IMPORTANT

Please ensure that you download the abstracts you require and select the presentations you wish to attend prior to attending the symposium as the Book of Abstracts will not be provided as a handout and will only be available to view at the registration desk.

IGNSS2009

Book of Abstracts

For

Oral and Poster Presentations

www.ignss.org

Oral Presentations
Abstracts – Tuesday 1st December, 2009

Session 1: Plenary Session 0900-1015

International Committee on Global Navigation Satellite Systems (ICG): A System of Systems

Sharafat Gadimova
Office for Outer Space Affairs/United Nations Office at Vienna/Austria
Phone: 00431 26060 5479; Fax: 00431 26060 75479; Email: sharafat.gadimova@unvienna.org
Hans Haubold
Office for Outer Space Affairs/United Nations Office at Vienna/Austria
Phone: 00431 26060 4949; Fax: 00431 26060 74949; Email: hans.haubold@unvienna.org

Following the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in 1999, the United Nations General Assembly endorsed the "Vienna Declaration: Space Millennium for Human Development." The Vienna Declaration called for action to improve the efficiency and security of transport, search and rescue, geodesy and other activities by promoting the enhancement of, universal access to and compatibility among, space-based navigation and positioning systems. The International Committee on Global Navigation Satellite Systems (ICG) held its first meeting in Vienna on 1- 2 November 2006 to review and discuss matters relating to global navigation satellite systems (GNSS) and their applications. The ICG work plan includes compatibility and interoperability; enhancement of performance of GNSS services; information dissemination and capacity building; interaction with national and regional authorities and relevant international organizations; and coordination. The ICG members cooperate, as appropriate, on matters of mutual interest related to civil satellite-based positioning, navigation, timing and value-added services. In particular, they cooperate to the maximum extent practicable to maintain radio frequency compatibility in spectrum use between different GNSS systems in accordance with the International Telecommunication Union (ITU) Radio Regulations. The United Nations Office for Outer Space Affairs, as the Executive Secretariat of the ICG develops a wide range of activities focusing on capacity building, specifically, in deploying instruments for the international space weather initiative (ISWI), developing a GNSS education curriculum, and utilizing regional reference frames that support sustainable development, particularly in developing nations. In the coming year, we will assist the process of the establishment of the ICG Information Centres for training and information dissemination on global applications of GNSS and their socio-economic benefits for humanity.

KEYWORDS: UNISPACE III, ISWI, GNSS education curriculum, ICG.

U.S. Space-Based PNT Policy, Programs, and International Cooperation

David A. Turner
United States Department of State/Office of Space & Advanced Technology
Phone: 001-202-663-2392; Fax:001-202-663-3236; TurnerDA@state.gov

This presentation will be the official United States Government update on the status of the GPS and augmentation system programs, current U.S. Space-Based PNT Policy; and international cooperation activities related to global navigation satellite systems (GNSS). Bi-lateral and multi-lateral international activities will be discussed, including the latest activities of the International Committee on GNSS (ICG) of particular interest to the United States.

KEYWORDS: GPS, GNSS, ICG, U.S. Space-Based PNT Policy, international cooperation

---

GLONASS System Status and Progress

Sergey Revnivykh
Central Research Institute of Machine Building
Phone/Fax: (+7 495) 5133936 E: sergey.revnivykh@mcc.rsa.ru

GLONASS system as well as other GNSS, is a global utility to benefit users all over the world to provide economy sustainable development. Considering the GLONASS as an element of the critical state infrastructure to provide the national security and economy growth the Russian authority continuously supports the GLONASS Federal Program implementation. According to the GLONASS Program the full

constellation of 24 Glonass-M satellites will be deployed in 2010 with four triple launches by the end of 2010. Program also envisages the constellation sustainment at this level in future and system modernization based on new satellite Glonass-K with improved performance and new CDMA signals. Encouraging the GNSS compatibility and interoperability is a priority in the international cooperation to make navigation service more beneficial for the world user community.

KEYWORDS: GLONASS, navigation, infrastructure, modernization, interoperability

COMPASS Satellite Navigation System Development

Yuanxi Yang
China National Administration of GNSSS and Applications, Bejijing, CHINA

NO ABSTRACT PROVIDED

QZSS Status and Joint Application's Demonstration in Asia Oceania Region

Satoshi Kogure
Quasi-Zenith Satellite System project team, Japan Aerospace Exploration Agency, JAPAN
Phone: 029-868-5511, FAX: 029-868-5975, and E-mail address: kogure.satoshi@jaxa.jp
Koji Terada
Quasi-Zenith Satellite System project team, Japan Aerospace Exploration Agency, JAPAN
Phone: 029-868-5507, FAX: 029-868-5975, and E-mail address: terada.koji@jaxa.jp

Quasi-Zenith Satellite System, QZSS, is the planned regional space based Positioning Navigation and Timing (PNT) system by Japanese government. It will be able to enhance current and future modernized GPS capability widely in Asia and Oceania region, especially in urban canyon which is the challenging environment for satellite PNT services in East Asian countries surrounding Japan. The first satellite of the QZSS will be launched in summer of 2010, after evaluating the results of technical and applications demonstration, second and third satellite will be launched for full system demonstration. This paper introduces the concept of the QZSS, the developing status and suggests potential role in the new GNSS era which multi-GNSS systems are being operated collaboratively. The QZSS can be a very important infrastructure which augments not only GPS but also other GNSS systems and contribute to the sustainable development in the region. Considering the unique geographical property which all planned GNSS systems can be observed in Asia Pacific region, the future joint collaborations, called as "Multi-GNSS technology demonstration in Asia Oceania region" among countries in Asia Oceania and GNSS providers is proposed in this paper.

KEYWORDS: QZSS, GPS, Multi-GNSS

An update on the status of Galileo

Presented by Professor Chris Rizos
University of New South Wales

NO ABSTRACT PROVIDED

On the acquisition sensitivity of GNSS signal

WITHDRAWN

A Sensitivity Enhancement Method for Weak GPS signals

Ji-Hee Park
Department of Information and communication Engineering
Chungnam National University/Korea
Tel:+82-42-821-7607, Fax: +82-42-824-6807, applearoma@naver.com
Hyun-Ja Im
Department of Information and communication Engineering
Chungnam National University, Korea
Tel:+82-42-821-7607, Fax: +82-42-824-6807, rrrr7@cnu.ac.kr
Tae-Kyung Sung
Division of Electric and Computer Engineering
Chungnam National University, Korea
Tel:+82-42-821-5660, Fax: +82-42-824-6807, tksaint@cnu.ac.kr

In order to acquire weak GPS signals, long integration techniques for sensitivity enhancement are commonly used in AGPS receivers. In coherent integration, integration loss is determined by frequency residual, whereas by SNR in non-coherent integration. To minimize the integration loss, coherent/non-coherent hybrid scheme should be employed. After the SNR is improved by coherent integration, non-coherent integration is subsequently done in the hybrid method. As the coherent integration time increases in the hybrid method, the integration gain becomes larger if the frequency error is sufficiently small.

This paper presents a hybrid integration method using frequency residual estimation to maximize integration gain. FFT is used in the frequency residual estimation, and the optimal size of FFT is proposed for L1 C/A GPS signals. Experimental results show that the frequency estimation error is less than 7.3Hz with signal power of -149dBm.

KEYWORDS: Assist-GPS, sensitivity enhancement, FFT, residual frequency, coherent/non-coherent integration

---

Post Detection Integration Strategies for GPS L2C Signal Acquisition

Sana Ullah Qaisar
School of Surveying & Spatial Information Systems, University of New South Wales, Australia
Phone: +61 2 9385 4208, Fax No: +61 2 9313 7493, Email: s.qaisar@student.unsw.edu.au
Tung Hai Ta
Electronics Department, Politecnico di Torino, Italy
Phone: +39 011 2276414, Fax: +39 011 2276 299, Email: hai.ta@polito.it
Andrew G. Dempster
School of Surveying & Spatial Information Systems, University of New South Wales, Australia
Phone: +61 2 9385 6890 & Fax No: +61 2 9313 7493, Email: a.dempster@unsw.edu.au
Fabio Dovis
Electronics Department, Politecnico di Torino, Italy
Phone: +39 011 2276414, Fax: +39 011 2276 299, Email: fabio.dovis@polito.it

L2C is the second civilian signal introduced on the modernized block of Global Positioning System (GPS) satellites. The two PN sequences employed in L2C, named CM and CL, have periods of 20 milliseconds and 1.5 seconds respectively. With longer PN codes, the search space for L2C acquisition becomes huge. In this paper, the Generalized Post Detection Integration (GPDI) technique is introduced to enhance the L2C acquisition sensitivity. The GPDI combines available correlator-output samples in several ways to maximize the processing gain. Monte Carlo simulations verify a GPDI gain of approximately 0.7 dB, over non-coherent techniques, in the L2C detection probability. Time-domain partial correlations are investigated for efficient acquisition of L2C signal. It is identified that a coherent integration interval of 1 millisecond with 20 correlator-output samples combined through GPDI is good enough to detect the L2C signal with C/N_0 level of 33.82 dB-Hz or above (covering outdoor range), making it 20 times faster than conventional coherent integration over

CM code period. On the other hand, for signals as weak as 17.55 dB-Hz (nominal indoor level), it is shown that coherent integration interval of 20 milliseconds with 75 correlator-output samples combined through GPDI is a better acquisition strategy than coherent integration with pilot code.

KEYWORDS: Acquisition sensitivity, coherent integration, mean acquisition time, partial correlation, post detection integration.

FPGA-based GNSS "Search Engine" using Parallel Techniques in the Time-Domain

Shahzad A Malik
School of Surveying and Spatial Information Systems
University of New South Wales, NSW 2052, Australia
Tel: +61 (2) 93854190, Fax: +61 (2) 93137493 E: malik@unsw.edu.au
Nagaraj C Shivaramaiah
School of Surveying and Spatial Information Systems
University of New South Wales, NSW 2052, Australia
Tel: +61 (2) 93854185, Fax: +61 (2) 93137493 E: nagaraj@unsw.edu.au
Andrew G Dempster
School of Surveying and Spatial Information Systems
University of New South Wales, NSW 2052, Australia
Tel: +61 (2) 93856890, Fax: +61 (2) 93137493 E: a.dempster@unsw.edu.au

This paper describes an FPGA-based GNSS "Search Engine" architecture that is capable of acquiring both GPS and Galileo signals. The various GPS and Galileo signals have different frequencies and code structures which requires a design that can incorporate all of these differences. The proposed design consists of a number of multi-tap channels that are independently configurable to be searching for any GNSS signal. It was tested with the GPS L1, Galileo E1 and GPS L2C signals to compare its performance with different signals. The results showed that an increase in the number of channels and/or taps decreases the acquisition time. The best acquisition times were achieved when the signals of more than one satellite were being searched for simultaneously. On the other hand, the worst acquisition times were observed when only one signal was being searched for. Furthermore, on a chip-by-chip basis, an architecture with less channels/taps benefits shorter codes whereas an architecture with more channels/taps benefits longer codes.

KEYWORDS: Search Engine, FPGA, GNSS, Acquisition.

Significance of Cell Correlations in Matched Filter GPS Acquisition Engines

Tung Hai Ta
Electronics Department, Politecnico di Torino, Italy
Phone: +39 011 2276414, Fax: +39 011 2276 299, Email: hai.ta@polito.it
Nagaraj C Shivaramaiah
Surveying & SIS, University of New South Wales, Australia
Phone: +61 2 9385 4185, Fax: +61 2 9313 7493, Email: nagaraj@unsw.edu.au
Andrew G Dempster
Surveying & SIS, University of New South Wales, Australia
Phone: +61 2 9385 6890, Fax: +61 2 9313 7493, Email: a.dempster@unsw.edu.au

Due to their attractive acquisition time performance, matched filter correlators are widely used in GPS signal acquisition engines. Existing methods to evaluate the GPS signal acquisition engine performance parameters viz. probability of detection and mean acquisition time are based on the assumption that the detection among the neighbouring test cells is independent. However in a matched filter correlator, depending on the spacing between the test cells, there could exist strong correlations among the consecutive outputs which affect these performance parameters. Taking into account these correlations in the analysis does not make the acquisition faster, but make the performance parameters more accurate. These improvements then contribute to the quality of the threshold setting process, which is very important in receiver design. This paper provides a detailed analysis of the significance of the cell correlations in the matched filter correlators used in GPS L1 C/A signal acquisition. Justifying the theoretical analysis with Monte Carlo simulations, it is shown that the error caused by omitting the cell correlations in estimating the probability of detection and the acquisition threshold will be around 6-7% at the signal strengths of 32-33 dB-Hz, even for the search step size of 0.5 chip. The trend also shows that the error worsens for lower signal strengths.

KEYWORDS: GPS L1 C/A, serial acquisition, matched-filter, cell-correlation, mean acquisition time.

Range and Range-Rate Measurements Using DSRC: Facts and Challenges

Nima Alam
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 4174, Fax: +61 2 9313 7493, nima.alam@student.unsw.edu.au
Asghar Tabatabaei Balaei
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 4202, Fax: +61 2 9313 7493, asghart@unsw.edu.au
Andrew G Dempster
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 6890, Fax: +61 2 9313 7493, a.dempster@unsw.edu.au

Vehicular network with communication among vehicles and between roadside units and vehicles is a recently emerged field of challenge for researchers. Dedicated Short Range Communication (DSRC) is the nominated communication channel specifically designed for this network. Using DSRC, besides sharing information among vehicles, the distances between the nodes of the network can also be estimated for their positioning solutions. In the literature, many algorithms and strategies are presented for radio ranging with less emphasis on constraints and difficulties of distance estimation in vehicular networks. In this paper, different methods of radio ranging like Received Signal Strength (RSS), Time of Arrival (TOA), and Time Difference of Arrival (TDOA) for distance estimation are introduced with emphasis on some important aspects of these methods which should be taken into account by researchers and engineers. Considering some important concerns, related to ranging and positioning with radio signals, some special aspects of each method are presented and discussed. Finally, with regard to the limitations imposed by vehicular networks and DSRC, the preferred ranging approach is proposed.

KEYWORDS: ITS, DSRC, TOA, RSS, Doppler shift

Integrated wireless solutions for precise GNSS positioning services

Yanming Feng, Mark Looi and Jared Ring
Queensland University of Technology, Australia
07 3138 1926/0731381214, y.feng@qut.edu.au

Matt Higgins
Queensland Department of Environment, Resources and Mines
Matt.higgins@derm.qld.gov.au

Today, many different communication bearers exist, each one optimised for a specific set of applications. Some cannot be used for mobile applications, some only at low speeds, while others at high speed but at low bandwidths, or can only be broadcast, etc. For GNSS positioning services, it is clear that one perfect communication technology does not exist.

This presentation provides an overview of some important communication bearers, such as Land multipoint distribution services (LMDS), WiMAX, 2G/3G cellular technology, Dedicated Short-Range communications (DSRC), millimetre media (MM) radio technology,. The paper will also review the standards of these different radio technologies, spectrum issues, and advantages, advantages and disadvantages for possible GNSS positioning applications.

The paper also identifies the increasing need for an integrated solution that comprises a few most important communication bearers and hides its heterogeneity. This integrated solution does not exist currently, but can refer to the efforts by International Standard Organization (ISO) Working Group 16 (ISO TC204 WG16), which is working on the specifications for Continuous Air-Interface for Long and Medium (CALM), currently the most important development for integrated communication solutions, with draft standards available for the majority of the core functions. CALM is to provide a Standardized set of air interface protocols and parameters for medium and long range, high speed communication using one or more of several media, with multipoint and networking protocols within each media, and upper layer protocols to enable transfer between media. This service includes the communication modes of not only between Infrastructure and Vehicle (V2I, I2V), but also Vehicle and Vehicle (V2V). In V2I and I2V communication, multipoint communication parameters are automatically negotiated and subsequent communication may be initiated by either roadside or vehicle. The V2V communication mode provides a low latency peer-peer network with the capability to carry safety related data such as collision avoidance, and other vehicle-vehicle services such as ad-hoc

networks linking multiple vehicles. From GNSS positioning application perspective, while vehicles represent any mobile users, the infrastructure implies the fixed differential GNSS base stations.

Key words: 2G/3G cellular technology, DSRC, GNSS, CALM, integrated wireless solution

Geometric and error analysis for 3D map-matching

Aire Olesk
School of Surveying & Spatial Information Systems,
University of New South Wales, NSW 2052, Australia
Phone: +61 2 9385 4185 Fax: +61 2 9313 7493 Email: Aire.Olesk@student.unsw.edu.au

Jinling Wang
School of Surveying & Spatial Information Systems,
University of New South Wales, NSW 2052, Australia
Phone: +61 2 9385 4203 Fax: +61 2 9313 7493 Email: jinling.wang@unsw.edu.au

Three dimensional maps have recently made their way into mass production and are becoming a common feature in in-car navigation systems and as well as in mobile phones. 3D and photorealistic navigation provides a variety of new applications through photorealistic and textured 3D city models and navigable maps. Three-dimensional navigation is a relatively new concept for land vehicle navigation and requires a well defined digital model of the navigable area. For map-matching purposes, monocular vision can be used for image capture, feature extraction and description. Images captured with monocular vision can be used in real-time for matching 2D images with the photorealistic 3D model. Detecting, extracting and describing features for 3D matching purposes will aid INS and also GNSS signal tracking, and could provide a seamless navigation solution for dense urban areas.

Most of the map-matching technologies used for 2D maps are not fully capable of efficient and reliable navigation support for intelligent transport systems (ITS) applications needed in dense urban areas. Therefore vision and proximity sensors such as cameras and lasers are introduced to fill the gap as dense urban areas cause serious problems for algorithms to meet stringent positioning requirements in terms of integrity and accuracy. Especially in critical junctions, it is crucial to identify the main limitations of 3D map-matching and feature detection algorithms and to carry out further experiments to address their shortcomings.

The aim of this work is to outline the error sources and geometric constraints of 3D map matching based on the reconstructed 3D model, fusion of images and INS/GPS data. The objectives of this paper are: a) to highlight the potential map-matching algorithms for establishing integrity with minimised errors in map-matching solutions, and b) to integrate positioning data with digital road network data so that vehicles can have accurate positioning solutions across different environments, especially in urban canyons. Map-matching characteristics are described through discussions on geometric limitations, and a variety of error sources and their propagation. To address the positioning challenge of under urban environments, discussions on 3D map-matching algorithms, the quality of the visual measurements, the technical details concerning 3D maps and the use of measurements made by integrating GPS/INS and vision for positioning are presented.

KEYWORDS: 3D, map matching, Vision, photogrammetry, GPS, INS

The Use of GNSS Data for a Fatigue and Speed Monitoring System

Ken Foong
Engineer, Graduate Program, Roads and Traffic Authority, New South Wales
101 Miller St, North Sydney, NSW 2060, Australia

Shaun Talko
Senior Engineer, Development Services, Transport Certification Australia Ltd.
Level 12, 535 Bourke St, Melbourne, VIC 3000, Australia

Dr Charles A Karl
General Manager, Development Services, Transport Certification Australia Ltd.
Level 12, 535 Bourke St, Melbourne, VIC 3000, Australia

Corresponding author:
Shaun Talko, shaunt@tca.gov.au, tel: (03) 8601 4691

Presented by Mr Peter Girgis, Transport Certification Australia, Melbourne, AUSTRALIA

This paper will provide an insight into the use of GNSS data for a regulatory heavy vehicle driver fatigue and speed monitoring system in Australia. The paper will follow on an earlier paper and presentation to the IGNSS Symposium in 2004 on the Intelligent Access Program (IAP). Since that time, the governments have established Transport Certification Australia (TCA) to implement the program. The IAP is now operational in Queensland, New South Wales and Victoria and IAP is provided by four certified Service Providers from industry. A paper reporting on the progress of IAP is also being submitted to the Symposium.

In September 2008, legislation for heavy vehicle driver fatigue management was introduced in Australia. TCA is currently responsible for the development of the supporting specification to enable this legislation. The paper will introduce the requirements of a driver fatigue and speed monitoring system, discuss the challenges in conversion from the current paper based system to an electronic system and report on the use of GNSS data and its quality parameters in the specification being developed by TCA to meet the current legislation.

The paper will also touch upon some of the support systems which may be required to ensure governments' confidence in the quality and accuracy of GNSS, fatigue and speed data.

Reference:

Li, F. and Karl, C.A., 2009 "*The use of GNSS data in a regulatory telematics application*". IGNSS Symposium, Surfer's Paradise, December (abstract).

Petridis, P. and Koniditsiotis, C., 2004 "*Intelligent Access Program (IAP)*". IGNSS Symposium, Sydney, December.

Readers Arrangement and DOP of TDOA Based Position Tracking System for Logistic Vehicles

Hee Won Kang (1)
Department of Electronics Engineering, Chungnam National University, South Korea
+82-42-821-7709, +82-42-823-5436, kaki127@cnu.ac.kr
Dong-Hwan Hwang (2)
School of Electrical and Computer Engineering, Chungnam National University, South Korea
+82-42-821-5670, +82-42-823-5436, dhhwang@cnu.ac.kr

When position is determined by radio navigation systems, the geometric arrangement of readers affects the position errors that is represented as DOP(Dilution of Position). This paper presents a relationship between readers arrangement and DOP of TDOA based position tracking system for the logistic vehicles. A reader arrangement which guarantees minimum of the DOP value is presented by using the relationship. An arrangement of readers for positioning tracking system of a logistic vehicle is configured and the effectiveness and usefulness of the relationship are shown through simulation and real-time experiment.

KEYWORDS: TDOA DOP, Readers Arrangement, Radio Navigation

Positioning at the 'mm' level: Challenges for a Future Spatial Reference System

Michael Moore
NGRS/Geoscience Australia
Ph: +61 2 6249 9052 & FAX: +61 2 62499929 michael.moore@ga.gov.au

Australia's current datum, the Geocentric Datum of Australia, 1994 (GDA 94) is able to meet today's requirement of positioning at the several cm level. However positioning technology has been improving by an order of magnitude every decade, while the number of users has also been increasing by an order of magnitude.

Users of high precision positioning services are now beginning to approach a level where positioning is being seen more as a utility. That is to say, there is now an expectation to have positioning available in real time, with a large base of users who are not professional practitioners, and a high level of availability.

This presentation will give an overview of the activities undertaken by NGRS to provide a coordinate framework that is accurate, reliable and accessible. In particular, we will cover the activities being carried out to support the refinement of the International Terrestrial Reference Frame (ITRF), the provision of routine analysis products, as well as an overview of Geoscience Australia's role in supporting real-time systems in Australia.

KEYWORDS: GDA94, ITRF, Reference Frames, NCRIS

A centralised metadata management system for GNSS networks

Manoj Deo
Geoscience Australia
Phone +61 2 62499031 Fax +61 2 6249 9929

A centralised metadata store is fundamental for the efficient management and operation of GNSS networks. The metadata store should be accessible, reliable, accurate, and form a single-point-of-truth containing metadata for hundreds of stations. This paper presents an outline of Geoscience Australia's Oracle based centralised metadata management system for maintaining station metadata for GNSS networks operating at state-wide, to national and regional levels. The benefits of the system in supporting several key GNSS operations such as monitoring data quality, generating IGS formatted station log files, validating RINEX header files and generating summary files in customary formats is demonstrated. This paper also discusses the system architecture for maintaining station metadata through manual data entry by Geoscience Australia operators and authorised state users responsible for designated stations or networks. Processes for automatic metadata maintenance for core IGS stations used in routine data analysis are also summarised.

KEYWORDS: GNSS networks, metadata management.

