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Oral Presentations
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Session 1: The GNSS Global Perspective Part 1 0850 - 1015

U.S. Space-Based Positioning, Navigation and Timing: A Policy and System Update

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Scope: This presentation will focus on the development of the U.S. space-based positioning, navigation and timing policy. It will review the background of that policy and will look at measures that have been taken to implement the policy. The talk will address the establishment of the National Space-based PNT Executive Committee and provide some insight into the issues that are currently under consideration.

U.S. Approach: Questions concerning the U.S. modernization schedule will be addressed in the U.S. presentation. GPS modernization and the associated implementation of the two new Global Positioning System (GPS) civil signals, completion of ongoing civil augmentation systems, and finally, the compatibility and interoperability with other providers and potential providers will be discussed. These new signals, L2C and L5, coupled with the L1 band, are improving the positioning, navigation, and timing capabilities that GPS provides to the vast array of civil and commercial applications.

New international structures are taking into account the increasing global nature and use of GPS as well as other GNSS systems. The presentation will conclude with a brief summary of U.S. collaboration with other GNSS providers as well as the outcome of the 2nd Annual Meeting of the International Committee on Global Navigation Satellite Systems.

Conclusion: Satellite navigation will be one of the key enabling technologies of our future 21st century transportation and airspace management system. GPS has provided worldwide users with navigation, positioning, and timing services since becoming operational in late 1993. The United States hopes to improve those services through modernization, augmentations, and working closely with other GNSS providers.

US Diplomatic Efforts on International Satellite Navigation Issues

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Abstract to be provided

Current status of the Japanese Quasi-Zenith Satellite System (QZSS)

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QZSS (Quasi-Zenith Satellite System) is a Japanese satellite navigation system that consists of space segment and ground segments. In space segment, there are three QZS (Quasi-Zenith Satellite) whose orbit is designed that one QZS out of three satellites always exists near zenith over Japan at least. The benefit of QZSS is that QZSS can provide a seamless service from a high elevation angle to improve the positioning availability in downtown and mountainous areas. QZSS signals from high elevation angle can provide substantially better positioning availability than that of GPS alone. QZS will transmit 6 signals on 4 frequencies, and has 2 types of the GPS interoperable and GPS augment.

JAXA (Japan Aerospace Exploration Agency) is taking part of the R&D of QZSS with other national research institutes. JAXA has responsibility to develop the first satellite of QZSS (QZS-1) which consist of satellite bus system and navigation payload and the ground segment including MCS (Master Control Station), MS (Monitor station) and satellite tracking & control stations.

This paper describes the QZSS total system design such as the QZS-1 configuration, payload performance and ground system. It also describes current status of the development of the system. JAXA has been conducting critical design of QZSS and conducting functional and performance tests of the Engineering models of Navigation payload. QZS-1 will be launched in JFY(Japanese Fiscal Year) 2009.

KEYWORDS: QZSS (Quasi-Zenith Satellite System), QZS-1 (the first satellite of QZSS) GPS (Global Positioning System)

Session 2A: Personal Navigation 1045 - 1225

Adaptive knowledge based system based on artificial neural networks and fuzzy logic for pedestrian navigation

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The primary objective of the research presented in this paper is to develop theoretical foundations and implementation algorithms, which integrate the Global Positioning System (GPS), Micro-electro-mechanical inertial measurement unit (MEMS IMU), digital barometer and compass, and human pedometry to provide seamless navigation and tracking of military and rescue ground personnel. This paper discusses the current design, implementation and the performance analyses of the multi-sensor personal navigator prototype, currently under development at The Ohio State University Satellite Positioning and Inertial Navigation (SPIN) Laboratory. The system model represents an open-ended architecture, designed to incorporate additional navigation and imaging sensors to extend the system's operability to confined and GPS-denied environments. A key component of the current system architecture is a simplified dynamic model of human locomotion used for navigation in the dead reckoning (DR) mode. The adaptive knowledge system, based on the Artificial Neural Networks (ANN) and Fuzzy Logic, is implemented to support this functionality. The knowledge system is trained during the GPS signal reception, and is used to support navigation under GPS-denied conditions. The human locomotion parameters, step frequency (SF) and step length (SL), are extracted from GPS-timed impact switches (step frequency) and GPS data (step length), respectively, during the system calibration period. SL is correlated with several data types, such as acceleration, acceleration variation, SF, terrain slope, etc. that constitute the input parameters to ANN. An alternative knowledge based system has been implemented using the Fuzzy Logic, where the membership functions defining the dynamics of motion and the corresponding SL were formulated through an analysis of various sensory data collected in a controlled environment. These functions are then used to determine the motion dynamics and SL of the operator in GPS-denied environment. The ANN- or Fuzzy Logic-predicted SL, together with the heading information from the compass and gyro, support the DR navigation. The current target accuracy of the system is 3-5 m CEP (circular error probable). This paper addresses the design architecture of the integrated system and the preliminary performance analysis, with a special emphasis on DR navigation supported by the human locomotion model.

KEYWORDS: Personal navigation, knowledge systems, neural networks, fuzzy logic

Selected systems for Indoor and Pedestrian Navigation

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Within the last decade navigation systems have become popular. Especially in outdoor environments location-based services (LBS) play an important role for supporting the way-finding process. Vehicle drivers have started to trust in the information provided by car navigation systems and even pedestrians are gaining interest in reliable guiding instructions. Most of the available systems on the market, however, are limited to outdoor areas, whereas way-finding within buildings has mostly been neglected so far. Merely some museums and exhibitions offer digital guiding services to their customers. Even though the range of some positioning sensors may be sufficient for navigation tasks, they are rarely available within buildings and hardly ever fulfil the minimum conditions concerning cost. Firstly in our research available indoor location systems have been analyzed and their performance was investigated. For some of these systems (e.g. using infrared and ultrasonic signals), however, the user has to expect high costs as an installation of a large number of

sensors is required in the building. One approach to reduce costs is the use of already available wireless infrastructure such as Wireless Local Area Networks (WiFi). Such a positioning system has been installed in an office building of the Vienna University of Technology and can be employed for location determination of user's which are equipped with WiFi enabled mobile devices. As an alternative the use of Radio Frequency Identification (RFID) tags at selected known points, so-called active landmarks, is currently investigated. Then the user can be located using cell-based positioning if he is in the read range of such a tag. Currently the deployment of such a concept in our office building and in the surrounding outdoor environment is investigated. In addition, a combination with WiFi and dead reckoning shall be performed in the near future to provide continuous position determination of a user.

KEYWORDS: Location-based services, Indoor positioning, WiFi fingerprinting, RFID positioning, Multi-sensor integration.

Proposed Model for PEEPEL Tracking: Key Technical and Business Considerations

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Location Based Services (LBS) have been described as the next big killer applications, with predicted revenue of billions of dollars. They can be defined as systems which collect or deliver information based on the location of a mobile device. They include concierge services, routing, navigation, emergency response and tracking. Such services are generally described as consumer services, although tracking does not fit comfortably within the consumer label; including consumer services such as friend tracking, as well as the tracking of goods and services for business (e.g. fleet tracking). Tracking services have been developed to track Alzheimer's patients and children in the consumer market. Fleet tracking has also been adopted in order to improve service delivery. While a number of tracking applications have been developed, there are several technical and business challenges that need to be addressed before they will be more widely adopted. The greatest of these are in the area of privacy and security. There are two types of security involved here – technical security (user authentication and data encryption) and the personal security/privacy of individuals. PEEPEL provides a security model for tracking family and friends, which will address both types of security.

KEYWORDS: tracking; security; privacy; location based services; mobility.

Performance of High-Sensitivity GPS for Personal Navigation at Schiphol Airport, The Netherlands

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Schiphol Airport, located in Amsterdam, The Netherlands, is one of the main airports in Europe. To improve many of the daily processes taking place at this airport positioning and/or navigation information is becoming more important. For example, both travellers as well as airline companies are interested in navigation of the traveller to his gate. Also security personnel and rescue teams may benefit from accurate navigation information. In this paper we will investigate whether GPS can provide accurate and reliable information for such airport Location Based Services. Since Schiphol Airport is a densely built area with many environments in which GPS signals are attenuated, we conducted some tests with High-Sensitivity GPS (HSGPS) receivers. These HSGPS receivers are state-of-the-art and applied for both indoor and outdoor experiments. The indoor experiments were carried out inside the main terminal building (departures and arrivals) as well as at two piers. Outdoor GPS measurements were collected close to the terminal and piers at ground level in presence of lots of obstructions masking parts of the sky. With respect to performance of HSGPS we focused on two aspects, i.e. the accuracy and the availability of the position fixes. As a main conclusion it follows that indoor GPS positioning is not possible at many locations at Schiphol Airport as due to the coating applied in the windows. The performance of GPS outdoor close to the terminal building is of course much better and useful for Location Based Services at the airport.

KEYWORDS: High-Sensitivity GPS, Location Based Services, indoor, personal navigation, degraded signal environment.

Adaptive Calibration of a Magnetometer Compass for a Personal Navigation System

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This paper discusses experiences in estimating the heading angle for a personal navigator prototype, currently under development at The Ohio State University Satellite Positioning and Inertial Navigation (SPIN) Laboratory. A 3-axis Honeywell HMR3000 magnetometer has been considered to provide heading measurements. The magnetometers are used for absolute heading determination with reference to local magnetic north, where the heading is derived from the horizontal force of the magnetic field. However, any ferromagnetic materials near the sensor superimpose extra magnetic fields to the local earth magnetic field. This disturbance could affect the local magnetic field intensity and eventually the heading measured by the magnetometer.

To calibrate the HMR3000 sensor, we first implemented an autocalibration procedure (without need for any external reference directions) to compensate the local variation of the earth's magnetic field (permanent and induced magnetisms). The autocalibration procedure was intentionally designed to (1) estimate the magnetic field effects, (2) compensate these effects on the magnetometer measurements in terms of bias and scale factor for each axis, (3) compensate the tilt angle, and (4) apply the magnetic declination angle.

The field experiments clearly confirm that the calibration procedure strongly depends on the location and the environment of the sensor. If the sensor's location is changed and it is exposed to a new environment, a new calibration is necessary for the different magnetic fields. In this paper, we propose and implement a multilayer perceptron network for dynamic calibration. The inputs to the network are (1) raw compass heading calculated from the uncalibrated magnetometer, (2) total magnetic flux density, (3) temperature, and (4) the vertical component of the gravity vector (inclination angle). For last, it is derived from the production of the accelerometer output and the vector of the earth magnetic field. The network is trained based on the true heading measured either by the GPS velocity (in case of accessible GPS), rate gyro (in case of calibrated gyro), or map-direction constraint (in case of Dead Reckoning (DR) supported by map data). The adaptivity in choosing the reference heading will be achieved by implementing a fuzzy-logic system with respect to all possible true heading measurements.

The simulation analysis shows that for a 500 m DR trajectory reconstruction to meet the target accuracy of 3-5 m CEP (50%), it is necessary to measure the heading angle with the accuracy better than 5º in dynamic conditions. The proposed algorithms, autocalibration and dynamic calibration based on the neural network, have been tested on real data. The numerical results show the accuracy better than 3º in autocalibration and 4-5º in dynamic calibration for heading estimation. These results suggest that the proposed algorithms can provide reliable heading measurements from the HMR3000 magnetometer sensor for the project.

KEYWORDS: Personal navigation, magnetometer compass, calibration, neural networks, fuzzy logic

Session 2B: New Zealand Research Activities 1045 – 1225

Video and Photogrammetry Products from UAV Derived Data

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The Geospatial Research Centre (GRC), based in Christchurch, New Zealand, is developing a series of low-cost Unmanned Aerial Vehicle (UAV) systems for gathering video and high-resolution aerial imagery. Four small, low-cost UAV systems have been constructed and successfully flown to date carrying a range of imaging and geo-referencing sensors as well as miniature data management and communications solutions.

This paper will explore the range of image data captured from the GRC's UAV platforms in 2007 including composite video in visible and thermal bands, and digital photographs from a commercially available SLR (Cannon 400D). Examples will be presented of how this data has been processed with on-board GPS and orientation data to generate DTMs, orthoimages etc.

A key differentiator of the complete system is the use of a total hardware package that costs less than $10,000 and the exclusive use of low-level flight lines. Details of how this both positively and negatively affects the raw, and value-added, data products will be presented including:

- The need for in flight stabilisation of the image platform
- Issues around vibration (including a comparison between electric and petrol propulsion systems)
- Requirements for an onboard autopilot systems capable of flying restricted flight lines

The GRCs plans for future research will also be presented including:

- Direct (real-time) geo-referencing of on-board image sensors using low cost (<$5,000) GPS/INS hardware
- Generation of map products from video data
- The increased use of imagery derived value-added information (eg velocity and relative orientation) as an in-flight autopilot and payload augmentation.

KEYWORDS: UAV, photogrammetry, video analysis, DTM, orthophoto

The Role of Government in the Implementation of a CORS Network in New Zealand

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Land Information New Zealand (LINZ) is the Government Department in New Zealand responsible for managing Land and Seabed Information that includes the cadastral survey and land titles systems, hydrographic and topographic mapping, and the geodetic system. In 2001 LINZ commenced installation of a Continuously Operating GNSS Reference System (CORS) known as PositioNZ. Station stability was of prime importance and the network was designed to deliver 30 second RINEX hourly and 24 hourly files. Currently 30 stations operate in New Zealand with a further station on the Chatham Islands and 2 in Antarctica. The business case developed for PositioNZ's installation and operation was based on the premise that the network would be used to monitor and manage New Zealand's semi-dynamic datum. Explicitly excluded from the PositioNZ business case was the development and use of the network by LINZ as a real time positioning network for use in applications such as RTK. Now that considerable investment has been made in developing the PositioNZ network, interest has been shown in its use for real time positioning applications. LINZ has carried out tests and can now stream real time 1 second data from the majority of sites. Further tests are underway in conjunction with Otago University to test the viability of the network for real time applications. However, current policy within LINZ limits the development of the network to the delivery of data and precludes the development of value added products for commercial purposes. LINZ is exploring ways that it might work with third parties who would use the data and their own stations to provide a unified GNSS CORS across New Zealand that would deliver real time products to users. This paper discusses the New Zealand Government's role in the current and future development of the PositioNZ network.

KEYWORDS: GNSS CORS New Zealand

Development of a sub-$5000, twin GPS antenna aided INS system

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The Geospatial Research Centre (GRC) in New Zealand has developed an innovative, low-cost, integrated INS and twin-receiver navigation system to provide high accuracy position and orientation for applications such as marine and aerial surveying, vehicle testing, and UAV guidance and control.

A system has been developed using two low cost single frequency Novatel Superstar II receivers and either Crossbow IMU440 or Microstrain 3DM-GX1 inertial measurement units. It is well recognised that for a GPS position and velocity aided low cost INS, the observability of the heading error is poor, unless horizontal dynamics are experienced by the vehicle in which the sensors are installed. Therefore to improve system observability, two low-cost GPS receivers are used on a fixed baseline to estimate heading directly to control heading errors.

A Kalman filter was developed using a tight coupled architecture where the raw pseudorange, carrier phase and Doppler measurements from the GPS receiver are used directly in a Kalman filter to correct the errors from the INS. The GPS measurements are used to directly estimate position, velocity and heading corrections to aid the INS. This has the significant advantage that partial measurements can be used in the filter during periods of obstructed GPS measurements. Furthermore, since the INS provides accurate heading estimates over short periods, the INS can be used to re-initialise the integer ambiguity search for instantaneous ambiguity resolution after short GPS outages.

This paper demonstrates the real-world performance achieved using low cost sensors by directly comparing the results to a high accuracy Novatel SPAN integrated GPS/INS system installed on a vehicle. In particular attitude accuracy is analysed, particularly with regard to heading estimation, and the ability for the INS to aid the integer ambiguity search for attitude determination.

KEYWORDS: GPS, INS, Attitude, Integration, Kalman

Developing Low Cost UAVs for Commercial Applications

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The Geospatial Research Centre (GRC), based in Christchurch, New Zealand, is developing a series of low-cost Unmanned Aerial Vehicle (UAV) systems for gathering video and high-resolution aerial imagery. Four small UAVs have been constructed and successfully flown to date carrying a range of imaging and geo-referencing sensors as well as miniature data management and communications solutions.

There is a global consensus that the use of low-cost, Unmanned Aerial Vehicles (UAVs) offers great commercial and operational potential across a range of civilian monitoring and mapping applications including: agriculture and forestry; environmental management; engineering surveying, geomorphology and hydrology and as an invaluable source of visual data in times of natural or man-made disaster. To date, however, very little research or development has been presented in public showcasing the actual performance and potential of low-cost, accessible UAV solutions in these application areas.

Within this presentation, details will be presented of each of the GRCs UAV aircraft as well as the range of on-board and ground-based sensors and systems currently under development (including data loggers, communications systems, camera systems, positioning and orientation solutions, and autopilots).

Flying at low levels (typically <200m) and offering the potential for very high temporal resolution data capture, the hardware costs for the current UAV systems including airframe, control and stabilization systems, GPS receivers and IMUs are less than $10,000 per aircraft. .

The presentation will conclude with a summary of GRC's experiences and thoughts to date regarding (potential) operational issues and solutions along with summary details of the GRC's plans for further technology and commercial developments in this exciting field.

KEYWORDS: UAV, commercial applications, sensor integration, operational issues, low-cost

‘Point and Click’ Target Location from Georeferenced Video Streams

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We present a novel interactive tool for locating ground features in a live downward pointing video stream from an unmanned aerial vehicle (UAV) platform. The UAV carries position and orientation sensors (typically GPS and INS) which are calibrated with reference to a video camera. The video stream and position/orientation data is transmitted back to a ground-based user over distances of up to 2km. The user simply points to ground features in the video display in order to compute the location of those features.

When 3D terrain models are available the latitude, longitude, and elevation may be determined by projecting a ray from the positioned camera centre. The orientation of the camera platform and the location of the ground feature within the image determine the direction of this ray, which is intersected with the terrain model to determine the feature’s location. If no such model is available then an estimated latitude and longitude may be given assuming that the terrain has locally constant elevation. An analysis of the errors in the system shows that the key constraint is the accuracy of the orientation estimate. Since low-cost inertial systems are less accurate in yaw than in pitch/roll, a method for determining heading from GPS and video is proposed, and its performance compared with reliance on navigation sensors without the use of imagery.

The UAV test platform is low-cost, with a total hardware outlay of less than $10,000 including airframe, inertial and GNSS sensors, control systems, autopilot, camera, and transmission hardware. Such a platform opens up a wide variety of applications from search and rescue and disaster recovery to precision agriculture and environmental monitoring. Further applications may be enabled by using sensors beyond the visible spectrum, and early results from early trials with thermal infra-red cameras are presented.

KEYWORDS: Imagery, UAVs, interactive systems, navigation sensors, sensor integration.

Session 2C: Snapshot + Interactive Poster Presentations 1045 - 1225

Sidereal filtering based on GPS single differences for mitigating the effects of multipath and diffraction

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The accuracy of global positioning system (GPS) in small area engineering applications is mainly limited by the effects of signal multipath and diffraction. A filtering method is developed based on GPS single difference observations for mitigating the effects. First GPS postfit double-difference carrier-phase residuals are converted into postfit single-difference residuals on each day. The single-difference residuals thus obtained are then used as a multipath signal model after removing the diffraction effects. The multipath model is subtracted from single-difference residuals of the subsequent days. The final coordinates are resolved by using the double difference residuals formed based on the corrected single difference residuals. Test examples show that the new filtering method can reduce effects of GPS signal multipath and diffraction effects more effectively and 10-40% improvements in the coordinate series can be achieved compared with the standard data stacking method. The method is also more advantageous in that it can be implemented in real-time.

KEYWORDS: GPS; Multipath; Diffraction; Sidereal filter; Single differences.

GNSS Indoor Positioning using Multipath Signal Propagation Analysis

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The large popularization of GNSS (based on GPS, Glonass and forthcoming Galileo) devices and the increase market interest for Location Based Service (LBS) equipments have motivated interesting studies in modeling the radio channel propagation for dense urban and indoor geolocation, where two key problems need to be addressed: weak signal operation and multipath, both leading to receiver range errors and consequently its position calculated with large biases.

In this work we introduce a modified ray tracing radio frequency propagation approach, designed specially to follow the signal from GNSS space vehicles and accounting for all the physical characteristics of the indoor environment, by the use of a computationally optimized semi-deterministic approach for radio propagation for moving transmitters. Exploiting the resulting GPS C/A code correlation curve distorted by the incidence of multipath, a signal deconvolution technique is applied to this distorted curve in order to identify multiple individual correlation curves that contribute to its generation. These deconvoluted individual curves are then stochastically analyzed, resulting in the extraction of corresponding signal "signatures", whose pattern is observed during a complete orbit of the space vehicle. We show that, due to the inherent repeatability of the GNSS satellites orbits, these signal propagation signatures in the indoor test bed also repeat themselves on a daily basis. These signatures are then combined in order to associate specific signal signatures with corresponding unique positions in the test bed.

