Commission 4 – Positioning and Applications

http://enterprise.lr.tudelft.nl/iag/iag_comm4.htm

President: Sandra Verhagen (The Netherlands)
Vice President: Dorota Grejner-Brzezinska (USA)

Structure

Sub-commission 4.1: Multi-Sensor Systems
Sub-commission 4.2: Applications of Geodesy in Engineering
Sub-commission 4.3: Remote Sensing and Modelling of the Atmosphere
Sub-commission 4.4: Applications of Satellite and Airborne Imaging Systems
Sub-commission 4.5: High-Precision GNSS
Study Group 4.2: GNSS Remote Sensing and Applications
Study Group 4.3: IGS Products for Network RTK and Atmosphere Monitoring

Steering committee

President : Sandra Verhagen (The Netherlands)
Vice-president : Dorota Grejner-Brzezinska (USA)
Chair SC 4.1 : Dorota Grejner-Brzezinska (USA)
Chair SC 4.2 : Günther Retscher (Austria)
Chair SC 4.3 : Marcelo Santos (Canada)
Chair SC 4.4 : Xiaoli Ding (Hong Kong)
Chair SC 4.5 : Yang Gao (Canada)
Member-at-large : Pawel Wielgosz (Poland)
IAG representative : Ruth Neilan (USA)

Overview

Terms of reference

To promote research into the development of a number of geodetic tools that have practical applications to engineering and mapping. The Commission will carry out its work in close cooperation with the IAG Services and other IAG Entities, as well as via linkages with relevant Entities within Scientific and Professional Sister Organisations.

Recognising the central role that Global Navigation Satellite Systems (GNSS) plays in many of these applications, the Commission's work will focus on several Global Positioning System (GPS)-based techniques, also taking into account the expansion of GNSS with Glonass, Galileo and Beidoe. These techniques include precise positioning, but extending beyond the applications of reference frame densification and geodynamics, to address the demands of precise, real-time positioning of moving platforms.

Several Sub-Commissions will deal with precise kinematic GNSS positioning technology itself (alone or in combination with other positioning sensors) as well as its applications in surveying and engineering. Recognising the role of continuously operating GPS reference station network, research into non-positioning applications of such geodetic infrastructure will

also be pursued, such as atmospheric sounding. Thereby, other geodetic techniques such as VLBI will be considered as well.

The commission will also deal with geodetic remote sensing, using (differential) InSAR, and GNSS as a remote sensor with land, ocean and atmosphere applications.

Objectives

The main objectives of Commission 4 are:

- Research into (integration of) new navigation and deformation measurement / sensor technologies, and their applications.
- Encourage research and development into new applications in e.g. "precise navigation", "geodetic remote sensing", "engineering geodesy".
- Collaboration with geodetic organizations and services to promote and enable the use of GNSS and geodetic infrastructure for positioning as well as non-positioning applications.

The following activities were planned to reach these objectives:

- Interface with IAG sister organisations and other organizations - e.g. FIG, ISPRS, IEEE, ION
- Promote Geodesy and GGOS to a wide (professional) community
- Offer outreach opportunity through its conferences and seminars (jointly organised with other organisations)
- Forums, collaborative research, and exchange of data through the various sub-components.

Linkages between IAG Commission 4 and FIG, ION, ISPRS

Commission 4, by its rather more "practical" nature than other IAG commissions, has stronger links with sister organisations such as FIG, ISPRS and the U.S. ION. This is reflected in the broad activity of its members, who tend to support conferences organised by these other organisations. Often the officers of Commission 4 are also members of WGs, SGs and committees of the sister organisations. Hence there are a lot of cross-links between organisations. The links with the FIG Commission 5 ("Positioning and Measurements"), FIG Commission 6 ("Engineering Surveys"), ISPRS Commission I ("Image Data Acquisition – Sensors & Platforms"), and ISPRS Commission V ("Close Range Sensing – Analysis and Applications") are now particularly strong, as evidenced by a permanent series of joint symposia (see below).

Memorandum of Understandings between IAG and FIG initiated and prepared by Chris Rizos and Matt Higgins (FIG)

Memorandum of Understanding between IAG and U.S. ION facilitated by Dorota Grejner-Brzezinska

Collaboration with FIG

Foundation of the FIG WG 5.5 on Ubiquitous Positioning Technologies and Techniques: A collaborative WG with IAG Commission 5 and Commission 6 at the XXIV FIG Congress held in Sydney, Australia, 11-16 April 2010

Joint conferences / sessions:

- FIG Working Week 2008
  - Sandra Verhagen chaired a joint IAG – FIG session on Geodetic Networks, Reference Frames and Systems
  - Sandra Verhagen gave a presentation on behalf of IAG Commission 4 on New Positioning Technologies
  - discussion forum chaired by Sandra Verhagen, Chris Rizos …
- ISPRS Congress 2008, Beijing Dorota Grejner-Brzezinska chaired a special session SS-4: Modern Navigation and Earth Observation that is jointly sponsored by IAG and ISPRS
- ION International Technical Meeting, 26-29 January 2009, Anaheim CA session on "Applications in Surveying, Geodesy, Science and Timing", organized and chaired by Dorota Grejner-Brzezinska
- 2009 6th International Mobile Mapping Symposium co-sponsored/co-organized by IAG, ISPRS and FIG Dorota Grejner-Brzezinska is Science Chair
  - IAG 2009 Scientific Assembly "Geodesy for Planet Earth"
  - session 4 "Positioning and remote sensing of land, ocean and atmosphere" convened by Sandra Verhagen and Pawel Wielgosz, with the following sub-sessions:
    - Session 4.1 "Technology and land applications" convened by Dorota Grejner-Brzezinska and Xiaoli Ding (related to SC 4.1, SC 4.4, SC 4.5 a.o.)
    - Session 4.2 "Modelling and remote sensing of the atmosphere" convened by Marcelo Santos and Jens Wickert (related to SC 4.3 and SG 4.3)
    - Session 4.3 "Multi-satellite ocean remote sensing" convened by Shuanggen Jin and Ole Andersen (related to SG 4.2)
  - session 6 "Joint IAG/FIG/ION/ISPRS session on Navigation and Earth Observation", convenors: Dorota Grejner-Brzezinska and Charles Toth
- 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 13th FIG Deformation Measurement Conference, May 12-15, 2008 in Lisbon, Portugal
- Joint International Symposium on Deformation Monitoring (JIS-DM), including 5th IAG Symposium on Geodesy for Geotechnical and Structural Engineering, 14th FIG Symposium on Deformation Measurements and Analysis, and International Workshop on Spatial Information Technologies for Monitoring the Deformation of Large-Scale Man-Made Linear. November 2-4, 2011 in Hong Kong, P.R. China
- Symposium series (2007 – 2011) on 'Location Based Services and Telecartograpy', joint with ICA.
- FIG/IAG workshop to be held at the 7th Symposium on Mobile Mapping MMT 2011 from June 13-16, 2011 in Cracow, Poland.

Linkages with other IAG commissions and services

Commission 1

- IC-WG 1.1: Environment Loading: Modelling for Reference Frame and positioning applications, Chairs: Tonie van Dam (Luxembourg), Jim Ray (USA) [Joint with Commission 4 and IERS]
- IC-SG1.2 Quality of geodetic multi-sensor systems and networks, Chair: H-G. Kutterer (Germany) [Joint with ICCT, Commission 4]

GGOS

- Sandra Verhagen in steering committee, and participated in the SC meeting in December 2008. Dorota Grejner-Brzezinska is substitute delegate.
- Chris Rizos and Dorota Grejner-Brzezinska contributed to the GGOS Reference document (chapter 4)

ICCT

- IC-SG2: Quality of geodetic multi-sensor systems and networks (see Commission 1, IC-SG1.2)
- IC-SG6: InSAR for tectonophysics, Chair: M. Furuya (Japan) [Joint with Commission 3 and 4]
- IC-SG9: Application of time-series analysis in geodesy, Chair: W. Kosek (Poland) [Joint with Commission 1, 2, 3 and 4]
- Organization of Hotine-Marussi 2009 symposium on Theoretical Geodesy:
  - Sandra Verhagen in scientific committee
  - Session 2 "Geodetic sensors and sensor networks" convened by Sandra Verhagen
  - Poster on behalf of commission 4 "Geodetic sensors and sensor networks – IAG's perspective"
- Organization of QuGOMS in Munich, 2011. Sandra Verhagen in Scientific Committee.

IGS

- Third meeting of International Committee on GNSS: contributions by Chris Rizos and Ruth Neilan.
- IGS is linked to SG 4.3 (see report)

Commission 4 sponsorships

- International Conference on Geo-Spatial Solutions for Emergency Management to be held September 14-16, 2009, Beijing, P.R.China, to celebrate CASM's 50th anniversary.

  Chris Rizos is member of the Steering Committe
- ION International Technical Meeting, January 26-29, Anaheim CA Session on "Applications in Surveying, Geodesy, Science and Timing", organized and chaired by Dorota Grejner-Brzezinska.
- IEEE International Geoscience & Remote Sensing Symposium (IEEE IGARSS 2009), Cape Town, Africa, 13-17 July 2009 Session on GNSS Remote Sensing Applications in Atmosphere, Ocean and Land, see SG4.2 report.
- International Workshop on Geodetic Theory-IWGT 2009, 1-3 June 2009 at Tongji University, Shanghai, China. Yanming Feng was in the technical program committee, see WG 4.5.4 report
- 2nd International Colloquium – Scientific and Fundamental Aspects of the Galileo Programme, October 14-16, 2009, Padua, Italy
- 2010 International Conferenceon Indoor Positioning and Indoor Navigation IPIN from September 15-17, 2010 in Zurich, Switzerland
- 2011 International Conferenceon Indoor Positioning and Indoor Navigation IPIN from September 21-23, 2011 in Guimarães, Portugal
- International Conference on Ubiquitous Positioning, Indoor Navigation and Location-Based Service UPINLBS 2010 from October 14-15, 2010 in Helsinki, Finland; Dorota Brzezinska was one of the keynote speakers at this conference

Highlight: publications

Commission 4 published two papers which are the result of a collaborative effort (co-authored by the different SC and SG chairs), and represent the views, activities, and objectives of the Commission:

- "Geodetic sensors and sensor networks – IAG's perspective" to be presented at Hotine-Marussi 2009 symposium on Theoretical Geodesy, July 2009, Rome, Italy
- "Positioning and applications for planet Earth" to be presented at the IAG2009 Scientific Assembly "Geodesy for planet Earth", September 2009, Buenos Aires, Argentina

Commission meetings

The steering committee had several meetings during the reporting period:

- kick-off meeting at the IUGG 2007 Symposium in Perugia, Italy
- ION GNSS 2007, Savannah, USA
- IAG 2009 Symposium, Buenos Aires, Argentina. During this meeting representatives from FIG (Mikael Lilje, Rober Sarib) were present to discuss collaboration.
- IUGG 2011, Melbourne, Australia
- informal meetings with different members during various conferences and symposia

Sub-Commission 4.1: Multi-Sensor Systems

President: Dorota Grejner-Brzezinska (USA)

Website: http://www.ceegs.ohio-state.edu/IAG-SC41/

Terms of Reference
To coordinate research and other activities that address broader areas of multi-sensor system theory and applications, with a special emphasis on integrated guidance, navigation, positioning and orientation of airborne and land-based platforms. The primary sensors of interest will be GNSS and inertial navigation systems; however the important role of other techniques used for indoor and pedestrian navigation environmental monitoring is also recognized. The Sub-commission will carry out its work in close cooperation with other IAG Entities, as well as via linkages with relevant scientific and professional organizations, such as ISPRS, FIG, IEEE, ION.

Objectives
- To follow the technical advances in navigation sensors and algorithms, including autonomous vehicle navigation, based on
  - positioning sensors and techniques such as GPS (and pseudoliltes), INS, including MEMS IMU, wheel sensors, ultrasonic and magnetic sensors, and
  - positioning methods based on cellular networks and their hybrid with GPS
- To follow the technical advances in mapping sensors, such as CCD cameras, laser range finders, laser scanners and radar devices
- To standardize definitions and measurements of sensor related parameters
- To study and report on the performance of stand alone and integrated navigation systems
- Report on the development, possibilities and limitations of new multi-sensor system technologies.
- To stimulate new ideas and innovation in
  - navigation algorithms, sensor calibration, synchronization and inter-calibration
  - real-time sensor information processing and georeferencing
  - sensor and data fusion
  - automation techniques for information extraction from multi-sensor systems using expert systems
- To study and monitor the progress in new applications (not limited to conventional mapping) of multi-sensor systems (transportation, engineering, car navigation, environmental monitoring personal navigation, indoor navigation, etc.)
- To promote research collaboration and to organize and to participate in professional workshops, seminars, meetings
- To promote research and collaboration with countries with no or limited access to modern multi-sensor technology
- To establish a web page providing information on the SC 4.1 activities, technology updates, and professional meeting calendar.