A software receiver adaptive phase lock loop method

Marco Rao
Università di Palermo/DIEET/ITALY
marco_rao@dieet.unipa.it
Letizia Lo Presti
Politecnico di Torino/DELEN/ITALY
letizia.lopresti@polito.it
Maurizio Fantino
ISMB/NAVSAS/ITALY
maurizio.fantino@ismb.it
Giovanni Garbo
Università di Palermo/DIEET/ITALY
giovanni_garbo@dieet.unipa.it

Since the early 90's, software defined radio (SDR) technology has gained growing attention in the telecommunication community. The reason of such a great popularity has to be found in the flexibility of this technology, that allows to emulate a wide range of radio devices with the same hardware.

In the field of satellite navigation, a SDR Global Navigation Satellite System (GNSS) receiver is a useful tool in a research environment, because it allows to gain access to every single block of the receiver, to remove it and to substitute it with a new block.

In this paper we will consider one of the most important functional blocks of a GNSS receiver, the phase lock loop (PLL), and in particular we will show a way to make it adaptive with respect to the input signal.
Our goal is to show a criterion upon which the system can rely to vary the PLL bandwidth. A wider bandwidth system is characterized by a wider pull-in range, which is useful whenever the frequency lock loop (FLL) before the PLL does not manage to provide the tracking loop with a good carrier frequency estimation. Moreover, a wider bandwidth makes the filter more reactive, so that the initial error can be recovered in a short time.

Wide bandwidth becomes a disadvantage when the PLL estimated frequency gets closer to the actual carrier frequency. When the estimation error gets smaller, it is better to have a system with a narrower bandwidth, in order to cut off a larger amount of noise and to obtain a smaller variance of the estimation error.

The method we will show relies upon the discriminator output covariance to make its bandwidth wider or narrower. The result is a filter capable to recover big initial error and to track the actual frequency minimizing the error noise variance.

KEYWORDS: software receiver, phase lock loop, adaptive filter, loop filter.

Analysis of DLL Tracking Performance for GNSS Signals: A Theoretical Framework

Nagaraj C Shivaramaiah
School of Surveying and Spatial Information Systems, UNSW, Australia
+61293854185(P), +61293137493(F), nagaraj@unsw.edu.au
Andrew G Dempster
School of Surveying and Spatial Information Systems, UNSW, Australia
+61293856890(P), +61293137493(F), a.dempster@unsw.edu.au

With the development and potential usage of new satellite navigation signal structures, it is imperative that the theoretical performance analysis methods should also be broadened to cover these new signal structures. From the signal's perspective, most of the new signals differ in their modulation scheme, the majority belong to the Binary-Offset-Carrier (BOC) family of modulation. Due to this, the ranging performance mainly depends on the Delay-Locked-Loop (DLL) performance used for the code tracking. Unlike the Phase-Locked-Loop (PLL) used for carrier tracking which has periodic phase detector characteristics, the characteristics of the phase detector used for DLL (discriminator) is locally aperiodic and the non-linearity and aperiodic nature of the phase detector is a function of the code modulation scheme. The Fokker-Planck equations of the DLL phase error renewal process yield different solutions due to the phase detector characteristics i.e. the different signal structures. This paper revisits the theory of statistical characterization of the DLL performance parameters and analyzes the performance different BOC type signals that are currently in use.

KEYWORDS: DLL, tracking performance, GNSS signals, BOC modulation

A New Design Method of DLL using C/N0

Deok Won Lim
Department of Electronics Engineering, Chungnam National University, Korea
+82-42-825-3991, +82-42-823-4494, hero0710@cslab.cnu.ac.kr
Chansik Park
Department of Electronics Engineering, Chungbuk National University, Korea
+82-43-261-3259, +82-43-268-2386, chansp@chungbuk.ac.kr
Sang Jeong Lee
Department of Electronics Engineering, Chungnam National University, Korea
+82-42-825-3991, +82-42-823-4494, eesjl@cslab.cnu.ac.kr

In a GPS receiver, a DLL (Delay Locked Loop) is being used for the code tracking, and the DLL consists of a discriminator, a loop filter and a NCO (Numerical Controlled Oscillator). The discriminator similar to a phase detector estimates the code phase difference between input signal and replica signal, the role of the loop filter is the same as the compensator and the NCO as a plant generates the source clock of the replica signal.

Among these, the discriminator estimates the code phase difference with the discriminator's function, which is changed by signal power and noise power. Although the function could not be affected by the signal power by normalization, the slope of the function depends on the noise power as ever. If the slope of the function is lowered by the noise power, loop gain of the DLL would be also lowered and it eventually affects on the tracking accuracy of the DLL.

This paper proposes new design method of a DLL which provides more accurate tracking accuracy than a traditional DLL. The proposed method can compensate the lowered slope of the function by estimating the C/N0. Finally, the experimental results are also given and the feasibility of the proposed DLL is confirmed.

KEYWORDS: DLL, Discriminator, C/N0

Theoretical Noise Performance of Code Tracking with BOC-Gated-PRN Discriminator

Jinghui Wu
School of Surveying and Spatial Information Systems,
University of New South Wales, Sydney 2052, Australia
jinghui.wu@student.unsw.edu

Andrew G. Dempster
School of Surveying and Spatial Information Systems,
University of New South Wales, Sydney 2052, Australia
a.dempster@unsw.edu.au Ph: +61 2 9385 6890 Fax: +61 2 9313 7493

Code tracking performance is a critical property of Global Navigation Satellite Systems (GNSS) receivers and other ranging systems. This paper presents analytical expressions for the evaluation of the noise performance of code tracking with the implementation of a BOC-Gated-PRN (or simply BOC-GPRN) delay-locked loop (DLL) discriminator. The unified Cross Spectral Density Function (CSDF) describing the correlation of BOC-GPRN with arbitrary gating window is also derived. The given code jitter expression considers the output signal-to-noise ratio with arbitrary signal spectrum, arbitrary gating window and Gaussian noise. The design is assessed for MBOC(6,1,1/11). Simulation has been used to verify the derivation. Results show that the theoretical expression for the noise jitter of the non-coherent code tracking with BOC-GPRN discriminator can well describe the effect of Gaussian noise with small error and without considering other sources of interference.

KEYWORDS: Jitter, Delay Lock Loop, Discriminator, Gating, BOC

On the evaluation of multipath-induced bias error in GPS early-late envelope discriminators

Suleyman S. Demirsoy
Altera Europe Ltd.
Holmers Farm Way, High Wycombe, HP12 4XF, United Kingdom
sdemirsoy@ieee.org

Andrew G. Dempster
School of Surveying and Spatial Information Systems,
University of New South Wales, Australia
a.dempster@unsw.edu.au

Multipath signals in GPS receivers lead to undesirable tracking errors and inaccurate ranging information. In this paper, the bias error due to the multipath signals on the early-late discriminators is analytically derived. The derivations are compared against the existing estimates for two different scenarios with low and high front-end bandwidth.

KEYWORDS: Multipath

fLogger - A WiFi and GSM information logging system for positioning purposes

Binghao Li
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854189, Fax 93137493 Email: binghao.li@unsw.edu.au
Jiahuang Zhang
School of Computer Science and Engineering, UNSW, Australia
Email: z3207792@student.unsw.edu.au
Chris Rizos
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854205, Fax 93137493 Email: c.rizos@unsw.edu.au

The use of existing wireless communications infrastructure for positioning to meet the increasing requirement of the location based services is now a viable option. In recent years, the so-called signal “fingerprinting” technique based on WiFi and cellular phone information has been widely accepted as an effective method for indoor and urban positioning (it can also be used as an alternative when the user device does not incorporate a GPS receiver). Fingerprinting has two phases: training and positioning. During the training phase the received signal information across the area of interest is collected. This information includes MAC address (for WiFi), Cell ID (for cellular phone network), signal strength (for all), the position where the information is collected, etc. The software ‘fLogger’ was developed to collect WiFi and cellular station information in as an efficient manner as possible. There are two types of environment: indoors and outdoors. In outdoor situations GPS is used to provide the position (and time) information. Indoors a map of the building is utilised and position based on pixel coordinates is used. The data collected is analysed and stored in a database for the subsequent positioning phase, or other application.

KEYWORDS: WiFi, GSM, fingerprint, positioning

Sensitivity Enhancement in WiBro Geolocation System

Ji-won Park (1)
Department of Information and Communication Engineering
Chungnam National University, Korea
Tel: +82-42-821-7607, Fax: +82-42-824-6807, jwjsjk@gmail.com

Seung-Hun Song (2)
Department of Information and Communication Engineering
Chungnam National University, Korea
Tel: +82-42-821-7607, Fax: +82-42-824-6807, lsphoenix4th@gmail.com

Tae-Kyung Sung (3)
Division of Electric and Computer Engineering
Chungnam National University, Korea
Tel: +82-42-821-5660, Fax: +82-42-824-6807, tksaint@cnu.ac.kr

WiBro, a Korean mobile WiMAX, is a wireless broadband internet service based on IEEE (Institute of Electrical and Electronics Engineering) 802.16e. In WiBro system, preamble symbols are broadcasted by RAS at the beginning of each frame. Using the correlator, TDoA (Time Difference of Arrival) measurements can be obtained. For two-dimensional positioning, more than two RASs need to be detected. Since WiBro is a cell based system, neighboring RASs are hard to detect. To increase the sensitivity of the receiver and detect the preamble from the neighboring RAS, coherent integration is used. However, due to residual Doppler frequency in the carrier, length of the integration is limited. This paper takes account of the WiBro channel model based on ITU-R m.1225 and carries out hybrid integration with Doppler estimation. When the residual frequency is estimated within 1 Hz accuracy, simulation result shows that it is able to detect more than two preambles in 35% area of the cell. This limitation is due to interference caused by Near-Far problem. Detection area can be extended applying interference cancellation methods.

KEYWORDS: WiBro, hybrid integration, residual Doppler estimation

Wi-Fi + GPS for urban canyon positioning

Thomas GALLAGHER
School of Surveying & Spatial Information Systems,
University of New South Wales, Sydney, Australia
Phone: +61 (2) 9385 4189 Fax: +61 (2) 9313 7493 Email: gallagth@gmail.com
Yong Khing TAN
School of Surveying & Spatial Information Systems,
University of New South Wales, Sydney, Australia
Phone: +61 (2) 9385 4208 Fax: +61 (2) 9313 7493 Email: yk.tan@student.unsw.edu.au
Binghao LI
School of Surveying & Spatial Information Systems, University of New South Wales,
Sydney, Australia
Phone: +61 (2) 9385 4189 Fax: +61 (2) 9313 7493 Email: binghao.li@unsw.edu.au
Andrew G DEMPSTER
School of Surveying & Spatial Information Systems,
University of New South Wales, Sydney, Australia
Phone: +61 (2) 9385 6890 Fax: +61 (2) 9313 7493 Email: a.dempster@unsw.edu.au

GPS is now widely accepted as a reliable, available and accurate source of positioning, able to operate across the globe. However, it generally requires at least four satellites to be in view of the receiver, in order to resolve the three co-ordinates of the receiver, and the local receiver time offset. In indoor environments or urban canyons, this requirement can often not be achieved, as walls or tall buildings block the signals emitted by the satellites. Developing alternative positioning systems in such environments has attracted a lot of research in the past few years. In this context, Wi-Fi based positioning systems have emerged as being accurate enough for most users and most importantly because they don't require any additional hardware or infrastructure. However, such systems fail to reach the same level of accuracy as GPS. The ultimate goal of ubiquitous positioning would be to combine these two technologies so that an accurate position can be delivered, even in poor GPS environments. This paper will examine a method to combine a Wi-Fi obtained position with the output of a two satellite positioning algorithm developed at the University of New South Wales. It will first explore the performances that can be expected from both systems, and then show that better results are obtained when combining both. Tests were conducted using data collected from the CBD area of Sydney and a rooftop mounted GPS antenna in UNSW.

KEYWORDS: Wi-Fi positioning, fewer than 4 satellites, indoor positioning, urban canyon positioning, GPS-Wi-Fi integration

---

Interference cancellation in Geo-location Using WiBro

Seung-Hun Song
Department of information communications Engineering / Chung-nam National University/South Korea
42-82-824-6807, lsphoenix4th@gmail.com
Ji-won Park
Department of information communications Engineering / Chung-nam National University/South Korea
42-82-824-6807, jwjsjk@gmail.com
Tae-Kyung Sung
Division of Electrical Engineering and information and Communication Engineering /Chung-nam National University/South Korea
42-82-821-5660, tksaint@cnu.ac.kr

In Korea, mobile WiMAX called WiBro (Wireless Broadband) is currently in commercial service. At every 5ms, each RAS (Radio Access Station) of WiBro network transmits its own preamble signal that is orthogonal to others. Therefore, the mobile PSS (Portable Subscriber Station) is able to distinguish the RAS by preamble detection and then easily obtain TDOA (Time difference of Arrival) measurements. However, since the WiBro network has a cellular structure, insufficient number of RAS signals is occasionally detected. In order to get user position using TDOA, long-integration and interference cancellation techniques for sensitivity enhancement should be employed. This paper presents hybrid integration and interference cancellation scheme for WiBro network. The performances of hybrid integration and interference cancellation method are analyzed by computer simulation.

KEYWORDS: WiBro, geolocation, interference cancellation, hybrid integration

Trials of commercial Wi-Fi positioning systems for indoor and urban canyons

Thomas GALLAGHER
School of Surveying & Spatial Information Systems,
University of New South Wales,Sydney, Australia
Phone: +61 (2) 9385 4189 Fax: +61 (2) 9313 7493 Email: gallagth@gmail.com
Binghao LI
School of Surveying & Spatial Information Systems,
University of New South Wales,Sydney, Australia
Phone: +61 (2) 9385 4189 Fax: +61 (2) 9313 7493 Email: binghao.li@unsw.edu.au
Allison KEALY
Department of Geomatics,
The University of Melbourne,Melbourne, Australia
Phone: +61 (3) 8344 6804 Fax: +61 (3) 9347 2916 Email: akealy@unimelb.edu.au
Andrew G DEMPSTER
School of Surveying & Spatial Information Systems,
University of New South Wales,Sydney, Australia
Phone: +61 (2) 9385 6890 Fax: +61 (2) 9313 7493 Email: a.dempster@unsw.edu.au

It is now widely accepted that GPS meets, under ideal operational conditions, all attributes of a ubiquitous positioning system, i.e. accuracy, reliability and availability. However, its performance quickly deteriorates in certain environments, such as indoors or in urban canyons. In such environments, the demand for location based services (LBS) is growing exponentially, mainly because of the rapid expansion of the smart-phone market. In this context, 802.11-based positioning systems can be used as they are accurate enough for most current LBS and most importantly because they do not require any specialised hardware or additional infrastructure. In this growing market, two main companies, Skyhook and Ekahau, have emerged, proposing two different Wi-Fi positioning solutions, both relying on the fingerprinting technique. The purpose of this paper is to test these two different 802.11 positioning systems in environments where one cannot rely on GPS alone to obtain a position, i.e. indoors and in urban canyon environments. First, the results obtained indoors are detailed, and then those obtained in urban canyons. An attempt was also made to link the positioning error with observable parameters of the wireless network such as the number of access points scanned. Static and mobile tests were conducted, both indoors and outdoors, and with different types of hardware. The results show that the Ekahau system performs well indoors with position errors less than 10 metres most of the time, and that Skyhook has accuracies up to 10 metres outdoors, but is very dependent on the environment.

KEYWORDS: Wi-Fi positioning, indoor positioning, urban canyon positioning, Skyhook, Ekahau.

Fast LAMBDA-based ambiguity resolution combined with WARTK technique for Galileo data simulated using ESA's Galileo Signal Validation Facility

Dennis Odijk (1)
Department of Spatial Sciences, Curtin University of Technology, Australia
Tel: +61 8 9266 3369, Fax: +61 9266 2703, Email: d.odijk@curtin.edu.au
Peter de Bakker (2)
Delft Institute of Earth Observation & Space Systems, Delft University of Technology, The Netherlands
Tel: +31 15 278 2569, Fax: +31 15 278 3711, Email: p.f.debakker@tudelft.nl
Sandra Verhagen (3)
Delft Institute of Earth Observation & Space Systems, Delft University of Technology, The Netherlands
Tel: +31 15 278 4545, Fax: +31 15 278 3711, Email: a.a.verhagen@tudelft.nl
Peter J.G. Teunissen (4)
Department of Spatial Sciences, Curtin University of Technology, Australia
Tel: +61 8 9266 7676, Fax: +61 9266 2703, Email: p.teunissen@curtin.edu.au
Delft Institute of Earth Observation & Space Systems, Delft University of Technology, The Netherlands
Tel: +31 15 278 3546, Fax: +31 15 278 3711, Email: p.j.g.teunissen@tudelft.nl
Manuel Hernández-Pajares (5)
Research Group of Astronomy and Geomatics, Technical University of Catalonia (gAGE/UPC), Spain
Tel: +34 93 4016029, Fax: +34 93 4015981, Email: manuel@ma4.upc.edu
Jaron Samson (6)
ESA/ESTEC, Noordwijk, The Netherlands
Tel: +31 71 565 6591, Fax: +31 71 565 4596, Email: jaron.samson@esa.int

This contribution addresses the effect of having a triple frequency Global Navigation Satellite System (GNSS) on ambiguity resolution of long baselines, i.e. baselines for which the differential ionospheric delays cannot be ignored. Although it is recognized that a combination of GNSS's is more effective for integer ambiguity resolution –the key to highly accurate positioning– than the use of three frequencies, it is still of interest to investigate single GNSS triple-frequency ambiguity resolution, especially since it is expected that the quality of the code data of Galileo triple-frequency signals will be better than of current dual-frequency GPS. For this purpose we have simulated triple-frequency Galileo signals using ESA's Galileo Signal Validation Facility for a Wide Area network of permanent stations and user stations receiving Wide Area RTK (WARTK) ionospheric corrections from this network. The three user stations are located at 100-400 km from the network's master reference station. Applying the ionospheric corrections by means of simple ionosphere-weighted processing demonstrated that instantaneous LAMBDA-based ambiguity resolution is feasible for the 100-km user baseline. However, as a result –in this simple approach– of poorer ionospheric corrections for the longer baselines, the instantaneous success rates drop to close to 0%, even using triple-frequency data. Despite this, the availability of a third frequency is beneficial in reducing the mean ambiguity initialization time when more epochs are used; depending on the noise levels of the code data the times to first fix the ambiguities are in the order of 10-50 sec for the 400-km baseline, applying the WARTK ionospheric corrections.

KEYWORDS: GNSS, Galileo, Triple-Frequency, Ambiguity Resolution, Wide Area RTK, LAMBDA method, GSVF simulator

---

Estimation of float solution in LAMBDA Method using Kalman Filter

Sung Lyong Cho
Department of Electronics Engineering, Chungnam National University, Korea
+82-42-825-3991, +82-42-823-4494, jackycho@ cnu.ac.kr
Heon Ho Choi
Department of Electronics Engineering, Chungnam National University, Korea
+82-42-825-3991, +82-42-823-4494, heonho@ cnu.ac.kr
Chansik Park
Department of Electronics Engineering, Chungbuk National University, Korea
+82-43-261-3259, +82-43-268-2386, chansp@chungbuk.ac.kr
Sang Jeong Lee
Department of Electronics Engineering, Chungnam National University, Korea
+82-42-825-3991, +82-42-823-4494, eesjl@cnu.ac.kr

The navigation using CDGPS(Carrier phase Differential GPS) can determine high accuracy position of cm-

level, but it requires the ambiguity resolution method to solve. Ambiguity resolution method is required to determine integer ambiguity in carrier phase measurements. The LAMBDA(Least-square AMBiguity Decorelation Adjustment) is most widely used to fixed integer ambiguities.

This paper analyzes the success rate of LAMBDA method in experimental condition. Kalman Filter is used to estimate augmented states including position, velocity, accelerometer, integer ambiguities and noise parameters. The estimated states with its variance-covariance values are fed into the second and the third step of LAMBDA. Experimental results will show that the success rate of the proposed algorithm is better than that of original LAMBDA.

KEYWORDS: CDGPS, Ambiguity Resolution, LAMBDA. Kalman Filter

Single Epoch Integer Ambiguity Resolution after Pseudorange Adjustments

Anthony Cole
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 4185, Fax: +61 2 9313 7493, a.cole@student.unsw.edu.au
Jinling Wang
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 4203, Fax: +61 2 9313 7493, jinling.wang@unsw.edu.au
Andrew G. Dempster
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 6890, Fax: +61 2 9313 7493, a.dempster@unsw.edu.au
Chris Rizos
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 4205, Fax: +61 2 9313 7493, c.rizos@unsw.edu.au

,

Precision agriculture is a growing area of research and development as agricultural operations undergo significant cultural changes with increasing pressures from an ever increasing world population, an increase in the 'corporatisation' of the farming enterprise, as well as growing emphasis on sustainable farming from an environmental perspective. One of the methods currently being investigated to address these issues requires the use of Precision Agriculture to increase the efficiency of farming operations, in particular, the implementation of autonomous vehicle control or guidance of tractors. These tractors typically employ a GPS positioning system in order to provide precision navigation and guidance. In order to achieve the accuracies required in order to derive the full benefits of GPS guidance it is necessary to fix the carrier phase ambiguities in real time, thereby ensuring sub-decimetre level positioning accuracy. If the ambiguity-fixed solution is lost, it is important that it be regained (or "re-initialised") as quickly as possible in order to restart the guidance process.

This paper presents a method of adjusting the observed pseudoranges using estimated position information that improves the single epoch ambiguity resolution process. The additional position information could be sourced from an INS or from a model of the kinematic motion of a tractor operating in a field environment. The key advantage of this method is that it doesn't require any adjustments to an existing GPS positioning "engine", –the software module(s) that process GPS carrier phase data used to derive the position solution.

KEYWORDS: OTF Ambiguity Resolution, Precision Agriculture, Autonomous Guidance

On the Time-To-Fix for Single-Frequency GNSS-Based Attitude Determination

G. Giorgi
Delft Institute of Earth Observation and Space Systems,
Delft University of Technology, The Netherlands
+31 152782713 G.Giorgi@tudelft.nl

P.J.G. Teunissen
Department of Spatial Sciences,
Curtin University of Technology, Perth, Australia
+61 892667676 p.teunissen@curtin.edu.au

The GNSS-based Attitude Determination is a demanding application which requires a precise relative positioning solution. In order to obtain an accurate estimate of a platform's orientation, a GNSS receiver must fix the integer ambiguities inherent to the phase observables: the ambiguity resolution process is the key for exploiting the higher precision of carrier phase measurements with respect to the code measurements. Among the set of admissible integer ambiguity estimators, we focus on the optimal Integer Least-Squares

estimator, which has been modified to include a geometrical non-linear constraint on the baseline length that arises when considering two antennae separated by a known distance. The challenge of reliable and fast integer estimation is particularly hard for single-frequency applications: the method proposed in this contribution leads to a strong reduction on the Time-To-Fix, i.e. the number of epochs needed to achieve a sufficient reliability on the fixed ambiguity vector. Simulation and experimental results showed the large improvement obtained when applying the non-linear constrained model.

KEYWORDS: Attitude, GNSS, LAMBDA, ILS, TTF

Abstracts – Wednesday 2nd December, 2009

Session 5: Plenary Session 0900 - 1040

GPS Modernization: GPS IIIA – On the Road to the Future

Dr, Don G. DeGryse
Vice President, Navigation Systems
Lockheed Martin Space Systems, USA
Phone: +1 215-497-2392 Fax: +1 215-497-1144 Email address: donald.g.degryse@lmco.com
Mr. Scott D. Lindell
Director, Navigation and Surveillance Systems Business Development
Lockheed Martin Space Systems, USA
Phone: +1 303-977-5419 Fax: +1 303- Email address: scotrt.d.lindell@lmco.com
Mr. Michael E. Shaw
Director, Navigation Systems Global Business **Development**
Lockheed Martin Space Systems, USA
Phone: +1 703-413-5894 Fax: +1 703 413-5819 Email address: michael.e.shaw@lmco.com

The GPS modernization program is currently underway bringing new capabilities to positioning, navigation, and timing users throughout the world. In May 2008, the U.S. Air Force awarded a contract to Lockheed Martin Space Systems to develop the next generation of GPS satellites, the GPS IIIA.

