Aided Inertial Technology: Positioning for the Future

M. Zywiel, Applanix Corporation

Published in Traffic Technology International, January 2003

Without a doubt, positioning technologies, and GPS in particular, have had a significant impact on the development of ITS (Intelligent Transportation Systems) technologies. From fleet tracking to vehicle navigation systems, GPS has brought the ability to easily position oneself (or one's vehicle) virtually anywhere. The result has been an explosion of technologies relying on real-time positioning.

Aided inertial systems are able to provide a continuous, accurate positioning solution in all vehicular environments: in tunnels, under underpasses, and in urban environments.

Nonetheless, GPS has always come with limitations. Until recently, selective availability (intentional degradation of the GPS signal by the US government) limited accuracy to around 100 meters. Two years ago, selective availability was turned off, and GPS accuracy improved considerably, with autonomous positioning now showing accuracies of 10m or better. Using a Real-Time Kinematic base station and rover system, users can even achieve centimetre-level positioning.

However, GPS still faces one significant limitation - the requirement for line-of-sight visibility to at least four satellites in the sky (five for Real-Time Kinematic applications) for position data to be extracted. Not only does this limitation render GPS ineffective in tunnels, in mountainous terrain and in urban cores, but even low-rise buildings and trees can obstruct the signals. Because of the number of variables that affect GPS performance (reflected signals, satellite constellation, etc), it is difficult to predict just how well GPS will perform in a particular type of environment. However, even in suburban subdivisions, it is not uncommon to have less than 50% GPS coverage while driving down the road. Similarly, urban areas may have between 40 and 80% of their road mileage obstructed to GPS at any one time.

For some applications, interrupted availability is not a significant disadvantage. For cross-country vehicle tracking, for example, occasional position updates to base are more then sufficient to know where the vehicle is in its route. However, there are several future applications (and doubtless many more that have yet to be dreamed up) that require more robust positioning – positioning data that can be relied upon to be always there, always accurate. For example, given an accurate base map and reliable vehicle positioning to within 10cm in all environments, it would theoretically be possible to develop an autonomous vehicle system based on that data alone. After all, 10cm accuracy would be enough to constrain the vehicle to a particular lane of a particular road, and if communicating with other vehicles, keep them a sufficient distance apart to prevent accidents.

One of the technologies that is already addressing the limitations of GPS-only positioning is aided inertial technology (AIT). This technology is based around an inertial sensor, which senses both linear and rotational accelerations of the host vehicle along all three axes. Given a known starting point of a vehicle, and all the accelerations that vehicle has experienced since the known starting point, an aided inertial system can compute in real-time the displacement of the vehicle from the known starting point, and thus its current position. The principle is not unlike the sensations felt while driving an automobile. If you were sitting blindfolded in the passenger seat of a car, you are able to feel when the vehicle accelerates, decelerates or turns a corner. Your body senses these accelerations without any other sensory inputs. Similarly, an inertial sensor will sense, and quantify, these accelerations. The more

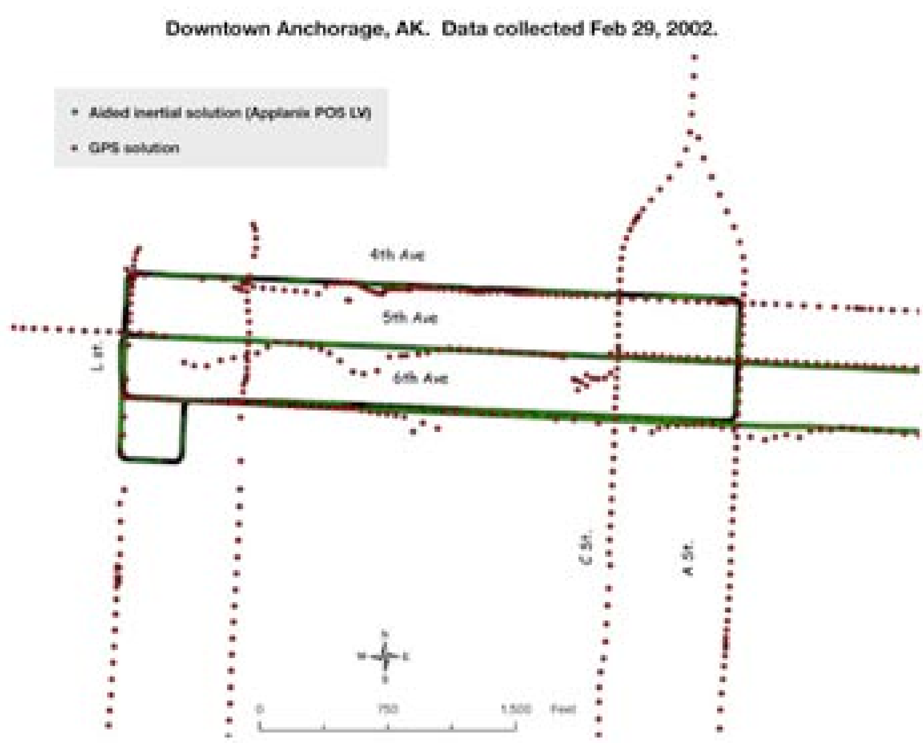
The top-of-the-line Applanix POS LV 420 aided inertial system consists of: the inertial sensor, two GPS antennas, a DMI to measure wheel rotation, and the processing unit