WG 4.1.1: Alternative integration algorithms

Chair: Dr. Aboelmagd Noureldin (Canada)

Major Developments and Achievements:

1. Development of a unique method based on Particle Filtering for accurately navigating wheel-based platforms in challenging GPS environments. This method has resulted in a patent and the technology is licensed by Trusted Positioning Inc. (Dr. Noureldin and Dr. Kornberg)
2. Development of innovative hybrid INS/GPS integration methods combining the benefits of artificial intelligence (AI) and Kalman filtering (KF) for navigation in urban environments (Dr. Chiang and Dr. Noureldin).
3. Enhancement of multi-sensor system integration using spectral estimation techniques employing robust orthogonal search methods for the development of accurate nonlinear error models of INS (Dr. Kornberg, Dr. McGaughy and Dr. Noureldin).
4. Augmented KF / NN modules for reliable INS/GPS integration for airborne navigation (Dr. Noureldin and Capt. Armstrong).
5. Parallel cascade identification of reliable stochastic nonlinear error model of inertial sensor errors (Dr. Kornberg and Dr. Noureldin).
6. Development of Methods for Attitude and Misalignment Estimation for Constraint Free Portable Navigation. This method has resulted in a patent and the technology is licensed by Trusted Positioning Inc. (Dr. Noureldin)

Research Team:

Name	Position	Department / Institute
Dr. Aboelmagd Noureldin	Chair	Cross-appointment Associate Professor, Departments of Electrical and Computer Engineering, Queen's University and Royal Military College of Canada.
Dr. Kai-Wei Chiang	Vice Chair	Assistant Professor, Department of Geomatics, National Cheng Kung University.
Dr. Michael Korenberg	Member	Professor, Department of Electrical and Computer Engineering, Queen's University.
Dr. Don McGaughey	Member	Associate Professor, Department of Electrical and Computer Engineering, Royal Military College of Canada.
Capt. Justin Armstrong	Member	Canadian Air Force, Department of National Defence, Canada

In addition to the above principal team members, at least 20 postgraduate students were involved on the different phases of the developments.

Publications:

1. Patents

Syed Z., Georgy J., Goodall C., Noureldin A. and El-Sheimy N.: "Methods for Attitude and Misalignment Estimation for Constraint Free Portable Navigation" US Provisional Patent # 61/466,840, Filed: March 23, 2011.

Georgy J. and Noureldin A.: "Method and Apparatus for Improved Navigation of A Moving Platform" US Patent Application No. 13/037,130, Filed: February 28, 2011.

2. Journal Papers

Georgy J. and Noureldin A.: "Tightly Coupled Low Cost 3D RISS/GPS Integration Using a Mixture Particle Filter for Vehicular Navigation" Sensors. (In Print) ID: 7153.

Georgy J., Karamat T., Iqbal U. and Noureldin A.: "Enhanced MEMS-IMU/Odometer/GPS Integration Using Mixture Particle Filter" GPS Solutions, Springer. (In Print)

Georgy J., Noureldin A., and Mellema G.: "Clustered Mixture Particle Filter for Underwater Multi-Target Tracking in Multistatic Active Sonobuoy Systems," IEEE Transactions on System Man and Cybernetics -- Part C: Applications and Reviews. (In Print)

Shen Z., Georgy J., Kornberg M. and Noureldin A.: "Low Cost 2D Navigation Using an Augmented KF/FOS Module for RISS/GPS Integration" Transportation Research – Part C, Elsevier. (In Print) TRC-D-09-00183R1.

Atia M., Noureldin A. and Kornberg M.: "Gaussian Process Regression Approach for Bridging GPS outages in Integrated Navigation Systems" Electronic Letters, IET, V47(1), January 2010.

Iqbal U., Georgy J., Kornberg M., and Noureldin A.: "Nonlinear Modeling of Azimuth Error for 2D Car Navigation Using Parallel Cascade Identification Augmented with Kalman Filtering" International Journal of Navigation and Observation, V2010, 13pp, 2010.

Noureldin A., El-Shafie A. and Bayoumi M.: "Robust Mobile Multi-Sensor Data Fusion Utilizing Dynamic Neural Network for Vehicular Navigation" Information Fusion, Elsevier, V12 (1), pp:48 – 57, 2011.

Atia M., Georgy J., Kornberg M. and Noureldin A.: "'Real Time Implementation of Mixture Particle Filter for 3D RISS/GPS Integrated Navigation Solution" Electronic Letters, IET, V46(15), pp: 1083 – 1084, 2010.

Georgy J., Noureldin A., Kornberg M and Bayoumi M.: "Modeling the Stochastic Drift of a MEMS-Based Gyroscope in Gyro/Odometer/GPS Integrated Navigation" IEEE Transactions on Intelligent Transportation Systems, V11(4), pp. 856-872, December 2010.

Shen Z., Georgy J., Kornberg M. and Noureldin A.: "FOS-Based Modeling of Reduced Inertial Sensor System Errors for 2D Vehicular Navigation" Electronic Letters, IET, V46(4), pp: 289 – 299, 2010.

Georgy J., Noureldin A., Kornberg M and Bayoumi M.: "Low Cost 3D Navigation Solution for RISS/GPS Integration Using Mixture Particle Filter" IEEE Trans. on Vehicular Tech., V59 (2), pp: 599-615, Feb 2010.

Noureldin A., Karamat T., Eberts M. and El-Shafie A. "Performance Enhancement of MEMS Based INS/GPS Integration for Low Cost Navigation Applications" IEEE Transactions on Vehicular Technology, V58 (3), pp: 1077 – 1096, March 2009.

Perreault J., Iqbal U., Okou A. and Noureldin A. "RISS/GPS Integration Utilizing an Augmented KF/NN module" European Journal of Navigation, V6 (3), pp: 15-21, November 2008.

El-Sheimy N, Chiang K-W and Noureldin A.: "Developing a Low Cost MEMS IMU/GPS Integration Scheme Using Constructive Neural Networks;" IEEE Transactions on Aerospace and Electronic Systems, V44 (2), pp: 582 – 594, April 2008.

3. Conference Papers

Atia M, Georgy J, Noureldin A and Kornberg M.: "Embedded Real-Time Realization of Mixture Particle Filter for 3D RISS/GPS Land-Vehicles Navigation," In Proc of ION ITM 2011, San Diego, CA, January 24 – 26, 2011.

Abdelfatah W, Georgy J, Iqbal U and Noureldin A: "Real - Time Realization of 2D RISS/GPS Integrated Navigation on Xilinx´s MicroBlaze Soft-Core Processor for Land Applications," In Proc of ION ITM 2011, San Diego, CA, January 24 – 26, 2011.

Shen Z, Noureldin A and Kornberg M.: "A Real-time Approach to Nonlinear Modeling of Inertial Errors with Application to 3D Vehicle Navigation" In Proc of ION ITM 2011, San Diego, CA, January 24 – 26, 2011.

Iqbal U., Georgy J., Korenberg M., and Noureldin A.: "Modeling Residual Errors of GPS Pseudoranges by Augmenting Kalman Filter with PCI for Tightly-Coupled RISS/GPS Integration", In Proc. Of ION GNSS 2010, Portland, Oregon, September 21 – 24, 2010.

Georgy J. and Noureldin A.: "Low-Cost Post-Mission Positioning and Orientation Solution for Land-Based Mobile Mapping Using Nonlinear Filtering" In Proc. Of ION GNSS 2010, Portland, Oregon, September 21 – 24, 2010.

Syed Z., Noureldin A. and El-Sheimy N.: "Positioning Platform for Low-cost, Accurate, Infrastructure-free Machine Control", In Proc. Of ION GNSS 2010, Portland, Oregon, September 21 – 24, 2010.

Iqbal U., Georgy J., Korenberg M., and Noureldin A.: "Augmenting Kalman Filtering with Parallel Cascade Identification for Improved 2D Land Vehicle Navigation" In Proc. Of IEEE Vehicular Technology Conference (VTC 2010-Fall), Ottawa, Canada, September 7 – 9, 2010. (Peer Reviewed – Full Paper)

Karamat T., Georgy J., Iqbal U. and Nouerldin A.: "A Tightly-Coupled Reduced Multi-Sensor System for Urban Navigation" In Proc. Of ION GNSS 2009, Savannah, GA, Sept 22 – 25, 2009.

Shen Z., Nouerldin A. and Kornberg M.: "Nonlinear Modeling and Identification of Inertial Errors with Application to 2D Vehicle Navigation" In Proc. Of ION GNSS 2009, Savannah, GA, Sept 22 – 25, 2009.

Yuksel Y., El-Sheimy N and Noureldin A.: "A new AR modeling method for MEMS inertial sensors based on wavelet decomposition" In Proc. Of ION GNSS 2009, Savannah, GA, Sept 22 – 25, 2009.

Georgy J., Noureldin A. and Bayoumi M.: "Mixture Particle Filter for Low Cost INS/Odometer/GPS Integration in Land Vehicles" In Proc. Of IEEE Vehicular Technology Conference, Barcelona, April 27 – 30, 2009. (Peer Reviewed – Full Paper)

Georgy J., Iqbal U. and Noureldin A.: "Quantitative Comparison Between Kalman Filter and Particle Filter for Low Cost INS/GPS Integration" In Proc. Of the 6th International Symposium on Mechatronics and its Applications, Sharjah, UAE, March 23 – 26, 2009. (Peer Reviewed – Full Paper)

Georgy J., Iqbal U., Bayoumi M. and Noureldin A.: "Reduced Inertial Sensor System (RISS)/GPS Integration Using Particle Filtering for Land Vehicles" In Proc. ION GNSS 2008, Savannah, GA, Sept 2008.

WG 4.1.2: Indoor Navigation Systems

Chair: Günther Retscher (Austria)

Almost 70 to 80 % of our daily information is closely related with spatial and temporal aspects. Spatial positioning with time mark exhibits considerable significance in contemporary information services. However, provision of spatial location with both proper reliability and availability is still hindered by a number of challenges and obstacles due to technical and political reasons, and exploration for ubiquitous positioning needs great efforts and becomes our utmost destination. In our research, therefore ubiquitous positioning techniques with alternative sensors and multi-sensor solutions has been investigated.

Nowadays, metropolitan cities in the world are provided with different multimedia services through mobile communications using for example GSM, GPRS and 3G with an affordable service charge. Moreover, popular GPS and WiFi (Wirless Fidelity) integrated mobile devices are readily available on the market to strengthen handset based services and applications. An-

other function of wireless technologies, in addition to communication, is position determination. Therefore, the integration of GPS/WiFi mobile devices (Mok and Retscher, 2007), wireless communications and positioning technologies, as well as geographic information and mapping systems have created new services to mobile users, namely location-based services (LBS). LBS also play an important role for supporting the wayfinding process in navigation systems (Retscher, 2009a). Guiding services, however, have some limitations. For example, localization accuracy is insufficient for pedestrian's needs in many cases and route suggestions usually rely on road networks and do not meet the demands of walking people, as pedestrians have more degrees of freedom in movement compared to car drivers. Moreover, most of the common services rely only on the positioning with GNSS. This works well in open outdoor environments where the satellite signals can be received, but not in areas surrounded by dense high rise environments, and indoors.

Especially in complex buildings, visitors often need guidance and support. One of the main disadvantages inside buildings affects the sense of orientation: people tend to lose orientation a lot easier within buildings than outdoors especially if not moving along windows. Instead of passive systems that are installed on the user's device and frequently position them as the user moves along, new technologies originated in ubiquitous computing could enrich guiding systems by including information captured from an active environment. This would mean that the user is perceived by a ubiquitous environment and receives location-based information that is suitable for the respective device or is supplied with helpful notes via a public display or similar presentation tools. Additionally to the function of information transmission poles, these smart stations substitute or complement traditional indoor positioning methods by sending coordinates of the station instead of locating the user. Based on the concept of "active landmarks", which actively search for the user and build up a spontaneous "ad-hoc network" via an air-interface, a ubiquitous solution, where an information exchange between different objects and devices is accomplished, was investigated for the use in navigation and location-based services (Retscher, 2009a).

This evolutionary method of ubiquitous guiding in smart environments where sensors at active landmarks are present brings a paradigm shift to contemporary wayfinding. As opposed to conventional navigation systems, which are based on preinstalled software, ubiquitous positioning responds to an individual user at his present location in real-time. Interactivity is facilitated and wayfinding aid is more flexible, which provides new opportunities and challenges to the field of navigation and will require research in positioning techniques with alternative multi-sensors. Thereby intelligent fusion algorithms play also a major role (Retscher, 2007 and 2009b).

The WG members have gained experience in the field of indoor and ubiquitous positioning using different technologies and have good track records in this area of research. At the Vienna University of Technology, Austria, positioning with WiFi and active RFID was investigated intensely (Retscher et al. 2007; Fu and Retscher, 2008). On the other hand, positioning with WiFi, UWB (Ultra-wide Band) and Zigbee was investigated and analysed at the Hong Kong Polytechnic University in cooperation with Sun Yat-Sen University in Guangzhou, China (Mok and Gartner, 2008; Mok et al., 2010; Mok et al., 2011). In addition, the colleagues at RMIT University, Melbourne, Australia, have worked on indoor positioning using MEMS-based INS in combination with RFID (Zhang et al., 2008; Zhu et al., 2009; Zhu, 2010; Zhu et al., 2011). WG members at Melbourne University, Australia, have also investigated positioning with MEMS INS (Kealy et al., 2010) and developed a location information taxonomy for LBS (Kealy et al, 2009). Due to the different expertise of the WG members

significant progress for the development of ubiquitous and seamless positioning technologies has already been achieved.

In addition, in 2010 the collaborative FIG WG 5.5 'Ubiquitous Positioning Technologies and Techniques' with IAG has been established (see http://fig.net/commission5/wgroups/wg5_5.htm). The WG is chaired by Allison Kealy and Guenther Retscher. One of the main goals of this WG is to develop an open source platform through which theoretical and practical research into ubiquitous positioning can be enhanced. The platform will be designed in a modular fashion to enable research partners and users to develop their own functionality that can then be easily interfaced and integrated into the platform. Modules will include but not be limited to: performance testing of different types of positioning sensors such as INS, WiFi, RFID, and Zigbee technology; evaluating and data logging of sensors; data integration, algorithm testing and validation either in real-time or post processed; and quality control. Besides the demo platform, demo applications of ubiquitous positioning in combination with analysis of human behaviour are our innovative test and unique output of the collaboration between the two WG's.