The results from these preliminary experiments will serve as baseline for the development of a novel signal propagation model to enable GNSS indoor positioning, whereby local, site-specific support (based on previous knowledge of the indoor environment). The results discussed in this paper relate to tests performed in a confined and controlled environment, and the most relevant output of this work is therefore its contribution to the development of innovative algorithms to be applied to GNSS receivers, aimed at developing robust positioning equipment, able to support location-based services with the accuracy and reliability demanded by this emerging market.

KEYWORDS: GPS; Indoor; software; multipath; GNSS.

Multipath Fading Mitigation

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Satellite navigation is becoming increasingly important for location based services and emergency caller location. Both applications require positioning in urban and indoor areas, where obstacles give rise to reflections, diffraction, and scattering. These obstacles are often near the receiver and lead to multipath signal propagation. Measurement campaigns in urban environments have shown that most multipath components are within an excess delay of less than 500 ns, which corresponds to an excess distance of 150 m. Multiple signal echoes therefore combine at the receiver antenna with a sub-chip distance. Depending on their phase offset, they cause constructive or destructive interference. This then leads to a widely varying amplitude of the combined multipath signal. The resulting fading process degrades the receiver performance. This paper presents a multipath fading mitigation technique that reduces the negative impact of the fading process by adaptively adjusting the detection threshold. The optimal detection threshold is thereby estimated on-the-fly for an unknown fading channel. In relevant environments for mobile phone positioning, the power distribution of the received signal can be modelled with a Rice distribution. The presented technique dynamically adjusts well over a wide range of different Rice factors. The optimal detection threshold is lower for signals with a high Rice factor. A relevant multipath proportion leads to a low Rice factor and the optimal detection threshold is set at a higher level to prevent excessive false detections. If the detection threshold for a line-of-sight signal was applied to a strongly fading signal, false detections would occur frequently. The adaptive detection threshold technique therefore automatically calculates the optimal detection threshold for any Rice factor of the propagation channel.

KEYWORDS: Multipath, Fading, Rice, Detection, Threshold.

Single Frequency Precise Point Positioning using Different Ionospheric Error Mitigation Methods

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With the advent of precise satellite orbit and clock products from the International GNSS Service (IGS), absolute point positioning technique using a single GPS receiver has proven to be an attractive alternative to the popular relative positioning technique. Precise Point Positioning (PPP) using dual frequency receivers is capable of providing centimetre level point positioning accuracy anywhere around the world, without the need for a base station. However, when using single frequency receivers, the accuracy of the solution decreases, particularly in the height component. One main factor for this degradation in accuracy is the unmodeled ionospheric error.

This paper investigates the performance of three different ionospheric error mitigation methods used in single frequency PPP in the Australian regions. They are the single frequency ionosphere-free code and phase delay known as GRoup And PHase Ionospheric Correction (GRAPHIC) algorithm, the IGS Global Ionospheric Map (GIM) products and the Klobuchar model together with the broadcast ionospheric coefficients. 24 hours observation data from eight Australian Regional GPS Network GPS stations are postprocessed with the different ionospheric error mitigation methods using the Natural Resources Canada (NRCan) Canadian Spatial Reference System- PPP (CSRS-PPP) processing software. The estimated solutions based on each ionospheric error mitigation method are then compared with the accurately known station coordinates. Numerical results show that for short observation sessions, typically less than an hour, both the GRAPHIC and GIM methods are able to provide position accuracy better than 1m using geodetic quality single frequency receivers. For 12 to 24 hours data sets, the solution accuracy can be as good as 10cm under favourable conditions. On 2 the contrary, the Klobuchar model with the broadcast coefficients could only provide a few metres level point positioning accuracy.

KEYWORDS: Single Frequency, PPP, IGS, Ionospheric Error.

Single Frequency PPP Algorithms Based on GR Models with Ionospheric Models and Hardware Biases

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In this paper, we present the performance of single frequency PPP (Precise Point Positioning) algorithms based on GR models (GNSS Regression models) that involve the accuracy and convergence speed of positioning solution by focusing on the ionospheric delay models as well as on the effect of modelling of the so-called receiver's hardware bias. GR models have been introduced by the authors for PPP. Our derived PPP algorithms achieved the positioning accuracy in decimeter error level without any external information such as from WAAS. In order to achieve rapid and accurate positioning, we focus on the ionospheric delay handling in our PPP algorithms. The ionospheric delay will be one of the biggest error sources for single frequency PPP. Previously our PPP algorithms have utilized the broadcast ionospheric model (Klobuchar model) to approximate the ionospheric delay. In this paper, we examine another ionospheric delay model from the global ionosphere maps (GIMs) provided by the Center for Orbit Determination in Europe (CODE). Then our PPP algorithms with two ionospheric delay models are comparatively evaluated for positioning accuracy. Also the positioning errors of modeling effect of the receiver's hardware bias in our PPP algorithm are shown comparatively by using real GPS data (so-called GEONET data) provided from the Geographical Survey Institute (GSI) of Japan

KEYWORDS: precise point positioning, GNSS regression models, Kalman filter, ionospheric delay models, receiver's hardware bias.

The navigation of parking stations and parking spaces

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This contribution is a discussion concerning parking space navigation. It is based on existing technologies for orientation determination and telecommunications. The design depends on the classification of the parking stations or areas. In this paper, the parking station classification distinguishes between centralised parking lots and dispersed parking lots. Based on their similarities and differences, the navigation for centralised parking stations will be relative to the model's generation and sensors, while the navigation for dispersed parking lots is based on calculations using parking meter information. In addition, the requirements, process and components of design are also discussed.

KEYWORDS: parking space, navigation, GIS, classification, model.

The Impact of LEO Satellites' Orbital Parameters on the Pattern of the GPS-LEO Radio Occultation Occurrence

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GPS radio occultation (RO) is a new technique of imaging the atmosphere with the potential for providing high vertical resolution atmospheric profiles. Recent launches of COSMIC low earth orbiting (LEO) satellites in conjunction with the advent of the new generation navigation satellite systems have opened new avenues of research in exploring the synergy of advanced geodetic techniques and meteorology.

The impacts of key orbital parameters of a single LEO satellite on the distribution and number of radio occultation events (ROEs) are investigated by means of numeric simulation method using force models for generating the orbit of the LEO satellite and models of occultation antenna. Results show that the adjustment of Argument Of Latitude, Right Ascension of Ascending Node, orbit height and inclination angle does not affect the longitudinal distribution of ROEs much. The number of ROEs reduces when the orbital height increases. The selection of orbit inclination angle has an apparent impact on the latitudinal distribution of ROEs. The ROEs mainly occur over low-latitude sites when the inclinations are low. However, even distribution occurs with high inclination. The impacts of different numbers of satellites and different values of *k* - key parameters of rose-type LEO constellations- on the temporal and spatial distribution of ROEs are also investigated. It is shown that a constellation composed of at least four LEO satellites can significantly improve the temporal and spatial resolution of the ROE observation over certain regions. If the constellation parameter *k* is set to zero or its maximum value, the temporal distribution of the ROEs is not even. It is also shown that the number of ROEs is preferable when *k* equals to the number of LEO satellites minus 3.

KEYWORDS: Radio Occultation; GPS; LEO satellite; Orbital Parameters; Constellation

Validation of GNSS Radio Occultations' Performance Using NCEP Data in Australia

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GNSS RO (radio occultation) meteorology technology has attracted much attention since the promising results were obtained in 1996 from the pioneering GPS/MET (Global Positioning System/Meteorology) studies that applied GPS RO technique for atmospheric observations. Many follow-up projects and experiments have also demonstrated exciting outcomes for the GNSS RO applications in weather and climate studies. GNSS RO method has opened new avenues for measuring the Earth's atmospheric parameters with sufficient accuracy, resolutions, global coverage and near real-time that advances our knowledge of both Earth's atmospheric structure and processes. This research evaluates the performance of GPS RO using NCEP (National Centres for Environmental Protection) model in Australia. The atmospheric parameters derived from CHAMP RO are compared with NCEP's model produced data over 10 selected sites across the entire Australian continent. Numerical results present that a good agreement of atmospheric parameters between GPS RO derived and NCEP modelled can be achieved. Finally, further research questions pertinent to Australian context are discussed and some useful conclusions are given.

KEYWORDS: Radio Occultation, Global Navigation Satellite System, NCEP, GPS Meteorology, CHAMP,

Benefit Analysis of Airborne GPS Occultation Approach: A Case Study for the Australian Region

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This paper aims to present a preliminary benefit analysis for airborne GPS occultation technique for the Australian region. The simulation studies are based on current domestic commercial flights between major Australian airports. With the knowledge of GPS satellite ephemeris data, occultation events for any particular flight can be determined. Preliminary analysis shows a high resolution occultation observations can be achieved with this approach, for instance, about 15 occultation events for a Perth-to-Sydney flight. The simulation result agrees to the results published by other researchers for a different region. Of course, occultation observation during off-peak hours might be affected due to the limited flight activities.

High resolution occultation observations obtainable from airborne GPS occultation system provides an opportunity to improve the current global numerical weather prediction (NWP) models and ultimately improves the accuracy in weather forecasting. More intensive research efforts and experimental demonstrations are required in order to demonstrate the technical feasibility of the airborne GPS technology.

KEYWORDS: GPS; Airborne Radio Occultation; Simulation.

Validation and Performance Evaluation of Two Different Inertial Navigation System Design Approaches

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For many years, the design and implementation of a practical INS algorithm have been a subject of great interest in consideration of the certain issues, such as the computing load, precision, speed/updating rate and computer memory. In the last decade, as the rapid development of computer hardware/software technology, the concern of the computing competency is not critical anymore; therefore the classic sophisticated INS design method may be simplified by taking the advantages of modern computer's capabilities.

This study is to implement and evaluate two different INS design approaches. Specifically for the classic two-speed digital INS design, the discrete INS models, the high/low speed digital integration algorithms, coning/sculling/scrolling compensations for the low speed calculation in attitude/velocity/high precision positioning determination are implemented in a C programming environment. For the simplified INS design, the single high-speed INS algorithm free of coning/sculling/scrolling compensations is investigated. Moreover by utilising Matlab Simulink's capability to solve the continuous-mode differential equations, instead of using the discrete INS models, the continuous INS models are directly employed in the simplified INS design.

The performances of the two developed INS designs are validated and evaluated inside an integrated GPS/INS solutions based on a practical loosely-coupled Kalman filter. Real-time IMU raw measurements logged from the tactic-grade Ring Laser Gyros (RLG)/accelerometers and GPS solutions corresponding to various road testing trajectories are utilised in the validation and evaluation. The comparison of the two INS solutions shows that, for the similar processing time, both of the INS designs reach to the same level of precision with respect to the provided references, specifically the attitude/velocity/position errors of the classic two-speed INS is improved by 10-15% compared with single speed continuous-mode INS, whereas the algorithm/software complexity is reduced by 50-60% for the single speed INS which will permit the fast-prototyping and easy-to-understand design.

KEYWORDS: INS, Kalman filter, two-speed INS, IMU

Mitigating the Effect of Multiple Outliers on GNSS Navigation with M-Estimation Schemes

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As GNSS has been increasingly used in a wide range of applications, including safety-of-life and liability critical operations, it is essential to guarantee the reliability of the GNSS navigation solutions. Although a number of GNSS Receiver Autonomous Integrity Monitoring (RAIM) algorithms have been developed, a reliable procedure to mitigate the effects of multiple outliers on the navigation solutions is still lacking. In this paper, a robust Least Squares estimation scheme (called M-estimation) is investigated to demonstrate its potential in improving the reliability of the GNSS navigation solutions.

We have analysed the theoretical background for M-estimation procedures, which include 1) Huber scheme and 2) IGGIII scheme. Then, some detail simulations and analyses with integrated GPS/Galileo constellation have been carried out to evaluate the performances of the M-estimation schemes in the case of multiple outliers. In the simulated scenario with 14 satellites, the effects of up to 4 outliers can be successfully mitigated with the M-estimation procedures, whilst the classic least-squares solutions are significantly biased. These results from the initial studies are encouraging and indicating the potentially promising strategy to address the multiple outlier issues within multi-constellation GNSS navigation systems.

Keywords: GNSS, RAIM, Robust least squares, Multiple outliers.

GPS Integrity Monitoring with an Aerodynamic Model and Low Quality INS

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For civilian general aviation, the Ground-based Regional Augmentation System (GRAS) is a cost-effective system (compared to Space-Based Augmentation Systems) which is able to provide a high degree of GPS accuracy and integrity to meet aviation requirements for all modes of flight down to Approach with Vertical Guidance (APV). However, since GRAS corrections are transmitted to aircraft from ground-based VHF broadcast stations, the GRAS signal-in-space may not always be received. The signal may be masked by surrounding terrain when an aircraft is on approach, or there may be gaps in the network coverage. During a GRAS outage an alternative integrity monitoring system is required to allow continuous navigation. Another requirement is that a backup integrity monitoring system must be as low cost as possible. Building upon work presented in Greer et al. (2006), a new method is investigated which involves using a combination of GPS, low performance (low-cost) Micro-Electro-Mechanical Systems (MEMS) Inertial Navigation Sensors (INS), and an aerodynamic model of the aircraft. This information is combined in an Extended Kalman Filter (EKF). The novel aspect of this architecture is the inclusion of an aerodynamic model for the GPS integrity monitoring. During a GRAS outage, the aerodynamic model brings a greater level of robustness to the integrity monitoring procedure than the low quality inertial sensors can provide alone. This method is also highly autonomous because all measurements are local to the aircraft, without requiring external aids. By computer simulation it is shown that the aerodynamic model may replace the MEMS INS as a source of dynamic information in the EKF. This allows the benefits of using an EKF and filtered fault detection algorithm to be obtained. It is shown that a more stable and lower HPL is achieved under changing satellite conditions than a GPS-only RAIM algorithm.

KEYWORDS: GRAS, Integrity, Fault Detection and Exclusion, Aerodynamic Model, INS

Architecture Design for Multi-Sensor Fusion

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This paper describes the design and development of a generic software architecture for navigation filtering. The navigation literature contains much theoretical development on the processing of navigation data, however, there is less coverage on the design of tools and systems to perform the processing. This paper aims to address this by presenting an architecture that gives the developer the flexibility to interchange sensors, models, parameters and algorithms without significant software changes. It also presents results taken from a real-time implementation of the proposed architecture that illustrate how the design allows a quick and easy comparison between the performance of different configurations.

KEYWORDS: Navigation, Filtering, Architecture, Generic.

Vehicle Dynamics Based De-Noising for GPS/INS Integration

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This paper has investigated a novel method of using vehicle dynamic information in de-noising raw INS sensor noises. Vehicle dynamics can constitute additional observation information to be used for improving the integration performance. Since vehicle dynamic model has a low pass filter characteristic, passing the raw INS sensor measurements through it would effectively reduce the high frequency noises. This filtering processing has been implemented using a Kalman filer.

KEYWORDS: GPS; INS; Integration; De-noising.

The Application of a Multicorrelator Receiver in Bistatic Radar

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A height measurement using a GPS signal reflected off the ocean's surface can be used to assist in disaster early warning systems. This paper investigates the use of a multicorrelator receiver and piecewise linear regression to measure the height of sea level in a bistatic configuration using GPS as the radiator. The standard deviation of the error using this method is 1.6m, a significant improvement compared with that of standard correlation techniques.

A NordNav (NN) Quad Front-End R30 was used as the receiver. It is capable of measuring the altitude quantity, and had cross correlation capabilities that can measure the delay between the LOS and multipath signal components.

A Spirent simulator was used to fabricate the GPS signal. The signal was defined to include a LOS component and a single multipath component. This output was plugged directly into NN's antenna input for detection.

Delay measurements using NN were restricted by the correlation resolution. The minimum separation of the points in its correlation plot was 0.1875us, which equated to a distance of 56.2m. Hence, the resultant delay measurement had an error bound of +/-56.2m. Signal processing techniques were used to achieve more accurate results.

MATLAB was used to employ linear regression estimation on the correlation outputs, which could potentially position the correlation maxima more accurately. This technique improved the delay measurement error bound to +/-6.46m.

KEYWORDS: Multicorrelator, Bistatic, Oceanographic Altimetry, Regression

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Interseismic deformation of the northern Xianshuihe fault from InSAR data

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I generate the interseismic deformation due to the northern Xianshuihe fault slip using interferogram stacking method. An initial interseismic deformation model inferred from GPS observations is used to deramp the linear trend due to the orbit errors. The tropospheric delay errors are mitigated by stacking multi-pairs of interferograms. The interseismic deformation field is derived after interactively phase unwrapping. The profile of slip rate from InSAR is in good agreement with that from GPS observations. Using an infinite-length elastic dislocation model, I obtain the slip rate of 6 mm/yr and the locked depth of 14 km for the northern Xianshuihe fault.

KEYWORDS: Xianshuihe fault, interseismic deformation, InSAR, GPS

Online DGPS Correction Prediction using Recurrent Neural Networks with Unscented Kalman filter

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This paper focuses on applying a neural network model to predict pseudorange corrections (PRC) for differential Global Positioning System (DGPS). The class of nonlinear autoregressive recurrent neural networks is chosen as the basic

architecture. The neural networks are trained by an unscented Kalman filter due to its powerful capabilities for online parameters estimation. The paper first briefly introduces GPS and DGPS navigation performance principles. Following the discussion of temporal characteristics of the DGPS pseudorange corrections, a technique for predicting the DGPS corrections based on recurrent multilayer perceptrons with an unscented Kalman filter is presented. With a given set of data, the unscented Kalman trained networks can online predict the PRC precisely when the PRC signal is lost for a short period of time.

Key words: DGPS; recurrent neural networks; pseudorange differential corrections; sigma-point Kalman filter

AGPS Clock

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Assisted GPS has been a focus of research because of its ability to allow GPS to operate in conditions where it was not designed to work, such as indoors. In this paper, we examine the use of this technology to create an indoor clock which is accurate to microseconds. The GPS space vehicles (SV) carry an accurate atomic clock, and clock information is transmitted to GPS receivers so high accuracy GPS timing receivers are commonplace. The difference here is that the antenna is not mounted outdoors, and assistance data is transmitted to the clock, allowing the same level of accuracy to be achieved. The clock was also compared to a normal quartz clock.

KEYWORDS: GPS, Assisted GPS, AGPS, Clock, indoor

Session 3A: LBS/Location Infrastructure 1325 – 1505

Semiconductor Implementation of Differential Correlation and Noncoherent Integration

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Emergency caller location and location based services increasingly lead to navigation receivers being integrated into cellular telephones. The size constraints of cellular phones require highly integrated semiconductor solutions. The cost of microchips can be reduced by shrinking the silicon area. This can be accomplished by the optimum choice of the quantization resolutions in the digital baseband section and by the reuse of hardware resources within the integrated circuits. Since satellite navigation receivers for indoor applications are usually designed to host the equivalent of several thousand correlation channels, the benefit of reducing the bit sizes and reusing the signal processing blocks is substantial. The required amount of signal processing units can be reduced by operating the hardware resources with an increased clock rate and multiplexing different signal processing paths through the same hardware. The implementation of the differential correlation and the noncoherent integration methods in hardware description language allows the synthesizing of the signal processing units into a complementary metal-oxide semiconductor (CMOS) technology. This paper presents the resulting silicon area, power consumption, quantization loss, and timing characteristics. The quantization characteristics are chosen such that resulting degradation is sufficiently low for enhanced sensitivity Galileo/GPS receivers. The timing slack of the CMOS synthesis results are analyzed in order to estimate the degree of parallelization required for single shot positioning. When compared with the desired sample rates, the timing slack indicates how many correlation channels can be served in parallel by the respective unit.

KEYWORDS: Quantization Resolution, Timing Slack, Silicon Area, Power Consumption, CMOS.

Designing a GPS Receiver Network with GNSS Algorithm for Accuracy and Safety

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To provide a precise and reliable position information to diverse mobile devices in real-time, this paper introduces a GNSS receiver network built on a generalized GPS/GNSS software package which is named as GAFAS (GNSS Algorithm For Accuracy And Safety). The advantage of the GAFAS compared with other GPS/GNSS software packages is that it emphases on advanced fault detection and isolation capabilities for real-time kinematic applications. Base on the GAFAS, a receiver network is designed and implemented over the wireless internet.

