Tools

The AirGon Sensor Package, Revision 3

AirGon, AV-900 MMK

Lewis Graham
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When using imagery as a source of metric measurement, an up-front task that must be accomplished is determining the exact position (X, Y, Z) and orientation (Pitch, Yaw and Roll) of the camera at the precise time of each image exposure. This seven tuple of data is termed the dynamic exterior orientation (DEO or often simply EO) where time (the first of the seven parameters) is usually provided (but not always‼) by some external event such as a camera trigger. There are a number of algorithms for determining the position and orientation of the camera that require various external information such as known positions on the ground.

With our long background in photogrammetry, and the expectation of mapping customers, we knew from the beginning that our small Unnamed Aerial System (sUAS) would require direct geopositioning. Direct geopositioning onboard the sensor platform means that you do not have to use or at least you can minimize the use of ground control points (see one of our AirGon survey targets in Figure 1).

Figure 1: An AirGon Survey Target

We have done a lot (I mean a whole lot‼) of experimentation and analysis with software packages that perform Structure from Motion (SfM) processing to create point clouds and orthophoto mosaics from individual aerial images. Examples of commercial applications (that we sell and support) are Agisoft PhotoScan Pro and Pix4D's Pix4D Mapper. It turns out that these packages can self-resolve the orientation angles if they are given good *a priori* estimates of position (X, Y, Z). Thus we need a dynamic solution for finding good estimates of the camera position each time an image is collected but we can allow the software algorithm to solve for orientation. This means we need a high grade positioning system, but we do not need an orientation sensor (e.g. gyroscope). This luxury of finding orientation via software algorithms is not available when using a laser scanner, requiring the employment of a survey grade Position and Orientation System (POS).

One of the ways to accomplish finding the sUAS position at the time of each camera exposure is to put a high quality, dual band Global Navigation Satellite System (GNSS) differential receiver on board the sUAS and use *differential* positioning to resolve the location of the sUAS when camera images are snapped.

Differential GNSS is actually a fairly simple concept. If you were to place a high quality, dual band[1] GNSS receiver on a known point and allow it to collect information over a long period of time, the error in its positon solution would wander around the true location (see Figure 2). You can see in this figure that the position at particular points in time is off by as much as 6 meters in northing and 4 meters in easting. Obviously this is far too great for high accuracy mapping! By the way, this deviation over time from the true value is termed *precision* – that is, how much does the result of multiple measurements of exactly the same quantity (in our case, the known location of the reference station) vary from sample to sample. Some folks mistakenly call this *accuracy*.

[1] L1, L2. Dual band is needed to correct for errors introduced by atmospheric refraction of GNSS signals and to allow rapid convergence to a positional solution.