In 2007, 2008, 2009 and 2010 the WG 4.1.2 has jointly organized with the ICA Commissions on 'Maps and Internet' and on 'Ubiquitous Cartography' the symposium series on 'Location Based Services and Telecartograpy'. In 2007 the conference was held in Hong Kong, P.R. China; in 2008 in Salzburg, Austria; in 2009 in Nottingham, UK; and in 2010 in Guangzhou, P.R. China. Oral sessions on 'Indoor Positioning' and on 'Positioning in LBS' were held including presentations of members of the WG, e.g. (Retscher and Mok, 2007; Fu and Retscher, 2008; Mok and Gartner; 2008; Zhang et al., 2008). The participating WG members also discussed the future work and collaboration in the working group at these meetings. To continue this successful series of conferences, the WG is actively involved in the organization of the next LBS conference to be held from November 21-23, 2011 in Vienna, Austria (see http://www.lbs2011.org/).

The ION GNSS conference series provided further opportunities for exchanging ideas between WG members and other professionals. Guenther Retscher co-chaired a session on 'Algorithms for Multi-Sensor Fusion' at the ION GNSS 2008 conference which was held in Savannah, Georgia, USA. At the 2009 meeting in Savannah, Allison Kealy represented the WG as technical chair of track B and Guenther Retscher co-chaired a session on 'Multi-sensor Navigation'. Other relevant sessions in track B included 'Algorithms for Multi-sensor Fusion', 'Alternatives and Backups to GNSS' and 'GNSS – Inertial Navigation Systems'. Several papers have been presented, e.g. (Retscher and Fu, 2008; Zhu, 2008; Retscher, 2009b).

For the future work of WG 4.1.2, networking and knowledge exchange between members of the WG will be continued. In addition, co-organization of upcoming conferences in the field of GNSS and LBS is planned.

Publications

Fu Q., G. Retscher (2008): Using RFID and INS for Indoor Positioning. in: Gartner G., K. Rehrl (Eds.): Location Based Services and TeleCartography II - From Sensor Fusion to Context Models, Lecture Notes in Geoinformation and Cartography, Springer Verlag, Berlin, Heidelberg, 2008, ISBN: 978-3-540-87392-1, pp. 421 - 438.

Kealy A., S. Winter, G. Retscher (2007): Intelligent Location Models for Next Generation of Location-based Services. Journal of Location Based Services, Vol. 1, No. 4, pp. 237-255.

Kealy A., M. Duckham, G. Retscher, G. Roberts, S. Winter (2009): Location Information Taxonomy for Location Based Services. in: Papers presented at the 6th International Symposium on Mobile Mapping Technology, July 21-24, 2009, Presidente Prudente, Brazil, CD Rom Proceedings, 8 pgs.

Kealy A., G. Roberts, G. Retscher (2010): Evaluating the Performance of Low Cost MEMS Inertial Sensors for Seamless Indoor/Outdoor Navigation. in: Papers presented at the 2010 IEEE/ION Position, Location and Navigation Symposium PLANS 2010, May 4-6, 2010, Indian Wells/Palm Springs, California, USA, CD-Rom Proceedings, pp. 157-167.

Mok E., G. Retscher (2007): Location Determination Using WiFi – Fingerprinting Versus WiFi – Trilateration. Journal of Location Based Services, Vol. 1, No. 2, pp. 145-159.

Mok E., G. Gartner (2008): Navigation support for wayfinding in smart environments using ZigBee positioning technology, Proceedings of the 5th Symposium on Location Based Services and Telecartography, Salzburg, 26-28 November 2008, pp. 125-127.

Mok E., L. Xia, G. Retscher, T. Hui (2010): A Case Study on the Feasibility and Performance of an UWB-AoA Real Time Location System for Resources Management of Civil Construction Projects. Journal of Applied Geodesy, Vol. 4, No. 1, ISSN 1862-9024, pp. 23-32.

Mok E., L. Xia, G. Retscher (2011): Influential Factors for Decimetre Level Positioning Using Ultra Wide Band Technology. Paper accepted for publication in Survey Review.

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WG 4.1.3: Multi-sensors systems for environmental monitoring applications

Chair: Jan Skaloud

January (2008); Jan Skaloud (group chair) presented several research topics together with WG 4.1 activities at the Department of Geomatics Engineering, University of Calgary.

February (2008): **EuroCOW 2008**

This meeting intended to bring together the world experts, both from public and private sectors, to present and discuss the recent findings and developments on Sensor Calibration and Orientation. The meeting was a highly specialized forum which subject substantially overlapped with the IAG 4.1 topics. During this meeting Jan Skaloud (group chair):

- directed the session on INS/GNSS Technology and Applications
- presided the special Technology update session
- delivered paper "On the calibration strategy of medium format cameras for direct georeferencing"

May (2008): The airborne mapping scanning Scan2map designed in EPFL, Switzerland performed the world-first RTK-LiDAR airborne survey mission. The complete laser point cloud was generated in the real-time with 5 cm – level accuracy. The implemented technology opens the door to new environmental monitoring application.

June (2008): Yannick Stebler (group member) completed his work on GPS/INS Integrity in Airborne Mapping. His approach has been implemented and tested in close-range airborne mapping system suitable for environmental monitoring.

Meeting in Innsbruck, Austria for setting up a joint project related to WG 4.1 research activity. Participants: Jan Skaloud (group chair), Yannick Stebler (group member), Klaus Legat (group member), local industry and faculty members of TU Graz.

July (2008): **ISPRS Congress in Beijing**

The ISPR congress is the largest meeting of the International Society for Photogrammetry and Remote Sensing organized once per four years. IAG is a partner organization of ISPRS and activates within the ISPRS Commission I are closely related to IAG WG 4.1 research topics. During this meeting

- -Philipp Schaer (group member) was selected to deliver oral presentation in the highly competitive session on Integrated Systems for Mobile Mapping. He was the first author of the paper "Towards In-Flight Quality Assessment of Airborne Laser Scanning"
- Julien Vallet (group member) participated at ISPRS Congress in Beijing where he co-authored work on "Oblique Helicopter-Based Lasers Scanning for Digital Terrain Modeling and Visualization of Geological Outcrops."
- Jan Skaloud (group chair) was proposed to chair the ISPRS Commission I working group (WG I-5) on Integrated Systems for Sensor Georeferencing and Navigation. His appointment was later approved by the ISPRS council together with the appointments of Ismael Colomina (group member) as co-chair and Klaus Legat (group member) as secretary.

September (2008): Common meeting of WG 4.1 chair and co-chair was held in Switzerland. The meeting was aimed to update and synchronize the developments on multi-sensor mobile platforms within WG 4.1 leadership.

October (2008): Meeting in Innsbruck, Austria for continuing common research related to WG 4.1 activity. Participants: Jan Skaloud (group chair), Yannick Stebler (group member), Klaus Legat (group member) members of TU Graz.

November (2008): Christian Baumann (group member) spent three weeks in the Institute of Geomatics in Castelldefels, Spain. He was a host of the institute director Dr. I. Colomina (group member). This was a research oriented stay in the domain of sensor integration methods.

Jan Skaloud (group chair) participates at the 6th edition of the Swiss Geoscience Meeting and delivers a talk on the Real-Time Mapping and Monitoring Capability of Geological Features by Airborne Laser Scanning.

December (2008): The real-time analyses of the kinematic laser-scanning coverage and density have been implemented in the mobile laser scanning system Scan2map, EPFL Switzerland. The digital surface model is calculated in the real-time and presented to the operator as hill-shade raster image.

February (2010): **EuroCOW 2010**

This meeting intended to bring together the world experts, both from public and private sectors, to present and discuss the recent findings and developments on Sensor Calibration and Orientation. The meeting was a highly specialized forum which subject substantially overlapped with the IAG 4.1 topics.

March (2010): The group members started a new research project related to robust navigation for unmanned airborne micro-vehicles (<5kg). The project aims integrating redundant low-cost (MEMS) IMUs (RIMU), barometer data and GNSS/EGNOS signals together with high-resolution digital surface models. The new platforms shall carry different type of sensors for environmental monitoring.

April (2010): Group member published a joint journal paper on noise reduction of multiple low-cost IMUs in the journal of Measurement Science and Technology.

June (2010): Several group members participated at the Canadian Geomatics Conference held in Calgary, Alberta. This meeting brought together experts in the field of geomatics from Canada and the world.

September (2010): WG chair J. Skaloud presented invited lecture at the University of Calgary entitled Optimizing Computational Performance for Real-Time Mapping with Air-borne Laser Scanning. His visit initiated new exchange of airborne data and experience between group members.

Several group members participated at ION-GNSS in Portland, Oregon, the largest annual meeting in the field of satellite positioning.

November (2010): The group members met in Barcelona (Spain) to review the started project on robust navigation for micro-UAV platforms and to conduct a test-flight with a UAV helicopter platform equipped with hyper-redundant navigation systems comprising GNSS receivers (3), MEMS-IMUs(4), control tactical-grade IMU, barometer, thermo sensors, and terrain guidance.

January (2011): A new micro-UAV platform has been acquired for a joint environmental monitoring project between group members. This platform can carry up to 0.5kg payload and has a flying autonomy of ~30 minutes.

February (2011): There was a group meeting in Portugal between group members for analyzing and synthesizing the flight-results from November 2010.

March (2011): Two group members met in Switzerland for test and analysis of the capacity of a new MEMS-IMU at tactical-grade quality that is not yet in production.

Sub-Commission 4.2: Applications of Geodesy in Engineering

President: Günther Retscher (Austria)

Website: http://info.tuwien.ac.at/ingeo/sc4/sc42.html

Terms of reference

Rapid developments in engineering, microelectronics and the computer sciences have greatly changed both instrumentation and methodology in engineering geodesy. To build higher and longer, on the other hand, have been key challenges for engineers and scientists since ancient times. Now, and for the foreseeable future, engineers confront the limits of size, not merely to set records, but to meet the real needs of society minimising negative environmental impact. Highly developed engineering geodesy techniques are needed to meet these challenges. The SC will therefore endeavour to coordinate research and other activities that address the broad areas of the theory and applications of engineering geodesy tools. The tools range from conventional terrestrial measurement and alignment technology (optical, RF, etc.), Global Navigation Satellite Systems (GNSS), geotechnical instrumentation, to software systems such as GIS, decision support systems, etc. The applications range from construction engineering and structural monitoring, to natural phenomena such as landslides and ground subsidence that have a local effect on structures and community infrastructure. The SC will carry out its work in close cooperation with other IAG Entities, as well as via linkages with relevant scientific and professional organisations such as ISPRS, FIG, IEEE, ION.

Objectives

- To monitor research and development into new technologies that are applicable to the general field of "engineering geodesy", including hardware, software and analysis techniques.
- To study advances in dynamic monitoring and data evaluation systems for buldings and other manmade structures.
- To study advances in monitoring and alert systems for local geodynamic processes, such as landslides, ground subsidence, etc.
- To study advances in geodetic methods used on large construction sites.
- To study advances in the application of artificial intelligence techniques in engineering geodesy.
- To document the body of knowledge in this field, and to present this knowledge in a consistent frame work at symposia and workshops.
- To promote research into several new technology areas or applications through the SC4.2 Working Groups.

Initially it was planned to establish the following four Working Groups:

WG 4.2.1: Measurement Systems for the Navigation of Construction Processes

Chair: Wolfgang Niemeier (Technical University Braunschweig, Germany)

WG 4.2.2: Dynamic Monitoring of Buildings

Chair: Gethin Roberts (IESSG, Nottingham University, UK)

WG 4.2.3: Application of Artificial Intelligence in Engineering Geodesy

Chair: Alexander Reiterer (Vienna University of Technology, Austria)

Co-Chair: Uwe Egly (Vienna Univ. of Technology, Austria)

WG 4.2.4: Monitoring of Landslides and System Analysis

Chair: Gyula Mentes (Geodetic and Geophysical Research Institute of HAS, Hungary)

Co-Chair: Paraskevas Savvaidis (University of Thessaloniki, Greece)

The reports of the activities of WG 4.2.3 and WG 4.2.4 can be found below. These two WGs are very active. WG 4.2.3 has currently 8 members and WG 4.2.4 23 members. WG 4.2.4 has changed its title recently to "Investigation of Kinematic and Dynamic Behaviour of Landslides and System Analysis". WG 4.2.1 and WG 4.2.2, however, were not established in the reported period.

In the last two years SC 4.2 was involved in the organization of the following conferences:

1. **8th Conference on Optical 3-D Measurement Techniques**

   July 9-12, 2007 in Zurich, Switzerland
2. **4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 13th FIG Deformation Measurement Conference**

   May 12-15, 2008 in Lisbon, Portugal
3. **9th Conference on Optical 3-D Measurement Techniques**

   July 1-3, 2009 in Vienna, Austria
4. **6th International Symposium on Mobile Mapping Technology (MMT'09)**

   July 21-24, 2009 in Presidente Prudente, São Paulo, Brazil

The established WG's have supported these four conferences and were represented by WG members and/or chairs.

