Applanix POS LV 200

Generating continuous positioning accuracy in the absence of GPS reception

Frank Artes and Louis Nastro, Applanix Corporation

August 2005

Introduction

Mobile mapping vehicles equipped with GPS positioning systems are often subject to GPS satellite shading and signal dropout, when operating along tree-lined streets, in wooded areas and environments where tall buildings can block reception. In many jurisdictions this is often the case where approximately 80% of data collection missions are conducted in difficult GPS areas. Vehicle-mounted GPS positioning is further hindered by structures which cause satellites to go in and out of view, limiting a GPS receiver's ability to provide continuous, accurate position information. In addition, multipath problems encountered as a result of signals bouncing off reflective surfaces, often cause GPS systems to be unable to provide reliable positioning information in this type of area.

Faced with these limitations organizations which regularly operate under these conditions are now looking at augmenting their existing GPS systems with additional positioning technology. This paper highlights the use of one such system, the POS LV 200 produced by Applanix Corporation, which utilizes tightly-coupled integrated inertial technology. A test carried out in downtown Toronto is evaluated to determine the operational capabilities of the system both in real-time, and after logging and post-processing of data.

The Need for Increased Accuracy

The POS LV 200 was created in response to growing calls within the GIS community for increased accuracy in enterprise data. With data sharing increasing across agencies and internal departments, there is a demand for standardized geospatial data. However, depending on the diverse data collection methodologies and equipment employed in the field, such standardization has been difficult to achieve. For example, some GIS departments deploy personnel, even in dense urban canyons, with handheld GPS units to record assets and other points of interest. While this may seem to be cost effective, the labor involved to conduct a comprehensive asset mapping mission compared to the poor accuracy achieved, has a minimum return on the city's investment when data cannot be shared due to accuracy issues. Another approach involves the utilization of corrected signaling to increase the accuracy of the mission. This can be achieved by SBAS (satellite- based augmentation services), such as OmniSTAR and NavCom, utilization of DGPS (Differential GPS) or RTK (Real-Time Kinematic) surveying techniques. While all of these approaches offer increased accuracy, they are all subject to the effects of multipath. Satellite-based augmentation services, as will be demonstrated later, offer ubiquitous reach with no need for base stations, but real-time accuracy suffers tremendously. Utilization of RTK, while the most effective in terms of accuracy, requires the use of a base station and requires up to 30 minutes to initialize. If the receiver is located in or near adverse GPS environments and looses lock, the signal acquisition process must begin again wasting valuable time.

The Benefits of POS LV 200

With data accuracy and standardization a necessity for numerous applications, POS LV 200 is the only product which offers a cost-effective and comprehensive solution for missions requiring robust positioning and orientation. One such application can be illustrated by E911 legislation in the United States which requires all wireless carriers and emergency service providers to supply accurate street address data and the location of mobile handset users. This has placed increasing demands on GIS data acquisition. During the initial phases of the program, it was found that existing data, such as road centerline and address point locations that populated 911 databases, were inadequate[1]. The reason for this shortcoming was simply an attempt at cost reduction. City data, especially in built up areas, was cost-effective to acquire, but far from accurate enough particularly when life and death decisions depend on knowing exactly where emergency services need to be delivered[2].

In one pass, data can be acquired (viewed in real-time and/or collected for post-processing) and analyzed for precise results.

Also related to E911 legislation is the requirement for wireless carriers to ensure that their networks provide adequate coverage in all areas. This means measuring radio frequency intensity within two to five meters. However, multipath severely limits the accuracy of their measurements, necessitating multiple data collection runs or other less precise techniques to try and derive the data. This is where the POS LV 200 is so effective. In one pass, data can be acquired (viewed in real-time and/or collected for post-processing) and analyzed for precise results.

