The Department of Geodesy and Geoinformatics

Stuttgart University

2006

editing and layout:
volker walter, friedhelm krumm, martin metzner, wolfgang schöller

Dear friends and colleagues,

It is our great pleasure to present to you this annual report[1] on the 2006 activities and academic highlights of the Department of Geodesy and Geoinformatics of Universität Stuttgart. The Department consists of the four institutes:

- ▷ Institute of Geodesy (GIS),
- ▷ Institute of Photogrammetry (ifp),
- ▷ Institute of Navigation (INS),
- ▷ Institute of Applications of Geodesy to Engineering (IAGB).

Research

This annual report documents our research contributions in many diverse fields of Geodesy and Geoinformatics: from satellite and physical geodesy through navigation, remote sensing, engineering surveying and telematics to photogrammetry, geographical information systems and location based services. Detailed information can be found in the following individual institutes' sections.

Teaching

With our German Geodesy and Geoinformatics curriculum we have a vigorous programme with a total enrolment of about 150 students. Diversity is one of the programme's strengths: the female student population is about 35%, whereas foreign students account for nearly 50%. One of the academic highlights of the year 2006 was the successful accreditation and subsequent launch of our international Master Programme Geomatics Engineering (GEOENGINE[2]). The programme started with a limited number of students from such diverse countries as China, Indonesia, India and Germany in Winter Semester 2006/2007. Beyond these two core curricula, the institutes are involved in a host of other programmes around campus.

Academic Service

A number of important changes took place at the beginning of the Winter Semester 2006/2007. Prof. Fritsch (ifp) completed his tenure as rector of Universität Stuttgart. Prof. Kleusberg (INS) assumed the position of Dean of the Faculty of Aerospace Engineering and Geodesy. Prof. Sneeuw took over as Associate Dean (Academic) from Prof. Keller (both GIS).

Nico Sneeuw
Associate Dean (Academic)
sneeuw@gis.uni-stuttgart.de

[1] A version with colour graphics is downloadable from http://www.ifp.uni-stuttgart.de/publications/jahresberichte/jahresbericht.html
[2] http://www.geoengine.uni-stuttgart.de/

Institute for Applications of Geodesy to Engineering

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Head of Institute

Prof. Dr.-Ing. Wolfgang Möhlenbrink
Dipl.-Ing. Ulrich Hangleiter, Akad. Direktor (till 31.07.06)
Dr.-Ing. Martin Metzner, Akad. Rat (since 01.10.06)

Secretary

Christel Schüler

Emeritus

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

Scientific Staff

Dr.-Ing. Renate Czommer	Map matching
Dipl.-Ing. Alexander Beetz (since 01.04.06)	Sensor integration
Dipl.-Geogr. Wolfgang Fürst	Networks for Mobility
Dipl.-Ing. Andreas Gläser (till 30.04.06)	Sensor integration
Dipl.-Geogr. Thilo Kaufmann	Geodata and GIS applications
Dipl.-Ing. Ralf Laufer	Information quality
Dipl.-Ing. Katrin Ramm	Kinematic positioning
Dipl.-Ing. Ralf Schollmeyer	Vehicle positioning
PD Dr.-Ing. Volker Schwieger	Engineering geodesy
Dipl.-Ing. Matthias Wengert (since 01.09.06)	Geodata and GIS applications
Dr.-Ing. Thomas Wiltschko	Traffic information techniques

Technical Staff

Niklaus Enz, Ruping Hua, Martin Knihs, Lars 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 engineer-ing geodesy, geodetic measurement techniques, data processing, and traffic information techniques. 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 institute is responsible for the above mentioned fields within the curricula for „Geodesy and Geoinformatics“ as well as for „Geomatics Engineering“, the master course in English language established in 2006. In addition to the education in Surveying for Architects and Surveying for Civil Engineers, lectures on Acquisition and Management of Planning Data are presented to the diploma course of Technique and Economy of Real Estate. Furthermore, lectures are given to students of Geography and Traffic Engineering as well as two lecture in English within the master course Infrastructure Planning. Finally, eLearning modules are applied in different curricula e.g. for geodetic measurement techniques or for cartographic animations. The current research is reflected in most lectures and in diploma theses.

This report shows several research activities which refer to projects supported by public funds. Therefore chapter 3.3 is included into this report characterizing these projects and their environment by short descriptions.

Research and development

Engineering geodesy and positioning technique

Modelling of moving objects

Three different filter approaches for modelling of moving objects and generation of vehicle trajectories are developed and evaluated. Starting from a Kalman filter algorithm, which is based on circular driving under static conditions, a shaping filter, and an adaptive shaping filter approach were realised. Both are enabled to take inter-epochal correlations of GPS measurements into account. These correlations were determined from empirical GPS time series. Their functional description is an exponential function of the bell-shaped curve type. Due to the more correct stochastic modelling, it is expected to achieve an improved automatic and real-time detection of filter disturbances caused by GPS outliers. This is evaluated both in simulations with following variance- and sensitivity analyses, and on the basis of numerous data from test runs. Research in this topic is still going on.

Positioning by mobile phones

The project Do-iT (data optimisation for integrated telematic) deals with the acquisition of traffic state and the forecast of traffic on the basis of multiple trajectories generated from anonymous mobile phone data. Positions are generated for each participant in the GSM network. First results based on the analysis of arc sections, adjusted from distances to several GSM antennas. The distances were determined from signal strengths by use of attenuation models. In a second approach the signal strengths are directly matched onto a signal strength map, available for every GSM antenna. The position on the map, in which the least squares sum of the deviations between measured and given signal strength over all antennas is minimized, is the one searched for. Positions of one participant generated this way can be further on improved by smoothing. These positions are generating a kind of corridor based on the uncertainties of the position estimation. Within this corridor, data of the road network is extracted from the digital map (GDF). Most probable trajectories are derived on the basis of shortest path algorithm. The figures stated below show the results of the signal strength matching (RX-Matching) with following smoothing and the matching to the road network afterwards. Additionally, the measured GPS trajectory is shown in the first figure.

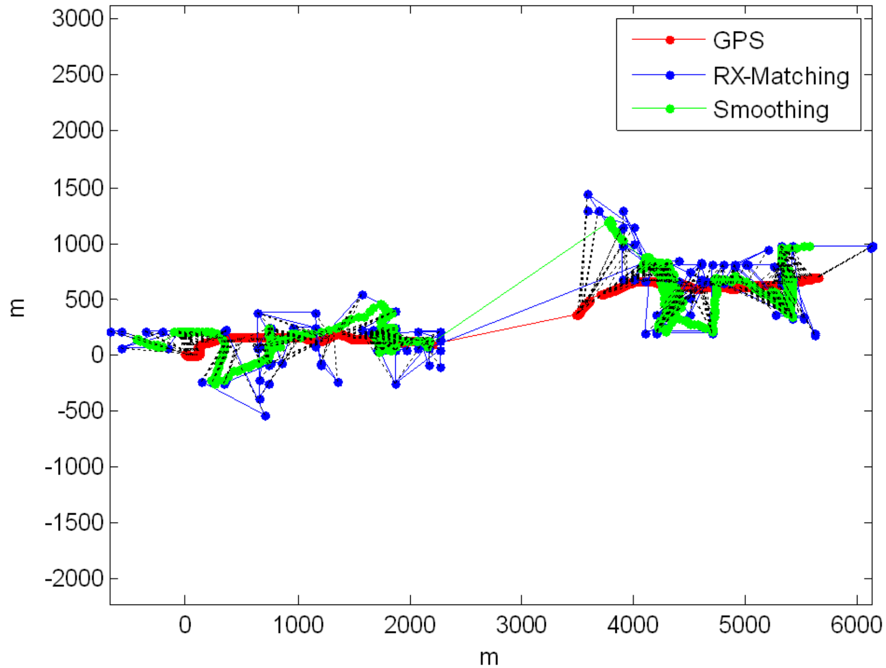

Fig. 1: RX-Matching

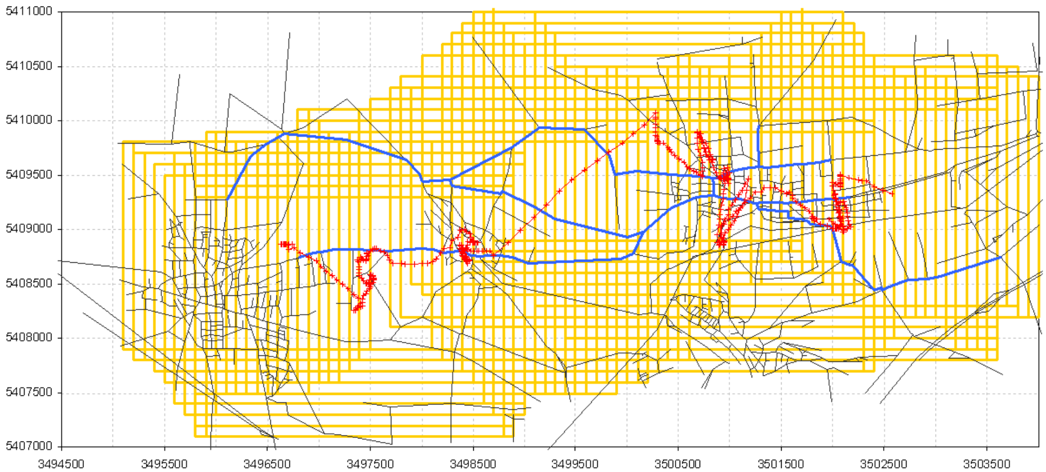

Fig. 2: Extraction of road data and determination of trajectories

Modular System for Construction Machine Guidance

For road construction, beside the classical guiding systems based on infrastructure equipment, virtual guiding wires for machine guidance are in use. The primary sensors for positioning of the machine are tachymeters or differential GPS. Due to machine orientation further sensors like inertial sensors are necessary. Extensive development work is required to integrate and adapt these sensors into the respective machines for any individual situation.

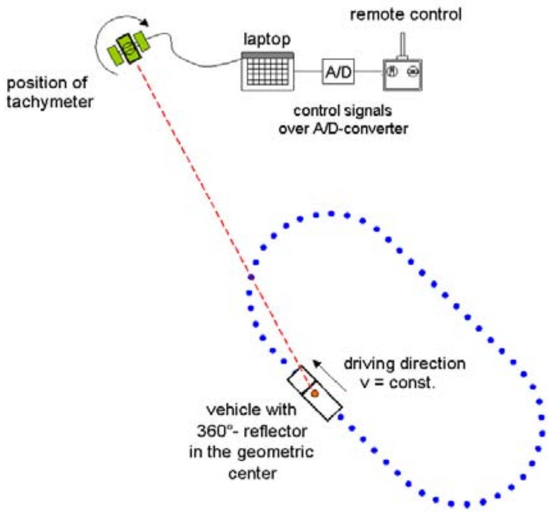

Fig. 3: Simulator for guidance of construction machine

For this reason a modular system was developed for guidance of a construction machine (PoGuide) at this institute. It was realized as a prototype using LabView®. All individual modules together form the PoGuide toolbox. Due to the modular design the toolbox can be used for individual tasks, for example automatic guidance of a vehicle on a given trajectory. For this purpose a simulator was developed, using parts of the PoGuide Toolbox and consisting of a remote control model truck, one robot tachymeter, and an interface between a PC and the remote control (shown in figure 3). Due to the modular design different control algorithms can be analyzed without bigger adoptions on the vehicle itself. In this year a notable improvement in control quality is reached by enhancing the guidance module with a Kalman-Filter. The vehicle guidance could be stabilized by an improved controller too. Further optimized control algorithms will be analyzed in the future. In addition, teach-in-processes may be used to generate predetermined trajectories, the model truck may follow to.

