3D MAPPING OF A VILLAGE WITH A WINGTRAONE VTOL TAILSITER DRONE USING PIX4D MAPPER

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Abstract. Today, many photogrammetric mapping methods have used drones to retrieve and record data about objects on earth. This is due to the fact that the use of a drone equipped with GNSS (Global Navigation Satellite System) for measurements is very efficient and cheaper compared to renting an aircraft, it also allows flying over hard to reach areas and significantly reduces the time. The development of UAV technology in Romania is still in its infancy, and the legislative framework imposes certain restrictions even for small drones. Thus, in order to use the aircraft, the approval of the Romanian Civil Aeronautical Authority is required, as well as an approval from the Ministry of National Defense. In this way, flights are regulated in terms of distance, altitude and area. The purpose of the research was the realization and technical detailing of a workflow for the generation of orthophotoplans and three-dimensional models, by photogrammetric techniques (UAS/UAV), which can be used in various topo-cadastral works or as primary geospatial data in overlay analysis, in various other fields: urbanism, agriculture, spatial planning, geomorphology, etc. This paper presents the results of the application of UAV photogrammetry data in the mapping of Labaşinţ locality from Arad County, using a WingtraOne VTOL tailsiter drone, equipped with a Sony RX1RII camera with a 42.4 megapixel CMOS sensor, 35 mm, fullframe and a GNSS system. high precision. The final stage of data processing includes the generation of orthophotoplanes, mosaics, raster images, TIN and DEM formats as well as the generation of point clouds. The use of drones in the field of geospatial science is currently in high demand due to its relatively easy operation and relatively affordable cost compared to satellite systems, especially high resolution images. One of the benefits of using drones is that they take aerial photographs that are then processed for mapping so that they can be used to support the acquisition of spatial data.

Keywords: WingtraOne, Pix4Dmapper, DEM, DTM, DSM, Labasint, territorial analysis.

INTRODUCTION

If initially the drones (*Unmanned Aerial Vehicle - UAV*) were manufactured and used by defense companies, their cost amounting to several million dollars, nowadays there are many types on the market, including cheap and small drones, which can be controlled by smartphone and which can be used successfully in scientific research.

The last ten years has seen a fast development in the use of drones to obtain space information from the surface of the earth. The use of drones is ideal for the acquirement of research data at resolutions from 0.5 cm to 2 cm. The photogrammetric software used for processing and monitoring data can vary from those obtained as Open Source to the most expensive, thus obtaining data at high resolutions (MILOŠ ET AL 2017).

Compared to traditional or photogrammetric analyzes, flight plans offer a deep operational variety in terms of time, cost and repeatability (NEX, REMONDINO, 2014). Because of this, drones are considered to be complementary to the traditional remote sensing platforms. Given the functional and economic side, we can say that compared to the market, it is developing for commercial manufacturers and civil applications of UAVs (HAARBRINK, 2012).

UAVs are in present a valuable source of data for mapping, inspections or 3D modeling (WALLACE ET AL. 2016; COJOCARIU ET AL. 2015; PRODANOV ET AL. 2020). Fixed-wing or rotary drones are able of purchasing photogrammetric data with digital cameras and they can fly in

autonomous, semi-automatic or manual modes. Following a exemplary photogrammetric workflow, the 3D results can be produced such as vector information, textured 3D models, field models, contours, even on large surfaces. (NEX ET AL. 2014; ŞUMULEAC ET AL. 2015).

A drone can be used to study large areas, when national regulations allow, for cadastral, cartographic or agricultural applications (HABIB ET AL. 2016; POPESCU ET AL. 2017; ŞMULEAC ET AL. 2016). The images obtained have a high resolution if the flights are performed at an altitude of 80-120 m above the ground (SIMON ET AL. 2017; RIEKE ET AL. 2011).

The quality of the 3D point clouds obtained is very high and this data can thus be used for analysis and for extracting the characteristics of the various components of the environment.