New commercial opportunities, such as geo-visualization, have found a role for the POS LV 200 as well. In working with organizations providing geospatial data services, and researching the needs of the GIS community as a whole, it became

[1] *Wallace, Sam "The Hard Truth About GIS Mapping and E911" Directions Magazine, February 19, 2002.*
[2] *Williams, David "Wireless Carriers as Making Great Progress Implementing Wireless E911…So What's the Problem?" Directions Magazine, September 22, 2004.*

clear that the market needed an entry level product that could cost effectively provide accurate position and orientation information. For data providers creating GIS databases, collecting content for internet search engine services, or the real estate industry, this data has tremendous value. POS LV 200 ensures that with one pass, data is collected accurately and reliably. This is the core value proposition that makes this product unique. Single pass data capture saves the user time eliminating the need for re-collection and additional post-processing of data. Further benefits are realized when one considers the frequency of data collection necessary to keep it up to date. Having the re-collection conducted using the same system allows seamless integration with data sets already incorporated into a client's geospatial database.

Integrated Inertial Technology

A basic integrated inertial system is a combination of GPS/IMU (Inertial Measurement Unit) technology specifically designed to generate accurate and continuous position and orientation information. The POS LV 200 has been designed for integration with the client's existing GPS receiver/antenna-equipped vehicle.

System Components

The POS LV 200 system comprises three major components:

1. POS Computer System (PCS) – a powerful processing unit which operates with either 12v or 24v power supply

2. IMU – a compact and lightweight component that uses miniature RLG (Ring Laser Gyro) technology

3. DMI (Distance Measurement Indicator) – wheel-mounted odometer technology designed to prevent position drift when the vehicle is stationary

- Plus user-supplied GPS receiver

Figure 1 illustrates the relationship between the individual components within an integrated inertial system. The system integrates inertial data from the IMU which contains three accelerometers and three gyros, one for each axis. The IMU is designed to measure position and orientation differences and provide a true representation of motion in all axes. The DMI, which is attached to one of the vehicles rear wheels, produces linear distance traveled data in addition to velocity aiding. The GPS receiver generates additional position and velocity information.

In its tightly-coupled navigation mode, the system does not use the position and velocity data provided by the GPS receiver, instead, it automatically integrates raw GPS satellite data directly into the system. This allows for the utilization of position-aiding data when just one GPS satellite is observed. No position solution would be generated by standalone GPS is this case, since a minimum of four satellites must be visible to generate a position solution.

Integrated inertial technology enables a vehicle's position to be accurately maintained. The system's full six-degree-of-freedom mechanization allows the position (latitude, longitude and height), heading, roll and pitch of the vehicle to be known at all times.

The AgGPS® 132 is a high-performance receiver that uses either free public or subscription-based differential correction services to calculate sub-meter positions

