The Department of Geodesy and Geoinformatics

Stuttgart University

2003

editing and layout:
volker walter, friedhelm krumm, ulrich hangleiter, wolfgang schöller

Preface

Dear colleagues and friends,

this little brochure is to inform you about the highlights of the Department of Geodesy and GeoInformatics in the year 2003. As in the previous years it aims at an information of our friends, colleagues and students about the achievements and changes in research and education. We consider the work done in 2003 as our contributions to the development of satellite and mathematical geodesy, navigation, land surveying and engineering and engineering surveys, telematics, photogrammetry, remote sensing, optical inspection, geographic information systems and location based services in research, development as well as in education.

The continuity in the management of the four institutes representing the Department of Geodesy strongly benefits the successful work in 2003: As in the past also last year Prof. E. W. Grafarend was Director of the Geodetic Institute, Prof. W. Möhlenbrink was Director of the Institute of Geodetic Applications in Civil Engineering, Prof. A. Kleusberg was Director of the Institute of Navigation and Prof. D. Fritsch was not only President of the Universität Stuttgart but also Director of the Institute for Photogrammetry. Also the integration of the Department of Geodesy and Geoinformatics in the newly established Faculty of Aerospace Engineering and Geodesy further progressed, which is indicated by the election of Prof. A. Kleusberg as Vice Dean of the faculty.

All four institutes are involved in a number of curricula of the Universität Stuttgart and run also their own curriculum. The attraction of this curriculum is demonstrated by the growing number of foreign students, which matriculate in studies of Geodesy and GeoInformatics.

As before, this report is on the WEB to allow for colored figures and further services: downloads of papers, videos, lecture notes, etc. Please visit our website:

http://www.ifp.uni-stuttgart.de/jahresberichte/jahresbericht.html

Dieter Fritsch
Alfred Kleusberg
Detlef Wolf

Erik W. Grafarend
Wolfgang Möhlenbrink

Wolfgang Keller
Ralf Reulke

Institute for Applications of Geodesy to Engineering

Geschwister-Scholl-Str. 24/D, D-70174 Stuttgart,
Tel.: +49 711 121 4041, Fax: +49 711 121 4044
e-mail: Sekretariat@iagb.uni-stuttgart.de or
firstname.secondname@iagb.uni-stuttgart.de
url: http://www.uni-stuttgart.de/iagb/iagb.html

Head of Institute

Prof. Dr.-Ing. Wolfgang Möhlenbrink
Dipl.-Ing. Ulrich Hangleiter, Akad. Direktor

Secretary

Christel Schüler

Emeritus

Prof. Dr.-Ing. Dr.sc.techn.h.c. Dr.h.c. Klaus Linkwitz

Scientific Staff

Dipl.-Ing. Roland Bettermann	Traffic information
Dr.-Ing. Renate Czommer	Map matching
Dipl.-Ing. Andreas Gläser	Sensor Integration
Dipl.-Geogr. Thilo Kaufmann	Digital maps
Dr.-Ing. Heiner Kuhlmann (up to 31.07.03)	Surveying engineering
Dipl.-Ing. Katrin Ramm	Kinematic positioning
Dipl.-Ing. Ralf Schollmeyer	Vehicle positioning
Dr.-Ing. Volker Schwieger	Surveying engineering
Dipl.-Ing. Martin Stark (up to 30.09.03)	Information chains
Dipl.-Ing. Thomas Wiltschko	Information quality

Technical Staff

Niklaus Enz
Martin Knihs
Lars Dirk Plate
Doris Reichert

External teaching staff

Dr.-Ing. Max Mayer - Landesamt für Flurneuordnung

General View

The institute's main tasks in education and research traditionally reflect on geodesy, geodetic measurement techniques, surveying engineering, data processing and traffic information technologies. The daily work is characterised by intensive co-operation with other engineering disciplines, especially with aerospace engineering, civil engineering, traffic engineering and construction management. Co-operations also exist with other university institutes as well as with the construction and automobile industry and various traffic services.

In education, the new curriculum of Geodesy and Geoinformatics started in autumn of 2003. With respect to this fact, the contents of the lectures have to be changed and new lectures have to be prepared. In addition, the lectures of the „old curriculum“ have to be presented for transitionary periods. The institute is traditionally also responsible for the education in surveying of architects and civil engineers. A new lecture on „Acquisition and Management of Planning Data“ was presented within the diploma course of Immovables Techniques and Immovables Economy. Two special lectures in English are held within the master course Infrastructure Planning. Additionally, the eLearning modules were accomplished for different disciplines and curricula. The current research in the fields of geodetic measurement techniques and traffic information techniques is reflected in most lectures. This is also represented in various case studies and diploma theses, often realised in co-operation with industry and public administration.

Research Work

The institute's current research work can be summarized by the main topic 'Positioning and controlling of moving objects in the digitally described 3D-space'. The institute's current research and development work focuses on the following main fields:

- surveying engineering, vehicle positioning
- traffic information techniques
- eLearning

Surveying engineering, vehicle positioning

This working area comprises design, development, and application of multi-sensor measurement systems and data processing of static and dynamic information in civil engineering and surveying.

Map independent positioning of vehicles

A Kalman-filter algorithm for map-independent positioning is available at the institute. Using a new multi-sensor system that is built up with a GPS-receiver, two hollow shaft incremental encoders, a non-contact optical speed and distance sensor and a yaw rate sensor new measurement data were acquired in several test runs. The filter has been modified according to the new measurement data. Furthermore, additional stochastic tests were established to increase accuracy and reliability. Fig. 1.1 shows a sequence of a test run with GPS positioning of low quality. The detection of outliers by stochastic compatibility tests is shown in fig. 1.2. It can be seen, that this procedure leads to an optimal estimation of the trajectory. The investigations regarding the stochastic and automatic real-time detection of positioning errors via stochastic tests will be followed up.

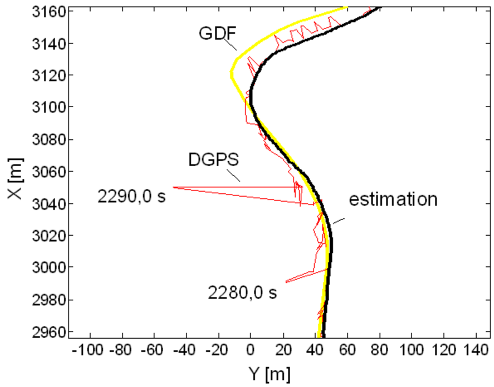


Fig. 1.1: Trajectory with GPS of less quality

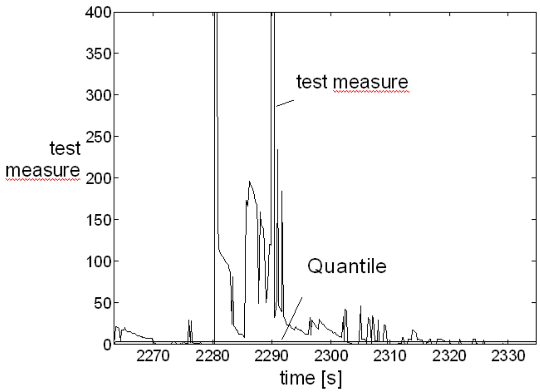


Fig. 1.2: GPS statistical test

Adoption of low-cost GPS-receivers for applications in forest

A project with the forest administration of Baden-Württemberg was accomplished to investigate the adoption of low-cost GPS-receivers in forest districts. The investigations mainly aimed for the attainable accuracy, the availability and the reliability for the survey of point shaped objects. The influence of shadowing effects in different kinds of forests was of special interest. Since the requirements for the accuracy of the survey of objects in the forest (stack of wood, for example) are approx. 15 m, and the availability and the reliability were approx. 100 % even in clustered/dense woods, there is a high potential for use of low-cost GPS-receiver in principle. Differences in accuracy, availability, reliability among the GPS-receivers and aspects regarding usability were investigated. By the tests, the Garmin eTrex was proved as the best receiver and was suggested for use in forests. Following, a small number of forest districts will firstly be equipped with GPS-receivers as a demonstration project.

Fig. 2: Configuration for simultaneous measurements of all receivers

Kinematic positioning using GPS

Two positioning systems were investigated within a test run; each with a GPS-receiver as main component for positioning. Furthermore, these systems dispose of filter-algorithms for position estimation. One system is a so-called hybrid low-cost system, i.e. further sensors are integrated to increase the reliability of positioning. The other system is a GPS-mouse not including further sensors for stabilisation. Both systems enable a vehicle positioning being independent from digital maps.

The characteristics of both systems regarding the method of positioning were analysed. The dead reckoning component of the hybrid system, that goes into action in case of GPS failure, does not generate the accuracy as requested. The system should be installed inside the vehicle for a long time, so the self calibration will lead to better results in dead reckoning. The capability of both systems has been valuated in comparison to geodetic GPS-receivers. They are especially distinguished by a better availability, just in close build-up areas. The accuracy of both systems is approx. 10m. This corresponds to the expectations.

Fig. 3: Hybrid positioning system with GPS-antenna and adapter for the speed signal of the vehicle

Precise Positioning using low-cost GPS receivers

Within several test drives and field trials the use of low-cost GPS receivers for positioning with geodetic accuracy was investigated. The tests were carried out for static and kinematic applications.

As a rule low-cost GPS receivers deliver accuracies within the scope of about 10 m. This fact is backed up by the used code measurements and the non-availability of post-processing of the original measurement data. Some receivers of the producer Garmin offer the possibility to load down code and phase information in realtime and store it on a computer, thus, the position is estimated using post-processing algorithms.

Fig. 4: Garmin eTrex-Vista and adapter

First test measurements have shown that in static modus (30 minutes observation time) an accuracy better than 10 cm may be reached, if multipath and diffraction effects could be avoided. Regarding kinematic positioning no accuracy improvements with respect to the relative code solution could be obtained. Further research is dedicated to special quality criteria for low-cost GPS receiver data.

Traffic Information Technology

Within the interdisciplinary field of traffic telematics, the IAGB is contributing with the traditional geodetic work of position determination, reality modelling in a digital map, as well as reliability of data acquisition and processing. A variety of activities is focussed on the development of future mobility services and driver assistance systems. One main topic is, beside others, the preparation and analysis of the complete information chain from source data to the end user, thus disposing data of a quality and safety standard required by the application.

Microscopic Accident Analysis

Within the framework of the BMBF-project INVENT an analysis of traffic flow in crossing areas was ordered by DaimlerChrysler AG. Due to accident data of police authorities an accident analysis was carried out for a representative part of Stuttgart. The microscopic analysis of accidents has the aim to identify traffic situations with highly dangerous potentials. For this analysis 590 accidents documented by the police were registered and analysed.

In order to analyse driver mistakes in accident situations an investigation in continuation of the study of 2002 was carried out. The results were used to appraise the potential of avoiding accidents for several driver assistance functions. A high potential was identified for driver assistance systems providing information to right of way, and supporting the control of safety distance.

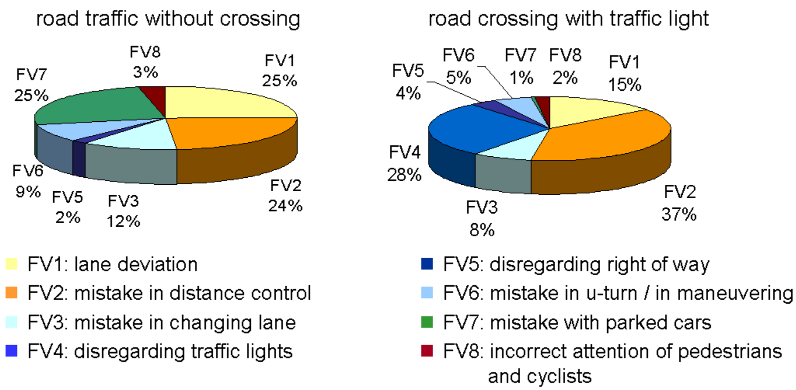


Fig. 5: Driver mistakes in accidents situations

Geodata in public transport

The realisation of a prototype of a Computerized Operational Control System (COCS) based on geodata is one of the aims of the Project RUDY. In this project research institutes, public transport companies, local authorities and technology suppliers cooperate with the aim to improve public transport by telematic.

The so called GeoCOCS extend the functionality of systems on the market by automated dispatching of transport on demand and incident management. The data model is nearly specified and will be applied next year into two demonstrators.

Monitoring of public transport fleets

Combining geodata and the schedule of the local public transport company „Stadtwerke Ulm - Verkehr“ (SWU) a simulation of the positions of all vehicles in use was created. These simulated data are displayed in a monitoring system based on the GIS System ArcGIS from ESRI. The monitoring system offers a current view on the operational status of the public transport system to the dispatcher.

The design of the map on the screens is adapted to the requirements of the disponent. The contents and the signature are depending on the scale. Dynamic information will be presented by interactive masks if not visualised within the map itself.

An important information for the dispatcher is the vehicle position in relation to stop points used for crossovers. The visual control is an effective support of decision making. Based on this monitoring system an interactive dispatching in an incident management will be worked out next year.

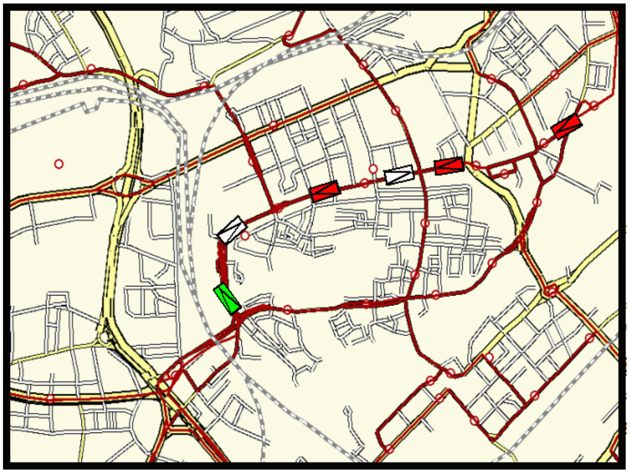


Fig. 6: Map of the monitoring system

Priorization of public transport at traffic lights

To control traffic lights for the priority of public transport vehicles the position must fulfil strong requirements on positioning quality. By approaching the intersection, two control points are defined to influence the traffic lights in such a way that the public transport vehicle can drive continuously over the intersection. If the vehicle has passed a third control point behind the intersection, the system will continue the regular turn.

Quality criteria like metric accuracy, availability and timelines have to be determined for positioning systems used in this context. Additionally a practical field test was carried out on a test track including three traffic lights. The positioning system is based on a commercial navigation system.

Test results show the suitability of the positioning system for this application. The advantages are:

- No roadside infrastructure necessary,
- Easier and more effective administration and updating of control points,
- Available also for vehicle operation on non-regular routes.

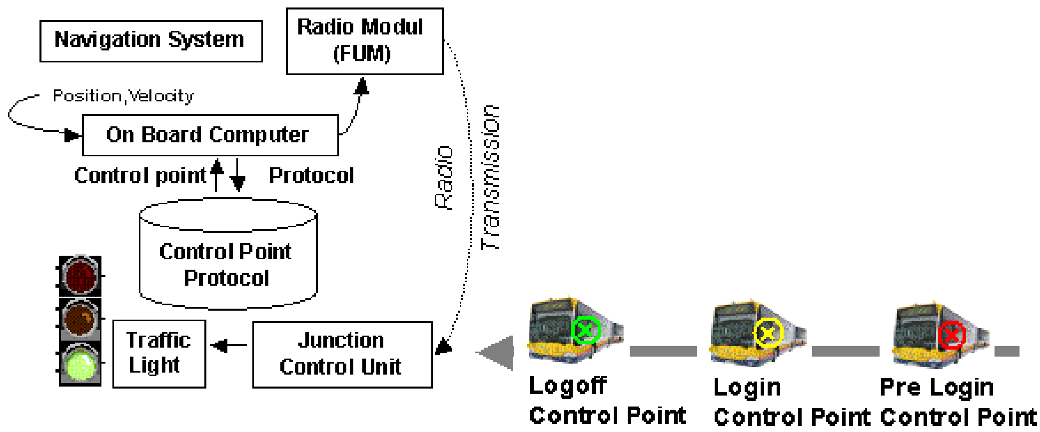


Fig. 7: Functional architecture of the field test equipment.

eLearning

BMBF-Project GIMOLUS

In co-operation with various university institutes from Stuttgart, Oldenburg, Würzburg und Duisburg an internet-based learning platform, called GIMOLUS (GIS- und modellgestützte Lernmodule für umweltorientierte Studiengänge' i.e. 'learning modules based on GIS and modelling in environmental courses') was built up. During the project from 2001 to 2003 eLearning modules were created using the web-technologies Flash, PHP and XML. The main focus in 2003 was the creation of WebGIS-based exercises with the technologies ArcIMS, Metaframe Citrix and TurboDemo-Videos. To give decision support for further development of exercises, the used WebGIS technologies were evaluated from the point of developer and from the point of the user.

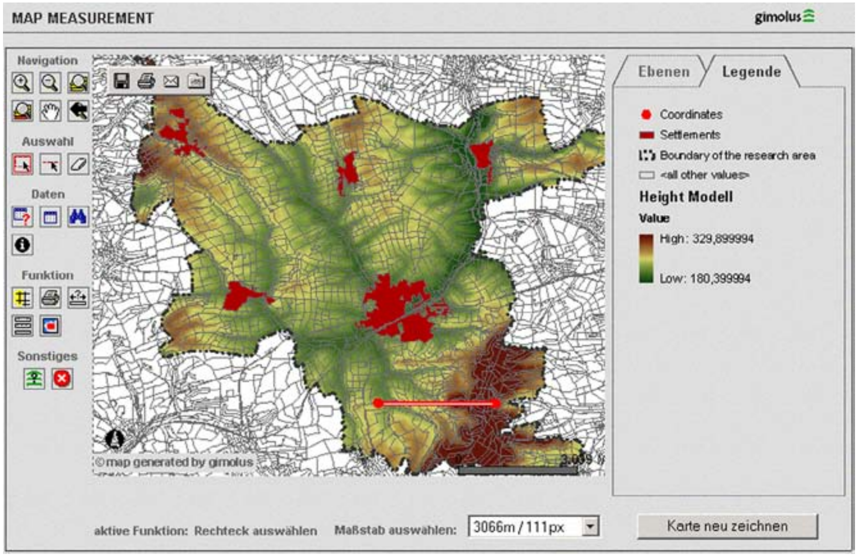


Fig 8: User interface of an ArcIMS-based exercise

The eLearning-modules 'shape of the earth', 'terrestrial measurements', 'satellite-based positioning methods', 'mapping', 'pre-processing in GIS' as well as 'ArcGIS help and tutorial' were finished at IAGB in 2003. Already in winter term 2003/04 selected eLearning modules were used and evaluated from students within the lectures 'Thematic Cartography' and 'Surveying for Architects'. In summer term 2004 further eLearning modules will continuously be used in the lectures 'Data Acquisition and Management' and 'Acquisition and Management of Planning Data' within the master course infrastructure planning.

Self-Study Online-project ActiveGeo

Within the framework of the project Active Geo (geodetic computation methods), sponsored by the University Stuttgart, an eLearning module is created, that mediates the basic geodetic computation methods to students of different disciplines and curricula. The following topics will be treated within the modules:

- intersection,
- resection,
- arc section and
- polar survey.

If the students have worked with the eLearning module they will have the competence to carry out the related computations autonomously. Furtheron the accuracies of the computation methods should be valuated in dependence of the geometry. The eLearning module will be imported into the GIMOLUS platform and used as a supplement to physical teaching.

The project ActiveGeo is subdivided into the phases media-didactic and technical conception, realization of the concept, and evaluation of the realized concept.

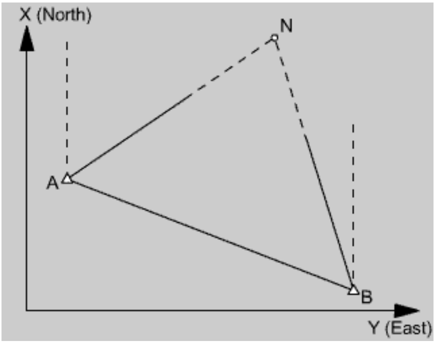


Fig 9: Title image of the eLearning module ActiveGeo

Activities of Prof. Dr.-Ing.Dr.sc.techn.h.c.Dr.h.c. K. Linkwitz

Formfinding of Lightweight Structures

The two-hour-lectures „Analytic Formfinding of Lightweight Structures“ for students of civil engineering, architecture and geodesy were successfully held again. The appertaining practical computer exercises have been performed on windows-NT-computers of the CIP-pool of the master course WAREM. As part of the exercises the students did also interdisciplinary project works in some institutes of civil engineering and architecture.

Further lectures of K.Linkwitz

As part of the obligatory course „Engineering Geometry and Design“ given to civil engineers in their first semester by the Institute of Construction and Design II, some lectures on the subject „Geometric methods for computer-aided design“ were held at the University of Stuttgart.

Publications 2003

Henninger, Heine-Nims, Schnittger, Bettermann: RUDY- Regionale unternehmensübergreifende und dynamische Vernetzung von Auskunfts-, Betriebsleit- und Planungssystemen im ÖPNV und Taxigewerbe, Tagungsband 19. Verkehrswissenschaftliche Tage in Dresden, 22. und 23. September 2003.

Gläser, A., Schollmeyer, R.: Bordautonome Ortung von Schienenfahrzeugen. DGON-Symposium, TRANSPONDER 2003, Hannover 2003.

Gläser, A.: Steuerung autonomer Baumaschinen - ein Simulator. Virtuelle Instrumente in der Praxis, VIP 2003, Hüthig Verlag, München, 2003. ISBN 3-7785-2908-0.

Kuhlmann, H.: Bestimmung der temperaturinduzierten Bewegung einer fugenlosen Brücke. VDI-Bericht 1757, VDI-Verlag, Düsseldorf.