The sub-commission is also involved in the organization of the following upcoming meetings:

1. **7th International Symposium on Mobile Mapping Technology (MMT'11)**

   June 13-16, 2011 in Cracow, Poland
2. **Joint International Symposium on Deformation Monitoring (JIS-DM), including 5th IAG Symposium on Geodesy for Geotechnical and Structural Engineering, 14th FIG Symposium on Deformation Measurements and Analysis, and International Workshop on Spatial Information Technologies for Monitoring the Deformation of Large-Scale Man-Made Linear**

   November 2-4, 2011 in Hong Kong, P.R. China

WG 4.2.3: Application of Artificial Intelligence in Engineering Geodesy

Chair: Alexander Reiterer

AI, in general, is the study and design of intelligent agents, where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success. Many real-world problems require the agent to operate with incomplete or *uncertain information*. Methods used for uncertain reasoning are probabilistic in nature, such as Bayesian networks, which represent a general tool that can be used for a large number of problems, for example, reasoning (using the Bayesian inference algorithm), learning (using the expectation-maximization algorithm), planning (using decision networks), and perception (using dynamic Bayesian networks). Probabilistic algorithms can also be used for filtering, prediction, smoothing and finding explanations for streams of data, helping perception systems to analyze processes that occur over time. AI techniques also include classifiers and statistical learning methods.

In the last years, Artificial Intelligence (AI) has become an essential technique for solving complex problems in Engineering Geodesy.

Current applications using AI methodologies in engineering geodesy are:

- geodetic data analysis,
- deformation analysis,
- navigation,
- deformation network adjustment,
- optimisation of complex measurement procedure.

The work of the WG 4.2.3 can be summarized as follows:

- networking and knowledge exchange between members of the WG,
- organisation of a meetings,
- organisations of two international workshops
- public relation in form of an website (http://info.tuwien.ac.at/ingeo/sc4/wg423/wg_423.html).

In 2008 the WG has organized the "First International Workshop on Application of Artificial Intelligence in Engineering Geodesy – AIEG2008" in Vienna/Austria. The meeting was co-sponsored by Leica Geosystems and FWF (Austrian Science Fund). About 20 experts from the US, from Germany, Italy and Austria have participated. The program consisted of presentations and tutorials. The workshop was an exciting opportunity to discuss the state of the art and recent developments of AI application in engineering geodesy. The two key notes were given by Prof. Dorota A. Grejner-Brzezinska from the Ohio State University (USA) and by Dr. Chmelina Klaus from Geodata (Austria). Oral presentations have been focused on the application of artificial neuronal networks, knowledge-based systems, intelligent sensor fusion, decision-support systems, etc. The workshop proceedings have been published in one Volume which has about 120 pages.

In 2009 the WG has organized a special session at the "9th Optical 3-D Measurement Techniques 2009" in Vienna. The session "Applications of Artificial Intelligence in Optical 3D-

Systems" has presented research work of different origin and content, e.g. basic research, application oriented research, etc.

In 2010 the WG has organized the "Second International Workshop on Application of Artificial Intelligence and Innovations in Engineering Geodesy – AIEG2010" in Braunschweig/Germany. The meeting was co-sponsored by Inmetris3D and Trimble. About 40 experts from Germany, Italy, Greek, Turkey and Austria have participated. The program consisted of presentations and tutorials. The key note was given by Prof. Hansjörg Kutterer from the Leibniz University Hannover. Oral presentations have been focused on the application of vector machines, artificial neuronal networks, intelligent sensor fusion, decision-support systems, etc. The workshop proceedings have been published in one Volume which has about 110 pages.

For an easy communication within the WG a central data exchange unit and a mailing list have been installed.
In 2010 some members of the WG have composed a paper about methods of AI in geodesy. The paper will be published in 2011 in the Journal of Applied Geodesy.

Publications:

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IAG WG 4.2.4: Investigation of Kinematic and Dynamic Behaviour of Landslides and System Analysis

Chair: Gyula Mentes

Surface mass movements can cause a lot of damages. Forecasting landslides is of crucial importance due to the potentially serious consequences to the society. It is a difficult and complex task which needs understanding of the relationships between landslide generating processes (geological, geophysical, hydrological, meteorological, etc.) and movements of the sliding block and its surroundings. In addition to the continuous recording geophysical, hydrological, meteorological, etc. parameters, there is an urgent need for continuous 3D geodetic measurements to determine the complex movements of the landslide prone area to understand the kinematic and dynamic behaviour of landslides. There is only a chance to develop an early warning system in exact knowledge of the moving process of the landslide area and all of other physical parameters. According to these requirements the working group laid a special emphasis on the following research areas:

- detection of potential landslides on large scale
- an efficient and continuous observation of critical areas
- a knowledge-based derivation of real time information about actual risks in order to support an alert system (Kahmen et al., 2007).

The main task of the working group in the last four years was the development of 3D geodetic measurement techniques. In the most cases different geodetic measuring methods were used simultaneously on the test sites, both to get more precise information about the movements and to test and compare the single measuring systems. For detection of landslide prone areas InSAR technique was used (Riedel and Walther, 2008). The InSAR technique was also combined with terrestrial geodetic measuring techniques for continuous observation of surface movements. As terrestrial geodetic measurement techniques new instruments and methods were developed and tested. Instead of geodetic measurements carried out in periodical campaigns a great stress was laid on the continuous geodetic measurements techniques to get data series directly comparable with continuously collected hydrological (water table, stream stage, pore pressure, etc.), meteorological (e.g. precipitation, temperature), etc. data series for the study of dynamic processes of landslides and to get more reliable and comprehensive information for development of early warning systems.

In Germany at the Institute of Physical Geodesy of the Darmstadt University of Technology and at the Braunschweig University of Technology ground-based microwave interferometry was used to monitor surface displacements in a quarry (Niemeier and Riedel, 2010; Rödelsperger et al., 2010). Time domain reflectometry (TDR) for the detection of surface displacements in boreholes and reflectorless video tacheometry (VTPS) and a low cost GNSS sensor array for 3D determination of surface movements were tested by the researchers of the Chair of Engineering Geology and Chair of Geodesy of Munich University of Technology and Institute of Geodesy of UniBw Munich (Thuro et al., 2010). At the Institute of Geodesy and Geophysics of the Vienna University of Technology and at the Geodetic Institute of the Darmstadt University of Technology automatic tacheometer measurement system was used for landslide monitoring and an adaptive Kalman-filtering method was developed to predict displacements (Schmalz et al., 2010) with the aim to develop an early warning system.

All members carried out measurements at different types of landslide areas: in mountainous and hilly regions, on streambanks. This makes possible to better understand the general relationships between movements and geological, geomorphological, hydrological, meteorological, etc. factors and their role in triggering landslides. The investigated test sites were: Steinlehnen test site in Austria (Northern Tyrol), Baota test site in China, the Aggenalm Landslide in the Bavarian Alps in Germany, Touzla overpass, Kristallopigi landslide, Basilikos landslide, Gkrika Cuts, Prinotopa site, Anthohori entrance, the Big Cut in Greek, the high loess banks of the River Danube at Dunaföldvár and Dunaszekcső in Hungary, Corvara test site in Italy.

All the participants collected their data in GIS (see e.g. Lakakis et al., 2009a; Mentes, 2008a and 2008b) and used these data to develop Spatial Decision Support Systems (SDSS) (e.g. Lakakis et al., 2009b) and early warning systems. To get reliable information about the landslide behaviour with the use of all available information Support Vector Machine (SVM) modelling was developed (Riedel and Heinert, 2008). An Adaptive Kalman-Filtering method was developed for the Calibration of Finite Difference Models of Mass Movements and for prediction of displacements on the basis of real time measurements (Schmalz et al., 2010).

In Hungary two characteristic landslide prone areas were investigated. Both test sites are streambanks along the River Danube. At the first test site in Dunaföldvár landslides occurred several times. Here continuous borehole tilt measurements have been carried out since 2002. Relationships between regional tectonics, subsurface structures and mass movements were investigated based on remote sensing data, gravity and tilt measurements in cooperation between the Geodetic and Geophysical Research Institute of the Hungarian Academy of

Sciences and the Berlin University of Technology, Institute of Geosciences, Department of Hydrogeology and Bureau of Applied Geoscientific Remote Sensing (Mentes, 2008a, 2008b; Mentes et al., 2009; Újvári et al., 2008). At this test site the relationships between hydrological effects (water stage of the River Danube, ground water table and precipitation) and streambank movements were also investigated in detail.

The other test site at Dunaszekcső in Hungary gave a good opportunity to investigate the whole process of the landslide mechanism, since a large landslide occurred at this test site on February 12, 2008. The high bank on this area was sliding slowly with increasing velocity since September of 2007 till February 12, 2008. On this day there was an abrupt sliding. About 500.000 m^3 loess was sliding toward to the Danube. The movements before, during and after the sliding process were monitored by GPS and borehole tilt measurements. The study of the movement is a good possibility to understand the kinematics and dynamics of the slope (Újvári et al., 2009) and therefore the investigations are continued. The high bank is still moving and a next slide event is expected to take place on the South part of the test site in the near future.

The Institute of Geodesy and Geophysics of the Vienna University of Technology in cooperation with the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences develops measurement methods and their mathematical background for detecting very small displacements by accelerometers and borehole tiltmeters with very high resolution (1 nrad). These small movements are not detectable by geodetic methods but their early detection is very important for forecasting of a possible landslide. The most important issue of this research is that how can be the small movements caused by the initial phase of a landslide separated from the background noise (Kahmen et al., 2007; Mentes, 2008b and 2008c).

In this period the inactive members of the working group were replaced for other members working actively in landslide research. As the presented examples showed the member of the working group actively cooperated with each other and achieved new scientific results. If the work of the group can be continued in the next period, then a workshop will be organized in Sopron, Hungary.

Publications:

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Lakakis, K., Charalampakis, M., Savvaidis, P. 2009a: A Landslide Definition by an Integrated Monitoring System. Fifth International Conference on Construction in the 21st Century (CITC-V), Collaboration and Integration in Engineering, Management and Technology. May 20-22, Istanbul, Turkey. pp. 1-8.

Lakakis, K., Charalampakis, M., Savvaidis, P. 2009b: A Spacial Decision Support System for Highway Infrastructure. Fifth International Conference on Construction in the 21st Century (CITC-V), Collaboration and Integration in Engineering, Management and Technology. May 20-22, Istanbul, Turkey. pp. 1-8.

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Mentes G. 2008c: A new method for dynamic testing of accelerometers. INGEO 2008 – 4th International Conference on Engineering Surveying, Slovak University of Technology, ISBN 978-80-227-2971-0, Bratislava, p. 10.

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Riedel, B., Heinert, M. 2008: An adapted support vector machine for velocity field interpolation at the Baota landslide. AIEG 2008 First Workshop on Application of Artificial Intelligence in Engineering Geodesy. pp. 1-13.

Riedel, B., Walther, A. 2008: InSAR Processing for the recognition of landslides. Advances in Geosciences. 14, 189-194.

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Schmalz, T., Buhl V., Eichhorn, A.: An Adaptive Kalman-Filtering Approach for the Calibration of Finite Difference Models of Mass Movements. Journal of Applied Geodesy. 2010, 4(3), 127-135.

Thuro, K., Singer, J., Festl, T., Wunderlich, T., Reith, C., Heunecke, O., Glabsch, J., Schubäck, S. 2010: New landslide monitoring technique developments and experiences of the alpEWAS project. Journal of Applied Geodesy. 4(2), 69-90.

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Újvári, G., Mentes, G., Bányai L., Kraft, J., Gyimóthy, A. Kovács, J. 2009: Evolution of a bank failure along the River Danube at Dunaszekcső, Hungary. Geomorphology, 109, 197-209. (doi:10.1016/j.geomorph.2009.03.002).

Working Group 4.2.5 – Ubiquitous Positioning Systems (Joint with FIG Working Group 5.5)

Chair: Allison Kealy

Objectives

The challenge of delivering ubiquitous positioning capabilities i.e. geopositioning in all environments, has raised numerous philosophical, technical and operational questions, many of which are currently under investigation by a vast, multi-disciplinary, international research community. This working group has been established as a response to these questions and aims to draw together these international efforts under a common umbrella project of ubiquitous positioning.

Terms of Reference

This group will focus on the development of shared resources that extend our understanding of the theory, tools and technologies applicable to the development of ubiquitous positioning systems. It has a major focus on:

- Performance characterization of positioning sensors and technologies that can play a role in the development of ubiquitous positioning systems.
- Theoretical and practical evaluation of current algorithms for measurement integration within ubiquitous positioning systems.

- The development of new measurement integration algorithms based around innovative modeling techniques in other research domains such as machine learning and genetic algorithms, spatial cognition etc.
- Generating formal parameters that describe the performance of current and emerging positioning technologies that can inform FIG and IAG members.

Report on activities

In 2009, the FIG working group WG5.5 collaborative with IAG working group 4.2.5 – Ubiquitous Positioning Systems - held two international workshops. These workshops kicked off a longer term practical study into understanding the signals used in ubiquitous positioning systems. Low-cost MEMS inertial navigation sensors (INS) were the focus of these tests. With the overall aim of characterizing the operational environment for mobile users (using a range of low-cost MEMS INS) the first workshop was held at the University of New South Wales, Sydney. The second workshop was held at the Ohio State University with the aim of acquiring benchmarking datasets for GNSS/INS systems that could be used by the broader research community.

To evaluate the performance of low-cost MEMS INS within the context of bridging GPS outages and maintaining the availability of a position solution, a time synchronisation software package has been developed as a generic data capture platform for ubiquitous positioning, and allows for the addition of new sensors by simply configuring a few parameters describing the communications interface, data output format, field descriptions and data conversion factors. The program uses the GPS pulse per second (PPS) when it is available to synchronize the incoming data while native kernel32 is used between GPS time updates. This software package will soon be available on a resources website currently under development by this working group.