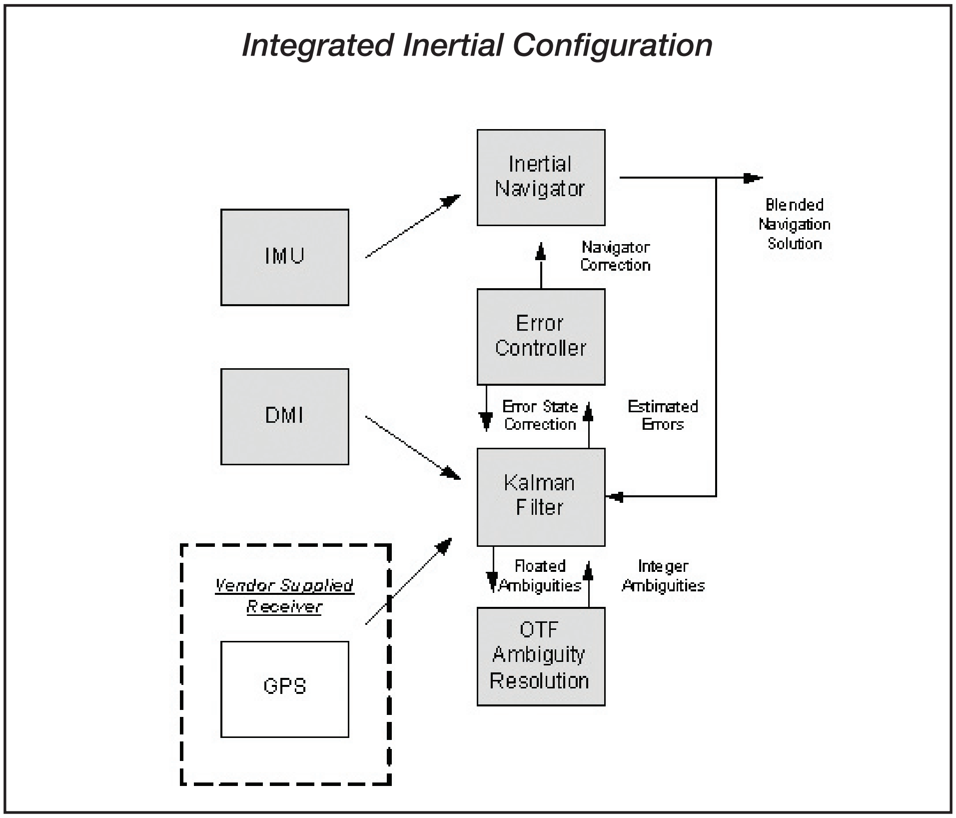

Figure 1

85 Leek Crescent, Richmond Hill, Ontario CANADA L4B 3B3
Tel: 905-709-4600 **Fax:** 905-709-6027 **Web:** www.applanix.com

in real-time. The AgGPS 132 includes Trimble's The Choice™ technology that allows you to choose between satellite-based private subscription differential correction services and the government's differential correction radio-beacon network. WAAS (Wide Area Augmentation System) corrections can also be used.

The AgGPS 132 outputs sub-meter accuracy DGPS positions using NMEA or TSIP messages. It is also equipped with the EVEREST ™ multipath reduction option which automatically rejects multipath signals before positions are computed.

The Toronto Test

The route chosen for the test covered approximately 60 kilometers, taking three hours to complete, with the Applanix head office in Richmond Hill, Ontario acting as the start and end point. The highlight of the test was the real-time and post-processed performance characteristics of the system in the heart of downtown Toronto, which presents a formidable challenge for GPS signal reception. The test trajectory is shown in figure 2 projected onto an orthophoto of downtown Toronto, and in figure 3 as the POS trajectory results post-processed using POSPac Land 5.0 software.

In addition to conducting the test to show the robust positioning accuracy of the POS LV 200, the team chose to integrate the unit into a passenger vehicle, to illustrate the ease of use and plug-and-play nature of the system. The entire system was installed, calibrated and tested in under two hours.

Test Results

After a brief system initialization process the test began in an open area where GPS reception was good. The accuracy on the way to the Toronto test site was in the order of 0.5m to 1m RMS, which is the expected performance from the AgGPS 132. However, as figure 4 illustrates, as soon as the vehicle approaches the periphery of the downtown core, accuracy starts to degrade. The peaks and valleys in the data set are a function of two variables. The first is the availability of GPS data. The POS LV 200 can use the raw observables from as few as one satellite to integrate into the positioning solution.

This is a critical differentiator as most other IMU/GPS systems will need a minimum of four satellites to allow the GPS position fix to be incorporated into the positioning solution. The second factor is operator training and conducting a zero velocity update (ZUPT) at certain intervals. The ZUPT allows high-accuracy position to be maintained by recalibrating velocity estimates. The ZUPT process is complete within 30 seconds of coming to a complete stop and handled automatically by POS LV.

Notice that apart from the positioning error spikes at 5.5m and 7.5m RMS, the rest of the mission was conducted with errors lower than 3.2m RMS. This included extended runs under bridges where not even raw observables could be incorporated into the positioning solution.

What is interesting to note is the real-time performance of DGPS alone as compared to the POS LV 200. The blue dots represent

