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# How Good is that Gear? Drones versus Surveyors!

The integration of three-dimensional (3D) vision in drones or unmanned aerial vehicles (UAVs), has contributed a great deal to improving fine-scale mapping and monitoring applications. Passive imaging systems have been the most popular technologies used in this regard. This is mainly due to the availability of off-the-shelf, low cost, and light-weight digital cameras. Advancements in photogrammetry and computational stereo vision have also fostered this popularity (Abdullah, 2019 ).

As a survey engineer, a photogrammetric engineer, and a computer-vision scientist, I have given and received many debatable comments about these technologies. A question that it is still being debated by many stakeholders is this: can drone-photogrammetry result in survey-grade topographic products? The answer to this question cannot be summarized in a single word as each term used in this question is itself interpretable in several ways. In this column, we take a closer look at this question.

First, we review the main steps involved in the procedure of turning images into 3D topographic products (Figure 1). This workflow is more or less the backbone of any black-box commercial software or open-source solution available.

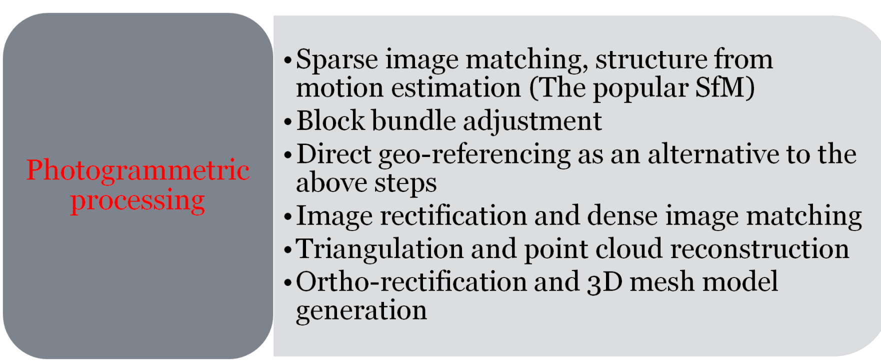


Figure 1. Steps in photogrammetric processing.

## Drone Platforms

A conventional drone system for geospatial applications can be broken down into three discussable components: the platform, the navigation system, and the imaging sensor. Regarding the platform, the minimum specifications to consider are the payload capacity, endurance, degree of autonomy, ease of operation, and, last but not least, compliance with various regulations.

## Navigation Sensors

GNSS-aided inertial navigation sensors are commonly deployed in drone-photogrammetry systems for two purposes: auto-piloting the platform and, optionally, **georeferencing** the images. In most systems, an independent navigation system is dedicated to the latter. Georeferencing means determining the external orientation parameters of the images resolved in the mapping reference coordinate system. It can be performed in three ways: indirect georeferencing (InDG), direct georeferencing (DG), and integrated sensor orientation (ISO).

In InDG, georeferencing is performed by adding the observations of ground control points (GCPs) to the block bundle adjustment. Essential factors in the success of this method include the quality of the GCPs, their number, and their geometric distribution. The accuracy of GCPs dictates the achievable georeferencing accuracy; the georeferencing accuracy cannot supersede the average GCP accuracy. Georeferencing accuracy should not be confused with the reconstruction accuracy explained below. The only way to measure the georeferencing accuracy is to establish a fair amount of well-distributed ground checkpoints. Comparing their absolute measured coordinates with their photo-estimated coordinates yield a measure of georeferencing accuracy. In some commercial software, e.g. Pix4D Mapper, a variable is reported after initial processing, known as GCP error. It is worth mentioning that GCP error simply summarizes the difference between the observed coordinates and adjusted coordinates of the GCPs. High GCP errors can indicate either a gross error or an issue with the block bundle adjustment. Thus, a low GCP error should by no means be interpreted as high georeferencing accuracy. This is, unfortunately, a common mistake made by service providers when discussing their data quality.

In traditional airborne photogrammetry, the best configuration for GCPs is to set full control points at the corners and along the borders of the site, and height control points every 4-6 models and every 2-4 strips (Figure 2). However, in drone photogram-

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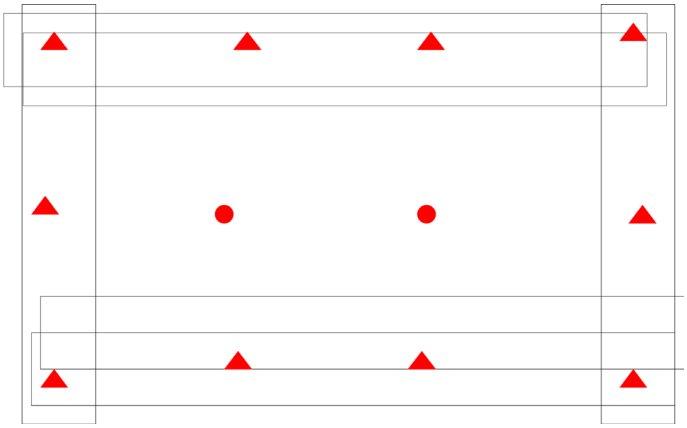