In this sense, the purpose of the research was the realization and technical detailing of a workflow for the generation of orthophotoplans and three-dimensional models, by photogrammetric techniques (UAS/UAV), which can be used in various topo-cadastral works or as primary geospatial data in overlay analysis, in various other fields: agriculture, urbanism, spatial planning, geomorphology, etc.

MATERIALS AND METHODS

The research presented in this paper - case study - was conducted in western Romania, south of Lipova, Arad County, in the commune of Şiştarovăţ, Labaşinţ village (Figure 1) located in a hilly area part of the Lipovei hills.
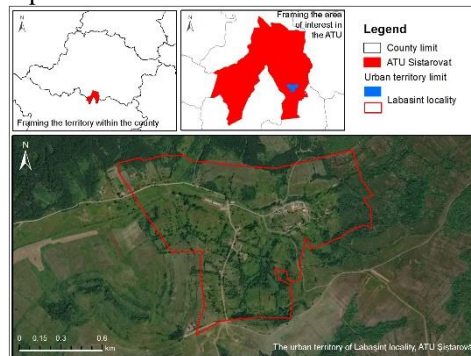

Figure 1 Location of the study area (processing after ANCPI; geospatial)

The studied area is located on the meridian of 21^o45^IE and the parallel of 46^o4^IN, 69 km from Timisoara, 10 km S-E of Lipova and on the NW direction 42 km from Arad.

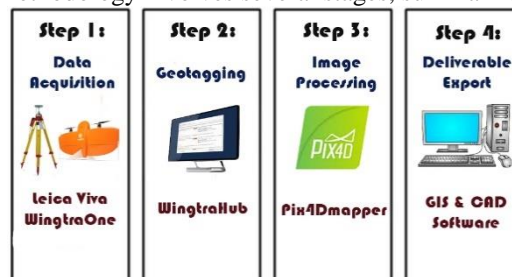The working methodology involves several stages, summarized in Figure 2.

Figure 2. Working methodology

WingtraOne is a fixed wing drone that has VTOL - *Vertical Take-Off and Landing* (Figure 3), ie takeoff and vertical landing (PRODANOV ET AL. 2020). This means that it does not

involve throwing from the hand or from a launching system on rails, thus avoiding possible accidents. In addition, vertical take-off allows us to avoid obstacles, during a hand or catapult launch, there is a risk of misjudging the distance to trees, mountains or buildings. With the help of VTOL, these risks disappear, the drone goes straight to the sky, without obstacles in its way.

Figure 3 WingtraOne and Leica Viva GS08

WingtraOne switches to horizontal mode by tilting 90° in the air. After entering the horizontal flight mode, similar to that of an airplane, the drone flies at a speed of 60 km/h. No piloting skills are required to fly with this type of equipment, the missions are fully autonomous and operated by an advanced autopilot (WINGTRA-ONE, 2021). However, it is always possible to take control of the drone both vertically and horizontally.

WingtraOne weighs 4.5 kg and has a wingspan of 125 cm, being equipped with dual frequency GNSS equipment, which uses GPS-NAVSTAR, Glonass and is prepared for Galileo and Beidou. The operational cruising speed is 60 km/h and the ascending cruising speed is 20 km/h, with a wind resistance of up to 45 km/h and a maximum flight time of up to 55 minutes depending on the atmospheric conditions. A minimum space of 2 m x 2 m is required for take-off and landing, the maximum altitude at which it can fly is 3 km (WINGTRA-ONE, 2021). The camera, Sony RX1RII, is the best quality for high resolutions with a 42.4 megapixel CMOS sensor, 35 mm, fullframe and ISO 50-102400 (SONY, 2021).

GNSS recordings will be made using a Leica Viva GS08 antenna (Figure 3). This smart antenna is the universal GNSS instrument for obtaining a professional reliability when we need a very high precision (LEICA VIVA GNSS). The antenna will be used as a reference station, its location being made in an area without obstacles, with visibility to satellites and with minimal interference. The antena will collect RINEX observations at 1 Hz.