The GPS IIIA program recently completed a highly successful Preliminary Design Review and is scheduled to undergo a Critical Design Review in Fall of 2010. The fist launch of a GPS IIIA satellite is projected for 2014 in support of both normal constellation sustainment and continuing the implementation of the GPS modernization program.

Beginning in 2014, the GPS IIIA satellites will broadcast the new fourth civil signal, called L1C, in addition to the second and third civil signals as well as the military M-code signal. Significantly, the signals from GPS IIIA will be both compatible and interoperable with the Open Service broadcast by the European Galileo system.

This presentation will update the conference on the current status and capabilities of the GPS IIIA program.

KEYWORDS: Satellite navigation; GPS; modernization; L1C; interoperable.

Space Passive Hydrogen Maser – Performances, lifetime data and GIOVE-B related telemetries

Marco Belloni
Selex Galileo, Italy
Phone: +39 0331 1753354, Fax: +39 0331 1753093, marco.belloni@selexgalileo.com
Fabien Droz
SpectraTime SA, Switzerland
Phone: +41 32 732 16 66, Fax: +41 32 732 16 67, droz@spectratime.com
Pierre Waller
European Space Agency / ESTEC, the Netherlands
Phone: +31 71 565 41 87, Fax: +31 71 565 45 96, pierre.waller@esa.int
Co authors:
Qinghua Wang, Pascal Rochat, Pierre Mosset, Daniel Boving, SpectraTime SA, Switzerland
Marina Gioia, Simone Beretta, SELEX GALILEO, Italy
Alberto Resti, Alessandra Ostillio, European Space Agency / ESTEC, the Netherlands

Galileo navigation programme development is progressing under the responsibility of the European Space Agency (ESA). GIOVE-B, an experimental satellite, has already been launched and is providing the first results. The development of four In Orbit Validation (IOV) satellite is in progress. Atomic clocks represent the key technology for the success of any satellite navigation system mission, and their development has been continuously supported by ESA. PHM is the Passive Hydrogen Maser used as master clock on Galileo navigation satellites.

In parallel with the in-orbit experimentation of GIOVE-B satellite, a technology project has been initiated to develop and test on ground four PHM QMs with the aim of highlighting and overcoming possible PHM lifetime limitations, before starting the full production of the navigation satellite constellation. Preliminary results of this ground lifetime testing are already available, along with the complementary data collected from the orbit. This paper gives an overview of PHM performance and telemetry data collected so far. The most relevant telemetries and their lifetime trends are compared and discussed. Long term frequency stability performance tests have achieved a clock stability at one day (including the drift) of 10^{-15}. The consistency among all the telemetry measurements, their ageing trends, and the excellent frequency stability provide confidence on the capability of the instrument design of meeting Galileo mission requirements.

KEYWORDS: GALILEO, GIOVE-B, Navigation, Passive Hydrogen Maser.

Indoor navigation supported by image-based and Artificial Intelligence techniques

Dorota A. Grejner-Brzezinska
Satellite Positioning and Inertial Navigation (SPIN) Laboratory
The Ohio State University
dbrzezinska@osu.edu

Charles Toth
Center for Mapping,
The Ohio State University
Toth@cfmohio.state.edu

J. Nikki Markiel
Satellite Positioning and Inertial Navigation (SPIN) Laboratory
The Ohio State University
clouddragon9@gmail.com

Shahram Moafipoor
Satellite Positioning and Inertial Navigation (SPIN) Laboratory
The Ohio State University
shahram@cfm.ohio-state.edu

The ability to determine one's position in absolute or map-referenced terms, relative to objects in the environment, and to move to a desired destination point is an everyday necessity. Recent years brought an explosion in the development of portable devices that support this functionality. Systems that were traditionally used for sensor geolocation in mobile mapping, such as the Global Positioning System (GPS) and inertial measurement units (IMUs), are now miniaturized and cost effective, facilitating portable, inexpensive navigation of mobile users. A Personal Navigation Assistant (PNA) also known as Personal Navigation Device (PND) is a portable electronic tool, which combines positioning and navigation capabilities, usually provided by GPS, and possibly by other sensors (not necessarily of the navigation type in the traditional sense).

For location determination of pedestrians in buildings, the Wireless Local Area Networks (WLAN), or transponders or beacons installed inside the buildings are increasingly used. Other indoor positioning systems include so-called Active Badge Systems (IR-based) and RF-based tagging. Robustness of the ultra wideband (UWB) signal to multipath fading and its high penetration capability makes it another technique suitable for indoor positioning. An alternative method used in indoor navigation is based on optical tracking systems, also referred to as image-based systems.

This paper will discuss two unconventional methods for indoor-outdoor navigation, one based on the integration of GPS, IMU, digital barometer, magnetometer compass, and a human locomotion model handled by Artificial Intelligence (AI) techniques that form an adaptive knowledge-based system (KBS), which is trained during the GPS signal reception, and is used to support navigation under GPS-denied conditions. A complementary technique used in our solution, which facilitates indoor navigation, is the image-based method (Flash LADAR). Navigation from 3D Flash LADAR scene reconstruction utilizes the range distance to static features common in images acquired from two separate positions, which allows for triangulating the user's position. The challenge, given limited a priori knowledge of the sensor environment, is to locate and match *n* features from an initial image in the subsequent image. Algorithms enabling this objective are limited in the instance of true 3D scene reconstruction and frequently invoke the use of nonlinear estimation techniques. In the current system implementation, motion of both the acquisition device and features in the environment are subject to movement. By utilizing the Flash LADAR image in tandem with the IMU, a linear feature-based algorithm to achieve the identification of common static features between two images, along

with the error estimates is facilitated. Since the algorithm is based on linear methodologies, it enables rapid processing while generating robust, accurate position and error estimation data. The algorithm provides an effective solution to the problem of feature identification and provides an essential link towards enabling navigation from 3D ranging imagery.

In this paper, system design, as well as a summary of the performance analysis in the mixed indoor-outdoor environments will be discussed.

KEYWORDS: indoor navigation, sensor integration, Artificial Intelligence, image-based navigation.

Australian Space Science Program

Dr Michael Green
General Manager, Space and Innovation Branch, Manufacturing Division
Department of Innovation, Industry, Science and Research Canberra, Australia
+61 2 6276 1166 space@innovation.gov.au

Presented by Michele Clement, Manager Space Policy Unit, Department of Innovation, Industry, Science and Research Canberra, Australia

The Space Policy Unit (the Unit) and the Australian Space Research Program were announced in the 2009-10 Budget as part of the Australian Government's Australian Space Science Program with a charter to better engage with the global space community, collaborate with international space organisations, and support and develop domestic space-related research, innovation and skills capability.

The Unit is the Australian Government's central point of contact and coordination for all civil space activities and provides advice to the Government on national and international space issues. The Unit is also responsible for administering the Australian Space Research Program; coordinating the response to the Australian Senate inquiry into space; and developing a National Space Policy to provide a vision for Australia's use of space and space-related technologies.

KEYWORDS: Australia, Space, Science, Program, Policy

A Space Policy for Australia: Some Industry Implications: Threats and Opportunities

Brett Biddington
Consultant
Phone +61 401 890 368, Email bbidding@tpg.com.au

2009 represents a tipping point for Australia's involvement in space. This follows five years of persistent and increasingly well-reasoned public discussion in Australia, culminating in a Senate inquiry in 2008. It also follows on quite substantial changes in the international space landscape from political, environmental and security perspectives.

That Australia has enormous dependencies on assured and secure access to space-based services, including GNSS is now well-accepted, if not entirely understood, by Government. The National Security Statement delivered by Prime Minister Rudd to Parliament in December 2008, made clear that Australia is seeking to become more resilient as a society and that one means of achieving this will be by identifying and better protecting Australia's critical infrastructure. The Statement also calls for Australia to become more active internationally through the use of creative middle power diplomacy. A credible voice on space matters, will be a necessary element in the realisation of this ambition.

My talk will examine these trends and describe subsequent developments. It will show where pockets of strength exist in Australian industry and in the research community as well. These elements, taken together, form the seeds of a nascent space industry which is quite capable of supporting national requirements. The extent to which this sector develops and prospers will, to large measure, be determined by how it behaves. The is no room for the exaggerated claims and poorly developed business cases which have so typified behaviour in the past.

KEYWORDS: space, Australia, policy, industry national security

Characterising the Signal Structure of Locata's Pseudolite-based Positioning System

Joon Wayn Cheong
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93854206/ cjwayn@unsw.edu.au
Xiaowei Wei
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93854206/ smile_wei@hotmail.com
Nonie Politi
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 9385 4526/ nonie@unsw.edu.au
Andrew G. Dempster
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93856890/ a.dempster@unsw.edu.au
Chris Rizos
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93854205/ c.rizos@unsw.edu.au

Locata is a Pseudolite-based Positioning System (PPS) operating in the licence-free 2.4GHz Industrial Scientific and Medical (ISM) frequency band. Unlike its predecessors, Locata utilises time-diversity methods to overcome the near-far problem. Therefore Locata is able to operate over larger regions than previous PPS. Since the School of Surveying & Spatial Information Systems at the University of New South Wales has considerable experience in designing GNSS receivers, an attempt to integrate PPS signal processing into our developed GNSS receiver (i.e. Namuru) is currently being investigated. Research into Locata's signal structure is aimed at gaining insights and detailed technical knowledge to support alternate receiver designs for processing terrestrial PPS-type signals.

In this investigation, several important signal variables were identified via coaxially connecting the Locata transmitter to a Radio Frequency (RF) down-converter, high speed digitiser and signal recorder. Using spectral analysis methods, and having apriori knowledge of the signal's operating frequency range (i.e. the ISM band), the centre frequency of the signal was found. It was assumed that the signal has CDMA-type characteristics. This is further verified by fine tuning the centre frequency, and sampling the down-converted signal at very high frequency. Exploiting its autocorrelation function, the code sequence and code period was also deciphered. Other signal parameters (e.g. code chipping rate, code sequence generator, and Time Hopping sequence) were then progressively discovered via various signal processing methods.

Results to date indicate that the adopted signal structure is a modified version of the typical GPS L1 signal structure. Time-diversity is then achieved by masking the generated signal of each transmitter with its distinct and orthogonal Time Hopping sequence. Such an implementation eases receiver design while being able to mitigate the near-far problem.

KEYWORDS: Time Hopping, Pseudolite Positioning, pulsed CDMA, burst CDMA, Locata

Tropospheric Correction for Locata when Known Point ambiguity resolution technique is used in Static Survey- Is it required?

Mazher Choudhury
The University of New South Wales
mohammad.choudhury@student.unsw.edu.au
Bruce Harvey
The University of New South Wales
Phone: +61 2 9385 4178, Fax: +61 2 9313 7493 email: b.harvey@unsw.edu.au
Chris Rizos
The University of New South Wales
Phone: +61 2 9385 4205, Fax: +61 2 9313 7493, email c.rizos@unsw.edu.au:

Locata's positioning technology provides positioning solutions via a network of time synchronised ground-based "pseudolite" transceivers which can operate where GNSS is challenged. However, as Locata's signal propagates through the lowest atmospheric layer, tropospheric error effects are different from the case of GNSS and should be modelled properly. The aim of this research is to analyse published tropospheric delay

models and propose an appropriate model for Locata.

Tropospheric delay models for pseudolite-type positioning technology as well as a “length ratio” based tropospheric model are investigated. A modified length ratio based tropospheric model, referred to here as the Locata Tropospheric Model (LTC), is introduced for use with Locata technology. Each of these models is implemented and experiments conducted to carry out performance analysis. Results show that tropospheric correction is not required for static point measurement when the “known point” ambiguity resolution method is used. On the other hand, LTC performs better than other tropospheric models when the Locata receiver is not at a known point.

KEYWORDS: Locata; tropospheric corrections.

Kalman Filter Based Adaptive Loop Aiding for Performance Improvement in Low $C/(N_o + I)$ Environments

Faisal A Khan*
Andrew Dempster
Chris Rizos

School of Surveying and Spatial Information Systems
University of New South Wales
*faisal@student.unsw.edu.au

Carrier tracking in GNSS receivers suffers in environments where platform dynamics, received noise and interference are expected simultaneously. Similar is the case of a Locata receiver which operates on the same basic principles as GNSS receivers. A reduction in tracking loop bandwidth may offer noise rejection, but at the same time it makes tracking more vulnerable to oscillator and platform dynamics. This paper aims to stabilise Locata receiver tracking in the presence of received noise and interference in a dynamic environment. It first compares two existing solutions: Adaptive Loop Aiding and the use of Kalman filters for noise reduction. It then proposes a Kalman filter based loop aiding scheme for further reduction in noise without making tracking more vulnerable to signal dynamics and loss of lock. It is shown that the proposed scheme offers reductions of 93% and 85% in error for static and dynamic platform cases respectively, as compared to adaptive loop aiding without a Kalman filter.

KEYWORDS: Loop Aiding, Carrier Phase Jitter, Kalman Filter.

Tracking of Time Hopped DS-CDMA Signals for Pseudolite-based Positioning

Joon Wayn Cheong
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93854206/ cjwayn@unsw.edu.au
Andrew G. Dempster
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93856890/ a.dempster@unsw.edu.au
Chris Rizos
School of Surveying and Spatial Information at the University of New South Wales/Australia
+61 2 93854205/ c.rizos@unsw.edu.au

Locata’s positioning technology was designed to be used as an alternative to GNSS in classically-difficult GNSS signal environments. A network of time-synchronized terrestrial transceivers (*LocataLites*) forms a positioning network (*LocataNet*) that can operate entirely independent of GNSS. Operating in the 2.4GHz ISM license-free band, the Pseudolite Positioning System (PPS) is immune to near-far problem due to the usage of TH/DS-CDMA signal. Conversely, the usage of such signals results in the degradation of code tracking performance in comparison to an equivalent DS-CDMA system. The relative performance degradation is proven via theoretical derivation and simulation to be directly related to the duty factor of the TH/DS-CDMA signal. The transient behavior of the signal is also observed and compared to the conventional DS-CDMA signal. This type of signal enables an advantageous and efficient way to track multiple transmitter using only one tracking loop. In a nutshell, the TH/DS-CDMA provides immunity to near-far problem and enables an efficient tracking algorithm while exhibiting performance degradations that could be countered using longer integration intervals.

KEYWORDS: Time Hopping CDMA, pulsed CDMA, burst CDMA, Locata, pseudolite positioning

SPOT in Location Based Emergency Positioning, LBES Detailed Analysis

Ali Sarwar
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854185, Fax 93137493 Email: ali.sarwar@student.unsw.edu.au

Binghao Li
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854189, Fax 93137493 Email: binghao.li.@unsw.edu.au

Andrew G. Dempster
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93856890 Fax 93137493 Email: a.dempster@unsw.edu.au

SPOT satellite messenger has been a subject of widespread discussion both in public and private sector for its reliability and practicality, recently in Location Based Emergency Services (LBES). This paper reports tests of the SPOT system and presents the performance, reliability and availability benchmarking test results with reference to other methods like Assisted, High Sensitivity and Low Sensitivity GPS in comparable environments. Test results led to the conclusion that AGPS demonstrated better availability, collectively in all environments with fewer chances of failure and superior performance overall. Assisted GPS can potentially provide superior availability and coverage at a reasonable cost.

KEYWORDS: SPOT, AGPS, GPS, LBES, Reliability, Performance.

THE USE OF GNSS DATA IN A REGULATORY TELEMATICS APPLICATION

Fei Li
Engineer, Development Services
Transport Certification Australia Ltd.
Level 12, 535 Bourke St, Melbourne, VIC 3000, Australia

Dr Charles A Karl
General Manager, Development Services
Transport Certification Australia Ltd.
Level 12, 535 Bourke St, 3000 Melbourne, VIC 3000, Australia

Corresponding author:
Fei Li, feil@tca.gov.au, tel:(03) 8601 4628

This paper will provide an update of the use of GNSS data in a recently introduced regulatory application in Australia known as the Intelligent Access Program (IAP). The paper will follow on an earlier paper and presentation given to the IGNSS Symposium in Sydney in 2004 on the IAP. Since that time, the governments have established Transport Certification Australia (TCA) to implement the program. The IAP is now operational in Queensland, New South Wales and Victoria and IAP is provided by four certified Service Providers from industry.

The paper will introduce the IAP system architecture, data and quality parameters associated with the GNSS data used in IAP. TCA is currently developing other regulatory applications such as on-board mass and fatigue (using electronic work diaries) and speed monitoring which also uses GNSS data. These additional applications will also be described in the paper.

Finally, the paper will touch upon the emerging tools being developed by TCA to ensure that the IAP program and governments' confidence in the quality and accuracy of GNSS data, from the installed base of in-vehicle units now deployed in Australia, continues to function at the level at which the systems were certified for.

References:

Cai, D., Davis, L. & Karl, C.A., 2008 *"The development of an evidentiary on-board mass-monitoring application for heavy vehicles"*. 15th Intelligent Transportation Systems World Congress, New York City, November.

Foong, K., Talko, S. & Karl, C.A., 2009 "*The use of GNSS data for a fatigue and speed monitoring system*". IGNSS Symposium, Surfer's Paradise, December (abstract).

Karl, C.A., Davis, L. & Cai, D., 2009 "*A Regulatory On-Board Mass Monitoring Application for Heavy Vehicles in Australia*". 16th Intelligent Transport Systems World Congress, Stockholm, September (forthcoming).

Ma, J.C., Karl, C.A. & Dyukov, A., 2009 "*Certification and Audit of the Intelligent Access Program for the monitoring of heavy vehicles in Australia*". IEEE IV09 Conference, Xi'an China, June.

Ma, J.C., Karl, C.A. & Dyukov, A., 2009 "*Intelligent Access Program: System Architecture*". IEEE IV09 Conference, Xi'an China, June.

Petridis, P. and Koniditsiotis, C., 2004 "*Intelligent Access Program (IAP)*". IGNSS Symposium, Sydney, December.

All Scenario Health Monitoring & Intelligent Positioning System, ASHIPS A Hybrid Positioning Concept

Ali Sarwar
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854185, Fax 93137493 Email: ali.sarwar@student.unsw.edu.au
Binghao Li
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854189, Fax 93137493 Email:binghao.li@unsw.edu.au
Andrew G. Dempster
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93856890 Fax 93137493 Email: a.dempster@unsw.edu.au

This paper presents a novel approach to integrating contemporary technologies proposed to work in different scenarios as stand-alone or aiding positioning devices. Applications can range from everyday to location based emergency services, LBES. Despite many claims, no GPS chipset or positioning device has performed well in all scenarios ranging from indoors to outdoors and urban to rural, due to factors like multipath, attenuation, satellite unavailability or GPS insensitivity. However, few improvement techniques and mitigation studies have been proposed.

With the exponentially increasing demands of quick, efficient and reliable positioning systems, more sophisticated and intelligent systems are required, especially for emergencies. A survey conducted to verify the reliability of existing and in use systems by emergency services revealed the needs for improvement. After reviewing current trends in specific positioning and identifying shortcomings, a hybrid positioning (HP) concept has been proposed.

All-Scenario Health Monitoring and Intelligent Positioning System, ASHIPS can potentially provide significant improvements in terms of reliability, time to first fix (TTFF) and general GPS availability and correction. Health monitoring has been incorporated for comprehensive periodic health probes making the device capable of automatically responding and seeking assistance according to the bearer's personal health. It will continuously and automatically update the remote device and back-to-base relative to diagnostics independent of activation. The paper presents detailed design layout and operational information flow-chart of the device. A detailed analysis highlights the need for such a device in future LBES.

KEYWORDS: ASHIPS, LBES, MNT, Hybrid Positioning.

Outdoor localization of a WiFi source with unknown transmission power

Ryan J R Thompson
School of Surveying and Spatial Information Systems, UNSW, Australia
Phone (02) 9385 4208 Fax (02) 9313 7493 Email: r.thompson@unsw.edu.au
Asghar Tabatabaei Balaei
School of Surveying and Spatial Information Systems, UNSW, Australia
Phone: (02) 9385 4202 Fax: (02) 9313 7493 Email: asghart@unsw.edu.au
Andrew G Dempster
School of Surveying and Spatial Information Systems, UNSW, Australia
Phone: (02) 9385 6890 Fax: (02) 9313 7493 Email: a.dempster@unsw.edu.au

A threat to the reliability of GNSS systems is RF interference. One possibility for localising interference sources is to take received signal strength (RSS) measurements. To explore this scenario a sensor network

is created in a 100m^2 outdoor environment using a number of Wi-Fi stations that can measure the received signal strength of a Wi-Fi access point. The log-normal path-loss model is used to relate the RSS value to distance. Although methods that create a radio-map of an environment through a survey give good performance it may not be practical to conduct such a survey in all locations for a large outdoor environment. As an alternative the path-loss exponent of the propagation environment can be calculated along with position and transmission power. This makes more sense in an outdoor environment where the propagation environment is better behaved. The localisation performance is compared with the theoretical performance given by the Cramer-Rao lower bound. Immediate applications of this idea include the passive localisation of a unknown Wi-Fi mobile station or an Wi-Fi access point that is unintentionally degrading the performance of a positioning system that operates in the ISM band such as Locata.

KEYWORDS: passive localisation, position algorithms**,** path-loss exponent, shadowing.

Statistical Testing in Quality Control of GNSS Measurements

Dr Ahmed El-Mowafy
Senior Lecturer, Curtin University of Technology, Australia
Phone: +61 (8) 9266 2704; Email: A.El-Mowafy@.curtin.edu.au

The paper discusses statistical testing methods for initial diagnosis of the presence of outliers in GNSS measurements during the phase of quality control of measurements, before using them in the process of estimation of the unknowns. First, traditional global (detection) and local (isolation) methods that test the distribution of measurement residuals are discussed. Next, additional tests were proposed including examining the difference of the mean of the residuals between consecutive epochs. Testing using dynamic control limits of the range, the mean and standard deviations of the residuals is also proposed. To identify the satellites with faulty measurements, a test is presented utilizing the control limits of the residuals' moving range between epochs for each satellite. Testing of the proposed methods was carried out using GPS measurements in the kinematic mode. Results show that the proposed methods are efficient for detection of outliers in any epoch. However, for the isolation of the satellites of faulty measurements, it is recommended to use more than one method to confirm decisions made.

KEYWORDS: Quality Control, Statistical Testing, Reliability, Positioning, GNSS.

RTK Receiver Autonomous Integrity Monitoring (RTK-RAIM) Algorithms and Performance Analysis

Jun Wang
Queensland University of Technology/Australia
Email:jun.wang@student.qut.edu.au
Yanming Feng
Queensland University of Technology/Australia
Email:y.feng@qut.edu.au

Monitoring the integrity of real time kinematic (RTK) positioning solutions is of great interests to life-critical and liability critical applications, attracting much research attentions in recent years. Unlike the existing receiver autonomous integrity monitoring (RAIM) algorithm with pseudorange measurements, RTK positioning uses double-differenced carrier phase measurements, and involves ambiguity resolutions (AR). Therefore RTK receiver autonomous integrity monitoring is a complex issue.