Kuhlmann, H.: Kalman-Filtering with Coloured Measurement Noise Deformation Analysis. 11th FIG International Symposium on Deformation Measurements, Santorini, Greece.

Kuhlmann, H., Eichhorn, A.: Positionsbestimmung von PKW mit Sensoren der Serienausstattung. POSNAV 2003, DGON-Symposium Positionierung und Navigation 2003 in Dresden, Deutsche Gesellschaft für Ortung und Navigation, Bonn.

Linkwitz, K.: Computer-Aided Design and Manufacture of Timber Roof Shells. In: New Technologies in Architecture II & III 2003, Cambridge Harvard University, Design and Technologiy Report Series.

Ramm, K., Kuhlmann, H.: „Manipulationspotenzial bei der Bauabrechnung durch den Einsatz von frei programmierbaren Messsystemen"'. Allgemeine Vermessungsnachrichten (AVN), 110 (2003), S. 384-391, Wichmann-Verlag. Heidelberg.

Schollmeyer, R.: „Modulares Messwerterfassungskonzept am Beispiel einer bordautonomen Gleisvermessung“, Virtuelle Instrumente in der Praxis, VIP 2003, Hüthig Verlag, München, ISBN 3-7785-2908-0

Schwieger, V.: Using Handheld GPS receivers for precise positioning. Proceedings on 2nd FIG regional conference, Marrakesh, Marocco, December 2-5, 2003.

Schwieger, V.; Kaufmann, T.: Internetbasierte Lernmodule zur Geo-Datenerfassung - Allgemeine Vermessungsnachrichten (AVN), Heft 7, 2003, S. 248-254, Wichmann-Verlag. Heidelberg.

Wiltschko, T. und Möhlenbrink, W.: Möglichkeiten und Grenzen eines infrastrukturgestützten Kreuzungsassistenten. DGON-Symposium TRANSPONDER 2003. 2.-3. April 2003 in Hannover.

Wiltschko, T. und Möhlenbrink, W.: Analyse der Informationsqualität von Telematikanwendungen anhand des Systementwurfs. In: Entwurf komplexer Automatisierungssysteme EKA 2003. 11.-13. Juni 2003 in Braunschweig. S. 373-389.

Wiltschko, T. und Möhlenbrink, W.: Analyse der Informationsqualität von Telematikanwendungen anhand des Systementwurfs. atp Automatisierungstechnische Praxis 45 (2003), Heft 6. 69-76.

Wiltschko, T.: Mikroskopische Unfallanalyse zur Identifikation von Wirkungsfeldern zukünftiger Fahrerassistenzsysteme. Tagungsband 19. Verkehrswissenschaftliche Tage, Dresden, 22. und 23. September 2003. 107.1-107.17.

Diploma Thesis

Beetz, A.: Entwicklung ausgewählter Komponenten eines Regelkreises zur Fahrzeugsteuerung und deren Realisierung in einem Testsystem

Engelhardt M.: Ermittlung und Klassifikation von Portierungshemmnissen von Geodaten im ÖPNV

Hell, V.: Datenintegration und -analysen für Anwendungen im Geomarketing Jöns, O.: Entwicklung eines Fahrzeug-Positionierungsmodells für software-basierte Fahrerassistenzsysteme

Philipp, M.: Untersuchung der charakteristischen Eigenschaften zweier Ortungssensoren

Pfeiffer, M.: Nutzung von Geodaten beim ÖPNV-Netzentwurf - Identifikation von Hemmnissen und Entwicklung einer Strategie zur Datenintegration

Semmelmann, A.: PDGPS-Positionsbestimmung mittels GPS Low-Cost-Empfänger.

Master Thesis (Post-graduate course Infrastructure Planning)

Contreras Leal, I.: A Contribution to the Development of Internet-based GIS Applications for Geo-data Acquisition in the Context of Urban Planning.

Doctoral Thesis

Wiltschko, Thomas: Sichere Information durch infrastrukturgestützte Fahrerassistenzsysteme zur Steigerung der Verkehrssicherheit an Straßenknotenpunkten.

National and International Activities in Scientific and Professional Organisations

Wolfgang Möhlenbrink:

Member of Deutsche Geodätische Kommission (DGK)
Member of Deutscher Verein für Vermessungswesen (DVW)
Member of Deutsche Gesellschaft für Ortung und Navigation (DGON)
Member of steering committee „Vermessung“ of Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV)
Corresponding member of the „Strategic Advisory Group for Telematic Applications for Transport and Related Services“
Member of Deutsche Verkehrswissenschaftliche Gesellschaft (DVWG)
Member of Working Group „Vermessung und Abnahme Feste Fahrbahn“ of Deutsche Bahn AG
Coordinator of Working Group „Traffic Guidance and Control“ of IAG
Speaker of the directory of Centre of Infrastructure Planning of the University of Stuttgart
Speaker of the Centre of Transportation Research at Stuttgart University (FOVUS).

Ulrich Hangleiter:

Member of the International Association of Shell and Spatial Structures (IASS)
Manager of the Centre of Transportation Research at Stuttgart University (FOVUS).

Heiner Kuhlmann:

Member of Working Group „Vermessung und Abnahme Feste Fahrbahn“ of Deutsche Bahn AG
Member of Working Group „Absteckung und vermessungstechnische Kontrolle“ of Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV)
Member of Working Group „Ingenieurvermessung“ of DVW

Volker Schwieger

Member of Working Group 3 „Messmethoden und -systeme“ of Deutscher Verein für Vermessungswesen (DVW), Head of Sub Working Group „GNSS“
Member of Working FIG-Group 8.4 „Risk Management“
Member of Working Group „Geodäsie“ of Normenausschuss Bauwesen of DIN
Member of Working Group „Ausgleichungsrechnung und Statistik“ of Normenausschuss Bauwesen of DIN, Head of Sub Working Group „Auswertung kontinuierlicher Messreihen“

Education - Lecture / Practice / Training / Seminar

By introducing the new curriculum of Geodesy and Geoinformatics in autumn of 2003, some new lectures had to be presented in addition to the lectures of the „old curriculum“. These are marked in the following list by „**NEW** Curriculum“.

Surveying I, II for Civil Engineers (Möhlenbrink / Schollmeyer)	3/1/3/0
Surveying for Architects (Möhlenbrink, Wiltschko / Kaufmann)	2/0/1/0
Acquisition and Management of Planning Data (Möhlenbrink / Kaufmann)	3/1/0/0
Fundamentals to Surveying for Geodesists I, II (Wiltschko / Ramm)	4/1/3/0
Information Studies for Geodesists II (Wiltschko / Ramm)	2/2/0/0
Adjustment Theory and Statistics I, II (Schwieger / Bettermann, Ramm)	3/2/0/0
Geodetic Measurements - (Wiltschko)	2/2/0/0
Surveying I, II for Geodesists (Kuhlmann / Gläser)	3/2/0/0
Field Practica in Surveying (Gläser, Schwieger)	10 days
Special Tasks in Surveying (Kuhlmann / Schollmeyer)	1/1/0/0
Surveying Engineering I (Möhlenbink / Stark)	1/1/0/0
Surveying Engineering II, III (Schwieger / Gläser, Ramm)	3/2/0/0
Adjustment and Analysis of Geodetic Networks (Schwieger / Gläser)	2/1/0/0
Digital and Thematic Cartography (Bettermann / Kaufmann)	1/1/0/0
Geodetic Measurements I - **NEW** Curriculum (Wiltschko / Ramm)	2/1/0/0
Statistics and Error Theory I - **NEW** Curriculum (Schwieger / Schollmeyer)	1/1/0/0
Surveying Engineering I - **NEW** Curriculum (Schwieger / Gläser)	2/1/0/0
Thematic Cartography - **NEW** Curriculum (Bettermann / Kaufmann)	1/1/0/0
Analytical Formfinding of Lightweight Structures (Linkwitz)	2/0/0/0
Geodetic Seminar I, II (Fritsch, Grafarend, Keller, Kleusberg, Möhlenbrink, Reulke)	0/0/0/4
Land Consolidation I (Mayer)	1/0/0/0
Land Consolidation II (Mayer)	2/0/0/0

Institute of Geodesy

Geschwister-Scholl-Str. 24/D, D-70174 Stuttgart,
Tel.: +49 711 121 3390, Fax: +49 711 121 3285
e-mail: gis@gis.uni-stuttgart.de or SECONDNAME@gis.uni-stuttgart.de
url: http://www.uni-stuttgart.de/gi

Head of Institute

GRAFAREND Erik W, Prof. Dr.-Ing. habil. Dr.tech.h.c.mult. Dr.-Ing.E.h.mult.
KELLER Wolfgang, Prof. Dr. sc. techn.
KRUMM Friedrich, Dr.-Ing.
WOLF Detlef, Prof. Dr. rer. nat. habil.

Secretary: VOLLMER Anita

Academic Staff

AUSTEN Gerrit, Dipl.-Ing.	Gravity Field Modeling GRACE/CHAMP
BAUR Oliver, Dipl.-Ing.	Satellite Gravity Gradiometry
BÖLLING Karla, Dipl.-Ing. (until 31.05.)	Geoid determination
CAI Jianqing, Dipl.-Ing. M.Sc.	Deformation Analysis, Mathematical Statistics
FINN Gunter, Dipl.-Ing.	Geoid determination
GÖTZELMANN Martin, Dipl.-Ing. (since 1.9.)	Satellite Geodesy
MARINKOVIC Petar, Dipl.-Ing. (until 31.07.)	Statistical Aspects of Satellite Geodesy
MOGHTASED-AZAR Khosro, M.Sc. (since 20.10)	Geodynamics
NAGEL Stephan, Dipl.-Ing. (until 31.07.)	Earth Rotation and Gravity Field Modeling
NOVÁK Pavel, Ph.D.	Gravity Field Modeling GRACE
REUBELT Tilo, Dipl.-Ing.	Gravity Field Modeling CHAMP
SHARIFI Mohammad A, Dipl.-Ing. M.Sc.	Gravity Field Modeling GRACE

Administrative/Technical Staff

BAYERLEIN Wolfgang, Dipl.-Ing. (FH)
HÖCK Margarete, Phys. T.A.
KARBIENER Ingeborg
SCHLESINGER Ron, Dipl.-Ing. (FH)

Guests

ABDEL-MONEM SM, Dr., Cairo/Egypt, 2.10.-31.12.03
ARDALAN AA, Prof. Dr., Tehran/Iran, 24.3.-14.4.03, 4.8.-22.9.03
BILKER M, Masala/Finland, 9.11.-21.11.03
BORKOWSKI A, Dr., Wrozlaw/Poland, 10.6.-18.6.03, 15.-21.12.03
CHEN Y, Prof., Shanghai/China, 1.1.-22.8.03
KAKKURI J, Prof. Dr., Helsinki/Finland, 31.1.-1.2.03
LIU L, Prof. Dr., Wuhan/China, 1.1.-21.2.03
MIRA S, Prof. Dr., Bandung/Indonesia, 30.11.-31.12.03
VARGA P, Prof. Dr., Budapest/Hungary, 15.9.-27.9.03, 1.12.-13.12.03
WANG J, Prof. Dr., Shanghai/China, 1.9.-31.12.03
YAO L, Prof., Shanghai/China, 1.1.-15.3.03

Additional Lecturers

ENGELS J, Dr., Stuttgart
HAUG G, Dr., Stadtplanungs- und Stadtmessungsamt, Esslingen/Neckar
RICHTER B, Dr., Deutsches Geodätisches Forschungsinstitut, München
SCHÖNHERR H, Präsident Dipl.-Ing., Landesvermessungsamt Baden-Württemberg, Stuttgart

Honorary Professors

HINTZSCHE M, Prof. Dipl.-Ing, Fellbach

Trainees

SAMARAS K (FHT Stuttgart)

Research

Gravity field determination from kinematic LEO-ephemeris

Three LEO (low earth orbiting) satellite missions have been designed to fly in the next years. One of their main topics is the improvement of existing gravity field models. The first two missions, CHAMP - Challenging Minisatellite Payload for Geophysical Research and Application - and GRACE -Gravity Recovery and Climate Experiment- have already been launched successfully in summer 2000 and march 2003. GOCE - Gravity field and Steady-State Ocean Circulation Earth Explorer - should complete the gravity field determination in 2006. Besides various measurement principles applied in the different missions orbit analysis is carried out to determine the low frequency part of the gravity field. Since the LEO orbit (h $\approx$ 400 km) can be tracked with cm-accuracy in the kinematic mode, an algorithm has been designed which enables the determination of the parameters of the Earth's gravity field. The procedure is as follows:

First, the accelerations acting on the satellite are computed by means of the second order functional of Newton interpolation from quasi-inertial GPS tracked LEO ephemeris. Second, the Newton interpolated accelerations are reduced from disturbing accelerations. Third, the reduced accelerations are balanced by the quasi inertial vector of gravitational field intensity. A Cartesian representation of the gradient is applied. The Cartesian gradient is obtained by means of Chain rule from the spherical gradient in order to apply the efficient recurrence relations of the spherical derivatives. The resulting overdetermined system of equations is solved by means of the special linear Gauss-Markov Model. Numerical instabilities are diminished via regularisation of type Tikhonov-Phillips, especially the regularisation matrix is based upon Kaula's rule.

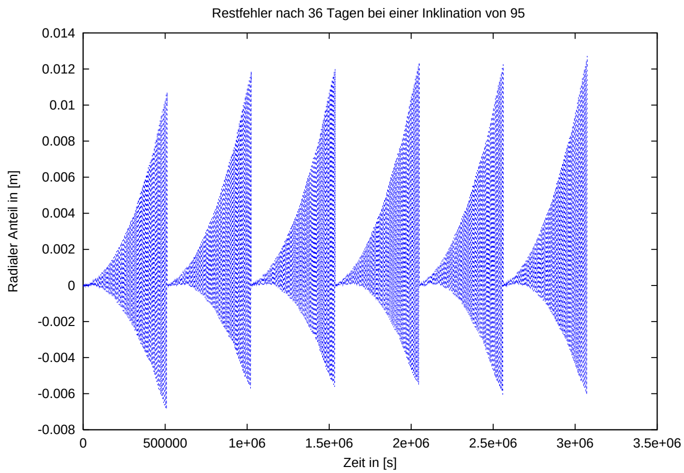
Detailed simulations exhibit that the interpolation error of the determined accelerations from an orbit of degree 50 is smaller than $3 * 10^{-9} m/s^2$ and thus a determination of the long and medium wavelength coefficients with an accuracy of 10^{-14} is possible (corresponding to a geoid error in the sub-mm level). As soon as realistic measurement errors are introduced in the orbits, the accuracy of the coefficients decreases to 10^{-9} - 10^{-10} which means a geoid error of 1 - 2 dm up to degree/order 30/30. First analyses of preliminary real CHAMP orbits (dynamic and kinematic, accuracy of 10 cm) illustrate by comparisons to existing models, that already from short arcs (1 month or less) a geoid accuracy of 1 - 3dm can be achieved. This means, that an analysis of the whole CHAMP mission should lead to a geoid error of a few cm and thus shall improve the long-wavelength parts of existing models. An enhancement is additionally expected from an increasing accuracy of kinematic orbits.

Additionally, further methods of interpolation such as spline interpolation and smoothing interpolation schemes (regression polynomials, smoothing splines) in order to reduce noise have been tested. It has turned out that the accuracy of the determined accelerations can be improved by a factor of 2-4 by means of smoothing interpolation methods. But it has to be investigated if the noise of the gravity field coefficients is also reduced by these methods, or if to much signal is smoothed out.

The progression of the CHAMP-mission is demanding a higher resolution of the gravity field (up to degree 90 - 120), since the data sets get larger and the descent of the satellite leads to an increase of signal. In order to deal with the limited memory of the computer, an iterative solution of the system of equations is implemented, where only one row of the design matrix has to be stored in the memory. A suited procedure is the method of conjugate gradients, which can be accelerated by means of adequate preconditioning. A solution can be achieved after 5 - 10 iterations if a block diagonal approximation of the normal matrix is applied for preconditioning.

Ocean circulation from CHAMP data

Present orbit models for altimeter satellites and models for the stationary sea-surface topography have considerable errors in the length-scale 1000 - 4000 km. Gravity field models derived from CHAMP orbit observations will improve the knowledge about the gravity field in exactly this spectral band. Based on the improved gravity field new orbits for the altimeter satellites could be computed. Since orbit computation is a very complex task, a technology for incremental orbit improvement exclusively due to changes in the gravity field model was developed. With the help of the incremental orbit improvement technique a radial orbit accuracy of 1cm for a complete repeat cycle of the ERS1/2 satellite could be achieved.



A reprocessing of the ERS1/2 altimeter data based on the improved orbits will be the next step. The final step of the DFG-sponsored project will be the assimilation of the CHAMP-improved geoid model and of the reprocessed altimeter sea-surface heights into the ocean circulation model LSG of the Alfred-Wegener-Institute (AWI) in Bremerhaven.

Gravity field determination from temporal variations of the relative motion of two satellites: GRACE Mission

The launch of the GRACE satellites in March 2002 succeeding the start of the CHAMP mission in July 2000 is the next step for the detailed mapping of the Earth's gravitational field and its temporal variations. The overall scientific goal is the determination of the spherical harmonic coefficients of a terrestrial gravitational field model up to degree and order 140 to 160. To fulfil the demands it is necessary to solve a linear overdetermined system of equations consisting of several ten thousands of unknowns and a few million observations. Making use of standard least squares (Gauss-Markov Model) parameter estimation procedures for the solution of the addressed problem leads to difficulties on conventional PC systems due to hardware restrictions, predominantly memory limitations with the extensive matrix operations. And it turns out that the application of iterative solvers is often to time-consuming because of numerous iterations. For this reason current investigations focus on the development of software involving the use of numerical libraries such as BLAS and LAPACK or PBLAS and SCALAPACK to be in the position to take advantage from high-performance parallel computing platforms.

Direct Measurement of a Linear Combination of the Earth's Gravitational Tensor Components Using a Satellite Pair

The GRACE (Gravity Recovery And Climate Experiment) mission consists of two identical satellites that follow each other in the same orbit. They are equipped with GPS receivers and a very accurate inter-satellite ranging system. The mission has substantiated Low-Low Satellite to Satellite Tracking (LL-SST) concept. LL-SST configuration can be combined with the previously realized HL-SST concept in CHAMP mission to provide a much higher sensitivity, although LL-SST can be individually employed for mapping the earth's gravity field.

The line of sight (LOS) acceleration difference between the satellites as the simplest form of the combined observable is fairly used for mapping the global gravity field of the earth in terms of spherical harmonic coefficients. Furthermore, the configuration can indeed be viewed as a huge one-component gradiometer with an arm length of 250 km. Hence, gradiometry with GRACE can be done with high level of precision due to the long arm length of this virtual one-dimensional gradiometer. This unique geometric characteristic of the spacecrafts configuration motivates to switch from the first derivatives of the gravitational potential to the second derivatives of the field. In other words, the observation equation can be considered as a linear combination of the gravitational gradient tensor components instead of gravitational acceleration differences along the LOS.

Mathematical formulation as well as computer realization of the innovative approach has been performed. In addition, the mathematical formulae have been validated using simulated data.

In LL + HL combination, inter-satellite range and its time derivatives play the main role, so the higher accuracy of the quantities results the better estimates of the earth's gravitational potential. In this regards, a special type of polynomial approximation has been employed to derive a better accuracy with respect to the already implemented methods. Various mathematical formulations have been developed and numerically tested. The proposed algorithms yield promising results, so the coefficients can be estimated with a higher accuracy.

Due to different sampling frequencies of the ranging system and the mounted GPS receivers on the satellites, we should either resample the ranging observations or increase GPS measurements density to get an identical sampling rate for both types of the measurements. Among different data fusion algorithms, polynomials-based fusion has been developed mathematically and some primary results achieved. A study of the idea generalization is now being carried out.

The GRACE processor for a spherical harmonic analysis of temporal variations of geopotential

The US-German satellite mission GRACE (Gravity Recovery and Climate Experiment) consists of two identical low-orbiting satellites equipped with GPS receivers, very accurate inter-satellite ranging system and other sensors. Observed data collected from these sensors can be used for global recovery of the geopotential. Moreover, due to the relatively long duration of the GRACE mission, long-periodic temporal variations of the geopotential can be also determined.

Alternative algorithms for recovery of the geopotential from the GRACE observables have been formulated and tested at the Geodetic Institute of the Stuttgart University during 2003. They are based on the Newton equation of motion linking observed acceleration of the satellites to the unknown geopotential. Considering all observables, observation equations can be written for both acceleration of individual satellites (GPS data) and inter-satellite acceleration differences (ranger data). The equations can be solved in the time domain approximating the geopotential by a truncated spherical harmonic series or in the space domain representing the geopotential by integral means defined on the surface of a reference sphere for a selected grid of spherical coordinates. The time-domain solution is based on a system of linear equations with unknown Stokes coefficients of the geopotential. The space-domain solution leads to the discretized Fredholm integral equation of the first kind that is based on the well-known Abel-Poisson integral. Numerical solutions of both approaches are very tedious and special numerical techniques are required. As a consequence of using the inter-satellite acceleration differences, the geopotential gradient refers to locations of the two satellites. Alternatively, the geopotential expanded at the barycentre of the two satellites can replace the geopotential gradient differences. The advantage of this approach is based on referring the unknown function to a single location. However, only approximated version of this model can be used for actual numerical evaluations. The effect of omitted higher-order terms in a series expansion was investigated and found negligible.

Various modules of the software package intended for processing the GRACE data have been developed and tested. They include modules for transformation between a quasi-inertial frame of reference (frame with space-fixed primary directions but moving origin) and the Earth-fixed frame, modules for numerical differentiation using the Newton interpolation formula and Savitzki-Golay algorithm, modules for solving systems of normal equations for the different approaches. The Newton formula was tested extensively using noise-free and noisy data and its applicability for differentiation of data with positively-correlated noise was verified. Concerning the system of linear equations, the model for the satellite acceleration was successfully tested using both simulated and actual data (CHAMP data were used as replacement for currently unavailable GRACE data). The model for the inter-satellite acceleration differences was tested using simulated data. Independent algorithms showed the availability of recovering the signal from simulated observations.

