QUALITY MATTERS

Experiences in UAS Photogrammetry

UAS mapping is widely accepted as a new method for acquiring spatial image data. The main business opportunities clearly lie in projects which are too small to be of interest for aircraft and helicopter platforms and too big for field mapping. Nevertheless, performing UAS operations profitably and with high-quality results is quite demanding. At the end of the day, the paying end customer is not really interested in whether the data was produced using UAS or more traditional methods; data quality is all that matters. This article focuses on UAS mapping productivity topics, shedding light on the practical challenges of UAS operation and data processing.

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Today's Unmanned Aerial System (UAS) mapping market is divided into three main groups: UAS manufacturers, data-processing technology providers and aerial oper¬ators who fly the systems to meet the needs of paying end customers. While there are alliances between UAS manufacturers and processing technology providers, it is important to note that each of the three technological and service-providing roles require quite different know-how and operational processes (Figure 1).

A mapping UAS typically comprises the following components: unmanned aircraft with autopilot (fixed or rotating wing), mission planning and ground station software with radio link, camera and optionally a launch and landing control system for high-speed fixed wing systems (Figure 2). Photogrammetric software is used to process the acquired images into data products, orthomosaics and 3D point clouds so that they are ready for use in GIS and planning systems.

PERFORMANCE FACTORS

A UAS is a decisive working instrument for an operator, which in terms of investment is comparable to a robot tachymeter or a terrestrial laser scanner system. There are number of commercials systems to choose from. When planning a system purchase, the component which has by far the greatest effect on the end product results is the on-board camera. Nowadays, options range from high-performance and lightweight full frame (35mm) consumer cameras to metric cameras specifically built for UAS applications. Another fundamental choice is whether to select a rotary or fixed wing device. Fixed wing vehicles usually fly faster and are capable of covering larger areas of interest. Meanwhile, rotating wing

UNMANNED AERIAL SYSTEMS

This article forms the first part of a series of articles to be published in GIM International on Unmanned Aerial Systems (UAS). The series will address various aspects of UAS in relationship to geomatics. If you would like to contribute to the series, please contact wim.van.wegen@geomares.nl.

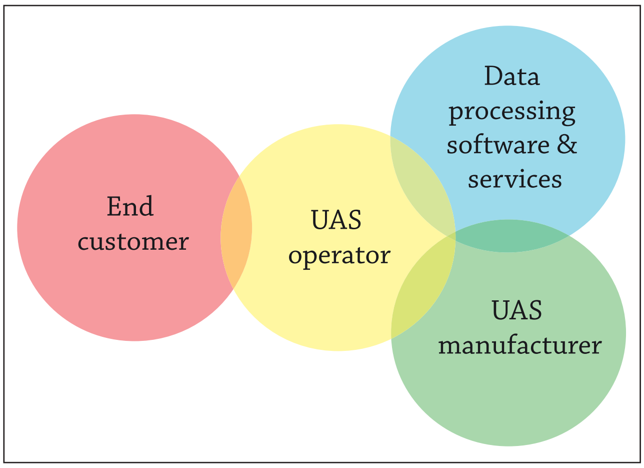


Figure 1, Stakeholders in the UAS mapping market.

Figure 2, A typical UAS (Image courtesy: C-Astral).

systems typically have lower cruising speeds but are capable of operating in limited spaces and in urban areas without problems.

There are a number of design features which have a direct impact on operational performance and thus on the productivity of a UAS. Since the system should be suitable for one-person operation in order to typically reduce operating costs by half, system design is being forced towards simplicity. Moreover, operators should be able to control a UAS manually in the air – not only to comply with legal requirements by the relevant authorities, but also as an important safety feature in the case of unexpected mechanical failure or air traffic.

A mapping mission using lightweight systems can be started with a manual toss whereas heavier systems need a launcher system – a trade-off between operation simplicity and added hardware enabling larger areal capacity. Lighter system cans usually be landed manually into a small space. Meanwhile, a heavier system should have an option for parachute landing; to land a UAS on its belly may require quite a lot of open space, which cannot always be provided, and expose the sensitive camera to repeated bumps and shocks during landings.