Precise Positioning with GPS navigation type receivers

The investigations for use of GPS navigation type receivers for static positioning on geodetic accuracy level are continued. The receivers are calibrated together with an especially constructed adapter at the Geodetic Institute of the Technical University of Dresden. Afterwards baseline measurements were realized. The baselines were measured using two navigation receivers as well as one navigation receiver and one Leica SR530 receiver. The measurement time was defined to 30 minutes and the baseline lengths were chosen up to 1.1 km. Evaluation of the measurements was carried out by using the software Wa1 developed by the engineering office Wanninger. The software Wa1 is adapted to the evaluation problems occurring to the navigation receivers (half cycle slips). The next figure shows the deviations of the measured coordinates to the given coordinates for the three individual coordinate components, and the total 3-dimensional deviation. The standard deviations show values of 1.5 cm for the horizontal components and below 2 cm for the height.

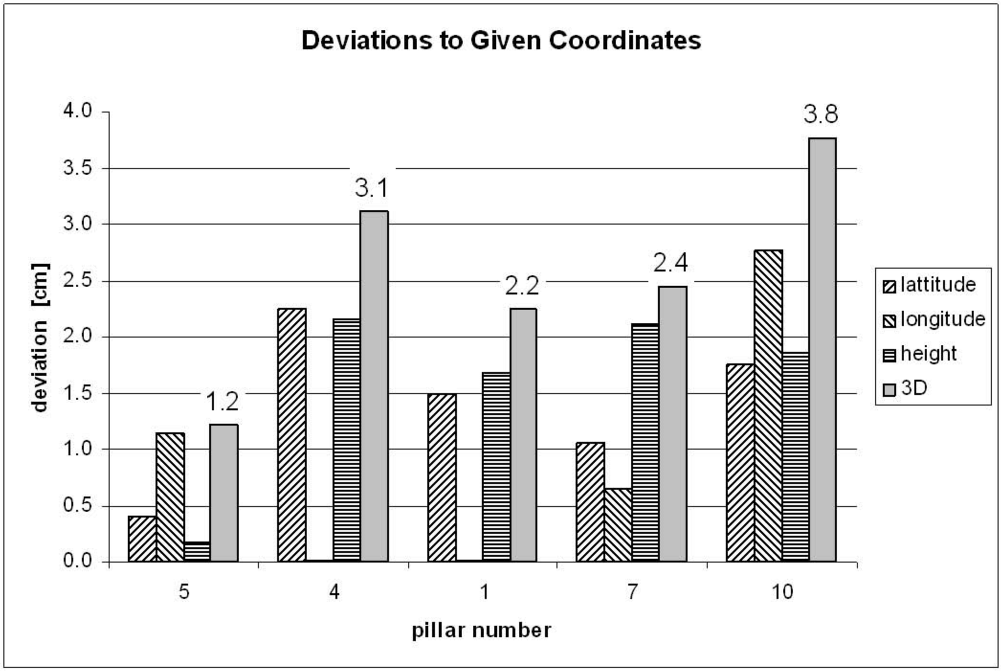

Fig. 4: Deviations of navigation receiver to given coordinates

Traffic information techniques

With its activities in this area the IAGB is contributing to the interdisciplinary research and development field of transport telematics with two core competences of geodesy and geoinformatics: positioning of dynamic objects and provision of high-quality (geo) data and information. A variety of activities is focussed on development of future mobility services and map-based driver assistance systems. Verification and validation of innovative telematic services and systems are performed by means of prototypical realisations, and using of suitable test sites and simulation environments.

Main topics, besides others, are determination of vehicle position by using available on-board location and movement data, and the correlation of the vehicle position to the digital transport network by appropriate map-matching-technologies. The necessary application-specific geo-database and transport information are specified and modelled. Capturing, maintenance, and provision of data and information are designed and exemplarily implemented. To realize a quality assured data capturing and provision the analysis of the entire information chain from source data to end user is necessary. Usage of an adapted quality concept of (geo) data guarantees provision of data in an applied quality and safety level.

Data modelling and preparation of geo data - assembling of a digital map as data base for positioning of cellular phones and FPD calculation

Determinating traffic participant routes using cellular phone positioning techniques requires a merged database of the cellular phone infrastructure, and a map of the road and railway network. This database is called „location network“. Traffic information calculated by cellular phone data is named „Floating Phone Data (FPD).

Main constituents of the localisation network, implemented during project Do-iT are:

- Position and direction of radio antenna of the cellular radio infrastructure
- Geometry and topology of the cells
- Radio wave propagation models and signal propagation data of cellular radio network planning systems
- Digital road network of individual traffic based on a commercial road map
- Traffic networks and timetables of public transport, e.g. railways of long distance trains and local trains, route networks of line busses of several transport companies.

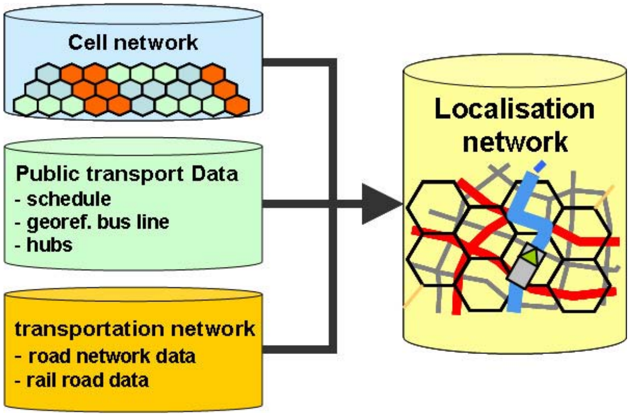

Fig. 5: Data sources for establishing the localisation network

To analyse the cellular phone data with total coverage and as fast as possible, a process-optimised calculation is essential. The data model of the localisation network was optimised for time efficient data access and pre-proceeded for fast processing in operation. During the second part of the project Do-iT the localisation network is implemented into the „FPD-Server". The appropriateness of the data network is tested in real time operations. By using these new technical expertises the model will be optimised.

Identification of active traffic participants by using cellular phone data

For individual traffic state detection using cellular phone data a differentiation of active and non-active behaviour of the subscriber in traffic is essential. Subscribers staying in buildings, or pedestrians, or those subscribers using public transport have to be identified and filtered out of FPD. In the project Do-iT the IAGB develops methods to ascertain and describe the moving behaviour using anonymous cellular phone data and to find out the kind of transport vehicle the subscriber is using.

Figure 6 shows a general view of the identification steps to be implemented. Analysis functions calculate a numerical membership for each traffic class. Using a plausibility model these traffic classes get higher membership values agreeing best to the results of the analysis function. So the positioning data of the anonymous cellular phone subscribers get more information on the traffic class memberships and the individual traffic class „active" or „non active".

Timetables and line routes of the public transport vehicles (line busses, local trains, long-distance trains) are included into the localisation network. Departure and arrival times of the public transport schedules were transformed with a fuzzy technique, due to imbalances in schedule times. Figure 7 shows the result of a test drive. The position membership of the subscriber going by bus to traffic class „line bus" of the analysis method is highlighted in red.

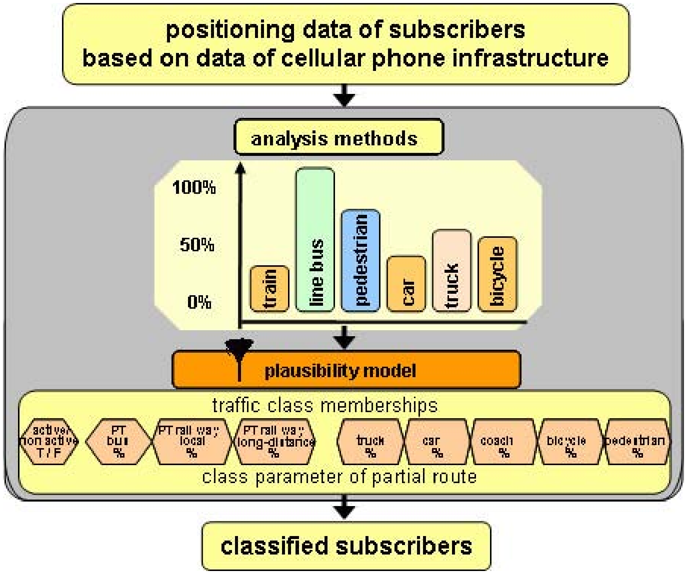

Fig. 6: Schematic data flow of traffic class determination of cellular phone subscriber

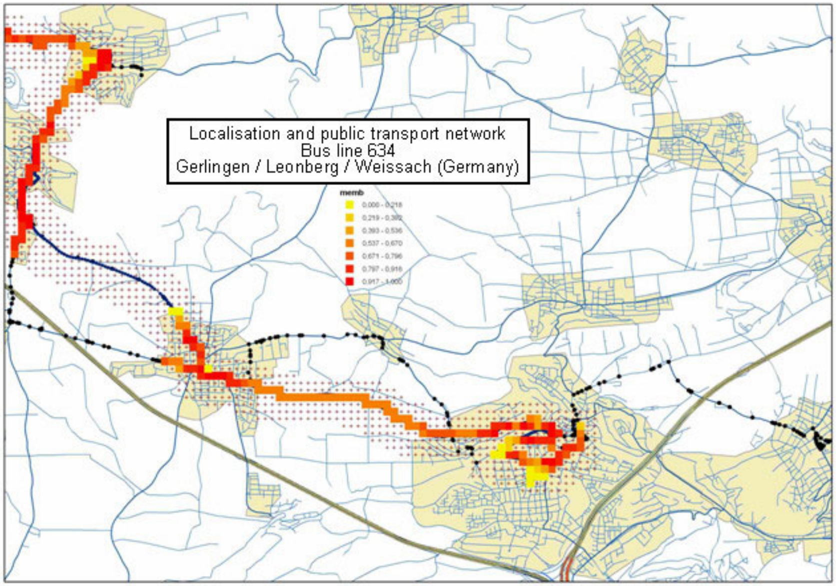

Fig. 7: Test drive to verify the analysis method for subscriber detection in public transport vehicles

A quality concept for geo data - Researches about impact of capturing and processing on geo data quality

Basis of the IAGB quality management concept is a fixed set of inherent quality characteristics, concretised by quality parameters (e.g. rate of change of attributes, rate of correctness of attributes). For determinating quality parameter values suitable evaluation methods are to be used. Management and exchange of quality values are effected by using metadata. The quality concept can be used within the entire information chain from capturing via processing up to mobility services.

The practicability of the quality concept was investigated within the demonstrator of the EC-project EuroRoadS. Therefore quality of collection and provision of speed limit information within a digital road database were analysed for a speed advice system.

The impact of acquisition processes on data quality was researched within the county of Ansbach (Bavaria) in cooperation with the project partners PTV AG and Bavarian Board of Building. Speed limit information from different public data sources were georeferenced on a commercial road network by using the INTREST-System. The quality of the captured data was evaluated by a detailed analysis of the capturing processes; e.g. rate of up-to-dateness, rate of change. Based on this experience recommendations were derived for quality assured area-wide capturing of speed limit information.

