

APPLICATION OF UAVS IN EDUCATION AND RESEARCH

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Abstract: *The paper deals with the application possibilities of UAVs ((Unmanned Aerial Vehicles) in education and in research activities carried out in university level. We can find several software applications for mission planning and execution of flight plans for UAVs (Unmanned Aerial Vehicles) on the market. Some of them are fully free or very cheap, and they are suitable for teaching purposes. Choosing an appropriate evaluation software is also an important issue in education and team research processes. A series of experiments showed us, that the UAS (Unmanned Aerial System) technology is a good tool for deepening the knowledge in photogrammetric evaluation techniques and algorithms.*

Keywords: *UAV, 3D modelling, camera calibration*

1. Introduction

1.1. Short summary of UAVs

In digital photogrammetry the Unmanned Aerial Vehicles (UAVs) are getting to play an important role thanks to their price, efficiency and sophisticated software applications and services. At the same time this rapid spread involves university professors and educators from photogrammetric and remote sensing disciplines to get and share knowledge about the different solutions, possibilities, and requirements to produce photogrammetric outputs and end products in good quality. The digital photogrammetric workstations (DPWs) face new challenges upon processing UAV imagery. This relatively new way of evaluation offers the possibility of automation of essential tasks of photogrammetry, like creating digital terrain models and orthophoto production.

One of the most important problems is to plan and accurately accomplish flight missions with UAVs. During the mission planning we must consider several aspects, parameters and accuracy issues.

In the last few years many producers developed and commercialized various types of unmanned aerial systems. These vehicles are commonly known as drones, but this name was formally used only for military purposes. Professional platforms apply UAS and UAV.

There are many available literatures on this topic and there are factories and users, amateurs and professionals in both cases. It may be expected from real professionals to use more valuable and of course more expensive equipment which bears service background and complete controlling and processing software.

2. Technological process

For the whole technological process when selecting a suitable UAV-serving application we should consider the following aspects to be fulfilled [1]:

- Project Parameters (PP)
- Flight Plan (FP)
- Autonomous Aerial Survey (AAS)
- Data Quality Control (DQC)
- UAV Block Triangulation (UAV BT)
- DSM, Orthophoto, 3D Model (DO3D)

Unfortunately, it is very hard to find a software which completely covers the above listed technological steps. Especially for educational purposes, we need a well suited and easy to understand software with logical procedural steps.

The software solutions dedicated for UAVs can be grouped into three categories:

- Programs for planning and execution of flight plans (PP, FP, AAS and sometimes DQC).
- Programs for evaluation of UAV imagery (UAV BT and DO3D).
- Programs for complete solution (mission planning, execution of flights and evaluation of images).

Let's see some examples:

The Litchi is very popular for its price and simplicity and it is ideal solution for mission planning and flight execution, but it is not designed primarily for photogrammetric purposes, although it is suitable for completing small projects.

The Trimble Inpho UASMaster is a complete Photogrammetric Workstation for UAS and Terrestrial Close-Range Imagery based on well-known algorithms used in photogrammetry for 30 years (see Fig. 1.) The full orientation and evaluation procedure is based on photogrammetric concept and methodology. The software offers highly unified and automatic processes, but it also gives the user the possibility to setup the project parameters in flexible way relying on the photogrammetric engineering knowledge and know-how. With this application we can carry out the following tasks:

- Fully automatic geo-referencing, calibration, refinement and analysis.
- Creation of colorized dense point clouds, surface models and topographic terrain models.
- Creation of classical and true digital orthophotos.