The aim of the second workshop was to generate representative datasets that could be used in benchmarking the performance of MEMS INS as well as providing a data resource for the research community involved in the development of GPS/INS sensor fusion algorithms. A range of MEMS INS with small variations in the manufacturer performance specifications and a navigation grade INS were used in these tests. The datasets collected and all associated information will also be made freely available to the broader FIG/IAG research community on the working group website.

Meetings:

A kick-off meeting was held in December 2009 in Sydney, Australia to confirm the terms of reference, initiate participation and outline work packages to be completed in the first year of this working group. The working group was formally launched at the FIG meeting in April 2010 and a second meeting for current participants was held in May 2010 at the Ohio State University, USA. Working group activities planned for 2011 include participation in the FIG Working Week in Marrakech, Morocco, the ION GNSS conference in Portland, Oregon, the IUGG Symposium in Melbourne, Australia, the IGNSS conference in Sydney, Australia, the International Mobile Mapping Symposium in Krakow, Poland in June 2011, and the Location-Based Services Symposium in Vienna, Austria

Sub-Commission 4.3: Remote Sensing and Modelling of the Atmosphere

President: Marcelo Santos (Canada)
Vice-President: *Jens Wickert* (*Germany*)

Terms of Reference

The objective of Sub-Commission 4.3 (SC 4.3) is to coordinate research dealing with the treatment, interpretation and modelling of measurements collected in the atmosphere for the purpose of improvements in geodetic positioning as well as for better understanding the atmosphere itself. Even though GNSS techniques are seen here as the primary research tools, other sensors also bring important information on the atmosphere and as such should be considered in the context of this Sub-Commission. Dedicated satellites, having on-board GNSS receivers, can also contribute to atmospheric studies by exploring the atmosphere-induced bending of GNSS signals while propagating through the atmosphere, to furnish round-the-clock weather data, monitor climate change, and improve space weather forecasts. Geodetic positioning can benefit and contribute to atmospheric models, such as Numerical Weather Prediction (NWP) models. Novel advancements in modelling the atmosphere as applied to positioning, error sources, instrumentation, dedicated missions, and real- or near real-time data access should also be contemplated. SC4.3 will foster linkages with sister scientific and professional organizations, such as IAG, ISPRS, FIG, IEEE and ION.

Meetings

As a sub-Committee activity, two Symposia were organized during IAG Assemblies. One of them during the IAG General Assembly, Buenos Aires, Argentina, Aug 31 – Sep 4, 2009, with title "Remote Sensing of the Troposphere." The other being organized for the IUGG General Assembly, 28th June to 7th July, 2011, Melbourne, Australia, with the title "Space geodesy-based atmospheric remote sensing." (joint with IAMAS)

Study Group 4.3.1 - Ionosphere Modelling and Analysis

Chair: Michael Schmidt (Deutsches Geodätisches Forschungsinstitut, Munich, Germany), schmidt@dgfi.badw.de

Co-Chair: Mahmut O. Karslioglu (Middle East Technical University, Ankara, Turkey), karsliog@metu.edu.tr

Members:

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Terms of Reference

The general objective of this study group is the development of strategies for establishing ionosphere models which can be used for both, the correction of electromagnetic measurements and the study of ionospheric features and their spatial-temporal evolution. Thus, our overall intention is the combination of physics, mathematics and statistics to derive a high-resolution multi-dimensional ionosphere model.

Research Activities:

- At DGFI a multi-dimensional ionosphere model was developed within the last years which can be used for modelling ionospheric target functions such as the electron density and the vertical total electron content (VTEC) globally, regionally or locally. Depending on the chosen area spherical harmonics, endpoint-interpolating B-splines, trigonometric B-splines, Chapman functions, etc. can be used for the spatial representation. For the temporal representation empirical orthogonal functions, B-splines, a Fourier series, etc. can be chosen. The unknown coefficients of the resulting spatio-temporal multi-dimensional ionosphere model based on tensor products of the different kinds of base functions are estimable from a combination of ground-based GNSS measurements, dual-frequency altimetry and COSMIC/FORMOSAT-3 GPS measurements; data gaps can be handled efficiently by a regularization procedure using prior information.
- Much of the ionospheric modelling efforts in South Africa have been concentrated on practical applications and for contributions towards improvements to the International Reference Ionosphere (IRI). The main areas that the group has concentrated on in the last 2 years are (1) improvements to the South African Bottomside Ionospheric Model (SABIM), (2) the development of a neural network based global foF2 model, (3) the variability of F1 and F2 layer parameters and (4) the development of an ionospheric map for South Africa.
- The research work on ionosphere at NCU is to carry out studies of the structure and dynamics of near-Earth space plasma distribution and investigation of space weather under different solar-geophysical conditions. The proposed research will be carried out by ionosphere profiling and modeling and on the base of ionosondes, low-orbital (American TRANSIT and Russian TSIKADA/PARUS) and high-orbital (American GPS and Russian GLONASS) navigational satellite systems.
- The DLR at Neustrelitz is establishing an ionosphere weather service via the project SWACI (http://swaciweb.dlr.de) which is essentially supported by the German state government of Mecklenburg-Vorpommern. The service includes the provision of data products deduced from ground- and space-based GNSS measurements. Whereas ground-based GNSS measurements provide VTEC maps and corresponding derivatives, spaced-based measurements provide vertical electron density profiles and 3D reconstructions of the topside ionosphere/plasmasphere systems. All retrieval techniques are model assisted:

  - The DLR model NTCM is used as a background model for creating TEC maps by data assimilation.
  - A Chapman layer based model is assisting the retrieval of vertical electron density profiles from radio occultation measurements onboard CHAMP and GRACE satellites.
  - The PIM model is used as a background model for 3D reconstructions of the topside ionosphere/plasmasphere systems using navigation data from the CHAMP satellite

- With its standard X/S-band dual frequency observing sessions Very Long Baseline Interferometry (VLBI) provides consistent ionospheric delays from 1979 until today. The network of geodetic/astrometric VLBI guided by the International VLBI Service of Geodesy and Astrometry (IVS) consists of sites with a globally distribution, which take part in routine observing sessions more or less sparsely. At DGFI first considerations have been carried out evaluating a potential contribution of slant total electron content (STEC) from IVS data to a combined model of the ionosphere.
- In the last 2 years the Institute of Geodesy and Geophysics (IGG) of TU Vienna has successfully accomplished the development of combined global VTEC models from GNSS and altimetry. To achieve this goal spherical harmonics of degree 15 were used. Global Ionosphere Maps (GIMs) with spatial resolution of 2.5^o latitude, 5^o longitude and temporal resolution of 2 hours are estimated. Next VTEC measurements derived from FORMOSAT-3/COSMIC occultation data were combined with the GIMs by recursive parameter estimation. Different empirical weighting methods were applied. The results clearly show improvement of VTEC maps in the time when occultation measurements are carried out in regions with low number of GNSS stations, i.e. mainly on ocean.
- At the Middle East Technical University (METU) B-spline functions were used to model VTEC on the basis of real GPS observations collected over Turkey. For 2D case, VTEC is modeled in sun-fixed reference frame while 3D approach including the time to represent the temporal variations the modelling was performed in an Earth-fixed reference frame. Iteratively re-weighted least squares (IRLS) with a bi-square weighting function as a robust regression algorithm was carried out for the parameter estimation procedure in order to reduce the effects of outliers. Another iterative method, i.e. Conjugate Gradient Least Squares (CGLS) method was performed to bring about regularization effect for ill-conditioned problems in large equations.
- In a second project at METU an efficient algorithm with Multivariate Adaptive Regression Splines (MARS) was developed for regional spatio-temporal mapping of the ionospheric electron density using ground-based GPS observations. MARS is able to handle very large datasets and is an adaptive and flexible method, which can be applied to linear and non-linear problems. The base functions are directly obtained from the observations and have space partitioning properties resulting in an adaptive model that provides solutions in region with rare observations without regularization. Since the fitting procedure is additive it does not require gridding and is able to process large amounts of data with large gaps. The performance and adaptivity of the MARS algorithm were applied to real GPS data over Europe.
- The work at Goddard Space Flight Centre (NASA/GSFC) was concentrating on the validation of the International Reference Ionosphere (IRI) using in situ measurements from GRACE K-Band ranging and CHAMP planar langmuir probe (PLP). The ionospheric delay derived by combination of dual frequency K-Band ranging measurements of GRACE infers the electron density integrated between the two satellites along the orbit with a baseline length of approximately 220 km at the altitude of around 450 km. We

compared the GRACE KBR and PLP measurements with the electron density derived from IRI and validated the recent advances in IRI.

- The research activities within SG4.3.1 will be bundled in a special issue of Journal of Geodesy, which will be published hopefully next year. General Topic of the Special Issue reads: Geodetic contributions to ionosphere research. List of individual papers:
  1. Schmidt, M.: Introduction
  2. Hernandez-Pajarez, M., J.M. Juan, J. Sanz, A. Aragon-Angel, A. Gracia-Rigo, D. Salazar: The Ionosphere: effects, modelling and benefits in the Space Geodetic techniques
  3. Bilitza, D., L.-A. McKinnell, B. Reinisch, T. Fuller-Rowell: The International Reference Ionosphere (IRI) today and in the future
  4. Dettmering, D., M. Schmidt, R. Heinkelmann, M. Seitz: Combination of different satellite observation data for regional ionosphere modeling
  5. Alizadeh M.M., H. Schuh, S. Todorova, M. Schmidt: Global Ionosphere Maps of VTEC from GNSS, Satellite Altimetry and FORMOSAT-3/COSMIC Data
  6. Brunini, C., F. Azpilicueta, M. Gende, E. Camilion, A. Aragón-Ángel, M. Hernández-Pajares, J.M. Juan, J. Sanz, D. Salazar: Ground- and space-based GPS data ingestion into the NeQuick model
  7. A. Krankowski, I. Zakharenkova, A. Krypiak-Gregorczyk, I.I. Shagimuratov, P. Wielgosz: Ionospheric electron density observed by FORMOSAT-3/COSMIC over the European region and validated by ionosonde data
  8. N. Jakowski, M.M. Hoque, C. Mayer: A new global TEC model for estimating transionospheric radio wave propagation errors
  9. Tsai, L.-C., K. Kevin Cheng, C. H. Liu: GPS radio occultation measurements on ionospheric electron density from low Earth orbit
  10. Lee, C.-K., S.-C. Han, D. Bilitza, J.-K. Chung: Validation of the International Reference Ionosphere models using in situ measurements from GRACE K-Band ranging and CHAMP planar langmuir probe

Meetings:

- TUJK, Annual Scientific Meeting, 2007-11-14/16, Ankara, Turkey (Karslioglu, Nohotcu, Schmidt, Heinkelmann)
- EGU 2008, General Assembly, 2008-04-14/18, Vienna, Austria (Schmidt, Alizadeh, Heinkelmann)
- URSI 2008, General Assembly, 2008-08-07/16, Chicago, USA (Schmidt, Tsai, Bilitza, McKinnell)
- EGU 2009, General Assembly, 2009-04-19/24, Vienna, Austria (Schmidt, Dettmering, Tsai, Alizadeh, Bilitza, Krankowski, Wielgosz, Han)
- Splinter Meeting of IAG SG 4.3.1, 2009-04-23, TU Vienna, Austria (Schmidt, Dettmering, Tsai, Alizadeh, Bilitza, Krankowski, Wielgosz)
- Real-time IRI Task Force Workshop, 2009-05-04/06, Colorado Springs, USA (Schmidt, Bilitza)

– A. Krankowski, M.O. Karslioglu and myself organize the session G5.1 Monitoring and modelling of the ionosphere from space-geodetic techniques at EGU 2011 in Vienna. The topic of the session is closely related to the objectives of the IAG Study Group.

Publications:

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Heinkelmann R., T. Hobiger, and M. Schmidt: Contribution of VLBI to a combined model of the ionosphere. Poster presented at the EGU 2009 General Assembly, Vienna, Austria, 19-24 April 2009.

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McKinnell L.A., and Friedrich M., "A neural network based model for the auroral zone", Journal of Atmospheric and Solar Terrestrial Physics, doi:10.1016/j.jastp.2007.05.003, 69, pp. 1459 – 1470, 2007.

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Working Group 4.3.1 - Atmospheric refractivity, TEC and Ionospheric Scintillation

Chair: Lucilla Alfonsi (INGV, Italy)
Co-Chair: Sybille Vey (TU Dresden)

Terms of Reference

To collect experimental data to derive information on precipitable water vapour, TEC and ionospheric scintillation by means of GPS monitors/receivers, at high and mid latitudes, and to study the tropospheric and ionospheric impact on precise positioning operations, during both quiet and disturbed conditions at middle and high latitudes.

Report on activities

During the first months of the WG the work has been mainly dedicated to the first attempts of exchange data and expertise on ionospheric imaging and mitigation of ionospheric effects on GNSS signals. A feasibility study on the use of Antarctic measurements, run by both geodetic and ionospheric teams, for water vapour reconstruction is currently in progress by using the GPS data collected at the Italian station "Mario Zucchelli" (Terra Nova Bay, Antarctica).