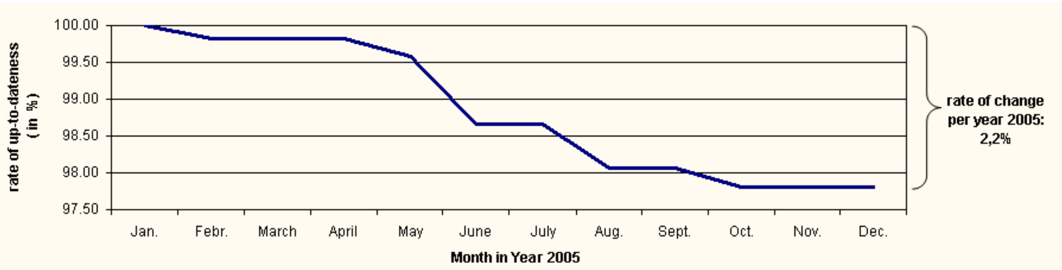

Fig. 8: Impact of annually updating (permanent and variable speed limits on highways in 2005 in North Bavaria)

The impact of processing on data quality was exemplarily researched by using test data of French and Austrian mapping and surveying authorities. The impact of coordinate thinning on data quality was evaluated. Furthermore the net matching and merging processes were evaluated regarding their impact on correctness and completeness. Based on these knowledge recommendations were derived for quality assured provision of speed limit information.

Fig. 9: Impact of Net-Matching on correctness and completeness (example roundabout)

A quality model for traffic information

In the research project Do-iT a quality model was developed, enabling the description of different types of data, occurring within the generation of traffic data, in a consistent and comparable quality frame. We succeeded in merging of suggestions of different stakeholders to a set of quality parameters which are important for the internal project data flow. Another aim of the project is the allocation of adequate quality parameters for users of the generated traffic data. For that purpose interviews with motorists at motorway stations and a survey of traffic providers were performed to shed light on kind and extend of desired quality descriptions. It turned out that the motorists are mostly interested in an amendment of traffic congestions by quality information, however, rather by additional information allowing the motorist to estimate quality of traffic information on his own than by direct quality parameters, such as standard deviations (see figure 10). Sometimes these kinds of information, such as expected dead time or congestion tendency are already broadcast by radio stations.

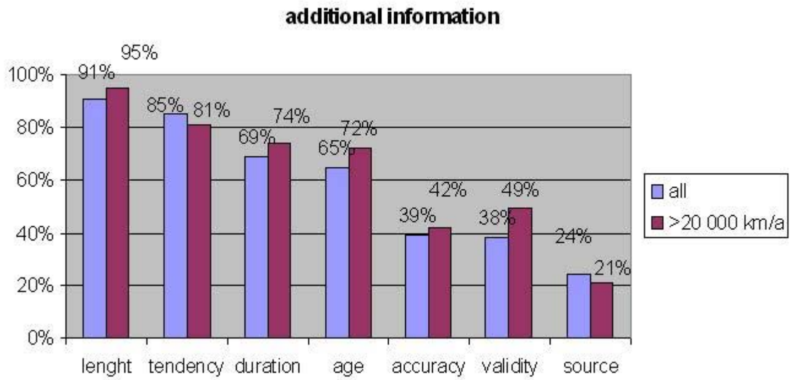

Fig. 10: Desired additional information to traffic reports (source: performed interviews within Do-iT; sample size: N = 150)

The survey of the service providers showed a high interest in direct quality parameters, however, with strong variations within the data type desired, as well as the corresponding quality description due to very different applications in parts. Applying cognitions of the surveys, instructions, containing hints and suggestions for an adequate editing of quality information, were developed.

Analyses of information structures and information chains occurring in the processes of the partners within Do-iT as well as the development of quality assurance methods are on focus for the coming year.

Microscopic accident analysis to identify application fields for advanced driver assistance systems (ADAS)

By order of DaimlerChrysler AG the study made in 2003 within the project INVENT, is updated. For the study area Stuttgart East all accidents of the years 2003 and 2005 are added. Together with the already available accident data of 1996 and 2001 the data base is increased to 1,274 accidents. Estimation of efficiency is focused on advanced driver assistance systems at intersections within urban road traffic, based on situational description of accidents and misbehaviour. In this way, traffic situations with high conflict and hazard potential are detected and correlated with the misbehaviour which is causal for the accident. The method microscopic accident analysis, developed at the institute and applied in different studies, uses accident data from the police as data source.

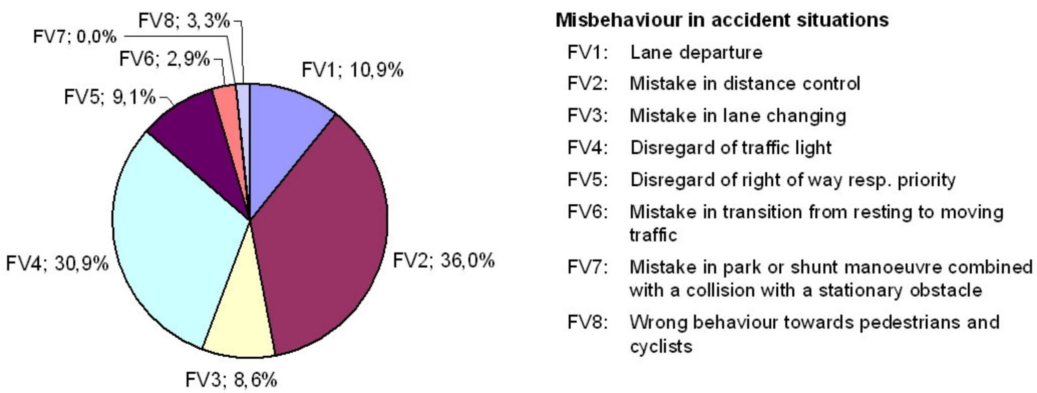

Fig 11: Frequency of misbehaviour at intersections with traffic lights at Stuttgart East (N = 1,274 accident situations, accident data from 1996, 2001, 2003, and 2005)

Projects - short descriptions

EuroRoadS (Pan-European Road Data Solution)

EuroRoadS is a project funded by the European Commission within the eContent-programme and finalized in August 2006. Aim of the project was the development of a platform for delivering public road data. By harmonised data exchange access will be simplified.

Focus of IAGB was development and implementation of a quality management concept for road data. Therefore a quality model was developed to be applied within the entire information chain and being part of the specified metadata catalogue. Feasible evaluation methods allow measuring of actually reached data quality and are an essential part to deliver quality assured road data. The approach with the specified data exchange model and quality management concept was realised and verified in different test sites.

Project website: www.euroroads.org

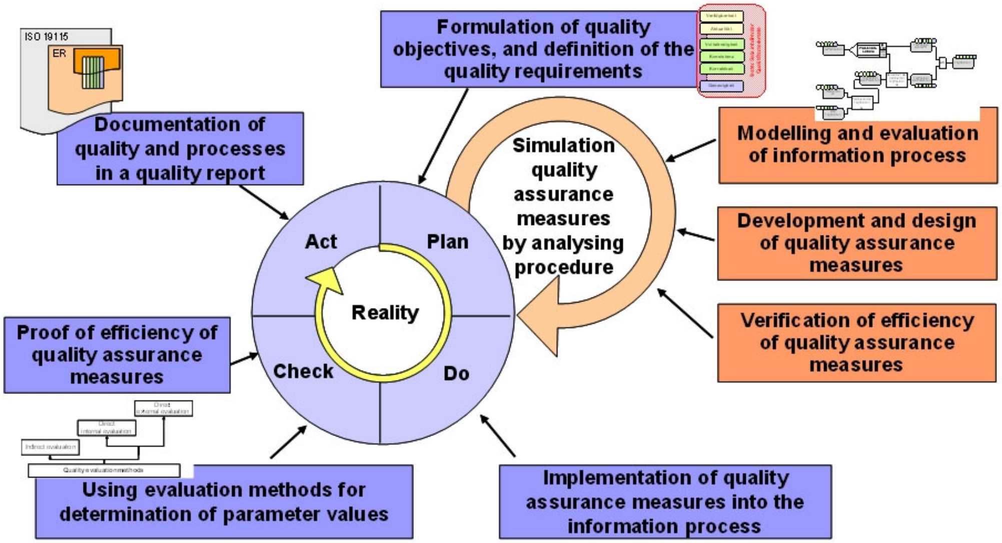

Fig. 12: Tasks for quality management of road data processing according the PCDA-cycle

Do-iT (Data optimisation for integrated Telematics)

Do-iT deals with acquisition of traffic data using mobile phone data. The application of the so-called floating phone data (FPD) for traffic planning and traffic control is investigated. The project is funded by the German Federal Ministry of Economics and Technology (BMWi) within the research initiative „Verkehrsmanagement 2010“. Duration is from April 2005 to June 2008.

Main activities of the IAGB are as follows:

- ▷ Localisation by mobile phone data
- ▷ Generation of routes using map-matching-technologies
- ▷ Identification of active road users
- ▷ Implementation of an accompanied quality management.

Project-website: www.vm2010.de/web/projekte/do-it.html

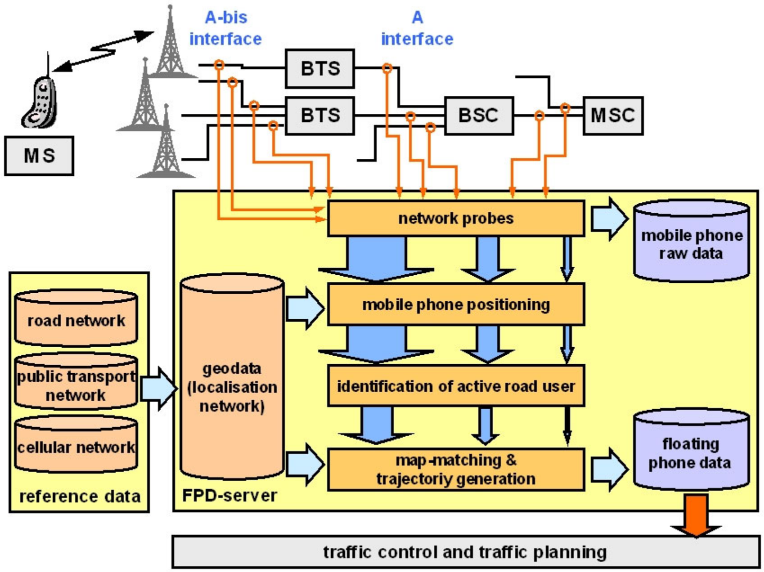

Fig. 13: System architecture and information flow for generation of floating phone data

GeoITCS

The IAGB and the Institute for Railway and Transportation Engineering of the University of Stuttgart work together in close co-operation with an industrial enterprise on the implementation of the results from research project RUDY. Within the project the achieved findings from integration of geo-information into intermodal transport control systems (ITCS) shall be transferred into a saleable product. Following topics are of peculiar interest:

- a board-autonomous map-based location including control of all operational events such as passenger information, communication of deviations from timetable, priorisation at traffic lights.
- a central disposition of standard operation, in case of incidents, and public transport on demand.
- a tool for capturing and managing the necessary geo-database
- a planning tool for provision geo-coded timetable and operation data.