Simultaneously with the geopotential recovery from the GRACE data, gravity field variations were investigated. The effect of deglaciation was studied due to its dominant magnitude among secular effects. The local effect caused by deglaciation of Fennoscandia was computed using a five-layer visco-elastic model of the upper mantle. The gravitational potential of topographical and atmospheric masses assuming time-varying mass density distribution was formulated theoretically and first results for static masses were computed.

SGG - Satellite Gravity Gradiometry

After CHAMP and GRACE, the ESA satellite mission GOCE (Gravity field and steady-state Ocean Circulation Explorer) arranges as the third innovative enterprise in the field of satellite geodesy at the beginning of the new millennium. Yet CHAMP and GRACE have launched successfully in 2000, respectively 2002. The launch time of the GOCE satellite is planned for 2006. It is the primary aim of these three missions to estimation of the Earth's gravitational field - respectively the physical shape of the Earth - with respect to both high-precision and high-resolution. Present satellite-only Earth gravitation models (e.g. GRIM5-S1) don't meet today's requirements in the various scientific areas like Geodesy, Geophysics or Oceanography. The combined results of the three missions mentioned above will provide the static Earth gravitational field in terms of geoid accuracy of 2cm with a spatial resolution of about 80km (half wavelength). Additionally, it will be possible to deliver information about the temporal variation.

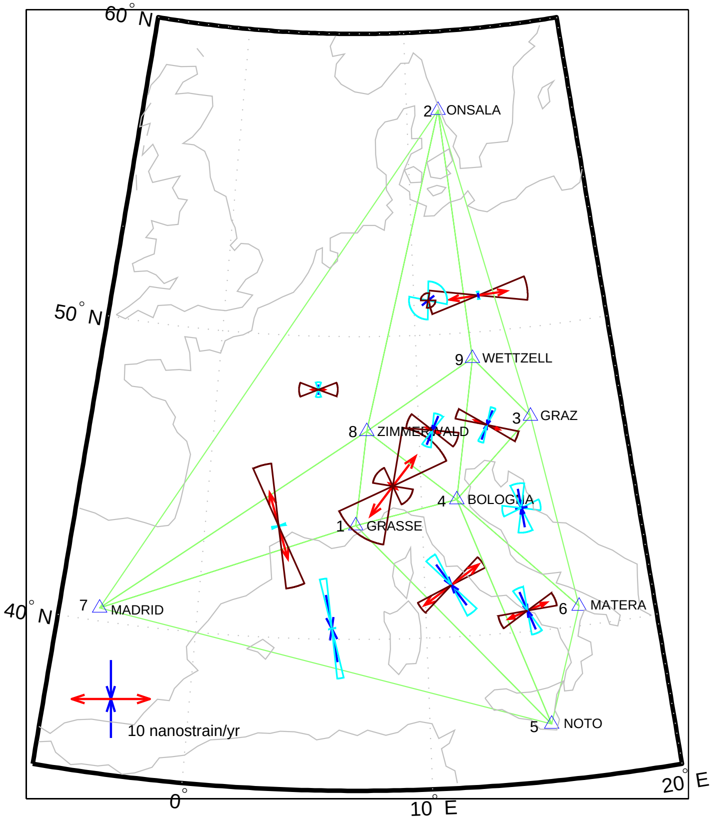
In the first place, the GOCE mission will contribute to the modelling of the short wavelength part of the Earth's gravitational field. To meet that, for the first time in satellite geodesy a three-axes gradiometer will deal as measurement unit. Combined with a low satellite orbit of about 250km, the gradiometer instrument responds extremely sensitive to gravitational forces caused by the Earth's masses and with that it guarantees the resolution of the harmonic expansion of the Earth's gravitational field up to degree and order 250-300. The three-axes gradiometer consists of six accelerometers whose combined measurements allow to set up the so-called gravitational tensor. The coefficient matrix of this tensor is both symmetric and trace free; thus only five of the nine elements (gravitational gradients) are linear independent. The gravitational gradients (GG) correspond to the second derivatives of the gravitational potential (twice application of the gradient operator). With that the functional model between the pseudo observations (GG) and the unknown Stokes coefficients of the harmonic expansion of the Earth's gravitational potential - its functionals respectively - is directly given.

It is useful to avoid any rotation of the gravitational tensor from the gradiometer frame in an other frame of reference since this would affect the accuracy of the GG in a negative manner. This is why not the GG itself but the so-called fundamental invariants of the gravitational tensor deal as observations. These values behave independently with respect to any rotation of the underlying reference frame. Furthermore the invariants are independent from the parameterisation of the Earth's gravitational field (e.g. spherical or ellipsoidal parameterisation). The three fundamental invariants can be calculated via the eigenvalue problem by solving the auxiliary equation. The first invariant is identical to the trace of the gravitational tensor. The further two invariants are composed of summed up products between the GG. This leads to a non-linear functional relationship of the observations (invariants) with the unknown Stokes coefficients. It is thus necessary to estimate corrections to the approximated values of the unknowns in an iterative procedure. This is done on the basis of least squares adjustment methods.

The dimension of the problem can be expressed by the following. The GOCE satellite is aimed to collect data covering a time span of one year with a sampling rate of 1s. This results in about 30millions observation points. Each of them provides three observations, namely the fundamental invariants. Further there are about 100.000 unknown coefficients when assuming a spatial resolution of 70km, respectively a spectral resolution up to degree and order 300. Therefore the normal equation matrix needs memory requirements for just 100GB. Additionally, one has to be aware of the enormous costs to set up the design matrix of the mentioned problem. There is no doubt about the fact that nowadays such a problem cannot be solved with a common PC. Hence on the part of the institute active effort is done to use the computational resources of the HöchstLeistungsRechenzentrum Stuttgart (HLRS). Following that way timely research in the field of satellite geodesy can be established.

Hypothesis tests and sampling statistics of the eigenvalues and eigendirections of a random tensor of type deformation tensor

For the validation of a symmetric rank-two random tensor, for instance of strain and stress, the eigenspace components (principal components, principal directions) play a key role. They classify deformation and stress patterns in earthquake regions, of plate tectonics and of glacially isostatic rebounds. The main purpose of this research project is to develop the proper statistical inference for the eigenspace components of a symmetric deformation tensor. Let us assume that the strain or stress tensor has been directly observed or indirectly determined by other measurements. According to the Measurement Axiom such a symmetric rank-two tensor is random. For its statistical inference, we assume that the random tensor is tensor-valued Gauss-Laplace normally distributed. The eigenspace synthesis relates the eigenspace elements to the observations by means of a nonlinear vector-valued function establishing a special nonlinear multivariate Gauss-Markov model. For the linearized form, based on the estimate theory about the eigenspace components of a two-dimensional, symmetric rank two tensor, we have succeeded to construct BLUUE of the eigenspace elements and BIQUUE of its variance-covariance matrix for the three-dimensional case. The test statistics, such as Hotelling's T^2, Lawley-Hotelling's trace test, likelihood ratio statistics and Growth-Curve model are proposed. In two case studies both model and hypothesis tests have been applied to the two- and three-dimensional, symmetric rank two strain rate tensor observations in the region of Central Mediterranean and Western Europe, which are derived from ITRF92 to ITRF2000 series station positions and velocities. The related linear hypothesis test has documented large confidence regions for the eigenspace components, namely eigenvalues and eigendirections, based upon real measurement configurations. They lead to the statement to be cautious with data of type extension and contraction as well as the orientation of principal stretches (see Figure).



Ever since Tykhonov (1963) and Phillips (1962) introduced the hybrid minimum norm approximation solution (HAPS) of a linear improperly posed problem there has been left the open problem to determine an optimal weighting factor α between the least-squares-norm and the minimum norm of the unknown parameters. Numerical tests have documented that the best linear unbiased estimator of the parameter vector within a linear Gauss-Markov model is not robust against outliers in the stochastic observation vector. It is for this reason that we give up the postulate of unbiasedness, but keeping the set-up of a linear homogeneous estimation. Different groups of researchers have systematically derived the best linear estimators of type homBLE (Best homogeneously Linear Estimation), S-homBLE and α-homBLE of the fixed effects ξ, which turn out to enhance the best linear uniformly unbiased estimator of type BLUUE, but suffer from the fact being biased. We have developed a new method of determining the regularization parameter α in uniform Tykhonov-Phillips regularization (α-weighted BLE) by minimizing the trace of the Mean Square Error matrix (A-optimal design) in the general case. The model was successfully tested using simulated direct observations of a random tensor of type strain rate.

Determination of the equipotential value of the geoid W0 from the Baltic Sea Level Project and the new models of the gravity satellite missions

One of the aims of the new gravity field models determined from the satellite missions is the improvement of the geoid's potential value W_0, which plays an important role in oceanography, in the definition of a height system and height determination with GPS. Based on the method of Ardalan and Grafarend the new gravity field models of the satellite missions CHAMP and GRACE and additional inland points of the Baltic Sea Level Campaign are included in a common Project with the FGI (Finnish Geodetic Institute, Masala/Finland)

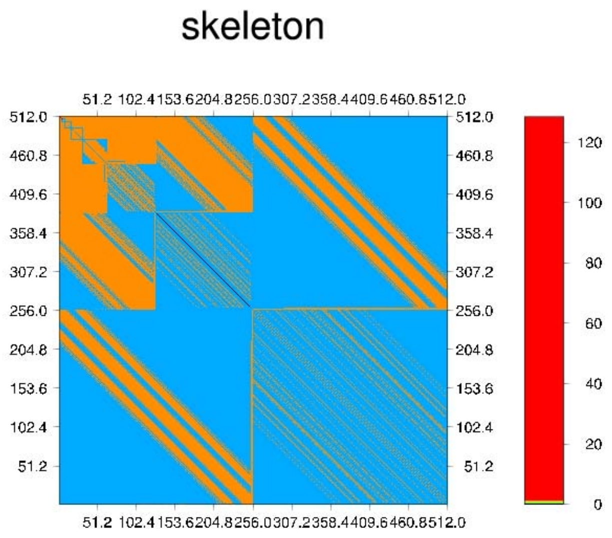
At first, the potential value of the Baltic Sea Level points, which are determined from GPS measurements, is computed by means of a global gravity field model. Second, these potential values are reduced on the geoid or on sea level. Since the orthometric heights of the inland points are known from the Finnish levelings, inland points can also be included in the computations. Finally the geoid's potential value and its accuracy are determined by the computation of the mean value. By inclusion of inland points and application of new gravity field models an improvement of the present day's value is expected. Another reduction is in discussion, where differences between the geoid from global gravity field models and the Finnish geoid (determined from terrestrial data as levelling and GPS measurements) should be considered for an adaption to local effects.

As a preparation for the computations, the new global gravity field models are compared with local Finnish and Scandinavian models as well as with the ground truth (levelling, GPS measurements). The differences between the global models and the ground truth will serve on the one hand as an independent evaluation of the global models and on the other hand as a correction for the global models used for the determination of W_0, as described before.

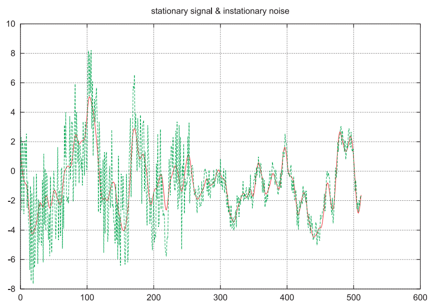
Wavelet Application in Geodesy and Geodynamics

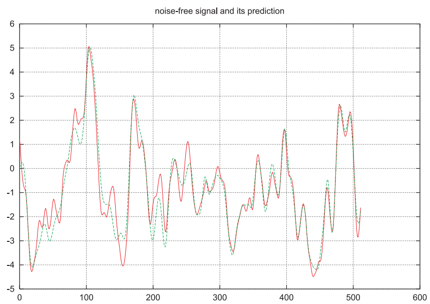
Wavelets are a recently developed tool for the analysis and interpretation of signals of various types. Compared to Fourier analysis, the standard tool for digital signal processing, wavelets provide two appealing features: (1) localization both in the time- and in the frequency domain and (2) discrete wavelet transformation algorithms, which are numerically even more efficient than the FFT. The DFG sponsored wavelet project aimed at an utilization of these properties in four fields of geodetic applications

- ▷ 1. Data compression. For an optimal compression of smooth data like geoid undulations or geoid heights the underlying wavelet has to be both smooth and orthogonal. As the results of the investigations a wavelet, derived from the quadratic spline wavelet showed the best overall performance for different types of data. Wavelet analysis and synthesis algorithm taylored to this special wavelet were developed.
- ▷ 2. Operator compression. Weak singularities are a typical feature of kernels of geodetic integral formulas. Using wavelets for their discretization thanks to the localization property of wavelets a very sparse matrix structure can be obtained. Then sparse matrix techniques can be applied for a numerically efficient treatment of the integral equation. Even more: Diagonality of the system matrix can be obtained, if the signal and the data are represented by different specially designed base function systems: wavelets and vaguelettes. For the planar approximation of the Stokes operator a corresponding wavelet-vaguelette pair together with the corresponding decomposition and reconstruction algorithms were developed.

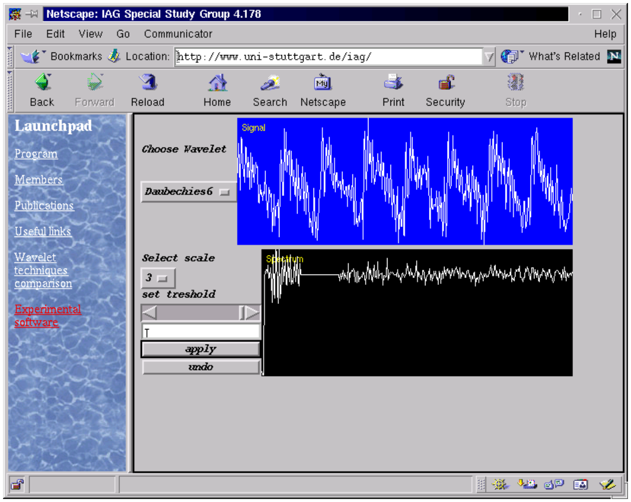


▷ 3. Non-stationary collocation. Under the stationarity assumption the Wiener-Kolmogorov equations of collocation theory become convolution equations and can efficiently be solved by FFT techniques. In reality many data exhibit instationarities and the resulting Wiener-Kolmogorov equations are non-convolution integral equations. Applying the above mentioned operator compression techniques efficient numerical algorithms for the non-stationary case could be developed. For example this technique can be applied to filter a signal with varying noise intensity.





The international cooperation in the field of wavelet application was organized in the framework of the IAG Special Study Group 4.187. One important outcome of this cooperation is a wavelet package for the most common wavelet algorithms both in a command-line driven C version as in a platform independent JAVA version. Both versions can be downloaded from the SSG 4.178 homepage http://www.uni-stuttgart.de/iag.



Deformation, sea-level and gravity changes: indicators of processes in the system solid earth-cryosphere-ocean

1. Postglacial sea-level change

The global relative sea-level change during the past 10000 years constitutes an important tool for the determination of the glacial-isostatic response of the earth to the last Pleistocene glaciation. The reconstruction of the past sea level is based on fossil samples deposited near the shore. After the determination of altitude and age, they constitute sea-level indicators (SLIs), which may be used for the inversion of the glacial-isostatic deformation of the earth in terms of the mantle viscosity. For this, the SLIs were archived in a data bank. At present, the focus of the data analysis is on Fennoscandia (ca. 750 SLIs). In addition, the data bank contains SLIs from the Barents Sea (ca. 400 SLIs) from North America (ca. 9030 SLIs), from Britannia (ca. 1050 SLIs) and from the equatorial region (ca. 405 SLIs).

2. Lithospheric root below Fennoscandia

Using SLIs for Finland, a relaxation-time spectrum may be determined, which contains the glacial-isostatic response of the earth's mantle below Fennoscandia in compact form. For the inversion of the spectrum in terms of the viscosity distribution, an axisymmetric configuration with a lithospheric root in the central region was assumed (Fig. 1). It could be shown that a laterally heterogeneous viscosity model with a centrally thickened lithospheric root of 200-km thickness surrounded by an asthenosphere satisfies the spectrum similarly well as a laterally homogeneous viscosity model with a lithosphere of 100-km thickness, but without asthenoshere (Fig. 2). In contrast to this conventional model, the laterally heterogeneous model is also consistent with the results of seismic, geomagnetic and thermal studies.

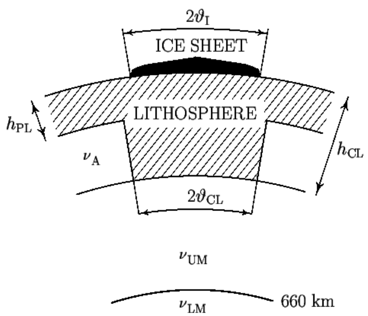


Fig. 1. Axisymmetric configuration of the Fennoscandian ice model with parabolic cross section and of the viscosity model with lithospheric root.

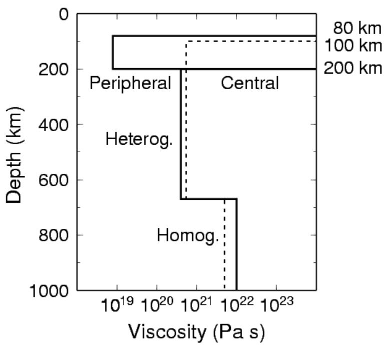


Fig. 2. Best fitting Fennoscandian viscosity profiles for the laterally homogeneous model (dashed line) and the laterally heterogeneous model (solid line).

3. Present sea-level change

Combined with a global model of the Pleistocene glaciation, the Fennoscandian viscosity model can be used to predict the glacial-isostatically induced contribution to the present relative sea-level change in Fennoscandia. For this purpose, linear trends were determined from selected tide-gauge records and compared with the calculated changes (Fig. 3). As expected, the sea-level fall observed in Fennoscandia almost exclusively results from the glacial-isostatic land uplift. By calculating the difference and the mean, the preliminary value of ca. 0.6 mm/a is obtained for the absolute sea-level rise in this region. This is smaller than the global average value of ca. 1.8 mm/a

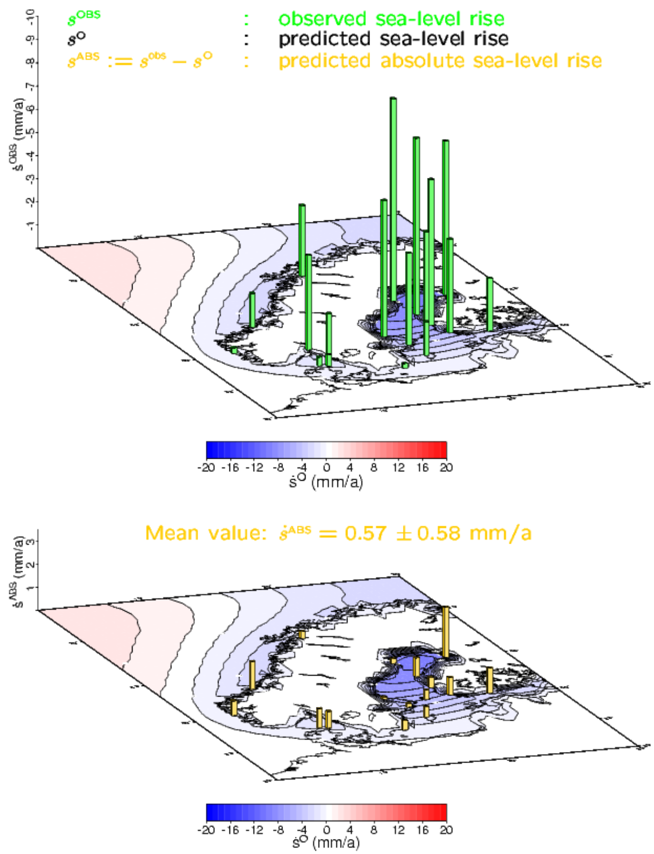


Fig. 3. (a) Observed present-day sea-level rise (green columns) and predicted glacial-isostatically induced contribution (contour lines). (b) Predicted absolute contribution (yellow columns) and predicted glacial-isostatically induced contribution (contour lines).

4. Geoid change

With 28 million gigatons, the Antarctic ice sheet has almost ten times as much mass as the Greenland ice sheet. Recent investigations have suggested that, annually, Antarctica loses ca. 30 gigatons of ice to the ocean (Fig. 4a). Apart from the geoid change caused by this melting - for West Antarctica, a geoid fall of up to 4 mm/a was computed (Fig. 4b) - the geoid signature is also influenced by the ongoing glacial-isostatic adjustment in response to the melting of the more massive Pleistocene ice load. Assuming a plausible deglaciation history (Fig. 4c) and a standard viscosity model, a geoid rise of up to 2 mm/a resulted for West Antarctica (Fig. 4d). A more accurate determination of the Antarctic ice-mass balance and of the superimposed glacial-isostatic signal is expected from the GRACE satellite mission, which records the geoid changes with sufficient spatial and temporal resolution for this purpose.

