WHAT MINERS WANT

THINKING OF USING UAVS TO SURVEY MINES? LEWIS GRAHAM LOOKS AT SOME OF THE PROBLEMS YOU'LL ENCOUNTER AND THE BEST WAYS OF MEETING YOUR CLIENTS' REQUIREMENTS

In the three previous instalments of this series (GeoConnexion International October 2014, January 2015, September 2015), I discussed fabricating UAV hardware, camera considerations and adding direct geopositioning (RTK/PPK) hardware. With this quite capable man-portable mapping system, it is time to meet the clients!

Since the previous article in this series, our various configurations of UAVs have met a wide variety of customers through our AirGon Services division. Primarily intended to inform our designs and introduce clients to UAV mapping technology, we have conducted more than 500 mapping flights of aggregate/sand quarries and industrial sites such as paper mills. And in this article, I will relay some of the experiences we have had when UAV mapping met customer!

When we first set out to develop end-to-end small site sUAS mapping technology, our focus was on volumetric analysis and, indeed, this is a core product of the clear majority of our mapping projects. However, most mine site operators want topographic contours in vector form of the pit areas of the mine. These contours, usually delivered in DWG or DXF format, are fed into downstream mine planning and analysis tools. I am going to report units here in the metric system but one rude awakening we had as we 'metric' electrical engineers encountered US mining companies was that the lingua franca is feet and cubic yards – none of that metres stuff, thank you very much!

Accuracy is a design criterion for a UAV mapping project. The reference (local or geodetic network) and level of required horizontal and vertical accuracy are determined by the products to be generated. Most mining engineers with whom we work provide a feeling of desired accuracy but do not specify it in a surveying vernacular. Thus, we hear requirements such as volumes to be accurate within '2% of true' and contours with an interval of 'one foot'. There is a very high degree of trust placed on us by our clients with respect to the metric accuracy of the data we produce. While we supply American Society of Photogrammetry and Remote Sensing (ASPRS) standard horizontal and vertical accuracy reports, we have never been questioned as to how these are generated or interpreted.

All products except relative volumes and 'view only' orthophotos will require some amount of ground control/check (see Figure 1), even if the UAV is equipped with an RTK or PPK direct geopositioning system. Control and check points are needed both to decorrelate scale from camera focal length and to verify accuracy relative to the survey reference network. I have recently seen proclamations from some of the web-based UAV data mapping services that 'control is old fashioned!!' as if they have just invented real time or post-processed kinematic (RTK/PPK) direct geopositioning. In truth, on-board RTK/PPK can dramatically improve accuracy and reduce the number of ground control points but for high accuracy network survey work, some amount of control is needed. Of course, for validation of a project's accuracy, check points are always required.

Figure 1. Survey targets are nearly always required for a UAV mapping project

Biggest requests

I recently reviewed the projects we have completed over the past several years to assess the most requested mapping products. With all projects, regardless of the primary product requests, a site orthophoto is expected and we always include one for the entire mapping area. In descending order of popularity, the most requested products are:

1. Volumes
2. opography (contours) of select areas such as the pit (30cm intervals)
3. Volumes, topo using a priori model constraints (breaklines, mass points)
4. Differential volumes ('borrow pit computations)

The first, straightforward volumes can be achieved with no tie to a geodetic reference, just good local accuracy. If the customer does not need the stockpile toes placed on a reference map, these sites can be collected with no direct geopositioning and no ground control. However, a well calibrated camera is mandatory because an incorrect camera focal length will result in an incorrect scale, which, in turn, produces erroneous volumes. It is important to note that in the absence of direct positioning or ground control points, the calibration phase of dense image matching software cannot decorrelate focal length from scale.

In brief, do not expect to fly stockpiles, compute dense image matching clouds with one of the popular image to point cloud tools (or web services) and get correct results. However, with on-board PPK and a calibrated camera, you can make short work of these projects. On very rare occasions you will find projects with neat, cleanly separated stockpiles on horizontal surfaces (see Figure 2) but this is the exception rather than the rule. You will usually be doing some level of data cleaning, classification and toe editing. Having tools purpose-built for these tasks will significantly reduce processing times.