Activities of Prof. Dr.-Ing.Dr.sc.techn.h.c.Dr.h.c. Klaus W. Linkwitz in 2006

Formfinding of Lightweight Surface Structures

The two-hour-lecture „Analytic Formfinding of Lightweight Surface Structures“ was incorporated into the 4-Semester Master Course „Computational Mechanics of Materials and Structures (COMMAS)“ for foreign students. It was given as a 32-hour compact course in the summer semester 2006. The additional appertaining practical computer exercises were performed on windows-NT-computers of the CIP-pool of the course „Water Resource Engineering and Management (WAREM)“ of the department „Civil- and Environment Engineering“ in the University Campus Pfaffenwald. The exercises were intensified, as a final, formally rated, project-work was demanded from the students

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, two lectures on the subject „Typical examples of computer-aided geometric design“ were held.

Publications

Dobeschnisky, H., Schollmeyer, R., Tritschler, S. und Wiltschko, T.: Advanced incident management in public transport by integration of geo data. Networks for Mobility - Proceedings of the 3rd International Symposium, 5 - 6 October 2006 in Stuttgart. Stuttgart: FOVUS.

Kaufmann, T., Schwieger, V: E-Learning for GIS, Cartopgraphy and Data Acquisition. GIS@development Middle East, Heft Nr. 2, März - April, 2006.

Kaufmann, T., Wiltschko, T: Metadata Catalogue. EuroRoadS project report deliverable D6.8

Kaufmann, T., Wiltschko, T: Quality Management Concept. EuroRoadS project report deliverable D2.4

Kaufmann, T., Wiltschko, T: Final Report on Quality Evaluation. EuroRoadS project report deliverable D2.6

Kaufmann, T., Wiltschko, T.: Quality assured road data by using the PDCA-cycle - experiences from EuroRoadS. Proceedings on Transport Research Arena Europe 2006. Göteborg

Kaufmann, T., Wiltschko, T.: Zum Einsatz von Metadaten im Qualitätsmanagement - ein Metadatenkatalog für Straßendaten. Strobl, J. et al (Hrsg.): Angewandte Geoinformatik. Beiträge zum 18.AGIT-Symposium 2006, Wichmann Verlag, Heidelberg, 2006.

Kaufmann, T. / Haspel, U.: Evaluation and Quality Management. EuroRoadS external workshop, Paris IGN, 09.03.2006

Michael, L., Kaufmann, T., Wiltschko, T, Haspel, U.: Measuring Results. EuroRoadS project report deliverable D7.6

Möhlenbrink, W., Schwieger, V: Navigation and Quality of Construction Processes. Proceedings on XXIII International FIG Congress, München, 8.-13.10.2006.

Möhlenbrink, W., Wiltschko, T., Kaufmann, T.: Zur Nutzung von Geodaten in Telematiksystemen. 9.Österreichischer Geodätentag 2006. Krems.

Ramm, K.: Enhanced Kinematic Positioning Methods by Shaping Filter Augmentation. Proceedings on 3rd IAG International Symposium on Geotechnical and Structural Engineering and 12th International Symposium on Deformation Measurements, Baden, Österreich, 22.-24.05.2006.

Ramm, K., Czommer, R., Schwieger, V.: Map-based Positioning using Mobile Phones. Proceedings on XXIII International FIG Congress, München, 8.-13.10.2006.

Schwieger, V.: Sensitivity Analysis as a General Tool for Model Optimisation - Examples for Trajectory Estimation. Proceedings on 3rd IAG International Symposium on Geotechnical and Structural Engineering and 12th International Symposium on Deformation Measurements, Baden, Österreich, 22.-24.05.2006.

Schwieger, V., Wanninger, L.: Potential von GPS Navigationsempfängern. GPS und Galileo. Beiträge zum 66. DVW-Seminar am 21. und 22. Februar 2006 in Darmstadt, Wißner Verlag, Augsburg, 2006.

Wiltschko, T. und Schollmeyer, R.: Potenzial von Geodaten bei Planung und Betrieb von öffentlichem Personennahverkehr. Fachbeitrag in Newstix - Informationsportal für den öffentlichen Personenverkehr

Wiltschko, T., Kaufmann, T., Haspel, U., Landwehr, M.: Speed limit acquisition and maintenance for administrative and safety related purposes. Experiences from the EuroRoadS-test site Bavaria. Proceedings on 13th World Congress and Exhibition on Intelligent Transport Systems and Services. London, UK, 8-12 October 2006

Wiltschko, T., Kaufmann, T., Landwehr, M.: A way to quality assured road data for a speed alert system. Networks for Mobility - Proceedings of the 3rd International Symposium, 5 - 6 October 2006 in Stuttgart. Stuttgart: FOVUS.

Wiltschko, T., Schollmeyer, R., Möhlenbrink, W., Tritschler, S. und Dobeschnisky, H.: Geodatenbasierte Ortung als Schlüssel zu einer effizienten Steuerung und einem flexiblen Betrieb im ÖPNV. DGON-Symposium „System Verkehr - Steuern, Regeln, Entwickeln“, 29.-30. November 2006 in Göttingen.

Wiltschko, T., Schwieger, V, Möhlenbrink, W.: Generating Floating Phone Data for Traffic Flow Optimization. Networks for Mobility - Proceedings of the 3rd International Symposium, 5 - 6 October 2006 in Stuttgart. Stuttgart: FOVUS.

Doctorates

Roland Bettermann: Integration von Geoinformation und Geodaten-gestützter Positionsbestimmung in Rechnergestützte Betriebsleitsysteme des öffentlichen Personennahverkehrs.

Diploma Theses

Kies, Markus: Qualitätsmanagement von Geodaten - Eine Untersuchung in ausgewählten Unternehmen, Behörden und Planungsbüros.

Prändl, Tobias: Qualitätsprüfung und -sicherung für Verarbeitungsprozesse von Geodaten - Planung und Implementation am Beispiel PTV AG.

Schnelle, Sigrid: Erstellung eines interaktiven internet-basierten Lernmoduls zum europäischen Satellitennavigationssystem Galileo.

Vlachou, Olga: Erstellung eines GIS-gestützten E-Learning-Moduls zur kartographischen 3D-Visualisierung - dargestellt am Beispiel von Geodaten in Stuttgart-Vaihingen.

von Vangerow, Philipp: Optimierung prognostizierter Fahrzeiten aus Ortungsdaten zur Steuerung von ÖPNV Fahrzeugen im Projekt RUDY.

Tsoupas, Apostolos: Erstellung eines E-Learning Moduls für die Immobilienwirtschaft - dargestellt am Beispiel einer GIS-gestützten Standortplanung für ein Hotel im Stuttgarter Süden.

Zhou, Tong: Überführung eines Straßendatensatzes in eine Knoten-Kanten-Struktur.

Study works

Miao, Qiong: (Teil-)automatisierte Integration von Geschwindigkeitsdaten in ein Straßennetz mit ArcGIS.

Ye, Zi: Erstellung eines E-Learning-Moduls zur Kartengestaltung - am Beispiel der (teil-) automatisierten Visualisierung von Straßendaten mit ArcGIS.

Education

Surveying I, II for Civil Engineers (Möhlenbrink, Laufer)	3/1/2/0
Surveying for Architects (Möhlenbrink)	2/0/0/0
Acquisition and Management of Planning Data (Möhlenbrink, Kaufmann, Schollmeyer)	2/1/1/0
Geodetic Measurement Techniques I, II (Wiltschko, Wengert, Ramm)	4/2/0/0
Statistics and Error Theory I, II (Schwieger, Metzner, Ramm)	2/2/0/0
Basic Geodetic Field Work (Ramm, Beetz)	5 days
Integrated Field Work (Schwieger, Laufer)	10 days
Surveying (Möhlenbrink, Beetz)	2/1/0/0
Surveying Engineering I, IV (Möhlenbrink, Czommer)	4/2/0/0
Surveying Engineering II, III (Schwieger, Beetz)	4/2/0/0
Multisensor Systems for Terrestrial Data Acquisition (Schwieger, Schollmeyer)	1/1/0/0
Causes and Impacts of Deformations in Structures (Möhlenbrink)	2/0/0/0
Geodetic Seminar I, II (Fritsch, Keller, Kleusberg, Möhlenbrink, Sneeuw)	0/0/0/4
Thematic Cartography (Möhlenbrink, Kaufmann)	1/1/0/0
Traffic Telematics (Wiltschko, Czommer)	2/1/0/0
Reorganisation of Rural Regions (Mayer)	1/0/0/0
Terrestrial Multisensor Data Acquisition (Schwieger, Schollmeyer)	2/1/0/0
Data Management and Analysis (Möhlenbrink, Kaufmann)	$\frac{1}{2}$/$\frac{1}{2}$/0/0
GIS Based Data Acquisition (Schwieger, Kaufmann)	1/1/0/0

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VOLLMER ANITA, Secretary

Guests

AWANGE J, Prof. Dr., Maseno/Kenia, 3.5.-23.6.06
BORKOWSKI A, Prof. Dr., Warschau/Polen, 30.11.-9.12.06
CHEN J, Shanghai/China, 17.1.-16.4.06
FEATHERSTONE W, Prof. Dr., Perth/Australien, 4.1.-18.10.06
GHITAU D, Prof. Dr., Bukarest/Rumänien, 12.6.-8.9.06
HOOIJBERG M, Dr., Genderen/Niederlande, 2.5.-11.5.06
HU C, Prof. Dr., Shanghai/China, 17.1.-16.4.06
KAKKURI J, Prof. Dr., Helsinki/Finnland, 8.5.-13.5.06
KOIVULA H, Masala/Finnland, 20.2.-24.2.06
KUHN M, Dr., Perth/Australien, 4.1.-19.1.06
LELGEMANN D, Prof. Dr., Berlin, 2.5.-6.5.06
MIRA S, Prof. Dr., Bandung/Indonesien, 1.3.-15.3.06
MORITZ H, Prof. Dr., Graz/Österreich, 3.5.-11.5.06
VARGA P, Prof. Dr., Budapest/Ungarn, 15.5.-15.6.06
WANG J, Prof. Dr., Shanghai/China, 17.1.-26.1.06
WU J, Prof. Dr., Shanghai/China, 17.1.-16.4.06
XU C., Prof. Dr., Wuhan/China, 2.3.-21.12.06
ZALETNYIK P, M.Sc., Budapest/Ungarn, 1.12.06-28.2.07

Additional Lecturers

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

Honorary Professors

HINTZSCHE M, Prof. Dipl.-Ing, Fellbach

Research

Spaceborne Gravimetry

Gravity field recovery from kinematic CHAMP-orbits by means of the acceleration approach

For the gravity-field analysis from CHAMP-data an acceleration approach was developed and applied successfully for the analysis of real satellite data. In the acceleration approach, the satellite's accelerations are computed from the kinematic orbit, which had been transformed into the quasi-inertial reference frame before. This is realized by means of numerical differentiation of second order, where the application of Newton-interpolation turned out to be suitable. Normally numerical differentiation leads to an increase of noise, but if the noise is correlated, the effect of noise can be diminished. In our case, since the noise of kinematic orbits is correlated, numerical differentiation can be classified as unproblematic in our case. In the next step, the obtained accelerations are reduced from disturbing gravitative and non-gravitative effects. By means of Newton's Law of Motion, these reduced accelerations are balanced by the gradient of the gravitational potential. The gravitational potential is represented by means of a spherical harmonics series expansion, where the spherical harmonic coefficients appear linear in the system of equations. For a resolution up to degree 90 from a two years' kinematic orbit data set 8278 parameters have to be estimated out of 6 millions of observations. In order to solve the system of equations for such dimensions, the method of preconditioned conjugate gradients (PCCG) is implemented, which ensures a stable and fast convergence. The convergence rate (5-15 iterations) can further be enhanced by application of a block-diagonal preconditioner.

