Aerial Mobile Mapping for Infrastructure Data Gathering

By

Tahir Shafiq, Andrew Stott, Joe Hutton

Mobile mapping, defined as the act of creating geo-spatial information from a moving platform, is currently the single-most cost effective way available of direct data georeferencing and robust mapping. With today's ever-increasing demands for temporally accurate data, there is no doubt that moving from static to dynamic mapping methods is the way of the future and promises enormous gains in results and productivity.

Applanix, a wholly owned subsidiary of Trimble Navigation Ltd, is pioneering this field with products and solutions for mapping and positioning from mobile platforms from the air, land, and sea. These systems integrate precision Global Navigation Satellite System (GNSS) with advanced inertial technology (accelerometers and gyros) to provide uninterrupted measurements of the position, roll, pitch and true heading of moving vehicles. These technologies make fully integrated, turnkey solutions for high-productivity in-motion surveying, direct data georeferencing, and robust mobile mapping possible and available today.

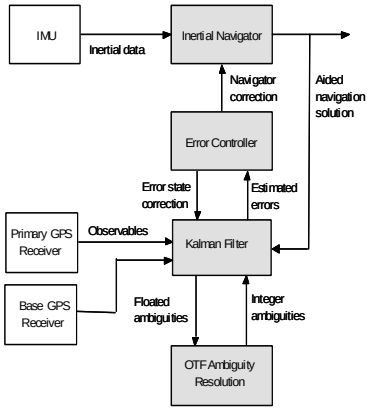
A Revolution in Aerial Mobile Mapping

To date, GNSS-Aided Inertial Navigation for Direct Georeferencing of aerial imagery and sensors such as LIDAR have achieved position accuracies of 10 cm RMS horizontal and 15 cm RMS vertical when using post-processed kinematic ambiguity resolution (KAR). Strict operational restrictions for this method however due to the nature of the airborne environment have significantly reduced the efficiency of airborne mapping. These limitations have included flying turns of less than 20 deg bank angles, flying less than 30 km from a reference GNSS receiver in order to correctly fix integer ambiguities, and keeping the maximum baseline separation to less than 75 km once the ambiguities are fixed.

To overcome these limitations, Applanix has developed patent pending, post-processed GNSS-Aided INS software called POSPac Mobile Mapping Suite (formerly POSPac Air 5.0). This software incorporates Applanix IN-Fusion^{TM} and SmartBase^{TM} technologies.

Applanix IN-Fusion for Aerial Mapping

Previous methods for aerial mobile mapping required a continual lock on GPS signal to each satellite in order for the solution to remain converged and for producing the estimation of the ambiguities. For aircraft turns of greater than 15 to 20 deg bank angle however, the wing of the airplane tended to block the view of the satellites from the GNSS antenna, causing the solution to reset. Being restricted to flat turns also increases the time required to fly the survey and poses problems in restricted flight zones where there is limited room to manoeuvre, thus increasing the stress level on the crew and leading to fatigue and potential operational errors.



These problems are solved using Applanix IN-Fusion^{TM} technology, which implements an Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) algorithm to compute the GNSS ambiguities. In this approach the inertial data and raw GNSS observables (phase and range measurements) are

processed in a single tightly integrated Kalman filter, allowing the inertial data to be used to solve for the integer ambiguities. If there is a cycle slip or outage in the GNSS data, the inertial data keeps a "memory" of the ambiguity, allowing the correct integer ambiguity to be quickly re-established immediately after the outage.

For airborne applications this means there is no longer any need to fly flat turns to avoid signal outage, meaning turns can be made in approximately half the time and radius, simply by doubling the banking angle, say to 30 degs from 15 degs. This savings means either the mission is flown in less time (reducing fuel costs), or more lines are flown per mission. The smaller radius also allows more flexibility for flying missions in restricted airspace.

Applanix SmartBase for Aerial Mapping

Figure 1 IAKAR Architecture

A significant productivity improvement in Real-Time Kinematic (RTK) positioning has been achieved using the concept of a "Virtual Reference Station" or VRS (Landau H., 2002), illustrated in Figure 2. Here observables from a dedicated network of GNSS reference stations are processed to compute the atmospheric and other errors within the network. These are then interpolated to generate a complete set of GNSS observations as if a reference station was located at the rover.