The designed receiver network consists of a single broadcaster, several servers, and bulks of clients. In the designed configuration, each server is paired with at least one high-quality dual-frequency receiver and provides reference information to the broadcaster after an authentication process. Each client is paired with a single or dual-frequency receiver and computes accurate real-time kinematic position estimates by the GAFAS. The broadcaster connects all the servers and clients in the network, authenticates each server and client, and distributes measured or processed information to the clients.

Several key results will be presented to show the functionality, accuracy, and reliability of the introduced GPS receiver network that is under the development.

KEYWORDS: GNSS, receiver, wireless, network, algorithm

Title – Location Based Services – Are we there yet?

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The presentation discusses some of the challenges introducing Location Based Services in urban, regional and outback Australia. The focus is on three component topics as discussed below.

The first topic provides an overview of the Location Industry within Information and Communication Technology (ICT). It describes the different market sectors (e.g. consumer, enterprise and industrial) and highlights the challenges for delivering solutions in urban, regional and remote environments.

The second topic describes the emergence of Location Infrastructure. The presentation discusses how Location Infrastructure draws on existing Spatial Information, Mobile Communications and Positioning infrastructures to deliver end user solutions.

Finally the presentation discusses the current state of Location Based Services in Australia in the context of the first two topics and poses the question – Are we there yet?

KEYWORDS: Location, Infrastructure, LBS.

Delivering Precise Positioning Services in Regional Areas

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On July 1 2007, the Cooperative Research Centre for Spatial Information (CRCSI) commenced a new research project to investigate the issues associated with extending Global Navigation Satellite Systems (GNSS) precise positioning services into regional areas. Such regional services are required for a growing number of applications in agriculture, mining, utilities, construction, tourism, defence and environmental protection.

Around the world there are now many networks of GNSS Reference Stations delivering real time centimetre accuracy positioning to users. Most of those networks are in areas of high population density with excellent Internet and mobile communications infrastructure. This project will address the issues associated with delivering such GNSS Reference Station networks in rural and remote areas of Australia, which are characterised by sparse populations and lesser quality Internet and communications infrastructure. The project is divided into two parts; the first part addresses business issues and the second part addresses the technical issues.

This paper concentrates on the first part of the project, which is researching and defining the business enablers to service adoption (commercial, operational and institutional) when extending a service into regional areas.

It is intended that Project 1.4.1 will develop a prototype for partnering among the project participants that can more effectively deliver precise positioning services to regional areas. While the prototyping will be based in Queensland, it is possible that such a business and partnership models may also be attractive for application in other states of Australia and to other sparsely populated areas of the world.

KEYWORDS: GNSS Reference Stations, Network RTK, Business Models, Partnership Models, Regional Areas, CRCSI.

The Internet Location Services Model

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Broadband deployment has led to an appreciation and expectation of the always-on model of Internet access. The increasing proliferation of 3G networks, WiFi hotspots, and the emerging 4G technologies is now leading to the demand for and expectation of Internet-everywhere. The increasing influence of nomadic and full mobile Internet access means that “location services” become more pertinent than ever. This is highlighted by the example of VoIP emergency calling and the need to determine caller location to properly provide this service.

This paper will introduce the architectures and protocols associated with the provision of a location service in Internet, and general IP, access networks. The IETF defined protocol “HTTP Enabled Location Delivery” (HELD) will be described including the semantics of its use with some example applications. Finally, some examples of implementations of location servers for different types of Internet access will be described

KEYWORDS: IP-Location, LIS, HELD, Internet, VoIP

Session 3B: Survey/Mapping 1325 - 1505

Benefits of a Partial Three-Frequency GPS Constellation for Real-Time Kinematic Positioning

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The capabilities of the US Global Positioning System (GPS) are in the process of being enhanced via the addition of satellites with three free-to-air civil frequencies. GPS Block IIF satellites are the first to include triple-frequency capabilities, with the initial satellite launch planned for 2008. The third civil frequency band, denoted L5, has been designed to support a broad range of user applications including aviation, marine and consumer markets.

Triple-frequency transmissions also offer significant benefits for high-precision (cm-level) Real-Time Kinematic (RTK) users. Previous studies have shown a clear benefit for initialization reliability and performance when using a fully populated constellation of satellites with three carriers instead of the current two. Based on the current Block IIF launch schedule, and the relatively slow failure rate of existing dual-frequency satellites, the GPS community will face a period of say 4-7 years when only some of the satellites in view will support three-frequencies. This paper presents a detailed study of what implications mixed dual- and triple-frequency GPS operation will have for RTK users.

A variety of transitional dual- / triple-frequency GPS tracking scenarios were simulated and processed using a PC-version of the Trimble RTK engine. Data containing three-frequency observables for a number of satellites are shown to improve initialization time and reliability compared to results obtained with dual-frequency-only processing. On short baselines, three-frequency ambiguity resolution is virtually instantaneous given a sufficient number of L5-capable satellites. Improvements were also seen in position precision and the RTK operating range.

KEYWORDS: GPS, RTK, ambiguity resolution, three-frequency, L5

Procrustean solution of the GNSS related transformation problems

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Modern Global Navigation Satellite System (GNSS) transformation software, e.g., EasyTrans Pro-Edition (http://www.huethig.de/shop/product.html?id=85039&top) and Trafox (http://www.koordinatentransformation.de/data/trafox.pdf) incorporate the solution of 7 and 9-parameter transformation problems. In these software, the traditional least-squares method is employed as the computing engine. The disadvantages of the least-squares solution for solving transformation problems are the requirements of linearization and initial approximate starting values, some of which are normally not be known. This contribution presents the Procrustean "matching bed", which offers direct solution to transformation problems. Its power is demonstrated in solving three simulated networks and one real geodetic network. In the first case, a minimum three-point network is simulated. The second and third cases consider the over-determined eight- and one million-point networks, respectively. The one million point simulated network mimics the case of an air-borne laser scanner in which an anisotropic scale is required (i.e., 9-parameters), since scale factors vary in the direction of X, Y and Z. A real network is then finally considered by computing both the 7 and 9 transformation parameters, which transform the Australian Geodetic Datum (AGD 84) to the Geocentric Datum Australia (GDA 94). The mean square root of the trace of the error matrix are 0.013m, 2.31×10^{-13}m, and 1.20×10^{-5}m for cases 1, 2 and 3 respectively. For the real network, 0.438m was obtained. The results indicate the effectiveness of the Procrustean method. The Procrustean algorithm presented here can thus be in-built in GNSS transformation software.

KEYWORDS: Procrustes, transformation, GNSS, Frobenius, singular value decomposition.

Application of Mobile Mapping technology within a Roads and Traffic Authority

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This paper describes the application of Mobile Mapping technology within a Roads and Traffic Authority to assist individual business units, and the organisation as a whole, to achieve operational objectives.

We discuss a specific implementation of a Mobile Mapping System and describe the different datasets produced from that technology, as well as how the derived data can be used within different business units to extract information and/or aid decision support.

Some specific examples of applying Mobile Mapping technology will be described, showing how such utilisation leads to the provision of better services to clients in terms of efficiency and road user safety.

Thus it will be shown how the application of Mobile Mapping technology within a Roads and Traffic Authority is becoming recognised as essential technology within such an organisation.

KEYWORDS: Mobile Mapping, GPS, INS, Video, Road Authority.

Impact of Multiple Frequency GNSS Signals on Future Regional GNSS Services

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The key limitation of existing Real-Time Kinematic (RTK) systems is the service distances between reference stations and user receivers due to the impact of distance-dependent biases such as orbit error, and ionospheric and tropospheric signal delay. In current Network-RTK implementations, the inter-station distance is typically 70km to 90km. If coverage were to be extended to the whole Queensland at this density, the number of CORS receivers required would be of the order of several hundred, representing tens of millions of dollars in installation costs, and millions per annum for operations.

However, use of multiple-frequency GNSS signals and/or multiple satellite GNSS systems could possibly redefine future RTK services on both a regional and global basis. Possible future GNSS services could realize regional network-based RTK services at the centimetre to decimetre accuracy level. The reference stations equipped with triple-frequency GNSS receivers may be spaced up to a few hundred kilometres apart, to provide differential and RTK services over a region, typically state-wide or country-wide.

Realization of such regional RTK services depends on efficient and reliable ambiguity resolution procedures for double-differenced (DD) carrier phase measurements. This paper proposes an efficient three carrier ambiguity resolution (TCAR) method as the theoretical basis for regional RTK positioning, and demonstrates the performance potential using dual-frequency GPS measurements. In the paper, we provide an overview of TCAR scenarios and available techniques, and outline an efficient TCAR method that uses ionosphere-reduced virtual signals which promise more reliable and rapid ambiguity resolution over longer reference-to-user distances. Experimental results from dual-frequency GPS data over three baselines of 21km, 57km and 74km length demonstrate RTK availability of over 90% using phase measurements from single epochs, demonstrating performance potential able to support future GNSS centimetre-level RTK positioning services using dual- and triple-frequency GNSS signals over regional areas.

Keywords: GNSS, RTK, Three Carrier Ambiguity Resolution, Regional GNSS services

Title – A comparison of techniques for the transformation from Cartesian to geodetic coordinates

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The transformation from Cartesian to geodetic coordinates is performed very frequently in GNSS positioning and many other geodetic applications. However, its solution is not trivial, and many techniques to perform the transformation have been developed. The most important criterion when comparing different techniques for practical use is the computation speed. Several authors have compared the computation speed of various techniques, but the results are often inconsistent. The objective of this paper is to investigate the cause of these inconsistencies and to identify which method is the most efficient. It is shown that many inconsistencies are due to non-optimal implementation of techniques used in the comparisons. The most obvious example of this is Bowring's approximate method, which is often used as a 'benchmark' in comparisons. When programmed strictly according to Bowring's original formulation, it contains six calls of trigonometric functions, but a simple reformulation yields an implementation that includes only one trigonometric function, significantly reducing the required computation time. Claims by many authors that their method is faster than Bowring's only hold for the slow implementation of the latter. Of all methods tested, Fukushima's method using Halley's third-order formula is found to be the most efficient.

KEYWORDS: coordinate transformation, geodetic coordinates, Cartesian coordinates, coordinate systems, GNSS positioning

Session 3C: Locata 1325 - 1505

The Nottingham Locatalite Network

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The authors started using pseudolites some 5 years ago, in connection with a GPS bridge monitoring project they were involved with. This was to enable high quality positions in the North South direction, which is poor when using GPS alone in latitudes like the UK due to the GPS satellite constellation. Following on from this, the authors decided to investigate the use of locatalites, which are a ground based RF positioning system. The paper details the permanent locatalite network established at the University of Nottingham and results from using such systems. To date, various accuracy tests have been performed as well as interference tests with other wifi systems.

KEYWORDS: Locatalites, positioning, integration.

Recent Developments in *Locata* Technology and Applications

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Locata positioning technology was developed to address the shortcomings of current technologies for reliable positioning in challenging environments such as when GNSS satellite coverage is poor or not available. Locata's solution to these environments is to deploy a network of terrestrially based transceivers (*LocataLites*) that transmit ranging signals. These transceivers form a positioning network (called a *LocataNet*) that can operate in combination with GPS or entirely independent of GPS. One special property of the *LocataNet* is that it is time-synchronous, allowing single point positioning for a *Locata* receiver with cm-level accuracy. The *LocataLites* transmit their own proprietary signal structure in the 2.4GHz ISM band (license free) to ensure complete interoperability with GPS.

As a new technology *Locata* is rapidly evolving, and over the past twelve months there have been a number of significant technology developments. This paper will review core aspect of the *Locata* technology and discuss the most recent system developments. The positioning results and analysis presented in this paper will demonstrate the suitability of *Locata* technology in key application market areas, where GNSS positioning currently fails to meet user expectations.

KEYWORDS: *Locata*, kinematic positioning, GNSS augmentation, pseudolite

Indoor Positioning Using Fingerprinting With Locata Signals

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This research studies indoor positioning using power-level-fingerprinting with a time-synchronised Locata network. We compare our results to another fingerprinting-based positioning method using WiFi access points. With an accuracy of 1.2 - 1.5 metres, our technique can be a powerful fall-back option when regular Locata positioning fails due to difficult signal conditions. Moreover, our results serve as a benchmark for future research on indoor positioning with Locata.

KEYWORDS: Locata, Pseudolites, Fingerprinting.

Effect of different construction materials on the indoor propagation of Locata's 2.4 GHz signal

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Locata technology is the future of indoor positioning. It solves the problems faced by traditional positioning systems, by implementing a network of terrestrially based transceivers that transmit their own GPS-like signals, at the licence-free frequency of 2.4 GHz. However, electromagnetic signals are attenuated when passing through walls and other obstructions. This paper outlines the research carried out to test the effects of some commonly used construction materials on the pseudorange of Locata's signals. Reasons for these effects have been explored based on the properties of the tested materials. The effects of signal attenuation on the accuracy of the positioning solution have been further explored, by introducing a combination of construction materials at different locations within a network of LocataLites. This is aimed at enhancing the performance of Locata technology for indoor applications.

KEYWORDS: Locata, Pseudolite

ISM Band Interference and Locata

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Locata operates in the 2.4GHz ISM band, where there are an unlimited number of other transmitter types. It is well known that other radio trilateration systems such as GPS are significantly affected by interference so it can be expected that the performance of Locata will also suffer. In this paper, we examine the effects of some common ISM band transmitters, such as WiFi and Bluetooth, on Locata, and report these effects.

KEYWORDS: Interference, ISM, radio trilateration, WiFi, Bluetooth

Session 4A: Location Infrastructure 1535 - 1655

Spatial Information and Technologies – The LBS Challenge

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LBS is all about integration. The leaders seek emerging trends and make decisions on how best to position their business – an integration of time, technology, position and opportunity. But where does LBS sit in the spatial information industry in Australia?

ASIBA's path is one of identifying linkages between important political, social, and economic issues and spatial information and technologies (SI & T). There is no doubt that the Australian Government recognises the importance of the spatial information (SI) industry to our nation, particularly after the SI Action Agenda, and the horror of September 11, 2001. ASIBA evolved out of the Action Agenda, with the key role of representing the industry to governments.

Today's challenge is identifying a logical path for our diverse industry, and how best to represent the private sector. Are there common directions for the specialty technologies (including LBS, simulation and GPS) and the traditional spatial sectors (including surveying, mapping, and remote sensing)? Can ASIBA assist?

This paper looks at the history of our industry, some recent activity highlights, and offers suggestions on how to achieve a stronger, cohesive and more influential voice to Australian governments.

KEYWORDS: Spatial Information, ASIBA

Geospatial Infrastructure Solutions ... meeting the challenge in Australian utilities

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Australian utilities in transportation, water, power, telecommunications and gas, as well as local governments, own and manage the basic infrastructure that sustains our economy, our way of life, and our wealth. This infrastructure is also under constant threat of damage due to breakdown, natural disaster and (more recently) acts of terrorism ... not unlike in the rest of the world.

Australian utilities have made excellent use of spatial data and location-aware technologies to build and maintain this infrastructure, and protect it from damage.

Chris Stoltz will explain the role of GITA in supporting the utility infrastructure sector and, using some interesting examples, demonstrate the practical use of location-aware technologies.

KEYWORDS: Spatial, location, infrastructure, protection, technologies.

LBS and Regulation in the Telecommunications Industry

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Examples of LBS in a telecommunication environment and commentary on proposed LBS industry Guidelines

KEYWORDS: Telecommunications LBS .

Location Based Services Panel Session 1635 - 1655

Session 4B Receiver Design 1535 - 1655

Un-equally Displaced Correlators in Tracking-loop for Multipath Mitigation

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Multipath interference affects the accuracy of the pseudorange as well as the carrier phase measurements in the tracking-loop of a GNSS receiver. In the high precision applications, *RTK* for example, the multipath error is the dominant component of the error sources.

Many efforts have been made for the mitigation of the multipath errors. By examining the sampling ‘arms’ of the correlation peak/peaks (e.g., early & late arms) in the tracking-loop, we know that the multipath signals are the later arrival to contaminate the correlation profile. They appear on the ‘late’ shoulder related to the LOS (line-of-sight) centre. It suggests us that we should treat the ‘early’ and the ‘late’ differently in the delay estimation process of the tracking-loop in order to reduce the effect of the multipath interference.

Un-equalized correlator displacement means that in a tracking-loop, the 'early' and 'late' arms (or other type of sampling methods) do not necessary to be equally placed around the central position of the LOS signal. In order to reduce the multipath error, in principle, the ‘late’ arm should be placed more close to the centre to avoid being contaminated. This is different from the classical equal spacing for both ‘early’ and ‘late’ arms.

Analytical work as well as simulations has been done for C/A code tracking process. The results show clearly that it is an effective way for the multipath mitigation and it is more stable comparing with, for example, the so-called ‘*narrow correlator*’ approach.

KEYWORDS: Tracking-loop, multipath.

Galileo GIOVE-A Acquisition and Tracking Analysis with a New Unambiguous

Discriminator

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This paper focuses on realizing and designing an unambiguous and cost effective algorithm for tracking a Binary Offset Carrier (n,n) signal such as the BOC(1,1) Galileo signal. The aim of the Galileo receiver design is to acquire and track the E1 band BOC (1, 1) signal broadcast by the prototype Galileo satellite-GIOVE-A. Results show that it can be successfully acquired using a narrowband front end with low sampling rate utilizing conventional acquisition methods. To eliminate the effect of the ambiguous correlation function while maintaining all the features of the BOC (1, 1) spread spectrum signal, a novel non-coherent code tracking algorithm is introduced and two architectures of combining Costas loop and Delay Locked Loop (DLL) are proposed. The performances of different DLL discriminators are compared. The strength of the novel design lies in its low complexity, high robustness and lack of ambiguity with a relative high slope of discriminator function which has flexibility of choosing Early/Late spacing liked a conventional Narrow Correlator and possibility of maintaining the multipath rejection property.

KEYWORDS: Galileo; BOC (N, N); Costas Loop; Code Tracking Discriminator; Delay Locked Loop; Multipath.

An Analysis of L1-C/A Cross Correlation & Acquisition Effort in Weak Signal Environments

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Modern mobile devices are now equipped with GPS-receivers to provide E911 and other location based services. Working indoors, the GPS receiver is likely to experience a situation where some of the received signals are stronger than others. These strong signals can prevent the acquisition of a desired weak signal or lead to false acquisition, due to high cross correlation between the strong and weak signals. The C/A Gold code used in GPS L1 signal has an inherent correlation protection of about 24 dB. This becomes inadequate for weak signal acquisition in the presence of multiple strong signals. Various cross correlation mitigation techniques are used to deal with this problem. The impact of cross correlation on weak signal acquisition largely depends on the relative power level and carrier offset of the desired weak signal with reference to the strong interfering signals. This paper first presents an analysis of the L1-C/A cross correlation in the presence of multiple strong signals under different conditions of relative Doppler offset and dwell time. Acquisition of weak signals with different SNR levels is then performed under these conditions, using the “Tong” search algorithm and the results of acquisition are presented. The results indicate that, for certain relative Doppler offsets, extended dwell times assist in combating the cross correlation noise hence improving the detection probability.

KEYWORDS: cross correlation, acquisition, probability, interferer, dwell time, relative Doppler offset.

Semiconductor Implementation of Differential Correlation and Noncoherent Integration

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Emergency caller location and location based services increasingly lead to navigation receivers being integrated into cellular telephones. The size constraints of cellular phones require highly integrated semiconductor solutions. The cost of microchips can be reduced by shrinking the silicon area. This can be accomplished by the optimum choice of the quantization resolutions in the digital baseband section and by the reuse of hardware resources within the integrated circuits. Since satellite navigation receivers for indoor applications are usually designed to host the equivalent of several thousand correlation channels, the benefit of reducing the bit sizes and reusing the signal processing blocks is substantial. The required amount of signal processing units can be reduced by operating the hardware resources with an increased clock rate and multiplexing different signal processing paths through the same hardware. The implementation of the differential correlation and the noncoherent integration methods in hardware description language allows the synthesizing of the signal processing units into a complementary metal-oxide semiconductor (CMOS) technology. This paper presents the resulting silicon area, power consumption, quantization loss, and timing characteristics. The

quantization characteristics are chosen such that resulting degradation is sufficiently low for enhanced sensitivity Galileo/GPS receivers. The timing slack of the CMOS synthesis results are analyzed in order to estimate the degree of parallelization required for single shot positioning. When compared with the desired sample rates, the timing slack indicates how many correlation channels can be served in parallel by the respective unit.

KEYWORDS: Quantization Resolution, Timing Slack, Silicon Area, Power Consumption, CMOS.