From kinematic CHAMP-orbit data sets of the epoch March 2002 - March 2004, which were computed and provided by the IAPG (TU Munich) various gravity field solutions with a resolution up to degree and order $l_{max} = 90$ were estimated. Due to bad constellations of the GPS-satellites or too little observable GPS-satellites kinematic orbits may contain outliers and jumps which affect the accuracy of gravity field recovery quite strongly. For this reason, several outlier detection and removal strategies as wavelet-filtering, treshholding by means of orbit variances, treshholding by means of a comparison with reduced-dynamic orbits or robust estimation were tested. The best results were obtained with an application of the robust Huber-estimator within a re-weighted least-squares-algorithm, where already 2 iterations lead to convergence. Figure 1 shows a comparison of the estimated model GIS-CHAMP-Huber with the best pre-CHAMP-model EGM96 and two CHAMP-models EIGEN-3p und EIGEN-CHAMP03S, which were estimated with the classical approach. The figure indicates that CHAMP-data leads to a significant improvement in contrast to pre-CHAMP-models for long-wavelength features of the gravity field. The figure also reveals that the acceleration approach is able to compete with other methods for CHAMP-data-processing.

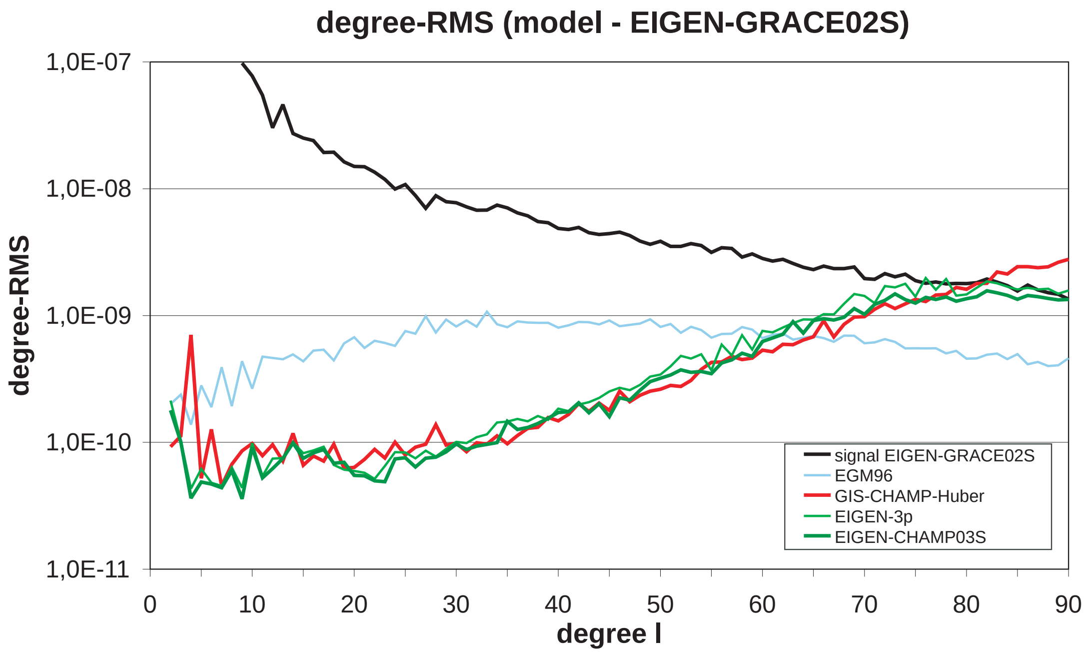

Figure 1: GIS-CHAMP-Huber compared to EGM96 and CHAMP-models, which were estimated by means of the classical method (EIGEN-3p, EIGEN-CHAMP03S)

Global and local gravity field recovery from CHAMP and GRACE using the energy balance approach

Applying the energy balance approach to CHAMP data yields gravity field solutions on the same level of accuracy as the official EIGEN-solutions of the GeoForschungsZentrum Potsdam, thus proving the suitability of this approach. In particular, the current research aims at a reprocessing of kinematic position data and at a refinement of the data processing strategies. Although the energy balance approach is theoretically simple, its implementation proved to be quite challenging. By refining the processing techniques an improvement of up to 30% is reached for the low degree spherical harmonic coefficients. Nevertheless, the solutions still depend strongly on the variability of the ground track. The quality of the monthly solutions can vary up to one order of magnitude, cf. Figure 2. Since CHAMP and GRACE data is available for overlapping time periods, it is possible to compare and combine the data for the calculation of spherical harmonic coefficients up to degree 70. It is important to note that the two GRACE satellites are considered independent, i.e., three single satellite missions of the CHAMP-type. The advantage is that the data availability is tripled and insight into the quality of the provided data is gained. Of course, by neglecting the highly precise inter-satellite range measurement the accuracy of the GRACE solutions like, e.g., GGM02, is not achievable. However, the new and unique combination method yields a more homogeneous set of solutions and reaches the edge of the recoverability of a time-variable gravity signal from high-low satellite-to-satellite tracking missions. Since the CHAMP satellite is at a lower altitude than the GRACE satellites for the same time period, the effects of upward and downward continuation can be studied. In addition, the energy balance approach provides in-situ potential values along the orbit, thus the gravity field recovery can also be done in local areas. The aim is to make optimal usage of the data distribution in the high latitude area. For this, interpolation and downward continuation techniques are investigated and an improvement, compared to the global solutions, is achieved. Overall, the analysis provides new and valuable insight into the data processing of satellite-to-satellite tracking data using the energy balance approach.

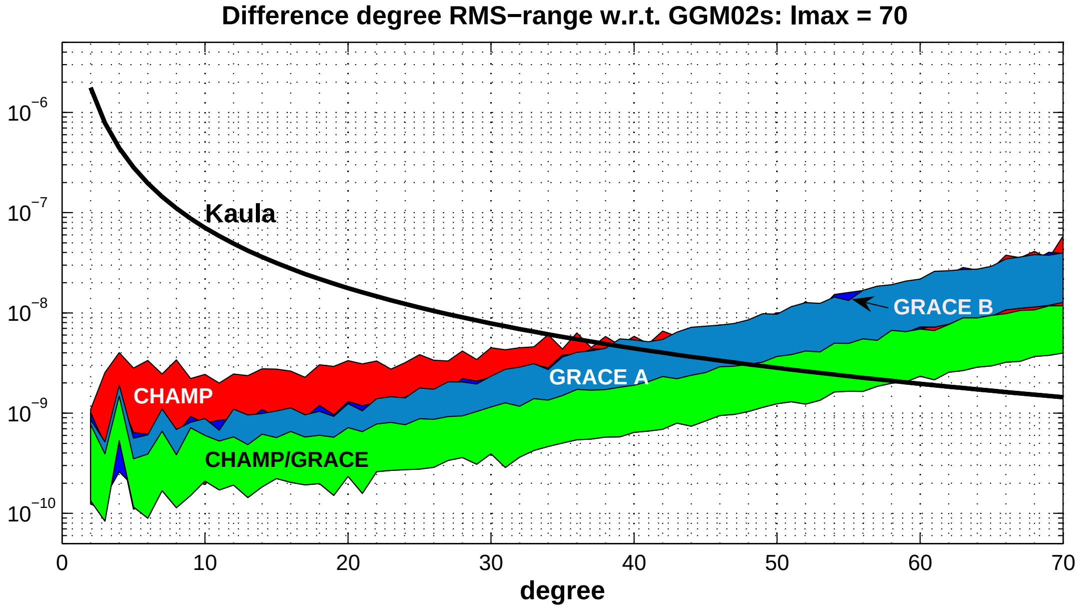

Figure 2: Spread of the difference degree RMS w.r.t. GGM02s of the monthly CHAMP and GRACE solutions

GOCE Gravity Field Recovery

Dedicated to be launched in autumn 2007, the ESA satellite mission GOCE (Gravity field and steady-state Ocean Circulation Explorer) will be the first gradiometer experiment in satellite geodesy history. To meet the scientific objectives, national programs have been designed to support the activities of the European GOCE Gravity Consortium (EGG-C). The German part is called GOCE-GRAND (GOCE GRavitationsfeldANalyse Deutschland). It is funded by the Federal Ministry of Education and Research (BMBF) and the German research foundation (Deutsche

Forschungsgemeinschaft) within the GEOTECHNOLOGIEN II program „Observation of the System Earth from Space“. Originally initiated in 2002, due to the successful activities in the first funding phase, GOCE-GRAND has been extended for funding until at least October 2008. Partners of the national project are the Universities in Stuttgart, Munich, Bonn, Hanover and Hamburg as well as the GeoForschungsZentrum (GFZ) Potsdam and the Federal Agency for Cartography and Geodesy (BKG) in Frankfurt.

In particular the GIS is concerned with gravity field processing from satellite tracking and gravity gradiometry data. More precisely we deal with the following topics: (i) Kinematic orbit analysis for long-wavelength structures recovery, (ii) Gradiometry analysis in terms of rotational invariants of the gravitational tensor, (iii) Investigation and solution of the polar gap problem, (iv) Stochastic characterization of the gradiometer instrument by means of residuals analysis, (v) Fast and efficient Least Squares solvers and (vi) Parallel implementation of the routines.

Slepian Functions for Satellite Geodetic Applications

From the mathematical point of view, global gravity field modeling is typically based on spherical harmonic expansion of the potential function. Legendre functions, and thus surface spherical harmonics, are defined globally and satisfy the orthogonality relations on the sphere. However, satellite ground tracks often leave out polar areas. Especially for the GOCE (Gravity field and steady-state Ocean Circulation Explorer) mission a double polar cap with a radius of more than six degrees ($\Theta_0 \sim 6.6°$) will not be covered by observation data, cf. Figure 3. The misfit between data measurements and the geopotential modeling is conventionally treated by augmenting data in the polar regions. Alternatively, we propose the Slepian approach. The philosophy of the approach is not to adapt the observation scenario to the modeling but, instead to adapt the parameterization of the geopotential to the observations. This results in band-limited base functions that are optimally concentrated on the spherical belt of data coverage. Exemplary for order $m = 0$ and the maximal function index 50, Figure 4 display the spatial concentration of Slepian functions.

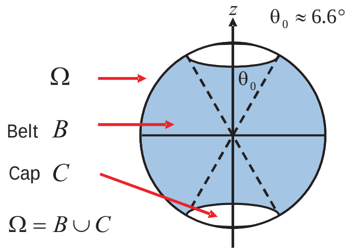

Figure 3: GOCE mission configuration

Besides the polar gap problem, Slepian functions can be used in geodesy for the modeling of arbitrary local phenomena such as surface mass densities due to hydrological changes. This field of research is based on time-varying gravity field models provided by the GRACE (Gravity

Recovery And Climate Experiment) satellite mission. Only base functions with local support allow adequately map regional physical properties. It is important to mention that basically the Slepian approach is to take into consideration for any band-limited problem. In this context, its special application in satellite geodesy with regard to GRACE and GOCE is just an example.