Recently available, global tropospheric models for water vapour retrieval were implemented in the analysis of geodetic observations with the purpose of improve the estimation process of

zenith total delay with GPS data. Comparisons with old models are being carried out and alternative techniques for water vapour content estimation, such as radiosonde. In particular, common data sets from different techniques and overlapping observations periods have been identified and adopted as test benchmarks on which cross checking can be performed and integrated water vapour can be computed. Analysis is currently in progress. A collaboration with the geodetic groups dealing with Mediterranean GPS data is planned to start multidisciplinary studies also at middle latitudes. From 2009 to 2011 the WG work has been dedicated to exchange data and expertise on ionospheric imaging and mitigation of ionospheric effects on GNSS signals at high and low latitudes. The use of Antarctic measurements, run by both geodetic and ionospheric teams, for water vapour and ionospheric electron density reconstruction is the core of an Action Group, titled "GPS for Weather and Space Weather Forecasting", endorsed by SCAR (Scientific committee for Antarctic Research) on July 2010. Collaboration with the geodetic groups dealing with Mediterranean GPS data has produced a prototype of real-time imaging of the Mediterranean ionosphere called MIRTO (Mediterranean Ionosphere With Real-Time Tomography).

Publications

L. Alfonsi, Y. Ping, C.N. Mitchell,G. De Franceschi, V. Romano, P. Sarti, M. Negusini, A. Capra, GPS imaging of the antarctic ionosphere: a first attempt. Presentation during the *SCAR Open Science Conference (St. Petersburg, July 2008)*. The work presents the potentialities of using the geodetic data also for producing ionospheric imaging, for the first time, over Antarctica.

Alfonsi, Lu., Spogli, L., Tong, J.R., De Franceschi, G., Romano, V., Bourdillon, A., LeHuy, M., Mitchell, C.N., GPS scintillation and TEC gradients at equatorial latitudes on April 2006, Advances in Space Research (2010), doi: 10.1016/j.asr.2010.04.020.

M. Negusini, P. Sarti, precipitable water vapour at vlndef gps network sites: an example of multidisciplinary investigation. Poster at the *SCAR Open Science Conference (St. Petersburg, July 2008)*. The work presents the potentialities of geodetic GPS Antarctic data for multidisciplinary applications.

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A. W. Wernik, A. Lucilla, M. Aquino, G. De Franceschi, A. Dodson, C. N. Mitchell, V. Romano, gps ionospheric scintillations monitoring and studying: bipolar capabilities during ipy. *Poster at XXIXth URSI General Assembly, Chicago, USA, 9-16 August 2008.* The state of art of GPS network is presented over Arctic and Antarctica for scintillation studies.

Luca Spogli, Lucilla Alfonsi, Giorgiana De Franceschi, Vincenzo Romano, Marcio Aquino, Alan Dodson, climatology of the ionospheric scintillations: first results over the auroral and cusp European regions. Poster at *V European Space Weather Week (Brussels,17-21 November, 2008).* The work deals with the use of GPS high rate data to investigate the scintillation scenario due to irregularities of perturbed ionosphere from cusp to auroral region during high solar activity.

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Alfonsi L., A. Kavanagh, Amata E., P. Cilliers, E. Correia, Freeman M., Kauristie, K., Liu R., Luntama J-P, Mitchell, C.N, Zherebtsov, G.A., Probing the high latitude ionosphere from ground-based observations: the state of current knowledge and capabilities during ipy (2007–2009, *Journal of Atmospheric and Solar-Terrestrial Physics*, 70, 18, December, 2008. The review includes also information on the international cooperation, in progress and planned, among the different communities handling GPS data at polar latitudes.

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Working Group 4.3.3 – Numerical Weather Predictions for Positioning

Chair: Thomas Hobiger (Kashima Space Research Center, Japan)

Terms of Reference

To study various technical aspects of using Numerical Weather Prediction (NWP) model data to map the effect of troposphere on space geodetic signals. To concatenate the terminology used by both meteorological and geodetic communities. To test and sediment procedures related to ray-tracing through NWP data layers. To suggest quality control criteria to be used for assessing the quality of tropospheric data and results obtained from them. To evaluate state of the art and report the progress achieved during the time-life of the WG on the use of NWP for positioning.

Report on activities

In order to draw conclusions about the best way for ray-tracing based on numerical weather data, two radiosonde profiles (kindly provided by A. Niell) were selected as basis for all investigations. At first, the focus was set on zenith hydrostatic (ZHD) and wet delays (ZWD) whereas six independent solutions were submitted for comparison. As for the hydrostatic components all solutions agreed within 1 mm, including the model by Saastamoinen (1972), which has been computed additionally. The wet delays showed larger scattering between the different solutions, likely caused by different interpolation strategies of the water vapour constituents. Some groups linearly interpolate relative humidity before converting it to water vapour pressure, other groups prefer to interpolate water vapour pressure levels using an exponential scheme. Nevertheless, all submitted solution were found to be within +/- 1 mm from the average over all results.

After comparison of zenith delays, a second call was made to submit ray-traced dry and wet slant delays, based on the same profiles under the assumption of spherical symmetry. In total, four WG members followed this call and submitted their results for elevations angles ranging from 3 to 90 degrees, in steps of one degree. In general, all solutions agreed well with each other, having only larger differences (~1 cm) at the very low elevation angles (i.e. below 10 degrees). These differences are thought to be caused by the different ray-tracing operators used for the calculation of the ray-path. In general, it could be stated that smaller integration steps are preferred rather than ray-tracing in coarse steps. Better modeling of asymmetric delays due to the Earth's ellipticity as well as proper consideration of bending angle effects have been pointed out as well.

Activities through 2009 involved (a) comparison of ray-traced delays based on radiosonde data (i.e. vertical profile), with submissions from A. Niell, MIT, USA, J. Boehm, VUT, Austria, T. Hobiger, NICT, Japan, R. Ghoddousi-Fard, UNB, Canada, F. Nievinski , UNB, Canada, S. de Haan, KNMI, Netherlands; (b) comparison of ZHD w.r.t. Saastamoinen Model; (c) basically good agreement in across all submissions; (d) differences due to: interpolation of water vapour pressure resp. rel. humidity, choice of ray-tracing model and Earth geometry.

Activities through 2010. "Ray-tracer workshop" organized by IAG SC 1.1. WG3 and IAG WG 4.3.3 held at the Vienna University of Technology in April, 2010. It involved a full 3D ray-tracing comparison. Good agreement between different ray-tracers was obtained. Remaining problem: Different weather model, resulting in totally different ray-traced delays. Suggestions based on the 2nd comparison campaign (from ray-tracer WS):

- Recommendation 1: Ray-tracing should be done at least up to 76 km as upper limit of the troposphere. The US Standard Atmosphere 1976 or the COSPAR International Reference Atmosphere are sufficient as extension for both slant and zenith directions.
- Recommendation 2: A latitude dependent formulae for the radius of curvature of the Earth needs to be applied. (The use of constant radius is not recommended.) The best suggestion for this case will be the more realistic Euler's formula, if ellipsoidal heights are not used directly.
- Recommendation 3: For converting geo-potential to geometric heights, it is recommended to use an expression for normal gravity from (NIMA (2000) or from the Federal Meteorological handbook No 3 (OFCM, 2007).

Meetings and communication:

A kick-off meeting was held during AGU Fall Meeting 2007 and a mailing list was established to distribute information between the WG members. Additionally, the WG homepage[1] has been set-up in "wiki" style, allowing the members to modify the content and upload results directly.

Relevant papers

Böhm, J., B. Werl, and H. Schuh (2006), Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium Range Weather Forecasts operational analysis data, J. Geophys. Res., 111, B02406, doi:10.1029/2005JB003629

Böhm, J., A. Niell, P. Tregoning, and H. Schuh (2006), Global Mapping Function (GMF): A new empirical mapping function based on numerical weather model data, Geophysical Research Letters, Vol. 33, L07304,doi:10.1029/2005GL025546 download from AGU

Böhm, J., R. Heinkelmann, and H. Schuh (2007), Short Note: A global model of pressure and temperature for geodetic applications, Journal of Geodesy , doi:10.1007/s00190-007-0135-3 download from JoGeod

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Hobiger T., R. Ichikawa, T. Takasu, Y. Koyama, and T. Kondo (2008), Ray-traced troposphere slant delays for precise point positioning, Earth, Planets and Space, vol. 60, no. 5, pp. e1–e4 download from EPS (free e-paper).

Hobiger T., Ichikawa R., Koyama Y., Kondo T. (2009), Computation of troposphere slant delays on a GPU, IEEE Transactions of Geoscience and Remote Sensing, accepted, doi10.1109/TGRS.2009.2022168.

Kouba, J. (2007), Implementation and testing of the gridded Vienna Mapping Function 1 (VMF1), Journal of Geodesy , doi:10.1007/s00190-007-0170-0 download from JoGe

Nievinski, Felipe G. (2009). Ray-tracing Options to Mitigate the Neutral Atmosphere Delay in GPS. M.Sc.E. thesis, Department of Geodesy and Geomatics Engineering Technical Report No. 262, University of New Brunswick, Fredericton, New Brunswick, Canada, 232 pp.

Urquhart, Landon (2011). Assessment of Tropospheric Slant Factor Models: Comparison with Three Dimensional Ray-Tracing and Impact on Geodetic Positioning. M.Sc.E. thesis, Department of Geodesy and Geomatics Engineering Technical Report No. 275, University of New Brunswick, Fredericton, New Brunswick, Canada, 166 pp.

Nafisi,V., L. Urquhart, M. C. Santos, F. G. Nievinski, J. Böhm, D. D. Wijaya, H. Schuh, A. A. Ardalan ,T. Hobiger, R. Ichikawa, F. Zus, J. Wickert, P. Gegout. (2011). "Comparison of ray-tracing packages for troposphere delays." Submitted to IEEE Trans. on Geoscience and Remote Sensing

[1] http://www.hobiger.org/wg433/tiki-index.php

Sub-Commission 4.4: Applications of Satellite and Airborne Imaging Systems

President: Prof. Xiaoli Ding (Hong Kong)
Vice-President: Dr. Linlin Ge (Australia)
Secretary: Prof. Makoto Omura (Japan)

Objectives

The main objectives of the Sub-Commission are to promote collaborative research in the development of satellite and airborne imaging systems, primarily including Synthetic Aperture Radar (SAR) and Light Detection And Ranging (LiDAR) systems, for geodetic applications, and to facilitate communications and exchange of data, information and research results through coordinated efforts.

Terms of Reference

(1) Development of methods, models, algorithms and software for geodetic applications of satellite and airborne imaging systems;

(2) Study of effects of field and atmospheric conditions on satellite and airborne imaging systems;

(3) Integration of satellite and airborne imaging systems with other geodetic/geospatial technologies such as GPS and GIS;

(4) Development and promotion of new geodetic applications of satellite and airborne imaging systems; and

(5) Development of collaboration with sister organisations such as FIG and ISPRS, and liaison with image data providers.

Working Groups

The SC has currently the following Working Groups:

WG 4.4.1: Quality Control Framework for InSAR Measurements

Chair: Prof. Xiaoli Ding

Terms of Reference:

To study quality measures and quality control procedures and formulate a quality control framework for InSAR measurements.

WG 4.4.2: Imaging Systems for Monitoring Local Area Surface Deformation

Chair: Prof. Makoto Omura

Terms of Reference:

To study satellite and airborne imaging systems such as InSAR and LiDAR for monitoring local area ground surface deformations such as volcanic and seismic activities, and ground subsidence associated with city development, mining activities, ground liquid withdrawal, and land reclamation.

Research Activities of the Working Groups

InSAR is a very active field of research in the geodetic research communities. The current research issues that the members of the SC are working on include

- The development of more effective methods/algorithms for InSAR solutions;
- The quality control and assurance of InSAR measurements;
- The study and mitigation of biases in InSAR measurements such as the atmospheric effects;
- Integration of InSAR and other geodetic technologies such as GPS and GIS; and
- New and innovative applications of the technology in geodetic studies.

Examples of some of the major research projects that the SC is working on include

- The development of new InSAR approaches such as multi-temporal InSAR (MT-InSAR) techniques. For example, a MT-InSAR technique named Temporarily Coherent Point InSAR (TCP-InSAR)) has been developed that has a number of advantages in applications especially in areas with a small number of SAR acquisitions only are available. Other work includes the development of some new and more effective interferograms filters, some phase unwrapping techniques, and the modeling of detectable deformation gradients when applying InSAR;
- Study of atmospheric effects on InSAR measurements. The effects of both the troposphere and ionosphere on InSAR measurements have been studied to understand their spatial and temporal variations and statistical properties. Various methods have also been studied for mitigating the effects including those based on external data such as GPS, ground and remote sensing meteorological measurements and meteorological models. Study has also been carried out to map the atmospheric water vapour variations and the ionospheric TEC anomalies with InSAR measurements. An interesting case study was conducted with InSAR to map the ionospheric TEC anomalies associated with the Wenchuan earthquake in 2008.
- A large number of projects have been carried in applying InSAR to study various geophysical phenomena associated with earthquakes, and engineering and mining activities. This includes a major collaborative project carried out to study ground deformations associated with mining activities and urban subsidence in many parts of the world. The project involves researchers from a number of countries. Members of the SC have also been working on ground deformations associated with major earthquakes such as the Mw 8.0 Wenchuan earthquake in China that occurred on 12 May 2008, and the Mw 9.0 Fukushima earthquake in Japan that occurred on 11 March 2011. Co-seismic ground deforma-

tions are mapped with InSAR measurements and used for calculating the fault structures of the earthquakes.