The proposed RTK RAIM algorithm comprises three major procedures. The first procedure is to compute the exact AR success probability, which is the probability that the ambiguities are successfully resolved and fixed to their correct integer values. We compute the exact AR success probability of the integer least-square (ILS) solutions using the multivariate normal distributions with a simplified pull-in region and full covariance matrix assumptions. Various geometry-based AR models, such as different combinations of L1 and L2 phase measurements, with or without constrains, are compared using the AR success probability criteria. The models with the highest predicted AR success probability are used for AR. The next procedure is to using different fixed carrier phase measurement to verify the RAIM algorithm in terms of probability of false alarm and missed detection. When an alert occurs, if the number of satellites is more than 6, the third procedure named fault exclusion is processed by screening all the sets of (n-1) satellite measurements.

Experimental analysis from two 24-h GPS data sets is given to demonstrate the performance of the proposed procedures. Comparing the computed AR success probability from real time data, it concludes that different models, such as different linear combinations of L1 and L2 signals, yields different AR success probabilities. The preliminary results from the test data set also show that the best WL and NL models perform better in terms of the probability of false alarm and missed detection through added different sizes of errors. Comparison between HPL/VPL and positional errors are also given, showing the consistence between theoretical concepts and actual statistical results.

KEYWORDS: RTK, RAIM, Carrier Phase Ambiguity Resolutions, Protection Level

GNSS Integrity Monitoring for Two Satellite Faults

Nathan L. Knight
School of Surveying and Spatial Information Systems
University of New South Wales, Sydney, NSW 2052, Australia
Tel: +61-2-9385 4185 Fax: 61-2-9313 7493 Email: n.knight@student.unsw.edu.au
Jinling Wang
School of Surveying and Spatial Information Systems
University of New South Wales, Sydney, NSW 2052, Australia
Tel: +61-2-9385 4203 Fax: 61-2-9313 7493 Email: jinling.wang@unsw.edu.au
Chris Rizos
School of Surveying and Spatial Information Systems
University of New South Wales, Sydney, NSW 2052, Australia
Tel: +61-2-9385 4205 Fax: 61-2-9313 7493 Email: c.rizos@unsw.edu.au
Songlai Han
School of Surveying and Spatial Information Systems
University of New South Wales, Sydney, NSW 2052, Australia
Tel: +61-2-9385 4185 Fax: 61-2-9313 7493 Email: songlai.han@student.unsw.edu.au

To enable the use of multiple satellite navigation systems in aviation, Receiver Autonomous Integrity Monitoring will be required to detect the presence of multiple satellite failures. The current methods of providing Fault Detection in the chi-square test and the outlier test provide adequate integrity for a single biased measurement. However, it is shown, with an example, that the current methods do not provide sufficient integrity against multiple faults. Consequently, a new chi-square test method for two biases is derived. In addition, the multiple outlier test method for two biases is presented with the associated Protection Levels. It is then shown that the new methods appear to provide adequate integrity against two biases.

KEYWORDS: GNSS, RAIM, Fault Detection, Multiple Faults

Integration of Locatalites and GNSS

Dr Gethin Wyn Roberts
The University of Nottingham, UK
T +44 115 9513933, F +44 115 9513881, e gethin.roberts@nottingham.ac.uk
Lukasz Bonenberg
The University of Nottingham, UK
T +44 115 9513880, F +44 115 9513881, e craig.hancock@nottingham.ac.uk
Craig Hancock
The University of Nottingham, UK
T +44 115 9513880, F +44 115 9513881, e isxlkb@nottingham.ac.uk

Locatalites, created by Locata Corp, is a terrestrial positioning technology, based on network of transceivers (LocataNet) synchronized to nanosecond (10-9s) using novel TimeLoc procedure. It operates in 2.4 GHz ISM, license free, frequency band. It is described as intelligent pseudolite transceiver, mostly due to ability to maintain constant time frame. Research identifies accuracy of the system on cm level. It share similar characteristic with GNSS and is also prone to a weak vertical component.

This paper outlines work being conducted at the University of Nottingham, addressing the tight integration of both GNSS and Locatalites. Focus is on time integration, reduction of noise and multipath.

Additional study is conducted on the assessment of geometry accuracy, especially in relation to weak vertical component. By analysing separate and combined geometry of both systems, optimal use of coupled systems in different environments is estimated.

The main goal is to maintain centimetre accuracy, especially in the areas traditionally regarded as “difficult” or impossible for GNSS – such as urban canyons, indoor and semi-indoors areas. Main utilization of this approach is expected to be civil engineering and monitoring.

KEYWORDS: GNSS. Integration. Locatalites

On-the-fly Ambiguity Resolution for Locata

Jonas Bertsch
School of Surveying and Spatial Information Systems, UNSW, Sydney, NSW 2052, Australia
Jonas.bertsch@gmail.com

Mazher Choudhury
School of Surveying and Spatial Information Systems, UNSW, Sydney, NSW 2052, Australia
Email: mohammad.choudhury@student.unsw.edu.au:

Chris Rizos
School of Surveying and Spatial Information Systems, UNSW, Sydney, NSW 2052, Australia
Phone: +61 2 9385 4205, Fax: +61 2 9313 7493, email c.rizos@unsw.edu.au:

Hans-Gert Kahle
Institute for Geodesy and Photogrammetry, ETH, Zurich 8093, Switzerland
hans-gert.kahle@geod.baug.ethz.ch

Locata’s positioning technology solution was developed as an alternative to GPS in ‘difficult’ GNSS environments. Previous research in this area has demonstrated the ability of Locata to deliver centimetre-level positioning accuracy using carrier phase measurements. In the current system, the floating point carrier phase ambiguities are commonly solved for using the technique of ‘static initialisation’, by commencing positioning on a precisely surveyed point. However, in practical kinematic applications it is preferable to be able to resolve the ambiguities ‘on-the-fly’. This paper will introduce an on-the-fly ambiguity resolution algorithm for Locata. In simulation tests integer ambiguity estimation for centimetre-level to sub-centimetre-level accuracy has been demonstrated.

KEYWORDS: On the fly ambiguity resolution, Locata

Implementation of microcontroller-aided PC104 platform for multisensor integrated system

Zhenkai Xu[1,2]
[1]Southeast University, Nanjing, China
[2]University of New South Wales, Sydney, Australia
Phone: 61-2-9385-4173, Fax: 61-2-9313-7493 Email: z.xu@student.unsw.edu.au
Yong Li
University of New South Wales, Sydney, Australia
Phone: 61-2-9385-4173, Fax: 61-2-9313-7493, Email: yong.li@unsw.edu.au
Chris Rizos
University of New South Wales, Sydney, Australia
Phone: 61-2-9385-4205, Fax: 61-2-9313-7493, Email: c.rizos@unsw.edu.au
Xiaosu Xu
Southeast University, Nanjing, China
Phone: 86-25-8379-3922 Fax: 86-25-8379-3922, Email: xxs@seu.edu.cn

The GPS-aided MEMS-based inertial navigation system is a topic of current interest by many researches. The performance of such systems relies on not only the quality of the MEMS inertial sensors, or the quality of GPS measurements and the geometry of the satellite constellation, but also implementation of time synchronisation of GPS and INS sensors on the integration platforms. The pseudolite-based transceiver positioning technology known as Locata can potentially fill in the gaps in availability in difficult GPS environments or even GPS outages. Therefore integration of GPS, Locata and INS provides an attractive solution to realise an ideal seamless navigation system. In this paper, a microcontroller-aided PC104 platform for multisensor integration is implemented. The time synchronisation is designed in both analogue and digital domains to flexibly meet different accuracy requirements. In a 24-hour test, the platform has demonstrated a time synchronisation accuracy of 1ms without any data loss. This time synchronisation accuracy can satisfy the accuracy requirement of a MEMS-based integrated system for many applications. However, when a higher accuracy is required, the analogue-domain time synchronisation mode must be used. This paper addresses the system implementation aspects including hardware and software, as well as presenting an evaluation of its time synchronisation performance.

KEYWORDS: Multisensor integration, PC104, microcontroller, time synchronisation, MEMS inertial sensors

Deformation Monitoring Using Locata - A Case Study at the Tumut Pond Dam

Mazher Choudhury
School of Surveying and Spatial Information Systems, UNSW, Australia
mohammad.choudhury@student.unsw.edu.au
Nonie Politi
School of Surveying and Spatial Information Systems, UNSW, Australia
nonie@unsw.edu.au
Chris Rizos
School of Surveying and Spatial Information Systems, UNSW, Australia
c.rizos@unsw.edu.au

Deformation monitoring of engineering structures is often necessary, for reasons ranging from ensuring operation of the structure within specifications through to monitoring due to a risk (real or perceived) of failure of such structures. Nowadays Global Navigation Satellites Systems (GNSS) are commonly used for precise structural monitoring, however the quality of GNSS position solutions is heavily dependent on the number and geometric distribution of the available satellites, and may vary significantly at different observation times.

To overcome these problems, Locata Corporation's positioning technology, "Locata", provides accurate position solutions using a network of time-synchronised pseudolite-like transceivers (LocataLites). The Locata network can be deployed over a structure to ensure an optimal network geometry under site constraints. Previous work has already demonstrated the feasibility of using Locata for deformation monitoring applications. This paper presents a case study of a deformation monitoring trial conducted at the Tumut Pond Dam in Cabramurra, NSW, Australia, where long term deformation history is available for comparison.

A Locata network, composed of six LocataLites, has been established for this trial after analysing the network geometry and LocataLite line-of-sight visibilities. Locata pseudo-range, carrier phase measurement data and atmospheric data have been collected, and post processed for deformation analysis using the batch least squares method. Single-difference data processing strategy is used to remove receiver clock biases. Measurement data is used to generate 3D coordinate solutions, and these coordinate solutions are

checked for statistically significant movement (deformation) by standard deformation analysis.

Results from the deformation analysis have been compared with previous total-station based deformation surveys. Results show that Locata can continuously deliver sub-millimetre positioning precision. This case study extends the previous work on the applicability of Locata for deformation monitoring applications and demonstrates that under diverse weather conditions Locata can still provide required precision and accuracy.

KEYWORDS: Locata, Deformation monitoring application

Parameter Estimation for Mine Navigation

Garry Einicke
CSIRO Exploration and Mining, Australia
Ph 07 3327 4615, Fax 07 3327 4566, garry.einicke@csiro.au
Gainluca Falco
Politecnico Di Torino, Italy
Ph 011 5646666, Fax 011 5646329, gianluca.falco@polito.it
John Malos
CSIRO Exploration and Mining, Australia
Ph 07 3327 4114, Fax 07 3327 4566, john.malos@csiro.au
David Reid
CSIRO Exploration and Mining, Australia
Ph 07 3327 4437, Fax 07 3327 4566, david.reid@csiro.au
David Hainsworth
CSIRO Exploration and Mining, Australia
Ph 07 3327 4420, Fax 07 3327 4566, david.hainsworth@csiro.au

This paper discusses the convergence of a Kalman filter-based Expectation-Maximisation algorithm for estimating unknown model parameters. Under prescribed conditions, the parameter estimates converge to the actual values. Mining navigation applications are discussed in which good parameter estimates are required. An inertial alignment example is presented, which demonstrates that the sequence of process noise covariance estimates is monotonically decreasing. A position tracking application is also discussed in which it is demonstrated that the sequence of state matrix estimates is similarly monotonic decreasing.

KEYWORDS: Kalman filtering, EM algorithm, parameter estimation, mine navigation.

GNSS Case Study for Queensland's Mining Industry

Rob Lorimer
Position One / Australia
+61 7 3821 5543
rob@positiononeconsulting.com

An overview of the uses of GNSS in Queensland mining and some of the companies who provide GNSS based solutions. This presentation is part of a series of six industry case histories sponsored by the Queensland Department of Employment, Economic Development and Innovation. The other five case histories were presented at IGNSS workshops in 2008 and early 2009.

This abstract will only be used for consideration for selection as part of the symposium program and will not be considered for the review process.

KEYWORDS: Mining, Industry Development, Queensland

The Application of Smoothing within Longwall Mine Navigation

Garry Einicke
CSIRO Exploration and Mining, Australia
Ph 07 3327 4615, Fax 07 3327 4566, garry.einicke@csiro.au

Jonathon Ralston
CSIRO Exploration and Mining, Australia
Ph 07 3327 4702, Fax 07 3327 4566, jonathon.ralston@csiro.au
Chad Hargrave
CSIRO Exploration and Mining, Australia
Ph 07 3327 4523, Fax 07 3327 4566, chad.hargrave@csiro.au
David Reid
CSIRO Exploration and Mining, Australia
Ph 07 3327 4437, Fax 07 3327 4566, david.reid@csiro.au
David Hainsworth
CSIRO Exploration and Mining, Australia

Ph 07 3327 4420, Fax 07 3327 4566, david.hainsworth@csiro.au

Longwall mining is the most efficient method of extracting coal within underground mines. Traditionally, longwall mining equipment is controlled manually, where the coal face is aligned using a string line. Longwall equipment can now be controlled by an automated system, which employs an inertial measurement unit. This paper describes the application of the recently developed minimum-variance smoother to aid navigation in support of longwall mine automation. Both continuous-time and discrete-time smoother results are discussed. It is demonstrated that the smoother out-performs the minimum-variance filter and some underground longwall mine positioning results are presented.

KEYWORDS: Minimum-variance smoothing, inertial navigation, longwall mining

The Impact of the 2009 New Zealand Fiordland Earthquake on the LINZ PositioNZ CORS Network

John Beavan
GNS Science
PO Box 30368, Lower Hutt, New Zealand
Tel 64 4 5704641 j.beavan@gns.cri.nz
Graeme Blick
Land Information New Zealand
Private Box 5501, Wellington 6145, New Zealand
Tel 64 4 4983833 gblick@linz.govt.nz

On 15 July 2009 a magnitude ~7.7 earthquake struck the south-west area of Fiordland, New Zealand. This was the largest earthquake to strike New Zealand in almost 80 years. The fact that the area of the earthquake is sparsely populated meant that damage from the event was relatively light; however, its impact was spread over much of the southern South Island. The effect of the earthquake was recorded at a number of the LINZ PositioNZ continuously operating GNSS stations (CORS). Significant shifts were detected at Puysegur Point (300 mm), Mavora Lakes (60 mm), Bluff (30 mm), Alexandra (20 mm) and Dunedin (10 mm). One of the principal objectives of the PositioNZ network is to monitor New Zealand's semi-dynamic datum, NZGD2000, and to contribute data towards determining a national deformation model which is an integral part of the datum. The information from the PositioNZ stations was used along with seismic information to determine a preliminary dislocation model for the earthquake. This talk details the effect of the earthquake on the PositioNZ CORS stations, how the GNSS data has contributed to an understanding of the earthquake, and the impact on the geodetic and cadastral system in the area.

KEYWORDS: Fiordland Earthquake, CORS, PositioNZ network, GNSS

CORS Local-site Finger-printing Using Undifferenced Least Squares GNSS Phase Residuals

Lennard Huisman (1)
Department of Spatial Sciences, Curtin University of Technology, Australia
Tel: +61 8 9266 2218, Fax: +61 9266 2703, Email: l.huisman@curtin.edu.au
Hans van der Marel (2)
Delft Institute of Earth Observation & Space Systems, Delft University of Technology, The Netherlands
Tel: +31 15 278 4907, Fax: +31 15 278 3711, Email: h.vandermarel@tudelft.nl
Peter Teunissen (3)
Department of Spatial Sciences, Curtin University of Technology, Australia
Tel: +61 8 9266 7676, Fax: +61 9266 2703, Email: p.teunissen@curtin.edu.au
Delft Institute of Earth Observation & Space Systems, Delft University of Technology, The Netherlands
Tel: +31 15 278 3546, Fax: +31 15 278 3711, Email: p.j.g.teunissen@tudelft.nl

CORS local-site dependent effects, such as multipath, can be separated from atmospheric delays by stacking undifferenced least squares residuals of a network processing over a period of two to three weeks. In the case of double difference processing an extra step is required in order to compute the undifferenced residuals, which are mathematically equivalent to the residuals that would have been obtained from undifferenced processing. Analysing the undifferenced phase residuals at a single site can reveal azimuth and elevation dependency of the residuals. Expressed in the form of an azimuth and elevation depended map, a so-called multipath map, the undifferenced residuals form a finger-print for a local-site. Local-site finger-prints are estimated from the undifferenced phase residuals in this contribution for the new installed GNSS sites in Western-Australia of the AuScope/Landgate CORS network. Different time periods are used to give insight into the repeatability and stability of the estimated finger-prints. Introducing the local-site finger-prints into CORS network processing does mitigate to some extend the local-site multipath and antenna effects, which results in more consistent time series of troposphere parameters and kinematic station coordinates. The technique cannot be used to replace absolute antenna calibrations, but it can be used to analyse the effect of antenna changes and detect hardware problems with the antenna.

KEYWORDS: CORS station finger-printing, multipath mapping, GNSS undifferenced least-squares phase residuals

Today's GNSS based monitoring solutions combining CORS networks, automated observations and automated processing through Trimble Integrity Manager software

Paul Drummond
Trimble Navigation Limited / New Zealand
Ph. +6439635527 (office) +64212437963 (cell) +6439635417 (fax) paul_drummond@trimble.com (email)

GNSS CORS networks are providing new opportunities for public and private sector business to offer GNSS based support to a variety of positioning needs. This paper will explore how networks and GNSS based monitoring technology advancements are combining to open new markets for positioning technology. Technology trends and business opportunities will be explored, along with the role of the surveyor in implementing this technology. These trends include the installation of active GNSS control, automation of observations and processing, and the advantages of multi-observable and multi-constellation observations. This presentation will explore the combination of existing GNSS CORS networks with project specific installations used for GNSS based monitoring. Examples will be drawn from international examples of hazard management and engineering projects where GNSS based monitoring is providing new insights. Experience is showing GNSS is able to provide a new level of comparatively high resolution data, which is providing new insight for decision makers and financial planners.

KEYWORDS: GNSS, networks, monitoring, CORS, hazards

Mobile Network Reference Station

Alan Fetherstonhaugh
Position Partners / Australia
Phone No 61 7 3717 211 Fax No 61 7 3717 2121 alanf@positionpartners.com.au
Dean Witherden
Position Partners / Australia
Phone No 61 7 3717 211 Fax No 61 7 3717 2121 dwitherden@positionpartners.com.au

Never before in our life time has the word productivity gain been used as often as it is today. Mainly because most businesses are trying to extract more dollars from equipment and personnel that they already have.

RTK Networks are a great way of doubling your output without purchasing more equipment, simply by using your existing base and rover system as two rovers.

But what happens when you move outside the area of the fixed RTK Network ?

Position Partners have been working with two solutions based on using Mobile Reference Stations which are controlled by the network software but don't actually form part of the actual RTK Network.

This presentation will demonstrate

- how we do it
- the mobile base station is setup as you would normally. The Mobile Base contacts our server and begins broadcasting the corrections via the internet over a 20 – 40km radius.
- how simple it is to use
- the connection is made either through our software or via a mobile phone depending on which solution is used
- how flexible it is
- it is designed to allow the field operator to move the base station as often as he would like
- display the expected accuracies of the two solutions

KEYWORDS: gps,rtk gps,network rtk,mobile reference station

The Namuru research receiver: a year in review

Peter Mumford
University of NSW, Australia
+612 93854189 p.mumford@unsw.edu.au
Kevin Parkinson
University of NSW, Australia
+64 9742778 kevin@dynamics.co.nz

The Namuru receiver has been used as a GNSS research tool since 2005. In that time the range of features, uses and users has increased steadily. The current Namuru hardware supports a wide range of functionality around an Altera FPGA chip with enough resources to satisfy many research directions. The reference software and baseband processor designs are open source and available from the Namuru FTP site. The Namuru Forum has become the central place for exchange of questions and solutions, helping to build a user community.

The GNSS hardware group at UNSW uses the platform to support the research of post-graduate students over a wide range of topics. The group has been active in expanding and testing Namuru functionality, and generating ideas for the next incarnation.

This paper seeks to highlight recent activities and developments on the platform at UNSW. First an overview of the current status of Namuru is provided. Examples of research on the platform follow, along with problems experienced and solutions found. It is hoped that by the end of the paper, the reader will be up to date with Namuru and inspired to explore its possibilities.

KEYWORDS: Namuru, FPGA, GNSS Receiver, Baseband processor, RF front-end.

The Future Roadmap of the Namuru Open Source GNSS Receiver

WITHDRAWN

.

Design Challenges of a Galileo E1 Correlator on the Namuru Platform

Nagaraj C Shivaramaiah
School of Surveying and Spatial Information Systems, UNSW, Australia
+61293854185(P), +61293137493(F), nagaraj@unsw.edu.au
Andrew G Dempster
School of Surveying and Spatial Information Systems, UNSW, Australia
+61293856890(P), +61293137493(F), a.dempster@unsw.edu.au

This paper details the design modifications required to receive and process Galileo E1b and E1c signals on the Namuru platform along with the existing GPS L1 C/A correlator. Modifications starting at the lowest level module in hardware up to the acquisition and tracking loop algorithms in the software are explained with the realization techniques. Even though the major differences are in obtaining the local code and sub-carrier, there are several challenges which are encountered in building a complete Galileo correlator. Some of these include the E-P-L shift register clock generation, code phase measurement generation, accumulator bit-width, handling B and C signals, code delay and Doppler programming during the acquisition etc. In addition, due to the code length, code search step and integration time requirements, search time for each Doppler bin is increased compared to the GPS L1 C/A case, which is reduced by parallel search of the frequency bins with different channels. The tracking is implemented in two stages, first to find the phase of the secondary code and then to look for the data. The E1b and E1c interfaces from the baseband hardware to the NIOS processor are kept independent so that the software has the flexibility in choosing the acquisition and tracking algorithms. Finally, the resource usage and the results of acquisition and tracking from the GIOVE-A and GIOVE-B satellites are presented.

KEYWORDS: Galileo E1, Namuru, Correlator, FPGA

An Integrated Diversity Switching GPS Receiver for Sounding Rocket Missions

Andreas Grillenberger (1,2), Rodrigo Rivas (1)
(1) German Aerospace Center (DLR),
German Space Operations Center (GSOC), D-82234 Wessling, Germany
Tel +49 8153 282444, Fax +49 8153 281450, andreas.grillenberger@dlr.de
(2) Space Systems Engineering,
Delft Institute of Earth Observation and Space Systems (DEOS)
Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands

GPS is widely used on sounding rocket missions for providing position, velocity and timing information for onboard control systems and experiment payloads. The spin stabilisation of many sounding rockets allows only one antenna fitted in the nosecone to give a reliable GPS performance. If the nosecone is not available for antenna placement due to experiment or vehicle restrictions, two different methods are currently used.

Wrap-around antennas do have an almost spherical field of view and provide an uninterrupted view of the GPS satellites. These antennas have to be adapted to each launch vehicle which results in high non-recurring engineering costs and high unit prices.

The common method for cost sensitive missions is the use of two or more antennas connected to a power combiner to produce an omni-directional field of view. This approach leads to destructive interference in certain directions and limits the maximum spin rate.

The paper presents a GPS receiver which uses multiple antennas and a diversity algorithm to eliminate the problems encountered with RF power combiners. The signal power of each antenna is constantly evaluated and used as an input into the diversity algorithm. The digital intermediate-frequency data is then combined and then subsequently used to calculate the PVT solution.

The limited performance of embedded systems poses restrictions on the complexity of the diversity algorithm. A selection combining approach is implemented in the Namuru GNSS receiver. A specialised FPGA hardware has been developed to take care of signal correlation and power calculation for each antenna. Special care is taken to ensure a correct demodulation of the navigation data.

Testing has been conducted using a two channel Spirent GSS7700 GPS simulator as well as on a 432mm diameter rocket structure mounted on a turning table. Spin rates of up to 4Hz have been successfully tested in simulation and 3Hz in field testing. The tests have shown the ability of the receiver to acquire satellites, decode navigation data and provide a PVT solution even at high spin rates. It has further been demonstrated that a continuous tracking of satellites is achieved during realistic spin rate profiles. The simulator and open sky tests are compared with a traditional two antenna power combiner and discussed in this paper.