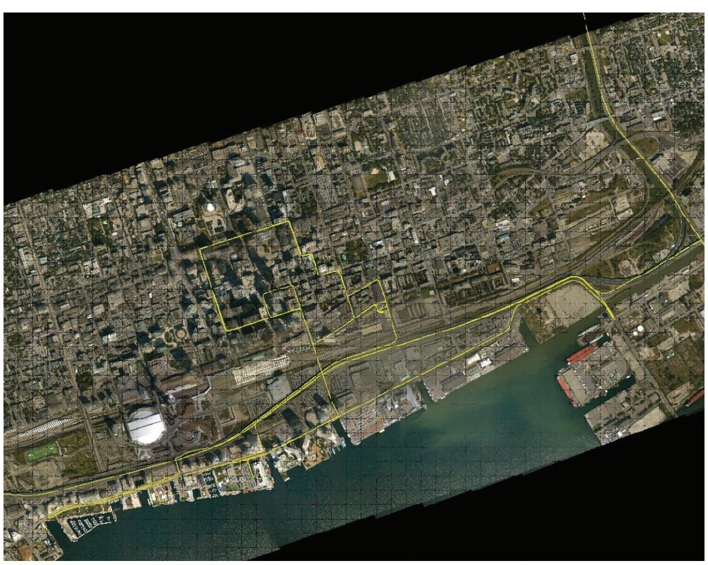

Figure 2 Downtwon Toronto

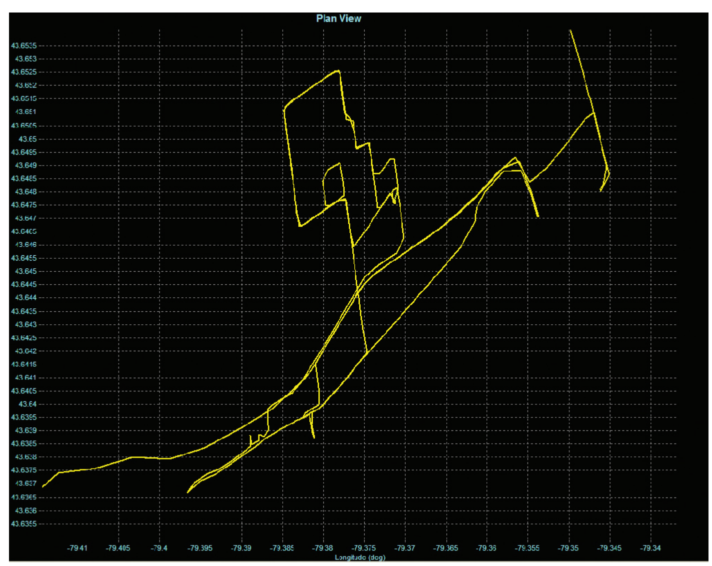

Figure 3 POS Trajectory

real-time GPS while the yellow lines show the real-time trajectory as calculated by the POS LV 200. For the majority of the course, the GPS data is spurious at best and even when available, position errors of over 50m were recorded. Another interesting observation can be made which shows how the POS LV 200 incorporates degraded raw observables into the solution and still maintains a precise track.

Figure 6 is magnified to illustrate how the unit tracks precisely, enabling repeatable results along a one way street, with differing levels of GPS signal reception. Notice how one set of blue dots (GPS reception) is quite close to the actual trajectory (indicating that the raw observables are reasonably close to the actual track).

However, on the second run, the GPS is off the actual track by over 10 meters, yet the POS LV 200 trajectory tracked right over 90% of its previous course. This is only possible through powerful filtering techniques.

With the real-time results discussed, we can now turn to how well the POS LV 200 data can be post-processed with POSPac Land 5.0 software. Nearly all GIS data is post-processed as part of a user's typical workflow. Post-processing becomes particularly important when using collected data for enterprise-wide use. In this magnified view (figure 7) of the most difficult portion of the test run, we can see that GPS coverage is quite sparse, and when available is clustered and quite divergent from the path of the vehicle. The trajectory calculated using POSPac Land 5.0 places the vehicle almost within the lane despite the poor GPS reception.

Also worthy of mention is the degree of overlap between the real-time and post-processed solutions. While at certain locations there is a high degree of convergence, POSPac Land 5.0 generates a smoothed best estimate of trajectory (SBET) which is critical for generating accurate positioning and removing the real-time errors generated during instances