The Pix4D is a set of modules offering solutions not only for mission planning and flight control, but it also covers many end products and solutions. Through the modular concept we can buy a software solution for the application areas of

- Surveying and Mapping
- Construction
- Agriculture
- Mining
- Public Safety

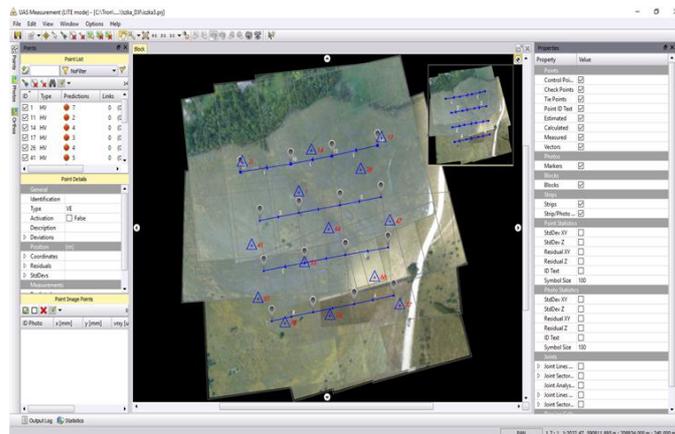


Fig. 1. GUI of UASMaster

3. Camera calibration of UAV cameras

During the camera calibration we need to determine the following parameters [2]:

- f_x, f_y : focal length measured in pixels with x and y components,
- c_x, c_y : coordinates of principal point (the where the camera axis goes through the image plane),
- b_1, b_2 : skew parameters,
- k_1, k_2, k_3, k_4 : parameters of the function describing the radial distortion,
- p_1, p_2, p_3, p_4 : parameters of the function describing the tangential distortion.

This task can be done in many ways. usually we use test fields or patterns with control points. Our faculty has an UAV test field with an area of 200x200 m (see Fig. 2).

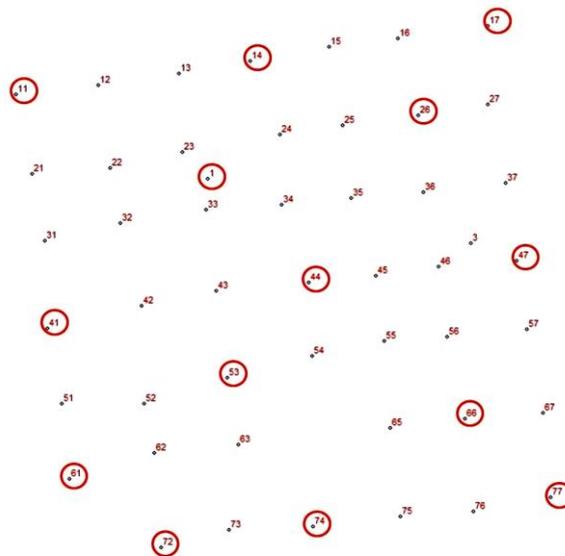


Fig. 2. UAV test field of control points

4. Research options

4.1. Typical research areas for UAVs

At our faculty we have been facing the following topics for research and investigations of photogrammetric processes:

- Aerial triangulation

- Production of digital terrain models and orthophotos

- 3D modelling of buildings and facades

- 3D modelling of interior spaces

- Camera calibration

Let's take one example project from the list above. As an example of a research topic, a 3D modeling of a structure is presented in this paper. Using this 3D model an accuracy assessment also was performed. To obtain images, an aerial survey was performed, using DJI Mavic Pro UAV. For modelling the Agisoft MetaShape software (earlier marketed as Agisoft PhotoScan) was used. The modeled object was a monument (Golden Bull monument) located in the surrounding of Székesfehérvár. The monument was erected in 1972 at the place where the Golden Bull was announced in 1222, which was the first piece of the Hungarian historical constitution.

4.2. Taking Photos

The great advantage of UAVs is the easy, rapid and smooth taking of photos. The aerial surveying could be well planned and automated.

In the case of complex, structured spatial objects, the main advantage of using UAV is that images can be taken from an optimal viewing angle. As a result, there will be no blind spots, no exposed parts (such as the roof of a building in ground training), resulting holes in the surface model. In addition, it is also possible to avoid significant errors in the model due to the small intersection angle of the projecting beams.