KEYWORDS: Antenna Diversity, Spinning Vehicle, Sounding Rockets

---

RF Front-End Design for Full Constellation SDR Based GNSS Receivers

Yacine Adane and Izzet Kale
School of Electronics and Computer Science,
Applied DSP and VLSI Research Group
University of Westminster, London, UK
Tel +44(0)20 7911 5165/5157 Fax Tel +44(0)20 7911 5089
Email: y.adane@wmin.ac.uk and kalei@wmin.ac.uk

The diversity of the GNSS signals that will be available in the future requires from the new generation of receivers the capability of processing multiple frequencies and diverse modulation schemes. Obviously the superheterodyne architecture can hardly meet the requirement of the new GNSS standard. Previous studies have proposed innovative architectures for multi-frequency GNSS receivers combining bandpass sampling based front-ends with a Software Defined Radio (SDR) back-end.

This paper presents a fully integrated solution for multi-frequency GNSS front-end compatible with SDR applications capable of processing the whole GNSS bandwidth in real-time. The key elements of the design are: high speed A/D, low jitter clock system, high gain amplifiers and dually diplexed microstrip filters. The first stages are formed of low noise and high gain amplifiers that have the function of elevating the received signals from the noise floor to the saturation level of the A/D. The amplified signal is selectively filtered with high Q microstrip filters based on miniaturised cross-hairpin resonators. The design technique for the filters is based on a unique architecture that furnishes custom, low cost and highly integrated filters. The gain blocks are formed of the amplifiers and the filters are interfacing with the analogue input of the A/D. The bandwidth and the conversion speed characteristics of the A/D deployed makes it ideal for GNSS signal digitalisation

with the bandpass sampling techniques. The clock for the A/D comes from a “jitter cleaner” device that uses low cost oscillators to generate a “low jitter” system clock. The clock speed can be reduced by a factor of 2 thanks to the interleaving properties of the A/D. The digital outputs of this front-end can easily interface with an FPGA or a DSP making it a convenient and flexible solution that is compatible with SDR based receiver.

KEYWORDS: Bandpass Sampling, High Speed A/D, Software Defined Radio, Cross Hairpin Filters, Jitter Cleaning Device.

A Wireless Indoor Localisation Network – System Introduction and Trial Results

Mark Johnson
CSIRO ICT Centre/Australia
+612 9372 4628, mark.johnson@csiro.au

WASP (Wireless Ad-hoc Self Positioning) is a mobile wireless localisation network, which has been designed to operate in complex indoor environments which are subject to significant multipath problems. Its original design was based on a desire to allow the flexible development of algorithms and concepts for localisation, using standard chips to keep costs as low as possible. The basic architecture uses a standard commercial WLAN chip, as well as FPGA and DSP devices to produce a compact wireless node with a mixture of localisation and networking functionality. Two versions of the node exist: a general purpose version; and a very compact version for personal use. The core functionality is identical, with differences based on extensibility and battery life.

To date the system has produced effective positioning in underground and open cut mines, industrial and commercial buildings, and indoor sports venues. Positional accuracy ranges from 0.15 metres in outdoor environments, to about 1 metre in hostile indoor applications. The ongoing development is based on trials for external customers in challenging real world environments. Current work is proceeding on technology upgrades, algorithm improvements, cooperative localisation and inertial and other augmentation. This paper will present a basic system overview; some results from current trials; and some of the ongoing development work on the system.

KEYWORDS: Wireless sensor networks, radio localization and tracking, cooperative localisation, inertial navigation.

Server-side spoofing and detection for Assisted-GPS

Neil Harper
Andrew Network Solutions Asia-Pacific, Australia
Ph: +61 2 42212974 Fax: +61 2 42212901 Email: Neil.Harper@andrew.com
Martin Dawson
Andrew Network Solutions Asia-Pacific, Australia
Ph: +61 2 42212992 Fax: +61 2 42212901 Email: Martin.Dawson@andrew.com
David Evans
Andrew Network Solutions Asia-Pacific, Australia
Ph: +61 2 42212929 Fax: +61 2 42212901 Email: David Evans@andrew.com

A Location Server (LS) is a network node that provides GPS assistance data to an Assisted-GPS (A-GPS) capable handset. The handset uses the assistance data to lock onto satellites much faster than if it had no assistance, and it also allows the handset to lock onto significantly weaker signals. That is, it significantly reduces the Time-To-First-Fix (TTFF) and increases the yield. In handset-assisted mode, the LS also calculate the location of the handset using measurements from the handset and the network.

The LS requires the handset to provide true and accurate measurements (and not false ones) in order to calculate an accurate location. The integrity of the resulting location is critical because it may be used by emergency services operators to find an injured person, or to provide value-added based services. One example is when the attacker fraudulently gains access to a broadcast that is limited to a particular set of geographically located users.

The aim of the spoofer (or attacker) is to convince the LS to provide the location that the attacker desires. The attacker does this by falsifying (or spoofing) the measurement data such that the location that is calculated on the LS is effectively predetermined by the attacker.

Spoofing research has been focussed on detecting false radio frequency signals arriving at the GPS receiver front-end and also authenticating location results provided to a third party. This paper however, discusses the effect of spoofed measurements being provided to the position calculation function (PCF) which is embedded in the LS, remote from the handset. Another potential application for this research is on the interface between the components that make the satellite measurements and the components that calculate the location such as exist in a software GPS receiver.

This paper discusses ways that the LS can be spoofed and the countermeasures to it. Some results of spoofing a naïve server are provided. This includes spoofing the location locally (suburb), regionally (state), nationally and internationally.

The paper then discusses methods that the server can use to protect itself from spoofers and demonstrates the effectiveness of the methods experimentally on different scales.

KEYWORDS: Assisted-GPS, Anti-spoofing, GPS Assistance.

Assisted-GNSS Performances on Embedded Systems Solutions

Paolo Mulassano
ISMB/NAVSAS/ITALY
paolo.mulassano@ismb.it
Fabrizio Dominici
ISMB/NAVSAS/ITALY
fabrizio.dominici@ismb.it
Antonio Defina
ISMB/NAVSAS/ITALY
antonio.defina@ismb.it

Assisted-GNSS following the SULP (Secure User Plane Location) approach is rapidly growing in importance due to the increased capabilities of generic embedded systems, due to the evolution of mass-market GNSS receivers and due to the availability of SUPL servers at the COM operators level. Generally speaking A-GNSS techniques have been developed to improve sensitivity of the SIS (Signal In Space) reception and reduce TTFF (Time To First Fix). The main idea is to provide assistance data generated by a reference (and static) receiver through a wireless network (GPRS or WiFi) to client GNSS terminals. For such reasons A-GNSS can be use in case of frequent power on and off or in case of shadowed (light indoor) environments.

This paper reports the experiences of the NavSAS Group in the field of Assisted-GNSS within a on-going cooperation among ISMB and CSIRO on GNSS technologies Australian Commonwealth Scientific and Research Organization (CSIRO) tailored to the mining sector.

R&D on A-GNSS results to be difficult due to the need of key HW+SW elements: assistance server (SUPL compliant), a SW capable to log assistance data, availability of a relatively open GPS receiver capable to apply assistance messages, a SW capable to control all the operations and all the raw data of such GPS receiver.

The NavSAS group developed a specific HW+SW platform named SAT-SURF that can be seen as a sort of extended evaluation kit having the possibility to mount GPS receiver of different manufacturers with a GSM modem. The innovation is in the capability of logging and exporting all the GPS raw data and the Assisted-GPS messages in various output formats including Matlab® and Excel®.

This tool has been extensively tested with the support of Telecom Italia that provided connection to its assistance server.

The final paper will show the impact of all the assistance parameters in the position computation proving the effectiveness of the technology directly on embedded system (that are today one of the key markets for GNSS).

KEYWORDS: Assisted-GNSS, Time To First Fix, assistance messages, embedded systems.

Development of AuScope CORS in New South Wales

Thomas Yan, Russell Commins
Survey Infrastructure and Geodesy, Land and Property Information
Department of Lands, Bathurst NSW 2795, Australia
Phone +61 2 6332 8389 Fax +61 2 8258 7555 Email Thomas.Yan@lands.nsw.gov.au

As part of the National Collaborative Research Infrastructure Strategy (NCRIS), the NSW government through its Department of Lands is working with the federal government to improve the nation's geodetic infrastructure. The $15.8 million funding allocated to the AuScope Geodetic Framework which is part of NCRIS includes the provision of 100 new Continuously Operating Reference Stations (CORS), ten of which will be located in New South Wales. Lands is building these NSW AuScope stations and will also take the roles of operator and custodian. This presentation outlines both the current development process and future operational phase undertaken by Lands. Various challenges such as scouting for possible sites, land acquisition, system design, site construction and data distribution are highlighted.

KEYWORDS: AuScope, GNSS reference stations, CORSnet-NSW, geodesy, NCRIS

A comparison of the VRS and MAC principles for network RTK

Volker Janssen
NSW Land and Property Management Authority, Bathurst NSW 2795, Australia
Tel: +61-2-63328426, Fax: +61-2-63328479, Email: Volker.Janssen@lpma.nsw.gov.au

The Network Real-Time Kinematic (NRTK) GPS and GNSS technology is increasingly being utilised for a wide range of surveying and mapping applications, providing users with instant and highly accurate position information over distances of several tens of kilometres. This paper reviews the principles behind the two prevalent NRTK methodologies currently available, the Virtual Reference Station (VRS) approach and the Master-Auxiliary Concept (MAC). The inherent differences are outlined, and the two concepts are compared from both the user's and the network operator's perspective. While both methods are supported by the major GNSS equipment manufacturers and deliver positioning results at the same accuracy-level, there are significant differences in regards to the distribution of processing load, correction data transparency, legal traceability and required bandwidth. Several CORSnet-NSW sites are used to empirically determine the average bandwidth required for NRTK operation under typical conditions based on differently sized networks ranging from 3 to 9 reference stations. While the bandwidth required for MAC is significantly larger than for VRS, particularly for large cells, results show that it can be readily supported by common radios.

KEYWORDS: Network RTK, VRS, MAC, GNSS, CORS.

Managing real-time GNSS data in CORS network: an operator's perspective

Thomas Yan
Survey Infrastructure & Geodesy, Land & Property Information
Department of Lands, Bathurst NSW 2795, Australia
Phone +61 2 6332 8389 Fax +61 2 8258 7555 Email Thomas.Yan@lands.nsw.gov.au

Real-time is now the default mode of operation in modern CORS networks today. As GNSS observation data are produced by multiple sensors in the network, they need to be disseminated immediately to various types of users. In some cases, further processing is carried out before the data are passed on to users. These users present various differences in their requirements, applications, access methods and locations. To achieve the best performance, it is essential that important aspects of the real-time data flow are understood and managed correctly. This paper provides an overview of the management of real-time GNSS data collection, processing and distribution in a CORS network. Issues such as choice of data formats and protocols are examined along with the latest examples and test results drawn from CORSnet-NSW and other CORS networks. Current challenges and future trends related to development in GNSS technology and packet-switched communication technology are also discussed.

KEYWORDS: real-time GNSS, CORS network, NTRIP, RTCM, Internet

CORSnet-NSW: Delivering a state-of-the-art CORS network for New South Wales

Adrian White, Thomas Yan, Volker Janssen, Kerin Yates
Land & Property Information
NSW Department of Lands, Sydney NSW 2000
Phone: +61 2 8258 7521 Fax: +61 2 9233 4454 Email: Adrian.White@lands.nsw.gov.au

Following the successful deployment and operation of the SydNET continuously operating reference station (CORS) network in the Sydney metropolitan region, Land and Property Information (LPI) is committed to expanding the network to cover the entire population of New South Wales. LPI has committed up to seven and a half million dollars for capital investment in the Survey Infrastructure Improvement Project – the majority of which will be invested in the CORS network – plus additional funds to operate the network. A strong team of eight technical and customer support staff was formed early this year to handle the development and operation of the network as well as the introduction of user fees. A new network name, CORSnet-NSW was announced in June to reflect the new effort. With 22 sites currently operational, the team aims to expand the network to 70 sites within the next five years.

Concluding a competitive and comprehensive tender process, a contract was awarded in June 2009 to deliver LPI with VRS^{3}Net, the latest generation of CORS network management software from Trimble Navigation. The deployment of VRS^{3}Net in CORSnet-NSW will significantly enhance the range and quality of services that LPI can provide to its customers. LPI aims to integrate VRS^{3}Net with its existing accounting and delivery systems, which is a first for this system. Currently, fully-fledged network control centres are being built at the Department of Lands' data centres in Sydney and Bathurst. Once completed, these control centres will provide a fully redundant network with future-proof capabilities for many years to come.

This new infrastructure will also enable a wide range of research projects in the areas of geodesy, surveying, positioning, navigation and telecommunications. LPI will be involved in research on long-term site monitoring, datum transformation, network-RTK algorithms and GNSS protocols in collaboration with universities and other government agencies.

KEYWORDS: CORS network, Network RTK, GNSS reference stations, surveying, geodesy

The Galileo E5 AltBOC: Understanding the Signal Structure

Nagaraj C Shivaramaiah
School of Surveying and Spatial Information Systems, UNSW, Australia
+61293854185(P), +61293137493(F), nagaraj@unsw.edu.au
Andrew G Dempster
School of Surveying and Spatial Information Systems, UNSW, Australia
+61293856890(P), +61293137493(F), a.dempster@unsw.edu.au

The Galileo E5 signal is by far the most sophisticated signal among all the signals used for Global Navigation Satellite System. This tutorial paper explains the Galileo E5 signal structure from the basics. With four codes modulated onto the two phases of orthogonal sub-carriers, the signal occupies a wide bandwidth of around 50 MHz (first two main lobes). The constant envelope modulation feature makes it more different from both the extremes of sinusoidal and binary signal types. Transmitted signal equations in the time domain, the constant envelope AltBOC modulation, frequency spectrum, autocorrelation function and the pre-correlation SNR details are provided.

KEYWORDS: Galileo E5, AltBOC, power spectral density, signal structure

How Quadrature Bandpass Sampling can be used in GNSS Receivers

Andrew G Dempster
School of Surveying and Spatial Information Systems,
University of New South Wales, Australia
+61 2 93856890 (T), +61 2 93137493 (F), a.dempster@unsw.edu.au

This is a non-refereed presentation that examines the use of *quadrature bandpass sampling* (QBPS), reviewing several of the results recently presented in [1]. Like bandpass sampling (BPS), this technique allows signals with a high frequency carrier to be sampled at a rate not less than twice the signal bandwidth. The actual available frequencies for sampling are shown to many more than for bandpass sampling. There are three restrictions, none of which can be breached when selecting sampling frequencies for bandpass sampling. For quadrature bandpass sampling, one of these may be breached. Examples of multi-frequency GNSS receivers are used to show that not only can QBPS generally be sampled using a lower minimum frequency than for BPS, but at frequencies above the minimum, there are far more choices when using QBPS.

[1] Andrew G Dempster, “Quadrature Bandpass Sampling Rules for Single- and Multi-Band Communications and Satellite Navigation Receivers”, accepted for publication in IEEE Trans Aerospace and Systems

KEYWORDS: Sampling, bandpass sampling, quadrature sampling, Nyquist.

Doppler Collision and cross correlation interference in GPS receivers

Asghar Tabatabaei Balaei
University of New South Wales, Sydney, Australia
Ph: +61 2 9385 4202, Fax: +61 2 9313 7493, asghart@unsw.edu.au
Dennis M Akos
University of Colorado Boulder
Ph: (303) 735-2987dma@colorado.edu

Global Positioning System (GPS) receivers use Code Division Multiple Access (CDMA) modulation. Although this modulation is immune to interference, cross correlation interference is still a threat to this system. In the situation when the difference between the Doppler frequencies of the two satellite signals is within the bandwidth of the receiver tracking loop, cross correlation has a unique behaviour. In this situation, the two signals behave like multipath with respect to each other. Unlike normal cross correlation interference problems, this does not necessarily happen in the case of strong and weak signal. Although this situation is not too frequent in GPS satellites, it happens quite frequently in SBAS satellites. In this paper this behaviour is analytically and experimentally investigated

KEYWORDS: Cross Correlation, Doppler Collision, Relative Doppler Carrier, Multipath

How Comb Filters can be used in GNSS Receivers

Andrew G Dempster
School of Surveying and Spatial Information Systems,
University of New South Wales, Australia
+61 2 93856890 (T), +61 2 93137493 (F), a.dempster@unsw.edu.au

This is a non-refereed presentation that examines the use of *comb filters* in GNSS receivers, reviewing some of the discussion recently presented in [1]. Because the GPS L1 C/A code signal has a spectrum made up of lines regularly spaced at 1kHz intervals, the use of comb filters, which have regularly spaced pass- or stop-bands, would on the face of it seem a logical step. It is shown, however, that each satellite channel would require its own comb filter, and that it can help with the speed of acquisition of weak signals in a sequential acquisition algorithm. It may also assist in the code tracking loop. There are some applications, such as search engines and FFT acquisition, where comb filters give little or no benefit.

[1] Andrew G. Dempster, “Use of comb filters in GPS L1 receivers”, GPS Solutions, vol 12, no 3, July 2008, pp179-185

KEYWORDS: Sampling, bandpass sampling, quadrature sampling, Nyquist.

The Benefits of High Accuracy Positioning Services for Victorian Agriculture, Mining and Regional Industries

James Millner, Peter Oates, Lynne Fairbrother and Jacqueline LeLievre (1)
(1) Spatial Information Infrastructure
Department of Sustainability and Environment
Level 13 Marland House
570 Bourke Street Melbourne Victoria 3000
james.millner@dse.vic.gov.au

Victorian government Global Navigation Satellite System (GNSS) positioning infrastructure Vicmap Position - GPSnet is currently being expanded to provide real-time solutions from a network of Continuously Operating Reference Station (CORS) across the entire state. When finished in 2011 it is expected that Victorian agriculture, mining and regional industries will benefit from the high accuracy positioning services supplied by commercial applications through Vicmap Position - GPSnet.

This presentation will review the development of commercial grade positioning infrastructure and provide an update on the Positioning Regional Victoria (PRV) project. The economic and environmental benefits to agriculture, mining and rural industries will be quantified with Control Traffic Farming (CTF) used as a case example. A model for Licencing data through Value Added Reseller (VAR) agreements will be demonstrated and the future challenges for pricing national data-sets discussed.

KEYWORDS: Economic Benefits, High Accuracy Positioning Services, Control Traffic Farming (CTF), Global Navigation Satellite System (GNSS), Continuously Operating Reference Station (CORS).

Communication Infrastructure Study for Precise Positioning Services in Regional Queensland

Charles Wang
Queensland University of Technology, Australia
+61 7 3138 1963, cc.wang@qut.edu.au
Yanming Feng
Queensland University of Technology, Australia
+61 7 3138 1926, y.feng@qut.edu.au
Matt Higgins
Department of Environment and Resource Management
+61 7 3896 3754, Matt.Higgins@derm.qld.gov.au
Mark Looi
Queensland University of Technology, Australia
+61 7 3138 5114, m.looi@qut.edu.au

Providing precise positioning services in regional areas to support agriculture, mining, and construction sectors depends on the availability of ground continuously operating GNSS reference stations and communications linking these stations to central computers and users. With the support of CRC for Spatial Information, a more comprehensive review has been completed recently to examine various wired and wireless communication links available for precise positioning services, in particular in the Queensland regional areas. The study covers a wide range of communication technologies that are currently available, including fixed, mobile wireless, and Geo-stationary and or low earth orbiting satellites. These technologies are compared in terms of bandwidth, typical latency, reliability, coverage, and costs. Additionally, some tests were also conducted to determine the performances of different systems in the real environment. Finally, based on user application requirements, the paper discusses the suitability of different communication links.

KEYWORDS: Precise Positioning, Communication, RTK, Regional QLD

GNSS + CTF = high performance for agricultural cropping systems

Dr Don Yule
CTF Solutions/Australia
+617 38710359 (Phone), +617 38710356 (Fax), don@ctfsolutions.com.au

The presentation will describe the current and future developments in agriculture from controlled traffic farming (CTF) systems and GNSS. CTF systems involve permanent wheel tracks for load bearing wheels for efficiency and compaction control; zero tillage for soil health, increased infiltration and erosion control; planned farm and paddock layouts for efficiency and runoff/waterlogging control; spatial technologies for location, performance measurement and efficiencies; and continuous improvement for productivity, profitability and sustainability.

GNSS provides the accurate spatial footprint, guidance and auto-steer, and topography measurement, and when linked with other tools allows automated measurement of yield and protein, crop, soil and machine properties, and automated applications of inputs such as chemicals, ameliorants and fertilisers.
GNSS ensures high quality CTF and the spatial footprint ensures other spatial technologies, such as remote and proximal sensing and yield monitoring, can be accurately analysed in GIS. This too can be automated.

There is now an estimated 1 million hectares of cropping in Australia with CTF and GNSS. CTF and GNSS have provided agriculture with triple bottom line benefits - major increases in production (some farmers have doubled yields) and profit, and major decreases in wind and water erosion, greenhouse gas emission, time to farm, fuel, inputs and machinery use and waterway pollution.

Consultants for the CRCSI have reported benefits to the national economy of $ billions each year.

An integrated national GNSS and Internet service is needed to provide the basic services to agriculture efficiently and effectively at affordable costs. This will revolutionise cropping and take rural communities into the modern age. Cropping needs updating of professional services and a breakaway from its conservative culture. The benefits to rural communities are critical to ensure provision of all necessary services to agriculture. CRCSI could be a major driver of the revolutions.

KEYWORDS: GNSS, controlled traffic farming, rural communities, national economy, applied spatial technologies.

Performance Evaluation of AHRS Kalman Filter for MojoRTK System

Yong Li
School of Surveying & SIS, UNSW, Sydney 2052
Tel: 02 9385 4173, Email: yong.li@unsw.edu.au
Mahmoud Efatmaneshnik
School of Surveying & SIS, UNSW, Sydney 2052
Tel: 02 9385 4190, Email: mahmoud.e@unsw.edu.au
Anthony Cole
School of Surveying & SIS, UNSW, Sydney 2052
Ph: 02 9385 4185, a.cole@student.unsw.edu.au
Andrew G Dempster
School of Surveying & SIS, UNSW, Sydney 2052
Ph: 0 2 9385 6890, a.dempster@unsw.edu.au

The GNSS/INS (Global Navigation Satellite System/Inertial Navigation System) systems have found widespread usage in industry especially in automated agriculture. These systems produce high frequency attitude solution for mobile agents. The MojoRTK, a product of Leica™, is based on integration of GPS and MEMS inertial sensors, and utilises a survey grade L1/L2 GPS antenna in addition to another L1 GPS antenna. A new algorithm based on loosely coupled GNSS/INS integration has been developed at the University of New South Wales (UNSW) for the MojoRTK known as AHRS (Attitude and Heading Reference System). The advantage of the AHRS is that it takes inputs from a single survey grade L1/L2 antenna, eliminating the need for the previous two antenna system. The initial analysis shows that the two systems (AHRS and old MojoRTK) have close and comparable performance.

In this paper we use a tactical grade GNSS/INS system known as SPAN (Synchronous Position, Attitude and Navigation), a commercial product of NovAtel™, as the reference system to compare the attitude solutions from AHRS and old MojoRTK algorithms. A test bed including SPAN and MojoRTK is installed on a small electronic car. The vehicle is driven in the UNSW Kensington Campus and the attitude data is collected from the SPAN and from the MojoRTK simultaneously. The AHRS Kalman Filter solution is derived in a post processing procedure by using the recorded L1/L2 GPS and the MEMS inertial sensors data on the log files of the Mojo console. The performance of the AHRS algorithm is then detailed, by extracting the time series of the errors in Yaw, Pitch and Roll solutions relative to the reference SPAN system. We conclude that the new AHRS is a capable replacement for the original attitude algorithm.