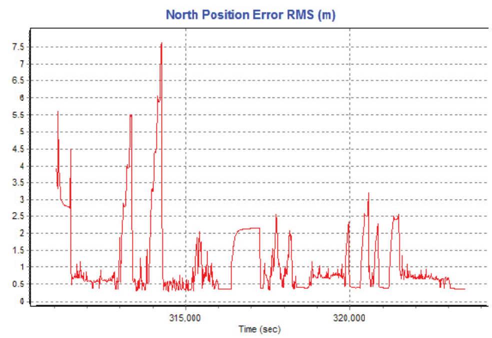

Figure 4 Position Errors

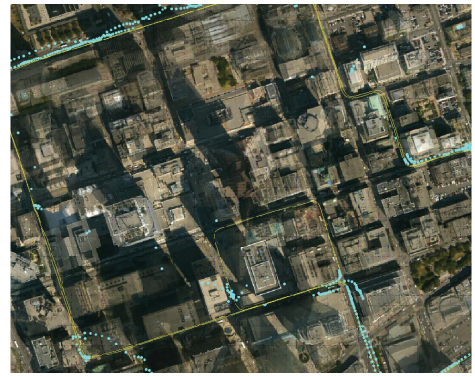

Figure 5 Downtown Core

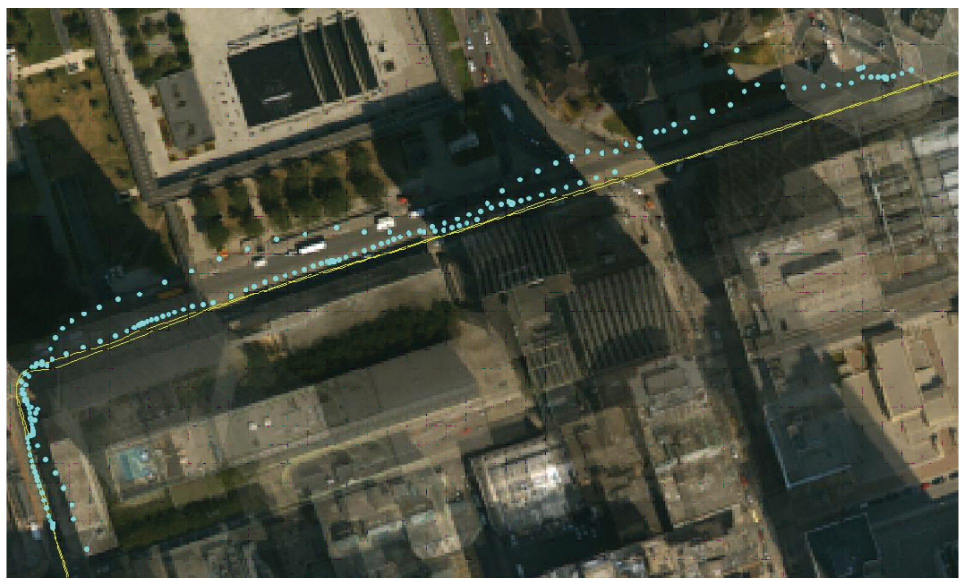

Figure 6 Precise tracking

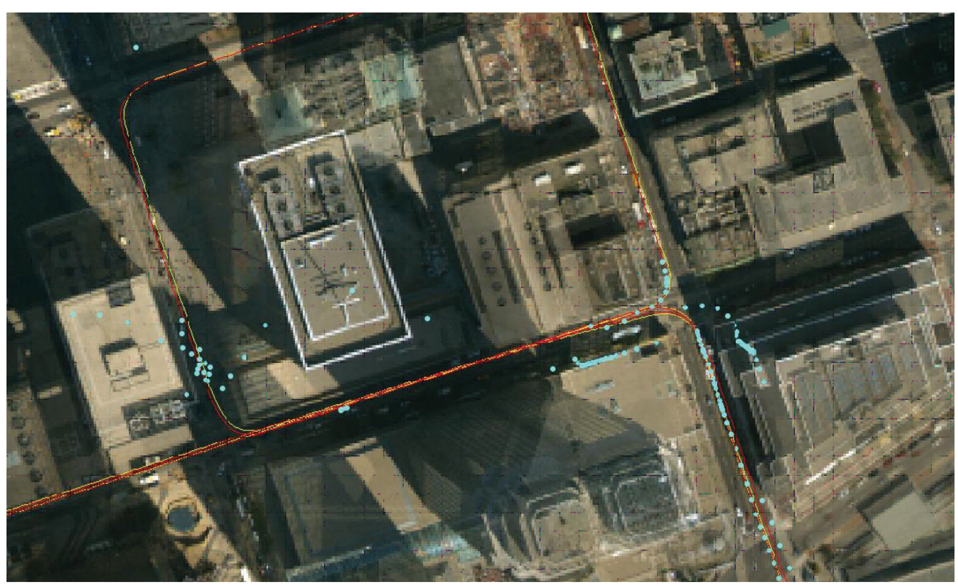

Figure 7 Sparse GPS coverage

of GPS signal loss and severe multipath conditions.