PRODUCTIVITY

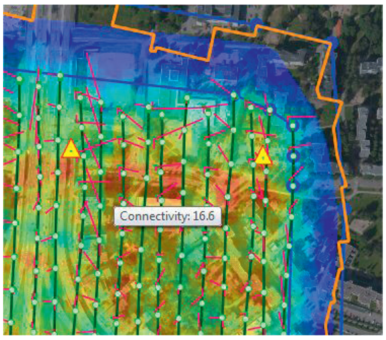
With regard to productivity, the most critical component is the auto pilot and its control software. The software should make it possible to simultaneously plan larger area missions which can be covered with multiple, overlapping flights. The shape of an area of interest should be freely defined. For example, a mapping mission stretching over a corridor several kilometres long may be possible in just one flight, or it may require splitting the area into multiple flights over a series of rectangular areas. This means an operator may have to spend significantly more time at the site and complete a mission in many different weather conditions and types of light.

There are differences in the way of optimising flying patterns and turns, and this has a direct influence on effective flying times. Finally, by controlling camera triggering based on the advanced ground distance rather than on a constant time interval, it is possible to eliminate the effects of head/tails wind on the image overlaps.

An operator usually prepares a UAS mission in the office before travelling to the site. Air space restrictions and obstacles should be checked in advance, and the flight patterns covering the areas of interest should be prepared using mission-planning software. The actual flights can be conducted when weather conditions allow: not too much wind, not too much rain, and sufficient light for the camera to operate at a short shutter speed. An operator should also have software for checking the captured data in the field, in order to monitor whether the right area is being covered, the image quality is satisfactory and the image overlaps appear as planned.

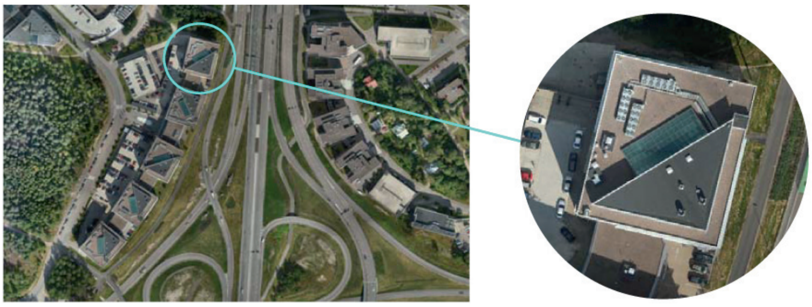
DATA PROCESSING OPTIONS

There is a clear need for two different data processing options: one for producing quick mosaics with so-called GIS accuracy and another to generate high-precision



▲ *Figure 3, Example of graphical quality reporting.*

▲ *Automatically generated DSM (10cm GSD) from a UAS mission.*



◀ *Automatically generated true orthomosaic from a UAS mission.*

results for the more demanding surveying industry. It is the latter which is the obvious target group for PIEneering. Mosaic solutions serve multiple end customer requirements, in many ways representing the vast business potential of UAS mapping applications outside of the traditional photogrammetry industry. Software solutions for this field need to produce results quickly and automatically. Completeness and spatial accuracy of the end result is typically only a secondary consideration for end customers, and geometrical faults may be visible, especially in forested and built-up areas.

In contrast, the surveying industry is accustomed to serving professional customers who require controlled quality assurance and error propagation. There are two aspects of quality affecting the output: accuracy and reliability. Accuracy describes the compatibility of the output with respect to any reference frame, such as the control points. Reliability refers to how sensitive the output is to system errors, such as uncompensated image deformations, blunders, etc.

EXPRESSING QUALITY

But how can quality be expressed to the end customer? Traditionally, a number of statistical quality indicators are used, such as residuals, variance components, etc., documented with alphanumeric listings. The problem is that relatively few people can interpret such statistics effectively. A more intuitive way to communicate quality is to use graphics extensively, along with numeric data (Figure 3). It should be possible for a survey professional to assess the quality level without needing a degree in photogrammetry.