KEYWORDS: GPS/INS, Loose integration, Automated Guidance Systems, Kalman Filter.

Impact of Water Vapour Radiometer Measurements on the Determination of GPS Baseline Length and Height

Chuan-Sheng Wang, Yuei-An Liou, Kefei Zhang, Ta-Kang Yeh and Suqin Wu
School of Mathematical and Geospatial Sciences, RMIT University, Australia
+61-3-99253272 / e80147@ems.rmit.edu.au

Global Positioning System (GPS) has revolutionised the practice of surveying and mapping due to rapid technology advancement and it has been widely used in a vast variety of areas where rapid and effective positioning is required, such as surveying and mapping and location-based services. The improvement of GPS positioning precision and algorithms has been an important research topic. One key feature of the GPS positioning is that its precision in estimated horizontal component is much higher than that of its vertical counterpart. One of the main contributing factors for the "poor" performance of the height component is the uncertainty and rapid variation of the atmospheric water vapour, and the difficulty of its modelling.

This research assesses the tropospheric effects on the determination of the GPS heights and baseline lengths using five short to medium baselines. Two approaches, namely parameter estimation and external correction, are used to correct the zenith total delay (ZTD) in the estimation. Water vapour radiometer (WVR) measurements at each of the six GPS stations are applied in the external correction approach. Test results indicate that for the short-medium range of the short baselines selected, the WVR corrections can improve the precision of the baseline determination by a few millimetres. It is also shown that effects of the WVR correction over the height component are at the centimetre level.

KEYWORDS: GPS, WVR, TROPOSPHERE, ZENITH TOTAL DELAY.

Impact of stochastic modelling on GPS height and zenith wet delay estimation

Johnny Lo
Curtin University of Technology, Australia
Phone: +61 (0) 8 9266 2704; Email: johnny.lo@postgrad.curtin.edu.au
Ahmed El-Mowafy
Curtin University of Technology, Australia
Phone: +61 (0) 8 9266 2704; Email: A.El-Mowafy@.curtin.edu.au
Nigel Penna
Newcastle University, UK
Phone: +44 (0) 191 222 8747; Email: nigel.penna@ncl.ac.uk
Will Featherstone
Curtin University of Technology, Australia
Phone: +61 (0) 8 9266 2734; Email: w.featherstone@curtin.edu.au

Most stochastic modelling techniques assume the physical correlations among the raw observations to be negligible when forming the variance-covariance matrix of the GPS observations. Such an assumption may, however, lead to significantly biased solutions. The Minimum Norm Quadratic Unbiased Estimation (MINQUE) method is an iterative technique that can be used to estimate spatial correlation among GPS measurements. Studies by previous authors have shown that MINQUE improves the accuracy and the reliability of the ambiguity resolution, and ultimately, the geodetic solution. However, its effect on the estimation of zenith wet delay (*ZWD*) is somewhat unknown. In this paper, an investigation into its impact on *ZWD*, as well as heighting, is carried out using simulated data. The results obtained from MINQUE for an observation window of five-days in static mode indicate an average improvement of 51% and 71% in the station height precision when compared against elevation-angle dependent and equal weighting models, respectively. This development, however, did not translate into better *ZWD* estimation, for which the differences between each respective stochastic model are generally at the sub-millimetre level.

KEYWORDS: Stochastic model; MINQUE; ZWD; height

Techniques for extracting the gravity frequency shift from GPS signals to determine the orthometric height

YANG Qian
School of Geodesy and Geomatics, Wuhan University, Wuhan 430079, China
Tel: +86 27 87153879; Fax: +86 27 68778825; Email: yang.q2006@gmail.com
SHEN WenBin
The Key Laboratory of Geospace Environment and Geodesy, Ministry of Education,
Wuhan University, Wuhan 430079, China
Tel: +86 27 68778857-815; Fax: +86 27 68778825; Email: wbshen@sgg.whu.edu.cn
Wan Junkun
School of Geodesy and Geomatics, Wuhan University, Wuhan 430079, China
Tel: 027-87153879; Fax: +86 27 68778825; Email: wjk2614@126.com
FENG Chen
School of Geodesy and Geomatics, Wuhan University, Wuhan 430079, China
Tel: 027-87153879; Fax: +86 27 68778825; Email:forrestgump@126.com
WANG Jinling
School of Surveying and Spatial Information Systems
University of New South Wales, Sydney, NSW 2052, Australia
Tel: +61-2-93854203; Fax: 61-2-93137493; Email: Jinling.Wang@unsw.edu.au

During the propagation of the GPS signal, its frequency changes due to the geopotential difference between the GPS satellite and the GPS receiver. The gravity frequency shift between the satellite and the receiver can be drawn from the GPS frequency observations, and consequently the gravity frequency shift between two points A and B on ground can be also determined using GPS signals. Then, based on the gravity frequency shift equation, the geopotential difference and the corresponding orthometric height difference between A and B can be determined. GPS signals contain not only the gravity frequency shift signal, but also other kinds of frequency shift noises. How to obtain the gravity frequency shift from the GPS frequency observations is the key problem in the gravity frequency shift approach. In this paper, two approaches based on the Doppler technique to draw the gravity frequency shift information from the GPS signals are provided. The simulation experiments were investigated to compare the advantages and disadvantages of the two approaches. In the simulation experiments, the ephemeris of the GPS satellite vehicle no.3 on 1 March 2006 provided by IGS and the basic geopotential information about USNO Station were used. There are two procedures in each simulation experiment: the data simulation procedure and the data calculation procedure. In the first procedure, the frequency shift observations of the GPS signal were simulated by modelling relevant frequency shifts and adding corresponding disturbing values. In the second procedure, the gravity frequency shifts were drawn from the simulated observations by different approaches, respectively. Numerical simulation results show that the second approach to realize the Doppler reduction technique is better to determine the orthometric height using GPS signals.

KEYWORDS: GPS signals, gravity frequency shift approach, Doppler reduction technique

---

A Multiple GNSS-based Orbit Determination Algorithm for Geostationary Satellites

Li Qiao
School of Surveying & Spatial Information Systems, University of New South Wales, Sydney, Australia
+61 2 9385 4174 & +61 2 9313 7493 Hl.qiao@student.unsw.edu.au
Samsung Lim
School of Surveying & Spatial Information Systems, University of New South Wales, Sydney, Australia
+61 2 9385 4505 & +61 2 9313 7493 Hs.lim@unsw.edu.au
Chris Rizos
School of Surveying & Spatial Information Systems, University of New South Wales, Sydney, Australia
+61 2 9385 4205 & +61 2 9313 7493 Hc.rizos@unsw.edu.au
Jianye Liu
School of Automation Engineering, Nanjing University of Aeronautics and Astronautics, China
+86 25 84892300 & +86 25 84895889 ljyac@nuaa.edu.cn

The application of Global Positioning System (GPS) technology to the Geostationary Earth Orbit (GEO) determination has been constrained by the poor satellite visibility and weak signal power. This situation is expected to improve when multi-constellation Global Navigation Satellite Systems (GNSS) are available in the future. This paper aims to investigate a navigation algorithm to determine the GEO state vector in real time, using multi-constellation GNSS measurements. The navigation algorithm is based on a Kalman filter where the estimated state includes position and velocity corrections to the nominal reference trajectory and

clock biases. The simulation results are presented in the paper. It is concluded that this algorithm meets the requirement for autonomous GEO satellite navigation.

KEYWORDS: Autonomous navigation, orbit determination, extended Kalman filter, spaceborne GPS.

Session 10A: Disturbances, Multipath, Interference & Ionosphere 1050-1250

Statistical analysis of early late phase for multipath detection

Omer Mohsin Mubarak
The University of New South Wales, Sydney Australia
Phone: +61 2 9385 4208 Fax No: +61 2 9313 7493 E-mail: omer@student.unsw.edu.au
Andrew G Dempster
The University of New South Wales, Sydney Australia
Phone: +61 2 9385 6890 Fax No: +61 2 9313 7493 E-mail: a.dempster@unsw.edu.au

A new variable called “Early Late Phase” (ELP) has recently been proposed for multipath detection, which may later be extended for multipath estimation (Mubarak and Dempster, 2007). This paper presents the results of computations of overall probabilities of detection and false alarm, in order to evaluate the effectiveness of ELP for multipath detection. Theoretical ELP has been computed and the distribution of ELP in the presence of normally distributed thermal noise is also determined. Assuming that it is equally probable to be affected by any multipath delay within the range of interest, the probability of occurrence of each ELP value is computed from the histogram of theoretical ELP values. A probability of detection for each value of ELP is then computed for a given C/No and ELP threshold, which corresponds to a fixed probability of false alarm. The overall probability of multipath detection is computed as the sum of products of probability of occurrence of each ELP value and the probability of multipath detection for that ELP value. This is then plotted against the C/No of the received signal for different values of the ELP threshold.

KEYWORDS: Multipath, GPS, ELP, statistical analysis.

Signal Quality Monitoring: Correlation mask based on Ratio Test metrics for multipath detection

Maurizio Fantino
ISMB/NAVSAS/ITALY
maurizio.fantino@ismb.it
Andrea Molino
ISMB/NAVSAS/ITALY
andrea.molino@ismb.it
Paolo Mulassano
ISMB/NAVSAS/ITALY
paolo.mulassano@ismb.it
Mario Nicola
Politecnico di Torino/DELEN/ITALY
mario.nicola@polito.it
Marco Rao
Università di Palermo/DIEET/ITALY
marco_rao @dieet.unipa.it

In any measurement process, the observation is error affected: calibration and careful measuring procedures can reduce the error components but are unable to completely eliminate them. The capability to monitor andto detect any disturbances on the spreading sequences transmitted by the satellites is then of primary importance.

Considering that a professional receiver takes advantage from the possibility to understand whether or not the processed signal is reliable or not, Quality Control strategy based on the continuous check of the correlation shape has to be considered as one of the core technologies within the development of this appliance.

Quality Control techniques based on a modified tracking architecture, which provides a certain number of correlator outputs, are analysed in this paper. Such outputs are used to build a metric used to monitor in real-time the reliability of the signal being tracked. In literature, several definitions of metrics can be found. The mainly used metrics are based on the following ratios: Ratio Test, Delta Test and Lambda Test. Once the test metrics built, their values are compared to predetermined thresholds during the Signal Quality Monitoring

(SQM) activity.

Although a huge amount of work on those metrics has been presented in the previous work, this paper will present a new way of operation for the threshold settings. A design criteria similar to the one applied to the acquisition blocks is here considered and deeply studied for the Ratio Test metric. A threshold mask is built around the shape of the correlation function in order to detect in real time the presence or absence of a distortion guaranteeing a desired confidence level.

The reliability of this design criterion will be proved in the paper. A simulations campaign is performed to determine and analyse the SQM techniques and their optimum parameters aim to obtain the so–called Receiver Operative Characteristic (ROC).

KEYWORDS: Quality Control, Multipath, Software Receiver.

GPS-based ionospheric tomography reconstruction to the magnetic storm on 21 August 2003 over China

Debao Wen
Department of Geodesy and Surveying Engineering, Changsha University of Science & Technology, Changsha, 410076, China
Kefei Zhang
School of Mathematical and Geospatial Sciences, RMIT University, Australia
Kefei.zhang@rmit.edu.au

The impacts of the 21 August 2003 geomagnetic storm on the ionosphere over China have been first investigated by using the so-called computerised ionospheric tomography (CIT) technique and GPS Continuously Operating Reference Stations (CORS) observations in China. Statistical comparisons are carried out to assessment reliability of the GPS-based CIT reconstruction results using the profiles obtained from ionosonde observations.

Results show that the main ionospheric effects of this storm over China are (1) the negative storm phase effect appears in F region, and (2) the positive storm phase effect occurs above F region. Key distinct features in the ionospheric structure have been revealed in the ionospheric images during the storm. This includes the ionospheric disturbances and mid-latitude troughs.

KEYWORDS: GPS, ionospheric tomography, magnetic storm, CORS.

JAMFEST – A Cost Effective Solution to GPS Vulnerability Testing

Paul H. Benshoof
746th Test Squadron, Holloman AFB, NM, USA
01 (575) 679-1769, paul.benshoof@holloman.af.mil
1Lt Nickolas Uptain
746th Test Squadron, Holloman AFB, NM USA
01 (575) 679-2011, nickolas.uptain@holloman.af.mil

From January 12-16, 2009, the 746th Test Squadron, located at Holloman Air Force Base (AFB), New Mexico (NM), planned and executed an innovative Global Positioning System (GPS) jamming program at White Sands Missile Range, NM. This program, known as JAMFEST, was aimed at providing low cost, realistic, GPS jamming scenarios for testing GPS-based navigation systems, as well as training personnel in unique GPS denied environments. Through sponsorship from the GPS Wing, the Joint Navigation Warfare Center (JNWC), and the 46th Test Group, the 746th Test Squadron was able to provide this diverse testing and training opportunity at a significantly reduced cost to each participant.

During JAMFEST, the 746th Test Squadron hosted multiple simultaneous, yet very dissimilar customers, including multi-service Department of Defense (DoD) agencies, several defense contractors, and civil organizations. Their objectives ranged from training personnel on the effects of GPS jamming to characterizing the performance of prototype advanced anti-jam technologies against operationally realistic threats. To accomplish these goals, participants drove, flew, or walked through diverse jamming scenarios specifically tailored to stress the systems under evaluation.

This presentation details JAMFEST strategies and conduct, as well as participant objectives and future JAMFEST activities.

KEYWORDS: JAMFEST, GPS, Jamming, Vulnerabilities, Holloman

A Study of Collocation Criteria of GNSS COSMIC Radio Occultation and Radiosonde Comparisons

Kefei Zhang, Erjiang Fu and Xiaohua Xu
School of Mathematical and Geospatial Sciences, RMIT University, Australia
Kefei.zhang@rmit.edu.au
Yuei-An Liou
Center for Space and Remote Sensing Research (CSRSR), National Central University, Taiwan
John Le Marshall and Yuriy Kuleshov
Bureau of Meteorology, Australia

Monitoring and predicting meteorological conditions with a high accuracy and reliability is a difficult task due to the extremely dynamic nature of our weather systems. This is particularly challenging for the countries in the Southern Hemisphere such as Australia, with much lower number (and density) of weather observation stations compared to the countries in the Northern Hemisphere. Recently, a new atmospheric observation technique, Global Navigation Satellite System (GNSS) radio occultation (RO) for Meteorology, has emerged as an alternative technique for acquiring the Earth's atmospheric characteristics. Recent research has demonstrated the great potential of the new technique to meteorological applications, such as global climate monitoring and numerical weather prediction. Thousands of high-quality globally distributed vertical profiles of refractivity, temperature and water vapour have been obtained on daily basis using the recently launched COSMIC LEO satellites. It is anticipated that GNSS RO technique will play an important role in meteorological studies. Evaluation of the quality of the new data using independent sources of measurements (e.g. reference observations obtained by radiosonde) is of great importance and consequently the requirement for collocation of the two different datasets (GNSS RO data and Radiosonde data) is essential for reliable comparisons.

This study investigates the impacts of different collocation criteria in evaluation studies. The COSMIC data and collocated radiosonde data from the 38 Australian weather observation stations for December 2006 and June 2007 are used in this study. Detailed results of refractivity and its analysis are presented.

KEYWORDS: GPS, COSMIC, Radio occultation, Climate change, NWP

Array Manifold Calibration Using GPS Sounding Source

Joy Li (1)
School of Electrical & Electronic Engineering / The University of Adelaide / Australia
Ph: (+618) 83038314 Fax: (+618) 83034360 jli@eleceng.adelaide.edu.au
Matthew Trinkle (2)
School of Electrical & Electronic Engineering / The University of Adelaide / Australia
Ph: (+618) 83034708 Fax: (+618) 83034360 mtrinkle@eleceng.adelaide.edu.au

This paper considers the use of GPS satellites to automatically calibrate the array manifold of a two element antenna array mounted on a model aircraft. The GPS satellites are used as sources of opportunity to measure the phase shifts between the antennas as a function of incidence angle. The array manifold is also measured in an anechoic chamber and the use of different antenna elements such as patches and helix antennas are considered as well as the impact of the model aircraft air-frame on the calibration result. The implications of the array manifold calibration results on DOA estimation techniques are also discussed.

KEYWORDS: GPS, Antenna Array, Calibration, DoA estimation.

Detecting Object Movement through the use of Two GNSS Satellites

Yong Khing Tan
The University of New South Wales, Australia
yk.tan@student.unsw.edu.au
Craig A. Scott
Seeker Wireless Pty Limited, Australia
Craig.Scott@seekerwireless.com
Andrew G. Dempster
The University of New South Wales, Australia
a.dempster@unsw.edu.au

Monitoring using GNSS technology has played a very important role in tracking all manner of items, ranging from dangerous firearms to cash, and to the tracking of stolen vehicles. In different environments there will be times when the surroundings pose problems to the GNSS receiver, such as in the case where shipping containers are being stacked on top of each other, thus limiting the view of the receiver to the open sky.

This paper introduces a technique for detecting whether an object has moved from its desired location using measurements from two satellites. This system uses a Time Difference of Arrival (TDOA) measurement obtained from the two range measurements and compares it with the theoretical value calculated using the ephemeris data. By taking the difference of the measured and the calculated TDOA values we are able to obtain a residual in which a probabilistic approach is used to assess if an object has moved from its desired location.

KEYWORDS: GNSS; Object Movement; TDOA; 2 satellites; object tracking; fewer than 4 satellites

GNSS for Closed Loop Control of Space Manipulators

Giovanni B. Palmerini (1)
DIAA Dipartimento di Ingegneria Aerospaziale e Astronautica/ Università di Roma La Sapienza/Italy
Ph.+39.06.44585335/981 Fax+39.06.44585670 giovanni.palmerini@uniroma1.it
Paolo Gasbarri (2)
DIAA Dipartimento di Ingegneria Aerospaziale e Astronautica/ Università di Roma La Sapienza/Italy
Ph.+39.06.44585324 Fax+39.06.44585670 paolo.gasbarri@uniroma1.it

Future space mission will be increasingly exploited by robotic manipulators to save risks and costs of human presence onboard spacecraft. The accuracy requested in such a lind of manouvres is very high and a completely autonomous control is likely to be mandatory. Feedback control loops need the knowledge of the state of the plant, usually gained in terrestrial applications by means of encoders located at the joints of the manipulator. Due to specific characteristics of space structures, i.e. the flexibility resulting from the limits on the mass to be launched, encoders are not really effective. The paper investigates the possible use of GNSS signal – and specifically of its phases - to define the kinematic state of the robotic arms during in orbit (rendez-vous, docking, grasping) operations. Limited dimensions of antennas allow for their distribution along the span of each manipulator's arm, to take into account flexibility effects. In such a way, a really accurate determination of the state of the system can be obtained, a result which should be a quite complicate achievement by other possible techniques like RF ranging or image analysis. The bandwidth granted for by GNSS receivers is suitable for orbital manoeuvres, typically slow. As a drawback, a substantial amount of computation is requested in order to perform a RTK process. Potential limitations due to multipath have to be considered. Preliminary experimental tests, performed with a two-link robotic arm moving on a limited friction table in order to validate the substantial amount of modelling and simulation work already carried out, are presented and discussed.

KEYWORDS: GNSS for Robotics, GNC (Guidance, Navigation and Control) loop, GNSS in Space, RTK.

Possibility studies of Integrated INS/RFID Positioning Methods for Personal Positioning Applications

Ming Zhu, Kefei Zhang, William Cartwright
Royal Melbourne Institute of Technology (RMIT) University, Melbourne, Australia.
telephone: +61 3 9925 3277, fax: +61 3 9663 2517
Günther Retscher, Qing Fu
Institute of Geodesy and Geophysics/Vienna University of Technology, Austria
telephone: +(43 1) 58801-12847, fax: +(43 1) 58801-12894

Precise positioning has been a challenging task in the areas of surveying, mapping, robotic movement control and especially personal navigation. To date, geodetic grade GPS systems such as *Trimble* R8, can provide a centimetre level of accuracy in real time over a large area using real-time kinematic (RTK) technique. However, the major drawbacks of the high accuracy GPS systems are expensive, not really portable and not suitable for indoor and urban canyon.

Some alternative techniques, such as the micro-machined electromechanical system (MEMS) Inertial Navigation System (INS) and the radio frequency identification (RFID) positioning technique have recently become attractive. This is because these systems meet the needs of personal guidance and tracking applications due to their indoor positioning capability, simple infrastructure requirement, portability and low cost.

In this paper, two integrated INS/RFID positioning methods have been proposed and their performances have been evaluated. Results show that both Cell-of-Origin (CoO) and fingerprinting positioning methods can provide effective positioning calibrations in the areas where GPS signals are either unreliable or not available. It shows that the integrated INS/RFID positioning techniques are generally more accurate than using RFID positioning technique alone. It is concluded that the integrated techniques can satisfy the requirements for personal guidance and tracking services in providing continuous and metre-level accuracy positions with a relatively low-cost device.

KEYWORDS: INS, RFID, Integration, Personal Positioning, GPS

Lunar Transfer Missions Navigation using GNSS Software Receivers

Filippo Rodriguez (1)
DIS - Università Roma “La Sapienza”, Italy
rodriguez@dis.uniroma1.it
Giovanni B. Palmerini (2)
DIAA - Università Roma “La Sapienza”, Italy
giovanni.palmerini@uniroma1.it

The work aims to investigate the level of achievable performance of the GNSS technique in navigating missions targeted to the Moon.

Two critical aspects arise: availability of the signal (very limited signal power at high altitudes), and dilution of precision (sources are viewed in a limited portion of the sky).

With respect to the availability of the signal, in order to recovery even faint levels, the use of software receiver techniques, integrating along extended time intervals, can help to significantly lower the threshold of the useful power to noise ratio. The substantial computation effort required is softened by the availability of long time windows due to very slow dynamics. Taking into account codeless pilot tone (e.g. Galileo), the combination of two signals (pilot and data) provides better performance than classical extended coherent integration to both acquisition and tracking tasks. Critical is the Doppler issue: in fact the lower the acquisition threshold, granted by long coherent integration, the higher is the limitation on maximum admissible Doppler. Results from numerical simulation complete this portion of the work.

The analysis of the DOP issue is based on the hypothesis of a multiple constellation receiver, and the account of secondary lobes patterns for all navigation sources. The possibility of augmenting beacon to be located on the Moon is considered to help in the most critical phases.

The aim of this second portion of the analysis is to indicate if, and up to which level, such an help is mandatory for the different kinds of possible transfer trajectories. This work should help in assessing if and how much (stand-alone or externally aided) GNSS can be actually used as an autonomous onboard navigation technique in the upcoming back-to-the moon effort.

KEYWORDS: GNSS (Space Applications), Software Receiver, DOP.

2D Barcodes for Location-Based Services

Mark Relling
New Zealand
Work Phone: (64)(3) 941-8249 Email: Rellingm@Gmail.com

I propose a free and open source system for smartphone location using 2D barcode signs. It would complement GPS in built-up and other man-made areas.

Background

- Most mobile phones now have a digital camera.
- There exist various barcode standards around the world, including 2D barcodes.
- Barcodes are designed to be read automatically by digital devices.
- Barcodes typically encode a small amount of data used for identification.
- Two main 2D barcode "open" standards: QR Code and DataMatrix.
- These 2D barcodes are already easily read by many mobile phones.
- Phone's camera takes an image of the barcode & software translates it into a short piece of digital "text" (e.g. A URL).

Proposal

My idea involves creating a physical sign of a 2D barcode that encodes the actual location coordinates of the sign itself (i.e. it would be self-referencing). Free software already exists on the internet for creating 2D barcodes. Sign is affixed at the physical location of the real world coordinates (e.g. longitude & latitude) and direction that are encoded in the sign itself.