Session 4C: Precision Agriculture 1535 - 1655

Robust Positioning for Controlled Traffic Farming in Victoria

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The Department of Sustainability and Environment (DSE) in Victoria has developed a Global Navigation Satellite System (GNSS) Continually Operating Reference Station (CORS) infrastructure called GPSnet^{TM}. With the successful implementation of Network Real-time Kinematic (NRTK) services in the metropolitan environs the next phases of development are designed to support high accuracy users in rural areas. Controlled Traffic Farming (CTF) in particular is a precision farming method that relies on robust 2cm real-time positioning to control soil degradation, increase moisture retention, reduce fuel use and achieve higher crop yields.

This paper describes the infrastructure required to provide robust, high accuracy, real-time positioning services for rural areas. Recent trials at Bacchus Marsh in Victoria used a satellite internet gateway and GNSS Internet radio to generate a virtual base station at the farm site. NRTK corrections were re-broadcast from a standard computer over a terrestrial radio/modem to a tractor for high accuracy automatic machine guidance, eliminating the need for a local base station. The successful transmission of NRTK corrections using a local re-broadcast model suitable for high accuracy Control Traffic Farming applications will be used as a case example. The potential economic and environmental benefits of building infrastructure to support Controlled Traffic Farming practices will also be discussed.

Key Words: GPSnet^{TM}, Precision Agriculture, Network Real Time Kinematic, Global Navigation Satellite Systems, GNSS Internet Radio, Controlled Traffic Farming, Economics, Environment

Networked Real-Time Kinematic Corrections for High Accuracy Machine Guidance - Dynamic Accuracy Trials

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The Department of Sustainability and Environment (DSE) in Victoria has developed a Global Navigation Satellite System (GNSS) Continually Operating Reference Station (CORS) infrastructure called GPSnet™. GPSnet™ provides Networked Real-Time Kinematic (NRTK) correction services that are suitable for many high accuracy applications such as surveying and construction. Surveyors in particular have benefited from these services with coordinate results routinely reported to be within the 2cm range.

Automatic machine guidance for precision agriculture is another application that relies on 2cm accuracy: pass-to-pass and year-to-year. In this paper the accuracy of a moving tractor automatically steered by GNSS using NRTK corrections from GPSnet is determined from a robotic total station. This paper describes how Internet based NRTK corrections from GPSnet are re-broadcast to a tractor in the field and the results of trials designed to verify and track the dynamic accuracy of the tractors' position as it moves real time.

KEYWORDS: GPSnet™, Precision Agriculture, Network Real Time Kinematic, GNSS Internet Radio, Controlled Traffic Farming

GNSS Applications in Cropping Agriculture using Controlled Traffic Farming.

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Controlled Traffic Farming (CTF) is a proven platform for profitable and sustainable cropping in the grains, cotton and sugar industries. CTF also provides continuous improvement opportunities through applications of new technologies, particularly GNSS, remote sensing and GIS.

CTF is an innovative farming system incorporating permanent wheel tracks (controlled traffic), zero tillage, property and layout planning, best agronomy, record keeping and minimum environmental impacts.

GNSS provide accurate location and records of farming operations with enormous implications. This links seamlessly with CTF's ability to spatially manage all farming operations.

CTF reduces soil compaction; manages runoff, erosion and waterlogging; increases farm efficiencies; and reduces time to farm. GNSS location and repeatability provide accuracies to allow inter-row management to 2cm with massive machines up to 30m wide (for planting, herbicides, fertiliser and fungicides) and automated steering, input applications, and recording systems. This is all based on our ability to conduct one operation in very close relation to previous or future operations. Examples will be presented of planting, spraying, harvesting, resource management, and record keeping.

Increasingly, this combination of CTF and GNSS is adding value to other technologies including satellite imagery, topographic mapping and GIS analyses, particularly for defining causes and management of paddock variability. Examples will be presented of forensic agronomy (what are the causes?) and farm/farmer R&D (farmer conducted on-farm research using these tools).

KEYWORDS: Agriculture, CTF, GNSS, applications, innovation.

An Innovative Method for GPS and INS Integration in the Agricultural Environment

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Agricultural applications, particularly row cropping applications which are the focus of this paper, are ideal candidates for automation through their continuous and repetitive nature, high dependence on manual labour and typically being conducted in locations that have a relatively unobstructed sky view. A key part of the automation process however, is determining the location of the machinery being automated. Traditionally, GPS and INS integration through either a loosely coupled or tightly coupled Kalman filter has been used to provide a robust positioning solution in both the long and short term. The innovative idea to bridge GPS outages presented in this paper will outline an alternate method for INS and GPS integration utilizing the existing GPS infrastructure specifically for the agricultural environment. While the focus of this paper is on agricultural applications this technique could be extended into all fields utilizing an integrated GPS and INS system to derive a position solution. This paper outlines and examines the problems involved in this new approach as well as presenting initial simulation results demonstrating the validity of the concept. Furthermore, a preliminary comparison between the simulation of this new technique and a simulation of the more traditional integration technique of a loosely coupled Kalman filter will be presented demonstrating the performance of this solution. A qualitative comparison between the new method presented in this paper and existing methodologies will also be discussed.

KEYWORDS: Integration, Machine Automation, Agriculture

Panel Session: The System of Systems: Will Interoperability work? 1700 - 1800

Moderated by Mr Matt Higgins, Department of Natural Resources and Water, Brisbane, Australia

Abstracts – Wednesday 5th December, 2007

Session 5: The GNSS Global Perspective Part 2 0900 - 1050

Towards a GNSS System of Systems

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Only seven years ago the U. S. Global Positioning System (GPS) was the only real Global Navigation Satellite System which could be used in practice. At that time the Russian GLONASS system consisted only of seven satellites. Europe had announced the build up of the Galileo system.

Meanwhile the modernization of GPS is under planning, the rebuilt and modernization of GLONASS has started, Europe has its first experimental satellite, GIOVE-A, since one year in space, and China has quite recently launched its first Compass satellite as part of a global system. With so many activities under way, we will have in near future four GNSS available.

Moreover, Japan is working on its regional system, the Quasi-Zenith Satellite System (QZSS) and India started also to build up its regional system (IRNSS and GAGAN). With the other existing augmentation systems EGNOS (Europe), WAAS (USA), MSAS (Japan) and GRAS (Australia, under development) two regional navigation system and five regional augmentation systems are available. Nigeria has launched its first communication and satellite navigation satellite NIGCOMSAT-1.

Considering these many activities on our globe, it is not too early to think about compatibility and interoperability between the different systems in order to come up with one GNSS System of Systems which the user can simply track with one single and simple device. The US and Europe have already achieved that goal with respect to GPS and Galileo by the June 2004 agreement.

The presentation is reviewing the present state-of-the-art in GNSS systems in terms of system architecture, frequency and signal structure as well as services. Several topics are discussed and proposed in order to come to an interoperable system of systems. Expected innovations like new atomic clocks, new frequencies, global integrity, indoor use and multi-mission concepts are outlined.

Finally a discussion about the institutional and political implications in order to achieve a GNSS System of Systems is closing the presentation.

GLONASS Status and Development

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Russian global navigation satellite system GLONASS is the critical element of the Russian state infrastructure ensuring the national security and economy growth. Designed in 70-es of the last century for military application mainly GLONASS is becoming the part of the global navigation utility beneficial for civil community worldwide. Presently GLONASS is in modernization phase aiming to meet present and future user requirements being compatible and interoperable with other global and regional satellite navigation systems. The GLONASS modernization plan is implemented according to the Federal GLONASS Mission Oriented Program for 2002-2011. The Presidential Decree of May, 2007 directs the Russian Government to extend the GLONASS Program up to 2022. By the Presidential Decree the free open access to the civil signals for all users has been confirmed. Modernization plan envisages launches of new generation satellites of GLONASS-K transmitting new civil navigation signals interoperable with GPS and future GALILEO. The launch program foresees two launches per year of PROTON rocket with three GLONASS-M satellites in each. With two launches in 2007 being completed successfully, the GLONASS constellation shall consist of 15-17 operational satellites transmitting two civil signals in L1 and L2. Full capability constellation of 24 satellites shall be

deployed by the end of 2010. GLONASS remaining of a Russian dual use system is open for all users worldwide to be incorporated to the international global navigation satellite 'system of systems' in the framework of international cooperation process.

KEYWORDS: GLONASS, satellite, navigation, interoperability.

Session 6A: GPS/INS 1120 - 1300

Positioning Buried Utilities using an integrated GNSS approach

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In the UK there are some 4 million kilometres of buried pipes and cables. Some of the water and sewerage pipes were laid down up to 200 years ago, and many during Victorian times. Any surveying carried out would have been relative to surface features that have now gone. Further to this, there has been very little coordination between utility companies to map their assets. This all leads to a situation whereby digging for a buried utility can be quite literally hit or miss. Dry holes are first dug to find the relevant utility, then the trench excavated has to be dug carefully in case there are other utilities buried adjacent. This all leads to a lengthened excavation process that leads in turn to congestion and disturbance, as well as increased excavation costs. One answer is to remotely locate the utility and coordinate it into a global coordinate system.

The University of Nottingham is involved with two projects; The EPSRC funded Mapping the Underworld and the dti funded VISTA projects. These are both four year projects and research methods that will allow continuous and reliable positioning in built up areas in order to position and re-locate buried pipes and cables. The positioning techniques include GNSS, GNSS simulation, INS, locatalites and smart stations. The following paper outlines the work carried out to date on the integration of these techniques as well as the results of field trials carried out to date.

KEYWORDS: GNSS, mapping, Locatalites, positioning, integration.

Real-time Data Analysis of Ultra-tight GPS/INS Integration

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The recent trend clearly shows that the ultra-tight GPS/INS integration system can demonstrate superior tracking performance in high dynamic environments. To validate this several simulation experiments have been carried out successfully. However, real-time experiments are scarce owing to its complex nature. To demonstrate the performance of the various algorithms developed for this complex system in addition to real-time data analysis an experiment was conducted with the GPS and INS sensors onboard a car. A Nordnav™ Software GPS receiver and a C-MIGITS INS were used to collect the raw measurements. The experiment was conducted in the suburbs of Sydney and data was logged for 15 minutes. The collected data was post-processed in a centralised Kalman filter configured in ultra-tight mode. This paper presents the results of this experiment and also emphasises on the implementation strategy and the field trails. An overview of the architecture is also provided.

KEY WORDS: Ultra-tight GPS/INS, Correlator, Kalman Filter, Measurement Model

Evaluating the Performance of Low-Cost Inertial Sensors for use in Integrated Positioning Systems

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Over the past decade inertial sensor technologies have undergone a significant evolution with regards to their size, weight, power consumption and cost. What is still relatively undefined is the potential of these 'new' devices to augment GNSS performance. This task is essential given the growing number of applications that rely on position solutions, combined with an increasing range of positioning accuracy and reliability requirements. This paper presents results obtained from an extensive study undertaken to characterise the performance of current generation inertial sensors. Seven commercially available, low-cost inertial sensors were rigorously evaluated both statically and dynamically. This paper presents a description of the software tool developed to capture the data from all sensors simultaneously and the test platform designed to evaluate the performance of the sensors. A detailed description of the tests performed and the results obtained from comparisons made against high performance inertial and GNSS sensors will also be documented in this paper.

KEYWORDS: inertial sensors, MEMS technology, integrated positioning

Performance Analysis Of An Integrated Navigation System In Urban Canyon Environment

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Motivated by the requirements to provide continuous accurate navigation solution to bridge the periods when there is a decreased in the availability of GPS satellites or/and distinctive landmarks operating in an urban canyon environment (e.g. DARPA Urban Challenge 2007) or integrated *pseudo* Simultaneous Localization And Mapping system (*p*SLAM) in a cluttered environment (Soon *et al., 2006*). This paper describes a simple and effective approach that incorporates standalone time differenced GPS L1 carrier phase (TDCP) measurements and vehicle dynamic constraints to aid INS in an urban canyon environment. The formulation of the TDCP observation model is described in tightly coupled GPS/INS iterative extended Kalman filter (IEKF) approach (Soon *et al.*, 2007). Land vehicle trial was conducted to analyse the accuracy performance of the integrated navigation system in an urban canyon environment.

KEYWORDS: IEKF, TDCP, Tightly-Coupled, INS, ZUPT

Compensating for GPS/MEMS INS Navigation Errors using a Kalman-Neural Architecture

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Using integrated navigation systems is especially useful in environments which degrade the GPS satellite signals, such as when driving a vehicle downtown. Civil applications are demanding inexpensive yet accurate navigation of vehicles which makes the combination of MEMS inertial sensors with single point mode GPS attractive. The Kalman Filter can be used to integrate these two navigation systems, but if not properly tuned the errors can diverge during long GPS signal outages. To compensate for poorly tuned filters an intelligent system was developed using feedforward backpropagation networks. This system can adapt for residual deterministic Kalman Filter errors and then compensate for future GPS signal outages. Training is performed on simulated outages then prediction/compensation on real outages. Testing results using both simulated and real test outages are analysed.

KEYWORDS: INS, GPS, MEMS, Kalman filter, Artificial intelligence

Session 6B: CORS Networks 11210 - 1300

Real-time CORS – Revolutionizing Surveying and Geodesy

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Following an upgrade of many conventional CORS to real-time, the number of post-processing GNSS users rapidly decreases. At the same time, the real-time GNSS community dramatically grows. With the exception of reference frame maintenance with utmost precision, there soon will remain only a few applications to be carried out in post-processing mode.

Developing, implementing, maintaining and promoting internationally agreed standards is the major enabler for that and RTCM with the vendors involved is a key player in it. Among the most promising standards we see today are the RTCM Version 3 data format and the NTRIP Version 1 streaming protocol. Taking advantage of wireless mobile Internet communication, they revolutionize almost any area in surveying and geodesy. Organizations like IGS and its continental densification networks use them to go online with regionally or globally distributed reference stations – allowing us to access GNSS observations from everywhere following an open data policy. Supporting Network RTK and real-time Precise Point Positioning are today's most attractive promises for many user.

Beginning with a status report covering the EUREF and IGS real-time projects, the presentation addresses the latest activities in RTCM to improve its standards. Efforts are made to overcome deficiencies and limitations resulting from challenging requirements. A new working group "State Space" has been set up to define messages for the transport of various types of parameters in the state-space domain (in contrast to the observation-space domain used at present). The presentation closes with an outlook on the further development of the NTRIP streaming protocol.

KEYWORDS: Real-time GNSS, RTCM, NTRIP

Current Developments of a Network-based RTK System in Victoria, Australia

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The paper presents the current progress of a network-based RTK system developed by a research consortium funded by the Australia Research Council (LP0455170). The research consortium consists of RMIT University, The University of NSW, University of Melbourne, The Department of Sustainability and Environment (State of Victoria) and The Department of Lands (State of NSW). The main challenge for Australia is that due to its large and sparsely populated landmass, high density continuously operating reference station (CORS) networks cannot be justified economically. It would be a major leap forward if a true real-time, high precision positioning service could be reliably deployed over a large area without significantly increasing the density of reference stations.

Apart from the significant infrastructure development of both *GPSnet* and *SydNET* CORS networks, a significant progress has been made by the research consortium to date. Much of the research has been published from time to time over the past a few years. This includes, for instance, the evaluation of some commercial products, interpolation algorithms for the network RTK; the troposphere related investigation; triple frequency issues associated with the modernised GPS and Galileo systems; the ionosphere related research (e.g. spatio-temporal variations of total electron contents); network RTK algorithms and implementation related issues; the long and short term stability of the *GPSnet* base stations under extreme environmental events; and a preliminary evaluation of the MELBpos network solution.

Most recently, a prototype network RTK software platform has been developed and a number of tests have been carried out under various scenarios in both *GPSnet* in Victoria and *SydNET* in NSW. The tests with different combination of baseline lengths and geometries are also conducted. Solutions from single-base RTK and network-based RTK methods are compared. The results have demonstrated that the developed network RTK system can provide positioning accuracy at the centimetre level consistently for medium-sized networks (several tens of kilometres). The comparisons with some commercial network-based RTK system indicate that the developed NRTK system can provide comparable results. Further research work is also discussed.

KEYWORDS: Global Navigation Satellite System, Network-based RTK, *GPSnet*, *SydNET*, CORS.

Managing CORS Infrastructure in NSW

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This paper presents the current status and future plans of GNSS CORS Network Infrastructure in NSW with particular emphasis on system and data management. After four years of Sydnet in-house development, the benefits and sort comings of a hybrid, “open source” CORS network management system are examined. For example, there are advantages to research having access to source code and being able to utilise a variety of reference station receivers with a independent open system. Comparisons are made with the functionality of commercially available CORS Network Management systems. One of the conclusions is that while an in-house system offers many benefits for learning, research and adaptability, the development resources available to large commercial companies produce software that is more robust and elegant for managing large CORS networks in an operational and production environment. SydNET was designed to support both professional user needs for high accuracy RTK in the Sydney basin area, as well as operate as a test platform for researching new GPS algorithms and processing methodologies. The needs of these two classes of users can be met, but only if most of the functions of the CORS Network Management system are separated, so that the demands of one class of user does not adversely impact on the other class of user. This paper describes the CORS management philosophy used.

KEYWORDS: GNSS, CORS, Infrastructure, System Development.

Real-Time Quality Control for CORS Networks and Mobile Users

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As real-time GNSS positioning becomes more affordable, accessible and reliable, the market for such services continues to grow as do the number and size of the CORS networks that underpin such positioning. This broadening of the GNSS user base that has occurred as a result of this expansion brings with it some interesting challenges for equipment manufacturers, software developers and the providers of CORS-based positioning services. In particular added responsibility - and in some cases legal liability - is being placed on CORS network operators to ensure that their positioning services consistently satisfy the requirements of users.

It is in light of this growing trend toward real-time positioning applied to an increasingly diverse range of non-traditional applications, that the need to supply users with dependable quality indicators has been identified. As a consequence, the

CRC-SI is facilitating a project to develop a robust, independent real-time system that will inform users of the quality, dependability and fitness-for-purpose of their positioning results. This paper will describe the current state of development of this system, dealing with the design philosophy, system architecture and the fundamental principles being applied to assess and report on the quality of real-time GNNS data received simultaneously from a CORS network and a mobile user.

KEYWORDS: Real-Time, Quality Control, CORS networks, Network RTK.

Atmospheric Effect Modelling for Victorian Network RTK - A Preliminary Performance Assessment

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GPS*net* is a state-wide CORS network developed, operated and managed by the Department of Sustainability and Environment, State of Victoria, Australia. The inter-station distances of *GPSnet* vary from tens of kilometres to 200 km. To overcome the limitation of the conventional RTK technique, a network-based RTK system is currently under intensive development and testing by an ARC research consortium consisting of Australian premier geospatial academic and government organisations. This research investigates various algorithms for network-based RTK (NRTK) including ambiguity resolution between GPS*net* reference stations and atmospheric error modelling for the areas of network coverage. To evaluate the performance of the proposed NRTK algorithm in GPS*net* environment, a number of tests for different configurations of the reference networks and different lengths of baselines are conducted. Preliminary results demonstrate that the differences in the accuracy of the interpolated/modelled atmospheric errors for different number of reference stations are not significant and the differences between the modelled double difference (DD) errors and the true DD errors are not necessarily proportional to the lengths of the baselines.

KEYWORDS: Network-based RTK, atmospheric modelling, correction, GPS*net*.

Session 6C: Snapshot & Interactive Poster Presentations 1120 - 1300

"Namuru-GPL", open source software for the Namuru FPGA-based GNSS receiver

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The "Namuru" field programmable gate array (FPGA) based receiver platform has been in development at the University of New South Wales since 2004. In late 2006 a project to port open-source GPS software to the platform began. This project is the focus of the paper.

The concept behind Namuru is to develop a fully open-source GNSS receiver platform to support research, development and teaching across a wide range of topics. While the baseband processor and circuit board are already released as open-source, the current position solution software (a port of the GPS Architect) is available to licence holders only. This presents a problem as Zarlink, the current 'owners' of the GPS Architect, do not support it any more, and are not interested in issuing licences. A natural progression was to take an appropriate version of the open-source GPS software originally developed by Cliff Kelly for Zarlink based receivers and port it to Namuru. The version chosen was Andrew Greenburg's port to the Signav MG5001 receiver.

In this paper, an overview of open-source GNSS software is provided, followed by a brief look at the Namuru hardware platform. The details of the porting process are then presented, along with outcomes, results of testing, problems found along the way and future activities.

KEYWORDS: Namuru, GNSS, GPS, eCos, open-source.

