574,92	102,8973
GPS5	478947,873	238529,907	99,9782	GPS19	478998,4071	238599,865	102,8633
GPS6	478902,9092	238498,192	99,9478	*TMIC9*	*478872,351*	*238506,115*	*102,6415*
GPS7	478906,4634	238517,078	98,1452	*INT7*	*478935,2289*	*238565,648*	*101,1011*
GPS8	478914,5456	238545,496	98,1054	*INT6*	*478902,5447*	*238516,549*	*98,053*
GPS9	478893,0948	238551,349	100,0047	*INT5*	*478975,67*	*238530,71*	*106,7927*
GPS10	478882,4946	238505,563	99,9654	*INT4*	*479049,0716*	*238483,42*	*103,3759*
GPS11	478923,0232	238604,629	101,7695	*TMIC1*	*479067,2863*	*238501,567*	*102,1107*
GPS12	478924,383	238634,051	102,7919	*TMIC2*	*479124,9429*	*238508,712*	*102,6469*
GPS13	478869,8698	238549,083	102,8562	*TMIC3*	*479069,033*	*238586,241*	*105,0858*

The steps involved in generating a cloud of points **3D-Point Cloud** along with the estimated position and the position of the camera stations and a solution for camera model parameters are similar regardless of the SfM/MVS software used. To accomplish this study, the main purpose was to ensure that all scenarios were based on the same **PhotoScan** project, resulting minimal differences in processing stages. This study, which contained 273 images of high quality, high resolution, from both nadir and oblique flights, has an overlap of 80% -90%. Any gloss of water (reflector) was masked from each image. The GPS navigation data on the UAV equipment was used to geocode the images, so an initial alignment was made based on these approximate positions.

Fig. 1. The type of target use in field

Fig. 2. Leica equipment GPS Leica GS08 use to determinated the target

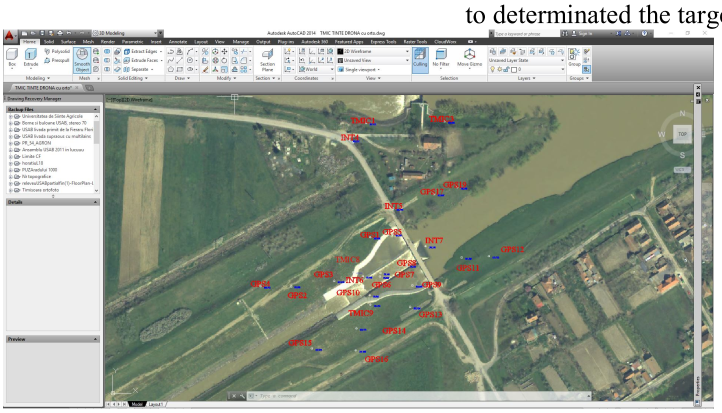


Fig. 3 – Identifying markers at the ground (GCP)

The 19 GCPs were loaded into the project, and primary alignment based on image coordinates helped identify the markers from each image. Each marker has been reviewed and edited when it is necessary, in order to ensure that it has been located and centered in as many images as possible. Once these markers were placed (Figure 4), the baseline project was used to: analyze and change the coordinate system for the drones images (Figure 4).