The final step of data processing includes the realization of raster images, mosaics, orthophotoplanes, DEM and TIN formats as well as the realization of the 3D point clouds. At the final of the processing of aerial data will be generated topographic models, the data can be exported in different formats, including *kmz* or *kml* for Google Earth, which can then be viewed and processed with other special softwares.

The post-processing of the collected data will be done with the help of software Leica Infinity, WingtraHub si Pix4Dmapper.

RESULTS AND DISCUSSION

In this study we performed a photogrammetric flight over the village of Labaşinţ using the UAS - WingtraOne PPK system. Unlike the DJI Phantom 4 Pro that we used in previous research (SIMON ET AL. 2018), which is a quadcopter drone, WingtraOne is a tailsitter type (TURNER ET AL. 2017).

The flight plan was made according to the urban limit of the locality exported from the Integrated Information System of Cadastre and Land Book (e-Terra) in shapefile format. This shapefile represents the flight plan that the drone will go through. In order to do this it was

necessary to convert the *.shp* file to a *.kml* file using the Global Mapper program. This file type is compatible with the flight mission software, WingtraPilot, which will build the optimal flight path to cover the study area.

As the flight was carried out in the built-up area, it was necessary to obtain the approval of the Ministry of National Defense regarding the flights performed for topographic determination activities at a scale greater than 1:20.000, aerial photography or aerial filming, performed with aircraft and drones. In this regard, I sent to the Ministry of National Defense, the Section Overflight, aeronautical relations and regulations, the Department Operations with unmanned aircraft on board, the necessary documents for issuing the filming permit. These documents include: an application containing data on the applicant, technical data on the aircraft, data on the aircraft operator and data on the flight. In addition to this request, the drone identification certificate, the technical specifications of the drone, a map of the required operating area as well as the certificate of competence - remote pilot will be attached.

In the WingtraPilot application on the tablet, after we have set the safety parameters, we will set the take-off/landing point as the home point, a setting that is done automatically based on the coordinates given by the drone's GPS. Once the home point is established, we can proceed to upload the flight plan, respectively the *.kml* file that was copied to the tablet (Figure 4). It will appear over the previously downloaded map and we can see the position of the drone but also information about the route.
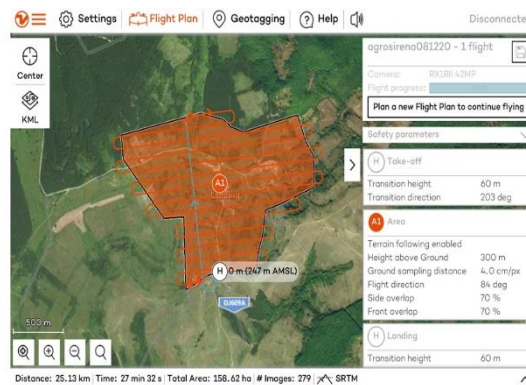

Figure 4 WingtraPilot interface

Next, we will set other flight parameters. First we set the height at which the drone will make the transition from vertical to horizontal, in our case this transition will take place at an altitude of 60 m. Then we establish the area where the transition from 60 m to the altitude will take place. at which the flight will take place.

The altitude at which the drone will fly will be determined, it will be 300 m. We can also change the route it will travel in flight and the degree of overlapping images. After setting all the elements we will have a preview of the mission, we notice that the drone will fly a distance of 25.13 km in a time of 27 minutes and 32 seconds and will cover an area of 158.62 hectares of 279 images.

If we are satisfied with the route created, we still have to make a final checklist (WINGTRAHUB), it must be completed before the flight and contains 14 stages, some will be done automatically, instead, others must be done manually.