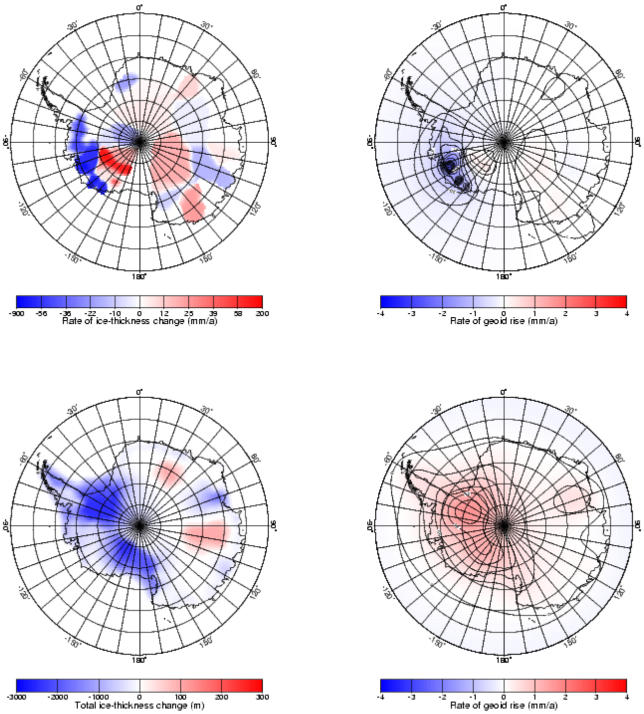


Fig. 4 (a) Secular ice-thickness change for Antarctica in mm/a and (b) associated present-day geoid rise in mm/a. (c) Total ice thickness change since the glacial maximum in m and (d) associated present-day geoid rise in mm/a.

ETRS89 in Baden-Württemberg

During the 88. and 96. Conference of the German working group of „Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV)“ in May 1991 and 1995 it was recommended to introduce the European terrestrial reference system 1989 (ETRS89) with the Universal Transversal Mercator Projection (UTM) as map projection on GRS80-ellipsoid uniformly into Germany and Europe. For this reason it is required to transform the existing two-dimensional Gauss-Krüger coordinates of German main triangular network (DHDN) into UTM coordinates of the ETRS89. The following aspects question have been studied in cooperation with the Landesvermessungsamt Baden-Württemberg: (1) transformation models and model analysis, (2) influence of heights and geoid undulations in Baden-Württemberg as well as impact of systematic and random height errors, (3) detection of homogeneous areas, (4) effects of net densification, (5) methods for residual distribution, (6) accuracy of the identical and transformed point coordinates.

Astro-Gravimetric Geoid Determination

A broad range of geodetic, geophysical, oceanographic and precise engineering applications exist, rendering the need for precise geoid determination methods more pressing than ever. The more accurate the geoid is known, the more problems can be satisfactorily analysed. A new theory is developed for high-resolution geoid computation based on vertical deflections as well as gravity values. Its algorithmic version can be described as following: Remove the long wave component from the observations. This effect can be modelled using a reference gravity potential field of very high degree/order. An example for such a reference field is SEGEN (Internet: http://www.uni-stuttgart.de/gi/research/paper/coefficients/coefficients.zip) an ellipsoidal harmonic expansion up to degree/order 360/360. Remove the effect of the centrifugal potential at the point of measurement (POM), in particular GPS positioned. Remove the short wave component (terrain effect) from the residual observations. The influence of local density disturbance in the near zone of the POM is modelled with a digital elevation model. The area’s size depends on the highest degree of the harmonic expansion. The remove steps aim at generating a harmonic gravitational field outside the International Reference Ellipsoid (IRE). The residual vertical deflections as well as the residual gravity disturbance are downward continued to the IRE by means of the inverse solution of the ellipsoidal horizontal / vertical boundary value problem based upon the modified ellipsoidal Abel-Poisson kernel. As a discretised integral equation of the first kind, downward continuation is Tikhonov-Phillips regularised by an optimal choice of the regularisation factor. Restore the effect of short / long wave component at the point on the IRE which corresponds to the POM. Convert the gravitational potential on the IRE to geoidal undulations by means of the ellipsoidal Bruns formula. Validate the results using GPS levelling data. As a case study, the Finnish geoid will be computed based on this algorithm.

List of Publications

ABOLGHASEM A M and GRAFAREND E: Finite element analysis of quasi-static earthquake displacement fields observed by GPS. Journal of Geodesy 77 (2003) 529-536

AWANGE J and GRAFAREND E: Closed Form Solution of the Overdetermined Nonlinear 7 Parameter Datum Transformation. Allgemeine Vermessungsnachrichten 110 (2003) 130-149

AWANGE J and GRAFAREND E: Explicit Solution of the Overdetermined Three-Dimensional Resection Problem. Journal of Geodesy 76 (2003) 605-616

AWANGE J and GRAFAREND E: Groebner-Basis Solution of the Three-Dimensional Resection Problem (P4P). Journal of Geodesy 77 (2003) 327-337

AWANGE J and GRAFAREND E: Multipolynomial Resultant Solution of the 3d Resection Problem (P4P). Bollettino di Geodesia e Scienze Affini 62 (2003) 79-102

AWANGE J and GRAFAREND E: Nonlinear Analysis of the Three-Dimensional Datum Transformation [Conformal Group $C_7(3)$]. Journal of Geodesy 77 (2003) 66-76

AWANGE J and GRAFAREND E: Polynomial Optimization of the 7-Parameter Datum Transformation Problem when Only Three Stations in Both Systems are Given. Zeitschrift für Vermessungswesen 128 (2003) 266-270

AWANGE J, FUKUDA Y, TAKEMOTO S, ATEYA I and GRAFAREND E: Ranging Algebraically With More Observations Than Unknowns. Earth Planets Space 55 (2003) 387-394

AWANGE J, GRAFAREND E and FUKUDA Y: Closed Form Solution of the Triple Three-Dimensional Intersection Problem. Zeitschrift für Vermessungswesen 128 (2003) 395-402

AWANGE J, GRAFAREND E, FUKUDA Y and TAKEMOTO S: Direct Polynomial Approach to Nonlinear Distance (Ranging) Problems. Earth Planets Space 55 (2003) 231-241

AWANGE J, GRAFAREND E, FUKUDA Y and TAKEMOTO S: Resultants approach to the triple three-dimensional intersection problem. Journal of the Geodetic Society of Japan 49 (2003) 243-256

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FLEMING K, MARTINEC Z and WOLF D.: A reinterpretation of the Fennoscandian relaxation-time spectrum for a viscoelastic lithosphere. In: Tziavos, I.N. (ed.), Gravity and Geoid 2002, Ziti Publishing, Thessaloniki, 432-438, 2003

FLEMING KM, MARTINEC Z, HAGEDOORN JM and WOLF D: Geoid change about Greenland resulting from past and present-day changes in the Greenland ice sheet. EOS, Trans. AGU, 84(46), Fall Meeting Suppl., Abstract, F503, 2003

GRAFAREND E: A Closed Form Representation of Somigliana-Pizzetti Gravity. In: Honoring the Academic Life of Petr Vanicek, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Technical Report # 218, pp. 71-79, Fredericton 2003

GRAFAREND E and MARTINEC Z: Comments on and Reply to „Solution of the Dirichlet and Stokes Exterior Boundary Problems for the Earth's Ellipsoid" by V.V.Brovar, Z.S.Kopeikina, M.V.Pavlova, Journal of Geodesy 74 (2001) 767-772. Journal of Geodesy 77 (2003) 357-360

GRAFAREND E and VOOSOGHI B: Intrinsic Deformation Analysis of the Earth's Surface Based on Displacement Fields Derived from Space Geodetic Measurements. Case Studies: Present-Day Deformation Patterns of Europe and of the Mediterranean Area (ITRF Data Sets). Journal of Geodesy 77 (2003) 303-326

GRAFAREND E, BAUR O, SHARIFI M and BÖLLING K: Spectral Harmonic Analysis of Gravity Gradients: Reference frames and orbital rotations. In: GEOTECHNOLOGIEN, Observation of the System Earth from Space, Status Seminar, Bavarian State Mapping Agency (BLVA), Munich, 12-13 June 2003, Programme & Abstracts; Potsdam: Koordinierungsbüro GEOTECHNOLOGIEN, 2003 (GEOTECHNOLOGIEN Science Report No. 3)

GRAFAREND E, MARINKOVIC P and REUBELT T: Spectral Harmonic Analysis from Semi-Continuous Ephemeris of CHAMP Geodetic Quality, BLACKJACK Class GPS Receivers. In: GEOTECHNOLOGIEN, Observation of the System Earth from Space, Status Seminar, Bavarian State Mapping Agency (BLVA), Munich, 12-13 June 2003, Programme & Abstracts; Potsdam: Koordinierungsbüro GEOTECHNOLOGIEN, 2003 (GEOTECHNOLOGIEN Science Report No. 3)

GRAFAREND E, NOVÁK P, AUSTEN G and SHARIFI M: The GRACE Processor for a Spherical Harmonic Analysis of Temporal Variations of Geopotential. In: GEOTECHNOLOGIEN; Observation of the System Earth from Space, Status Seminar, Bavarian State Mapping Agency (BLVA), Munich, 12-13 June 2003, Programme & Abstracts; Potsdam: Koordinierungsbüro GEOTECHNOLOGIEN, 2003 (GEOTECHNOLOGIEN Science Report No. 3)

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HAGEDOORN JM and WOLF D: Pleistocene and recent deglaciation in Svalbard: implications for tide-gauge, GPS and VLBI measurements. J. Geodyn. 35 (2003) 415-423

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LOU L and GRAFAREND E: GPS Integer Ambiguity Resolution by Various Decorrelation Methods. Zeitschrift für Vermessungswesen 128 (2003) 203-210

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NOVÁK P, BRUTON AM, BAYOUD FA, KERN M and SCHWARZ KP: On numerical and data requirements for topographical reduction of airborne gravity in geoid determination and resource exploration. Bollettino di Geodesia e Scienze Affini 62 (2003) 103-124

NOVÁK P, KERN M, SCHWARZ KP and HECK B: Evaluation of band-limited topographical effects in airborne gravimetry. Journal of Geodesy 76 (2003) 597-604

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NOVÁK P, ŠIMEK J, KOSTELECKÝ J: A detailed gravimetric quasi-geoid model VUGTK 2002 for Central Europe. In: Tziavos IN (Ed.): Gravity and Geoid 2002. Reviewed proceedings of the 3rd Meeting of the International Gravity and Geoid Commission, ISBN 960-431-852-7: 150-155

NOVÁK P: Geoid determination using one-step integration. Journal of Geodesy 77 (2003) 193-206

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REUBELT T, AUSTEN G and GRAFAREND E: Harmonic Analysis of the Earth's Gravitational Field by Means of Semi-Continuous Ephemerides of a Low Earth Orbiting GPS-Tracked Satellite. Case Study: CHAMP. Journal of Geodesy 77 (2003) 257-278

REUBELT T, AUSTEN G and GRAFAREND E: Space Gravity Spectroscopy - Determination of the Earth's Gravitational Field by Means of Newton Interpolated LEO Ephemeris. Case Studies on Dynamic (CHAMP Rapid Science Orbit) and Kinematic Orbits. Advances in Geosciences 1 (2003) 127-135

TENZER R, VANÍČEK P, NOVÁK P: Far-zone contributions to topographical effects in the Stokes-Helmert method of the geoid determination. Studia Geophysica et Geodaetica 47 (2003) 467-480

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WOLF D: Continuum mechanics in geophysics and geodesy: fundamental principles. Technical Report of the Department of Geodesy and Geoinformatics, University of Stuttgart, No. 2003.2, 94 pp., 2003

Doctoral Theses

None

Diploma Theses

GÖTZELMANN M: Short-Arc Bahnanpassung bei niedrig fliegenden Satelliten (Short-Arc Orbit Adjustment for Low Orbiting Satellites)

JÄGER A: Ausgleichung von Cross-Over Differenzen mit erweitertem Bahnmodell (Adjustment of Cross-Over-Differences using an Extended Orbit Model)

Study Works

GÖTZELMANN M: Simulation von Satellitenbahnen unter Berücksichtigung von direkten Gezeiteneffekten und Umsetzung in ein C-Programm (Simulation of Satellite Orbits taking into account direct tidal effects)

PHILIPP M: Die geodätische Anfangs- und Randwertaufgabe in Fermi- und Soldnerkoordinaten (The direct and the inverse Problem of Geometric Geodesy in Fermi- and Soldner coordinates)

THAMM Ch: Iterative Lösung von „Least-Squares“ Problemen großer Dimension mittels des LSQR-Algorithmus. Fallstudie: Schwerefeldmodellierung durch Analyse von CHAMP-Bahndaten (Iterative Solution of Least-Squares Problems of Large Dimension using the LSQR-Algorithm. Case study: Gravity Field Modeling through Analysis of CHAMP-Orbit Data)

WITTWER T: Interpolation und Verdichtung von Satellitengradiometriedaten (Interpolation and Densification of Satellite Gradiometry Data)

Guest Lectures and Lectures on special occasions

AMALVICT M, Doc. Dr. (Université Louis Pasteur, Strasbourg, Frankreich): Absolute Gravity Measurements and Geodetic Positioning Techniques in Antarctica: a review. Implications for the polar cap (6.2.03)

ARDALAN AA, Prof. Dr. (Department of Surveying and Geomatics Engineering, University of Tehran, Iran): A new Ellipsoidal Gravimetric-Satellite Altimetry Boundary Value Problem; Case study: High Resolution Geoid of Iran (3.4.03)

DIETRICH R, Prof. Dr. (Institut für Planetare Geodäsie, Universität Dresden): Gezeitenforschung in der Antarktis (7.11.03)

KUSCHE J, Prof. Dr. (Department of Physical, Geometrical and Space Geodesy, Institute for Earth Oriented Space Research (DEOS), Delft, Niederlande): The gravity field from GOCE: numerical and statistical aspects (16.1.03)

SEITZ F, Dr. (Deutsches Geodätisches Forschungsinstitut München): Studies on Chandler Wobble Excitation using a Non-Linear Gyroscopic Earth Model (18.2.03)

SÜNKEL H, Prof. Dr. (Institut für Geodäsie, Abteilung für Theoretische Geodäsie, TU Graz): Graz hebt ab - das Institut für Weltraumforschung der österreichischen Akademie der Wissenschaften - geodätische Bezüge (10.1.03)

WÄLDER O, Dr. (Institut für Kartographie, TU Dresden): Ein Beitrag zur statistischen Deformationsanalyse von bergbauinduzierten Landschaften (30.1.03)

WIESER A, Dr. (Institut für Ingenieurgeodäsie und Messsysteme, TU Graz, Österreich): Wenn Daten die Modelle nicht kennen: Ansätze zur robusten Schätzung für die GPS-Auswertung (15.5.03)

ZEILFELDER F, Priv.Doz. Dr. (Fachbereich Mathematik, Lehrstuhl für Mathematik IV, Universität Mannheim): Algorithmen zur Approximation mit Splines auf Triangulierungen (19.12.03)

Lectures at other universities and at conferences

AUSTEN G, REUBELT T and GRAFAREND E: Space Gravity Spectroscopy of GRACE data of type first time-derivative of range-rate. EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich (Posterpräsentation)

BAUR O, GRAFAREND E: GOCE-GRAND AP4 Statusbericht (Bestimmung einer GPS-Schwerefeldlösung aus kinematischen GOCE-Bahndaten in Kollokation mit GOCE-Gradiometerdaten), GOCE-GRAND Projekttreffen, München, 11.06.2003

BAUR O, GRAFAREND E: GOCE-GRAND AP4 Statusbericht (Bestimmung einer GPS-Schwerefeldlösung aus kinematischen GOCE-Bahndaten in Kollokation mit GOCE-Gradiometerdaten), Status Seminar GEOTECHNOLOGIEN II, München, 12.-13.06.2003

BAUR O, GRAFAREND E: GOCE-GRAND AP4 Statusbericht (Bestimmung einer GPS-Schwerefeldlösung aus kinematischen GOCE-Bahndaten in Kollokation mit GOCE-Gradiometerdaten), GOCE/CryoSat-Workshop, Friedrichshafen, 4.-5.11.2003

BAUR O, GRAFAREND E: Spectral Harmonic Analysis of Gravity Gradients: Reference frames and orbital rotations. Status Seminar des Geotechnologien-Programmes „Beobachtung des Systems Erde vom Weltraum“, 12.-13. Juni 2003, Bayerisches Landesvermessungsamt München

CAI J and GRAFAREND E: The statistical inference of eigenspace components of a three-dimensional, symmetric rank two random deformation tensor. EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich

CAI J and GRAFAREND E: The statistical inference of eigenspace components of a symmetric random deformation tensor. 2003 IUGG General Assembly, IAG Symposia G04: General Theory and Methodology. Meeting of IAG Section IV, Sapporo, Japan, June 30 - July 11, 2003

FINN G: Data Fusion for High-Resolution Geoid Determination. IUGG General Assembly 2003, Sapporo, Japan, June 30 - July 11, 2003

FINN G: High-Resolution Astro-Geodetic Geoid Determination, Case Study: Finland. EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich

FINN G: High-Resolution Determination of the Finnish Geoid: Project, Data and Methodology. Geodetic Seminar, Finnisches Geodätisches Institut, Masala (Finnland), 2. Oktober 2003

FLEMING K, MARTINEC Z, HAGEDOORN JM and WOLF D: Contemporary changes in the geoid about Greenland: predictions relevant to gravity space missions. (Poster). Second CHAMP Science Meeting, GFZ Potsdam, 3 September 2003.

FLEMING K, MARTINEC Z, HAGEDOORN JM and WOLF D: Contemporary changes in the geoid about Greenland: predictions relevant to gravity space missions. (Poster). 8th European Workshop on Numerical Modeling of Mantle Convection and Lithospheric Dynamics, Hrubá Skála, Czech Republic, 17 September 2003.

FLEMING K, MARTINEC Z, HAGEDOORN JM and WOLF D: Geoid change about Greenland resulting from past and present-day changes in the Greenland ice sheet. (Poster). 2003 AGU Fall Meeting, San Francisco, California, 10 December 2003.

GRAFAREND E: Harmonic analysis of the Earth’s gravitational field from semi-continuous ephemerides of Low Earth Orbiting („LEO“), geodetic quality, Blackjack-class GPS tracked satellites. Case Study: CHAMP. Department of Geodetic Science, Aristoteles University Thessaloniki, Greece, 27 March 2003

GRAFAREND E: The GRACE Processor for a Spherical Harmonic Analysis of Temporal Variations of Geopotential. Status Seminar des Geotechnologien-Programmes „Beobachtung des Systems Erde vom Weltraum“, 12.-13. Juni 2003, Bayerisches Landesvermessungsamt München

GRAFAREND E and NOVÁK P: The ellipsoidal topographical potential. 28th EGS General Assembly, Nice, April 2003.

GRAFAREND E, AUSTEN A, NOVÁK P and SHARIFI MA: Space gravity spectroscopy for observables of type GRACE. Working Meeting of the GRACE project, Oberpfaffen-hofen, February 2003

GRAFAREND E, BAUR O: GOCE observables - Variance-covariance functions of gravity gradients. EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich (Posterpräsentation)

GRAFAREND E, NOVÁK P, AUSTEN A and SHARIFI MA: The GRACE processor for a spherical harmonic analysis of temporal variations of geopotential. Geotechnology Meeting „Observing the Earth’s System from Space“, Munich, June 2003

HAGEDOORN JM, MARTINEC Z and WOLF D: A new time-domain method implementing the sea-level equation in glacial-isostatic adjustment (Poster). EGS-AGU-EUG Joint Assembly, Nice, 11 April 2003.

HAGEDOORN JM, MARTINEC Z and WOLF D: A new time-domain method of implementing the sea level equation in glacial-isostatic adjustment (Poster). 63. Jahrestagung der DGG, Jena, 25 February 2003.

HAGEDOORN JM, MARTINEC Z and WOLF D: A time-domain method of implementing the sea-level equation for a 3-D viscoelastic earth model. Workshop of IAG SSG 4.189, Lanzarote, Spain, 20 February 2003.

HAGEDOORN JM, MARTINEC Z and WOLF D: A time-domain method of implementing the sea-level equation in GIA for a rotating earth. (Poster). 8th European Workshop on Numerical Modeling of Mantle Convection and Lithospheric Dynamics, Hrubá Skála, Czech Republic, 17 September 2003.

HAGEDOORN JM, MARTINEC Z and WOLF D: Solution of the sea-level equation: theory, implementation and examples. 3rd SEAL Progress Meeting, GFZ Potsdam, 4 March 2003.

KELLER W: Wavelets in Geodesy. Seminar Geodätisches Institut , Universität Wroclaw, Oktober 2003

KLEMANN V and WOLF D: On the construction of shoreline diagrams and the inference of relaxation-time spectra for the earth (Poster). EGS-AGU-EUG Joint Assembly, Nice, 11 April 2003.

KLEMANN V and WOLF D: Optimizing the viscosity profile for NW Europe using shoreline diagrams. 3rd SEAL Progress Meeting, GFZ Potsdam, 4 March 2003.

KLOTZ J, REIGBER Ch, SASGEN I and WOLF D: GPS derived motion of the earthquake cycle and GRACE gravity changes: case Andes. GRACE Science Team Meeting, Austin, Texas, 9 October 2003.

KÖSTERS F, KÄSE R, SCHULZ M., SCHÄFER-NETH C, FLEMING K and WOLF D: Modeling transport limitations of Denmark Strait overflow between the last glacial maximum and early Holocene (Poster). EGS-AGU-EUG Joint Assembly, Nice, 11 April 2003.

MARTINEC Z and WOLF D: Inverting the Fennoscandian relaxation-time spectrum in terms of an axisymmetric viscosity distribution. Workshop of IAG SSG 4.189, Lanzarote, Spain, 19 February 2003.

MARTINEC Z and WOLF D: Inverting the Fennoscandian relaxation-time spectrum in terms of a 2-D viscosity distribution with cratonic lithosphere. (Poster). 63. Jahrestagung der DGG, Jena, 25 February 2003.

MARTINEC Z and WOLF D: Inverting the Fennoscandian relaxation-time spectrum in terms of a 2D viscosity structure with a cratonic lithosphere. EGS-AGU-EUG Joint Assembly, Nice, 11 April 2003.

MARTINEC Z and WOLF D: Viscoelastic relaxation of a 3-D earth model: theory, implementation and examples. 3rd SEAL Progress Meeting, GFZ Potsdam, 4 March 2003.

