GPS AND INERTIAL NAVIGATION - DELIVERING

FRANK ARTÉS AND JOE HUTTON EXPLAIN THE BENEFITS OF DIRECT GEO-REFERENCING

GPS aided inertial navigation systems have been available for commercial mapping applications for approximately a decade, pioneered by Canadian-based Applanix Corporation with their POS (Position and Orientation System) technology. The impact on the aerial survey and remote sensing industry has brought about a re-assessment of traditional photogrammetric methodology and the potential elimination of two fundamental mapping components, the ground control survey and corresponding aerotriangulation process.

By merging the GPS and inertial navigation technologies, accurate position and orientation of the airborne imaging sensor, with respect to the Earth, can be determined directly. Such an approach is referred to as Direct Georeferencing. This approach is opposite to that of aerotriangulation, which requires accurate control points to be surveyed on the ground and then identified in the stereo imagery. These are then used to "back-out" the position and orientation of each photo through a geometric adjustment. One main advantage of Direct Georeferencing is that it can be used with any type of airborne imaging sensor, such as an aerial camera, hyperspectral scanner, Synthetic Aperture Radar or LIDAR. This method of calculating airborne position and orientation data is now a proven and reliable technology that is becoming more robust and accurate every year with the ongoing development in GPS and inertial equipment.

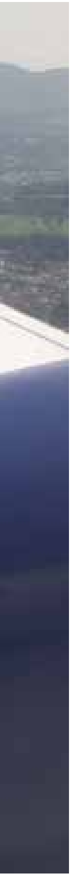
GPS and IMU Basics

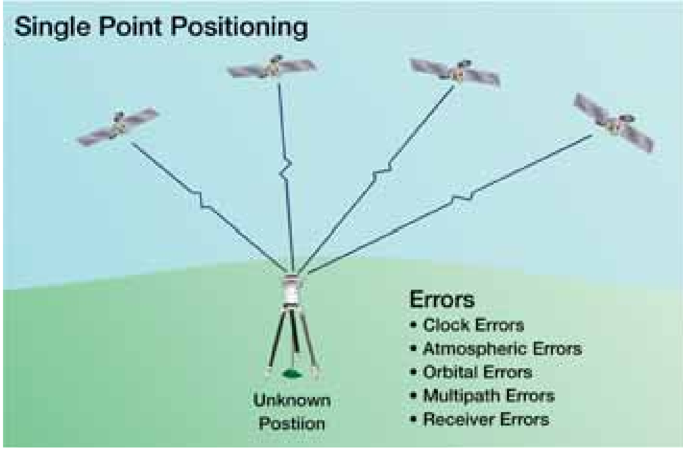
Since its inception in the 1980's, the 12 billion dollar GPS project, developed by the US Department of Defense, has matured to become an extremely valuable resource for those organizations which rely on accurate geopositioning information. The concept of GPS positioning is based on triangulation using a minimum of ranges to four satellites (whose positions are known) to determine the precise location of a point anywhere on the Earth's surface. Using a single receiver, this methodology is referred to as single point positioning and is the simplest but least accurate way of generating position data. Typical accuracies can vary from 2m to 10m, though for many mapping applications this level of accuracy is less than suitable.

The ranges between the GPS receiver and satellites are computed by measuring the precise time it takes the radio signal to leave the satellite and hit the GPS antenna, multiplied by the speed of light. Errors in the receiver's clock and the Satellite's clock cause errors in the ranges. Also, the signals can reflect off nearby surfaces before hitting the antenna, causing an incorrect range to be computed (called the Multipath effect). In addition, atmospheric conditions affect a GPS signal's ability to penetrate the Ionosphere and Troposphere, slowing them down as they travel earthwards. Finally there are residual errors in the positions of the satellites themselves.

A standard methodology, known as Differential GPS (DGPS), is used to eliminate the majority of these errors. By using multiple base stations set up over known surveyed locations, to collect satellite data at the same time as the mobile GPS receiver, very accurate positioning of the mobile receiver can be achieved. Since the locations of the base stations are known, the common errors in the ranges to each satellite can be calculated and removed from the mobile receiver. Accuracies at the cm level are then possible.