Figure 2. Suggested GCP configuration in airborne photogrammetry.

metry, usually higher model overlaps are recommended, and images are captured in unusual orientations, e.g. often highly oblique. Thus, this general suggestion for traditional photogrammetry might not be realizable as easily. Therefore, simpler configurations can be selected (Shahbazi et al., 2015)

In the case of direct georeferencing (DG), the external orientation parameters of the images are directly observed by the GNSS/INS without further modifications, i.e., one jumps directly to the dense matching step in the processing workflow. The accuracy of DG depends on three factors: the performance of the GNSS/INS components, the accuracy of platform calibration (determining the lever arm offsets and the boresight angles between the imaging and navigation sensors), and the multi-sensor time synchronization quality (depending on the flight speed, every microsecond of the synchronization bias matters!). Usually, DG is avoided unless the processing time is a priority, and one needs to skip the sparse-matching and bundle adjustment steps. The downside to this is that the DG errors directly propagate to the reconstruction errors. Finally, for ISO, the observations of the GNSS/INS are added to the block bundle adjustment as additional weighted observations. The main benefit of ISO is that there is no need for GCPs since the mapping datum gets defined by the GNSS/INS observations.

## Imaging Sensors

When selecting the camera, one needs to pay close attention to its controllable parameters as shutter speed, focal distance, depth of focus, gain value, image size, image format, and rate of acquisition. The worst enemies of accurate photogrammetric products are auto-focus and zoom lenses.

A frequently asked question is whether one should calibrate the internal parameters of the camera offline before starting the photo mission or it is sufficient to perform an on-the-job self-calibration. The answer to this question depends on the mission configurations. If the imaging network is geometrically well configured and there are enough check data available on the site, then on-the-job self-calibration can be sufficient. Otherwise, throwing internal camera parameters as additional unknowns to the block bundle adjustment is not helpful – neither to camera calibration nor to scene reconstruction. The choice of camera model and lens (narrow-angle, wide-angle, and fisheye) adds another confusing element we will leave for future discussion.

The sensor pixel size and the lens focal length, together with the flight altitude, define the ground sampling distance (GSD), otherwise known as spatial resolution. However, one should be careful about reporting this theoretical GSD on the metadata of their photogrammetric products. For instance, a spatial resolution of 1-cm does not guarantee that one can distinguish two objects separated by a 1-cm distance in the produced point cloud. There are many factors such as texture, exposure sufficiency, and the dense-matching method which impact the density of the point cloud and, thus, the real GSD. Besides, the GSD is a highly variable value depending on the distance of the drone to the ground and the view-angle towards the object. Ideally, the average horizontal reconstruction accuracy must be in a range of 1 to 1.5 times the average GSD. As discussed, there can be no guarantee of this assumption. Considering reconstruction accuracy, we should clarify this often-misused term. When reconstructing the 3D model of an object, how close the model gets to the ground "truth", e.g. vertical and horizontal distances and angles between corresponding points of the reconstructed model and the true model, is important. The reconstruction accuracy should not be confused with reconstruction completeness, which is a measure of how many detail gaps exist in the reconstructed model.

In conclusion, drone photogrammetry does have the potential of being used for surveying and high resolution mapping applications which demand high accuracy. However, many elements can negatively influence the correctness of this statement. In addition, considerable attention should be paid to the ways that service providers obtain, interpret, and represent the measures of precision, accuracy, and completeness for their topographic products.

## References

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## Author

Mozhdeh Shahbazi (PhD, PEng) joined the Department of Geomatics Engineering at the University of Calgary in 2016. Since 2018 she has also been an adjunct professor at York University in the Earth and Space Science and Engineering graduate program. In 2019 she took on the role of lead scientist at the Centre de géomatique du Québec, a college-based center for technology transfer. She is Secretary of Working Group I, Technical Commission I of the ISPRS, a Director on the Board of the Canadian Remote Sensing Society (CRSS), chair of Working Group III at the CRSS; associate editor of Canadian Remote Sensing Journal; and associate editor of the Journal of Unmanned Vehicle Systems. Since 2012 her research has focused on autonomous mapping via vision-based unmanned aerial systems.