NOVÁK P: Role of mathematics in geodesy. University of Western Bohemia, Plzen, November 2003

NOVÁK P, ŠIMEK J and KOSTELECKÝ J: Characteristics of the Earth's gravity field for Central Europe in context of some geophysical phenomena. 28th EGS General Assembly, Nice, April 2003.

REUBELT T, AUSTEN G and GRAFAREND E: Space Gravity Spectroscopy by means of interpolated and differentiated CHAMP-orbits - Case Study: kinematic and dynamic CHAMP orbits. EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich (Posterpräsentation)

REUBELT T, AUSTEN G and GRAFAREND E: Space Gravity Spectroscopy by means of interpolated and differentiated CHAMP-orbits - Case Study: kinematic and dynamic CHAMP orbits. Status Seminar des Geotechnologien-Programmes „Beobachtung des Systems Erde vom Weltraum", 12.-13. Juni 2003, Bayerisches Landesvermessungsamt München, Deutschland (Posterpräsentation)

REUBELT T, MARINKOVIC P and GRAFAREND E: The CHAMP - Processor: Spectral Harmonic Analysis from semi-continuous Ephemerides of CHAMP Geodetic Quality, Blackjack Class Receivers. Status Seminar des Geotechnologien-Programmes „Beobachtung des Systems Erde vom Weltraum", 12.-13. Juni 2003, Bayerisches Landesvermessungsamt München, Deutschland (Vortrag)

SASGEN I, HAGEDOORN JM, KLEMANN V, MARTINEC Z and WOLF D: Temporal variations of the geoid due to present and past glacial changes in polar regions. Second CHAMP Science Meeting, GFZ Potsdam, 3 September 2003.

SASGEN I, HAGEDOORN JM, KLEMANN V, MARTINEC Z and WOLF D: Temporal variations of the geoid due to present and past glacial changes in Antarctica. (Poster). 9th International Symposium on Antarctic Earth Sciences, University of Potsdam, 9 September 2003.

SASGEN I, HAGEDOORN JM, KLEMANN V, MARTINEC Z and WOLF D: Temporal variations of the geoid due to present and past glacial changes in Antarctica. (Poster). 8. Geodätische Woche/Intergeo, Hamburg, 17 September 2003.

WOLF D: Deformation and gravity fields: indicators of processes in the solid earth-cryosphere-hydrosphere system. Workshop of IAG SSG 4.189, Lanzarote, Spain, 19 February 2003.

WOLF D: Deformation and gravity fields: indicators of processes in the solid earth-cryosphere-hydrosphere system. EGS-AGU-EUG Joint Assembly, Nice, 7 April 2003.

WOLF D: Glazial-isostatische Prozesse und Meeresspiegeländerungen in Nordeuropa. Institut für Ostseeforschung, Warnemünde, 27. Mai 2003.

WOLF D: Gravity signatures of Pleistocene and modern glacial changes. European GRACE Science Team Meeting, GFZ Potsdam, 1 September 2003.

WOLF D, REIGBER Ch and GALAS R: Canadian PGR, GPS and GRACE signatures. GRACE Science Team Meeting, Austin, Texas, 9 October 2003.

WOLF D, WÜNSCH J, KLEMANN V: A reanalysis and reinterpretation of the tide-gauge record for Churchill, Manitoba. 8. Geodätische Woche/Intergeo, Hamburg, 17 September 2003.

Research Stays

AUSTEN G: Finnish Geodetic Institute, Masala / Helsinki, Finnland, 7.-19.9.2003

FINN G: Finnish Geodetic Institute, Masala / Helsinki, Finnland, 19.9.-4.10.2003

KELLER W: Guest Professorship, The University of Queensland, Brisbane Australia, July-October 2003

KELLER W: Geodetic Institut, Universität Wroclaw, October 2003

REUBELT G: Finnish Geodetic Institute, Masala / Helsinki, Finnland, 7.-19.9.2003

Lecture Notes

GRAFAREND E:
Adjustment and Statistics III, Teil 1 (Hypothesis Testing), ca. 175 pages
Mathematical Geodesy I and II, ca. 260 pages
Physical Geodesy I und II, ca. 250 pages
Map Projections, ca. 280 pages (plus 30 pages attachments)
Differential Geometry for Geodesists, ca. 220 pages
Introduction to Geodesy I und II, ca. 210 pages

HAUG G: Real-Estate/ Property Valuation I, 29 pages
Real-Estate/ Property Valuation II, 11 pages

KELLER W:
Satellite Geodesy, ca. 90 pages
Geodetic Coordinate Systems, ca. 90 pages
Wavelet Applications in Geodesy and Geodynamics (http://www.uni-stuttgart.de/iag)

RICHTER B:
Geodetic Astronomy, ca. 120 pages

WOLF D:
Continuum Mechanics in Geophysics and Geodesy: Fundamental Principles, ca. 100 pages

Participation in Conferences, Meetings and Workshops

AUSTEN G:

Status Meeting „Entwicklung des wissenschaftlichen Prozessierungssystems für GRACE“, 03.02.2003, GFZ Oberpfaffenhofen
EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich
Status Seminar des Geotechnologien-Programmes „Beobachtung des Systems Erde vom Weltraum“, 12.-13. Juni 2003, Bayerisches Landesvermessungsamt München

BAUR O:

GRACE Projekttreffen, München, DLR, 3.02.2003
EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich
GOCE-GRAND Projekttreffen, München, TUM, 11.06.2003
Status Seminar GEOTECHNOLOGIEN II, München, BLVA, 12.-13.06.2003
GOCE-GRAND Projekttreffen, Friedrichshafen, Astrium, 4.11.2003
GOCE/CryoSat-Workshop, Friedrichshafen, Astrium, 4.-5.11.2003

CAI J:

EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich

KELLER W:

SatNav 2003 Conference, Melbourne 22-25 July 2003

REUBELT T:

EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich
Status Seminar des Geotechnologien-Programmes „Beobachtung des Systems Erde vom Weltraum“, 12.-13. Juni 2003, Bayerisches Landesvermessungsamt München, Deutschland

WOLF D:

Workshop of IAG SSG 4.189 , Lanzarote, Spain, 18.-21. Februar 2003
63. Jahrestagung der DGG, Jena, 23.-28. Februar 2003
3rd SEAL Progress Meeting, GFZ Potsdam, 4. März 2003
EGS-AGU-EUG Joint Assembly, 7.-11. April 2003, Nizza, Frankreich
Second CHAMP Science Meeting, GFZ Potsdam, 1.-4. September 2003
9th International Symposium on Antarctic Earth Sciences, University of Potsdam, 8.-12. September 2003
8. Geodätische Woche/Intergeo, Hamburg, 16.-19. September 2003
GRACE Science Team Meeting, Austin, Texas, 8.-10. Oktober 2003

Activities in National and International Organizations

ENGELS J:

Member Special Study Group 4.189 (IAG): „Dynamic theories of deformation and gravity fields“

FINN G:

Managing Board „Studentenwerk Stuttgart e. V."
Vice member „Senatsausschuß Höchstleistungsrechenzentrum Stuttgart"
Chairman „FachschaftsvertreterInnenversammlung (FaVeVe)"
Member International Union for Geophysics and Geodesy (IUGG)

GRAFAREND E W:

Member Examining Board „Studiengang Geodäsie und Geoinformatik"
Member of the faculties of Stuttgart University
„Luft- und Raumfahrt und Geodäsie",
„Mathematik und Physik",
„Bau- und Umweltingenieurwissenschaften"
External Examiner, University South East London, UK
External Examiner, University of Nairobi, Nairobi, Kenya
Member German Geodetic Commission at the Bavarian Academy of Science
Member German Physical Society
Member German Geophysical Society
Member Gauß-Society e.V.
Member Scientific Committee German Geodetic Research Institute
Member „Deutscher Verein für Vermessungswesen"
Member „Deutscher Markscheideverein"
Member „Auswahlausschuss Alexander-von-Humboldt-Stiftung"
Chairman Special Study Group 4.195 (IAG): „Fractal Geometry in Geodesy"
Member of Section II (IAG), Special Commission SC7: „Satellite Gravity Field Missions"
Member Special Study Group 3.177 (IAG): „Synthetic Modelling of the Earth's Gravity Field"
Member of Section IV (IAG), Special Commission SC1: „Mathematical and Physical Foundations of Geodesy"
Member of Section V (IAG), Special Commission SC3: „Fundamental Parameters"
Member Royal Astronomical Society
Member American Geophysical Union
Member Bernoulli Society
Member Flat Earth Society

KELLER W:

Member „Promotionsausschuss"
Member „Erweiterter Fakultätsrat der Fakultät für Bauingenieur- und Vermessungswesen"
Member „Studienkommission Geodäsie und Geoinformatik "

HINTZSCHE M

Member Research Group „Bodenordnung und Bodenwirtschaft der Deutschen Geodätischen Kommission (DGK)"

Member „Gesellschaft für Immobilienwirtschaftliche Forschung (gif)“
President Research Group „Bewertungsvergleiche und -standards“
Vice President „Gutachterausschuß für die Ermittlung von Grundstückswerten in der Landeshauptstadt Stuttgart“
Member „Verband Deutscher Städtestatistiker (VDSt)“
Member „Ingenieurkammer Baden-Württemberg“
Mitglied Deutscher Verein für Vermessungswesen (DVW)

KELLER W:
Member German Mathematical Society
President Special Study Group 4.187 (IAG) „Wavelets in Geodesy and Geodynamic“
Member Society of Industrial and Applied Mathematics

NOVÁK P:
Associated member of the IAG. Special Study Group 3.167 Regional Land and Marine Geoid Modelling
Member IAG Special Study Group Forward gravity field modelling and global databases
Associate Professor, Czech Technical University in Prague

WOLF D:
Member Special Study Group 4.189 (IAG) „Dynamic Theories of Deformation and Gravity Fields“
Member Canadian Geophysical Union
Member American Geophysical Union
Member European Geophysical Society
Fellow International Association of Geodesy
Member German Geophysical Society

Education - Lecture/Practice/Training/Seminar

Adjustment and Statistics III (Krumm)	2/1/0/0
Applied Graph Theory (Grafarend)	2/1/0/0
Differential Geometry for Geodesists (Keller)	2/1/0/0
Geodetic Coordinate Systems (Keller)	1/1/0/0
Geodetic Reference Systems (ICRS-ITRS) for Satellite Geodesy and Aerospace (Richter)	2/1/0/0
Geodetic Seminar I,II (Fritsch/Grafarend/Keller/Kleusberg/Möhlenbrink/Wolf)	0/0/0/4
Geodynamics I: Fundamental Principles (Wolf)	2/0/0/0
Gravimetry and Earth Tides (Grafarend)	2/1/0/0
Integrated Field Work Geodesy, Navigation, Photogrammetry and Surveying (Fritsch/Grafarend/Keller/Kleusberg/Möhlenbrink/Wolf)	10 days
Introduction to Geodesy II (Austen)	1/0/0/0

Kinematic and Dynamic Geodetic Reference Systems II (Richter)	1/1/0/0
Lab Geodesy/Geodetic Astronomy (Grafarend/Richter)	0/0/1/0
Lab Satellite Geodesy I,II (Keller)	0/0/2/0
Map Projections (Krumm)	1/1/0/0
Mathematical Geodesy I,II (Krumm)	2/2/0/0
Numerical Methods in Geodesy (Keller)	1/1/0/0
Official Surveying and Real Estate Regulation (Schönherr)	2/0/0/0
Physical Geodesy I,II (Engels)	3/2/0/0
Physical Geodesy III,IV (Keller)	4/2/0/0
Potential Theory and Special Functions (Keller)	2/1/0/0
Real-Estate Cadastre II (Schönherr)	2/0/0/0
Real-Estate/ Property Valuation I,II (Haug)	2/1/0/0
Satellite Geodesy I,II (Keller)	2/2/1/0
Stochastic Processes for Geodesists (Keller)	2/1/0/0

Institute of Navigation

Breitscheidstrasse 2, D-70174 Stuttgart,
Tel.: +49 711 121 3400, Fax: +49 711 121 2755
e-mail: ins@nav.uni-stuttgart.de
homepage: http://www.nav.uni-stuttgart.de

Head of Institute

Prof. Dr.-Ing. A. Kleusberg

Deputy:	Dr.-Ing. Karl-Heinz Thiel
Secretary:	Helga Mehrbrodt
Emeritus:	Prof. em. Dr.-Ing. Ph. Hartl

Staff

Dipl.-Ing. Jürgen M i n g, Akad. Rat	Administration
Dipl.-Ing. Doris B e c k e r	Navigation Systems
M.Sc. Shan C h e n	Navigation Systems
Dipl.-Geogr. Thomas G a u g e r	Thematic Mapping
Ing. grad. Hans-Georg K l a e d t k e	Remote Sensing
Dipl.-Ing. Roland P f i s t e r e r	Laser Systems
Dipl.-Phys. Manfred R e i c h	Interferometry
Dipl.-Ing. Oliver S c h i e l e	Navigation Systems
Dipl.-Ing. Wolfgang S c h ö l l e r	Education
Dipl.-Ing. Alexandra S e i f e r t	Navigation Systems
Dr.-Ing. Aloysius W e h r	Laser Systems
Dipl.-Ing. (FH) Martin T h o m a s	Laser Systems
MSC(IP) José Marcelo Z á r a t e Encalada	Remote Sensing

EDP and Networking

Regine S c h l o t h a n

Laboratory and Technical Shop (ZLW)

Dr.-Ing. Aloysius W e h r (Head of ZLW)
Dipl.-Ing. (FH) Erhard C y r a n k a
Technician Edmund K ö n i g
Technician Peter S e l i g - E d e r
Mech. Master Michael P f e i f f e r

Guest Research Staff

M.Sc. Godfrey O g o n d a   Navigation Systems

External teaching staff

Dr.-Ing. Gerhard S m i a t e k - Fraunhofer Institute for Atmosheric Environmental Research
Dr.-Ing. Volker L i e b i g - Programme Directorate DLR-GE
Dr.-Ing. B r a u n - RST Raumfahrt Systemtechnik AG, St.Gallen

Research Projects

Signal Multipath and Electromagnetic Interference

In 1998, the USA launched a GPS modernization program, whose aim is to improve current GPS service performance for both military and civilian users. Modernization involves design and implementation of new civil and military signals. Figure 1 illustrates this modernization plan.

Just at the same period, in 1999 the European Commission set up a project named „GALILEO“. The task of GALILEO is to establish Europe-controlled global position system, which will though be independent of (USA) GPS, it is designed to be interoperable with GPS and provide more services than current GPS does. Figure 2 shows the proposed Galileo Signals.

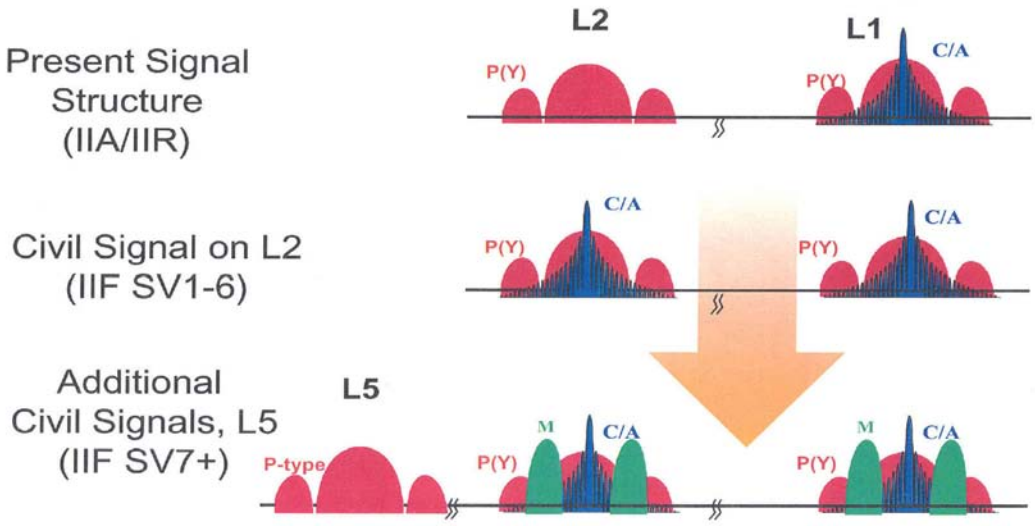


Figure 1 GPS Modernization

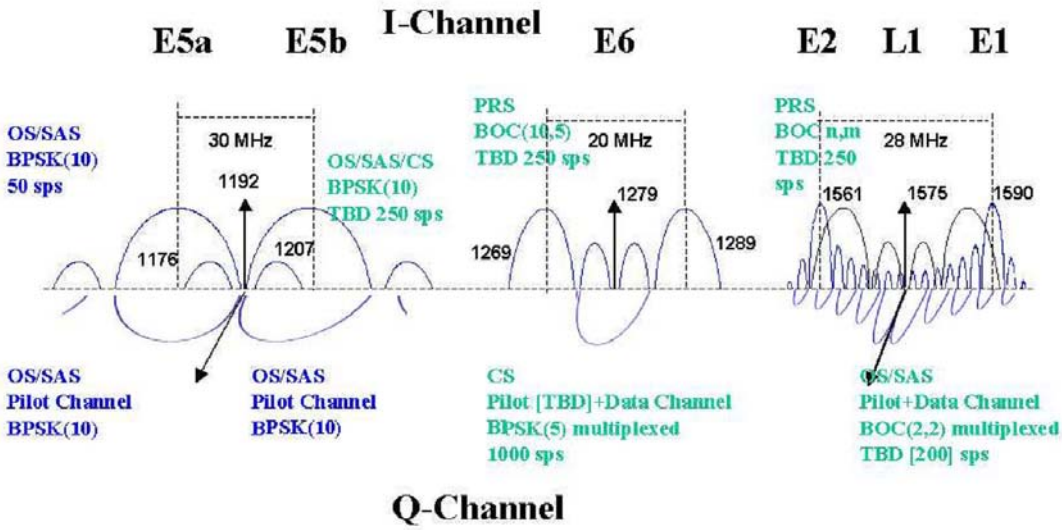


Figure 2 Proposed Galileo Signals

It is well known to us when a signal propagates from a satellite to a receiver antenna, it unavoidably suffers physical distortion such as free space loss, refraction and absorption from the atmosphere, reflection and shadowing from surrounding objects like trees and buildings, electromagnetic interference (also called jamming) and environmental noise as well. As a result, the accuracy of positioning is in some degree affected. Multipath is one of critical error sources, because it remains its corruption to satellite signals even by applying differential GPS technique. Besides multipath, electromagnetic interference is also of our interest.

The research work was mainly done through the GPS receiver toolbox (see Figure 3). Figure 4 is an example of simulation results, showing the effects of CW interference on signal acquisition.

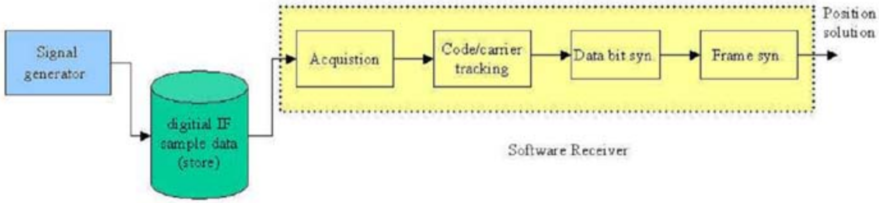


Figure 3 (GPS) receiver toolbox

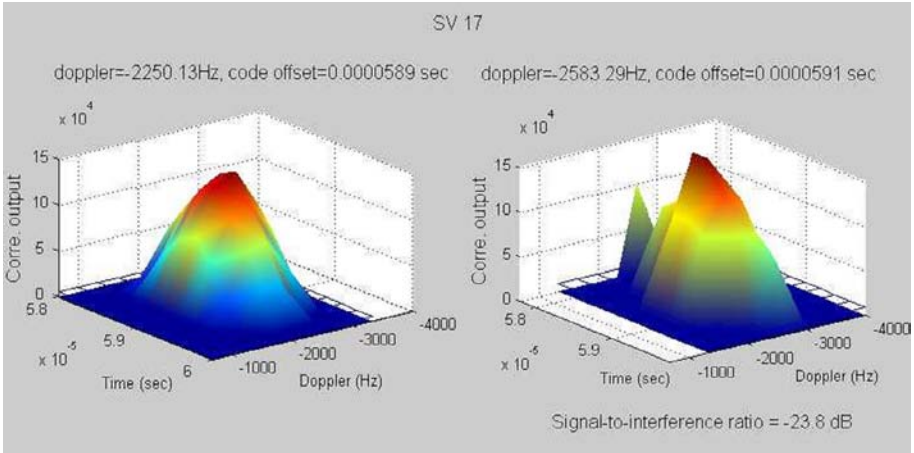


Figure 4 Effects of CW interference on signal acquisition with SIR = -17dB
(a) without interference (left) (b) with interference (right)

This research work was done in a DLR-funded project named UNITAS II and will go on in the following year (2004) with the focus on the implementation of tracking algorithms for Galileo signals.

Integrated positioning and orientation for airborne Laser scanning

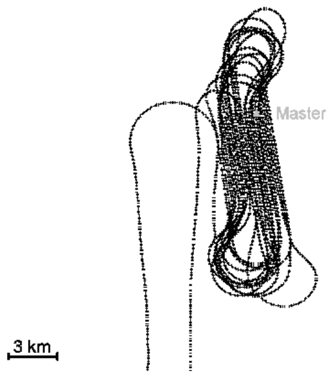
For years the integration of GPS and INS has ranked among the standard techniques in navigation. Kalman filters are predominantly used for the purpose of this integration, since they allow the estimation of positions and sensor errors in real time. In these systems the GPS-receiver serves as supporting sensor for the primary INS observations.