Conferences

Members of the SC have been active in both participating and organizing scientific meetings/conferences relevant to the activities of the SC. The following represent a sample of the meetings organized (or co-organized):

- A session on InSAR at the 13th FIG Symposium on Deformation Measurements and Analysis and 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering in Lisbon, Portugal, 12-15 May 2008.
- A special session on SAR at the Japanese Geoscience Union Meeting 2008 in Chiba city, Japan, 25-30 May 2008.
- A session on Earth Observation at the 26th ISTS (International Symposium on Space Technology and Science) in Hamamatsu, Japan, 1-8 June 2008.
- A special session on InSAR, Geodetic Remote Sensing, at the AOGS (Asia Ocean Geophysics Society) conference in Busan, South Korea, 16-20 June 2008.
- A special session, Modern Geodetic Techniques for Surface Deformation Monitoring, at the WPGM (Western Pacific Geophysics Meeting) in Cairns, Australia, 29 July – 1 August 2008.
- 2008 Earthquake Research Institute, University of Tokyo, Workshop on Monitoring and Analyzing Earthquakes, Volcanoes and Ground movements by using SAR and Infra-red Sensors in Tokyo, Japan, 16-17 September 2008.
- A session on SAR at the Japanese Geoscience Union Meeting 2009 in Chiba, Japan, 16-21 May 2009.
- A session on Earth Observation at the 27th ISTS (International Symposium on Space Technology and Science) in Tsukuba city, Japan, 5-12 July 2009.
- Sessions at the IAG Scientific Assembly, Buenos Aries, Argentina, 31 August – 4 September 2009.
- International Conference on Geo-spatial Solutions for Emergency Management (GSEM 2009), Beijing, 14-16 September, 2009.
- International Workshop Spatial Information Technologies for Monitoring the Deformation of Large-Scale Man-made Linear Features, Hong Kong, 11-12 January 2010.
- A special Session, Advanced Interferometric SAR Techniques and their Engineering and Geological Application, Progress in Electromagnetic Research Symposium (PIERS), Xián, 22-26 March2010.
- Asia Pacific Space Geodynamics Program (APSG) Workshop 2010: Progress in Space Geodesy and Earth Environment Change, Shanghai, 16-20 August, 2010.
- International Symposium on Precision Engineering Survey Theory and Spatial Information Technology for High-Speed Railway (HSRPES 2010), Chengdu, 20-22 August 2010.
- 1st International Conference on Sustainable Urbanisation, Hong Kong, 15-17 December 2010.
- Lidar and Radar Mapping: Technologies and Applications, Nanjing, 26-29 May 2011.

- International Symposium on Deformation Measurements, Hong Kong, 1-3 November 2011.
- IAG Symposium: Geodetic Remote Sensing, International Union of Geodesy and Geophysics (IUGG), Melbourne, 28 June – 7 July 2011.
- IEEE International Geoscience and Remote Sensing Symposium (IGARSS) in Sendai, Japan, 1-5 August 2011.

Special Issues

The SC is currently working on the following journal special issues:

- Special issue on InSAR and LiDAR in Journal of Geodesy
- Special issue on urban remote sensing in International Journal of Remote Sensing

Sub-Commission 4.5: High-Precision GNSS

President: Yang Gao (Canada) www.ucalgary.ca/~point/iag.html

Working Groups

WG4.5.1 Quality Measures for Network Based GNSS Positioning
Chair: Xiaolin Meng (The University of Nottingham, UK)

WG4.5.2 Precise Point Positioning and Network-RTK
Chair: Sunil Bisnath (York University, Canada) http://www.yorku.ca/sbisnath/iag/

WG4.5.3 Correction Models for Ultrahigh-Precision GNSS Positioning
Chair: Wu Chen (The Hong Kong Polytechnic Univ., Hong Kong)

WG4.5.4 Data Processing of Multiple GNSS Signals
Chair: Yanming Feng (Queensland University of Technology) http://www.gnss.com.au/iagwg454.html

Academic Activities

- WG4.5.2. "Precise Point Positioning and Network-RTK" forms a small, active, global group of members from academia and the public and private industry.
- A white paper "Current state of Precise Point Positioning and future prospects and limitations" presented at IUGG 24th General Assembly IAG Commission 4 session.
- A paper on "Precise Point Positioning: Past, Present, and Future" published in GPS World's Innovation.
- A working group website created for WG4.5.2: http://www.yorku.ca/sbisnath/iag/.
- A number of PPP and closely associated network RTK papers were presented at the ION GNSS 2008 conference in Savannah, Georgia, USA.
- Members at The University of Calgary has published and presented several papers on their research progress made in the area of GNSS biases and PPP ambiguity resolution central to the development next generation RTK technology
- Research results on Precise Point Positioning at The University of Calgary have been transferred in the form of software system to academic and industry sectors to support research activities and product development.
- Members at the University of New Brunswick have created a PPP software comparison website: http://gge.unb.ca/Resources/PPP/.
- WG4.5.1. "Quality Measures for
- 4 "Data Processing of Multiple GNSS Signals" forms a membership with members from academia and the private industry.
- A website has been created for WG4.5.4 "Data Processing of Multiple GNSS Signals": http://www.gnss.com.au/iagwg454.html, which provides a list of 145 papers.
- WG4.5.4 Chair Yanming Feng gave a keynote speech on "Three carrier Ambiguity Resolution: Generalized Problems, Models, Solutions and Performance" at International Workshop on Geodetic Theory 2009.

- WG4.5.4 members present four papers at ION GNSS 2008 session 6D "Multiple-frequency GNSS algorithms".
- WG4.5.4 members published fourteen journal papers and seven conference papers.
- SC4.5 has made significant contributions in advancing high precision GNSS technologies in the past four years through various academic activities from timely research publications, white papers, special journal issues, group discussions to the organization of numerous conference and technical sessions. Its members have also made many technical presentations to the industry sector to accelerate the dissemination and commercialization of new technological advances in high precision GNSS, including the launch of a PPP software centre for public access. Today PPP has become a widely recognized technology for high precision GNSS and its commercial uses are increasing with strong market demands. PPP is considered one of the most significant advances for precision positioning since the advent of RTK technology. Network RTK has also been further enhanced with many new progresses particularly in the area of RTK with multi-constellation signals and quality control of RTK solutions. SC4.5 will continue its contribution to the advance of future high precision GNSS technologies.
- WG4.5.1 created a website on "Quality Measures for Network Based GNSS Positioning".
- WG4.5.2 developed a PPP software centre: http://gge.unb.ca/Resources/PPP/ to promote the PPP concept and the evaluation of different PPP software packages.
- WG4.5.2 continued promotion of PPP for precision positioning, data and user algorithm development and testing: observables, multi-GNSS, error modeling, ambiguity resolution, etc. and evaluation of current network RTK positioning performance
- WG4.5.3 updated the publication list for research papers on multiple GNSS data processing.
- WG4.5.3 edited a special issue for Journal of GPS on data processing of multi-GNSS signals
- WG4.5.3 created a website to publish the reference list for research publications in the field of multiple GNSS data processing, currently with more than 100 papers (http://www.gnss.com.au/iagwg454.html)
- Network Based GNSS Positioning" forms a membership with members from academia and the private industry.
- A link to previous WG of IAG has been set up to integrate existing findings with this group: www.network-rtk.info/
- Members at The University of Nottingham conducted systematic studies on the quality issues of network RTK positioning and a systematic approach has been designed to quantify the quality of the RTK corrections in real time and relevant data processing and quality assessment platform has been developed. A number of papers have been published in journals (e.g. Journal of Applied Geodesy, GPS World) and international conferences (e.g. ION, ENC and FIG).
- Members at The University of Newcastle upon Tyne have conducted a series of field tests using the Ordnance Survey's facility aiming at creating best practice guidance to the surveyors using NRTK.
- Around 200 people attended the ground breaking Launch Day of the Network RTK Best Practice Guidelines that was organised by the University of Newcastle upon Tyne. This report can be downloaded from the website of The Survey Association (TSA) at http://www.tsa-uk.org.uk/guidance.php.

- Member at in Position worked on the combination of different GNSS into one seamless positioning network and solution. The use of observations of different GNSS constellations is relatively straight-forward as long as similar receiver types are used throughout the network configuration. Especially for an arbitrary mix of receivers of different manufacturers the overall concepts for processing GNSS observations in real-time need adaptation.
- New concepts for processing multiple receiver observation information and quality control techniques are desperately required. The publications concentrate the options for optimal use of a multi-GNSS receiver together with other GNSS receivers not supporting the complete set of GNSS. The computation scheme developed allows an arbitrary mix of GNSS receivers. Results based on post-processing and real-time processing have been published on various conferences (see literature list)
- WG4.5.WG4.5.3 developed a wiki-page "Three Carrier Ambiguity Resolution", which is currently under review.

Conferences, Workshops, Technical Sessions

- SC4.5 helped organize several technical meetings and workshops including International Technical Meeting on GNSS – "The Next Generation GNSS - Innovation and Applications" to be held in Beijing, August 7-9, 2009; Chinese Technical Application Association for GPS (CTAAGPS) on New Navigation Technologies and Innovations, Beijing, December 18-20, 2008; Scientific Workshop on Hazard Monitoring by Geosciences, Wuhan, China, May 22, 2008.
- SC4.5 President Yang Gao gave invited talks at several technical meetings such as IGS Workshop 2008, Florida, USA, 2-6 June 2008; CTAAGPS Annual Meeting on New Navigation Technologies and Innovations, Beijing, China, December 18-20, 2008.
- A session on PPP vs DGPS central to IAG Commission 4 "Positioning and Applications" held at the International Union of Geodesy and Geophysics 24th General Assembly, Perugia, Italy, 2-13 July 2007.
- WG4.5.2 organized a PPP workshop in June 2008, Niagara Fall, Canada: http://gge.unb.ca/Research/GRL/GNSS/NiagaraFallsPPP2008.htm.
- WG4.5.1 co-organised LBS 2009 Workshop in Nottingham
- WG4.5.4 co-organized International Workshop on Geodetic Theory 2009, Tongji University on behalf of AIG Commission IV, 1-2 June 2009.
- WG4.5.2 organized a PPP and network RTK session at the upcoming ION GNSS 2009 conference in Savannah, USA.
- SC4.5 helped organize CPGPS 2010 Technical Forum on Satellite Navigation and Positioning, August 18-20, 2010, Shanghai, China. IAG is a sponsor of the conference.
- SC4.5 helped organize 2nd Annual China Satellite Navigation Conference, May, 2011, Shanghai, China.
- WG4.5.1 co-organized the International Workshop on Geodetic Theory 2009 at Tongji University, June 1-2, 2009. IAG is the sponsor of the workshop.
- WG4.5.3 involved in the organization of LBS 2010 in Guangzhou, September 20 -22, 2010, as the vice chair for this conference.
- WG4.5.2 organized a technical session on "Precise Point Positioning and Network RTK" at ION GNSS 2010, Portland, Oregon, USA, September 20-24, 2010.

- WG4.5.3 organized a special session on "Data Processing of Multiple GNSS Signals" for IGNS2011, Canberra, Australia.
- WG4.5.1 co-organize "2011 International Symposium on Image and Data Fusion" http://isidf2011.casm.ac.cn.
- WG4.5.1 organize a workshop on "Network RTK Quality Control and Engineering and Environmental Applications" in Nottingham , July 2011.
- WG4.5.3 organize a joint workshop (e.g. with CPGPS) on "Data Processing of Multiple GNSS Signals"
- WG4.5.1 helped organize 6th International Symposium on LBS and TeleCartography, The University of Nottingham, 2009
- WG4.5.1 helped organize 7th International Symposium on LBS and TeleCartography, Guangzhou, China, 2010
- WG4.5.1 helped organize 8th International Symposium on LBS and TeleCartography, Vienna, Austria, 2011
- WG4.5.1 helped organize a special session at IEEE Intelligent Vehicles Symposium, Baden-Baden, Germany, June 5-9, 2011.
- WG4.5.1 helped organize ISPRS - The 2011 International Symposium on Image and Data Fusion, Tengchong, China, 2011

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Study Group 4.2: GNSS Remote Sensing and Applications

Chair: Shuanggen Jin (Shanghai Astron. Observ./Uni. Texas at Austin, USA)

Terms of Reference:

Nowadays, the Global Navigation Satellite System (GNSS), which is a very powerful and important contributor to all scientific questions related to high precision positioning on Earth's surface, has been widely used as a mature technique in geodesy and geodynamics. Recently, the versatility and availability of reflected and refracted signals from GNSS gave birth to many new GNSS applications for various environmental remote-sensing in atmosphere, ocean and land. Many countries have initiated efforts in this area of researches and applications. The focus of this Study Group (SG4.1) is to facilitate collaboration and communication, and to support joint researches with new GNSS remote sensing techniques. Specific objectives will be achieved through closely working with members and other IAG Commissions/Sub-Commissions. Meanwhile, close collaboration with the International GNSS Service (IGS), Institute of Navigation (ION) and IEEE Geoscience and Remote Sensing Society (IGRASS) will be promoted, such as joint sponsorship of international professional workshops and conferences.

Objectives:

- To promote/extend developments of current GPS reflected signal sensor and Radio occultation techniques and their applications;
- To improve the existing estimation algorithms and data processing for GPS reflected signals and Radio occultation;
- To coordinate data collection campaigns and to compare with terrestrial and satellite observations, in order to encourage research and development into the crucial measurement and applications;
- To investigate applications in atmosphere, ocean and land as well as space sciences.

Website:

http://www.geosensings.com/iag-sg4.1

Activities

2011

- **7-9 August 2011,** Shuanggen Jin organized an international workshop on GNSS Remote Sensing for Future Missions and Sciences, Shanghai, China
- **12-16 September 2011**, Shuanggen Jin Chaired one session "Remote Sensing using GNSS and other sensors" at Progress In Electromagnetics Res. Symp. (PIERS 2011) and gave one talk, Suzhou, China
- **8-12 August 2011**, Shuanggen Jin Chaired one session "Exploration and Science of Venus at Asia Oceania Geosciences Society (AOGS 2011) and gave one talk, Taipei, Taiwan.