Software to "read" 2D barcodes already exists for most smart-phones. The software would just need to be modified slightly to interpret the encoded text coordinates as geospatial coordinates (instead of, for instance, a WWW address). Coordinates can then be fed into a map system on the smartphone.

Additionally, digital cameras sold with software embedded could then "geotag" photos taken without requiring a built-in GPS chip.

Proposed international open standard

Here is an example of text decoded from a "sign" using the standard I suggest:
E.g: !,WGS84,-33.858645,151.213570,NW, 67 <CR> <LF>

Leading exclamation symbol indicates location data to follow, not a WWW address. 2nd characteristic is coordinate system being used. Then latitude & longitude. Compass direction is 5th characteristic followed by a checksum.

KEYWORDS: 2D barcode, QR Code, DataMatrix, location based services, smartphone

A Technical Design of Nationwide RTK Positioning Services Using the Current and Future GNSS Receivers and Constellations

Yanming Feng, Queensland University of Technology
y.feng@qut.edu.au
Matt Higgins, Queensland Department of Environment, Resources and Mines
matt.higgins@derm.qld.gov.au
Chris Rizos, The University of New South Wales
c.rizos@unsw.edu.au

In Australia, a nationwide GNSS-based precise positioning service is being designed as an essential layer of infrastructure to support services for machine automation in agriculture, mining, and construction, for utilities mapping and surveying, and others. Moving from the current isolated GPS-based local area Real Time Kinematic (RTK) services to a future single GNSS-based nationwide precise positioning service raises several technical challenges. It is necessary to develop an overarching technical framework that can enable mixed use of different reference GNSS receiver types, dual- or triple-frequency measurements, single or multiple systems, to provide RTK correction services to users equipped with any type of GNSS receivers. Addressing these challenges within a research project funded by Australian Cooperative Research Centre for Spatial Information, the paper discusses some implementation strategies of the framework from the point of view of network-based real-time data processing algorithms, network software architecture, CORS network architecture and system operations. The following are some results:

(1) The network-based real-time GNSS data processing problems can be formulated into two major estimation problems: dual and three carrier phase ambiguity resolution (DCAR/TCAR) on the one hand, and state estimation (SE) on the other hand. DCAR/TCAR is generalised as those real-time GNSS estimation problems for a continuously observing ground network, of large scale, based on double-differenced (DD) measurements. A general linear equation system is proposed that combines various geometry-free, geometry-based and geometry-constrained measurements. SE is generalized as those real-time estimation problems using continuous zero differenced (ZD) code and phase measurements, ambiguity-fixed DD phase measurements, as well as constraints for some state parameters at output epochs.
(2) The network-based software architecture is designed to allow for user positioning computations at different server nodes of the networks instead of on the user's device only, and can process measurements of any types: from single-, dual- and triple-frequency receivers. The network-based process system actually produces the real-time outputs, including precise ionospheric and tropospheric correction grids as well as satellite/receiver clock corrections. In addition, a Background Processing strategy is introduced, which uses advanced GNSS software, such as Bernese and GAMIT, to obtain Zenith Tropospheric Delay (ZTD) for each base station on quarterly basis. Predicted relative ZTD values are then used for improving network-based Ambiguity Resolution (AR) over long baselines or the ambiguity solution consistency check from epoch to epoch.
(3) With the generated correction grids and user RTCM data flows, the system in principle can support/enhance multi-mode operations and services in addition to the reverse RTK or server-based RTK. The existing local area Virtual Reference Stations (VRS) technique may enhance the user performance; and single-base RTK operators can extend the service radius. The server-based RTK operations can be placed at the local server nodes and/or central servers to serve any other users. The multi-mode concept is supported by using different end-user algorithms.
(4) The mix placement/use of dual- and triple-frequency receivers in the ground network is also optimized for given restrictions such as inter-station distances, candidates for reference station locations, and operational modes. Based on numerical analyses for long-range TCAR capacity and the predictability of tropospheric biases, the study suggests that triple-frequency receivers can be placed with inter-station distances that double those with dual-frequency receivers. For example, the inter-station distances between triple-frequency receivers can be doubled to 140 to 180km, while those between dual-frequency receivers being 70-90km in the same network.

Although the implementation of the above design is a long-term on-going process, the presentation will cover some numerical results obtained from can be given at this stage to demonstrate the performance of selected algorithms used in the above design and support new concepts such as the station placement with mix use of dual- and triple-frequency receivers. In general, the demonstrated superior AR performance achieved with the outlined TCAR algorithms and other experimental results directly provide the technical basis for deployment and operation of nationwide network RTK services with inter-station distances of a few hundred kilometres.

Simplified Equivalent Observation Equations for Multiple Baseline Solutions

Yunzhong Shen
Department of Surveying and Geo-informatics Engineering, Tongji University, China
Key Laboratory of Advanced Surveying Engineering of State Bureau of Surveying and Mapping, China
Tel: 086-21-65985236, Fax: 086-21-65985236 email: yzshen@tongji.edu.cn

Bofeng Li
Department of Surveying and Geo-informatics Engineering, Tongji University, China
Tel: 086-21-65985236, Fax: 086-21-65985236 email: Bofeng_LI@163.com

By using the characteristics of unit coefficients for both the satellite clock bias and the receiver clock bias parameters in the zero-differenced GNSS observation equations, we present the simplified double-differenced equivalent observation equations for multiple baseline solution in the case of each station tracking different satellites with elevation-dependent weights. In our equivalent representation, the transformation of the covariance matrix of original observables is no longer necessary and, thus the algorithm is rather convenient for programming and is efficient for computing. We also prove that the residuals are invariant in our equivalent representation with corresponding to the original equations. The numerical experiments are performed to demonstrate the computational efficiency of simplified equivalent algorithm in the different scenarios of multi-baseline solutions with tracking the different satellites. The results show that faster computational speed is always assigned to the simplified equivalent algorithm, comparing with the traditional method. In addition, the real measurements of multiple baselines from a local GPS network are carried out to show the potential of the equivalent algorithm, which will benefit the commercial or academic huge software development for GNSS data processing in the local, regional, even global network with multiple GNSS constellations.

KEYWORDS: GNSS data processing, multi-baseline solutions, equivalent representation, elevation-dependent weights

---

Wide-area sub-decimetre kinematic positioning in support of airborne LiDAR topographic surveys

Oscar L. Colombo
GEST/Goddard Space Flight Center, Code 698, Greenbelt, Maryland 20771, USA
Tel: +1-301-614-6102; Fax: +1-301-614-6522; oscar.l.colombo@nasa.gov
Volker Janssen, Glenn Jones, Shane Brunker
NSW Department of Lands, PO Box 143, Bathurst NSW 2795, Australia
Tel: +61-2-63328200; Volker.Janssen@lands.nsw.gov.au; Glenn.Jones@lands.nsw.gov.au;
Shane.Brunker@lands.nsw.gov.au
Chris Rizos
School of Surveying & Spatial Information Systems,
The University of New South Wales, Sydney NSW 2052, Australia
Tel: +61-2-93854205; Fax: +61-2-93137493; c.rizos@unsw.edu.au

Airborne LiDAR surveys produce high-resolution, very precise surface elevation models which are used for many applications in surveying and civil engineering, as well as for flood prevention and mitigation, monitoring coastal erosion and land subsidence, etc. The key to producing high quality elevation products is very precise geolocation and orientation (or “georeferencing”) of the LiDAR instrument at the times when the measurements are made, obtained with a combination of on-board GNSS and inertial sensors. The usual practice is to deploy reference GPS/GNSS land receivers in the area where the aircraft will be flying, and to obtain a precise trajectory by means of the short-baseline differential GNSS technique. This could mean installing and operating receivers at many sites during a flight mission if the area surveyed is a large one. In this talk, an example of an alternative approach will be presented: using as reference receivers those of a sparse network of Continuously Operating Reference Stations (CORS) in New South Wales, and a wide-area GNSS technique for obtaining the airplane trajectory with sub-decimetre accuracy even with baseline lengths of several hundred kilometres. This is comparable in precision and accuracy to the short-baseline method, but without the cost and logistical complications of having to deploy and operate one’s own reference receivers during a mapping mission. The presentation will be illustrated with the results of tests organised and conducted by the NSW Department of Lands, in collaboration with the University of New South Wales, in June 2009.

KEYWORDS: Wide-area positioning; kinematic positioning, airborne LiDAR; topographic surveys.

A Simplified Parameter Transformation Model from ITRF2005 to any Static Geocentric Datum (e.g. GDA94)

Richard Stanaway
School of Surveying and Spatial Information Systems,
University of New South Wales, Sydney, Australia
ph. +61 3 9486 7845 fax +61 2 9313 7493
email: richard.stanaway@student.unsw.edu.au
Craig Roberts
School of Surveying and Spatial Information Systems,
University of New South Wales, Sydney, Australia
ph. +61 2 9385 4464 fax +61 2 9313 7493
email: c.roberts@unsw.edu.au

The majority of PPP, global GNSS post-processing and RTK services (e.g. OmniStar, AUSPOS and OPUS) initially produce coordinates in either ITRF or WGS84 reference frames. Unless these services transform the coordinates into a local static geocentric datum such as GDA94 using a kinematic model, positional coordinates will also be kinematic, changing by up to several cm a year as a result of motion of the underlying tectonic plate. The precision of many GNSS systems currently in widespread use is sufficient to detect this movement over short periods of time. Unless this motion is modelled correctly, repeat surveys using the same technique over a span of a year or more will become misaligned.

This paper describes a strategy whereby ITRF or WGS84 coordinates can be transformed to a regional static geocentric datum by using a four parameter model derived from absolute rigid plate kinematic models. Within tectonically stable areas such as the Australian continent, this transformation strategy is shown to have a precision of 20 mm on decadal timescales, and is ideally suited for most surveying and positioning applications. A simplified paramaterisation from ITRF2005 to GDA94 is described as an example of how this strategy can be applied in practice.

KEYWORDS: Kinematic Datums, transformation, plate models, PPP

Using Real-time GPS data for monitoring natural hazards in New Zealand

Simon Edwards
GNS Science, New Zealand
t:+64 (0)4 570 4744 f:+64 (0)4 570 1444 s.edwards@gns.cri.nz
Nicolas Fournier
GNS Science, New Zealand
John Beavan
GNS Science, New Zealand
Nora Welch
GNS Science, New Zealand

GNS Science manages a CORS network of approximately 125 GPS receivers (including the 36 operated on behalf of Land Information New Zealand). A significant proportion of these are streaming high rate data in real-time via the Ntrip standard. Recently we have begun testing real time epoch by epoch processing as part of our on going monitoring of volcanic, tsunamigenic, landslide and seismic deformation in New Zealand. The aim of the real time GPS processing is to provide independent and supplementary data to existing real time sources such as strong motion sensors and tsunami gauges. This combination of sensors can provide crucial data in an early warning system. Here we present some of our early results and comparisons of a variety of precise point positioning and network processing strategies.

KEYWORDS: Real-time GNSS, NTRIP, Natural Hazards, Monitoring, New Zealand

---

An accuracy assessment of a GPS- enabled digital camera

Gabriel Scarmana
Spatial Science Officer
Department of Transport and Main Roads, Queensland Government, Australia.
gabriel.z.scarmana@transportandmainroads.qld.gov.au

As the consumer market embraces digital imaging, digital cameras are becoming less expensive while producing higher resolution images. This explosion in camera architecture combined with GPS technology

and consumer grade photogrammetric software can provide for noncontact, inexpensive, safe and practical measuring systems which can be used for direct geo-referencing of points of interest and 3D modelling.

This study investigates the accuracy of a measuring scheme based on a GPS-enabled digital camera (Ricoh 500SE) and photogrammetry software (PhotoModeler by Eos Systems Inc). The coordinate values of selected target points determined by this close-range photogrammetric system are compared to the coordinates of the same target points computed using a surveying total station. The target points were not chosen to satisfy the photogrammetry technique but were in fact natural targets part of a concrete noise barrier located along a busy motorway.

The results of this study showed that measurements with the proposed system differed from the more precise surveying measurements by an overall positional accuracy in x, y and z of 0.5 m. This expected accuracy result was essentially a function of the accuracy of the GPS unit and when a more accurate version becomes available and is incorporated with the camera, the accuracy should reduce to that approaching a total station. The efficiency of the GPS-enabled camera system was the important point disclosed by this study.

KEYWORDS: GPS, digital cameras, photogrammetry.

Galileo Payload Performance and Status Update

Geoff T.A. Burbidge, Gordon Robertson, Trevor J. Watson, Colin H. Mathew
Astrium Satellites, Portsmouth, United Kingdom
+44 2392 705010 (tel), +44 2392 704511 (fax), geoff.burbidge@astrium.eads.net
Maktar Malik, Martin Johansson
European Space Agency, ESTEC
PO Box 299, 2200 AG, Noordwijk, The Netherlands
+31 71 565 4079 (tel), +31 71 565 4369 (fax), maktar.malik@esa.int, martin.johansson@esa.int

The navigation payload on the Galileo satellites is at the heart of the Galileo system. The development and deployment of Galileo's navigation functionality has progressed from the Galileo In-Orbit Validation Element (GIOVE) test beds, through the build and test of the four In-Orbit Validation (IOV) payloads, and is now being completed through the contracting of the remainder of the Galileo infrastructure within the Full Operational Capability (FOC) phase.

This paper provides an overview of the Galileo payload development and the critical milestones through the respective phases of the programme. The history of the design and the development lifecycle is reviewed and the progressive enhancement in payload functionality and performance is described. The implementation of the payload is presented, illustrating the relationship and evolution between the respective GIOVE and IOV payload configurations and architectures. The key design drivers and operational requirements during each of the programme phases are recalled and described.

The in-orbit operational status and performance of the GIOVE-B payload, including the performance of the navigation signal currently being broadcasted by GIOVE-B is reported. The status of the on-ground test and verification of the IOV payload is provided. Preliminary information concerning the performance of the key IOV payload parameters is presented.

KEYWORDS: Galileo, Astrium, Payload, Navigation, Satellite

Positioning system based on communications satellites and Chinese Area Positioning System (CAPS)

Gou-Xiang Ai[1]
National Astronomical Observatories, Chinese Academy of Sciences, China
Phone : 0086-010-64888701 Fax No: 0086-010-64846485
Hu-Li Shi[2]
National Astronomical Observatories, Chinese Academy of Sciences, China
Phone : 0086-010-64807621 Fax No: 0086-010-64846485
Hai-Tao Wu[3]
National Time Service Center, Chinese Academy of Sciences.China

Chinese Area Positioning System (CAPS) based on communications satellites is principally different from 3"G" systems (GPS, GLONASS and GALILEO). Instead of using special navigation satellites in 3"G" systems, the normal constellation in CAPS is consisted of several communication satellites as a key element in positioning system, and can realize PVT functionality performance, as a result, CAPS has to solve some critical problems for positioning due to using communications satellite, they include navigation signal carrier stability in real time, insufficient transponder emission power solved by using single carrier over 36M band-width in transponder, and 3-D positioning by means of using RGEO and IGSO satellites. With more plentiful transponders in RGEO satellites, CAPS can also provide various communications services toward navigation/communications integration. The five applicable functionalities in CAPS are further developed with the addition of wide communications services, basically, it is summarized to five combination issues such as navigation and communication, navigation and high accuracy orbit determination,, navigation message and the wide/local area differential processing, alterability in respect of satellite, carrier frequency and code, as well as navigation message and barometer data, thus, CAPS can become PVT5C system with high positioning precision. In order to validate CAPS work principle and performance, a functionality demonstration system in two years had been established in order to accomplish relative validation tests costing about 20MUS$,. CAPS constellation consists of two GEO satellites at E87.5° and E110.5°, two RGEO satellites at E134° and E142° respectively, and a virtual constellation with barometer data. The static and dynamic validation tests were completed in high precision to cover on China major territory. The evaluation results are as follows: 1) Land static test, plane accuracy range: C/A code, 15~25 meters ; P

code, 5~10 meters; altitude accuracy range, 1~3 meters; 2) Land dynamic test , plane accuracy range, C/A code, 15~25 meters ; P code, 8~10 meters; 3) Velocity accuracy, C/A code, 0.13~0.3 m/s, P code, 0.15~0.17 m/s; 4) Timing accuracy, C/A code, 160ns, P code, 13ns; 5) Two way timing compared accuracy, average accuracy, 0.068ns; 6) Random error of satellite range, 10.7millimeters; 7) Orbit determination accuracy, better than 2 meters. Above measured random error is 1σ value. At present, this system with 3 GEO, 3 RGEO and 3 IGSO constellations has being established as a preliminary operation system.

KEYWORDS: Astronomy application, satellite navigation, satellite communications, astrometry, astronomic technique.

CAPS satellite navigation and communication system

WITHDRAWN

Session 11B: Organisational Issues 1350-1610

Performance Based Navigation (PBN) Implementation Plan - Australia

Mr Dirk Noordewier
Air Transport Inspector
Civil Aviation Safety Authority
+612 62171150 Dirk.Noordewier@casa.gov.au

This paper provides and overview on the progress of Australia's PBN implementation plan. It discusses Australia's PBN implementation concept, methodology and priorities and the affects of acquisition or non-acquisition of an SBAS capability on navigation in general and approach to land operations in particular.

PBN can be implemented through RNAV and RNP navigation specifications and Australia, like many regional States, must allow for wide variances in aircraft navigation capabilities across the IFR fleet. Australia has conducted an analysis of its IFR fleet and determined that:

- By implementing barometric vertical navigation through APV Baro VNAV and RNP AR APCH design criteria, Australia will be able to provide APV protection to 97% of fare paying passengers but only 15% of IFR aircraft
- By implementing barometric and augmented GNSS vertical navigation through APV Baro-VNAV, RNP AR APCH and APV I and II (SBAS) design criteria, Australia will be able to provide APV protection to 100% of fare paying passengers and 99% of IFR aircraft

Subsequently Australia's concept for PBN implementation without SBAS is:

- RNAV everywhere
- RNP where required
- APV through Baro-VNAV, and

Australia's concept for PBN implementation with SBAS is:

- RNAV everywhere
- RNP where required
- APV through Baro-VNAV and augmented GNSS

Australia's methodology for the implementation of PBN is to provide:

- RNAV specifications as the primary means of navigation and RNP as an alternate means of navigation for Oceanic and Remote Continental, Continental En-route and Terminal operations
- RNP approach specifications only for approach to land operations with GNSS as the primary means of LNAV and Baro-VNAV as the primary means of VNAV
- Should Australia acquire an SBAS then this augmentation would be used as an alternate means of VNAV

There are currently no plans of the acquisition of an Australian SBAS however Australia's PBN implementation strategy allows for navigation constructs that both include and exclude an SBAS capability.

KEYWORDS: PBN, RNAV, RNP, APV, SBAS

Strategy and change management for CORS networks in Australia

Martin Nix
Navonix consulting, Australia
Phone +61 437 013747 e-mail: martinjnix@gmail.com

CORS network infrastructure is at various stages of development around the world and in Australia, there are many initiatives at state, federal and private levels. One major study shows that a national standardised rollout of CORS infrastructure could add between $38 and $56 billion value to the Australian economy between 2008 and 2030 from just three key industries: mining, agriculture and construction. These values are additional to the estimated $73 to $134 billion added by current forms of high precision GNSS usage. Social and environmental benefits enhance the value of a national standardised CORS infrastructure. The paper will review some of the recent strategic initiatives to move from disparate jurisdiction and private networks to a standardised national network and identify benefits and risks.

Executing a strategic plan effectively requires two simultaneous management activities. The first is to prepare and articulate a strategic action plan, then project manage the parcels of work activity in line with resources and time lines. The second is to identify the issues which would inhibit the deployment of the strategy and manage the human aspects to create incentives for change. This moves resistance to commitment and enthusiasm and the paper identifies these particular aspects of maangement. The two management activities combine as a form of leadership. To shift industries to adopt CORS network correction services so that the economy gains the benefits requires these two strategic change management activities.

The paper identifies inhibitors in various industries to use CORS network corrections over current GNSS methods. It evaluates current activities to move toward a standardised national network against change management actions. Finally proposals for increased change management activities are put forward so that industries are mobilized to adopt CORS network corrections as soon as possible, gain their benefit and contribute the economic, social and environmental benefits already proposed in some reports.

KEYWORDS: CORS, GNSS reference stations, management, strategy, infrastructure.

The Provision of Access to a Nationally Coordinated CORS Network

Dan Paull (1)
PSMA Australia Limited, Australia
+ 61 (0)2 6295 7033, dan.paull@psma.com.au
Caroline McIvor (2)
PSMA Australia Limited, Australia
+ 61 (0)2 6295 7033, caroline.mcivor@psma.com.au

How Australia can benefit from a national coordinated GNSS Real Time Kinematic (RTK) network providing a brokered product that will be of the highest quality, national nature and government assured.

Global Navigational Satellite System (GNSS) Continuous Operating Reference Stations (CORS) networks are developing nationwide to increase the accuracy of GPS receivers to the extent that with the right equipment location accuracy can be reduced from metres to within 2cm. The flow on effect of this accuracy will be significant for a number of industries including agriculture, mining, construction, transportation and aviation.

PSMA Australia has a successful business model co-ordinating and distributing national spatial datasets and is looking to apply its existing business model to coordinate access to public and private CORS networks through a single point.

There currently exist a number of disparate publically and privately owned GNSS base stations and reference stations. These provide services to local areas for specific uses. There exists an opportunity to derive benefits associated with a much larger (national) network by simply coordinating access to the data collected by all of the individual networks.

A national coordinated network would enable end users to operate over a broader area, with greater confidence and without the expense of establishing and maintaining expensive infrastructure.

PSMA Australia is working on a potential solution in which it can be a participant whereby GNSS corrections are sourced from each network or in some cases individual reference stations to create national packets of network corrections and an interface for Value Added Resellers (VARs) to access the packets. End users

would licence access to the national network through VARs – a distribution model that PSMA Australia uses for distributing its current datasets.

Attendees will gain an understanding of the PSMA national CORS concept, how participation will work and the benefits that will be generated as a result.

KEYWORDS: GNSS, CORS, Coordinated national network, RTK

Legal Traceability of Position in Australia

Michael Moore
NGRS/Geoscience Australia
+61 2 6249 9052 & FAX: +61 2 62499929 michael.moore@ga.gov.au

Methods for establishing traceability of length measurements with surveyor's steel bands, electronic distance measuring equipment (EDM) and direction measurements from theodolites has existed for many years. Recently Geoscience Australia has completed a NATA accreditation process, that allows for the legal verification of position as determined by Continuous GPS reference stations.

The National Standards Commission (NSC) determined to adopt the Australian Fiducial Network (AFN) Geocentric Datum of Australia 1994 (GDA94) positions as a recognized-value standard of measurement in accordance with the National Measurement ACT.

Geoscience Australia has two key roles in the national measurement system, the operation of the AFN, which is a sub-component of the Australian Regional Global Navigation Satellite Systems (GNSS) Network (ARGN), and to ensure that key Continuous GPS reference sites across Australia that are operated by other agencies, such as state survey authorities, are appropriately linked to the AFN.