The results of post-processing are even more compelling when looking at the error plot (figure 8) as compared to the real-time graph (figure 9). While the peaks in that data are still evident, the magnitude of the error is decreased substantially. Recall that the two predominate spikes in the data during real-time were 5.5 and 7.5m RMS respectively. Those errors were reduced to 1.29m and 1.38m RMS respectively, a reduction in the error estimate by over six times. Another point that must be made is that over 80% of the data is accurate within 1m RMS. Consider that OmniSTAR quotes the accuracy of its standard service at less than a meter. However, this is in ideal GPS reception conditions.

The performance of the POS LV 200 is furher illustrated when comparing the positioning solution with the real-time GPS standard deviation results. The data being sent to the POS LV 200 was consistently over 50m RMS in error while the biggest position degradation experienced real-time was 7.5m. The other important factor worthy of mention is the standard deviation from the GPS increases and decreases dramatically during the mission. This poses a significant challenge to any system attempting to integrate raw observables into a positioning solution. It is a testament to the robustness of the POS LV 200, when such poor GPS can be utilized, even during prolonged outages and acute multipath conditions to produce sub-meter results post-processed.

Conclusion

The POS LV 200 system has been designed to provide operators with a plug-and-play solution, complete with the option of utilizing powerful post-processing software, to consistently achieve sub-meter position accuracy when required. The system provides impressive real-time positioning results even during extended periods when GPS is unavailable (GPS outage), which is confirmation of the robustness of the POS LV 200. The unparalleled performance and

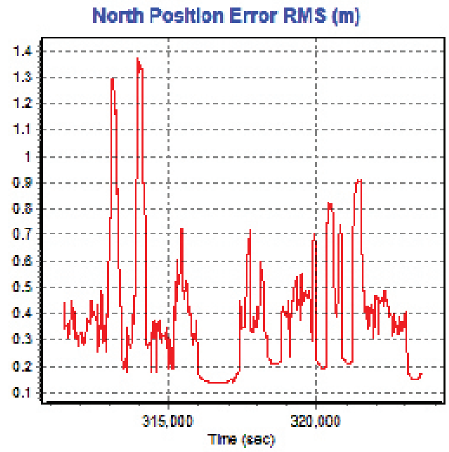

Figure 8 Position error plot

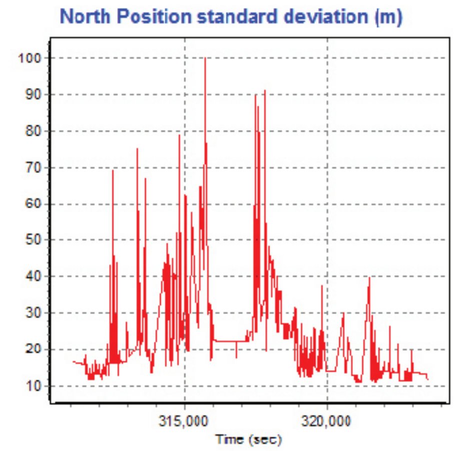

Figure 9 Real-time graph

simplicity of operation is a key enabler for users of mobile mapping sensors engaged in road profiling, asset management and GIS data capture etc. POS LV 200 is the only cost-effective solution which can demonstrate reliable, repeatable, and accurate data acquisition and processing, for a myriad of commercial mapping applications.

Acknowledgements & Thanks to:

Steve Szabo, Applanix Corporation for system installation and testing
Andrew Ko, Applanix Corporation for data processing and analysis
Alan Ip, Applanix Corporation for image processing
Rob McCuaig, Applanix Corporation, vehicle utilization