- **25-29 July 2011**, Shuanggen Jin Chaired one session "GNSS Remote Sensing in the Atmosphere, Ocean and Hydrology at the IEEE Int. Geosci. & Remote Sens. Symp (IGARSS 2011) and present two invited papers, Vancouver, Canada.
- **28 June-7 July 2011**, Shuanggen Jin participated in the XXV IUGG General Assembly (IUGG 2011) with one oral talk, Melbourne, Australia.
- **24-26 June 2011,** Shuanggen Jin Chaired one session "Remote Sensing and Climate Change" at the 19th International Conference on GeoInformatics and presented one paper, Shanghai, China
- **15-18 May 2011**, Shuanggen Jin participated in Chinese Satellite Navigation Conference (CSNC 2011) with one paper, Shanghai, China

2010

- **26-28 October 2010**, Shuanggen Jin was a Advisor Board Member, MarineTech Summit-2010 (MTS-2010), Dalian, China.
- **25-28 October 2010**, Shuanggen Jin attended the GGOS/IAU Workshop on Observing and Understanding Earth Rotation and chaired one session with two presentations, Shanghai, China.
- **4-8 October 2010**, Shuanggen Jin gave one invited talk at the URSI-F Symposium on Microwave Remote Sensing of the Earth, Oceans, and Atmosphere, Florence, Italy.
- **3 October 2010**, Jose M. Sánchez Reales (Ph.D student, University of Alicante, Spain) is welcomed to visit the Shanghai Astronomical Observatory, Chinese Academy of Sciences, China from October 2010 to April 2011.
- **18-20 August 2010**, Shuanggen Jin attended the CPGPS Technical Forum on Satellite Navigation & Positioning and Chaired one Session with one talk, Shanghai, China.
- **11 May 2010**, Shuanggen Jin gave a seminar talk on GNSS, Gravity and Geodesy at the Center for Space Research, University of Texas at Austin, Austin, Texas, USA.
- **9-25 April 2010**, Shuanggen Jin visited gave several talks at Shanghai Astronomical Observatory, CAS, Wuhan University, University of Science and Technology of China, Nanjing Aeronautics & Astronautics University, Hehai University, Institute of Geodesy and Geophysics, CAS, etc.

2009

- **31 August-4 September 2009**, Shuanggen Jin attended the International Association of Geodesy (IAG) Scientific Assembly, Buenos Aires, Argentina and Chaired one sub-session "Multi-satellite Ocean Remote Sensing" as well as presented two papers.
- **8-10 August 2009**, Shuanggen Jin attended International Technical Meeting on GNSS (ITM-GNSS)-Innovation and Application, Beijing, China with one presentation and Chaired one session.
- **13-17 July 2009**, Shuanggen Jin and Attila Komjathy Chaired one Joint IAG/IEEE/ION/ ISPRS session "GNSS Remote Sensing of Atmosphere, Ocean and Land" at the IEEE Geoscience and Remote Sensing Symposium (IGARSS), Cape Town, South Africa and presented two papers.
- **19-24 April 2009**, Shuanggen Jin Chaired one session "GPS/Gravity Applications in Active Tectonics and Geophysics" and Co-Convened one session "Secular changes of the Planetary Earth system and its Physical Mechanism" at the European Geosciences Union (EGU) General Assembly, Vienna, Austria.

2008

- **15-19 December 2008**, Shuanggen Jin Chaired one session "High-Rate and Low-Latency Data for Earth Science Applications", American Geophysical Union (AGU) Fall Meeting, San Francisco, USA.
- **24-25 September 2008**, GNSS Reflectometry Course and Workshop organized by the European Space Agency was held at ESTEC in Noordwijk, The Netherlands.
- **29 July-1 August 2008**, Dr. Shuanggen Jin Co-Convened one session "Towards the synergy of geodesy, environment and atmosphere" at the Western Pacific Geophysics Meeting (WPGM) of American Geophysical Union (AGU), Cairns, Australia and presented one paper.
- **5-12 July 2008**, Dr. Attila Komjathy Convened one session "Ionospheric Remote Sensing by GPS" at the joint 2008 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting (Commission G, Ionospheric Radio and Propagation), San Diego, CA, USA.
- **June-July 2008**, Shuanggen Jin had worked as Research Scientist at the Department of Reference Systems and Geodynamics, Royal Observatory of Belgium, Brussels, Belgium.
- **16-20 June 2008**, Shuanggen Jin participated in the fifth Annual Assembly of Asia Oceania Geosciences Society (AOGS), Busan, South Korea and Chaired one session "GPS/Gravity and Applications in Active Tectonics and Geophysics" and Co-chaired on session "Geodetic Techniques (GNSS, VLBI, SLR...) and Its Applications on Atmosphere/Geodynamics" as well as presented two papers.
- **5-8 May 2008**, Dr. Susan Skone of SG4.1 member Chaired one session **"**Earth Observation & Remote Sensing" at the Position Location and Navigation Symposium 2008 (PLANS2008), Monterey, California, USA.
- **13-18 April 2008**, Dr. Shuanggen Jin attended the European Geosciences Union (EGU) General Assembly, Vienna, Austria, where he Chaired one session "Monitoring of the lower atmosphere and ionosphere by space geodetic techniques" and presented one paper "Retrieval of Ionospheric slab thickness and its variations from 3-D GPS observations".
- **28-30 January, 2008**, Dr. Susan Skone of SG4.1 member Co-Chaired one session "Atmospheric Effects" at the 2008 National Technical Meeting, San Diego, CA, USA.
- **5-7 January 2008**, Dr. Shuanggen Jin attended the Second CPGPS Youth Forum on "The Next Generation GNSS - Opportunities and Challenges", Guangzhou, China as member of Technical Committee and Co-Chaired one session as well as presented the paper "GPS models/combinations and its applications: Progresses and Challenges".

2007

- **1 November 2007**, Dr. Shuanggen Jin's paper "Ionospheric slab thickness and its seasonal variations observed by GPS" was published in the Journal of Atmospheric and Solar-Terrestrial Physics, 69(15), 1864-1870, doi: 10.1016/j.jastp.2007.07.008.
- **29 October-4 November, 2007**, Shuanggen Jin visited/collaborated with the University of Bath and University of Oxford, and attended the International Navigation Conference & Exhibition, Royal Institute of Navigation (RIN), London, UK.
- **1-4 October 2007**, The GNSS Remote Sensing Session was held at the 1st Colloquium Scientific and Fundamental Aspects of the Galileo Programme, Toulouse, France. Dr. J. Garrison of SG4.1 member presented the paper "Considerations in Utilizing Galileo

Signals for GNSS-R Ocean Sensing" and Prof. G. Ruffini of SG4.1 member presented the paper "Soil Moisture Monitorization Using Galileo Reflected Signals".

- **October-November 2007**, Report initial activities of SG4.1 to Commission 4.
- **October-November 2007**, Expand members to join the Study Group (SG4.1).
- **September-November 2007**, Made a website for the SG4.1 to show the terms of reference, objectives and members list, report activities and progress as well as related linkage, etc.: http://www.gnss.googlepages.com/IAG-SG4.1
- **14-16 September 2007**, Dr. Shuanggen Jin invited Prof. Dr. Jeffrey T. Freymueller (University of Alaska, Fairbanks, USA) to visit the Korea Astronomy & Space Science Institute, Daejeon, South Korea and then he attended 21st COE conference at the University of Tokyo, Japan.
- **31 July-4 August 2007**, Dr. Shuanggen Jin attended the 4th Assembly of Asia Oceania Geosciences Society (AOGS), Bangkok, Thailand and chaired one session "Geodesy, Geodynamics and Geohazards" as well as presented three papers.
- **1-9 July 2007**, Dr. Shuanggen Jin attended the IUGG XXIV General Assembly, Earth: Our Changing Planet, Perugia, Italy and presented three papers with two oral presentations.

Journal publications

Afraimovich, E.L., A.B. Ishina, M.V. Tinin, Y..V. Yasyukevich, and S.G. Jin (2011), First evidence of anisotropy of GPS phase slips caused by the mid-latitude field-aligned ionospheric irregularities, Adv. Space Res., 47, doi: 10.1016/j.asr.2011.01.015.

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Jin, S.G., L. Han, and J. Cho (2011), Lower atmospheric anomalies following the 2008 Wenchuan Earthquake observed by GPS measurements, J. Atmos. Sol.-Terr. Phys., 73, doi: 10.1016/j.jastp.2011.01.023.

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Jin, S.G., O. Luo, and J. Cho (2009), Systematic errors between VLBI and GPS precipitable water vapor estimations from 5-year co-located measurements, J. Atmos. Sol.-Terr. Phys., 71(2), 264-272, doi: 10.1016/j.jastp.2008.11.018.

Jin S.G., O.F. Luo, and P. Park (2008), GPS observations of the ionospheric F2-layer behavior during the 20th November 2003 geomagnetic storm over South Korea, J. *Geodesy*, 82(12), 883-892, doi: 10.1007/s00190-008-0217-x.

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Komjathy A, Armatys M, Masters D, Axelrad P, Zavorotny V, Katzberg S (2004) Retrieval of Ocean Surface Wind Speed and Wind Direction Using Reflected GPS Signals. Journal of Atmospheric and Oceanic Technology, 21(3): 515-526.

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Wu Y., S.G. Jin, Z. Wang, and J. Liu (2010), Cycle slip detection using multi-frequency GPS carrier phase observations: A simulation study, Adv. Space Res., 46(2), 144-149, doi: 10.1016/j.asr.2009.11.007.

Study Group 4.3: IGS Products for Network RTK and Atmosphere Monitoring

Chair: Robert Weber (Austria)

Website:

http://mars.hg.tuwien.ac.at/Research/SatelliteTechniques/IAG_Study_Group_43/iag_study_group_43.html

Objectives

- To promote the use of IGS products for Network RTK and Atmosphere Monitoring
- To identify the current needs of near real-time atmospheric monitoring and Network-RTK in terms of IGS product quality, delivery time and spatial resolution
- To investigate options how to provide IGS products in standard real-time formats

Terms of Reference

The International GNSS Service (IGS) provides GPS & GLONASS station data and derived products like satellite orbits, clock corrections, electron content models and tropospheric delays of superior quality and within different time frames in support of Earth science research and multidisciplinary applications. Special applications like Network RTK in order to allow for fast access of a globally consistent reference frame for all position applications and near/real-time atmospheric monitoring for weather prediction require GNSS products with greatly reduced delays. Soon these products will be made available to the user community by means of the IGS RT Project in near-real via Internet and other available streaming technologies.

This Study Group identifies the needs of near real-time atmospheric monitoring in terms of orbit and clock-correction quality and investigates if the suite of IGS real-time products match the requested quality and spatial resolution necessary for correction data within regional RTK networks. Another topic deals with the coding of IGS products and models to be useful as a state space representation of error sources within the real-time standard formats RTCM and RTCA.

This Study Group is directly linked to IAG sub-commissions 4.3 and 4.5 as well as to the International GNSS Service (IGS).

Research Activities

In the period 2008 till mid 2009 the influence of IGU (IGS Ultra Rapid) products on the fast calculation of Zenith Wet delays has been studied in depth. An operational system to provide ZWD-estimates to Meteorological Offices has been set up. In conclusion the predicted part of the IGU orbits can be used for close to real time ZWD estimation. IGU satellite clock corrections are usually not suitable for this purpose due to their low resolution (15 minutes) and the 6h –update rate accompanied by frequent clock mis-modelling. It is recommended to obtain real-time clock corrections delivered by the upcoming IGS RT project. Close to Real-Time Ionospheric Models utilizing IGS TEC maps as well as the potential of increasing the spatial

resolution of the ionospheric delay information have been studied in 2009 and 2010 within the project OEGNOS.

From 2009 onwards TU-Vienna contributed to the IGS RT Working Group by means of real-time GPS clock and orbit information. This product is in principal based on the IGS IGU orbits and the combined RT-streams will complement the IGU product line in the near future. The IGS RT correction stream is thought to support RTK as well as PPP applications. To take advantage of this new IGS product for RT applications the RTCM format has to be upgraded to support State Space Representation. This upgrade process is currently under progress and shall lead to a new version of the RTCM standard in 2011. This study group has tested both the combined IGS RT data streams as well as individual Analysis centre solutions as source for RT-PPP solutions (see publication list below)

A list of reports as well a complete publication list can be obtained from the SG 4.3 Website accessible via http://mars.hg.tuwien.ac.at/Research/SatelliteTechniques/IAG_Study_Group_43/iag_study_group_43.html

Scientific Meetings

Members of the SG have been active in both participating and organizing a number of scientific sessions at the AGU, EGU and IGS-conferences relevant to the goals of this SG. As these meetings are not co-sponsored by IAG the complete list is not given here but can be obtained from the Study-Groups Website

Publications and Presentations

Boehm J. and R. Weber, *Neutral Atmosphere Delays in GNSS Analysis.* European Journal of Navigation, Vol. 7, No. 2, pp. 4-9, 2009.

Bröderbauer V., Opitz M. and R. Weber: *Automated quasi-realtime prediction of GNSS clock corrections*, Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), Heft 2 (2007), 95. Jahrgang; S. 53 -58.

Hobiger T., Kondo T., Koyama Y., Ichikawa R., and R. Weber: *Effect of the Earth's oblateness on the estimation of global vertical total electron content maps*; Geophysical Research Letters, **34** (2007), 11.

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