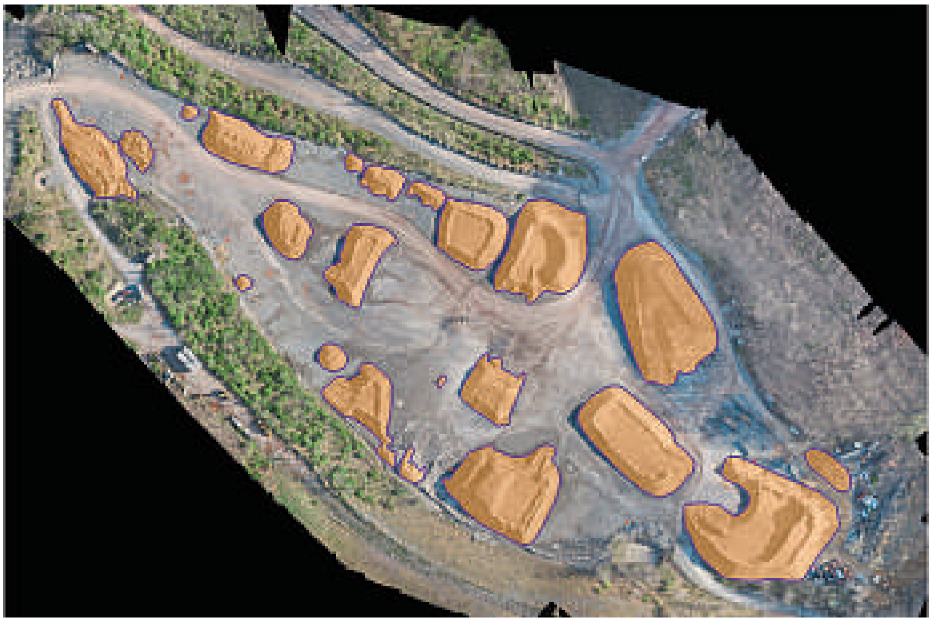

Figure 2. An almost perfectly clean stockpile yard

Figure 3. A typical sand mine site

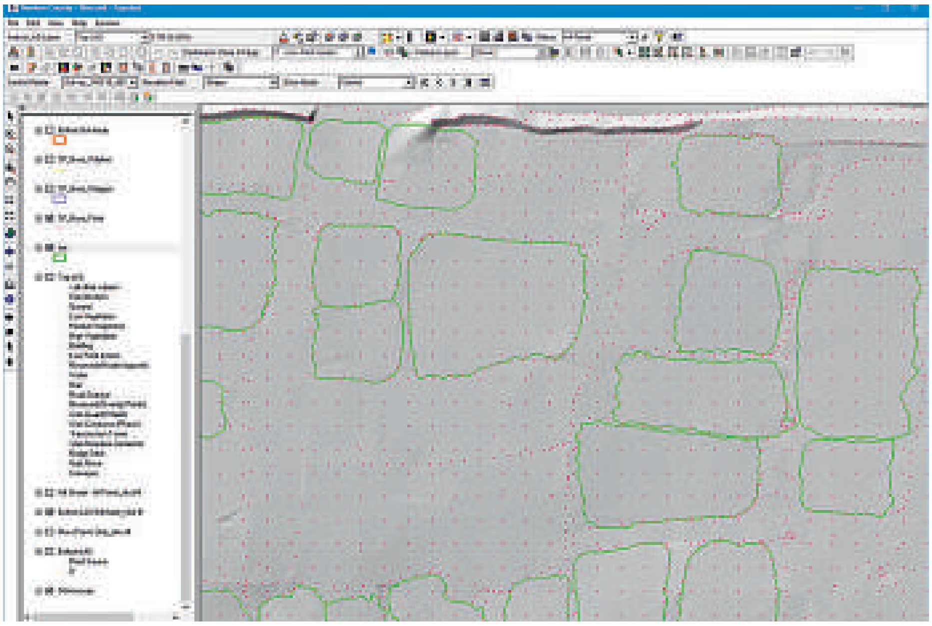

Figure 4. Synthetic bottom surface constructed from mass points (green lines are toes)