WingtraOne with the PPK module allows high-precision mapping without the need for ground control points (GCP) to correct a map generated from its captured data (LALAK ET AL.

2020). Geographic labels on images are corrected to centimeter accuracy after flight. This is done by comparing the WingtraOne PPK raw measurements of the satellite locations with the raw measurements obtained through a base station that acts as a reference station.

Kinematic post-processing uses the correction data of a fixed ground base station to correct the GNSS data of the drone after the flight has been performed (ZHANG ET AL. 2019). This geotagging process takes place in the WingtraHub application where we need the following data: images from the WingtraOne camera; GNSS data from the WingtraOne PPK module; basic files (RINEX) from the reference station.

Base station data recorded from a fixed position during flight serves as a reference for calculating positions for each flight image. RINEX base files must cover the entire flight period (ARROYO-MORA ET AL. 2019), therefore the reference station must be turned on before take-off and stopped after landing.

The drone will then follow its predetermined mission and upon completion it will return above the landing site, where it will be switched to manual mode to land safely.

The post-processing was done with the WingtraHub software in which I selected the project, and then I uploaded the RINEX data as a reference for PPK processing. Next we need to add the location of the reference station with high precision coordinates, these coordinates were later recorded via the same antennas by RTK - *Real-Time Kinematic* method in the WGS84 system and after setting all options, we can start processing. At this moment, we have obtained a *.csv* file in the WGS84 coordinate system, in order to transform this file into the STEREO70 coordinate system, we will use the TransDatRO program provided by ANCPI.

The processing of data sets from WingtraOne in Pix4Dmapper is done in a few simple steps that must be completed only at the beginning of the project (Figure 5), unlike Agisoft PhotoScan which we used in previous research (COJOCARIU ET AL. 2020), where after each step was ready, the next one had to be done and so on.

Figure 5 Importing images and trajectory

After creating a new project, it is necessary to select the images collected by the drone, in this case the 279 images. In the next steps we define the coordinate system we want to use (Stereographic 1970), then select the *.csv* file created for the precision of the image positions. Finally, we choose a processing template, which defines the resolution and quality of the results, the necessary computing resources but also the types of formats we want to offer. For this study we opted for orthophotoplan in GeoTiff format, point clouds in LAS format, but also DSM and DTM elevation models as well as a processing report.

Once you have completed these steps (Figure 6), all you have to do is start processing and wait more or less depending on the specifications of the computer used.
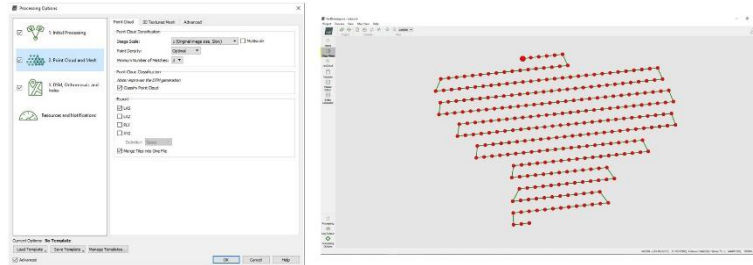
Figure 6 Setting the parameters

At the end of the processing, the quality report of the project will open automatically, the first page of this report is shown in figure 7 where we can view the orthophotoplan made with the DSM and information to the total covered area which was 220.53 hectares although the flight plan was made for 158.62 hectares. This difference of almost 62 hectares results from the fact that the flight was performed at 300 meters and the photos had a large coverage outside the flight plan. The resolution of the orthophotoplan is 3.99 cm GDS.
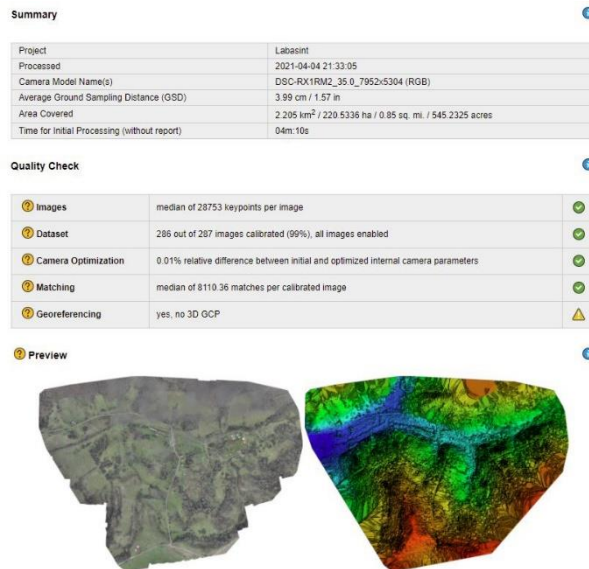