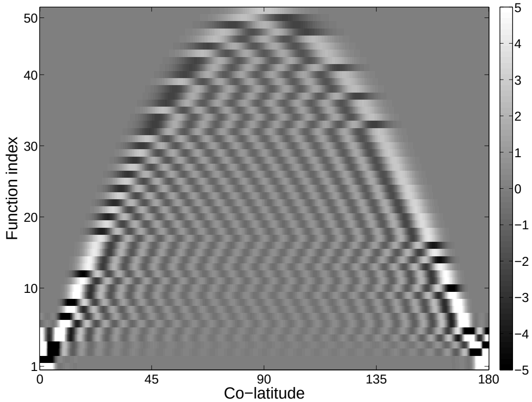

Figure 4: Slepian functions (L = 50, m = 0)

Future mission design

Through its monthly Earth gravity field solutions, the twin satellite mission GRACE has an enormous impact in geodesy, hydrology and related Earth science disciplines. Nevertheless it suffers from a number of weaknesses:

- ▷ 1. Of all potential satellite formations, the GRACE scenario, i.e. an in-plane leader-follower configuration, is one of the weakest choices in terms of gravitational signal in the satellite-to-satellite tracking (SST) observable.
- ▷ 2. The combination of along-track SST and a mainly North-South ground-track causes a strong North-South error behaviour in the gravity field and geoid solutions.
- ▷ 3. Time-variable gravity signals with typical timescales below one month are aliased into the monthly solution.

The concept of formation flying (FF) would solve the former two problems. Several formation types, beyond the GRACE configuration, are subject of research: Pendulum configurations, as for the planned geomagnetic mission SWARM; CartWheel formations, as designed for InSAR applications; and relative circular motion, as it is planned for the gravitational wave detection mission LISA. Each of these alternative mission scenarios outperforms a GRACE-type scenario in terms of signal strength and error behaviour of the resulting gravity fields and geoids.

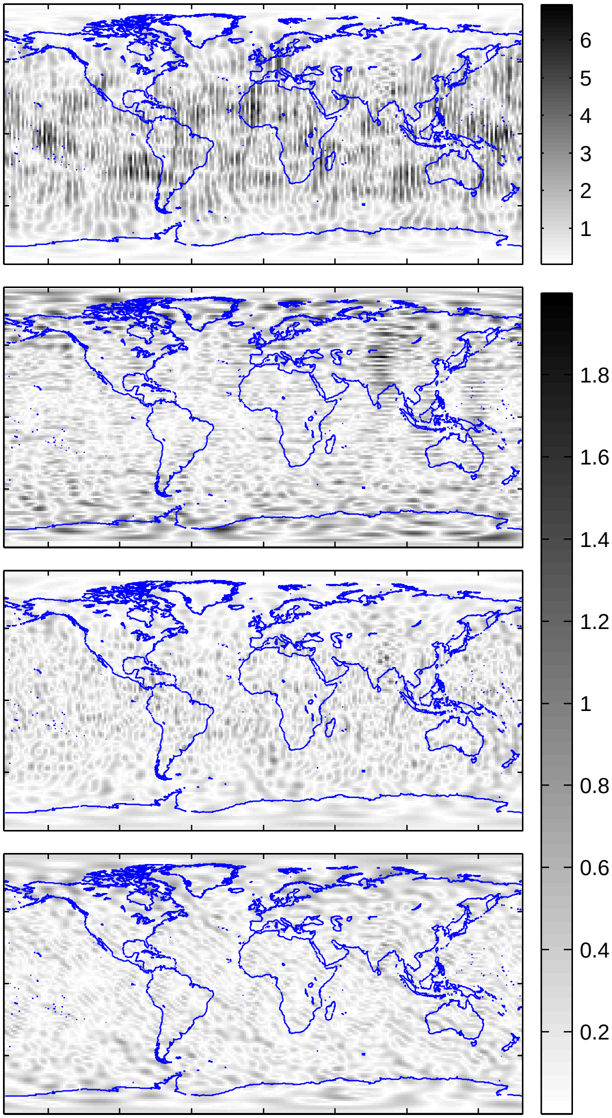

Figure 5: Typical error characteristics from gravity field recovery using satellite formations. Geoid height residuals in meter (from top: GRACE, Pendulum, Cartwheel and LISA). Note the different gray scale for GRACE.

GRACE Hydrology

The GRACE gravity field mission produces time series of the Earth's gravity field with a monthly sampling. Gravitational signals at lower frequencies will necessarily alias into the monthly solutions. After dealiasing, i.e. by applying global models for atmosphere, tides and oceans, the remaining time-variable gravity signal is mainly due to changes in the hydrological mass budget.

In the framework of the DFG-funded Priority Programme „Mass Transport and Mass Distribution in the Earth System", SPP 1257, the Institute of Geodesy is leading the project „The global continental water balance using GRACE spaceborne gravimetry and high-resolution consistent geodetic-hydrometeorological data analysis". In a joint effort with hydrologists and atmosphere scientists it is attempted in this project to model gravitational changes and hydro-meteorological parameters like river run-off, evapo-transpiration and atmospheric moisture fluxes in a consistent way. The first phase of this 6-year project is concerned with the validation and calibration of GRACE mass budget estimates in climatological zones of known, e.g. zero, hydrological signal.

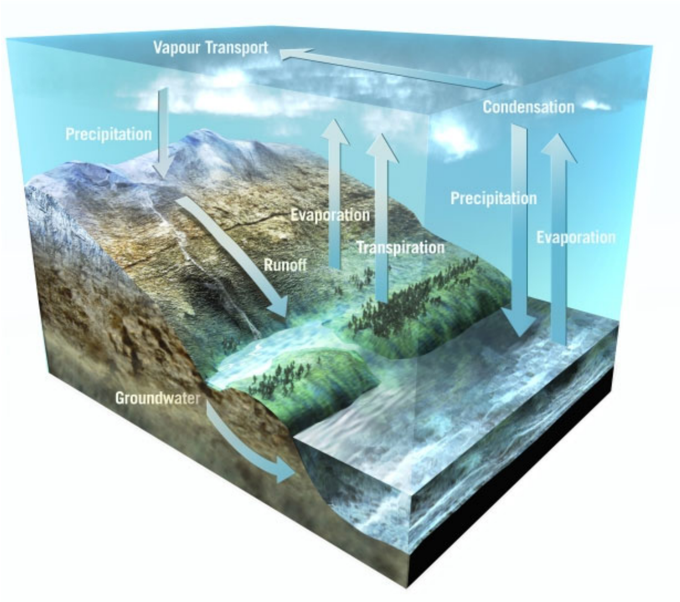

Figure 6: Water cycle, courtesy of ESA

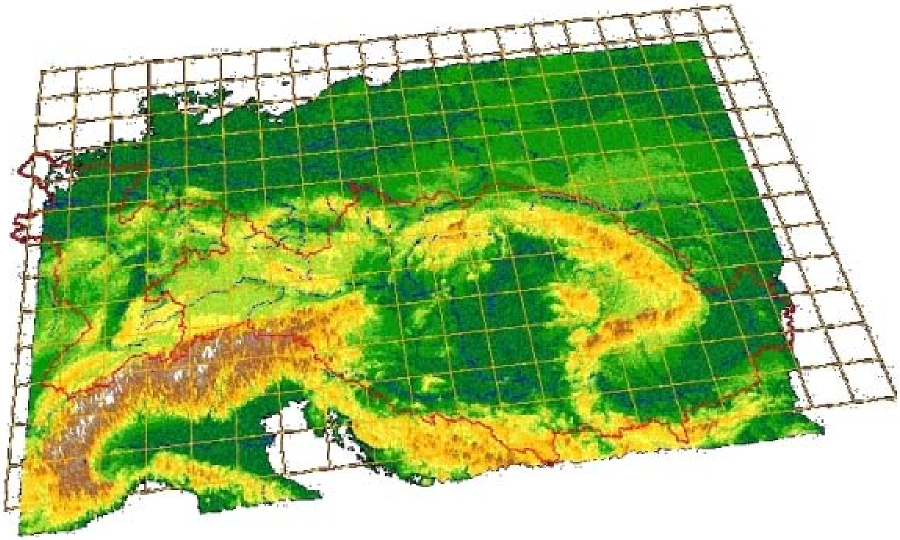

Figure 7: Rhine / Danube system

GOCE Oceanography

The European satellite gradiometry mission GOCE, which is due for launch late 2007 or early 2008, will provide a high-resolution geoid of high and homogeneous accuracy. In combination with sea surface height information from satellite altimetry the GOCE geoid will enable to derive the difference of these two surfaces: the sea surface topography. Although in principle a simple subtraction, this is not a trivial task. Two signals of about ± 100m are subtracted to yield a sea surface topography signal of a few dm in magnitude. This procedure is highly sensitive to errors. One of the problems is resolution: a typical footprint of satellite altimetry is about 7 km, whereas the GOCE resolution is rather 100 km. Subtraction in the spectral domain, which would be the obvious solution to this problem, is not directly feasible either, since the sea surface height from satellite altimetry is only provided over the ocean surfaces. To solve these problems, or at least to hide them from future oceanographic users of GOCE products, has been the topic of research of the European Space Agency project GOCE User Toolbox Specification.

