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CSRS-PPP: AN INTERNET SERVICE FOR GPS USER ACCESS TO THE CANADIAN SPATIAL REFERENCE FRAME

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In October 2003, the Geodetic Survey Division of Natural Resources Canada introduced an on-line service for GPS users that facilitates access to the Canadian Spatial Reference System (CSRS). CSRS-PPP (CSRS - Precise Point Positioning) allows GPS users in Canada (and abroad) to achieve accurate positioning by submitting GPS observations from a single receiver over the Internet. The resultant precision is comparable to phase-differential GPS without the need to access or process data collected simultaneously at a base station or to ensure that the coordinates of the base station are properly referenced. CSRS-PPP can process GPS observations from single or dual-frequency GPS receivers operating in static or kinematic mode. Depending on user equipment, receiver dynamics and duration of the observing session, this application can improve positioning results by a factor of 2 to 100 in comparison to uncorrected point positioning using broadcast GPS orbits. This level of improvement can often be reached with reduced cost and increased operational efficiency by eliminating the requirement for GPS users to acquire base-station data. The key to this PPP approach is the use of precise GPS orbit and clock products generated through international collaboration which are typically 100 times better than those contained in the GPS broadcast navigation message.

While the service estimates user positions based on satellite orbits established in the International Terrestrial Reference Frame (ITRF), transformation parameters to NAD83 (CSRS) are applied internally to link the user directly to the CSRS. NAD83 (CSRS) is being increasingly adopted as the standard of reference for positioning in Canada. Positioning with respect to recognized standards greatly facilitates sharing and integrating geo-referenced datasets to ensure their long-term spatial compatibility at the highest precision, permitting interoperability of related applications.

AIRBORNE KINEMATIC POSITIONING USING PRECISE POINT POSITIONING METHODOLOGY

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Currently, high precision kinematic GPS positioning with centimetre-level accuracy can only be carried out using a differential GPS (DGPS) positioning approach which requires the deployment of a GPS receiver at each base station. The DGPS approach, spatially limits the operating range of the rover receiver to about 20 km from the base stations. As a result, it increases not only the operational cost of equipment and human resources but also the logistical complexity of many applications such as land and geodetic surveying, and airborne mapping. With the increased availability of precise GPS satellite orbit and clock data with reduced latency from the International GPS Service (IGS) and many other organizations, high precision kinematic positioning at centimetre to decimetre-level is now possible using a single GPS receiver. This paper describes a method known as precise point positioning and its application to airborne kinematic positioning. Different from the conventional DGPS approach, the new method does not need a base station since the position determination is based on the processing of un-differenced code and carrier-phase observations from a single GPS receiver. It therefore eliminates the dependency on base station and the rover range limitation associated with conventional methods, resulting in instant advantages in field operations. A software system that has been developed at the University of Calgary will also be described in this paper along with numerical results to demonstrate the positioning accuracy obtainable.

COLLOCATION-BASED MULTIPLE REFERENCE STATION POSITIONING USING THE COVARIANCE OF THE CORRECITONS

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The multiple reference station approach is a method of integrating the information from multiple nearby reference stations to further improve precise carrier-phase positioning relative to the traditional single reference station approach. Network RTK uses data from a network of reference stations to model the correlated atmospheric and orbital errors to predict the errors at the location of a rover within the network. One method for predicting the errors is using least squares collocation. Multiple reference station positioning is currently somewhat limited due to the processing options of off-the-shelf receivers. Network RTK corrections are converted into a single reference station corrections format so that a roving receiver can interpret them. Due to this limitation, focus has been on calculating the value of the corrections and ignoring any stochastic information because it could not be used. This paper examines the performance of the collocation-based multiple reference station approach using both the value and estimated variance-covariance of the correction. Tests on the Southern Alberta Network, Canada, show that this approach reduces L1 and L2 carrier-phase measurement residuals by 13 to 35 percent and 3D position errors by 16 to 35 percent.