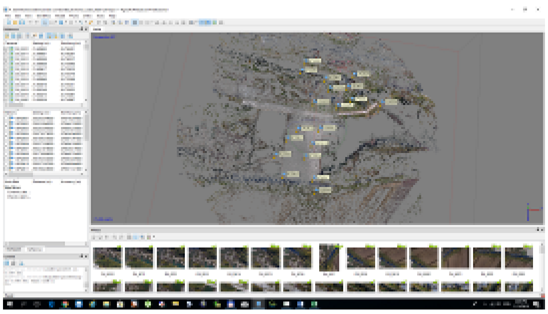


Fig. 4 – Presentation of GCP ground points

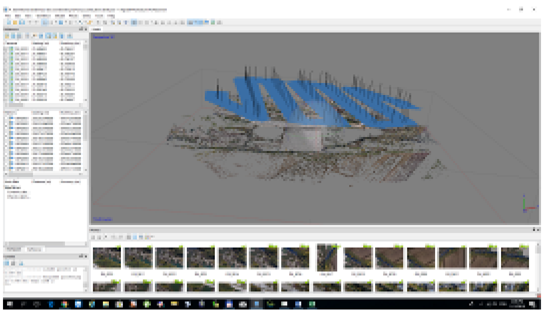


Fig. 5 First alignment of aerial images

The steps taken to process the data were as follows

1. Importing photos and viewing the WGS1984 coordinates obtained - 273 images were imported (Figure 6).**Calibrarea imaginilor cu AgiSoft Lens**.

2. Gross data processing and **image alignment with Agisoft PhotoScan Professional** Version: 1.4.0 build 5650 (64 bit). It was found that from each image was extracted 40000 points

3. View the **errors of the ground markers** at the time of their completion and their positioning on land marks from the ground (Table 2).

4. Obtaining dense point clouds (**Build Dense point Cloud**) - For a results near reality with high resolution, we will go on representing the cloud points by opting for Hight and an aggressive filtering (Figure 6).

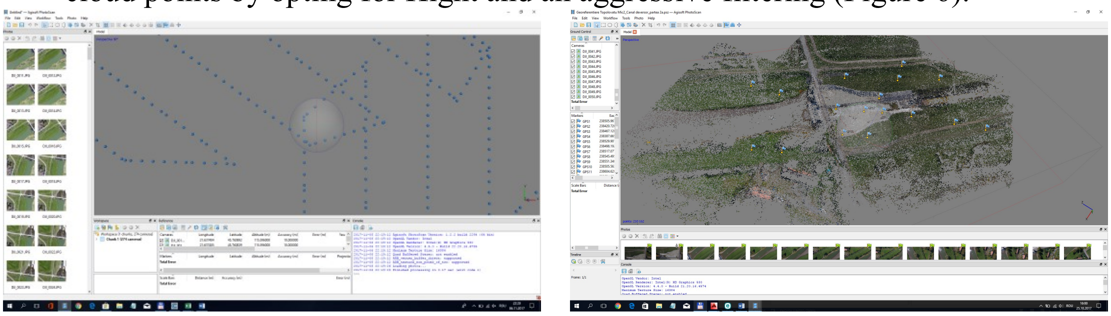


Fig. 5 – Importing the aerial images in WGS 1984 coordinates

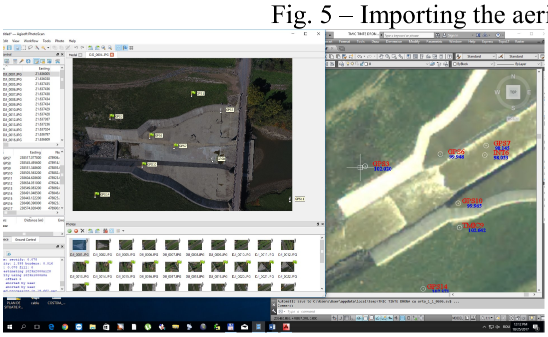


Fig. 4 – Control ground point presentation

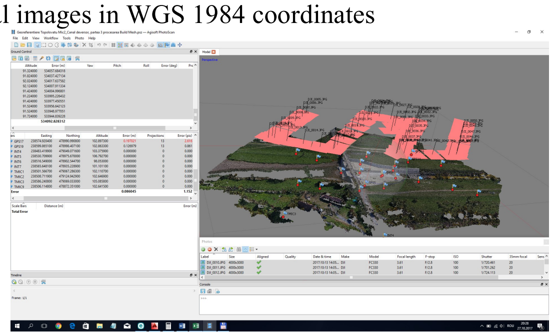


Fig. 6 – Presentation of the point clouds

5. Mesh Representation (**Construction Mesh**) - PhotoScan reconstruction parameters support several reconstruction methods, which ultimately help to achieve optimal reconstruction for a particular set of data. **The polygon contour (Polygon Count)** specifies the maximum number of faces formed in the mesh. Additionally, the following advanced parameters can be adjusted: polygon type, namely high (**Height**) in our case we have a number of 32.119.727 points. If we had opted for a poorer generation of point clouds we would have: for the Medium module **(Medium)** a number of 16.119.058 points, for the low module (**Low)** a number of 2.832.594 points or it can opt for a custom module **(Custom)**. The result of Mesh generation can be seen in Figure 7.