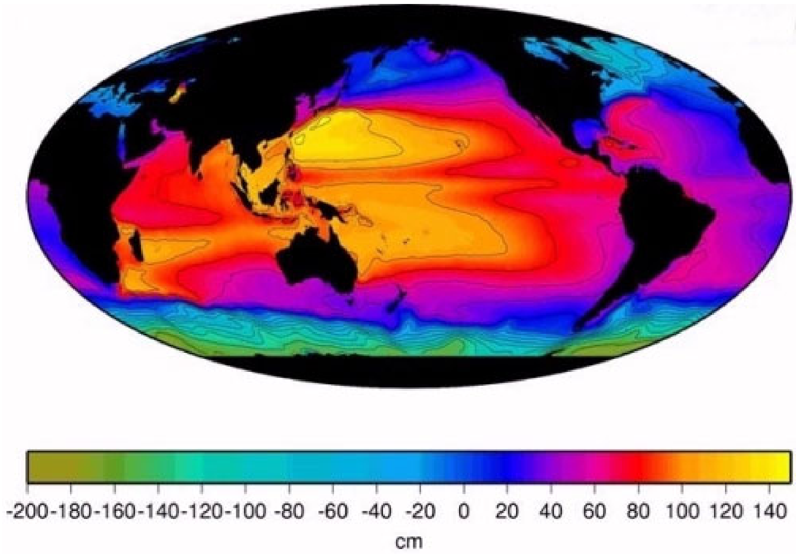

Figure 8: Sea surface topography, courtesy of NASA-JPL

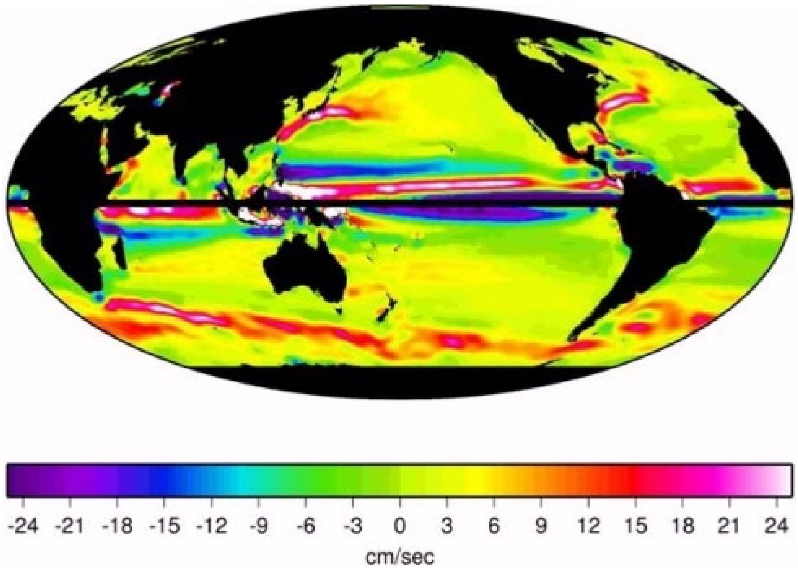

Figure 9: Geostrophic ocean circulation, courtesy of NASA-JPL

Gravity and Geoid Modeling

Geoid modeling in the singularity-free gravity space formulation

The classical geodetic boundary value problem (GBVP) is a linear free boundary value problem, which implies considerable mathematical difficulties for the investigation of its existence and uniqueness properties. Almost 30 years ago F. Sansò has pioneered a break-through concept for solving the GBVP, which has become known as the gravity space approach. F. Sansò proposed a solution of the GBVP by mapping it into an auxiliary space referred to as gravity space by using the well-known Legendre transformation, the simplest form of a contact transformation. Prompted by the fact that F. Sansò's transformed problem suffered from a singularity at the origin, W. Keller suggested several years later a modified contact transformation. His singularity-free gravity space approach holds, after linearization with respect to a spherical normal potential, the same mathematical structure as the simple Molodensky problem. Thus, all well-known and commonly used algorithms and procedures developed for the solution of the traditional Molodensky problem can be used further on. Despite conceptual advantages of treating the geodetic boundary value problem in gravity space, the numerical evaluation of the linearized problem implies certain difficulties originating mainly from linearization at a spherical normal potential. Lately, remedy is sought-after in adopting an ellipsoidal normal potential as linearization point. Therefore, the aim of present research is to examine the suitability of using an ellipsoidal normal potential as linearization point. The key questions to be answered are, whether the mathematical structure of a simple Molodensky problem can be preserved and whether introducing an ellipsoidal normal potential is numerically advantageous. For the first time, numerical experiments have been conducted to verify the theoretical concepts of the various gravity space formulations. They give indication that gravity field determination can also successfully be carried out in gravity space.

Astro-Gravimetric Geoid Determination

A broad range of geodetic, geophysical, oceanographic, and engineering applications require precise geoid models. An advanced geoid determination method has been developed, based on the remove-restore concept. The availability of GPS coordinates of the observation point leads to a fixed-free boundary value problem. In contrast to existing methods, all reductions are formulated according to ellipsoidal geometry. Furthermore, a new definition of the deflection of the vertical in 3D space at observation level leads to a significantly better approximation of the measured quantities. It results in a smoother signal which causes smaller errors in the downward continuation process. It should be emphasized that this method is open for any kind of observables related to Earth's gravity potential. They are formulated as integral equations of the first kind. The inversion combines all different types of observations. Each type can contribute its particular strength to the solution. This allows the combination of historic data with recent measurements. The method has been successfully tested for the determination of the Finnish geoid.

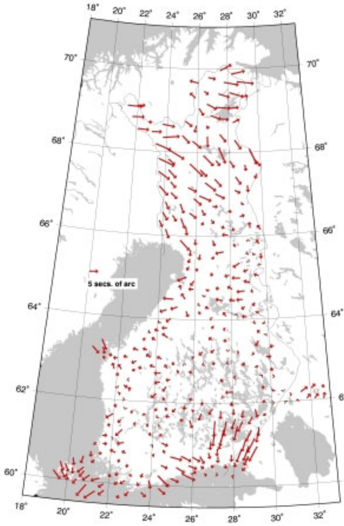

Figure 10: Vertical Deflections at Stations of 1st Order Triangulation Network

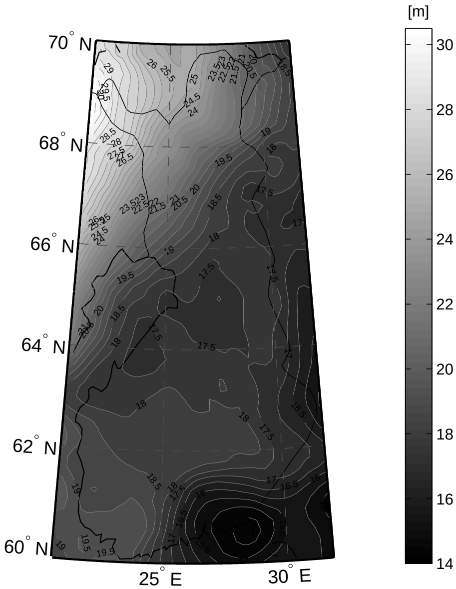

Figure 11: FINN2004 Geoid Model

Microgravimetry

In summer of 2006, the Institute of Geodesy acquired a Scintrex CG-5 Autogravimeter. Now we are able to precisely measure gravity differences in microgal resolution with present state-of-the-art technology. The device is a full automatic relative gravimeter with a quartz spring. This involves no more influence by the Earth magnetic field and reduces the influence from mechanical shocks and radio link systems. The CG-5 is able to reduce tidal effects, tilt corrections and internal measurement errors - like drift of the quartz spring - in situ. Position and time for the tidal correction are retrieved with an associated GPS antenna.

Of utmost importance is the precise determination of the gravimeter calibration factor. At Zugspitze, the Universities in Hannover and Munich installed a calibration line with high accuracy and a large gravity range ($\sim$ 500mGal). We will work close together with these established research groups in gravimetry to determine the best calibration factor for our gravimeter. Another intention is to find out more about behaviour and special manners of the new CG-5 type series. In cooperation with the Landesvermessungsamt Baden-Württemberg we perform local gravity survey campaigns. Our objective for the near future is the investigation of the local gravity field as well as the validation of data provided by airborne gravimetry.

Figure 12: Scintrex CG-5 and LCR No.754 of Institute of Geodesy at Hornisgrinde

Geodynamics

Surface Deformation Analysis of Dense GPS Networks based on Intrinsic Geometry (Deterministic and Stochastic Concepts)

Here we present a method of differential geometry, an intrinsic approach that allows deformation analysis of the real surface of the Earth on its own rights for a more reliable and suitable estimate of the surface deformation measures. The method takes advantage of the simplicity of the two-dimensional Riemannian manifold spaces versus the three dimensional Euclidean spaces without loosing or neglecting information and effect of the third dimension in the results. Here we describe the regularized Earth's surface as a graded two-dimensional Riemann manifold, namely a curved surface, embedded in a three dimensional Euclidean space. Thus, deformation of the surface can be completely specified by the change of the first and second fundamental tensor, namely metric and curvature tensor, of the surface, which changing of curvature tensor is responsible for detection of vertical displacements on the surface. This study describes analytical modelling, derivation, and implementation of the surface deformation measures based on the proposed method, particular attention to the formulation and implementation of the tensors of rotation and tensor of change of curvature in Earth deformation studies. The method is applied to a real data set of dense space geodetic positions and displacement vectors across Southern California. A comparison of the patterns with the geological and geophysical evidences of the area indicated how well the patterns were able to reveal different geodynamical features of the region. The eigenspace components, e.g. principal components and principal directions of two-dimensional symmetric random tensor of second order, are of central importance in deformation analysis. In the second step of this research we present the statistical inference of the eigenspace elements of symmetric random deformation tensor. Both of deformation tensors, namely Lagrange deformation tensors of first and second kind are given in two dimensional Riemann manifold with standard positive-definite metric. In order to have eigenspace components namely eigenspectra-eigendirections, we are led to simultaneously diagonalized quadratic forms of both deformation tensor and standard positive-definite metric. Then by solving the eigenvalue-eigenvector problem we get the eigenspectra components. With other words, without loss of generality we mapped eigenvalues as well as orientation parameters from the Riemann manifold onto equal corresponding quantities in the two-dimensional Euclidean space, namely the plane. Due to the nonlinearity of function between eigenspace components in two-dimensional Euclidean space and the assumption of random tensor components, is established a special nonlinear multivariate Gauss-Markov model. For its linearized form the best linear uniformly unbiased estimate (BLUUE) of eigen-space elements is done. Based on the knowledge of variance-covariance of tensor elements on the Riemann manifold, e.g. changing of metric and changing of curvature tensors, variance-covariance matrix of eigenspectra-eigen directions is also obtained in the Euclidean space.

The statistical analysis of the eigenspace components of the strain rate tensor derived from FinnRef GPS measurements (1997-2004)

In the deformation analysis in geosciences (geodesy, geophysics and geology), we are often confronted with the problem of a two-dimensional (or planar and horizontal), symmetric rank-two deformation tensor. Its eigenspace components (principal components, principal direction) play an important role in interpreting the phenomena like earthquakes (seismic deformations), plate motions and plate deformations among others. With the new space geodetic techniques, such as VLBI, SLR, DORIS and especially GPS, positions and change rates of network stations can be accurately determined from the regular measurement campaign, which is acknowledged as an accurate and reliable source of information in Earth deformation studies. This fact suggests that the components of deformation measures (such as the stress or strain tensor, etc.) can be estimated from the highly accurate geodetic observations and analyzed by means of the proper statistical testing procedures. In this study we have investigated the geodynamic setting of the selected investigated regions: Fennoscandia (see Fig. 13). Then the annual station positions and velocities of FinnRef through the regular GPS observations in Finnish permanent GPS network (FinnRef) are prepared. Thirdly the methods of derivation the two-dimensional geodetic strain rates tensor from the surface residual velocities and the newly developed estimates BLUUE of the eigenspace elements and BIQUUE of its variance-covariance matrix are implemented. In the case study both BLUUE and BIQUUE models are applied to the eigenspace components of two-dimensional strain rate tensor observations in Fennoscandia, which are derived from 1997 to 2004 annual station positions and velocities of FinnRef. Further detailed analysis of the results is also performed with respect to geodynamical and statistical aspects.

Glacial-isostatic adjustment in a 3-D viscoelastic earth

The retarded glacial-isostatic adjustment (GIA) of the earth to the last deglaciation ($<$20,000 years before present) is evident in raised paleo-shorelines. The adjustment to decadal ($<$100 years) and recent ($<$10 years) glacial changes can be recorded by GPS, tide-gauge, altimetry and gravity measurements. For the computation of GIA, it is necessary to use a viscoelastic earth model. The importance of predicting the glacially induced adjustment of the earth is that it allows us to extract from the observations non-GIA processes also contributing to the records, such as ground-water and ocean-circulation changes. To predict the earth's viscoelastic response correctly, lateral variations of the lithosphere thickness and mantle viscosity related to the plate-tectonic units on spatial scales of thousands of kilometers must be taken into account. For this purpose, a 3-D viscoelastic earth model has been developed. In comparison to 1-D models, the 3-D model has the advantage that it allows us to compute the global-scale response of the earth induced by glacial loads acting simultaneously on different plate-tectonic units. Another reason for developing a 3-D viscoelastic earth model is that it can also be used to predict the response for regions bisected by plate-tectonic boundaries, such as southeastern Alaska, Antarctica, Iceland, Patagonia and Svalbard, where recent glacial changes have occurred (Fig. 14/15).