Cross Correlation Mitigation Techniques for Software GPS C/A Code Receivers

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The cross correlation properties of the 1023 chip Gold (C/A) codes can cause difficulties in scenarios where both strong and weak GPS signals need to be processed. Such cases are increasingly likely given the new applications of GPS, with examples being the processing of GPS signals in E911 cellular phone applications and the use of bistatic GPS as a remote sensing tool. This coupled with the increasing use of software-defined radio (software correlation) for either cost-saving or flexibility enhancing reasons have resulted in a need to mitigate cross correlations within such systems. This paper provides details on two techniques developed by the authors for the mitigation of GPS cross correlations, both of which have been tested and implemented within a software correlator that has been written in the C programming language. Details on the software correlator are also provided as the table lookup requirements for the correlator are smaller than those previously reported. Test results indicating the effectiveness of the algorithms are presented, with a comparison between the two methods being performed., The datasets containing cross correlations were obtained by capturing the output of a GPS radio front end chip attached to a hardware GPS simulator.

KEYWORDS: cross correlation mitigation, near-far problem, GPS C/A code, software defined radio.

Receiving the L2C Signal with "Namuru" GPS L1 Receiver

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L2C is the first modernised GPS signal for civilians, broadcast by the new generation of satellites, designated Block IIR-M. Currently three of these satellites (PRN-17, PRN-31 and PRN-12) have been declared operational by the Air Force Space Command at Schriever Air Force Base, Colorado. The structure of the L2C signal is designed such that it achieves a number of advantages over the GPS L1 signal alone. This includes weak signal acquisition, ionospheric error elimination when both L1 and L2C are used, quicker operations and improved tracking performance. It was suggested that it would be interesting as well as challenging to acquire and track the L2C signal with a standard GPS L1 receiver. "Namuru" is an FPGA-based GPS L1 receiver, developed at School of Surveying & Spatial Information Systems, UNSW. In this work, the RF front end of "Namuru" has been modified by hardware augmentation, to process real L2C signals from Block IIR-M satellites. The modified RF front end provides real time samples of the L2C signal. These samples are recorded in a memory module on "Namuru" board and further processed in Matlab environment to perform the acquisition of L2C signal. The new structure of the L2C signal requires novel approaches for its acquisition. The L2C signal consists of two codes, L2C CM and L2C CL. The L2C CM-code is modulo-2 added to data and the resultant sequence is time-multiplexed with the L2C CL-code on a chip by chip basis. In this work, the replica code used for acquisition primarily contains CM chips while CL chips being replaced by zeros. This replica code is referred to as return to zero (RZ) CM code and can be used for signal search across any 20 milliseconds segment of an L2C signal record. The L2C signal is successfully acquired from all the three operational satellites and "Namuru" is now equipped with L2C acquisition capability.

KEYWORDS: L2C, up converter, replica code, acquisition, multiplexing.

Carrier phase analysis to mitigate multipath effect

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Although researchers have devised different methods to detect and correct effects of multipath, it remains one of the challenges in navigation receiver design. This paper explores the phase variations of the incoming carrier in the presence of multipath in GPS signals. Due to this change, while tracking an incoming signal, energy is shifted from the I channel to the Q channel. A novel technique has been presented to analyse the pattern of this energy shift to estimate the amplitude, delay and phase of the reflected signal. Although the delay and phase difference are related to each other, the algorithm obtains them independently. Once the estimates are computed, multipath can be removed from the incoming signal and the line of sight signal can thus be tracked.

Recently an additional civil signal, L2C has been provided for GPS users. The L2C signal has a different carrier frequency and it can be assumed that L1 and L2C from a satellite reach receiver following same path or paths. Thus, the proposed carrier phase analysis technique can also be applied to L2C to aid the removal of multipath. This extra information should allow better estimation of the multipath parameters. It will be particularly important to have this aiding

in noisy environments or in presence of more than one reflected signal, as the algorithm performance deteriorates in such conditions.

KEYWORDS: Multipath, L2C, GPS

Fast Code-Phase Alignment of GPS Signals Using Virtex-4 FPGAs

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This paper describes a Virtex-4 based system for aligning the code-phase of a received GPS signal. The core operation involves a multiplication of the received signal with a local replica of the code followed by integration of all possible alignments within the period of one code epoch. A speedup proportional to the code length is thus achieved. We outline the proposed system, which stores the code in on-chip memory blocks and uses both dedicated DSP hardware and user logic to perform MAC operations in parallel. We study area, time and energy usage as the ratio of user logic to custom blocks is varied and identify a design point and corresponding device size for which energy usage is minimized.

KEYWORDS: GPS, phase, alignment, FPGA.

Water Mass Variations in the Australian Region observed by Space Gravity

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Data from the Gravity Recovery and Climate Experiment (GRACE) has been demonstrated to be capable of detecting seasonal changes in hydrology as well as mass variations in glaciated regions. To date, there has been little use of the GRACE data in the Australian region, although the satellites provide global coverage of the temporal variations in the Earth's gravity field. We used the French (GRGS) GRACE solutions to study ocean mass variations in the Gulf of Carpentaria, where a strong seasonal variation of ~0.4 m amplitude occurs as a result of atmospheric forcing. We compare our GRACE results with observed sea surface heights from satellite altimetry and tide gauge records to estimate the accuracy of the mass variation estimates and to assess the sensitivity of the estimates to the spherical harmonic representation of the gravity field.

KEYWORDS: GRACE, space-gravity, surface mass variation

Heighting connections between CGPS sites and tide gauge sensors. An analysis of techniques and outcomes

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Recent emphasis on climate change has led to an increased interest in monitoring changes in absolute sea level. One approach for doing this is to measure sea level changes relative to the land using a tide gauge sensor and the vertical motion of the crust in an accurate global terrestrial reference frame using Continuous GPS (CGPS). The vertical deformations between these sensors must be monitored regularly to identify and eliminate any local deformations. This

paper compares GPS heighting to the Total Station Levelling technique for measuring height difference between CGPS and tide gauge sensors at locations outside the AUSGEOID98 coverage area. It is shown that whereas the Total Station Levelling technique yields sub millimetre accurate results well within first order levelling standards, GPS Heighting shows a repeatability of ±2mm. However, care needs to be taken when comparing the GPS heighting results with the orthometric heights derived from levelling when using the Earth Geopotential Model (EGM96) geoid separation values.

KEYWORDS: GPS Heighting, Total Station Levelling, Sea Level Monitoring, Geoid.

Comments on the Solution Stability of GPS Monumentation

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Recent discussions on the stability of concrete pillar style monuments for geodetic observation have led to an investigation on their use in Australia's GPS networks. In this study, the analysis of monument stability is separated into two components; monument noise and solution stability. Monument noise relates to the effect of coupling the monument with the Earth (bedrock) while solution stability relates to the influence of the monument on the GPS signal. The primary focus of this study was to examine the solution stability of concrete pillar monuments, such as the influence of near-field multipath, which has been repeatedly linked with such monuments. Comparison was made between estimates of the level of near-field multipath on GPS time series data collected on a concrete pillar monument with and without an aluminium shield. This shield was designed to prevent near-field multipath, by blocking the gap between the pillar surface and the antenna ground plane. This provided an indication to the amount of near-field multipath observed for a concrete pillar style monument, which was used as a reference point in a study comparing the solution stability of three different monument types; a concrete pillar, a braced tripod and a steel pole.

KEYWORDS: GPS, monument, near-field multipath

GPS phase tracking performance in the presence of ionospheric scintillation

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Ionospheric scintillation induces a rapid change in the amplitude and phase of radio wave signals. This is due to irregularities of electron density in the F-region of the ionosphere. It reduces the accuracy of both pseudorange and carrier phase measurements in GPS/Satellite Based Augmentation System (SBAS) receivers and can cause loss of lock on the satellite signal. Scintillation is not strong at mid-latitude regions, but severe effects occur mainly in a band approximately 20-degree latitude on either side of the magnetic equator and sometimes in the polar and auroral regions. Most scintillation occurs for a few hours after sunset during the peak years of the solar cycle. In Japan, several ionospheric scintillations were observed by Electronic Navigation Research Institute (ENRI). This work intended to statistically evaluate constant bandwidth PLLs and a Fast Adaptive Bandwidth (FAB) PLL performance under a typical ionospheric scintillation condition observed in Japan. The results show that the FAB PLL has the robustness against the scintillation effects compared with the constant PLLs and can minimise phase errors when the scintillation is not affective.

KEYWORDS: Ionospheric Scintillation GPS PLL FABPLL

Use of Directional Information in Wireless LAN based indoor positioning

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Wireless LAN (WLAN) positioning has received much attention recently and location fingerprinting has been widely accepted as an effect method. In WLAN positioning, the mobile user's (MU) orientation has a significant impact on the received signal strength from an access point. Many researchers have noticed this impact and considered it when the fingerprint database is generated. In this paper, directional information is used not only to increase the positioning accuracy, but also estimate the MU's orientation. A direction-based positioning fingerprinting technique is proposed. An experiment was carried out to verify the new approach. The results show the direction based approach can successfully localize the MU and estimate the MU's direction.

KEYWORDS: WLAN, positioning, fingerprinting, direction

Wi-Fi fingerprinting for outdoor positioning

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GPS is the most popular positioning system at presents but it does not perform well in indoor environments or urban canyons. While Wi-Fi has been accepted as one of the good candidates for indoor positioning, its performance in outdoor environment is also of interest as a Wi-Fi based positioning system may also be able overcome the shortcomings of GPS in urban cantons. An experiment was carried out in the Sydney CBD area, where Wi-Fi access points (AP) are densely deployed. The fingerprinting technique is utilized to determine the user's position, with 171 reference points in the fingerprint database and 26 test points. Analysis of the results show that outdoor fingerprinting is a viable technique for the provision of location based services (LBS).

KEYWORDS: Wi-Fi, positioning, fingerprinting, location based services.

Environmental Impact Assessment of Longwall Mining using Radar Interferometry

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The subsidence from longwall mining has the potential to impact on water quality and quantity, that in turn has the potential to impact on threatened flora and fauna, and biodiversity conservation. Subsidence can also impact natural and cultural heritage. This paper investigated the use of new technology, differential radar interferometry, that could inform the subsidence assessment process and provide a tool to avoid or mitigate potential impacts.

This paper investigated the use radar interferometry as a transparent subsidence assessment methodology to assess cumulative subsidence. It is also to inform the determination of future mining in previously mined areas. Further more, appropriate buffer widths for assets such as rivers and creeks, swamps, cliff lines, and heritage items may be determined by combining DInSAR results with known subsidence-related impacts.

In this study, 14 pairs of radar imagery from 4 different satellites in C- and L-bands of microwave were analysed with radar interferometry and further processed in GIS. Because of vegetation cover over the mining sites and the nature of mine subsidence, i.e. large displacement within a small spatial extent, InSAR with L-band radar satellite has demonstrated its clear-cut advantages in monitoring mine subsidence. Our earlier studies comparing InSAR result and ground survey data confirmed sub-cm accuracy of InSAR as well as its capability to reveal subsidence occurred in 24 hours with mm-level resolution.

KEYWORDS: radar interferometry, DInSAR, mining, subsidence

Positioning Performance of Ultra-wide Band and ZigBee Technologies

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Ubiquitous positioning technologies include, but not limited to, for example, Global Satellite Navigation Systems (GNSS), cellular and WiFi networks, Radio Frequency Identification (RFID), Ultra Wide Band (UWB), ZigBee, and their integrations. These technologies serve as backbones to support various location based services (LBS) requiring different accuracy of position information. Both UWB and ZigBee seem to be able to provide sub-metre positioning accuracy, but at present, the cost of ZigBee OEM is significantly lower than UWB. A series of tests were carried out in an open area inside the Hong Kong Polytechnic University campus, to study the positioning performance of both technologies. This paper discusses initial tests carried out on the positioning performance of UWB and ZigBee in June 2007. A testbed was selected on the roof of a building inside the Hong Kong Polytechnic University (HKPolyU) campus, for evaluating both positioning technologies in free space condition. The test area is a 10 m by 10 m square, to ensure good signal reception for ZigBee and UWB systems. Results have shown that UWB can generally achieve better than 0.5m accuracy at 95% level, while the ZigBee can achieve 3m to 4m accuracy at the same confidence level. The test results would be a good base for performance comparing of these two emerging technologies under various site conditions, so that proper decision can be made on system selection when the cost and accuracy have to be considered in designing a positioning infrastructure covering areas with different site environments and involving integration of different positioning technologies.

KEYWORDS: Ultra-wide Band, ZigBee, Positioning Technology

Single to Multi Frequency GNSS Signal Processing Solutions for Structural Monitoring Applications

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Nothing is static. Buildings and dams settle, bridges flex and vibrate, rock masses shift, mud slides, glaciers flow, volcanoes erupt. Whether by human activity such as mining or construction or by the natural processes of erosion, the world in which we live is continually changing. Management of this change is essential for social and economic advancement. Failure of a bridge can isolate communities, restrict commerce and cause loss of life.

Economies, even our daily lives, are dependent upon the health of bridges, dams, tunnels, elevated road systems, retaining walls, mines, and high-rise buildings. Engineers, geologists and other professionals are trusted to prevent such disasters.

Engineering companies and contractors are facing challenges never before experienced. They are being charged with – and being held liable for – the health of the structures they create and maintain. In order to surmount these challenges, engineers need to be able to detect structural movements to millimeter level accuracy and track these movements in real time in all atmospheric conditions.

Accurate and timely information on the actual status of the structure is highly valuable to engineers, enabling them to compare the real-world behavior of the structure against the design and theoretical models. When armed with such data, engineers can effectively and cost efficiently measure and maintain the health of these vital infrastructures.

Owing to the advantages of high accuracy, all-weather conditions and no requirements of inter-visibility between measuring points, GNSS, the acronym standing for Global Navigation Satellite System and including the US Global Positioning System, GLONASS its Russian equivalent and the future European GALILEO and the Chinese BEIDOU (Big Dipper) is playing more and more important role in high precision positioning missions in structure/construction health monitoring.

For achieving a particular purpose, a properly configured GNSS measurement system can meet most of the possible static and dynamic measurement needs in such applications for absolute positioning and relative displacement. In other words the required precision and accuracy can be approached with architecture of the GNSS single/dual (L1 or L1/L2) frequency carrier phase, data sampling rate, communication between GNSS receivers and control data centre and the method of data processing. The authors will review the innovative solutions Leica Geosystems is developing in term of software and hardware.

KEYWORDS: GNSS Receivers, Engineering, Structural Monitoring, Signal processing, Software.

GNSS Radio Occultation for Weather and Climate Research - A Case Study in Australia

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Global Navigation Satellite Systems (GNSS) meteorology refers to the science and technology that makes use of GNSS for active remote sensing of the Earth's atmosphere. It consists of two parts: space-based and ground based. The ground-based technique has been developed in the last decade to a valuable tool for determining near real time atmospheric water vapour. The space-based technique has attracted much attention since the feasibility study of the pioneering GPS/MET project in late 1990s when GPS radio occultation (RO) technique was tested as a new means of atmospheric probing. A number of experiments have been carried out and very exciting results have been presented in the past a few years. GNSS RO method has opened a new avenue for measuring the Earth's atmospheric parameters near real-time with a high accuracy, high resolution and global coverage. It is expected that this emerging technology will significantly advance our knowledge of Earth's atmospheric structure and processes. This paper first overviews the technology and its historical development. Potential applications of the new technology for weather and climate studies in Australia are discussed. Current joint research effort between RMIT University and the Australian Bureau of Meteorology is outlined and major findings are presented. Finally, further research questions pertinent to Australian context are discussed and some useful conclusions are given.

KEYWORDS: Radio occultation, Global Navigation Satellite System, GPSMeteorology, NCEP, CHAMP.

The International GNSS Service: In the Service of Geoscience and the Geospatial Industry

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The IGS is an international activity with more than 200 participating organisations in over 80 countries celebrating over 13 years of successful service (http://igscb.jpl.nasa.gov). The IGS primarily develops the scientific research and analysis of long-term, highly precise and accurate Earth observations using the technologies of the Global Navigation Satellite Systems (GNSS), primarily the U.S. Global Positioning System (GPS). The mission of the IGS recently revised at the IGS Strategic Planning Meeting held in December 2006 is:

'…to provide the highest-quality GNSS data and products in support of the terrestrial reference frame, Earth rotation, Earth observation and research, positioning, navigation and timing and other applications that benefit society …'

The IGS will continue to support the International Association of Geodesy's (IAG – http://www.iag-aig.org) initiative to develop an approach to coordinate cross-technique global geodesy for the next decade - the Global Geodetic Observing System (GGOS – http://www.ggos.org), which focuses on the needs of global geodesy at the mm-level. The IGS activities are fundamental to scientific disciplines related to climate, weather, sea-level change, and space weather. However, the IGS also supports many other applications, including precise navigation, machine automation, surveying and mapping. This presentation will discuss the IGS strategic plan and future directions, and describe the many working groups and pilot projects as the world anticipates a truly multi-system GNSS. How the Real-Time IGS Pilot Project may integrate with Australia's AuScope Project, and in turn with numerous state government and private CORS stations, will be a particular focus.

Key words: IGS; IAG; GGOS; AuScope; CORS networks; geosciences

GPS Blind Beamforming Technique

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In this paper, a new blind beamforming algorithm which incorporates a subspace technique is presented to improve the antiinterference performance and increase the CarriertoNoise ratio (C/No). The simulation shows this technique is capable of achieving high gain without knowing GPS direction of arrival (DOA).

KEYWORDS: GPS, Blind Beamforming, Subspace, mutiple beamformers

Phase Centre Location Determination for Locatalite and Rover Antenna in the Locata System

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Commonly, distances measured in radiowave surveying are approximated to that between the geometrical centres of the transmitting and receiving antennas. However, for millimetre-level accuracy, as is possible using the Locata System, this approximation is unacceptable. The phase centres of both antennas are required as the reference points. Several techniques were implemented to find the variation in phase centre of the proposed Locata antennas with azimuth, elevation, and frequency. This paper presents the results of these tests.

KEYWORDS: Antenna, phase centre, locata, psuedolite

GPS/INS Integration in Real-time and Post-Processing with NovAtel's SPAN System

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NovAtel offers a GPS/INS solution with a uniquely robust architecture. The SPAN (Synchronized Position Attitude Navigation) system builds on the OEMV receiver, by integrating inertial measurements to provide a high-rate, continuous navigation solution. The integration is tightly coupled with access to the GPS receiver core, with both the GPS and inertial processing benefiting from the integration. Typically, GPS measurements are used to aid the inertial solution, providing update measurements to model IMU errors and control error growth during GPS outages. With SPAN, GPS performance is also improved. A SPAN enabled receiver features rapid signal requisition and a faster return to fixed integer carrier phase status (RTK) after signal outages. By improving the quality and availability of the GPS signals, the INS solution is also improved since there are more updates available.

The GPS/INS solution provided by SPAN includes real-time position, velocity and attitude estimates, in addition to raw data logging capability for post-processing. Post-processing functionality comes with Inertial Explorer, a software package featuring a fixed interval smoother to minimize errors during GPS outages.

To demonstrate the performance of the SPAN system, results from real world applications will be presented. Data sets collected in an aircraft and in a land vehicle will be presented. The airborne data set illustrates how SPAN can be incorporated in a aerial photogrammetry application. The land vehicle data set is very similar to an urban mapping application. Test results will show SPAN system performance with various levels of GPS aiding, demonstrate the benefits of a tightly coupled system, and the accuracy improvements possible with post-processing.

KEYWORDS: GPS/INS, tightly coupled, smoother, reacquisition

A low-cost field re-configurable real-time GPS/INSintegrated system – design and implementation

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This paper describes the development of a real-time GPS/INS integrated system based on a field programmable gate array (FPGA) platform. The objective is to develop a generic hardware/software platform for positioning and imaging sensor integration. Compared with the application-specific integrated circuit (ASIC) approach, the FPGA approach can shorten the research and development (R&D) cycle. Its reprogrammable hardware provides a system design methodology of lower risk. It also allows maximum flexibility, being able to integrate a wide range of GPS and INS sensor packages.

The hardware design is built on the Altera's Nios II development kit. A time-sync universal asynchronous receiver/transmitter (UART) is implemented, which accesses a free-running clock counter and reads the count at the instant of start bit of a serial transmission. The count is then used to align the time of the INS data with the GPS time frame. The embedded software is implemented in a multi-thread configuration based on the Embedded Configurable Operating System (eCos). Four threads perform tasks that include; real-time decoding GPS and INS binary streams, time synchronisation, strapdown INS computation, and integration Kalman filtering. The system records the raw data and the solution onto a compact flash card for replay or postprocessing purposes. The real-time solution is also sent out through a serial port to a mobile device which can access the internet. As a result, the real-time solution can be visualised on GoogleEarth as well as monitored from a command centre.

Preliminary tests demonstrate the feasibility of this type of system on the FPGA platform, and the functionality of the system including; the stability and accuracy of the time synchronisation mechanism, the performance of the hardware and software architecture, and the workability of the algorithm.

