# Aspects of Mission Planning for UAVs

Tamas Jancso

*Institute of Geoinformatics, Alba Regia Technical Faculty, Óbuda University*
*Pirosalma u. 1-3, Székesfehérvár, H-8000, Hungary*
jancso.tamas@amk.uni-obuda.hu

*Abstract*— **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, others are working like services on monthly price basis and few of them have desktop versions with perpetual license. The main question is which software is useful for photogrammetric purposes and which are the most essential parts when planning a flight mission. The paper lists important photogrammetric aspects like flight height, ground resolution, image overlap, flight patterns, and expected measurement accuracy by following an example of a mission plan and execution carried out by the UgCS program.**

***Keywords*— UAV, photogrammetry, mission planning, flight plan**

## I. Introduction

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 professionals form other disciplines and there is an increasing demand to get 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 interior and exterior orientation, digital terrain extraction 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.

## II. Important Aspects

If we decide to plan and carry out flight missions with UAVs, we need to consider several aspects including the following:

- Ground Sampling Distance (GSD)
- Contrast and measurability of points
- Height measurement accuracy (it depends on the base-height ratio)
- Accuracy of determination of ground control points
- Camera calibration accuracy
- Introduction of additional parameters

The GSD value can be calculated from the average photo scale and the pixel size. In order to calculate the average photo scale ($S_{avg}$), we must know the average flight height ($H_{avg}$) and the camera constant or focal length ($c_k$), see Eq. 1 and Fig. 1. [2]

$$S_{avg} = \frac{H_{avg}}{c_k} \qquad (1)$$

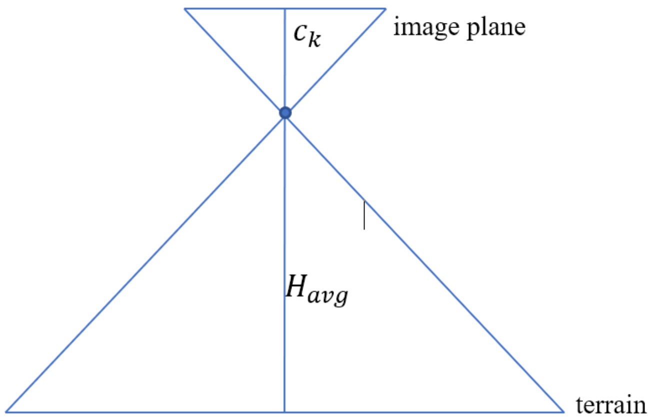


Figure 1. Projection of terrain to image plane

Based on the calculated $S_{avg}$and pixel size $\Delta_p$, we can get the GSD value, in other words the ground resolution by the following equation:

$$GSD = S_{avg} \cdot \Delta_p \qquad (2)$$

The GSD is an important parameter and usually this vlue is the starting point for planning the flight height and other mission parameters. Let's take an example. We intend to reach the GSD value as $5\,cm$. We know the focal length of our camera and its calibrated value is $3.7546\,mm$. The pixel size $\Delta_p$ equals $1.625\,\mu m$. Now our task is to plane the flight height. Substituting $S_{avg}$ from Eq. 1. to Eq. 2. and expressing $H_{avg}$, we gain the following equation and result:

$$H_{avg} = GSD \cdot \frac{c_k}{\Delta_p} = 0.05\frac{3.7546}{0.001625} = 115.5\,m$$

In UAV projects usually we use ground control points and these points are better being artificial signs. Besides the GSD, the size, form and colour of these signs will affect the measurability. Concerning the size, the main thumb rule is to use signs at least 10 times larger than GSD value. Which means in our example of sign size of 50 cm. As you can see in Fig 2., the original sign even with a good contrast and suitable size can be hardly visible in photos. Therefore, it is a good strategy if we test several forms with different colours before we apply the signs in real projects.

Figure 2. Ground control point sign and its image

To keep in mind the GSD value is important from another aspect as well. The positional (horizontal) measurement accuracy can be estimated as 1/3 of GSD. Besides the GSD, the vertical measurement accuracy $\sigma_Z$ also depends on the height-base ratio ($\frac{H_{avg}}{B}$) by the following equation:

$$\sigma_Z = \frac{GSD}{3} \cdot \frac{H_{avg}}{B} \tag{3}$$

The height-base ratio also affects the angle between the intersecting projection rays of stereo images and this angle affects the vertical measurement accuracy as well. As shown in Fig, 3, the same image coordinate uncertainties give different error ellipses around point P in object space [1].