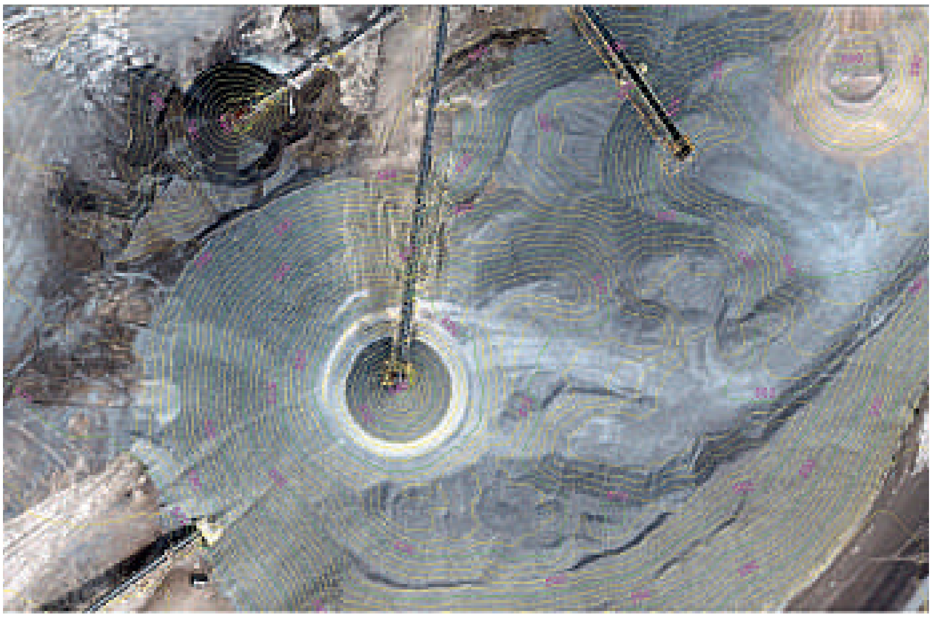

Figure 5. A site with a contour delivery requirement

Figure 6. Vegetation covering areas of stockpiles

A more typical site is shown as Figure 3. Here we have many overhead conveyors, piles where ramps have been created within the pile itself (presenting a difficult topology for our automatic toe extraction algorithm) and stockpiles that are comingled. Such sites are complex but easily processed, assuming you have the right tools in your kit.

Unexpected requirements

A requirement we had not foreseen when we first entered this business was the need to incorporate 'bottom' data into our volumetric models. Photogrammetrists would refer to these customer-supplied a priori data as model constraints or breaklines. This baseline data usually comprises a set of 3D points and polylines that were collected either from ground surveys or derived from aerial photogrammetry at some past time. Mine sites tend to use this fixed base data to help maintain consistency in volumetric reporting. Rather than constructing a base surface from toe vertices, the toe is projected on to the surface formed by the 'bottom' data.

An example of a constrained model is depicted in Figure 4, showing the base on which the stockpiles reside. This base was constructed solely from a priori mass points and breaklines. Fortunately for us, our modelling software, LP360 for sUAS, already contained the necessary modelling constraint functions due to its LiDAR modelling heritage.

Projects of this nature and those that deal with differential volumetrics (cut and fill or time analysis) require very high vertical accuracy. When computing differential volumes, a vertical error of 5cm still translates to a volumetric error of 1m^3 for every 20m^2 of surface area (assuming unidirectional error). If your output product is topographic contours only (no differential volumes), vertical accuracy can theoretically be relaxed to about 1/3 the contour interval. For example, delivering 30cm contours (see Figure 5) will require a network vertical accuracy of 10cm or better.

An additional issue that adds complexity to a project is vegetation. At the moment, we are using dense image matching in all of our UAV collection projects. This type of 3D model construction results in point clouds that adhere to the surface of vegetation with no penetration to the ground. While LiDAR would clearly solve this problem, low-cost UAV-mountable systems have poor range and still come in at US$80,000 or so. Purveyors of these systems typically advertise a range of 100m but reality is more like 30m. Additionally, they tend to have rather poor precision, typically on the order of 6cm or greater. For these reasons, we are holding out a bit longer for the next generation of low-cost LiDAR systems. In the meantime, we deal with small areas of vegetation (such as those shown in Figure 5) by using an RTK survey pole to collect mass points ('pogo' topology!).

Conclusion

In summary, UAV-based data collection has proven to be quite cost effective for small site mapping. Very high accuracy can be achieved with careful planning and on-board direct geopositioning. I recommend always tying the project to a geodetic datum since this gives historic value to the data that can be used in trend analysis, for example. Some amount of control and check points must always be available for removing inevitable vertical bias and verifying the accuracy of the overall project. This means that standard ground surveying equipment must be part of the on-site UAV mapping tool kit.

As technology evolves over the next few years, the price of on-board RTK/PPK will decline to the point that it will be the standard positioning technology for all mapping UAVs. That said, with current technology, mapping with UAVs can certainly give miners what they want.

MAPPING WITH UAVS CAN CERTAINLY GIVE MINERS WHAT THEY WANT

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SAFETY FIRST!

When flying mapping missions with a UAV, it is not a question of 'will a crash occur?' – it is 'when will the crash occur?' We have experienced 'total loss of control' failures (a polite euphemism for a crash…) with both UAVs of our design and third-party mapping systems.

So, when flying a UAV, you must assume that the craft could fall out of the sky at any point in time. You must therefore ensure that the UAV is never above unprotected people. Fortunately for us, our primary customers are mine sites and industrial plants. The premises of these sites are well controlled and outside personnel are usually in protected vehicles. When we do have to fly in locations where we are not completely in control of the safety environment, we sacrifice accuracy by using a flying wing UAV. These systems tend to flutter down when a catastrophic failure occurs, presenting little danger to those below.

SUAVS are super-cool attention getters when you show up at the client's site. Sometimes we can get so enamoured with the technology that we lose sight of the real objective – delivering mapping products that exceed the client's expectations. It is the reception of these products that will determine if you get the next job, not the 'cool' factor of the acquiring technology.

Crashes do happen! This is the result of a motor failure at a recent mine site mapping project