KEYWORDS: GPS; INS; FPGA; multisensor integration; embedded system.

Position and Velocity Determination for Sport Applications Using an Integrated Low-cost GPS, INS and Magnetometer System

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Global Positioning System (GPS) and Inertial Navigation System (INS) integrated systems are expected to become widely available as a result of low cost Micro-Electro-Mechanical Systems (MEMS) sensor technology. However, the current performance achieved by low cost sensors is still relatively poor due to the large inertial sensor errors. This is particularly prevalent in a harsh environment where there are significant periods of restricted sky view. Currently GPS and low cost INS are commonly integrated using a loosely coupled architecture which is suitable in most applications where there is good satellite availability. However, significant performance improvements can be achieved in a harsh environment by integrating GPS at the measurement level using the tightly coupled approach. Furthermore, when it is not critical to obtain the position solution in real-time, a Kalman filter smoothing algorithm can be applied to post process the data. Kalman filter smoothing is rarely considered in the case of low cost INS; however it can result in significant performance improvements, particularly for low cost INS integration. The aim of this research is to improve the precision of position and velocity determination using an integration of relatively low-cost GPS and INS systems, predominantly for people mobility tracking. The performance of a low cost INS integrated with GPS measurements in a harsh environment is investigated. The tightly coupled integration filter is combined with a Kalman filter smoothing algorithm to obtain a high quality integrated solution. Preliminary results have demonstrated that an integrated GPS and low cost INS system is capable of meeting the performance requirements for a number of sport applications where GPS availability is restricted. Furthermore, by integrating GPS and INS data using a Kalman filter smoother, it is demonstrated that in post processing, high performance positioning can be achieved for a range of applications where low cost and high quality, continuous positioning is required.

KEYWORDS: Global Positioning System, Inertial Navigation System, Kalman Filter, Sport Application.

An Investigation of Pedestrian Positioning Algorithms Based on Integrated Low-cost INS, GPS and Magnetometer

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Despite of the advantages of integrated Inertial Navigation Systems (INS) and GPS, their Application in pedestrian positioning is still a challenge. Instead, most of the pedestrian positioning systems use dead reckoning (DR) or integrated DR/GPS systems rather than integrated INS/GPS systems to avoid the significant biases and noise from the low-cost sensors. These DR systems, however, have a main drawback which is difficult to determine the distance travelled and the position from the pedestrian step detection when the pedestrian moves smoothly. It would be better to use low-cost INS and a new integration algorithm to estimate the position accurately during smooth movements of the pedestrian. The integration algorithm, however, must provide a robust estimation to tackle the noise and biases from the low-cost sensors.

In this paper a new algorithm is proposed for a low-cost integrated INS, GPS and magnetometer system. This algorithm uses the transformation matrix from the alignment stage and the magnetometers' measurements determining the attitude in order to avoid the attitude estimation drifts generated by INS. It also uses the velocity measured by the GPS signals' Doppler shifts measurements to correct the velocity determinations and uses the GPS position measurements to correct the drifts of the position estimations. A number of experiments were conducted in metropolitan Melbourne. The results

show that an average positioning accuracy using this new algorithm of 4.3 m with a standard deviation 2.2 m can be achieved. The comparison of the results of different scenarios indicates that the constraints and corrections added into the new algorithm make the system more robust to the errors from the low-cost INS and give a higher position update rate than using GPS alone. These advantages make the integrated system ideal for pedestrian positioning applications.

KEYWORDS: Positioning, Pedestrian, INS, GPS, Magnetometer.

Session 7B: Systems & Applications 1400 - 1520

Performance Evaluation of Acquisition Scheme Based on Timing-synchronized Network for AGPS High-sensitivity Receiver

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A function of automatic location identification from an emergency call is required in Japan and many other countries. How to give a reliable position promptly is a problem in places where the GPS signal is extremely weak. We propose an acquisition scheme for the Assisted GPS (AGPS) architecture based on a timing-synchronized mobile network. With this method, the C/A code search and frequency search range are significantly reduced and long-time coherent correlation becomes possible. Simulations prove that the method is efficient, fast and power saving for the user handset. Furthermore, the AGPS receiver can begin with hot start even in a cold start condition. An important measure of GPS receiver performance TTFF (Time To First Fix) is shortened.

KEYWORDS: Acquisition, high-sensitivity receiver, Assisted GPS, timing synchronized network

Test results from the next generation of NTRIP

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Since its inception and acceptance as an RTCM standard in September 2004, the NTRIP (Network Transport of RTCM via Internet Protocol) Protocol has become a widely accepted standard for streaming GNSS data over the Internet. NTRIP support is found in many current GNSS hardware and software. NTRIP is in continuous development and a draft of the next generation, NTRIP2 has been available since early this year. This paper describes the various tests carried out with the new specifications of NTRIP. These tests include backward compatibility with NTRIP1 and proxy servers compatibility. Also tested is the new UDP option included in NTRIP2. Results in terms of performance comparison in data completeness, bandwidth, network congestion and latency will also be presented.

KEYWORDS: NTRIP2, protocols, UDP, RTCM, internet

FPGA Implementation of GPS Carrier and Code tracking loops

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This paper describes the implementation of a GPS carrier and code tracking loop on an FPGA using the Matlab Simulink toolbox and Xilinx System Generator software. The aim of this paper is to show how high level tools such as System Generator together with low cost FPGA evaluation boards can be used to implement a complete GPS tracking loop

relatively easily making it a useful teaching tool for students. This paper also gives all of the design equations that are necessary to implement such a tracking loop, focusing in particularly on how to set the various constants in the tracking loop to ensure the design equations are valid. The design process for both a carrier and code tracking loop will be discussed for a given dynamic stress and thermal noise requirement, along with the Simulink and FPGA implementation results.

KEYWORDS: GPS, FPGA, Software Receiver, Carrier Tracking Loop, Code Tracking Loop.

A Preliminary Investigation of Space Junk Positioning and Tracking Techniques

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The prediction of motion of space objects have had a history of half a century since the first Russian satellite Sputnik I was launched in 1957. With the advancement in technology, space positioning and tracking techniques have been also enhanced, which leads to the accuracy improvement of positioning from metres or even kilometres to now centimetres and opens up new methods of space object tracking. Complex calculations and state-of the- art models have been developed to accurately predict the movement of space objects, and constant refining of prediction models are employed. However, with insufficient spatial data, our current achievable prediction is still insufficient to accurately predict space objects and their orbit to our space industry's satisfaction.

Atmospheric density is currently the major error factor affecting signals that propagate through the atmosphere, with atmospheric density models that are only accurate to 85%. Numerous different methods have been developed to manipulate existing data to formulate and achieve better predictions, such as modelling errors of a model or using least squares to put weight on different factors, but yet to achieve an acceptable standard. This paper first reviews a number of methods of positioning and tracking and their pros and cons are assessed. The key factors affecting the accuracy of positioning and tracking, such as the atmospheric density and the atmospheric drag are identified and some preliminary conclusions are given.

KEYWORDS: Atmospheric Density; Space Junk; Space Debris; Positioning; Tracking

Session 7C: Telematics 1400 – 1520

GNSS for ADAS - Advanced Driver Assistance Systems

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A new generation of automotive safety technology will feature adaptive cruise control, lane and road departure warning, adaptive front light control, collision avoidance and smart transmission control. These applications that enhance the driver's ability to react to the road environment and other vehicles are enabled by a new generation of digital maps and on-board sensors including radar, light detection and ranging (LIDAR), and on-board video cameras. Sensor development has enabled initial ADAS development, but the increased precision of digital maps to include road geometry with relative accuracies of 1 meter, and attributes such as speed limits, special speed situations, lane counts and markings, exit lanes, curve radius, road height and slope, add new capabilities. Curve speed warning, slope powertrain adaptation, and speed limit advisory functionality are enhanced with this information, resulting in a more realistic driving experience that could improve safety, and increase driver confidence.

Speech Enabling for In-Car Navigation Systems

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Abstract not submitted

Global ICT Convergence – from Telematics to InfoMobility?

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Abstract not submitted

Anonymous Electronic Toll Collection (ETC)

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Electronic Toll Collection (ETC) has attracted major attention to charge toll from motorists without the need for them to stop at toll plazas. For ETC to perform its operations, it requires the identification information of the transponder attached to the windscreen. This convenience of a faster trip is at the cost of the loss of personal autonomy and privacy. This paper studies the loss of anonymity in current systems and highlights the importance of anonymous operation from an ethical, legislative, standards-based, and technical point of view. This paper also presents a cryptographic solution for achieving ETC that eliminates the need for patrons wishing anonymous operations to pre-pay, and minimises the need for taking pictures of all vehicles at toll gantries.

KEYWORDS: Electronic Toll Collection, anonymous, location privacy, transport surveillance, Intelligent Transportation Systems.

Session 8A: GPS/INS in Vehicles 1550- - 1710

Vehicle Navigation Using Constraints in Tightly Coupled INS/GPS Integration

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Land vehicle navigation is a challenging environment where Global Positioning System (GPS) signals from four different satellites are not always available due to a number of reasons. Inertial Navigation Systems (INS) can be used since they do not require external aiding. Fortunately, low cost and compact Micro Electro Mechanical System (MEMS) sensors are readily available and can be used in vehicle navigation. However, these sensors can only provide aiding for short time periods due to their high drift errors. As a result, integration of GPS and INS in some optimal sense is the best solution. This can be achieved using Kalman Filter that utilizes all the available information from both systems in a least squares sense. This paper uses tightly coupled integration scheme that incorporates raw GPS signals with the INS data. The main benefit in using this scheme is its flexibility to utilize the GPS signals even for suboptimal conditions. The main contribution of this study is the implementation of constraints on the tightly coupled scheme when GPS signals are available from only one satellite. Non-holonomic constraints and Zero Velocity Updates (ZUPTs) were implemented as observations. The non-holonomic constraint imposes physical constraints to the vehicle movement by using the fact that the upward and sideways velocity of the vehicle should be zero during normal vehicle usage. ZUPTs use the fact that as a vehicle stops, there should not be any position and heading drift. Both of the constraints were applied during GPS signal fading cases separately and then combined to see the most optimal observation type for cases when GPS is unable to provide navigation results. The results of the study shows that non-holonomic constraints as observations significantly improved the drift errors while ZUPTs did not make as significant contributions.

KEYWORDS: Non-holonomic constraints, ZUPTs, Tightly coupled integration, vehicle navigation, Integrated INS/GPS

Extended Particle Filter (EPF) for Land Vehicle Navigation Applications

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Navigation comprises of the integration of methodologies and systems for estimating the time varying position, velocity and attitude of moving objects. Navigation with an integrated INS/GPS system requires extensive evaluation of nonlinear equations involving double integration. Presently, integrated vehicle navigation systems are implemented by using Kalman Filter, Extended Kalman Filter (EKF), and most recently Unscented Kalman Filter. These filters approximate the process and/or measurement models by linear or Gaussian fits which is unrealistic for highly nonlinear systems. To overcome these limitations, particle filter was developed. Particle filter is non-parametric filter and therefore it can easily deal with non-linearities and non-Gaussian noises.

In this paper Extended Particle Filter (EPF) is developed as an alternative to EKF for navigation applications. Experimental GPS/INS datasets including dual frequency carrier phase GPS receiver data and inertial measurements from two different MEMS grade inertial sensors installed on same vehicle will be used to validate the proposed filtering technique. The performance of the proposed EKF will then be compared with the performance of current estimation techniques like EKF for the same datasets in terms of navigation errors.

KEYWORDS: Loosely Coupled, Non-holonomic constraints, vehicle navigation, Integrated INS/GPS

A Fast GPS Signal Acquisition Method for High Speed Vehicles Using INS and Multiple Correlator

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GPS/INS integrated navigation systems have been used for unguided munitions. By adding the navigation system into the unguided munitions, the accuracy can be improved. In these applications, The GPS receiver has to meet certain requirements for guidance including gun-hardening, fast signal acquisition and jammer tolerance. Especially, the GPS signal should be acquired as early as possible since flight time is very short.

This paper proposes a fast acquisition method using INS and multiple correlator for high speed vehicle. The Doppler frequency uncertainty is reduced by using INS velocity information. Even though the Doppler information has uncertainty due to the INS velocity error, the number of frequency search bin is sufficiently small. The number of code bins to be searched can be reduced by using multiple correlator. As a result, total search time can be greatly reduced. In order to evaluate the performance of the proposed method, Monte-Carlo simulation was carried out. The simulation results show that average acquisition time is less than 2 second in 1000 m/s speed environment.

KEYWORDS: Smart munitions, Fast acquisition, INS, Multiple correlator.

High Precision Machine Guidance on Hydraulic Excavators

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This paper describes methods to implement machine guidance on hydraulic excavators used in mining. To gain operator acceptance such systems must be robust, responsive and easy to use. Immediate benefits include: accurate selective mining; excavations dug to design; and elimination of field pegging. Benches are smoother and ramps are dug to a consistent grade, which results in faster truck cycles and reduced tyre wear. Further features are the automatic generation of as builts, productivity monitoring and objective assessment of operator performance.

A Strategy to Use Ionospheric Scintillation Indices to Study Receiver Tracking Performance and Mitigate Positioning Errors

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The widely used ionospheric scintillation indices S4 and represent a high level and practical measure of the intensity of amplitude and phase scintillation affecting GNSS (Global Navigation Satellite Systems) receivers. The IESSG (Institute of Engineering Surveying and Space Geodesy, University of Nottingham) recorded this type of data between June 2001 and December 2003 in the UK and Norway using specialized GPS scintillation monitor receivers, the GSV4004 (GPS Silicon Valley, 2004). Although these indices have been frequently used to monitor and measure the impact of scintillation, they do not provide sufficient information regarding the actual instantaneous values of phase and amplitude fluctuations that will affect GNSS receiver performance. A further, lower-level measure of scintillations, is given by the power spectral density (PSD) of fluctuations in the amplitude and carrier phase output after correction for all other effects such as integrated Doppler due to satellite motion, satellite clocks, user clocks and tropospheric delay (in a process referred to as detrending). The PSD may be obtained by considering high-rate (e.g. 50Hz) amplitude and phase measurements. This paper presents a strategy devised to enable the combination of a high-quality database of scintillation indices and high-rate GNSS phase and amplitude data with state-of-the-art receiver tracking models in order to study receiver tracking performance under scintillation conditions. The experiments described in this paper demonstrate that scintillation indices such as those archived by the IESSG during the above mentioned period of time can be successfully used to compute the receiver tracking error variance using existing receiver tracking models. Further in the paper we analyse the potential use the scintillation indices to mitigate GPS positioning errors using a technique that relies on improving the least squares stochastic model with the aid of these receiver tracking models.

KEYWORDS: Ionosphere, Multipath, GPS, Scintilation, GNSS.

Composite Data Weight Analysis of Ionosphere Model Determination

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This paper presents an idea to establish the region ionosphere model using Bayes least square with the circumstance that lacking of real observation data in special region. Besides real observation data, data calculated by Global Ionosphere Model (GIM) has been used as a background. Weights of GIM data and real observation data should be estimated with a standard weight before using them because accuracies of these data were different. So weights intra two kinds of data have been discussed with the covariance matrix respectively at first. And then weight inter two kinds of data have been analysed, an integer weight factor has been put forward for the determination of the weight inter two kinds of data. Lastly, the feasibility of the idea and the method to estimate the data weight were proved by an investigation scenario. The accuracy of the model established using this idea reaches 85% in the region where has none real observation data, which make it extraordinary suitable for precisely region satellite navigation data simulation purposes.

KEYWORDS: Global Ionosphere Model, Real Observation Data, Data Weight, Polynomial Ionosphere Model.

Performance analyses of typical ionospheric models in Australia

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This paper presents a performance evaluation of four typical empirical ionospheric models using three IGS stations in southern hemisphere. The four empirical models tested are the GPS broadcast Klobuchar model, the post-fit Klobuchar-style model, the International Reference Ionosphere (IRI) model (IRI-2001) and the Global Ionospheric Model in IONEX format supplied by Centre for Orbit Determination in Europe (CODE). Carriersmoothed- code GPS observations in 2004 from three Australian International GNSS Service sites are used to estimate the ionospheric total electron content (TEC). This TEC values are used as “true” values for the comparison with TEC derived from the four typical ionospheric models and the performances of different models in Australia are investigated.

KEYWORDS: GPS; Klobuchar; IRI-2001; GIM

Solar radio burst effects on GPS: A study of the impact of the December 2006 solar activity on GPS in the Australian region

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In December 2006 a series of massive solar flares occurred on the sun. The flares were associated with intense solar radio-wave bursts that peaked in intensity in the GPS frequency range and produced some of the strongest recorded fades in GPS signal strength resulting from solar activity. We quantify the effect of this solar activity on GPS users in the Australian region with a view to improving modelling of the effects of solar radio interference.

Solar radio bursts compromise GPS operation by increasing the system noise of the GPS receiver lowering the C/No of the signal from each satellite being tracked by the receiver. We observed significant signal degradation in many of the geodetic-quality dual-frequency GPS receivers studied. The solar radio bursts were at times sufficiently intense to result in many GPS receivers failing to produce a navigation solution near the peak of the burst.

During radio interference the C/No of tracked satellites varies systematically with elevation, antenna gain, solar flux and zenith angle. This enables modelling of solar flare effects on GPS systems, in particular satellite availability and DOP. Variability in the tracking efficiency of different types of GPS receiver produces scatter in this relationship and this is addressed.

Although solar radio bursts of this scale are not common, particularly during solar minimum, they are likely to increase in occurrence frequency as solar activity increases towards solar maximum. The resultant interference and degraded GPS

satellite tracking have implications for GPS applications requiring a high degree of precision and reliability such as GPS augmentation systems.

KEYWORDS: GPS, Solar, Radio, Interference, Noise

Session 8C: Interference 1550 - 1610

Comparison between GPS and Galileo satellite availability in the presence of CW interference

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GNSS receivers have been shown to be most vulnerable to CW interference. It affects the acquisition process of the signal and can also pass through the tracking loop filters to affect the received satellite signal quality. Carrier to noise density ratio (C/No) is an indicator of received signal quality to the receiver. Lower C/No means lower quality of the received signal. Galileo satellites will be soon in place operating together with GPS satellites. Considering the designer's intention of maintaining interoperability between different satellite navigation systems, it is reasonable to seek a quantified comparison between the different systems in terms of vulnerability to CW interference. In this paper, considering the signal structures, the characterization of the effect of CW interference on the C/No for GPS and Galileo is investigated and compared. It is shown that for the available Galileo signal (GIOVE-A BOC(1, 1) in the E1/L1 band), the worst spectral line happens far from the L1 frequency. A frequency was selected which is midway between the GPS and Galileo worst spectral lines, and for the same power of RFI, GPS is shown to be more vulnerable to interference. Also the probability of availability of one GPS satellite is compared with that of one Galileo satellite in terms of interference power and frequency. It is shown that these two systems can be considered as alternatives to each other in the presence of different RFI frequencies as their availability in the presence of CW RFI is different in terms of RFI frequency (L5, L2C, E5 and E6 are not considered).

KEYWORDS GPS, Galileo, Interference, C/No

Miniaturized GPS interference canceller for UAVapplication

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An implementation of a two-channel Power Inversion null steering antenna array is described in this paper along with laboratory test results. The unit is designed to protect a GPS receiver from a single broadband interference and is particularly targeted for use in small UAV applications. To maximise the interference power that the unit can handle, the adaptive LMS algorithm is implemented in the digital domain using FPGA technology. A high dynamic range RF front end and ADC is thus required for each antenna element and this paper also explores the feasibility of building a small RF front end with high dynamic range using commercial off the shelf (COTS) RF chips.

KEYWORDS: GPS anti-jamming, power inversion, LMS, NLMS, FPGA

UNSW GNSS Interference Detection Device

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The radio frequency signals transmitted by Global Navigation Satellite Systems (GNSS) have very low power and are susceptible to radio frequency interference. Most GNSS receivers do not measure and quantify any interference they may be suffering; they just do what they can with the signals they receive. Interference can lead to poor receiver positioning performance and, if severe, such as in a jamming environment, complete positioning failure. Interference monitoring could be beneficial in areas such as airports where GNSS positioning will soon be more critical and interference could be present.

This paper outlines the work to date on developing an interference detection device based around the Namuru GNSS receiver platform developed at the University of New South Wales (UNSW). The detection device is a hardware and embedded software realization of detection schemes and algorithms developed at UNSW. The detection technique is briefly explained followed by a discussion of the hardware design, software implementation, testing and results, some conclusions and finally, a discussion of possible future activities.