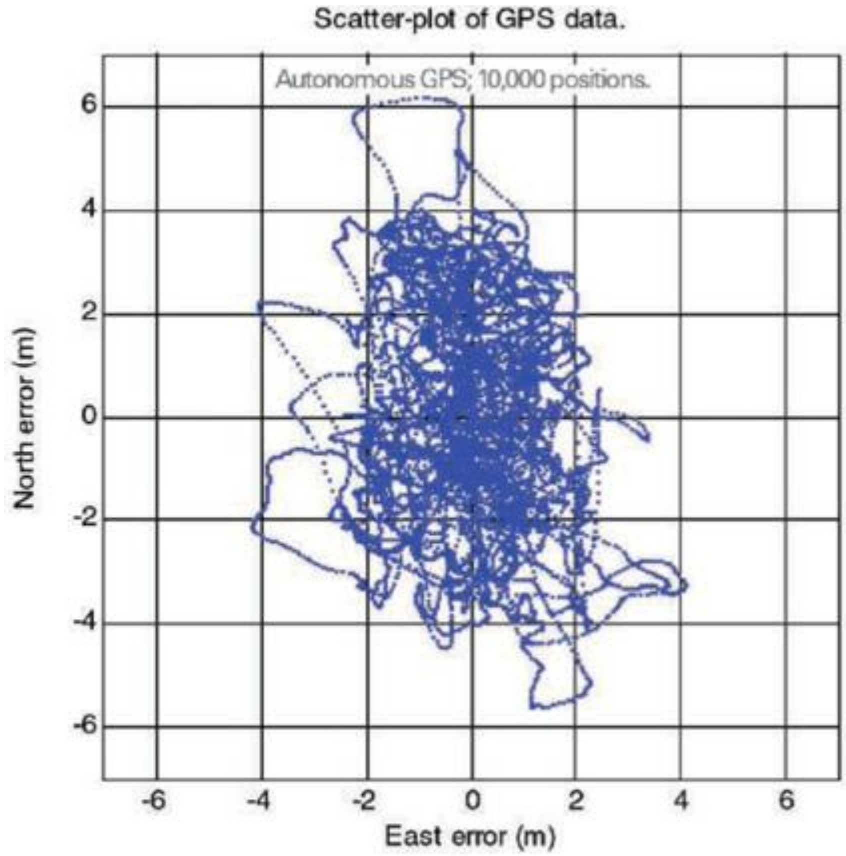

Figure 2: GNSS Error Plot over time, Fixed Reference Point

It turns out that if you were to place two GNSS receivers in close proximity to one another (say within a few kilometers), their error plots would be identical to within a few millimeters. I think you see where this is going. All we have to do is have a fixed GNSS over a well known location (the *reference location)* and record the error (that is, the difference between where the GNSS thinks it is in terms of X, Y, Z and the known location of our reference point). The GNSS receiver at this location is referred to as the *base station.* We then allow our moving GNSS (which is on the sUAS) to record its location. This moving GNSS receiver is referred to as the *rover.* If we apply the corrections from the base to the rover, we will have a *differentially corrected* location. This location will be correct, relative to our reference point, to within a few millimeters.

There are a number of ways to realize this scheme. If you need to know where the moving station (the rover) is in real time (for example, you are using it for real time guidance) then a radio link is needed to transmit the error vector from the base to the rover. This mode of operation is termed Real Time Kinematic (RTK) positioning. If you do not need to know the location in real time (as is the case for aerial mapping), you can simply record the collection data from the mobile GNSS receiver and do the corrections back at the office. This mode of operation is termed Post-Processed Kinematic (PPK) positioning.

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We have implemented a rover to operate in post-processed kinematic (PPK) mode into our AirGon Sensor Package (ASP) version 3 (see Figure 3). We use the very high quality Septentrio AsteRX-m as the GNSS engine on the ASP-3. Since we are operating in PPK mode, we record positional information on an SD card and extract these data in a post-processing step.