However, in 3D photogrammetric modeling, special aspects should be taken into account during the surveying. While the classic aerial photogrammetry survey is done in horizontal flight, this method is not sufficient for 3D modeling, even with oblique images.

In 3D modeling, the spatial object typically has a large vertical (Z) dimension, so it is recommended to take pictures at several levels of height. This is particularly true, for example in the modeling of facade or tower-like buildings, where the vertical dimension is often larger than the horizontal dimension. Another specific point is that the pitch angle of the gimbal of UAV is not around 90 degrees, but rather around 0 degrees.

It is also useful to take advantage of the beneficial features of UAVs in 3D modeling of buildings, but there are fewer opportunities to choose appropriate mission planner software. Such a mission planner and controlling software for this purpose are, e.g. the UgCS with Vertical Inspector function (or Façade Scan Tool) [3], or the 3D Map POI function of the DJI Ground Station Pro (DJI GS Pro) mission planner and flight control software.

The latter, DJI GS Pro, has been used for this modeling project. This software is only available for DJI UAVs and is ported only for iOS. At the same time, basic features, including 3D mission planning, are free, easy to use and comfortable software. [4]

Using DJI GS Pro a flight plan could be established where the UAV operates around a designated point within, at the height between designated altitudes.

For the 3D Map POI function, two flight modes can be used:

- Circle mode — in this case, UAV will fly at different altitudes around the designated point,
- Vertical mode — the UAV operates in the along the vertical lines of the cylindrical surface.

Mission planner has the usual setting opportunities (e.g. image overlapping). Having set all parameters, the mission planner will generate 3D flight path with waypoint for the UAV.

In the real world, however, the surroundings of objects are not always accessible and can be flown freely. Therefore, care should be taken during the planning of surveying. If necessary, the automatic recording must be completed by photographs taken manually or by images taken from the ground. In this recent project, images with UAV were taken at a distance of 15–20 meters.

4.3. Modelling in Agisoft MetaShape

Agisoft MetaShape is today's popular and reliable photogrammetric modeling software. It can be used in a universal way, not only for aerial mapping, but also for the production of a digital elevation model, or for modeling of buildings and variety of objects. Its usability in the research is ensured by the fact that it has a number of options for setting up parameters. The software produces a dense point cloud, or a photorealistic TIN mesh surface fitted to point cloud. In the Agisoft MetaShape pre-calibration of the UAV camera is not required, the calibration will be performed for each image separately (practically every image seems to be a picture taken by different cameras). [5]

The functions of Agisoft MetaShape follow the steps of the photogrammetric process. For the first step image matching and orientation were necessary to be done. This is done automatically by detecting tie point in the images. As a result of the orientation, the spatial position of the images is obtained in the subject coordinate system. Using ground control points (GCP) the model could be transformed into the geodetic coordinate system. For this modeling project the Hungarian HD72 datum was used. As a final product, the dense point cloud and the photorealistic TIN surface model was produced. (See Figure 3.)

Additional products can be derived from the model. True orthophoto, digital elevation model can be produced, and furthermore the 3D model can be exported to other systems.



Fig. 3. Photorealistic TIN surface model generated by Agisoft MetaShape

4.4. Accuracy assessment

In Agisoft MetaShape control point can be marked in the model using the Marker function.

This is a very useful feature in MetaShape, which can be used for a variety of purposes. Markers can be selected in the images. Distances between the markers could be measured on the object in order to increase accuracy of the model. Markers also allow take dimensions from the model. Using markers as ground control point it is possible to transform the model from model coordinate system to geodetic coordinate system, and in addition markers are usable for accuracy testing, as it was performed in the recent project.