KEYWORDS: radio frequency interference, GNSS, RFI detection

GPS Interference detected in Sydney-Australia

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Radio frequency interference affects the integrity, continuity and availability of the GPS system. These are the highly important parameters for critical applications like aviation. Interference also has an adverse impact on accuracy. Continuously operating reference stations (CORS) networks are employed to improve the accuracy of GPS position measurements used by surveyors. Interference can affect the normal operation of these stations. The goal of this work was to find if there is an interference source for GPS L1 in Sydney. It was shown that the third harmonic emission from a TV station lies within the L1 bandwidth. This source of interference is characterized in terms of frequency and power and the effect that it can have on the RF front-end of the receiver.

KEYWORDS: GPS, Interference, Detection, TV station

Panel Session: How Long till Ubiquitous Personal Navigation? 1710 - 1800

Moderated by Dorota Grejner-Brzezinska, Ohio State University, USA

Oral Presentations
Abstracts – Thursday 6th December, 2007

Session 9: The GNSS Global Perspective Part 3 0900 - 1030

Recent GNSS Developments at NavCom Technology

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At NavCom several areas of research have yielded improvements in receiver design and in the application of GNSS receivers to practical problems. Regarding receiver design, NavCom has developed a new method of minimizing the effect of interfering signals and a new technique for minimizing the effect of multipath upon both the code and carrier phase measurements. Strong continuous wave interference is overcome by looking only at the sine wave peaks of the interfering signals. The multipath is removed by comparing the phase transition path to the ideal path when no multipath is present. These two techniques are described and the resultant improvements are illustrated. In the area of application software, NavCom has recently improved the reliability and accuracy of long distance RTK. The improvement is dramatic and results from solving for distance dependent biases and the use of a partial search technique. The techniques employed will be described along with some sample results.

KEYWORDS: GNSS receivers, electromagnetic interference, multipath mitigation, long distance RTK, carrier phase.

Time and Frequency Activities of the U.S. Naval Observatory for GNSS

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The U. S. Naval Observatory (USNO) has provided timing for the U.S. Department of Defence since 1830 and, in cooperation with other institutions, has also provided timing for the United States and the international community. The data used to generate UTC (USNO) are based upon about 70 HP5071 cesiums and 24 hydrogen maser frequency standards in three buildings at two sites, with a fourth building being made operational. The USNO would not be able to meet all the requirements of its users had it kept to the same technology it had 10 years ago. Several improvements are underway to meet our anticipated future demands, including requirements for GPS III and for interoperability between GPS and cooperating GNSS systems such as Galileo and QZSS. Our goal is to achieve subnanosecond timing precision in a thoroughly robust manner, and this requires improved frequency standards, physical facilities, electronic infrastructure, algorithms, and methodologies. Beyond this comes the need to improve all modes of time transfer, including carrier phase time transfer technology. Bringing each of these about is a matter of intense effort, which will be described.

KEYWORDS: Timing, GPS, Clocks, Time Transfer

Development of the Navigation Payload for the Galileo In-Orbit Validation (IOV) Phase

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The development of the Navigation Payload for the Galileo In-Orbit Validation (IOV) phase is now well progressed. The Payload prime contract is the responsibility of EADS Astrium Limited, Portsmouth, United Kingdom. This scope of this paper is to provide an overview of the IOV Payload design and report on the status of the development that will deliver this element of the Galileo system infrastructure.

By describing the Payload requirements and the ensuing architecture, the critical technologies, the key design issues and the programmatic environment, this paper demonstrates the factors that have influenced the IOV Payload development.

The IOV Payload has a legacy from the Galileo In-Orbit Validation Element (GIOVE) Payloads which provided a test bed for some of the key technologies. The areas where there has been an evolution in functionality and design from GIOVE are described.

The specific Payload functional breakdown and architecture for the IOV phase is presented. The paper also summarises the physical implementation of the Payload, including the heritage on which the Payload design is built. The practical issues of Payload accommodation within the satellite are illustrated, together with the configuration in which the spacecraft are deployed as part of the overall space segment.

The design, manufacture and verification of the IOV Payload follows a classical satellite subsystem development lifecycle, requiring a model-based development philosophy. There are also a number of technical and programmatic factors which have become important drivers on the Payload development, and these issues are discussed.

The design of the IOV Navigation Payload is now fixed. An optimised design for the IOV phase has been baselined, design reviews are progressively being completed, redesigned hardware is being qualified, and programme risks are being mitigated. The paper concludes with a discussion of factors that will influence the evolution of future Navigation Payload designs.

KEYWORDS: Payload, IOV, Galileo, Navigation, Astrium

Session 10A: Geodesy 1100 - 1240

Statistic analysis of daily position time series from the Hong Kong local dense GPS network

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Six-year continuous GPS observations of 12 GPS stations from the Hong Kong local dense GPS network are processed to obtain reliable coordinates and velocities of the stations in the ITRF2005. A spatial filtering algorithm using the principal component analysis is employed to remove the common mode signatures from the daily position time series. The noise characteristics of the filtered time series are assessed using the method of maximum likelihood estimation. The results indicate that spatially correlated common mode errors are a dominant error source in the daily GPS solutions and that there are strong seasonal signals in all the three coordinate components. The higher-order ionospheric effects are a limiting factor on the accuracy of the GPS coordinates. The noise in the filtered time series can be described as a combination of variable white noise plus flicker noise. The velocity uncertainties are about 3-4 times larger if only variable white noise is assumed. The maximum relative horizontal velocity between the sites is on the order of 2mm/yr, which indicates some local fault activities. In addition, there are local seasonal signals in the filtered position time series. The annual amplitudes are up to ~1.6mm for the horizontal components and ~2mm for the vertical components. The residual scatters of the filtered time series also show strong seasonal characteristics.

KEYWORDS: GPS, time series, spatial filtering, seasonal signals.

The value of SLR observations to GNSS: The Potential for TRF Definition

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The products of Satellite Laser Ranging (SLR) contribute to the definition (origin, scale, core network) of the Terrestrial Reference System. The SLR long term time series that provide the definition of the ITRS were mainly determined from global Lageos (and to some extent Etalon) observations. There are currently several GNSS satellites (two GPS, all GLONASS and GIOVE-A) that are also equipped with Laser Retro-Reflectors (LRR) and are observed daily by the global SLR network. It is also proposed that all Galileo satellites will be equipped by LRR.

Since 1994, several GNSS satellites have been periodically tracked by SLR. Together with the Etalons (which are also in a GNSS type altitude orbit), visibility and hence tracking data from single SLR stations to multiple GNSS satellites is available and can be utilised as in a multi-satellite solution.

The available data (since 1994) from eight GNSS and two Etalon satellites have been processed and combined; and the standard geodetic parameters are estimated together with the low degree spherical harmonic coefficients of the Earth's gravity field. In order to ascertain the level of contribution of the SLR GNSS determined variation of the Earth's centre of mass, this solution is compared to the Lageos only solution. A calibration of the respective satellite orbits from the two data types is also undertaken as a quality check. The potential of combined SLR GNSS and all other geodetically relevant satellites at various altitudes for improved centre of mass estimates is discussed.

KEYWORDS: SLR, GNSS, Centre of Mass, TRF

AUSPOS V2.0

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Geoscience Australia currently provides an Online GPS Processing Service (AUSPOS) which allows users to submit dual frequency geodetic quality GPS data via the internet, and receive back precise coordinates. This service is heavily reliant on using IGS (International Global Navigation Satellite System Service) products and including GPS network data to achieve precise solutions globally

The new version of AUSPOS will be using the Bernese software package as the GPS processing engine which will allow access to better processing models. It is also intended to start using non-IGS regional network GPS stations, provided they meet certain quality criteria in an attempt to reduce user occupation lengths. The various components of the processing logic, the expected accuracy and the future development will be outline in the paper.

KEYWORDS: AUSPOS, Online GPS Processing

National Geodesy: Providing the Link between the Global Geodetic Observing System (GGOS) and the Australian Spatial Industry

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The Geodetic Reference frame is the foundation upon which all spatial activities are based. In the modern era the science of geodesy is more then ever a global endeavour, based primarily on the prevalence of satellite based positioning systems. This talk will provide a description of efforts by the International Association of Geodesy to improve the accuracy of the International Terrestrial Reference Frame through the Global Geodetic Observing System. It will also highlight national initiatives to ensure that the GGOS outcomes are subsequently utilised to enhance our national reference systems, thus giving access to all Australian users' position with improved accuracies.

KEYWORDS: Geodesy, Reference Frame, GNSS, GGOS.

Analysis of Regional GPS campaigns and the alignment to the ITRF

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The products of the International GNSS Service are expressed in the International Terrestrial Reference Frame (ITRF). As such station coordinates of regional GPS campaigns estimated using IGS products are best expressed in the ITRF. ITRF has had several refinements since the first version (ITRF91) which coincided with the beginning of IGS activities, to the new release of the ITRF2005. The main objective of this study is to test the impact of the alignment of solutions for regional GPS networks to the ITRF. The progression of the ITRF versions is overviewed first. Then using the analysis of several regional GPS campaigns as case studies, the coordinate differences caused by different methods of frame alignment are presented. The results of the comparative studies show the importance of optimally expressing GPS solutions for station positions of a regional or local network in the ITRF correctly. The issue of frame alignment of the different antenna phase centre variation (PCV) models is also addressed.

KEYWORDS: Reference frame, GPS campaign, IGS.

Session 10B: New Products 1100 - 1240

Precision Positioning Technologies and Trends at Topcon

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Topcon is committed on the development of innovative, cutting-edge positioning technologies and products which form the foundation for delivering the best customer solutions in the precise positioning business. Topcon is focused on integrating existing technologies and on developing new technologies capable of providing uninterrupted high precision positioning 24 hours a day, 7 days a week. This is our "24/7 SQ" concept, SQ standing for "Standardized Quality". The key to the success of our 24/7 SQ concept is the seamless integration of all technologies driven by intelligent and easy-to-use software, delivering the best integrated hybrid solutions for our customers' needs.

Topcon's R&D is focused on the development and seamless integration of GPS-GLONASS-Galileo(G3)-GNSS, optical, laser, inertial navigation, imaging, scanning, automation&control, computer-vision, communications, and software technologies. This paper will discuss the state-of-the-art of these technologies and how these technologies are utilized and developed at Topcon to create products covering the entire spectrum from high accuracy 3D-surveying (e.g., mmGPS) to the automation and control of the job construction, mining, and agricultural sites and equipment(e.g., site-link communications).

The mmGPS technology, for instance, combines the advantages of laser and GNSS technologies to create a hybrid-system capable of providing within the "Laser-Zone" mm-level of accuracy. The site-link communication software combines mesh network technology with the latest short-range communication technologies to create the foundation for the automation of Job sites.

KEYWORDS: mmGPS, Laser-Zone, 24/7 SQ, G3, GNSS.

Beyond GPS – GNSS as an enabling technology

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Enhanced Trimble R-Track technology in the Trimble R8 GNSS and the new Trimble R7 GNSS allow you to take advantage of all of the current GNSS signals including GPS L2C and GLONASS and upcoming L5 GPS. Since 2003 when Trimble introduced Trimble R-Track technology, this innovative Trimble technology continues to provide productivity for the surveying community including increased field productivity and high quality results.

Trimble's in-house research and development team has continued to develop R-Track technology in response to the changes in worldwide GNSS. As a result, the surveying industry can now take advantage of the first surveying receivers to track new L2C signal and the coming L5 band of GPS modernization, plus GLONASS. This presentation will outline the capabilities of the Trimble R8 GNSS and the Trimble R7 GNSS, and demonstrate how the latest R-Track technology in conjunction with systems improvements will improve productivity on today's jobsite.

KEYWORDS: (R-Track, GNSS, GLONASS, GPS Modernization, Productivity).

An Innovative Web Portal Application for Delivering GNSS Network Based Services

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Leica SpiderWeb is actually the most advanced application for the convenient distribution of GNSS data sets from any network to end users and customers via the Internet. With this easy to use yet powerful software, GNSS Network administrators can quickly present their GNSS data sets for public or internal access via standard web browsers.

Leica SpiderWeb allows to keep track of data, downloads, users and costs while providing additional services such as constant overview of file availability and data quality, as well as RINEX file upload for automatic coordinate computation. This application is suitable for any GNSS Reference Networks without any consideration of brands as it accesses any directory structure used by GNSS networks reading standard RINEX format, that is supported by all leading GNSS Network software or web-enabled GNSS receivers. The data distribution is totally independent of the network's configuration. The innovative aspect is that optional value adding services can be integrated as and when needed

Once the administrator accepts the registration, clients can access Leica SpiderWeb services according to their specific authorisation. The appearance of Spider Web can be adapted according specific needs and company identity. That includes customize the layout, logos and colours, without the need for complicated web-page tools. Unlimited multiple languages can be selected online due to the easy translation based on XML files

Leica SpiderWeb uses Microsoft™ SQL database which can be located on separate computer, not visible to the Internet to ensure a maximum of security. All critical user credentials (passwords) are securely encrypted to prevent misuse and

secure HTTP (HTTPS) is supported. The users of this web portal can trace their own activities as well as the administrator can trace activities for all clients

The centralised automatic coordinate computation service is available for all users/clients who are unable to perform their own post processing through the full integration of Leica Geosystems' GNSS processing algorithms. Clients simply upload their GNSS raw data and SpiderWeb uses one or more nearest stations to process the coordinates of their data sets. Computation report with results will be sent to the clients registered email accounts.

Leica GNSS QC interfaces smoothly with SpiderWeb and reference station status can be shown on-line as well as station performance graphics and Data availability plots.

This new innovative Portal is bringing any GNSS Network data to the World Wide Web.

KEYWORDS: GNSS Network, World Wide Web, Portal, Data processing, Software.

Precise Surveying with L1 RTK

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Historically, Real Time Kinematic (RTK) GNSS has been synonymous with dual frequency (L1/L2) receivers. Many dual frequency RTK receivers available in the market are using L1 only to provide a fixed solution, while L1/L2 is used to get a quick GNSS fix. With recent advancements in GNSS technology and the improved health and number of satellites, using a single frequency receiver is now a viable alternative to using a dual frequency receiver.

The Promark3 RTK GNSS receiver is the first commercial single frequency RTK system in the world. This paper explores the real world application of this GNSSS receiver. A number of surveys are conducted under different conditions to ascertain its usefulness and accuracy. Comparisons between it and dual frequency RTK receivers are made.

The receiver was used to perform actual surveys, under a wide range of conditions. The tests evaluate its performance with respect to the number of GPS satellites available, the quality of the GNSS site, the length of the differential vector, the performance of the supplied and third party radios and its performance using Sydnet. Float accuracies of better than 0.3 metres, claimed by the manufacturer are investigated.

The results were very encouraging. Under the right conditions, centimetre accurate results were obtained. The receivers take a similar time to dual frequency receivers to achieve a fixed solution. The licence free radios provided work over only short range and need line of sight conditions. Third party radios, however overcome these restrictions.

Single frequency RTK surveying provides an alternative solution to dual frequency. Provided eight or more GPS satellites are available, centimetre level results are available in similar times to dual frequency receivers. The Promark3 receivers provide a very versatile solution, offering a navigation, GIS, post processed survey and GIS and RTK survey and GIS solutions, all in the one receiver. The weight and price of an on the pole setup is considerably less than for existing dual frequency solutions.

KEYWORDS: single frequency, Promark3, L1, RTK, GNSS

KeelClear – Using RTK to Increase Cargo Carried in Torres Strait

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KeelClear is a concept specifically developed by the Australian licensed pilotage provider Australian Reef Pilots to substantially increase the cargo carried in each ship through Torres Strait. This will be achieved by using highly accurate real-time RTK measurements to measure the vertical motion “squat” of the ship while underway in real time instead of the crude empirical methods used previously. GPS will also be used to survey the critical section to the required accuracy and provide horizontal position information and accurate measurement of ship speed. Squat is a function of the ship’s speed so accurate speed data is needed to control “squat” during the passage through the Strait. The paper also describes the portable GPS/Electronic chart equipment with special software which will be used by the pilot to enable precision navigation in the Virtual Electronic Fairway (35 miles long and 370 metres wide) in the most critical part of the Strait and the special techniques required to make the passage. In the Virtual Electronic Fairway visual clues normally used are not sufficiently accurate. Backup methods are also described in the paper. Such a concept when implemented

will not only change the economies of marine transport through Torres Strait but will also improve safety because “squat” will be known in real time and controlled by adjusting speed.

KEYWORDS: Increase cargo, RTK, real-time squat, precision navigation, Virtual Electronic Fairway,

Session 10C: Receivers and AGPS 1100 - 1240

The “System of Systems” Receiver: an Australian Opportunity?

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In the near future, there could be as many as four global navigation satellite systems (GNSS) and three regional navigation satellite systems (RNSS). This paper examines the visibility of these systems, identifying Australia as a good location to view all of them. The impacts on receiver design are also examined at sub-system level, revealing that a “system of systems” receiver would be far more sophisticated than a basic GPS L1 receiver.

KEYWORDS: Satellite navigation, GPS, Galileo, Glonass, GNSS

Namuru V2, a new open-source FPGA-based GNSS receiver platform; introduction and design details.

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Namuru V2 is a dual frequency field programmable gate array (FPGA) based GNSS receiver research platform. It has been under development since 2004 and is now available as a development kit. Namuru V2 provides a convenient platform for research, development and education in the GNSS realm. The inherent flexibility of FPGA combined with proven hardware, open source reference designs and quality development tools enables rapid prototyping and a quick start up for GNSS researchers.

In this presentation, the Namuru receiver is introduced, details of the circuit board is provided followed by an overview of reference designs for hardware and software. A brief look at some of the research directions being pursued at the University of New South Wales with the Namuru platform is followed by a discussion of possible future directions.

KEYWORDS: GNSS receiver, open-source, RF front-end, correlator.

Software-Defined GNSS Receivers – Why, Where and When?

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By definition, a software-defined radio (SDR) system is a radio communication system which can tune to any frequency band and receive any modulation across a large frequency spectrum by means of programmable hardware which is controlled by software. An SDR performs significant amounts of signal processing in a general purpose computer, or a reconfigurable piece of digital electronics. The goal of this design is to produce a radio that can receive and transmit a new form of radio protocol just by running new software. SDRs have significant utility mainly for the military and cell phone services, both of which must serve a wide variety of changing radio protocols in real time.

In the area of Global Navigation Satellite Systems (GNSSs), Software Receivers (SR) are quite valuable in evaluating potential improvements to extend the capabilities and to increase the robustness of GNSS receivers because of their flexibility. The development of a software receiver contains enormous perspective regarding numerous different areas and applications. First of all, the development establishes an in-depth knowledge of the GNSS signal structure and signal processing algorithms. Second, by definition the software receiver is already prepared to be customized to future changes in the GPS and GLONASS signal structure and more important by the future European positioning system GALILEO and emerging others like the Chinese BEIDOU/Compass. Finally, the possibility of supplying a test-bed to the development of receiver algorithms with focus on multi-path mitigation and/or use is very interesting. In addition, software receivers afford batch data processing options (pos-processing) that are not available in hardware implementations.

This work briefly discusses the approaches of software GPS receiver and GRC plans to integrate it with other wireless system for improved positioning. This includes:

- Brief discussion about software receiver and hardware capabilities at GRC;
- Integration of other potential range systems using the GRC's POINT software.
- Future outlook of GRC's GNSS SRs.

KEYWORDS: SR, SDR, GPS, DSP, GNSS.

A comparison of iterative and integrated time recovery methods for server-side position calculation

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The Mobile Location Center (MLC) is a node in a wireless network that is used to calculate the location of a handset in the network. The location may be required for an emergency situation or for a value-added service such as finding the location of the nearest pizza outlet.

The location may be achieved using Assisted–GPS (A-GPS) in either handset-assisted A-GPS or handset-based A-GPS mode. When using handset-assisted A-GPS, the device may not know the true GPS time when the measurement was made depending on when it last made an accurate time determination. Time recovery is the process of determining the time when a GPS measurement was made in order to produce an accurate location. In this paper, two techniques and their implementation are discussed: iterative time recovery and integrated time recovery. The accuracy and performance of the two methods are investigated using data logged from a GPS receiver. Integrated time recovery is shown to be superior.

KEYWORDS: GPS time recovery, Assisted-GPS.

An open source A-GNSS reference server

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Assisted-GNSS (A-GNSS) devices or clients require a source for providing the assistance data packets that enable positioning in a wide variety of environments, particularly areas of weak signal strength. While there are commercially reference server solutions available, these typically employ proprietary protocols, making the task of a developing a client that supports a range of reference servers more complex. In addition, these protocols and commercial server solutions may not be readily available, particularly to non-commercial research organisations such as universities. This may make research in this area more difficult, and an organisation may need to develop its own reference server and protocol.