6. Creation of 3D model's texture (**Building model texture**) - texture mapping mode determines how the texture of the object will be wrapped in the texture atlas. The correct selection of the texture mapping mode helps to achieve an optimal texture packaging, in consequence, a better visual quality of the final pattern obtained. Textures mapping methods (**Mapping mode**) shall be taken into account, by texture generation parameters (**Blending mode**) and the text dimension and number size (**Texture size/count**). In addition, other parameters can be adjusted **Advanced Parameters**. In Figure 8 is presented the result obtained.

7. Building the faience pattern (**Building Tiled Model**) - Data hierarchy format is a good solution for urban scale modeling. Enables fast 3D viewing of high resolution of 3D models, an open sandstone model with Agisoft Viewer - a complementary tool included in the PhotoScan installation package. Data processing lasted 7 hours and 12 minutes.

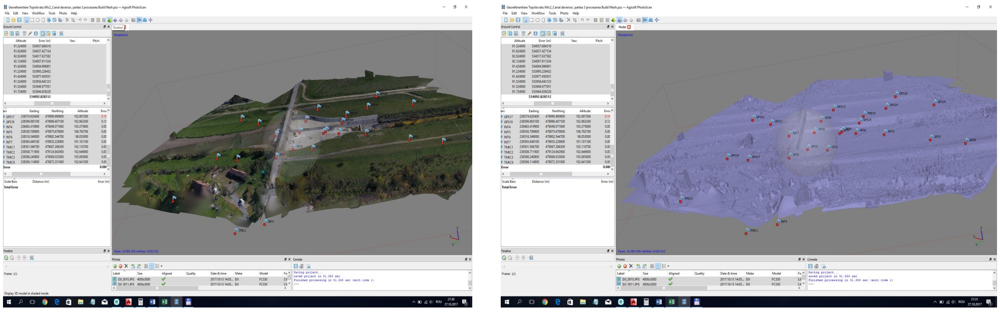


Fig. 7 – Obtain Mesh (Shaded to the Left and Solid to Right)

8. Making the Digital Elevation Model (**DEM**).

9. Obtaining Orthophotlan (**Build Orthomosaic**) based on aerial images and alignment of images on control points from the ground. In the continuation of the study, the newly obtained georeferenced Orthophotoplan (in 2018) was inserted in the **AutoCad** program where we compared the GPS data taken with the GSP Leica GS08 equipment (table 3), and then compared the new orthofotoplan with another older orthophotoplan from 2010, the results can be seen in Figure 9. Both Orthophotoplans are georeferenced in the Stereographic Projection System 1970 and superimposed over the **GCP** points taken from the **GPS.**

10. Final report of the paper covering all steps taken, the precisions, the images used, the number of control points, DEM, Mesh and the realization of the georeferencing.

Table 2

Presenting the coordinates of GCP control points and their errors in AgiSoft PhotoScan for NH Topolovățu Mic

The pictures	X error	Y error	Z error	Error (m)	Error (pix)
GPS1	-0,00082	-0,05338	-0,05578	0,086585	0,865
GPS2	0	0	0	0	0
GPS3	0,036718	-0,01016	-0,05006	0,066342	0,682
GPS4	0	0	0	0	0
GPS5	0,111514	-0,10573	-0,03657	0,166920	0,852
GPS6	-0,01769	-0,05901	-0,04148	0,051342	0,498
GPS7	-0,02703	-0,05565	0,044331	0,089025	0,628
GPS8	0,098082	0,206393	0,100105	0,294918	1,039
GPS9	0	0	0	0	0
GPS10	0,240903	-0,05648	-0,04699	0,284375	1,445
GPS11	-0,12949	-0,1157	-0,01983	0,143166	1,055
GPS12	-0,1046	-0,04651	-0,03665	0,101849	0,237
GPS13	-0,13328	-0,11733	-0,08312	0,169012	0,653
GPS14	-0,06569	-0,00166	0,01723	0,057242	1,115
GPS15	0,099543	0,055981	0,252045	0,529738	0,052
GPS16	-0,02441	0,050251	-0,02056	0,048090	1,217
GPS17	0,028593	0,170319	0,071616	0,197021	2,616
GPS19	-0,04183	0,071089	0,079123	0,12679	0,861
Total erori	**0,041659**	**0,029480**	**0,042573**	**0,066461**	**0,607**