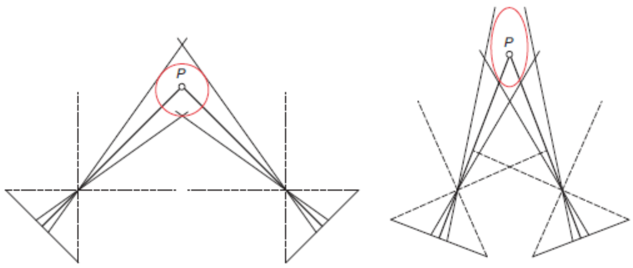


Figure 3. Intersection of projection rays

Based on these considerations, as an example, the maximum available vertical accuracy as a function of average flight altitude at 60% overlap and 1/3 base ratio equals 0.1 ‰. For example, at flight height of 115 m, the maximum attainable $\sigma_Z$=1.15 cm.

## III. Some Examples

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

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

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 example for these categories.

### A. *Litchi for DJI Mavic / Phantom / Inspire / Spark*

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 [4].


Figure 4. Main screen of Litchi application

Among the operational types we can find useful functions as it is shown in Table I.

Table I.
Functionality of Litchi

| Function/Mode | Useful for photogrammetry | Short description |
|---|---|---|
| FPV | No | It allows you to fly the aircraft manually using the joysticks. |
| Waypoint | Yes | It allows you to setup classic waypoint missions |
| Mission Hub | Yes | It lets you plan waypoint missions from a desktop or laptop PC |
| Follow | Not really | It causes the aircraft to follow the movements a subject. |

| | | |
|---|---|---|
| Orbit | Yes | It causes the aircraft to circle around a point of interest while optionally having the gimbal keeping focus on it. |
| Focus | No | It allows you to easily keep a subject (Point of Interest or Mobile Device) in the video frame while flying the aircraft manually. |
| Panorama | Yes | It allows you to easily shoot horizontal, vertical and spherical panoramas. |
| Track | Only for special projects | It uses state of the art computer vision algorithms to track a selected object on the video preview and keep it in the frame. |

### *B. Trimble Inpho UASMaster*

It 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. 5.) 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.

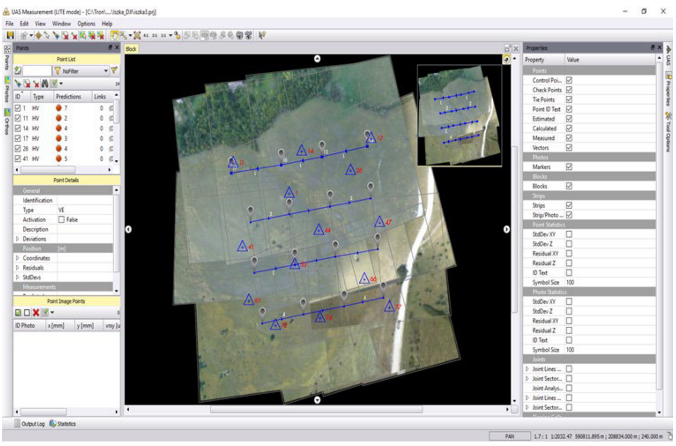

Figure 5. Measurement of tie and control points in Trimble UASMaster

### *C. Pix4D*

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 (see Fig. 6.). Through the modular concept we can buy a software solution for the application areas of

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

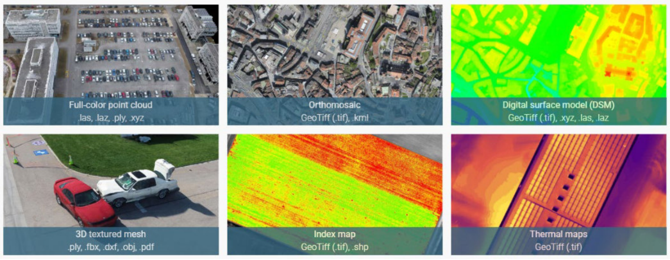


Figure 6. Possible export formats in Pix4Dmapper

In Table 2. we can see the different possible end products for each software module [3].