This paper introduces an Open Source GNSS Reference Server (OSGRS) and the interface protocol called GRIP (GNSS Reference Interface Protocol) that will help to alleviate these issues. OSGRS and GRIP will support researchers in developing A-GNSS algorithms with minimal investment and it will facilitate commercial operators in getting a reference server up and running quickly to test their A-GNSS client before investing heavily in a commercial service. In this paper, the design and implementation of the OSGRS and GRIP is discussed. The OSGRS is an open source application that provides relevant and specific assistance data for Assisted-GNSS clients. The client may be an Assisted-GPS handset or an application that serves a network of A-GNSS handsets. The OSGRS can be configured to connect to one or more data sources in order to cache it and serve it up to clients on request. The data is provided to the client in a format that is useful for A-GNSS satellite acquisition and handset location. The data source may be a local GNSS receiver or any other type of data streams such as an internet-based GNSS data server.

KEYWORDS: A-GPS, A-GNSS, reference server, GRIP, open source

Session 11A: Aviation Systems/Augmentations 1340-`1540

Operational Deployment of GPS Based Navigation Capabilities into Airline Operations

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Australia is an early adopter of GPS for aviation navigation applications. Qantas has led further local initiatives to enhance this capability by utilising the accuracy of GPS coupled with recent developments to New Generation Flight

Management Computers (FMCs) to derive improvements to safety, flexibility and operational efficiency. The procedures are known as Required Navigation Performance (RNP) which is a Performance Based Navigation standard.

The onboard capabilities of the B737-800 are further enhanced via a differential GPS position provided by a Ground Based Augmentation Systems (GBAS) for precision approach capabilities at Sydney airport. This capability is known as GNSS Landing System (GLS).

The paper and presentation will describe these capabilities and explains some of the benefits currently being realised by Qantas.

KEYWORDS: RNP, GLS, GBAS, FMC, GPS, GNSS, Performance, Navigation

GBAS and GRAS Activities in Australia

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Australian and international aviation uses the global navigation satellite system (GNSS) for navigation. Augmentation of GNSS improves the levels of safety and service. Airservices Australia has introduced a Ground-Based Augmentation System at Sydney Kingsford Smith International Airport, and is currently developing a Ground-based Regional Augmentation System. This presentation provides the current status of Australia's GBAS and GRAS activities.

KEYWORDS: Navigation, augmentation, GBAS, GRAS

Tropospheric Delay Correction in L1-SAIF Augmentation

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L1-SAIF (Submeter-class Augmentation with Integrity Function) signal is one of the navigation signals of QZSS (Quasi-Zenith Satellite System), which provides augmentation function for mobile users in Japan. In this paper, the outline of L1-SAIF signal and the detail of the tropospheric delay correction are presented. L1-SAIF augmentation aims to achieve sub-meter class accuracy and to provide integrity information of the GPS positioning. The structure of L1-SAIF signal is defined to have full compatibility to the SBAS (Satellite Based Augmentation System) L1 signal, and there are some additional messages supporting more sophisticated ionospheric and tropospheric corrections in order to improve correction accuracy. Especially, the tropospheric delay correction via satellites is first attempted in L1-SAIF signal. The tropospheric delay correction message contains the information of the zenith tropospheric delay (ZTD) values at many GEONET (GPS Earth Observation NETwork) stations in Japan. From this message a mobile user can acquire the ZTD value at some neighbouring GPS control points, and estimate the local ZTD value accurately by using a suitable ZTD model function. Several investigations using the actual data observed at many GEONET stations overall Japan have proved that only 3 messages are necessary to achieve the tropospheric delay correction in the whole area of Japan. Some additional features of this message to enhance its usefulness are also presented. The presented method is actually planned to be implemented in the augmentation system using L1-SAIF signal.

KEYWORDS: Quasi-Zenith Satellite System, GPS, Augmentation System, Tropospheric Delay

Sigma Point Kalman Filters for GPS Navigation with Integrity in Aviation

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This paper presents an investigation into the benefits of Sigma Point Kalman Filters (SPKF) applied to GPSOnly estimation problem for highintegrity navigation in aviation applications. Navigation systems used for aircraft approach and landing must meet strict requirements for accuracy, integrity, availability and continuity. Modern GPS is capable of meeting the accuracy and availability requirements, however the integrity and continuity required for approach navigation mandate the use of additional sensors to meet the standards. Modern signal processing techniques can allow greater capability of existing systems, lowering the costs for all users of the system, particularly in the General Aviation sector. This work begins by comparing the raw estimation performance of the sigmapoint filter against established approaches of the Extended Kalman Filter (EKF) and snapshot Leastsquares (LSQ). The fault detection algorithms are then developed for the SPKF filters based on an approach used for highgrade navigation systems. It is hypothesised that since the SPKF can provide a more accurate estimate of the state covariance, then the fault detection scheme, including the integrity protection level, will be more reliable. Comparisons of the faultdetection performance against current techniques are presented. Finally, conclusions are drawn as to the overall benefits of the SPKF approach to navigation integrity. It is demonstrated that whilst the accuracy of the SPKF is not significantly different than the EKF or Least Squares approaches, the covariance estimation and resultant integrity protection level is reliable.

KEYWORDS: GPS, Extended KF, SigmaPoint, Unscented KF, Integrity

L5 Satellite Based Augmentation Systems (SBAS) Protection Level Equations

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The current L1 SBAS protection level equations were agreed upon nearly a decade ago. These equations are provided for L1-only users and are based upon covariance propagation of zero-mean gaussian errors. While this description is reasonably accurate for some nominal error sources, it is not always a good model for actual error characteristics. When departures from the zero-mean gaussian model are significant, the broadcast confidence terms must be inflated in order to provide protection for all user geometries. This leads to a loss of availability even for users who do not observe the satellite with the problematic errors. Since these equations were first adopted, a significant amount of work has gone into accurate characterization of the error sources and the treatment of non-zero and non-gaussian errors.

An additional civil frequency at L5 is being planned and will be incorporated into future SBAS design. The protection level equations for L5 SBAS should updated to explicitly account for non-zero means and non-gaussian behaviour. By broadcasting bias magnitude terms in addition to overbounding sigma terms, non-zero means can be explicitly handled. Smaller sigma values may then be broadcast and so as not to adversely penalize all users. Further, the bias term allows a technique called paired bounding be applied to handle non-gaussian error sources.

The broadcast of a bias term requires additional information be transmitted to the user. However, the additional bandwidth needed may be quite small if the same UDREI index is used to indicate both the sigma and bias term. Flexibility is maintained by occasionally broadcasting a definition table for the bias magnitude terms. Each individual service provider would optimize this table for their own error characteristics. Including a bias magnitude term in the L5 protection level equations will allow for both a simpler certification process for the ground system, and higher availability for the user.

KEYWORDS: SBAS, integrity, protection level, bias

A Simulation Study for a Galileo External Regional Integrity System Configured for the Australasian Region

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The Galileo Global Navigation Satellite System will support External Regional Integrity Systems (ERIS) which will allow regions to provide their own independent integrity services. The objective of this paper is to explore the performance benefits, in terms of integrity, that an ERIS with regional sensor stations can offer with reference to the Galileo global sensor station network. In this research effort, a service region has been defined in the interest of Australasia.

A simulation software tool has been developed in MATLAB at Queensland University of Technology to apply the Galileo global integrity concept in the context of an ERIS. The regional integrity information to be broadcast with the Galileo navigation signals is assumed in this paper to be consistent with the global integrity concept. The metric used to evaluate the performance of each regional network is the broadcast Signal-In-Space Monitoring Accuracy (SISMAU).

Performance of the SISMAU is dependent on the geographic configuration of the regional sensor station locations. This paper will consider the case of an ERIS operating in augmentation to the global sensor station network, and also as a separate stand-alone network. The simulator has been designed to give the expected performance for the nominal 40 sensor station network of the global integrity concept.

KEYWORDS: ERIS, Galileo, Integrity, Augmentation, GNSS.

Session 11B: RTK/Nav Systems 1340 - 1540

On GNSS Ambiguity Acceptance Tests

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Integer carrier phase ambiguity resolution is the key to fast and high precision global navigation satellite system (GNSS) positioning and application. Apart from integer estimation, also acceptance tests are part of the ambiguity resolution process. A popular acceptance test is the so called ratio-test.

In this contribution we study the properties and the underlying concepts of the ratio-test. We discuss some misconceptions of the ratio-test and in particular show that the ratio-test is not a test for testing the correctness of the integer least-squares solution. We also show that the common usage of the ratio-test with a fixed critical value has shortcomings. Instead, the fixed failure rate approach is recommended. This approach, which is part of the more general theory of integer aperture estimation, has the advantage that the times to first fix are reduced, while it is guaranteed that the failure rate does not exceed a user-defined value. Results of the fixed failure-rate ratio-test are illustrated with a number of examples.

KEYWORDS: GNSS, integer ambiguity resolution, ratio test, integer aperture estimation, fixed failure rate.

A New Framework for Server-Based and Thin-Client Real-Time Kinematic Services

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Current Global Navigation Satellite Systems (GNSS) research has proposed new algorithms for multiple frequency ambiguity resolution, software-based receivers for re-configurability, network corrections for utilising redundancy, reverse real-time kinematic (RTK) schemes for quality/accuracy improvement, and a wide range of rover-side applications. This paper aims to integrate these “divide-and-rule” strategies into a new framework and facilitate information and communication technologies (ICT) in order to benefit network infrastructure such as continuously operating reference stations and local/regional GNSS networks. Operational models are proposed for precise point positioning and RTK services including “near real-time” applications, which require an optimal design to balance the computational overhead with communication latency. The proposed framework is designed as a comprehensive, server-based, and thin-client platform. Therefore it provides end-users with “out-of-the-box” services, i.e. end-users obtain extensive GNSS capabilities and high productivity by overcoming the conventional constraints of an expensive set of GNSS receivers, proprietary data formats, user-installed carrier phase processing software (for RTK), incomplete interoperability, limited communication links, etc. The framework also adopts database and web technologies that enable servers to perform data management and spatial analysis, while end-users are able to syndicate data and create their own business models. It is expected that the new framework will be versatile enough to cope with a diverse range of user performance requirements and operational requirements of communications and positioning computations.

KEYWORDS: GNSS, RTK, network, server-based, thin-client.

A Reference Station Placement Scheme in Deployment of Network Real-Time Kinematic Positioning Systems

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Reference station placement is an important problem when deploying a network based real time kinematic system. It directly affects the cost and performance of the system. However, there is lack of a theory or tool to deal with the reference station placement issue. Given a set of potential locations where reference stations can be established and the distribution of users, the reference station placement problem is to select positions among the potential reference station locations such that the total number of reference stations required is minimal subject to the maximum distance constraint between the users to their closest reference station, which is to guarantee the precision of positioning services. This paper presents a graph-theoretic model for the reference station placement problem. Based on the graphtheoretic model, an efficient algorithm for the reference station placement problem is proposed in this paper. The proposed algorithm has been implemented in Matlab and tested by simulation. In addition, an empirical study of the impact of the maximum distance constraint on the number of reference stations is conducted and the results are presented in this paper.

KEYWORDS: Reference stations, network-RTK, placement, graph-theory

Temporary CORS Networks for Land Reconstruction in Aceh, Sumatera

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Using CORS networks for land reconstruction after earthquakes and tsunamis is challenging due to the limited infrastructure remaining after the event. Normally, CORS networks are set up in well established cities or regions with developed infrastructure and utilities. The functionality of a CORS approach is suitable to re–establish more than 10,000 land parcels in Aceh affected by the tsunami, but can this method still be useful with limited infrastructure? Also, can a CORS network feasibly re–establish cadastral land parcel boundaries previously based on bearings and distances using coordinates? This is a very crucial problem as no survey marks exist to re– establish property boundaries. CORS networks can provide an external infrastructure allowing the identification of existing survey marks and the lay out of new and existing parcels for a large number of independent users. Using sophisticated network RTK algorithms, larger inter-receiver distances allow CORS networks to cover large areas with a minimal number of reference stations reducing the cost of operations. Also in equatorial regions, such as Aceh, where ionospheric activity is expected to be higher, a slightly denser array of CORS stations ensures reliable initialization. This paper will investigate utilizing a temporary CORS network approach; that is using some higher order stations as base station monuments, setting up a temporary CORS network over a small region and when operations are completed, packing up the system and moving to an adjacent network of high order monuments which comprise a new temporary CORS networks. Due to logistical considerations during the organization of this project, real– time communications were not used in Aceh and only GPS data was logged in the field. Reference stations logged 24 hours of GPS data and were processed using the free online service from AUSPOS. These coordinates are then used in a post–processed simulation mode using the Leica SpiderNet software.

KEYWORDS: Temporary CORS Networks, Land Reconstruction, AUSPOS, Cadastral Surveying.

A real time multi-channel GPS positioning system architecture

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The design of a system to deliver GPS observables for tracking multiple remotes in real time is discussed. The key objectives of this architecture are to allow the use of multiple small battery operated rovers and to provide low latency position measurements at a fixed central point. The GPS raw data is transmitted via a telemetry system to the central point, then presented to multiple Kalman filters. The selection of a GPS receiver for the application and design of the system architecture to distribute the load to multiple Kalman filters presents some interesting challenges. The focus of this paper is on the components, the architecture used to deliver the demanding real time processing requirements and the benefits of the system.

KEYWORDS: GPS receiver, Raw Data, DGPS, Telemetry

Determining Trip Information Using GPS Data

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With the development of lightweight, high sensitivity Global Position System (GPS) devices, there has been increasing interest in their use as a means to measure people's travel for travel surveys. Data-logging enables a person's position, speed, and heading to be recorded on a second by second basis. GPS devices cannot, however, collect data on the mode or the purpose of travel, both of which are frequently required for transport planning purposes.

In this paper, we describe a set of heuristic rules which we have developed for determining both the mode of travel and the purpose of trips recorded on GPS devices. Our processing utilises comprehensive GIS databases for the areas where the GPS surveys have been conducted. These include information on all public transport routes in the region of interest. The rules we have developed consider the average, maximum and minimum speeds when determining mode of transport. They also use information about the transport network and the availability of bicycles and cars to the survey participants. Data-cleaning procedures are incorporated to eliminate erroneous information obtained from the devices themselves. To determine the purpose of a trip, it is necessary to have full land use records for all locations in the survey area. We also ask people to tell us the addresses of all workplaces, schools, and most frequently used grocery stores visited by household members. Our procedure checks trip origins and destinations against these locations, and also the amount of time spent at the destination. We have applied our procedure to data obtained from a survey in Adelaide. The procedure gives results which are comparable to those obtained using a more burdensome travel diary.

KEYWORDS: Travel surveys, transport, GPS applications, trip analysis

Session 11C: Timing/GNSS Education 1340 – 1540

GPS Time Transfer and Applications to Time and Frequency Standards

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The National Measurement Institute (NMI), incorporating the former CSIRO National Measurement Laboratory, maintains Australia's standards of physical, chemical and biological measurement. To support dissemination of national standards for time of day and for frequency, NMI has developed reliable, high-integrity and remotely-operable GPS-based systems for precise time and frequency transfer. These systems combine an OEM GPS receiver with a PC, and have been developed to meet current and evolving demand for accurate time and frequency in diverse applications around Australia. They can be remotely operated with an integrated rubidium frequency standard to deliver accurate time and frequency to a distant location, or, equivalently, to provide continuous remote calibration of a frequency standard at a client's premises. Systems currently operated by NMI support calibration laboratories (for example, at Defence facilities); time dissemination by 'speaking clock' telephone services; charging and billing integrity for telecommunications providers; and electronic timestamping and notarisation services, through the VANguard project currently under development by the Department of Industry, Tourism and Resources (DITR) within the Australian Federal Government.

KEYWORDS: time transfer; time and frequency standards; traceability

Impacts of GPS-Based Synchronization Degradation on Cellular Networks

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GPS timing receivers have long been relied upon by various communications networks for achieving synchronization among the network nodes. Cellular networks, particularly CDMA cellular networks, actively employ GPS timing receivers

for making their time critical decisions, particularly handoff. Operations and parameters which set the network quality of service (QoS) require that these GPS receivers provide timing solution up to nano-second accuracy. Therefore, GPS timing receiver are required to provide a disturbance free solution. However, as all GPS receivers communicate with GPS satellites over the air interface; these are inevitably vulnerable to RF interference. This interference disturbs the timing receiver's performance, degrading its solution. This paper appreciates this issue, identifies the problems caused and discusses in detail the performance degradations of cellular networks due to instability of timing signals from GPS.

KEYWORDS: GPS timing receiver, Synchronization degradation, CDMA Cellular Network, GSM Cellular Network, UMTS Network.

Positioning Performance Study of the RESSOX System With Hardware-in-the-loop Clock

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A positioning performance analysis of the RESSOX synchronization network for the Japanese Quasi-Zenith Satellite System, QZSS, is presented. A hardware-in the-loop experiment setup has been developed to study concrete effects on positioning when a real space-born OCXO is employed in the atomic clock-less RESSOX architecture. This study focuses on a positioning performance analysis of QZSS used in conjunction with GPS. Particular focus is given to the effects of faulty synchronization on positioning, specifically when, because of unavoidable communication interruptions, the QZSS satellite clock has to function without remote control. Results show that the recently proposed RESSOX phase error compensation method can guarantee enough time accuracy even for communication interruptions of the order of one hour. The relationship between QZSS plus GPS positioning accuracy and QZSS clock quality is discussed.

KEYWORDS: QZSS, GPS, atomic clock, time synchronization.

GPS Carrier Phase and TWSTFT comparisons of clock ensembles at UWA and NMI

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The Frequency Standards and Metrology group at the School of Physics, the University of Western Australia (UWA) and the Time and Frequency group of the National Measurement Institute (NMI) are continuing to develop apparatus to compare clocks across the continental baseline of Australia, using both GPS carrier phase and two way satellite time and frequency transfer (TWSTFT) techniques. Clock ensembles at both sites include hydrogen masers, caesium beam clocks and ultra-stable liquid helium cooled cryogenic sapphire oscillators, and both groups are developing high-performance clocks based on laser-cooled atoms or ions. The aims of this work are to link the two ensembles, to compare high-precision time-transfer techniques and to extend Australia's national timing infrastructure. The link also underpins absolute measurements of optical frequencies at UWA. GPS and TWSTFT systems have completed laboratory testing and been commissioned at both sites, with the first successful TWSTFT session in January 2007. Comparison data will be reported at the Symposium.

KEYWORDS: time transfer; time and frequency standards; carrier phase; two-way satellite time transfer

GPS Time Transfer between ARGN Stations

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The Australian Regional GPS Network (ARGN) is a permanent network of geodetic-quality GPS receivers on geologically stable marks in Australia and its Territories. These sites provide the geodetic framework for Australia's spatial data infrastructure; contribute data to the International GNSS Service (IGS); and provide input for the measurement of earth processes such as crustal dynamics and sea level rise. A number of ARGN stations incorporate caesium-beam clocks or hydrogen masers as the local reference clock. GPS time-transfer techniques have been used to compare several of these ARGN reference clocks, in a collaboration between Geoscience Australia and the National Measurement Institute

(NMI). NMI maintains Australia's standards of measurement, and also operates the SYDN node of the ARGN at its site in Lindfield, Sydney. GPS time-transfer can therefore link high-performance ARGN reference clocks to national standards for time of day and for frequency at NMI Lindfield. The aim of this work is to verify the performance of time-transfer techniques on Australian baselines and to extend Australia's national timing infrastructure.

KEYWORDS: time transfer; time and frequency standards; ARGN

Internet Resources and a Web-based Learning Environment for the Enhancement of Satellite Positioning Teaching and Learning

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e-Education has played a significant role in contemporary teaching and learning in both tertiary education and professional training. The computerbased and web-based learning environments have many acknowledged advantages and are addressed as an essential alternative to the conventional lecture-based face to face education. Both satellite positioning and surveying are core components of the high-education (HE) and the technical and further education (TAFE) programs in geospatial science, RMIT University. With the rapid developments of global navigation satellite system (GNSS) technologies and the ever-increasing exposure of "unscrutinised" and often obsolete information in the internet, the demands for an effective IT-based education system arise to ease the difficulties in student learning process. Currently, there are over 17 GPS and surveying related courses at RMIT University across both HE and TAFE sectors. This contribution outlines a recent action research in T&L project at RMIT. A new mindset system using both IT and web-based technique is introduced. It is anticipated that this system will provide an easy access platform of acquiring categorised, reliable and "pin-point" information and learning resources in a welldesigned and adaptable knowledge structure for different levels of students to help the learners to know, to think and to understand better.

KEYWORDS: GNSS, Surveying, Web-based, e-Education, mind map

Symposium Closing Session