The most common reservations about UAS photogrammetry tend to focus on accuracy issues. Quality reporting enables an operator to demonstrate the quality of the delivered data. Hence, the project acceptance criteria can be set implicitly, and everyone is assured of getting their bills paid. There are particular challenges related to UAS data-processing software performance. A rather unstable UAS platform generates image blocks of varying image quality, including significant differences in image scale and image tilts and inaccurate initial camera orientation and exposure location data. As a consequence, processing UAS data is more demanding than processing traditional aircraft blocks. To get the job done, UAS blocks therefore require powerful software com¬bining the best image engi¬neering al¬gorithms of photogrammetry and machine vision.

When camera performance allows, it is preferable to capture images in RAW format instead of common JPEG. RAW images offer improved resolution power and accuracy by storing thousands of grey shades per pixel instead of the JPEG range of 0-255. However, processing UAS blocks tends to take time. One practical solution is to exploit powerful but cheap gaming graphic cards (GPUs) in a PC, thus

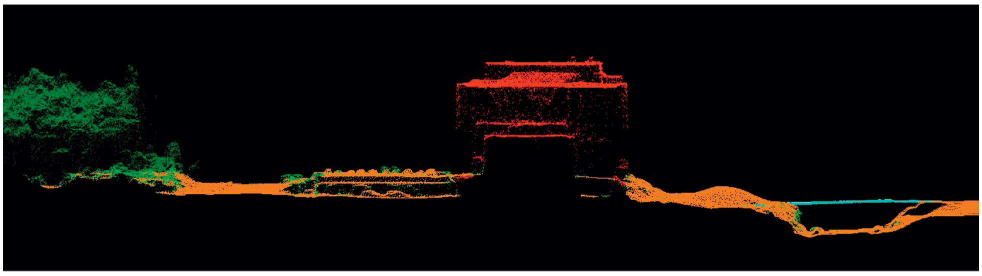


Figure 4, A cross section derived from a classified point cloud.

3D model of an open pit.

increasing the processing speed by a factor of 20-50 per installed card. Detailed 3D point clouds seem to be of particular interest to end customers, since the data can be used for numerous volume calculation applications and for generating true orthomosaics. End customers are quite often interested in more refined data output, such as 'bald earth' surfaces or classified data layers derived from a DSM. Point cloud and DTM management software, such as Terrasolid's Terrascan, can be used for this, for cross-sectioning and visualisation purposes for example (Figure 4).

Today, a UAS operator can choose between licensed software and cloud services as data processing options. Choices are welcome, as customers' needs vary – it is sensible for operators with less knowledge of photogrammetry to rely on services, while it is natural for professional photogrammetrists to choose the software option. In either case, UAS data processing software, or services, must provide automatic operation, the capability to meet the challenges of UAS specific blocks, provide a means for controlled quality, and be capable of rapidly processing thousands of images.

DATA ACCURACY

There are four main aspects which have the greatest influence on data accuracy: the number of ground control points, consistency of the photogrammetric block, image quality and camera optics. When GCPs cover the target area and are spread evenly, absolute accuracy over the target area can be controlled. Adequate image overlaps (70/70%) compensate for the instability of the UAS as an imaging platform and make the mathematical solution rigid. Once again, good image quality is essential. Consumer cameras are not built for metric operations, and the instability of the optics can cause varying deformation. Any deformation drastically reduces the accuracy and must be compensated with camera calibration, either with laboratory calibration or with self-calibration during data processing.

With everything in place, it is possible to achieve absolute accuracy of 0.5 pixel GSD in XY direction and 1 pixel GSD in height with aerial triangulation. For more details, please refer to the white paper [1].

CONCLUSIONS

As a method for acquiring aerial image data, UAS mapping is capable of providing high-quality results for the professional survey industry. Quality does not come easily, but instead requires advanced hardware and software, skilled operators and carefully executed mapping missions. Controlling quality throughout the entire production process increases productivity, helps to strengthen confidence in the UAS mapping method, and promotes project sales.

MORE INFORMATION

1. www.pieneering.fi