This presentation will give an overview of the processes involved in maintaining NATA accreditation for the legal verification of continuous GPS reference sites, and the provision of legal certificates

KEYWORDS: Legally Traceability, GPS Processing, Change Control

Positioning WA's Future – a CORS network for WA

Linda Morgan
Landgate Western Australia
08 9273 7133 linda.morgan@landgate.wa.gov.au
Doug Hardman
Landgate Western Australia
08 9273 7117 doug.hardman@landgate.wa.gov.au

Landgate, the Western Australian Land Information Authority, is building a network of 26 Continuously Operating Reference Stations (CORS) Global Navigation Satellite System (GNSS) sites across Western Australia. The project, now in its 3rd year, is being jointly funded by Landgate and the National Collaborative Research Infrastructure Strategy (NCRIS) under the direction of AuScope Limited. Western Australia is leading the way in this national project to build 90 CORS Australia wide, with the most sites constructed by any State. This new network will provide infrastructure that supports research into sea level monitoring related to climate change; atmospheric modelling for improved weather forecasting; crustal deformation/seismic monitoring; possible subsidence due to ground water extraction; and precise satellite orbits for improved satellite positioning services and accuracy. It will also provide the base framework upon which real time positioning services can be developed with applications in surveying and mapping as well as machine guidance/auto steering for engineering, mining and precision agriculture, vehicle navigation and tracking, location based services and speed limiting systems. Most importantly it will provide a new level of accuracy for the fundamental framework upon which all spatial data in WA is based. Landgate has prepared a short video to promote the project to industry, government and the wider community. This video shows how the sites are being constructed and the benefits to users both now and in the future.

KEYWORDS: Continuously Operating Reference Stations, Global Navigation Satellite Systems, AuScope, Landgate

International Standard GNSS Real-Time Data Formats and Protocols

Yong Heo
School of Surveying and Spatial Information Systems/UNSW/Australia
Phone: +61-2-9385-4526 Fax: +61-2-9313-7493 Email: yong.heo@unsw.edu.au
Thomas Yan
Survey Infrastructure & Geodesy
Land and Property Management Authority, NSW, Australia
Phone: +61-2-6332-8389 Fax: +61-2-8258-7555 Email: thomas.yan@lpma.nsw.gov.au
Samsung Lim
School of Surveying and Spatial Information Systems/UNSW/Australia
Phone: +61-2-9385-4505 Fax: +61-2-9313-7493 Email: s.lim@unsw.edu.au
Chris Rizos
School of Surveying and Spatial Information Systems/UNSW/Australia
Phone: +61-2-9385-4205 Fax: +61-2-9313-7493 Email: c.rizos@unsw.edu.au

The Differential Global Navigation Satellite System (DGNSS) and Real-Time Kinematic (RTK) positioning techniques have been introduced to address the need for high accuracy real-time positioning. Transmitting corrections or raw measurements from one or more reference stations to a mobile user receiver is the key to differential positioning. Most GNSS receiver manufacturers have been developing and maintaining their own data format(s). Although a manufacturer's proprietary protocol is arguably efficient and reliable, industry standards are often required. In particular, interoperability is an issue for managing networked reference stations comprising different types and brands of GNSS receivers. Receiver Independent Exchange (RINEX) format was introduced for exchanging GNSS data with a standard file format. However, it is not applicable for real-time data transmission. The Radio Technical Commission for Maritime Services SC-104 has introduced formats and protocols that are now accepted as international standards. The data protocol has evolved over many years by incorporating new message types. On the other hand, the Networked Transport of RTCM via Internet Protocol (NTRIP) and RT-IGS protocols were developed as network transport protocols to deliver GNSS data via the internet.

This paper describes the mechanisms for real-time delivery of GNSS data in terms of transmission protocol, data format, communication link issues, message structure, data types and content between the various versions of RTCM SC-104 formats, including recent amendments. Future message amendments and protocol proposals that incorporate new signals such as from the Galileo system are also discussed. Current usage of various RTCM formats and message types are investigated and analysed.

KEYWORDS: GNSS, RTCM, NTRIP, standard, protocol

Performance analysis of a Constrained Loosely Coupled for GPS/INS integration

Gianluca Falco (1)
Politecnico di Torino, Torino, Italy
ph +39 011 2276 299 email gianluca.falco@polito.it
Garry A. Einicke (2)
CSIRO Exploration and Mining, Pullenvale (QLD), Australia
ph (07) 3327 4615 email garry.einicke@csiro.au
John. T. Malos (3)
CSIRO Exploration and Mining, Pullenvale (QLD), Australia
ph (07) 3327 4615 email john.malos@csiro.au
Fabio Dovis (4)
Politecnico di Torino, Torino, Italy
ph + 39 0115644175 email fabio.dovis@polito.it

In this paper, a MAP constrained technique for loosely-coupled GPS/INS integration is presented. It is demonstrated that the use of MAP constraints provides performance improvement compared to unconstrained GPS/INS integration. The accuracy of a GPS system varies with the number of visible satellites and with the geometry of the satellite configuration (i.e. DOP). The performance of a GPS also depends on the way a position-velocity-time solution is computed (e.g. by exploiting carrier-phase or code-phase information). The GPS-only position error can be reduced through using alternative techniques such as DGPS. Unfortunately both the GPS-only and DGPS methods suffer a degradation in case of momentary obstructions (e.g. buildings), outages and other satellite availability problems. In order to overcome this short-coming, a technique combining loosely-coupled GPS/INS integration and constrained Kalman filtering has been developed. In the paper we have investigated loosely-coupled INS/GPS together with height constraints but this method could be easily extended for different kinds of constraints (i.e. velocity, horizontal position). For our testing purposes, the height information has been obtained by surveying a track. In more general situation, height measurements can be extracted from a cartographic tool or from a web mapping service application such as Google Maps. Experiments have been carried out by simulating different time length outages (1, 10, 15, 30, 60, sec. respectively) and by using a loosely coupled algorithm with and without height constraints. Tests have been conducted using both synthetic GPS, INS data and field measurements using a low cost INS. The calculated RMS position error results are presented. It is demonstrated that the performance of the constrained-loosely-coupled system improved significantly compared to that of the unconstrained system when the GPS outages last longer than 15 sec.

KEYWORDS: Loosely Coupled Integration, Kalman filter, Constraints.

The effect of the temperature-correlated error of inertial MEMS sensors on the integration of GPS/INS

Kedong Wang
School of Astronautics, Beihang University, Beijing 100191, China
Phone: 86-10-8233-9586, Fax: 86-10-8233-8798, Email:wangkd@buaa.edu.cn
Yong Li
School of Surveying & SIS, UNSW, Sydney 2052
Phone: 61-2-9385-4173, Fax: 61-2-9313-7493, Email: yong.li@unsw.edu.au
Chris Rizos
School of Surveying & SIS, UNSW, Sydney 2052
Phone: 61-2-9385-4205, Fax: 61-2-9313-7493c.rizos@unsw.edu.au

The integration of GPS/INS (Inertial Navigation System) based on inertial MEMS (Micro-Electro-Mechanical System) gyros and accelerators has been addressed recently because of the increasing use of these sensors due to their convenient miniature size and low cost. However, the MEMS sensors' accuracy is still too low, which limits their application in navigation. Although many efforts have made to compensate for the MEMS sensors' errors, it is still a challenge to adequately model and compensate for the temperature-correlated error. This paper discusses the influence of temperature-correlated MEMS sensor error on the integration of GPS/INS.

In simulation tests, the operating temperature of the MEMS sensors is modelled as an exponential function of time. The MEMS inertial sensor errors are modelled as a combination of bias, random walk and a first-order Markov process. It is assumed that the bias and the standard deviations of the random walk and the

Markov process are temperature-correlated. The temperature-correlated and temperature-invariant errors are compared in the simulations. The results show that the temperature-correlated error degrades the accuracy of the sensors dramatically. The random walk error has the greatest impact.

Two approaches are currently used to reduce the influence of the MEMS sensors temperature-correlated errors: (1) control the device's working temperature; or (2) modelling and compensation of temperature-related errors. In the latter, the outputs of the MEMS sensors are compensated for according to the model of temperature-correlated errors. However the compensation accuracy heavily depends on the accuracy of the model. This paper explores an adaptive estimation method in which the temperature-correlated errors are augmented in an adaptive integration Kalman filter. In this way the temperature-correlated errors are estimated adaptively and compensated for in real time. The influence of the inaccuracy of the temperature model on the integration is also explored via simulations.

KEYWORDS: GPS/INS integration, MEMS inertial sensors, temperature compensation.

Adding Optical Flow into the GPS/INS Integration for UAV navigation

Weidong Ding
School of Surveying and Spatial Information Systems/University of New South Wales/Australia
Phone 61-2-93854202 Fax 61-2-93137493 email weidong.ding@unsw.edu.au
Jinling Wang
School of Surveying and Spatial Information Systems/University of New South Wales/Australia
Phone 61-2-93854203 Fax 61-2-93137493 email jinling.wang@unsw.edu.au
Songlai Han
School of Surveying and Spatial Information Systems/University of New South Wales/Australia
Phone 61-2-93854185 Fax 61-2-93137493 email songlai.han@student.unsw.edu.au
Ali Almagbile
School of Surveying and Spatial Information Systems/University of New South Wales/Australia
Phone 61-2-93854185 Fax 61-2-93137493 email a.almagbile@student.unsw.edu.au
Matthew A. Garratt
School of Aerospace, Civil and Mechanical Engineering/University of New South Wales at the Australian Defence Force Academy Canberra /Australia
Phone 61-2-62688267 Fax 61-2-62688276 email m.garratt@adfa.edu.au
Andrew Lambert
School of Electrical Engineering/Australian Defence Force Academy Canberra /Australia
Phone 61-2-62688351 Fax 61-2-62688443 email a-lambert@adfa.edu.au
Jack Jianguo Wang
School of Electrical, Mechanical and Mechatronic Systems/ University of Technology, Sydney/Australia
Phone 61-2- 95142969 Fax 61-2- 95142655 email jwang@eng.uts.edu.au

Autonomously operating unmanned aerial vehicles (UAV) have a great potential for many applications such as reconnaissance, mapping and surveillance. Whilst needing low cost and light weight navigation systems in their implementations, sensors like GPS or low cost inertial sensors can't separately provide either the complete set of information or the required degree of accuracy. Multi-sensor solutions have to be sought to mitigate the shortcomings of individual sensors. Often in such systems, low cost MEMS INS is aided by GPS to provided position, velocity and attitude (PVA) measurements. Data fusion strategies and techniques like extended Kalman filter (EKF) are the kernel for estimating and compensating individual sensor errors to reach improved performance. One drawback of integrating GPS with low cost MEMS INS is the heavy reliance on GPS signal availability. The accuracy of PVA solutions would degrade sharply during GPS signal drop outs due to the poor performance of low cost MEMS INS, which would limit the UAV applications near heavy canopy or city canyon environments. In some applications like terrain following, integrated GPS/INS system can't provide the ground height which is essential for safety operation in near ground tasks. In this paper, besides integration of GPS and low cost MEMS INS, visual information acquired by a high-resolution CMOS image sensor will be used to augment the PVA estimation. Optical flow rate measurements are used as additional observations in the EKF fusion process. When the ground height is available through an additional sensor like a laser rangefinder (LRF), optical flow rate is used as backup velocity aiding in case of GPS signal drop out. When direct measure of ground height is not available, with velocity from the integrated GPS/INS system, optical flow is used as effective measure to provide UAV ground height in terrain following tasks. An extended Kalman filter is developed for tightly coupled integration based on INS psi model where optical flow error states have been augmented. The proposed integration scheme is evaluated with field data collected from real UAV platforms. Both performance improvements and limitations are discussed.

KEYWORDS: GPS, INS, Optical flow, Multi-sensor, Fusion

Low-cost airborne environmental mapping platform for the scientific community: concept and development

Peter Mumford
University of New South Wales
612 93854189 p.mumford@unsw.edu.au
Greg Nippard
University of New South Wales
612 93857176 g.nippard@unsw.edu.au

Environmental scientists often use airborne mapping and imagery data to aid research. Data products can be obtained from many sensors including: LiDAR, multi-spectral cameras, hi-definition digital cameras and various RADAR systems. When these data can be derived from existing data sets, the cost can be reasonable. However, if the data can only be obtained by a commissioned airborne mission, these data can be expensive and difficult to obtain. The options are to engage a commercial or public agency that has an airborne mapping platform, find a research organization that has one, or … build your own. The problem becomes greater if the data required is not available from the commercial or public agency operators; perhaps a novel sensor, or an unusual combination of sensors is required. Commercial and public agencies often use off-the-shelf turnkey systems, and these can be very expensive and not always particularly flexible.

The University of New South Wales (UNSW) in Australia carries out research using airborne imagery in the fields of oceanography, costal processes and environmental science in general. UNSW is in the fortunate position to be able to utilize the skills, assets and established research strengths of several departments to build a low-cost, flexible airborne imaging platform. The Department of Aviation has the aircraft and has the expertise and experience in fitting out and certifying airborne equipment. The School of Surveying and Spatial Information Systems (SSIS) has the required positioning and geo-referencing systems, skills and experience. This consortium has acquired a Riegl LMS-Q240i laser scanner (LiDAR) and Canon 5Dmk2 high definition digital SLR camera. The Department of Aviations Piper PA-44 Seminole aircraft has been prepared and certified to carry this equipment along with associated support systems.

Once the system is fully qualified, it is hoped that this flexible service will be of benefit to the scientific community in obtaining the data products they require for research at a reasonable cost. In addition, the possibility of using research sensors alongside the standard sensors may become an attractive option.

This paper presents an overview of the system; the hardware, the data flow and the end products. Results of testing the imaging and geo-positioning subsystem are summarized. Problems discovered during development are outlined, along with plans for the future.

KEYWORDS: GPS/INS, Imagery, LIDAR, Oceanography, Georeferencing

---

Experiments Utilizing Data Glove and High-Performance INS Devices in an Immersive Virtual Mining Environment

Tomasz P Bednarz
3D Visualisation Software Engineer / CSIRO Exploration and Mining / Australia
Phone: +61 7 3327 4706, Fax: +61 7 3327 4566, Email: tomasz.bednarz@csiro.au
Con Caris
3D Visualisation Coordinator / CSIRO Exploration and Mining / Australia
Phone: +61 7 3327 4568, Fax: +61 7 3327 4566, Email: con.caris@csiro.au
Chris Wesner
3D Application Programmer / CSIRO Exploration and Mining / Australia
Phone: +61 7 3327 4109, Fax: +61 7 3327 4566, Email: chris.wesner@csiro.au
Peter B Reid
Research Engineer / CSIRO Exploration and Mining / Australia
Phone: +61 7 3327 4704, Fax: +61 7 3327 4566, Email: peter.b.reid@csiro.au
Gianluca Falco
PhD Candidate, Politecnico di Torino, Italy
Phone:+11 5646666, Fax: +11 5646329, Email: gianluca.falco@polito.it
Garry Einicke
Senior Research Engineer / CSIRO Exploration and Mining / Australia
Phone: +61 7 3327 4615, Fax: +61 7 3327 4566, Email: garry.einicke@csiro.au

The present work concerns immersive virtual reality experiments for underground coal mine. The experiments demonstrate usability of used devices for tele-operation of underground mining equipment. The

visualisation is carried out using Unity3D 2.5 multiplatform game development tool that talks to a .Net socket server allowing continuous data feeding from: (a) 5DT Data Glove Ultra that measures finger flexures; (b) MicroStrain 3DM-GX2 high performance orientation sensor that gives information about acceleration and also rotational attributes such as pitch, roll and yaw. The user is placed at the focal point of 4-m dome and therefore has direct experience of being part of mining environment with the ability to navigate and manipulate the fields of view using orientation data and behaviour of the underground mining equipment using six different distinctive hand gestures. Later on, the same techniques can be applied to monitor real mining environments, in which the mining equipment is geo-referenced using the same IMU devices and surrounded by other sensor networks.

KEYWORDS: IMU, Data Glove, Virtual Reality, Dome, Immersive Environment.

Analysis of error characteristic of the single axis rotating SINS

LAI Ji-zhou
Navigation Research Center, Nanjing University of Aeronautics and Astronautics, China
+86 25 84892304-807& +86 25 84895889, laijz@nuaa.edu.cn
LIU Jian-ye
Navigation Research Center, Nanjing University of Aeronautics and Astronautics, China
+86 25 84892304-801& +86 25 84895889, ljyac@nuaa.edu.cn
LV Pin
Navigation Research Center, Nanjing University of Aeronautics and Astronautics, China
+86 25 84892304-851& +86 25 84895889, lvpin@nuaa.edu.cn

Inertial components were usually fixed on the foundation bed in strapdown inertial navigation system (SINS). With the development of rotating modulation technology, rotating strapdown inertial navigation system (RSINS) is widely used. In this paper, the rotating design is studied, and the error model of single axis RSINS is built such as bias, installation error, scale factor non-linear error and turntable obliquity error of the system. In this basis, the influence of different rotating modes is analyzed, and a new IMU installation scheme is proposed, which separated the rotating axis gyro off the rotary mechanism. Research shows that the new scheme inhibits the influence of both the scale factor non-linear error and the scale factor asymmetry error of the rotating axis gyro effectively. The simulation results of the new IMU installation scheme also show that positioning accuracy is significantly improved.

KEYWORDS: SINS; rotating modulation; modulation of errors

Posters

A Sampling Interval Compensation Scheme for Improving the Gain of Long Coherent Integrations

Uzair Ahmad (1)
Positioning Systems Research Team / Electronics and Telecomm. Research Institute,
Republic of Korea.
+82-42-860-1368, uzair@etri.re.kr
Choi Wan Sik (2)
Positioning Systems Research Team/Electronics and Telecomm. Research Institute,
Republic of Korea.
+82-42-860-5610, cws@etri.re.kr

Software-based or post-processing GPS receivers perform a coherent integration in order to acquire the C/A code phase and estimate the Doppler shift on L1 carrier. Generally one millisecond, the duration of the C/A code, long integration is enough for acquisition. However, in weak signal environments, an extended coherent integration is required over a long record of received signal. The weaker the signal power the longer the data record is required to be treated coherently. There are several challenges in performing such coherent integrations. First of all, the computational requirements increase tremendously as the code phase search in longer data records needed to be performed on finer frequency steps. Secondly, the navigation data bit sign may reverse its sign in a 20 millisecond data record. The sign reversal, if not compensated, can decimate the coherent integration gain altogether.

This paper establishes an interesting observation that such coherent integrations can still decimate the total gain even if there is no bit sign reversal or it is compensated properly.

A comparative analysis of four different coherent integration methods is presented to show that the observation holds across different methods. A sampling interval compensation method is presented to remove the decimation out of coherent integration process. Experimental results show that the proposed method can effectively recover the loss induced by uncompensated coherent integrations.

KEYWORDS: Coherent integrations, weak signal acquisition, sampling interval compensation.

Automated Near-Real-Time Integrated Water Vapour Profiling from the Australian Regional GPS Network

Ji Eun (Jasmin) Kim
UNSW / Australia
jasmin.kim@unsw.edu.au
Samsung Lim
UNSW / Australia
s.lim@unsw.edu.au

The Global Positioning System (GPS) is well-known for its use for positioning, navigation and timing applications. One of the main sources of error in the received signal is from the delay while propagating through the neutral atmosphere - troposphere - in particular due to the temporally and spatially variable water vapour.

Traditionally, water vapour radiometers have been used to measure the water vapour structure in the troposphere, however they have disadvantages such as high-cost, low deployment density and degradation of measurement accuracy in rain. On the other hand, GPS is well known as a relatively low-cost, all-weather space geodetic technology that is ideal for profiling the atmospheric water vapour in applications such as meteorology and climate monitoring. Some of these applications require real-time or near-real-time processing, therefore the post-processing design of currently available GPS applications restricts the potential benefits of Integrated Water Vapour Profiling using GPS signals.

There has been considerable research activities associated with using GPS for integrated water vapour (IWV) profiles. This paper describes some of the common methods of IWV profiling, with the main focus being on the design and implementation of a near-real-time automation process. The paper also investigates the effect of changing the observation step interval, the number of GPS observation sites, as well as using different types of IGS products (final, rapid, ultra-rapid) on parameter accuracy and processing time.

This abstract will only be used for consideration for selection as part of the symposium program and will not be considered for the review process.

KEYWORDS: IWV, GPS, NRT, meteorology

More freedom to Blind and Vision Impaired – A Proposed Navigation and Information System

Binghao Li
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854189, Fax 93137493 Email: binghao.li@unsw.edu.au
Euan Ramsey-Stewart
Ramsey Stewart Industrial Design
Email: euan@rsid.com.au
Kenny Johar
Vision Australia Email: kenny.johar@visionaustralia.org
Chris Rizos
School of Surveying and Spatial information Systems, UNSW, Australia
Phone 93854205, Fax 93137493 Email: c.rizos@unsw.edu.au

There are over 1.2 million Australians registered as having vision impairment. There are many more cases that go unrecognised and untreated in our society. Welfare for this group costs AUS$12 billion a year with lost business opportunity costs of AUS$42 billion. In the UK, the welfare cost is estimated at £49 billion per annum just for those Blind and Vision Impaired (BVI) that suffer from Glaucoma and Cataracts, indicating that the overall welfare costs of blindness are much higher. Any system which could increase the mobility and independence of the vision impaired has the potential to save significant taxpayer dollars. University of New South Wales, Vision Australia and Ramsey-Steward Industry Design have secured a four-year ARC Linkage project to develop a Mobility and Location Information system for BVI. The prototype we are working on is a system comprising a handheld device, Information and Communications Technologies (ICT), indoor and outdoor positioning technologies and Server Based Software that gives a BVI person information about where they are and how to get to where they want to go. Furthermore, a lot of location related information can be provided by the proposed system. This is an excellent example of a “location-based service”, which has been slated as the largest area of growth for ICT in the coming decade. This product will not replace the traditional white cane or guide dog, but is an additional device to enable the BVI to enjoy the mobility and have an improved sense of confidence and self assurance. This paper introduces the current progress of the project and discusses the challenges of this research.

KEYWORDS: BVI, Navigation, Positioning, Information

Single & Dual Frequency RTK Success with SBAS Ranging

Author: Kirk Burnell, P.Eng.
Product Manager,
Precision Products team,
Hemisphere GPS
University of Calgary
Graduate, 1994
B.Sc., Survey Engineering
13 years experience in OEM
GPS and Surveying
Hemisphere GPS Inc. Scottsdale Arizona U.S.A
Tel: +1 480 348 9919
Fax: +1 480 348 9919
Email: kburnell@hemispheregps.com

This paper explores the current issues and challenges around Single and Dual Frequency RTK. It looks at the impact, viability and success of utilizing SBAS satellites as a robust yet cost effective alternative to improving the speed and accuracy of L1 and L1/L2 RTK solutions through specific ranging techniques patented by Hemisphere GPS.

Traditional RTK techniques provide challenging situations for many users. Though there solution may be robust, constraints around the use of both L1/L2 bands, affordability, longer fix times and decreased performance ultimately may deter many users.

Two SBAS satellites are typically always visible from most locations around the world. SBAS ranges are valid even outside courage areas and can be tracked by receivers at no additional cost to the user. Hemisphere GPS has patented the use of SBAS ranges in RTK.

The method used to determine the results as outlined in this paper involves three basis steps:

Log raw data in simultaneous location over a 24 hr period

Replay the data using various combinations of base/rover, RTK firmware to compute solutions. Change the RTK firmware to USE or IGNORE either the SBAS ranges and/or the L2 data.

Analyze the results – Compare identical datasets with/without SBAS ranges in addition to the trends for L1 and L1/L2

Analysis of the data shows Hemisphere GPS's RTK with SBAS ranging technique delivers superior results and performance in both single and dual frequency RTK solutions

Adding additional ranges from signals that are in space today delivers an array of benefits to both single and dual frequency RTK uses:

Greatly improves the solutions overall robustness in low or moderate multipath environment and increased baseline distance.

- Reduce capital expenditure and equipment costs.

- Improves ambiguity fix times and makes the likelihood of achieving an L1 RTK solution within a five minute time frame a true and tangible reality.

KEYWORDS: RTK Issues & Techniques, Setup & Procedure, Observation & Analysis, L1/L2 Analysis, Conclusion & Solution