Figure 7 Quality report

The next step is to align the images, the algorithm looks for common points on the images and matches them by finding the camera position for each image (Figure 8). The program then calculates the camera positions and generates the first point cloud.

Another stage of the process is the creation of the orthophotoplan which represents a particularly valuable digital image, through the processing of which a series of quantitative, quantifiable, but also qualitative data and information, respectively attributes, of some registered land surfaces can be extracted (BENOIT ET AL. 2003; COJOCARIU ET AL. 2015).
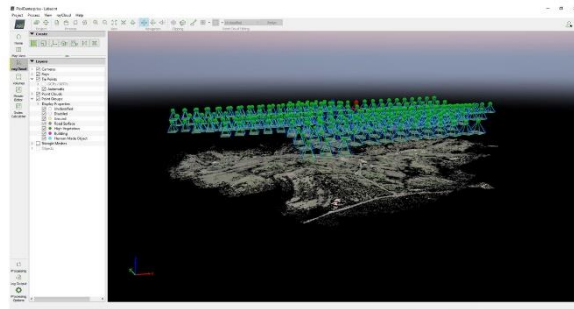
Figure 8 Aligning images

The orthophotoplan in digital format is an aerophotogrammetric product, with very high spatial resolution, georeferenced, which represents photographically a portion of the earth's surface (SEINIC ET AL. 2019). Made from a mosaic of orthophotoimages partially superimposed longitudinally and transversely, the orthophotoplan is actually a photo map that provides accurate visual information on a terrain surface (Figure 9).
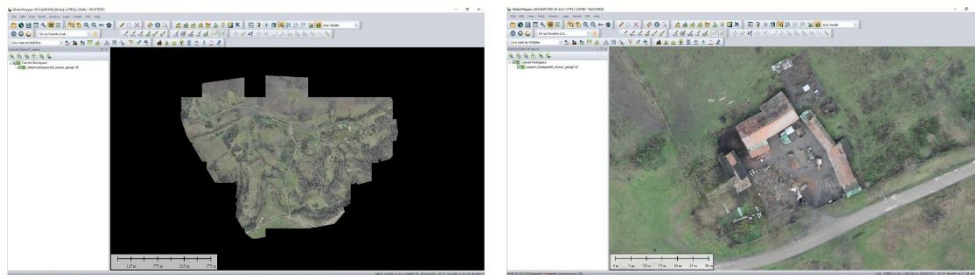

Figure 9 Orthophotoplane view

With the help of the obtained point cloud (Figure 10), we can create representations of the surface, exact measurements and analyze different details. Compared to traditional surveying techniques, the use of this data provides us with a wealth of information and provides us with new ways of analysis, measurement and monitoring.