Today the results of such measuring systems are not only applied in navigation, but are also used for the very precise position and orientation determination of airborne geodetic data recording equipment (geo-referencing of remote sensing measurements). This application has also been utilised at the Institute of Navigation, which has conducted flights with an in-house-developed Laser scanner for several years. Unlike in navigation applications, here the accuracy of the orientation angle determination plays a very important role. Those angles are needed to ascertain the Laser view angle pattern to be able to correct measured distances.

Software packages of the company Applanix (POSPac4.02/POSAV1.4) are used for the calculation of the position and orientation of this scanner. With these programs the trajectory can be produced in real time and in post processing mode. In both cases GPS and IMU data are integrated through a loosely coupled Kalman filter. The difference between the two solutions consists in the use of GPS carrier phase data instead of pseudo-range observations and following up the forward Kalman filter run by a backward smoother in the post processing mode.

Since 2002 the Institute of Navigation has developed a new data integration strategy based on observations concerning the typical flight characteristics of laser scanner flights or photogrammetric flights in general. As shown in the adjacent figure they are characterized by:

- straight line flights above the survey area
- lines that are typically not longer than 100 km
- mission duration that typically extends no longer than a few hours
- restricted roll angles to less than 20° - to avoid shading effects of the GPS satellite signals
- GPS base stations that lie within a 30km range to the survey plane



Those rather good flight conditions with low dynamics ensure an uninterrupted GPS receipt and a post mission GPS-only accuracy of better than 10cm. Therefore the positions of the flight trajectory are determined almost exclusively by this system and this way the GPS observations play no longer just the part of a supporting sensor. The importance of the IMU measurements is reduced instead; they serve primarily for the interpolation of the positions - both in data gaps and between two GPS epochs - and the very precise determination of the sensor orientation parameters.

Furthermore it is not important for these applications to get the results in real time; the precise trajectory is produced in the post processing mode instead. The new data integration strategy is a post processing tool which takes the complete GPS and IMU data sets into account. This new algorithm is supposed to replace the Kalman filter by a least squares estimation in which the observations are represented by the GPS position solutions and the unknowns are the initial values for positions, velocity and orientation angles, and the error parameters of the INS.

Scanning Laser Altimeter (ScaLARS)

Together with the surveying company ILV (Ingenieurbüro für Luftbildauswertung und Vermessung) located in Groitzsch/Wischstauden a laser scanning survey was carried out for a client. Very precise data with low noise were gathered. The marks on the runway in Altenburg were surveyed by DGPS. The laser scanner was flown several times over the runway, figure 1. The data of the laser scanner survey and of the survey on ground are used to develop a more automatically calibration process, which allows the derivation of the laser scanner´s calibration parameters out of data gathered during an airborne survey. These are among other things the inner and outer orientation of the laser scanner, the FOV of the scan and the scale. Up to now, these values have been costly determined or estimated by measurements on ground. The marks on the runway are filtered out of the data of the laser survey by using the intensity information. The calibration parameters are derived from the 3D information. This new process offers the potentialities to determine all relevant parameters very precisely directly from a laser scanning survey of a known area. Due to the very large number of measurements a statistical analysis is possible and a quality control of the calibration can be realized.

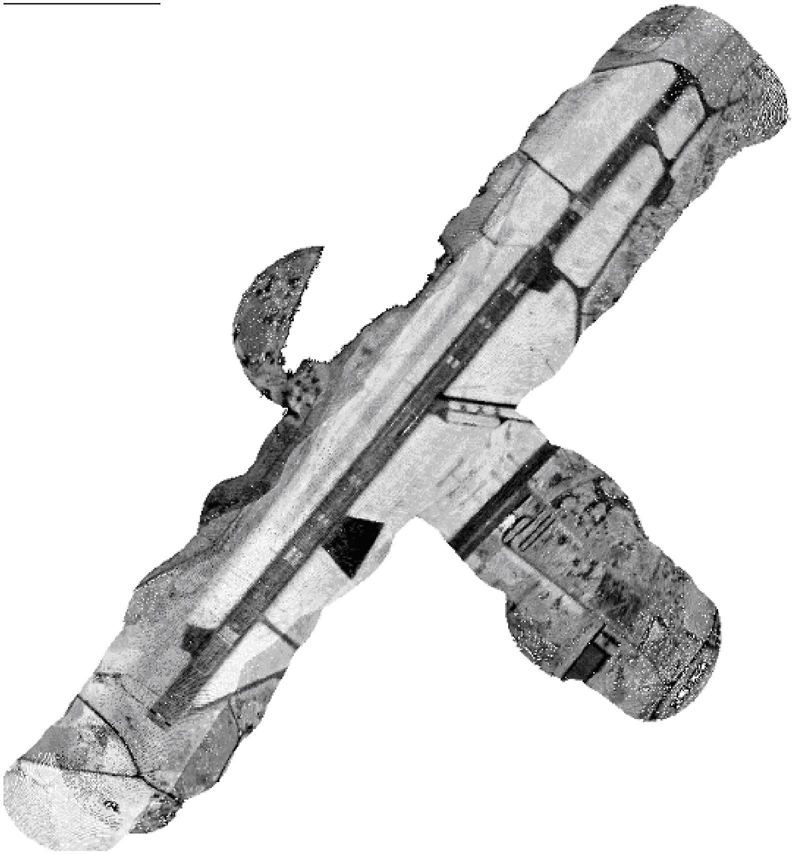


Figure 1: Runway of the airport Altenburg

Near Range Applications

Verification experiments were carried out using together a panoramic camera (PANCAM M3), a close range laser scanner (3D-LS), and a Position- and Orientation System (POS). This integrated system is called PLP-CAM (s. figure 2). POS comprises an inertial measurement unit and GPS. The experiments were performed together with the Institute for Photogrammetry (IFP). IFP made available POS. The other items were provided by INS. Before executing the experiment the INS designed and realized the synchronization between the different systems (s. figure 3). First laboratory experiments were carried out (s. figure 4). Then a survey were performed at castle Solitude close to the town of Stuttgart. Figure 5 shows typical results. The outcome of this experiment makes clear that the integrated system has the potential of gathering data for town models and of surveying extended objects.

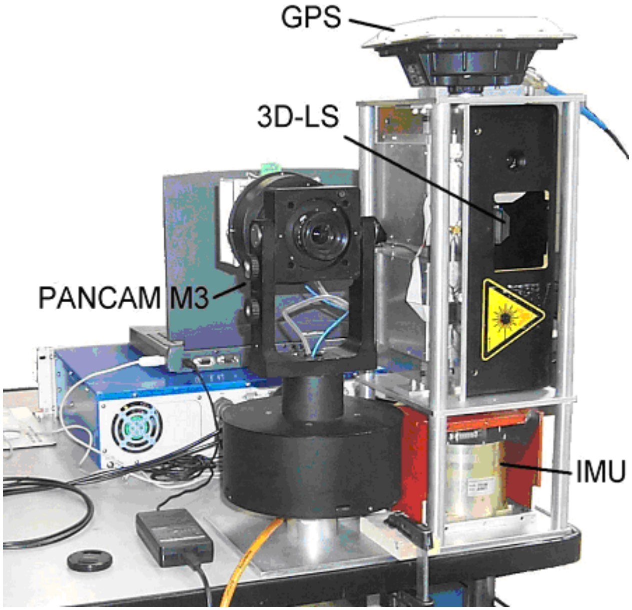


Figure 2: PLP-CAM

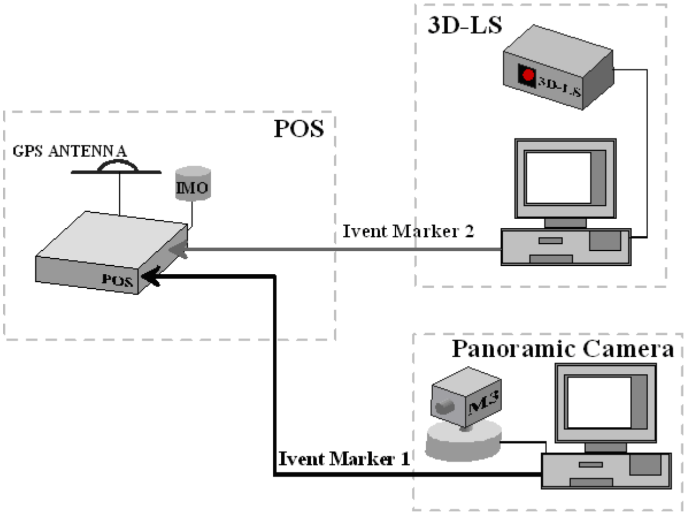


Figure 3: Synchronisation

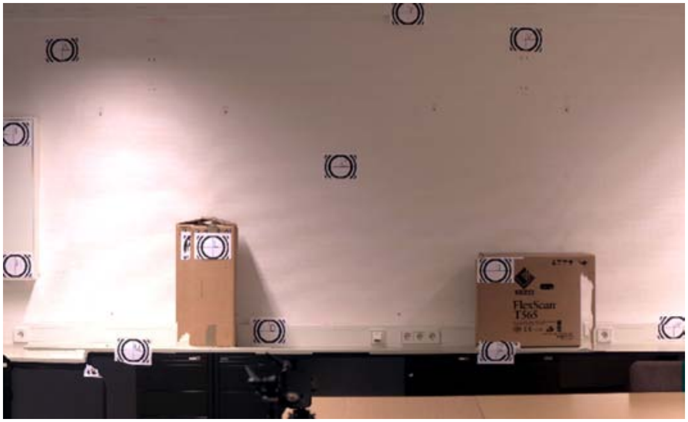


Figure 4: 3D-LS and PANCAM data in Orthoprojection (measurement in laboratory)

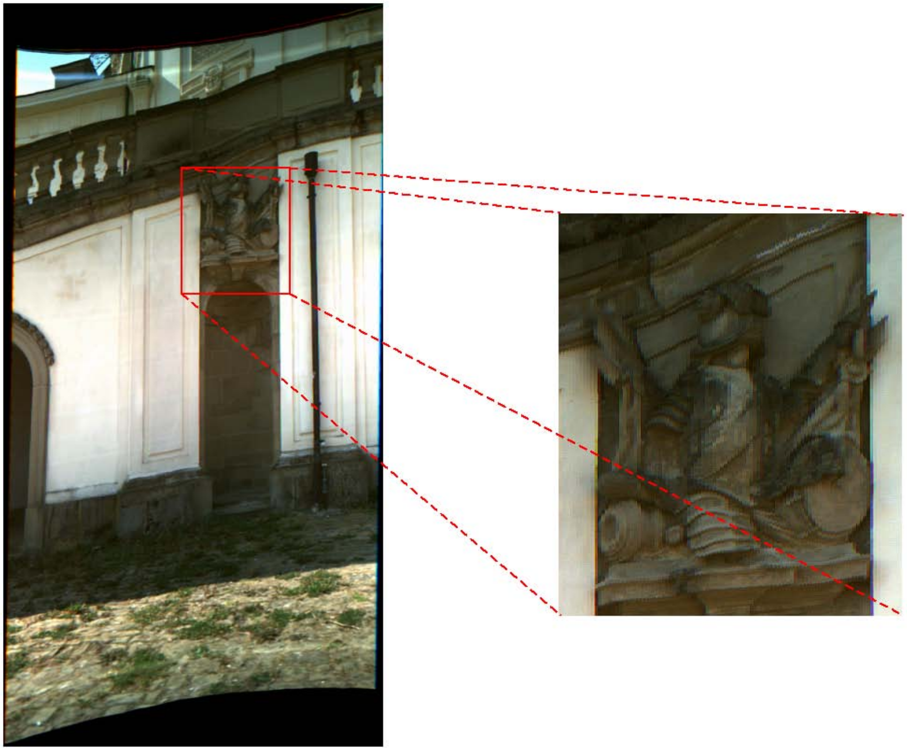


Figure 5: Castle Solitude taken by PLP-CAM

Remote sensing - PROJECT ERLEN-E

The INS is participating in the project ERLEN-E (Demonstrationsbeispiele für die **ER**fassung von **L**andschafts **E**lementen und **N**utzungsstrukturen auf der Basis von X - und L - Band SAR Daten - Extension). ERLEN-E is a remote sensing project of the ProSmart campaign coordinated by the InfoTerra company, where the potential of InfoTerra remote sensing data for the acquisition of land use information has to be demonstrated. ERLEN-E is part of the environmental research.

A set of multi-temporal multi-frequency and multi-polarisation L-Band and X-Band ESAR-data have been made available for the INS test area Ehingen, located in the „Schwäbische Alb“ region. These data have also been converted into InfoTerra simulation data. The data have been acquired in September 2000, March 2001 and May 2001, i.e. within two different vegetation periods.

The test area Ehingen is characterised by a hilly topography and small sized parcels. This makes it difficult for remote sensing and requires high standards. A detailed ground truth data acquisition of more than 1500 agricultural fields has been performed by the INS during the periods of the SAR-acquisition. Additional ground truth information for the forested areas and the heath land has been extracted from ortho-photos.

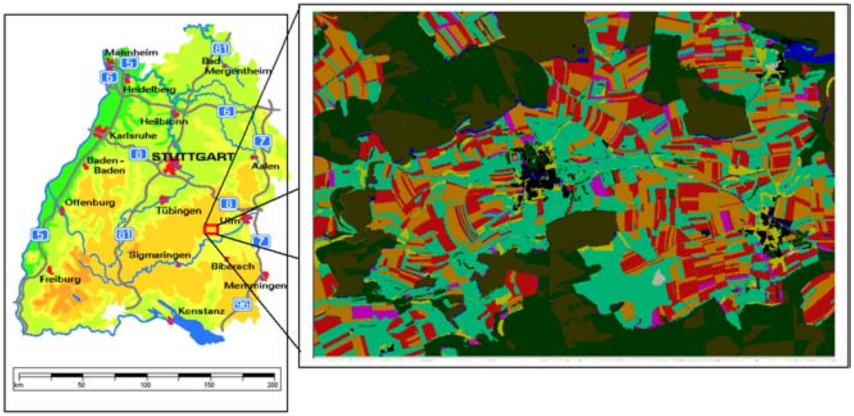
The SAR-data potential has been demonstrated with respect to the needs of typical reference clients: The Ministerium für Ländlichen Raum, Ernährung, Landwirtschaft und Forsten Baden-Württemberg (MLR) and the Landesamt für Flurneuordnung Baden-Württemberg (LfL) as well as the Landesvermessungsamt Baden-Württemberg (LV) have agreed a partnership to define their requests for the future remote sensing data, resulting in a DEBATE (**De**monstrations**b**eispiel **a**us **Te**chnologieentwicklungen) for each of the reference clients.

A multi-layer hierarchical classification process was developed by INS, where the final aim was to achieve a client specific product: Classification results from the multi-temporal radar data with a classification depth sufficient for the clients requests were used as a basis for the postprocessing, i.e. the generation of client specific products. We applied segment based classifiers (eCognition 3.0 software) for the classification. A statistical analysis of the radar features was performed for all different land cover types to define qualified customised channels together with suitable class membership functions for the classification hierarchy.

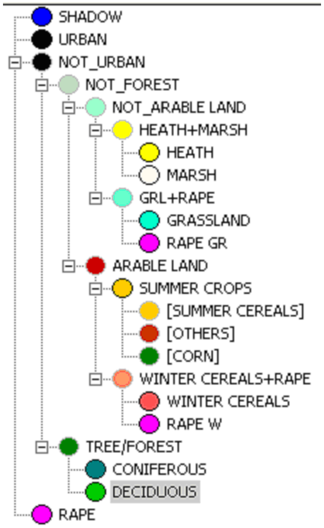
Classification accuracies of more than 98% could be achieved for the separation of forest and open land. Coniferous forest and deciduous forest were identified with 90% accuracy. The agricultural fields could be separated from the grassland with 90% accuracy. Due to the fact that the radar data were only available for an early stage of the vegetation development (March and May), the individual agricultural crops could not be separated from one another. It was however possible to isolate three groups (SUMMER CROPS, WINTERCROPS and RAPE) with an accuracy of 85% to 90%.

Heath and marsh could be separated from grassland. A mono-temporal classification within the grassland mask allowed the discrimination of short cut grass from high grass. The information of several mono-temporal grassland classifications shows the intensive or extensive use of the grassland.

The accuracies achieved are sufficient for many applications. After the installation of the InfoTerra system SAR remote sensing data will be regularly available every 2 - 3 weeks. With this high acquisition rate over the whole vegetation period we can expect higher classification accuracies and a better differentiation between the agricultural fruits.



Location of the test site Ehingen in Baden-Württemberg together with the classification result

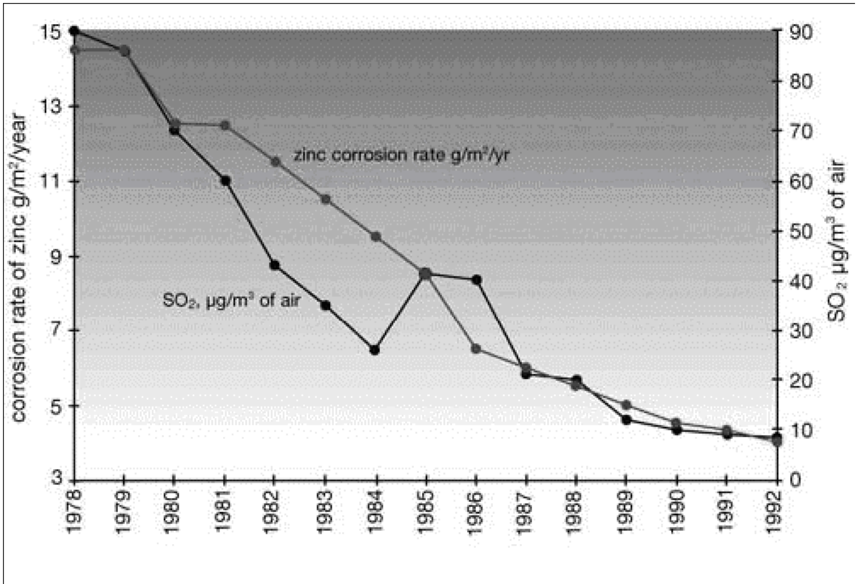


Hierarchical class structure of the multi-temporal detailed classification

Mapping material damages due to air pollutants

The research project „Mapping material damages due to air pollutants“ (BMU/UBA FE-NO. 201 43 205) is funded by Federal Environmental Agency (UBA). A major goal of the project is to produce maps showing the effects of air pollutants on the deterioration of materials. The research project is part of the research activities within the „International Co-operative Programme on Effects on Materials, including Historic and Cultural Monuments“ (ICP Materials). Within ICP Materials the scientific basics of the dose-response-relationships between air pollutants and climate on the one hand and the deterioration of materials on the other hand is established.

The mapping activities are based upon the results of an 8 years materials exposure programme. At 39 test sites in Europe and the Northern America specimen of materials often used to build monuments and buildings are exposed to climate and air pollutant conditions. From the results of the 8 years materials exposure programme dose-response-functions have been derived. These dose-response-functions describe the relationship between climate and air pollutants on the one hand and corrosion rates on the other hand quantitatively. Using the dose-response-functions actual corrosion rates of the materials can be calculated and mapped. The maps indicate the deterioration rate of the materials under actual climate and air pollutant conditions.



1*(Source: Knotkova D and Porter F 1994 Longer life of galvanized steel due to reduced sulphur dioxide pollution in Europe, Ed. proc. Intergalva 94, p GD 8/1-8/20 pub. EGGA, London)*

Correlation of air concentration of SO_2 and corrosion rates of zinc.

Publications and Presentations

Anshelm, F., Gauger, Th., Schuster, H., Droste-Franke, B., Friedrich, R. & Reichert, Th. (2003): Kartierung von Materialschäden in Deutschland. Forschungsvorhaben im Auftrag des BMU/UBA, FE-Nr. 201 43 205.

Gauger, Th. & Anshelm, F. (2003): Mapping of ecosystem specific long-term trends in deposition loads and concentrations of air pollutants in Germany and their comparison with Critical Loads and Critical Levels. Part 1: Deposition Loads. Part 2: Critical Levels Forschungsvorhaben im Auftrag des BMU/UBA, FE-Nr. 299 42 210.

El-Rabbany, A.; Kleusberg, A.: Effect of temporal correlation on accuracy estimation in GPS relative positioning. Journal of Surveying Engineering (129)1, 28-32

Kleusberg, A.; Schiele, O.; Patan, F.: Airborne sensor positioning and orientation: data rate requirements. GNSS2003, 22-25 April 2003, Graz, Austria

Reulke, R.; Wehr, A.: Fusion of Digital Panoramic Camera Data with Laser Scanner Data Optical 3-D Measurement Techniques VI Vol. II, Conference, Zurich Sep. 2003, pp. 142 - 149.