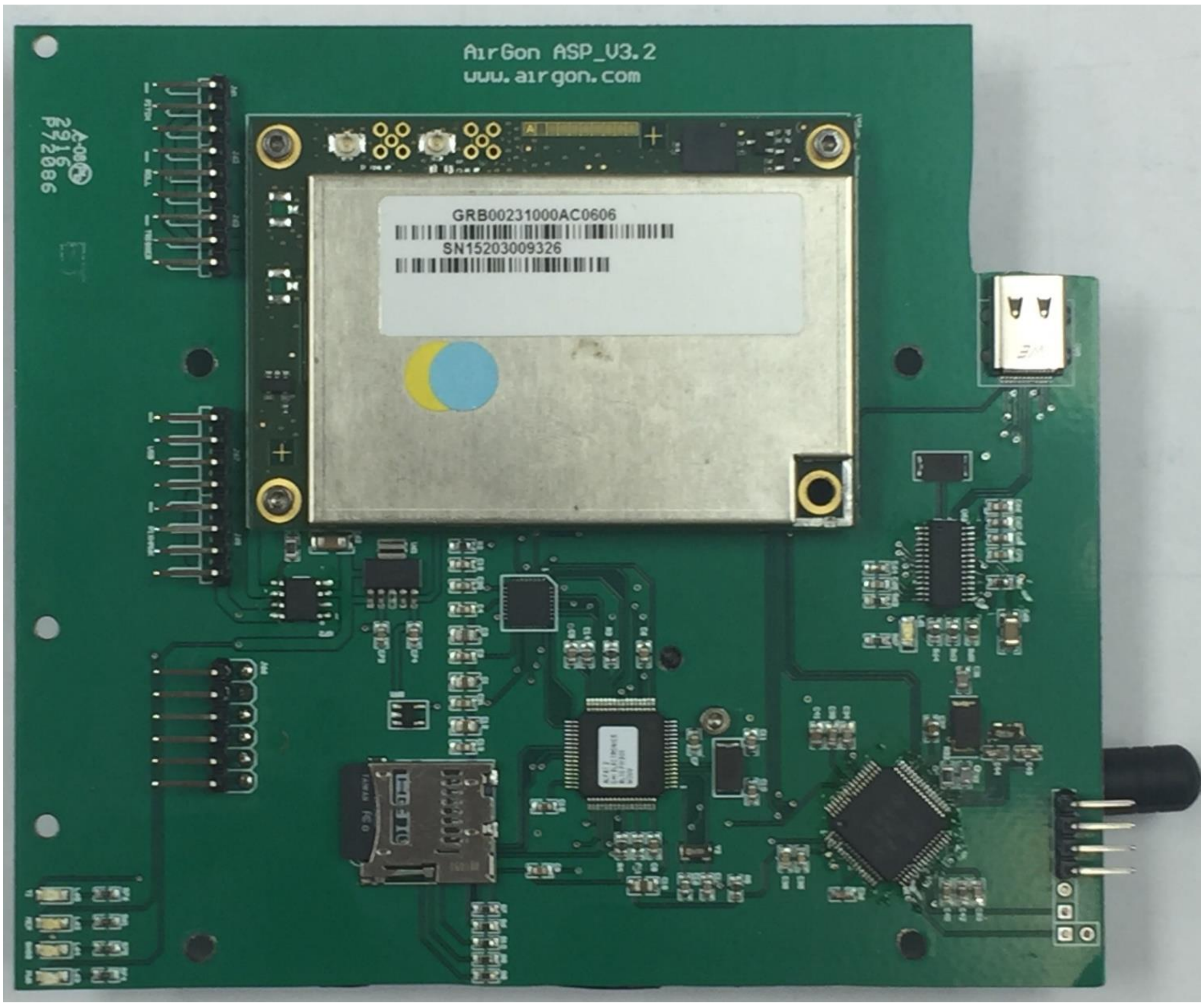

Figure 3: AirGon Sensor Package - Rev 3

The ASP-3 is quite an improvement over our earlier ASP iterations. We have added a daughter board on the two axis gimbal board that eliminates a tangle of 10 wires, replacing them with a single, reversible Thunderbolt 3 cable running from the ASP (which is mounted under the AV-900 battery) to the gimbal. This cable is reversible (the same form factor as a USB Type C cable) and thus there are no worries about cable polarity. We have also upgraded the microprocessor on the ASP, allowing us plenty of headroom for doing all the real time tasks that are necessary to integrate the camera into the GNSS positioning system. A summary of new features in the ASP-3 is:

- All data are transferred from the ASP and camera to a PC via a single USB 2.0 to USB-C cable (supplied)
- The camera can now be charged without removing it from the gimbal using this same USB 2.0 to USB-C cable.
- All aspects of the APS and autopilot programming are also handled via a single cable
- The GNSS dual band antenna mass has been reduced by over 200 grams
- Other than the Septentrio GNSS engine, there are no daughter boards on the ASP, greatly improving resistance to problems created by vibrations
- The connections to the camera gimbal board has been reduced from 4 separate cables with pin connectors to a single, reversible Thunderbolt 3 cable.

An upgrade for existing ASP-1 and ASP-2 fielded systems is available. Just contact support@airgon.com for information.

We have found an interesting phenomenon with SfM-derived point clouds. *Conformance* (how well the point cloud conforms to the actual object being imaged, such as a stockpile) is significantly enhanced with airborne direct geopositioning as compared to using ground control points. We have not determined the exact analytic reason for this observation, but we are working toward a mathematically plausible explanation.

Due to our observations of accuracy and the fact that we cater to this end of the mapping spectrum, we will be offering only the PPK version of the AV-900 going forward. After all, it takes a lot of logistics to fly a mine site; you should get the very best data possible!