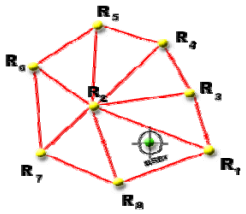


Figure 2 Virtual Reference Station (VRS) Concept

There are a number of significant benefits to a VRS approach, including the extension of the distance to the nearest station beyond 30 km, the elimination base stations and the associated costs, and real-time positional accuracies at the cm RMS level anywhere within the network (Hakli P., 2004).

With the POSPac MMS software, a post-processed version of VRS called the Applanix SmartBase™ is introduced. Based upon the Trimble© VRS™ technology, SmartBase has been optimized for large changes in altitude by the rover and extended to work with reference stations separated over very large distances. With this approach it is only necessary to be within the network and at least 70 km to the nearest reference station to initially resolve the correct ambiguities. Once resolved, the aircraft can then fly up to 100 km away from the nearest station within the network, while still achieving positioning accuracy at the 10 - 15 cm RMS level.

SmartBase with IN-Fusion together enable missions to be flown with bank angles above 20 degs, with the only restriction that turns be less than 70 km from the nearest reference station (Hutton, J. et al, 2007) while producing the same position accuracy as standard differential GPS with a dedicated reference station.

Mobile Mapping: Not just from the air anymore

POSPac Mobile Mapping Suite also enables Mobile Mapping onboard moving ground and marine based vehicles. The Applanix LandMark system is the industry's first commercial off-the-shelf (COTS) program for mobile mapping of road-side infrastructure from land vehicles. Designed to increase productivity for both data acquisition companies and end users, the system integrates a metric digital camera with a POS LV positioning system, data acquisition and processing software, and industrial computers. Using the geo-referenced imagery and smart algorithms, it allows the user to accurately geo-locates signs and other such structures along the road, dramatically increasing the productivity of collecting road-side inventory using traditional, more manual methods. Mapping

and characterizing an asset in the past has typically taken 120 seconds, but LandMark reduces that to less than 40 seconds. And with POS LV the need for data reacquisition even in the most adverse GPS environments is virtually eliminated, again increasing crew utilization rates and allowing operators to map vast distances reliably. The POS LV also ensures sub-meter accuracy, even during extended GPS outages and decimeter results with post processing.

The LANDMark Marine solution offers surveyors the possibility of collecting surface image data from a moving marine vessel. The first of its kind in the world, the system allows marine hydrographers to expand their sub-surface mission capabilities and provide accurate maps of coastal and offshore assets from the perspective of the water. LANDMark Marine can be operated with a single camera, six or more cameras, or a combination of cameras and laser systems. It has been designed to give users maximum flexibility when integrating with other equipment.

It can provide Geographic Information System (GIS) professionals with essential data for:

- Port and Harbour asset inventory
- Coastal zone management
- Marine Hazard Mapping
- Vessel-based shoreline verification
- Mapping of near-shore features such as piers, rocks, islets, and aids-to-navigation

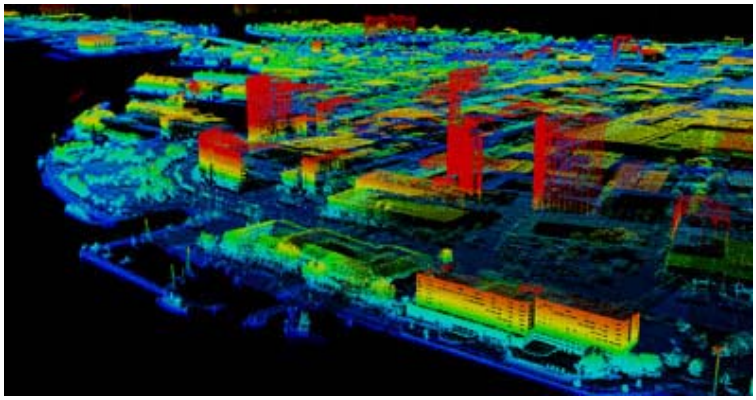


Figure 3 Mobile LIDAR elevation colour coded point cloud image of Norfolk, Va using Mobile Mapping and Positioning