Schiele, O.: Experimental Determination of Necessary IMU Data Rate Using POS/A 3rd European Applanix POS User Workshop, Barcelona February 06-07, 2003

Seifert, A.; Kleusberg, A.: An alternative formulation for the integration of GPS and INS measurements ISPRS Workshop Theory, Technology, Methodology and Realities of Inertial / GPS Sensor Orientation, Castelldefels (Spain), 22.-23. Sept. 2003

Thiel, K.-H.: Availability and accuracy of GPS and differential correction data for land navigation in different environment, Proceedings of International-Symposium of European Radio Navigation Networks Integration of GPS, EGNOS, Galileo and LORAN-C/EUROFIX, Munich, Germany, 04-05 June 2003

Diploma Theses

Patan, F.: Analyse zweier GPS/INS-Systeme zur direkten Georeferenzierung von Fernerkundungsdaten

Ogonda, G.: Setting-up of GPS Reference Stations and Investigating the Effects of Antenna Radome

Activities in National and International Organizations

Alfred Kleusberg - Fellow of the International Association of the Geodesy
- Member of the Institute of Navigation (U.S.)
- Member of the Royal Institute of Navigation
- Member of the German Institute of Navigation
- Adjunct Professor, University of Main, USA

Education (Lecture / Practice / Training / Seminar)

Introduction to Navigation (Kleusberg)	2/0/0/0
Flight Navigation und Avionic (Schöller, Wehr)	2/0/0/0
Introduction to Electronics for Geodesists (Wehr)	2/1/0/0
Electronics for Geodesists (Wehr)	2/1/0/0
Remote Sensing I (Thiel)	1/1/0/0
Remote Sensing II (Smiatek)	1/1/0/0
Navigation I, II (Kleusberg)	3/1/0/0
Navigation III / Radartechniques (Braun)	2/1/0/0
Electrical Engineering for Geodesists (Schöller)	3/1/0/0
Practical Course in Navigation (Schöller)	0/0/2/0
Practical Course in Electrical Engineering (Wehr, Selig)	0/0/2/0
Practical Course in Electronics (Wehr, Selig)	0/0/4/0
Applied Kalman Filtering (Schöller)	2/0/0/0
Software Development (Fritsch, Grafarend, Keller, Kleusberg, Möhlenbrink)	0/0/4/0
Geodetic Seminar I, II (Fritsch, Grafarend, Keller, Kleusberg, Möhlenbrink)	0/0/0/4
Satellite Systems and Programming in Remote Sensing (Liebig)	2/0/0/0

Institute for Photogrammetry

Geschwister-Scholl-Str. 24D, D-70174 Stuttgart,
Tel.: +49 711 121 3386, Fax: +49 711 121 3297
e-mail: firstname.secondname@ifp.uni-stuttgart.de
url: http://www.ifp.uni-stuttgart.de

Head of Institute

Prof. Dr.-Ing. Dieter Fritsch
Deputy: Prof. Dr. rer. nat. Ralf Reulke
Secretary: Martina Kroma
Emeritus: Prof. i.R. Dr. mult. Fritz Ackermann

Working Groups at the ifp:

Digital Photogrammetric Systems

Head: Prof. Dr. rer. nat. Ralf Reulke	Multisensor Photogrammetry
Dipl.-Inform. Jan Böhm	Spatial Segmentation and Object Recognition

Geographic Information Systems

Head: Dr.-Ing. Volker Walter	GIS and Remote Sensing
Dipl.-Ing. Jan-Martin Bofinger	GIS and CAFM
Dipl.-Inform. Martin Kada	3D-Visualisation
Dipl.-Geogr. Steffen Volz	Location Based Services
Dipl.-Geogr. Heike Weippert	eLearning

Image Data Collection and Processing

Head: Dr.-Ing. Norbert Haala	Multisensor Photogrammetry
M.Sc.Eng. Yahya Alshawabkeh	Heritage Documentation
Dipl.-Geogr. Timo Balz	SAR Image Analysis
Dr.-Ing. Michael Cramer	GPS/INS-Integration
Dipl.-Ing.(FH) Markus Englich	Sensor Labaratory
Dipl.-Ing. Darko Klinec	Pedestrial Navigation
Dipl.-Ing.(FH) Werner Schneider	Digital Photogrammetry Lab
Dipl.-Ing. Dirk Stallmann	Aerial Triangulation

External teaching staff

Dipl.-Ing. Volker Schäfer, Ltd. Verm. Dir., Wirtschaftsministerium Baden-Württemberg

Research Projects

Digital Photogrammetric Systems

Object Tracking and Fusion for Road Traffic Observation

This project is related to an integrated observation system for dynamic roads and traffic control based on computer vision approaches. Vision sensors with computational and real-time capabilities (so called sensor nodes) collect relevant traffic data. Efficient algorithms for robust and fast image processing extract objects, like motor vehicles and non-motorised traffic.

A serious problem in traffic observation is the occlusion of observed objects by other cars, traffic signs or trees. This occluded region can only be analysed with additional views on these objects from other cameras. Due to limited transfer channel capacity a camera node always transmits derived object information in this observation network. Therefore a data fusion process is necessary on object level. The object list from different camera nodes has to be analysed and unified. Different object features from different observation positions have to be analysed and compared. The result of this operation is one traffic object with accurate position, size and shape, etc. The requirements for this operation are time and spatial synchronised image data. The sequential processing of this list allows the derivation of more detailed information, e.g. track of traffic participants, removing false objects, etc.

The problem solution of object tracking and fusion is based on a Kalman filter approach. The synchronisation problem can be solved by using the prediction of the Kalman filter for a predefined timestamp (instate of the estimate). Fusion of the tracked data from different camera locations can be done with the derived object parameter (location, shape and grey or colour value).

The following figures show the result of this calculation for two different traffic participants. In Figure 1 the algorithm follows a pedestrian. The right part of the figure shows one image of the sequence and walking direction which was evaluated. On the left the track of the pedestrian is shown. Figure 2 and 3 shows the track and an example image for a turning car.

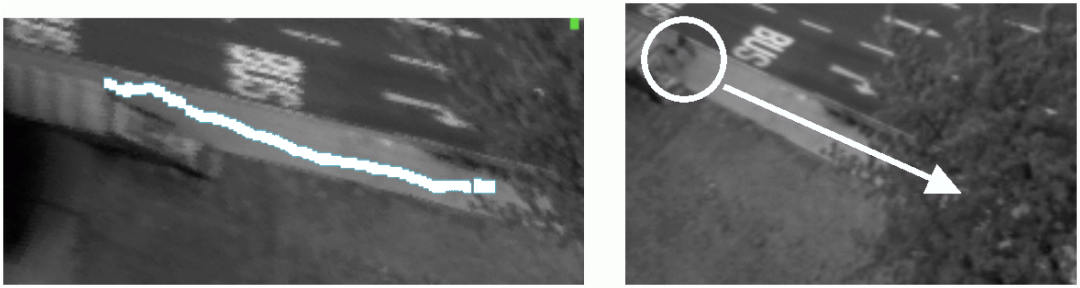


Fig. 1: Estimated track for a pedestrian (left) and an image from the evaluated sequence.

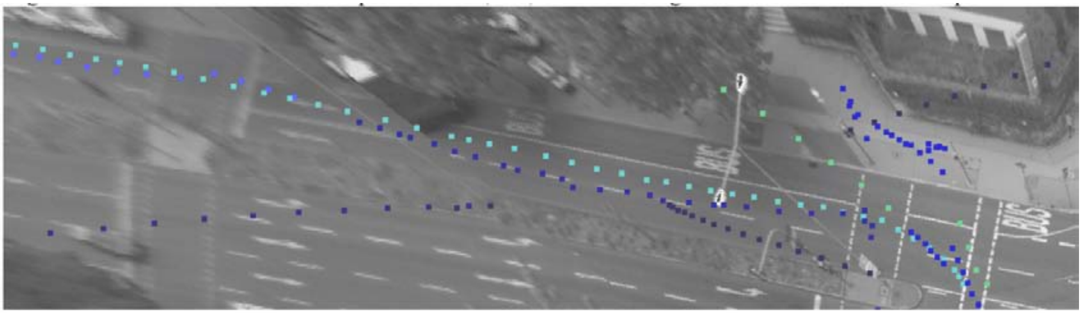


Fig 2: Estimated track.

Fig. 3: Image from the sequence.

Mobile Panoramic Mapping

Together with the Institute of Navigation we investigated the combination of panoramic camera and laser scanner with a navigation system for outdoor applications. The fusion of panoramic camera data with laser scanner data is a new approach and allows the combination of high-resolution image and depth data. Different applications are in the field of city modelling and computer vision as well as documentation of cultural heritage.

Panoramic geometry was realised by a CCD-line scanner, which was precisely rotated around the projection centre. In case of other possible movements, the actual position of the projection centre and the view direction was measured. Linear mobile panoramic mapping e.g. alongside a building facade is an interesting extension of such rotational panoramas. The position determination can be realised with an inertial navigation system.

First experiments were done with line scanner data from a moving platform at the Solitude castle. For rectification we use attitude data from the Applanix POS AV 510 system. The following Figure 4 shows the original data from the scanned area (left) from a photograph and the original scanned data (right). The result after correction shows Figure 5.

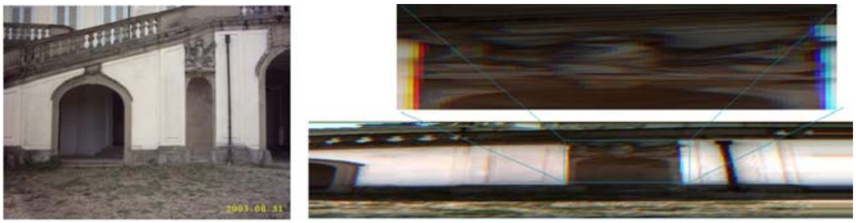


Fig. 4: Photographic data from the scanned area (left) and the original scanned data (right).

Fig. 5: Result after rectification.

Geographic Information Systems

Real-Time Visualisation of 3D Urban Landscapes

The advances in automatic data acquisition of urban sceneries have lead to an increasing amount of data covering large areas. Better and larger models are important for application areas like urban planning, emergency response, tourism, entertainment, traffic management, construction of large-scale projects and education. In these areas the interactive visualisation of the urban models is of great importance for an in-depth analysis of the data set. The project GISMO aimed on generating and interactively visualising a 3D urban landscape model of the city of Stuttgart. With respect to the desired flexibility to support walkthrough and flyover applications, a combined approach using continuous level of detail, the impostor technique and a method for generalising 3D building models was used to speed up the visualisation.

The data set of the virtual city of Stuttgart and the surrounding area includes a 3D city model provided by the City Surveying Office of Stuttgart, digital terrain models and the corresponding aerial and satellite images. The covered area was chosen so that the visualisation stretches as far as the virtual horizon. In order to improve the visual appearance, the facade textures of over 500 buildings that are located in the main pedestrian area were captured. Approximately 5.000 ground based close-up photographs of the building facades were taken using a standard digital camera. The textures were extracted from the images, perspectively corrected, rectified, and manually mapped to the corresponding planar facade segments. To simplify the task of texture placement, a specialised tool was developed. The user selects the facade and the corresponding texture, which is then initially snapped to the bounding box of the geometry. A user controlled affine transformation precisely adjusts the final texture coordinates.

Impostors are an image-based rendering technique. Like a billboard, an impostor replaces a complex object by an image that is projected on a transparent quadrilateral. A common example for the use of billboards is the visualisation of trees. Provided that the viewer stays close to the ground level, the image of a tree is a good approximation of the real geometry for all view points. As the viewer moves around the scene, the quadrilateral is rotated so that the image always faces forward. Because billboard images are created a priori and are therefore static, this technique can only be used for objects that look similar under rotation. In contrast to that, the images of impostors are dynamically generated by rendering the objects themselves for the current point of view. If consecutive viewpoints are close together, the impostor images of slowly moving objects that are located far from the viewer do not change notably with every frame. From this it follows that those impostor images can be reused for several frames and therefore speeds up the overall rendering process. A 3D city model consists of vast amounts of building objects. In an urban scene, these innately static objects extend over a large area so that only a fraction of the objects is actually close to the viewer. It can be assumed that in this context the majority of the building objects is located far enough from the viewer to cause few image updates and can therefore be visualised efficiently by impostors.

Fig. 6: Overview of the Stuttgart city model. A total of 36,000 building models are available for the densely populated area bordered by the woods at the top and bottom of the image

For the visualisation of the digital terrain model on which the buildings are placed, a continuous level-of-detail (C-LOD) approach is used. To suppress popping effects, which is due to the view-dependent simplification, a technique called geomorphing is applied. This is important since the rendering of the buildings consumes most of the time slice and there is little time left to render the terrain. As a consequence, the error threshold of the view-dependent simplification has to be set to high values to produce as few triangles as possible. Without geomorphing the rather coarse triangulation would lead to excessive popping.

Some of the most prominent buildings in the city centre of Stuttgart consist of a substantial number of triangles. For those buildings, an automatic generalisation process was devised which eliminates data acquisition artefacts, groups elements that lie in nearly the same plane, and throws away small protrusions while keeping the building symmetries.

Fig. 7: Close-up view of the texture mapped city centre

The experimental results have been measured on a standard PC equipped with a 2.0 GHz Intel Pentium P4 processor, 512 MB of memory and an NVIDIA GeForce4 Ti 4200 graphics accelerator with 64 MB of graphics memory. Without impostors (frustum culling alone), brute force rendering performance for the entire data set including terrain rendering was 2 fps. Enabling impostors led to a speed up to 11 fps on the average. The visibility of an impostor update is very low since the update happens quite far away ($>$ 1 km). In many cases the updated impostors are occluded by non-impostor buildings, so that the update is hardly noticeable.

Another aspect of this research is the visualisation of 3D-models on mobile devices. Due to the limited amount of computational power and small size of the displays on the one hand and the huge amount of data contained within a 3D city model on the other hand, the amount of information to be handled, stored and presented has to be reduced efficiently. Thus, the generalisation of the 3D building models becomes a topic of major interest. A generalisation process basically presumes the elimination of unnecessary details, whereas features, which are important for the visual impression, have to be kept. Especially for man-made-objects like buildings, symmetries are of major importance. For this reason, during the process of generalisation the preservation of regular structures and symmetries like parallel edges, perpendicular intersections or planar roof faces have to be guaranteed.

The following screenshots show part of the building model of the New Castle of Stuttgart as it was collected from stereo imagery and an existing outline from the public Automated Real Estate Map. Figure 8 (a) shows the original model whereas Figure 8 (b) shows the result of the generalisation process. As it is visible, parallelism and rectangularity have been preserved for the remaining faces.

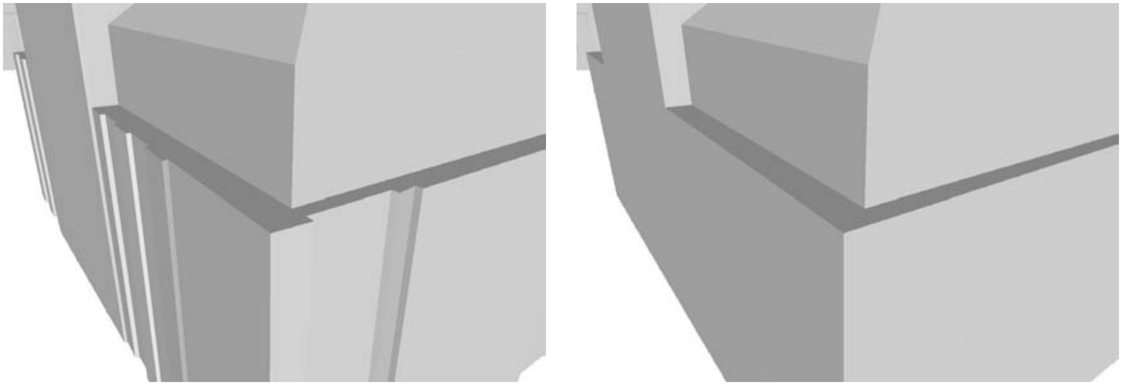


Fig. 8 (a) before and (b) after generalisation of a 3D building model. Protrusions were removed of the historical New Palace of Stuttgart

Object-based classification of remote sensing data for change detection

In this project a change detection approach based on an object-based classification of remote sensing data is developed. The approach classifies not single pixels but groups of pixels that represent already existing objects in a GIS database. The approach is based on a supervised maximum likelihood classification (see Figure 9). The multispectral bands grouped by objects and very different measures that can be derived from the multispectral bands represent the n-dimensional feature space for the classification. The training areas are derived automatically from the GIS database in order to avoid the time consuming task of manual acquisition. This can be done, if it is assumed that the number of changes in the real world is very small compared with the number of all GIS objects in the database. That assumption can be seen as true because we want to realise update cycles in the range of several months.

In a „normal" classification, the greyscale values of each pixel in different multispectral channels and possibly some other pre-processed texture channels are used as input. For the classification of groups of pixels, we have to define new measures that can be very simple (for example the mean grey value of all pixels of an object in a specific channel) but also very complex, like measures that describe the form of an object. This approach is very flexible because it can combine very different measures for describing an object. We can even use the result of a pixel-based classification and count for each object the percentage of pixels that are classified to a specific landuse class. Because the result of the approach is a classification into the most likely class, the decision if an object is updated or not can be done by a simple comparison of the classification result with the existing database.

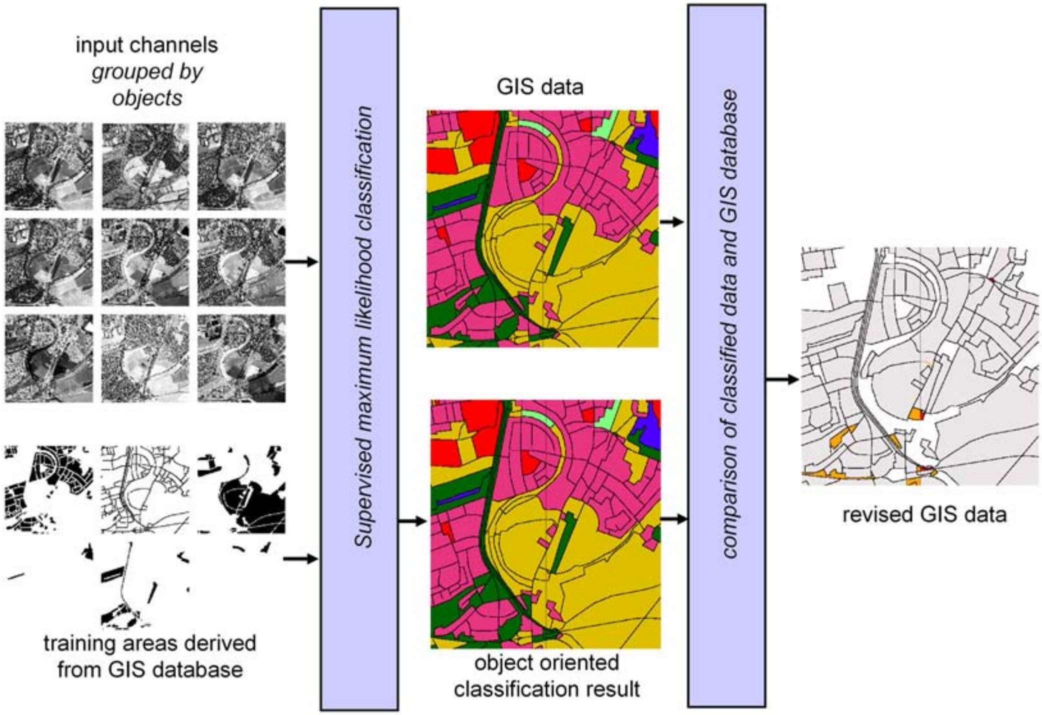


Fig. 9: Object-based classification approach

Tests were carried out with ATKIS datasets. ATKIS is the German national topographic and cartographic database and captures the landscape in the scale 1:25,000. The remote sensing data was captured with the DPA system which is an optical airborne digital camera. The original resolution of 0.5m was resampled to a resolution of 2m. The DPA System has four multispectral channels (blue 440 - 525nm, green 520 - 600nm, red 610 - 685nm, NIR 770 - 890nm).

Currently, 63 different object classes are collected in ATKIS. There are a lot of object classes that can have very similar appearance in an image of 2m (for example industrial areas, residential areas or areas of mixed use). Therefore, we do not use 63 landuse classes for the classification but subdivide all object classes into the five landuse classes water, forest, settlement, greenland and roads. The approach was tested on two test areas (16km^2 and 9.1km^2) with together 951 objects (194 forest, 252 greenland, 497 settlement and 8 water objects). The input channels are:

- mean grey value blue band
- mean grey value green band
- mean grey value red band
- mean grey value NIR band
- mean grey value vegetation index
- mean grey value texture from blue band
- variance blue band
- variance green band
- variance red band
- variance NIR band
- variance vegetation index
- variance texture
- percentage forest pixel
- percentage greenland pixel
- percentage settlement pixel
- percentage water pixel

The input channels are spanning a 16 dimensional feature space. All objects of the test areas are used as training objects for the classification. That means that also those objects are training objects that are wrong in the database. In a manual revision we compared the GIS data with the images. The number of objects that were not collected correctly or where it was not possible to decide if they are collected correctly without further information sources is 63 which is more than 6 percent of all objects.

Figure 10 (a) shows the GIS data and Figure 10 (b) the result of the object-based classification on a part of one test area. Approximately 8.6 percent of all objects (82 objects form 951) are marked as changes. From these 82 objects are 43 percent real changes and 31 percent potential changes where it is not clear, if the GIS objects were collected correctly. Higher resolution data or sometimes even field inspections are needed to decide if the GIS database has to be updated or not. Only 19 objects were wrong classified. That means that the interactive work can be decreased significantly by checking only the objects that are marked as changes. On the other hand, we have to ask if the object-based classification finds all changes. A change in the landscape can only be detected if it affects a large part of an object because the object-based classification uses the existing object geometry. If for example a forest object has a size of 5000m^2 and in that forest object a small settlement area with 200m^2 is built up, then this approach will fail.