finely tuned the inertial sensor, the more accurately the accelerations will be quantified and the more accurate the measured displacement.

Because no inertial sensor will measure accelerations perfectly, errors will gradually enter the positioning solution, and grow over time. To overcome this problem, the inertial sensor is aided (thus the name Aided Inertial Technology) with information from other sensors. For land vehicle systems, it will generally be aided with GPS, to provide occasional position updates whenever GPS is available, and a wheel rotation sensor to provide distance travelled information as a check to the inertial data. The result? Aided inertial systems are able to provide a continuous, accurate positioning solution in all vehicular environments: in tunnels, under underpasses, and in urban environments.

Two examples of the capabilities of AIT can be seen at the right. The first figure shows the results of a simultaneous comparison of an Applanix POS LV aided inertial system with GPS-only positioning. This test was carried out by the Alaska Department of Transportation as part of a feasibility study of Aided Inertial technology. In it, it can be clearly seen that even in a relatively good GPS environment (low buildings), GPS was having trouble maintaining integrity, and the GPS solution deviated significantly from the road track. By comparison, the aided inertial solution remained true to the route driven at all times. An oblique aerial photograph of Anchorage is included to illustrate the GPS environment found in downtown Anchorage.

The second figure shows the results of a test where a van equipped with an Applanix POS LV aided inertial system was driven through a suburban housing development north of Toronto, Canada. The figure shows the aided inertial trajectory (red) and GPS-only solution (green) overlaid over an orthophoto of the area. As can be seen, even in this environment, GPS dropouts are a concern, with a significant portion of the route driven being unavailable to GPS. This area was driven twice in each direction during this test. Between the two runs, a



Survey Data from Anchorage, Alaska

Aerial photograph of Anchorage, Alaska

Toront, Ontario survey through housing development

car had parked alongside the curb in the highlighted area. It can be seen that the resolution of the Aided inertial solution is high enough to show the test van having to drive around the parked car on the second run.

A further benefit of AIT is that data can be updated extremely frequently. Currently, higher-end systems will update up to two hundred times a second, while even the most advanced GPS receivers only update at about one-tenth of that rate. This may seem sufficient, but if a vehicle is travelling at 100 km/h, the vehicle will travel about 2 meters between GPS updates, while travelling only 14cm between aided inertial system updates. In addition, AIT systems are able to provide vehicle orientation data (pitch, roll, heading) at similar update rates.

In short, AIT systems are able to provide a full picture of vehicle motion, with high update rates and no vulnerability to GPS outages due to the surrounding environment.

The accuracy of aided inertial systems is primarily the function of two variables: the accuracy of the inertial sensor, and the quality of the algorithms used to blend data from the aiding sensors with the inertial data. The result is that AIT systems can be developed to a variety of price and accuracy requirements.

Currently, AIT systems are in their infancy, not unlike where GPS was a decade ago. In the ITS field, current markets for AIT are for high end, low-volume systems, and include van-based mobile mapping systems, vehicle dynamics tracking systems and prototype safety systems. Low-end systems are available that use an inertial sensor along one axis of motion. These are known as dead reckoning systems. Although capable of rudimentary continuity of position data, errors are easily and quickly introduced in such systems.

Inertial technology is however evolving quickly. Chip-based inertial sensors are starting to appear, and as their accuracy improves, they will inevitably be incorporated in future generations of Aided Inertial products. The two main benefits of this technology will be reductions in size and improved production, both resulting in significantly reduced cost. In the longer-term future, it will not be uncommon to see single-board AIT systems, with inertial sensors and a GPS receiver integrated onto one circuit board.

If your ITS application requires reliable positioning, why not look into Aided Inertial Technology?

Mike Zywiel is manager of the marketing & communications department at Applanix Corporation, Canada. He can be contacted via email at mzywiel@applanix.com.