TABLE II.
PIX4D MODULES

| Module | End products | Purpose |
|---|---|---|
| Pic4Dmapper | - Full-color point cloud<br>- Orthomosaic<br>- Digital surface model (DSM)<br>- 3D textured mesh<br>- Index map<br>- Thermal map | Accurate 3D maps and models, purely from images |
| Pic4Dbim | - 3D point cloud<br>- Classified point cloud<br>- Orthomosaic<br>- DSM<br>- 3D textured mesh<br>- Contour lines | 3D mapping software for earthworks and construction management |
| Pic4Dfields | - Orthomosaic<br>- DSM<br>- Field boundaries<br>- Vegetation index map<br>- Zonation map<br>- Prescription map | Advanced agriculture mapping software for aerial crop analysis and digital farming |
| Pix4Dreact | - 3D orthomosaic map<br>- Markers and measurements<br>- PDF report | 2D fast-mapping for emergency response and public safety |
| Pix4Dmodel | - 3D mesh model<br>- Fly-through video | Making 3D models from drone images |

| | | |
|---|---|---|
| | | has never been easier |
| Pix4Dcapture | Set of images captured by polygon, grid, double grid or circular trajectory plan | Free drone flight planning app for optimal 3D mapping and modelling |

## IV. PLANNING WITH UGCS

The UgCS (Universal Ground Control System) provides full functionality for planning and execution of UAV flight missions, The main functions of the program are

- Setup an UAV profile
- Camera setup
- Setup basic parameters
- Selecting the area
- Set flight and route formation
- Design of photogrammetric array of strips
- Flight simulation
- Upload flight plan to UAV
- Flight execution

Using this application, a project setup can be followed in this chapter.

### *A. Setup an UAV profile and the camera*

UgCS recognizes many tapes of UAVs. The payloads as cameras can be selected for the given UAV. The UAV together with the selected camera can be saved as a profile and we can reuse it later referring to the saved profile (see Fig. 7.).

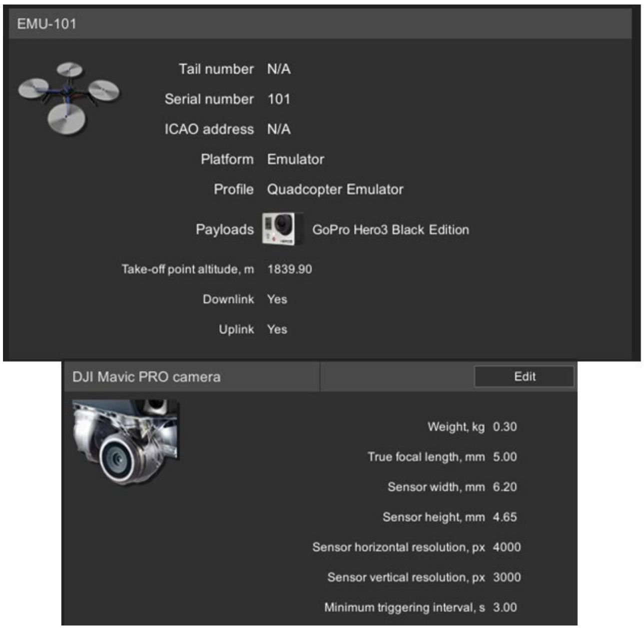


Figure 7. Building a profile form an UAV and a camera

For testing or for emulation we can select UAVs without connecting a real UAV to the application. This function is very useful for planning and flight simulation. Later on, we can change the UAV for a real one and we can execute a real flight with more safety.

### *B. Setup the basic parameters for the project*

Before planning the detailed flight plan parameters like area, resolution and son on, we must setup first the basic project parameters which include the following (see also Fig. 8.):

- Project name
- Home location
- Maximum altitude
- Emergency return altitude
- Vehicle profile
- Altitude mode
- Trajectory type
- Action on emergency situation

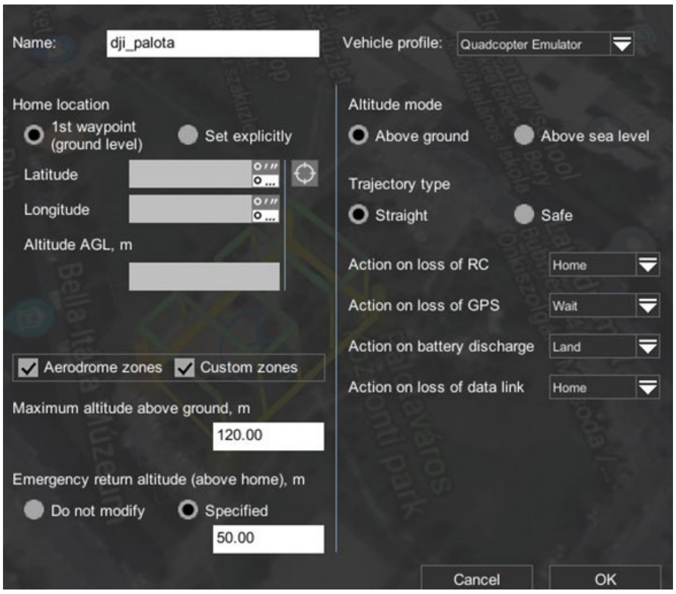


Figure 8. Setting up the basic project parameters

The home location is usually the first waypoint in our flight plan, but we can setup other location by geographic coordinates.