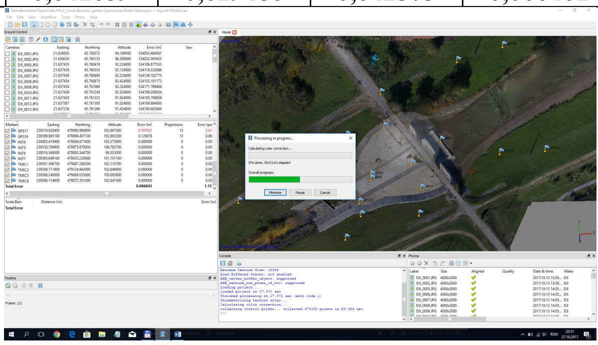
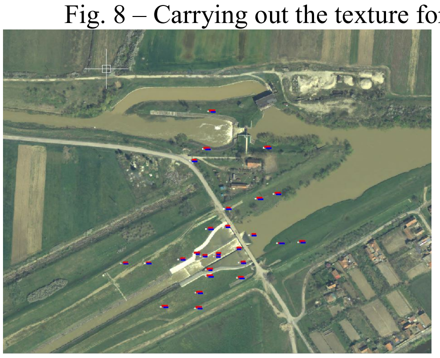
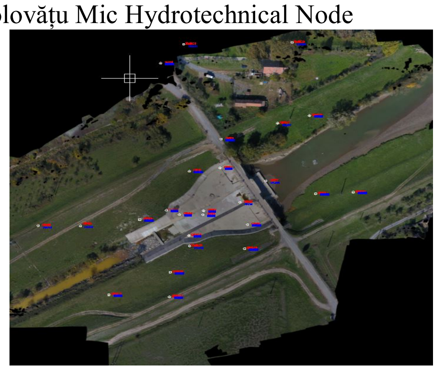


Fig. 8 – Carrying out the texture for the Topolovățu Mic Hydrotechnical Node



Ortofotoplan ANCPI - 2015



Ortofotoplan UAV - 2018

Fig. 9. Presentation of Orthophotlan obtained (right 2018, left 2010), NH Topolovățu Mic, Timiș County

CONCLUSIONS

In this study, photogrammetry data (273 images) were processed using AgiSoft PhotoScan making the georeferencing on the 19 GCP. The image analysis process for image generation includes image alignment, texture, geometry, Dense Point Cloud generation, construction and georeferencing. In addition, this can be done with Open Source programs, namely: Bundler, PMVS, Pix4D Mapper, AgiSoft PhotoScan, Photosyntch or ARC3D. It is very essential to make an assessment of the accuracy and accuracy of the acquired data and as a result the final 3D model and geometry calculation.

This is particularly important for topographic models in which they successfully undergo modeling, carrying out volumetric calculations based on daytime sky clouds obtained from air flights. The total number of points-**Points** being 32.119.727, resulting a DEM of 8,196x5,180, and 8,28cm /pix.

The purpose of this work is to create a 3D database on the current state of the Hydrotechnical Node and on time monitoring, the realization of orthophotoplanes necessary for the realization of the heritage documentation as well as the realization of the situational plans based on the ground and air elevations for the design and renovation of the node.

This material presents the current presentation of the hydrotechnical node through the creation of geo-referenced orthophotoplanes and the point clouds can be used in conjunction with terrestrial laser scanning to complete the top of the constructions and to visualize in time the riverbeds.

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