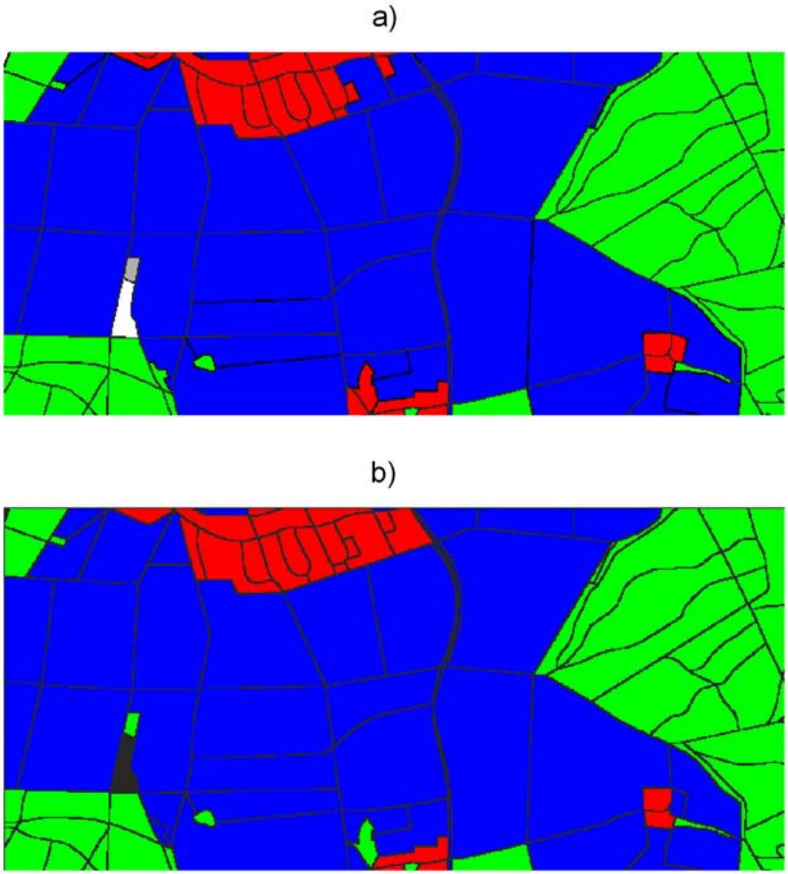


Fig. 10: (a) input data (b) result of object-based classification

Further techniques have to be developed in order to cover this problem. Because forest areas can be classified very accurately in pixel-based classification it could be additionally tested whether there are large areas in a forest object that are classified to another landuse class. The same approach could be used for water areas because water is also a landuse class that can be classified very accurately in pixel-based classification. More difficult is the situation for the landuse classes greenland and settlement which have typically an inhomogeneous appearance in a pixel-based classification. Here, we suggest using a multi scale approach to make additional verification of the objects.

Image Data Collection and Processing

Integrated sensor orientation

Although it is explicitly admitted that direct georeferencing is a powerful technology with wide influence on the georeferencing process the results from academic performance tests (extensively performed by ifp in the last years) typically suffer from the following points: Due to the lack of separated calibration and mission sites the calibration is performed in the mission area itself, which is different from later practical use. In order to estimate the maximum possible accuracy of GPS/inertial systems these test flights are carefully planned, the flight turns are flown with low banking angles to preserve good satellite constellation. In addition to that, highly skilled experts (sometimes the system manufacturers themselves) spend a lot of time for data processing and the overall system evaluation. Again, such test conditions are non-typical for the later use of GPS/inertial systems in operational production environments, showing quite clearly that the results from these performance tests might be too optimistic compared to the results from later practical use. From these points especially in the true production work there might be a need for an efficient calibration and control tool, which is solved by integrating GPS/inertial data in an (automatic) AT process, so-called integrated sensor orientation.

In general the additional use of GPS/inertial data should improve the quality of tie point matching and increase the overall stability and reliability of the block. In order to evaluate the influence of GPS/inertial data within AAT, some exemplary investigations were done with real data. These tests were based on image sub-blocks recorded during one of the Vaihingen/Enz test flights. Within this specific case, the data from the test flight June 2000 were chosen, where parallel to standard RMK wide-angle images m_b=13000, image scan resolution 14 (μm) GPS/inertial data from the AEROcontrol-IId system from IGI (Kreuztal, Germany) were acquired. Since the high quality of the direct exterior orientations was already proven as one part of the test, these orientation elements were introduced as high-performance direct exterior orientations in the MATCH-AT 3.3.0 program from inpho (Stuttgart, Germany) to perform a GPS/inertial assisted AAT process.

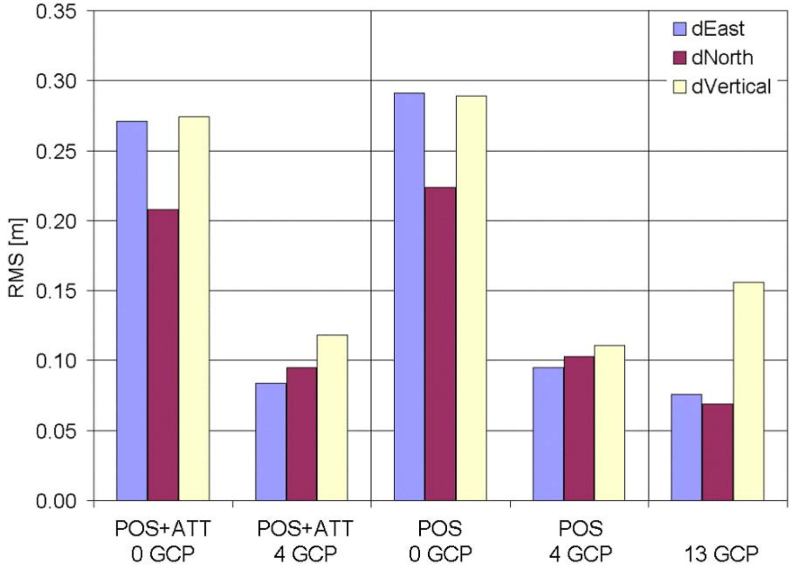


Fig. 11: Object point quality (RMS) from AAT based on different input data.

One exemplarily data set should be presented in the following. It consists of a small block with two parallel flight lines (7 images each) and standard overlap conditions, representing the more or less typical block configuration from standard AT in practice. Within this test, the GPS/inertial data were introduced with their estimated accuracy and compared to the results from GPS-assisted AT (with/without ground control points) and standard AT based on a sufficient number of ground control points only. The absolute accuracy values are obtained from independent check points. Some results for the chosen block configuration are given in Figure 11. It can be seen that for this specific data set the additional direct observation from GPS/inertial data (POS+ATT) for AAT is of almost no influence on the obtained quality of object point determination. The results from GPS/inertial assisted AAT are almost similar to the results where GPS positions (POS) are used only. The introduction of additional 4 ground control points (GCP) in the corners of the block is sufficient to obtain almost highest accuracy. Note the accuracy increase for vertical components when direct observations for exterior orientation elements are introduced compared to the standard approach based on ground control points only.

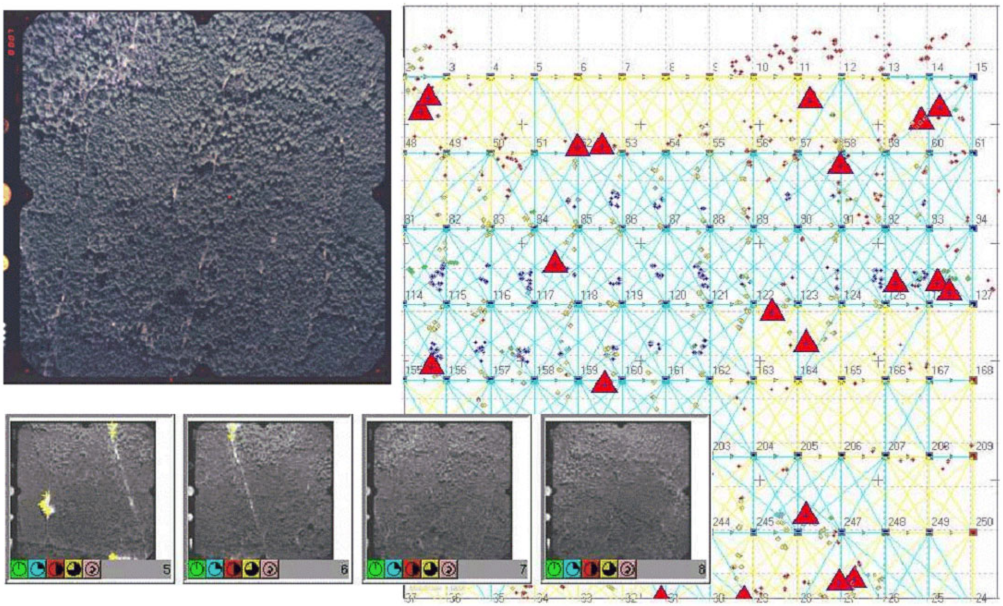


Fig. 12: AAT with problematic image data (©inpho 2003).

Although the added value from GPS/inertial data seems to be somehow disappointing at least from the test material presented, experiences from operational projects with very large scale images (i.e. m_b=2000) have already shown the important role of additional attitude observations from GPS/inertial systems. In one specific case numerous images were covered with wood exclusively preventing a sufficient automatic tie point measurement, even in the lower pyramid levels. From Figure 12 this situation is clearly visible. The brighter lines in the upper part and lower right of the block scheme indicate individual photos with no connection to the rest of the block. Without using GPS/inertial attitude data the quality of triangulation is very weak (at least) and in some cases might totally fail. Although a less accurate triangulation might be accepted for orthoimage generation in such areas, significant problems will occur when stereo mapping is performed (e.g. mapping of small forest tracks or clearings as they can be seen from the small flight strip). In such applications only the use of high-quality GPS/inertial attitudes could solve the problem and an acceptable block stability is established.

Pedestrian navigation and orientation

The development of tools and applications for Location Based Services (LBS) presumes the availability the user's current position and orientation in order to allow the personalized access for information. Thus, one task to be solved within the NEXUS project aims on the development of approaches for intuitive automatic positioning and navigation. For this purpose the combination of different sensor elements and positioning sensors is of interest. Additionally, image sensors can be applied, which are capable for object identification and position estimation if a model of the environment is available.

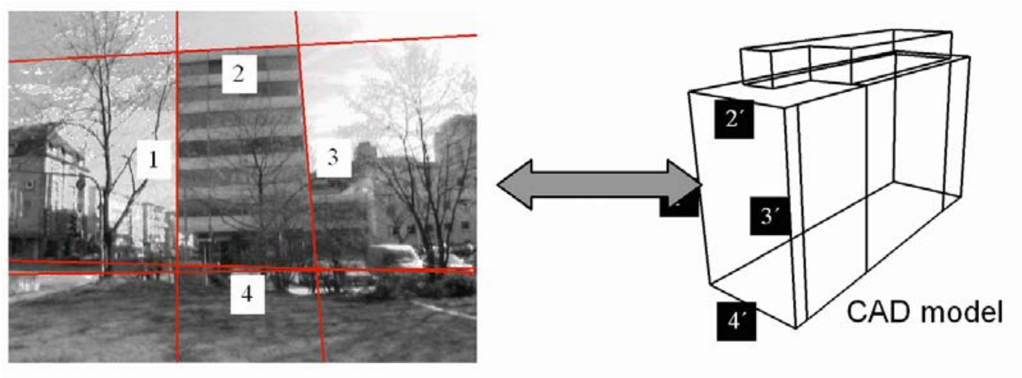


Fig. 13: Automatically extracted and correlated lines.

Especially for indoor applications new concepts for the integration of positioning sensors to precisely localize the user are investigated. Additionally, for the identification of real world objects in images an approach based on a general Hough transform was implemented. Within the algorithm, information of object silhouettes is used, which is provided by a fusion of sensor and model data. The identification of the object position in the image is a preparatory work for the following image to model registration and the image based positioning. For the image based positioning process, the spatial resection algorithm was extended to line features as input data. Based on an automatic line extraction and a photogrammetric spatial resection a co-registration of image and model data can be provided. This approach additionally enables an automation of the matching process, as lines detected in images are typically more stable than points. Therefore, future work will concentrate on automation of the matching process for object and image features.

Cultural Heritage

Within this project approaches for the documentation of heritage sites based on the application of terrestrial laser scanning and close range photogrammetry are developed. As an exemplary application, a 3D virtual model of the Al-Khaznah, a well known monument in Petra, Jordan is generated. The collection of the required data was performed in cooperation with the Hashemite University of Jordan. In order to allow for an efficient data collection, currently tools enabling the combined processing of range data from laser scanning and terrestrial images from digital cameras are developed.

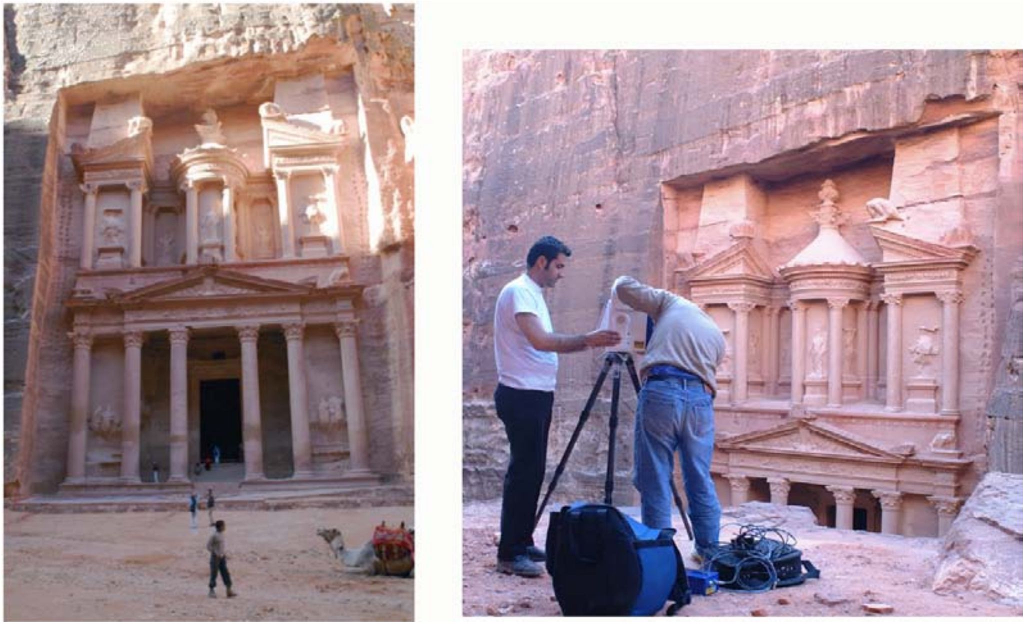


Fig. 14: Collection of LIDAR and image data.

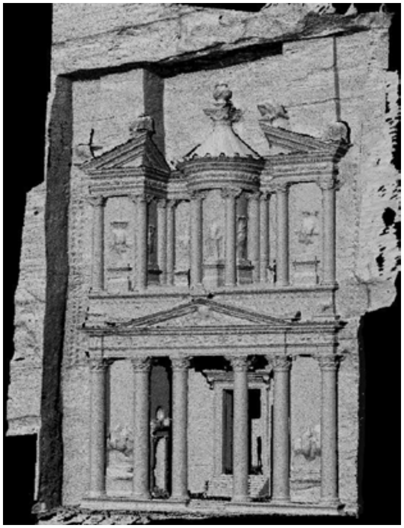


Fig. 15: Collected 3D data set from LIDAR measurement.

Tree species recognition by terrestrial laser scanning and high resolution panoramic imagery

The management and planning of forests presumes the availability of up-to-date information on their current state. In order to allow for the collection of relevant parameters like tree species and positions, an approach aiming on the integration of a terrestrial laser scanner and a high resolution panoramic camera has been developed. The integration of these sensors, which was realized as a part of the NATSCAN project, provides geometric information from distance measurement and high resolution radiometric information from the panoramic images. In order to enable a combined evaluation, in the first processing step a co-registration of both data sets is required. Afterwards geometric quantities like position and diameter of trees can be derived from the LIDAR data, whereas texture parameters as derived from the high resolution panoramic imagery can be applied for tree species recognition.

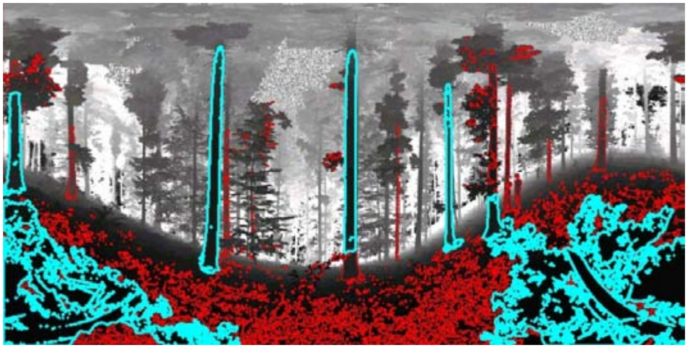


Fig. 16: Range image of the test site, result of preliminary range image segmentation overlaid.

Fig. 17: Section of range image (left), coregistrated panoramic image (middle) and result of combined segmentation (right).

SAR-image interpretation in urban environments

The acquisition of SAR-imagery can be advantageous compared to the application of other airborne sensors like aerial images or airborne laser scanners due to the range and weather independence of SAR systems. On the other hand, problems occur especially in urban areas due to the side-looking image geometry of SAR systems, which results in occlusions and other disturbing effects within the imagery. Thus, depending on the respective requirements a combination of different data types is optimal. Within the project the application of SAR imagery for data collection in urban areas is investigated. For this reason approaches aiming on semi-automatic building reconstruction and detection of inconsistencies in existing GIS data sets are developed. Both approaches presume the integration of given 3D vector models to a SAR-simulator in order to generate simulated SAR imagery based on existing 3D city models. By interactive manipulation of the 3D object shapes, this tool can be applied for semi-automatic building reconstruction. Additionally operators can be trained for the interpretation of SAR images.

Current work aims on the combined analysis of simulated and real SAR imagery in order to allow for a refined geoereferencing of the SAR data as a prerequisite for the combination of the imagery with additional data sets. Additionally, the comparison of real and simulated images can be used for the detection of changes in order to determine obsolete parts in the available 3D GIS data.

Fig. 18: Available 3D city model used as input for SAR simulator.

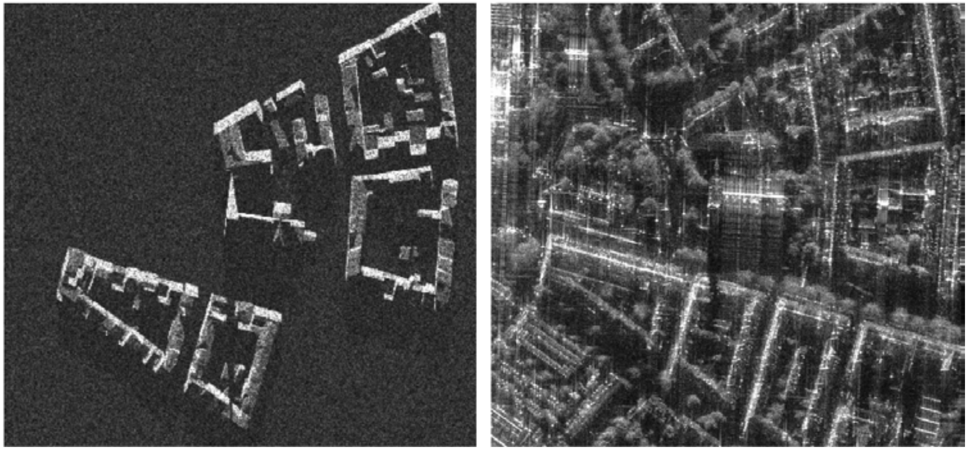


Fig. 19: Simulated SAR image based on given 3D city model and corresponding DOSAR image (EADS Dornier GmbH).

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Diploma Theses

Michael Kraut: Zuordnung und Conflation heterogener Straßendaten. Betreuer: Dipl.-Geogr. Steffen Volz.

Holger Bäsler: Entwicklung eines StereoSAR-Algorithmus für ein hochauflösendes Radar unterstützt durch Mustererkennungssoftware. Betreuer: Dr.-Ing. Norbert Haala, Dr.-Ing. Hans M. Braun (RST GmbH).

Charles Lemaire: Erzeugung von wahren Orthobildern in Stadtgebieten mit Kanten aus Laser-Raster-Daten. Betreuer: Dr. Norbert Haala, Dr. Eberhard Gülch (Inpho GmbH).

Steffen Lindenthal: Hardwarebasierte Texturextraktion mit OpenGL. Betreuer: Dipl.-Inform. Martin Kada.

Study Theses

Volker Hell: Photogrammetrische Erfassung und dreidimensionale Rekonstruktion eines Schwammes. Betreuer: Dipl.-Ing. Jan Böhm.

Mathias Jahnke: Automatische Auswahl optimaler Bildausschnitte für die Texturierung von Gebäudefassaden. Betreuer: Dr.-Ing. Norbert Haala, Dipl.-Geogr. Timo Balz.

Doctoral Theses Supervisor Dieter Fritsch

Karl-Heinrich Anders: Parameterfreies hierarchisches Graph-Clustering Verfahren zur Interpretation raumbezogener Daten.

Activities in National and International Organizations

Dieter Fritsch
- President of the University of Stuttgart
- Editor-in-Chief of the journal 'Geo-Informationssysteme GIS' qd

Education - Lecture/Practice/Training/Seminar

Adjustment theory and Statistical Inference I,II,III (Fritsch)	5/3/0/0
Aerotriangulation and Stereo Plotting (Cramer)	1/1/0/0
Cartography (Haala)	1/1/0/0
Civil Law (Schwantag)	2/1/0/0
Close Range Photogrammetry (Böhm)	1/1/0/0
Digital Elevation Models (Haala, Kada)	1/1/0/0
Digital Image Processing (Haala)	1/1/0/0
Geodetic Seminar I, II (Fritsch, Grafarend, Keller, Kleusberg, Möhlenbrink, Reulke)	0/0/0/4

Geographic Information Systems I,II,III (Fritsch, Walter)	5/1/0/0
Geographic Information Systems for Infrastructure Planning and WAREM (Walter)	2/1/0/0
Geographic Information Systems for Environmental Monitoring (Walter)	2/1/0/0
Geometry and Graphical Representation (Cramer)	1/1/0/0
Introduction to Photogrammetry (Cramer)	1/1/0/0
Image Processing and Pattern Recognition I,II (Haala, Balz)	4/1/0/0
Image Acquisition and Mono Plotting (Reulke, Cramer)	2/1/0/0
Practical Training in GIS (Bofinger, Kada, Volz, Walter, Weippert)	0/0/4/0
Practical Training in Digital Image Processing (Haala)	0/0/4/0
Programming in C++ (Böhm, Kada)	1/1/0/0
Signal Processing for Geodesists (Fritsch, Böhm)	2/1/0/0
Urban Planning (Schäfer)	2/1/0/0