Figure 10 "Mesh" model of the study area

The software used for data processing has the ability to automatically classify the point cloud into several categories (Figure 11): on the left, the point cloud is colored according to the 6 classes, and only roads and buildings were removed on the right.
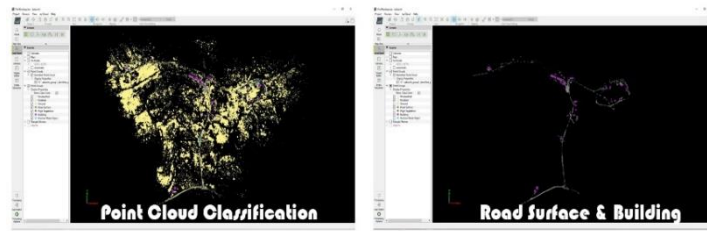
Figure 11 Classification of the point cloud

Another way to visualize the shape of the land in the area of interest is the Digital Elevation Model - DEM, the Digital Surface Model - DSM - and the Digital Terrain Model – DTM (Figure 12).
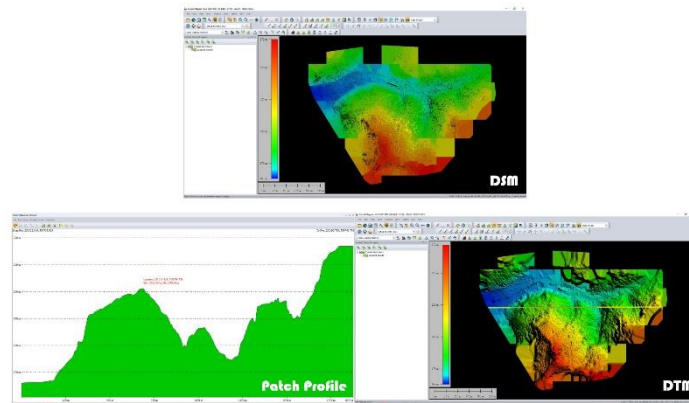

Figure 12 Digital Elevation Models

In the scientific literature (LEMAIRE, 2008, BAILLARD, 2004) are distinguished: Digital Elevation Model (DEM), Digital Terrain Model (DTM) and Digital Surface Model (DSM). In most cases, the DSM represents the surface of the earth and includes all objects on it. Unlike a DSM, the DTM represents the free surface of land without objects such as plants and buildings.

DEMs are the most common basis for digitally produced relief maps. While a DSM can be useful for landscape modeling, locality modeling and visualization applications, a DTM is often required for flood or drainage modeling, land use studies, geological applications and other applications.

The results can also be viewed digitally in Google Earth (Figure 13) by people who do not have specialized software, this data can be viewed on computer, laptop, phone and tablet. With the help of Google Earth and the *Timelapse* function, an changes analysis can be made, by comparison with satellite data recorded over a long period of time (over 30 years).
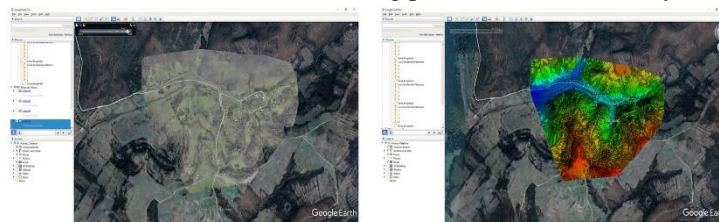

Figure 13 View in Google Earth

235

CONCLUSIONS

The use of a drone gives us the possibility to map inaccessible, dangerous or difficult areas. Measurements are made remotely, leaving no traces during the measurement in a short time and with high accuracy.

The use of the presented method helps us to study areas of interest with large areas, in this case, the mapped area is 220 ha, this mapping was done in 27 minutes, which is very good compared to a classic measurement that was performed in a few days and the details we obtained are far beyond what we could obtain from classical measurements.

The results obtained are orthophotoplanes, digital elevation models or 3D models that can be processed with specialized software, much easier.

The emergence of UAV technology combined with GNSS technology is a step forward in obtaining precision measurements (ȘUMULEAC ET AL. 2017), with an increased working speed. Another advantage of the new technologies is that they do not require measurements of angles and distances in the field, so many of the inconveniences of total stations will be eliminated, thus leading to a reduction in errors and costs.

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