A HYBRID AUTONOMOUS POSITIONING SYSTEM FOR PUBLIC TRANSPORTATION

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Transit systems commonly use traditional technologies such as Dead Reckoning (DR) and signpost systems for vehicle position determination. Unfortunately, these systems suffer from a number of drawbacks, which affect the operational efficiency of the transit system. To overcome the limitations of these conventional systems, a hybrid positioning system is developed in this paper. The integrated positioning system consists of a low-cost autonomous GPS system, supplemented by the already existing conventional DR/signpost systems. An optimal positioning solution is obtained using the Kalman filtering technique, which utilizes all the available sensor information. The biases of the conventional sensors are modelled as first order Gauss-Markov and random walk processes. In addition, the frequent bus stops are taken into consideration to estimate the gyro bias offset. To further increase the accuracy of the integrated system, the signposts are used as reference stations to correct for the positioning error.

Two field trials were conducted to evaluate the performance of the integrated system: one in an open area, the other in an urban area with high-rise buildings. It is shown that the DR solution was rather poor but could be improved by frequent signpost updates. A GPS-only solution was not adequate, by itself, to aid or update the DR system in the urban area. The integrated system, GPS, DR, and Signpost, gave a reliable solution in the open area, with GPS outages for 100 seconds with maximum error equal 22.9 m and 22.6 m in the north and east directions, respectively. The downtown test results were not accurate compared with the simulated outages and its deviation from the road centre line was in range from 30 m to 50 m. However, taking the bus dimension into consideration, it is clear that the obtained positioning solution is still sufficiently precise.

WAVELET MULTI-RESOLUTION ANALYSIS FOR ENHANCING THE PERFORMANCE OF INTEGRATED GPS AND MEMS-BASED NAVIGATION SYSTEMS

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Motivated by the demand for low-cost and small-size positioning/navigation systems; micro-electro-mechanical sensor (MEMS) technology has been utilized for manufacturing MEMS-based inertial sensors as a part of inertial measurement units (IMUs). These IMUs usually consist of three-axis gyroscopes and three-axis accelerometers and are usually integrated with the receivers of the global positioning system (GPS) to provide low-cost and small-size vehicular navigation systems. MEMS-based IMUs are usually employed as complementary systems to GPS to provide reliable short-term position and velocity information during satellite signal blockage. However, the inadequate performance of most of the present commercially available MEMS-based IMUs limit their utilization in providing reliable navigation systems. This research offers a new method based on Wavelet Multi-Resolution Analysis (WMRA) for improving the performance of MEMS-based IMUs. WMRA technique is used in this article to improve the sensors' signal-to-noise ratios, to remove sensor errors mixed with motion dynamics, and to provide more reliable position/velocity information during GPS signal outages. The proposed method was applied to a MEMS-based IMU containing Analog Devices MEMS gyroscopes and Colibrys MEMS accelerometers. Results have shown that enhancement in positioning accuracy by at least 50% during GPS outages can be obtained by applying the proposed WMRA technique, thus reaching positioning accuracy levels equivalent to those of some of the current tactical-grade systems but at a much lower cost.

USING GPS FOR AUGMENTING DEFORMATION MONITORING SYSTEMS IN OPEN PIT MINES—PROBLEMS AND SOLUTIONS

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Large open pit mines require continuous monitoring of the stability of the bench walls. In most cases, sub-centimetre accuracy at the 95% confidence level is required in displacement detection of hundreds of targets. Presently, robotic total stations (RTSs) with automatic target recognition provide the most efficient solution for the monitoring problem. In large open pit mines it may be necessary to place the RTS near the bottom of the pit in unstable conditions without visibility to stable reference points. Extensive testing has been performed in a large open pit mine to evaluate the use of GPS in controlling the stability of the RTSs. The goal was to achieve GPS corrections to the position of RTSs with a standard deviation of ≤ 2.5 mm for each of the three components (N, E, h). Five days of continuous GPS data from different levels of the open pit mine indicated that the main limitations in reaching the accuracy requirements are residual tropospheric delay and limited satellite visibility. To improve the performance of the combined RTS/GPS monitoring system, several alternative solutions have been suggested including the augmentation of GPS with pseudolites and the use of an adaptive filtering technique in processing the GPS data.