A number of countries have established their own network of base stations, such as CORS (Continuous Operating Reference Stations) in the United States, and ANN (Australian National Network) in Australia. Also, the IGS (International GPS Service) volunteer organization provides precise orbit and satellite clock corrections with a worldwide





LEFT: SINGLE Point Positioning
BELOW LEFT: Differential GPS Positioning
BELOW RIGHT: Direct Georeferencing with GPS/INS

GPS permanent tracking network using the combined systems of various nations.

For centimeter-level positioning accuracy required for precise photogrammetric applications, both the base station and the mobile receiver must be operating simultaneously, and receiving GPS data from at least four common satellites. The GPS datasets can then be post-processed off site to generate an extremely accurate position and orientation solution for the imaging sensor. The raw measurements produced by the GPS are processed together with inertial navigation data to calculate accurate position and orientation for each image.

The inertial navigation solution provides high rate measurements of position, velocity and orientation (roll, pitch, heading) by integrating the output from accelerometers and gyros. Accelerometers measure linear acceleration, while gyros measure angular rates. The accelerometers and gyros are contained in a unit called the Inertial Measurement Unit (IMU), which is physically attached to the imaging sensor. A common misconception within the airborne industry is that an IMU is the same as an INS (Inertial Navigation System). The IMU is actually one of the two components in an INS, the other being an inertial navigator, which turns the sensor measurements into position and orientation. The INS is a self contained autonomous system that does not rely on external signals for information to produce a full navigation solution. One drawback of inertial navigation systems is that over time their position and orientation errors grow unbounded.

Having accurate GPS positions however, means they can be used to aid the inertial navigation solution by controlling the position error, which in turn controls the orientation error.

The Benefit for Photogrammetry

With the introduction of GPS aided inertial navigation technology, the aerial survey and remote sensing industry has seen a change in the way geospatial data is now generated. Standard applications such as topographic mapping, corridor surveys, DTM generation, and environmental monitoring have all benefited from the technology's particular attributes, which translate into an increase in operational efficiency and a decrease in time-to-data-delivery.

The non-intrusive technology has simplified topographic mapping applications and made accessibility problems of little concern, particularly in rough terrain or disaster-prone locations. For example, generating photogrammetric data for a coal stockpile inventory, where surface contrast causes problems for traditional aerotriangulation tasks, the use of direct georeferencing can be very effective. Even from a safety standpoint, there is now no need for survey personnel to be working in and around heavy mining or construction equipment.

Also, with the heightened interest in Homeland Security, there is a recognized need for rapid response mapping to generate usable geospatial data in the wake of a national emergency, or in the case of natural disasters such as hurricanes, earthquakes and floods etc. Making current, georeferenced imagery available to first-responders and emergency personnel as quickly as possible cannot be overstressed. So without the requirement for ground control, integrated inertial/GPS technology can offer a significant advantage under these circumstances. In many cases it is the enabling technology behind various imaging sensors such as LIDAR, SAR (Synthetic Aperture Radar), and IfSAR (Interferometric SAR), providing the georeferencing component to the data.

Future Trends

With continued improvements in GPS technology and the move towards MEMS-based (Micro-Electro-Mechanical Systems) inertial components, integrated inertial/GPS systems are becoming more mainstream in being able to offer the airborne geospatial community the necessary accuracy levels they require.

By the year 2010 it is expected there will be a full constellation of next generation satellites to bolster the GPS numbers currently in use. The introduction of Galileo from a European consortium will make a major difference in accuracy and accessibility, with 30 new satellites in orbit. The Galileo system of satellites and ground stations will complement the existing GPS system in the same way that GLONASS is presently being used. A number of other countries, such as India and Japan, are looking at initiating their own satellite programs so the future of satellite positioning for the geospatial community looks very positive.

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