To setup all the other parameters is straightforward and logical.

### *C. Selecting the area and setup the photogrammetric array of strips*

After setting up the basic project parameters we can start the planning of the photogrammetric flight plan choosing the photogrammetry tool. The first step is to pin the corners of the mapping area out. For this we can use the google Earth engine. Then we can setup the flight parameters including the desired GSD, the forward and side overlap, the flight speed, the turn type between the strips, direction angle of strips, altitude type (above ground level (AGL) or above mean see level (AMSL)) and many other parameters and options. In Fig. 9. we can see that the GSD is set to 3 cm and the forward and side overlaps are 80%. These three parameters mainly determine the number of strips and the camera positions for shooting.


Figure 9. Setting up the photogrammetry tool parameters

The action in each planned waypoint is setup separately as it is shown in Fig. 10.

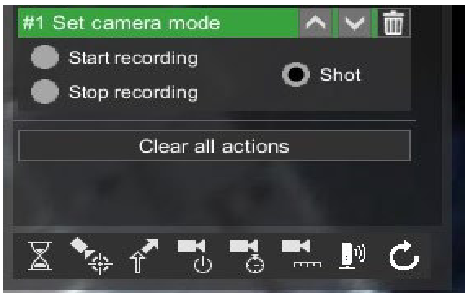


Figure 10. Setting up the camera action in each waypoint

After this the program calculate automatically the strips, the waypoints and shows it graphically in 3D. In Fig. 11. the lines indicating not only the strips but the flight direction as well. We can see the home position and the corners of the selected area. If we change the GSD or the overlap values, the program immediately changes the flight plan and we can decide which plan suits more our needs.

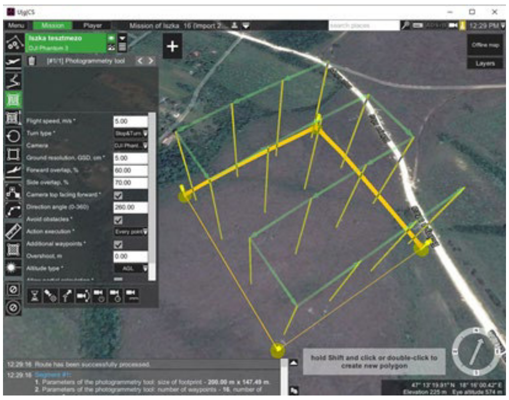

Figure 11. Photogrammetric block as a flight plan

### D. *Flight simulation and execution*

We can simulate the flight and we can follow the elevation profile (see Fig. 12.) during the flight. If we are satisfied with flight result, then we must change the profile connecting a real UAV to the project. This connection is done automatically when switching on our UAV.

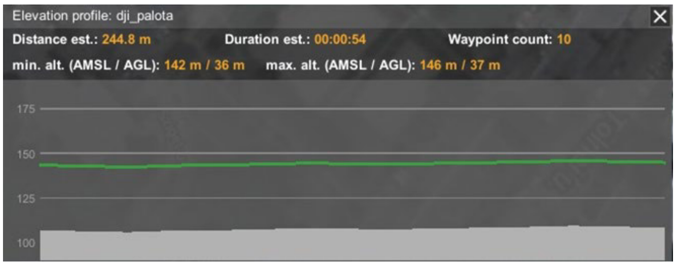


Figure 12. Elevation profile

After uploading the flight plan to the UAV, we can activate and start the real flight mission capturing all the necessary images for the photogrammetric evaluation.

## V. CONCLUSIONS

As a summary we can say that a good mission planner software supports the autonomous flight in all steps. A wide selection of project parameters is a very important aspect and it helps to reach the maximum attainable accuracy during the aerial triangulation, the point cloud generation and the orthophoto map production. The UAS software market is developing very fast and hopefully it brings new, more sophisticated solution to the traditional aerial photogrammetry as well.

## REFERENCES

[1] T. Luhmann, S. Robson, S. Kyle and I. Harley: Close Range Photogrammetry, Whittles Publishing, ISBN 1-870325-50-8, pp. 284., 2006

[2] Wilfred Linder: Digital Photogrammetry, A Practical Course, Second Edition, Springer-Verlag, ISBN: 978-3-540-92724-2, pp. 17.,2009

[3] https://www.pix4d.com/product/pix4dmapper-photogrammetry-software

[4] https://flylitchi.com/help