The aim of this project was to assess the accuracy of the 3D model and the photogrammetric process. To do this, number of markers was placed around the object and on the object. A total of 44 markers were placed. (See Figure 4.) Coordinates of markers have been surveyed by geodetic method and with geodetic precision. The markers were added to the model too. Markers in the foreground of the object were used for transformation between the model coordinate system and the geodetic coordinate system. A part of markers on the object were used to measure length, and mots of markers were used for accuracy assessment. In this process the computed coordinates of markers were compared the coordinates of physical markers on the object surveyed by geodetic method.

Based on the measurement data, four root-mean-square (RMS) errors were calculated according to the following formulas. Three errors (M_x , M_y , M_z) were calculated according to direction of coordinate axes, one error (M_{xy}) was calculated in the plane XY.

Formulas are the following:

$$M_x = \sqrt{\frac{\sum_{i=1}^n \Delta x_i^2}{n-1}}$$

$$M_y = \sqrt{\frac{\sum_{i=1}^n \Delta y_i^2}{n-1}}$$

$$M_z = \sqrt{\frac{\sum_{i=1}^n \Delta z_i^2}{n-1}}$$

$$M_{xy} = \frac{\sqrt{M_x^2 + M_y^2}}{2}$$

where Δx , Δy and Δz are the difference between measured and calculated coordinates of marker by the three coordinate axes. As a result, the RMS errors were found in the plane XY below one cm (0,7 cm), while in the Z direction the RMS error was 1,3 cm. This means that the 3D photogrammetric procedure can be used in everyday technical practice.

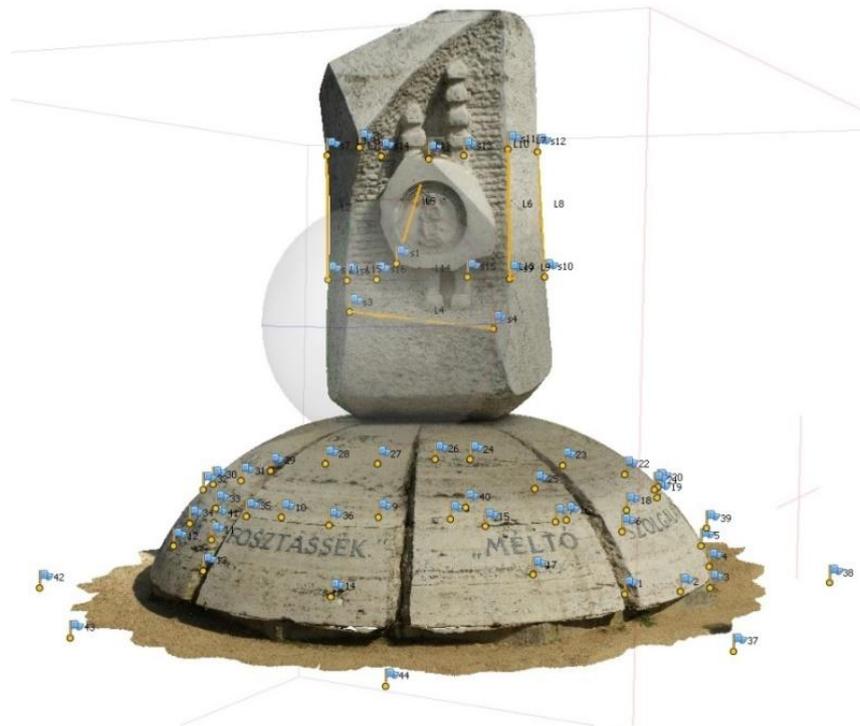


Fig. 4. Markers displayed on the photorealistic model

5. Conclusions

As a summary we can say that the application of UAVs brought new possibilities not only in the research field of photogrammetric tasks and mapping, but it gave also a broad list of tasks to strengthen the practical and theoretical knowledge of students during the teaching subjects like photogrammetry or remote sensing. In this short paper we missed to discuss in detail other important application areas like forensics, archeology, engineering, public safety, geology, etc.

6. References

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