Integrating GNSS and INS

GNSS provides accurate positional information with relatively low integrity, while INS offers position and attitude information subject to drift but with relatively high integrity. Integrating the two provides reliable and accurate information on position and attitude of vehicles on land, at sea, in the air and in space. Integrated GNSS/INS: I know what it is, I know what it does, but how does it work?

All sensor data such as aerial imagery acquired from an airborne platform needs to be geo-referenced to be of further use. In treating the subject of exterior orientation we here focus on aerial digital cameras, not least because this month’s product survey is devoted to the same subject. For geo-referencing of an aerial image the X, Y and Z coordinates of the camera projection centre have to be known as well as the orientation (attitude in 3D space) of the image plane in the camera. The rotation around the X-axis is conventionally called?(omega), the rotation around the Y-axis?(fie) and around the Z-axis?(kappa). Together, the X, Y and Z coordinates of the projection centre and the three orientation parameters are called the “parameters of exterior orientation”, and total six. The conventional way of geo-referencing airborne images is by using Ground Control Points (GCPs). These are reference points, usually connected to a national geodetic reference system, which have been accurately measured. The measurement and monitoring of GCPs is a time-consuming and thus costly process. Over the past approximately fifteen years the combined use of GNSS and INS has made possible a dramatic reduction in the number of GCPs and revolutionised airborne data acquisition.?

INS?
Assuming the reader is familiar with the principles of Differential GPS, we here focus on Inertial Navigation Systems (INS). This consists of a configuration of gyroscopes and accelerometers, the gyroscopes maintaining a fixed direction in space. Rotations around the gyroscopes caused by aircraft dynamics are measured and processed by computer connected to the INS. The accelerometers measure acceleration along three perpendicular axes. Twice integration of the accelerations over time allows calculation of aircraft position. Why use GNSS to determine position when INS provides the same? The table shows the differing properties and deficiencies of satellite positioning and inertial navigation systems. The deficiencies of the one may be compensated by benefits of the other system: the two technologies have complementary characteristics. For example, the sensitivity of GNSS to cycle-slip and loss of lock may be compensated by the high output rate and high short-term positional accuracy of INS. On the other hand, INS drift sensitivity, which introduces systematic errors in positioning, may be compensated by the high long-term positional accuracy of GNSS. If every second the GNSS system provides a new position, the INS system may be duly updated. A combination of both systems thus bridges the gap caused by deficiencies in each.

Kalman Filter
How are GNSS and INS measurements combined? The mechanism for eliminating failures in GNSS positioning using INS measurements, and vice versa, is a recursive data-processing algorithm called the Kalman Filter. The idea is to make use of GNSS and INS measurements, noise characteristics and possible outlier characteristics of the measurements, taking into account the dynamics of the aircraft (speed, tilt, pitch and yaw). In this way, position and orientation of a device can be optimally determined with respect to virtually any rational criterion. In particular, the sum of the squared errors is minimised. The Kalman Filter is “recursive”, meaning that unlike other data-processing methods it does not require all previous data to be kept in storage for reprocessing every time a new measurement is taken. In 1960 the Budapest-born Hungarian Rudolf Emil Kálmán published his famous paper describing the recursive solution to the problem of discrete data linear filtering. Although not the inventor of the method, he was the first to recognise its practical applications. Since then the Kalman Filter has been the subject of extensive research, and extremely successful in the accurate and reliable navigation and positioning of vehicles on land, at sea, in the air and in space.