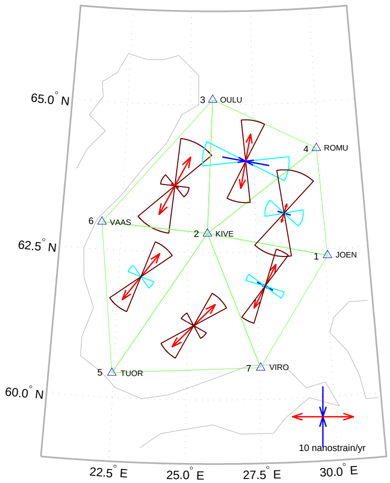

Figure 13: Eigenspace components (eigenvalues and eigendirections) of the two-dimensional strain rate tensors and their 95% confidence intervals, estimated from the strain rate observations of FinnRef97 to FinnRef2004 series in the seven triangle sites in the study region. Extension is represented by symmetric arrows pointing outward and contraction is represented by symmetric arrows pointing inward.

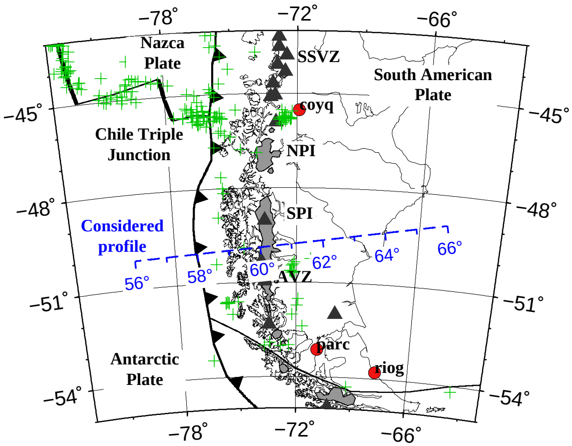

Figure 14: Tectonic setting of southern South America. The Patagonian ice field is shown in grey shading. The subduction zone is indicated by the line with triangles. The dashed line shows the profile considered in Figure 15.

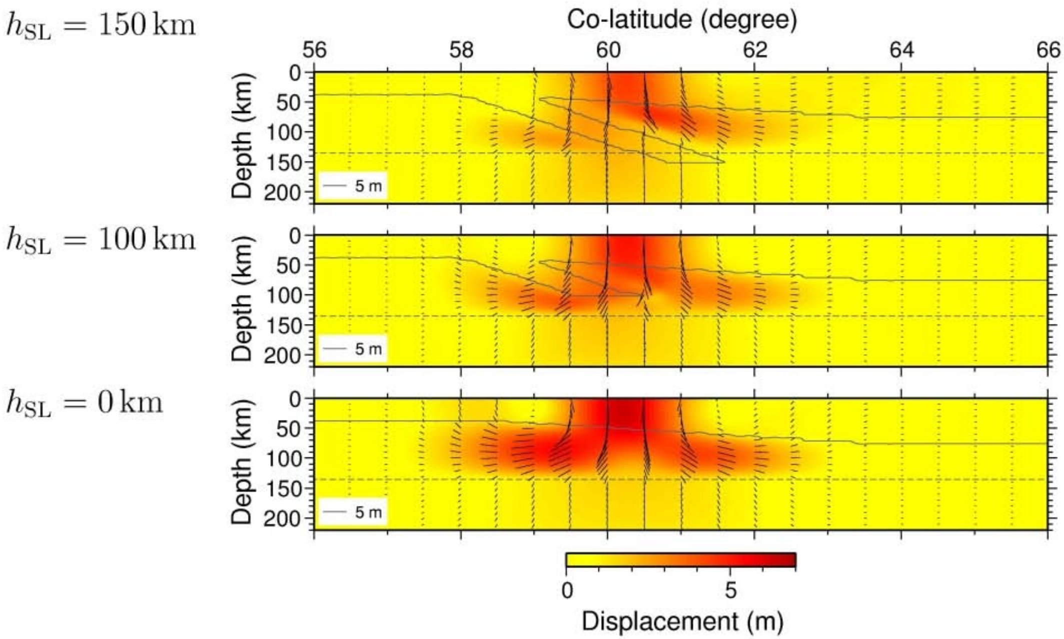

Figure 15: Present-day displacement field in response to recent melting of the Patagonian ice field (near 60° co-latitude) for viscoelastic earth models with slab penetrating below the asthenosphere (top), with slab terminating inside the asthenosphere (centre) and without slab (bottom). The solid line shows the base of the lithosphere and outlines the subducting slab, the dashed line shows the base of the asthenosphere.

Miscellaneous

Wavelet filtering of laser-scanning data

For the derivation of digital elevation models from laser-scanning data reflections from buildings, cars or foliage have to be removed in a pre-processing step. Due to the huge amount of data fast methods as wavelet analysis are desirable. The transition of the laser-reflection from the ground to a building and back to the ground is indicated in the wavelet spectrum by a pair of mirrored patterns. The detection of this pairs of patterns leads to a very fast method of cleaning of laser-scanning data.

Statistical estimation and hypothesis testing for the GPS mixed integer linear models

(1) The uniform Tykhonov-Phillips regularization (α-weighted S-homBLE) and its application in GPS rapid static positioning

In high accuracy GPS positioning the conventional least-squares method is widely applied in processing of carrier phase observation. But it will not be always succeed in estimating of unknown parameters, in particular when the problem is ill-posed, for example, there is the weak multicollinear problem in the normal matrix with shorter period GPS phase observation. In this study the newly developed method of determining the optimal regularization parameter α in uniform Tykhonov-Phillips regularization (α-weighted **S**-homBLE) by A-optimal design (minimizing the trace of the Mean Square Error matrix MSE) is implemented in the GPS mixed integer linear model. With A-optimal regularization the ill-posed problems in both GPS rapid static and real time kinematic positioning with single or dual frequency measurements, especially for the shorter period observations, are successfully overcome. In the case study, both the estimate methods are applied to process the two epoch L1 data in single frequency GPS rapid static positioning. The effects of the initial coordinate accuracy are also analyzed. The results show that the new algorithm with optimal regularization can significantly improve the reliability the GPS ambiguity resolution in shorter observation period.

(2) In the frame of this project the general criterion in estimating coordinates and ambiguities parameters with the GNSS carrier phase observations, directional statistics and its application in the hypothesis testing of GPS integer ambiguity resolution and the statistical property of the GNSS carrier phase observations and its effects on the hypothesis testing of the related estimators are studied.

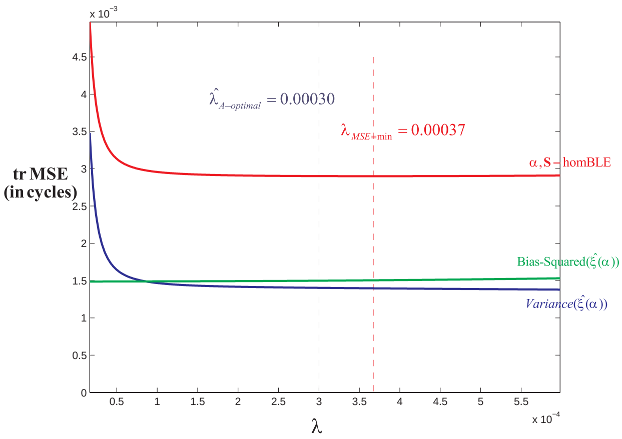

Figure 16: The trace of the MSE functions for the λ-weighted homBLE estimates of the unknown as functions of λ, where the minimum trace of MSE is arrived at 0.00037 (right dot line). The regularization factor $\hat{\lambda}$ estimated by the A-optimal design (left dot line) is about 0.00030.

High Performance Computing at the GIS

In the last few years the requirements to modern terrestrial gravity field modelling increased continuously with regard to both high accuracy and high resolution. In this context the computational part has dramatically gain in importance. Actually, present large-scale problems as occurring in geodesy can not be tackled by ordinary personal computers due to both runtime and main memory availability. Exemplary for the GOCE (Gravity field and steady-state Ocean Circulation Explorer) satellite mission, Figure 17 displays the number of observations dependent on the mission duration. Additionally, Figure 18 illustrates the number of geopotential model parameters as a function of the gravity field spectral resolution. With an anticipated sampling rate of only one second, the peak problem dimension of the scenarios considered is as follows: resolve around 63000 unknown parameters from more than 90 million observations. The philosophy for solving such huge-dimensioned systems of equations is based on using several CPUs (Central Processing Unit) at the same time referred to as parallel computing or High Performance Computing (HPC) if it is accomplished professionally.

Due to the cooperation with the High Performance Computing Center Stuttgart (HLRS) the GIS is in the excellent situation to collaborate with a highly qualified institution concerning HPC topics. To use their computational resources, a research project has been defined and accepted for funding by the Federal Ministry of Education and Research. Until the end of 2008 the GIS has free access to an annual 20000 CPU-hour budget. This corresponds to an overall financial support of around 280.000 Euro. Therewith the computational framework is given to compete in state-of-the-art gravity field research.

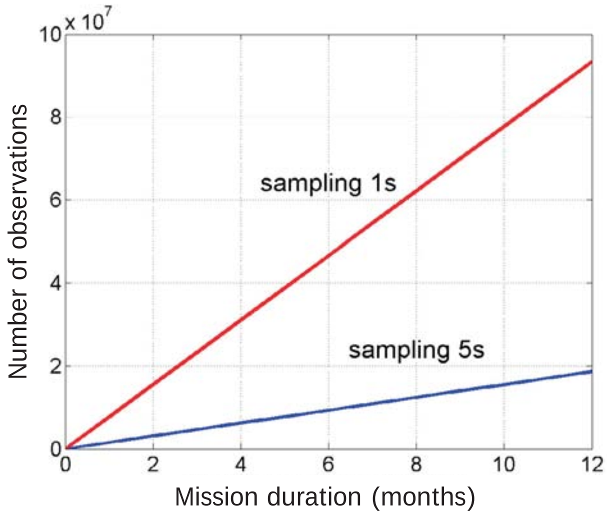

Figure 17: GOCE observations dependent on the mission duration

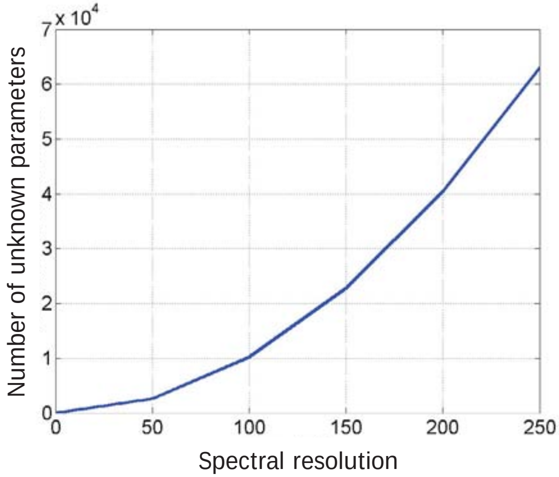

Figure 18: Number of unknown parameters dependent on the resolution

Theses

Doctoral Theses

SHARIFI M A: Satellite to Satellite Tracking in the Spacewise Approach (13.7.06)

Study Theses

BAUM M: Evaluierung und Kalibrierung von CHAMP-Akzelerometerdaten anhand von Atmosphärenmodellen (Evaluation and calibration of CHAMP-accelerometer data with atmosphere models)

FUCHS T: Statistische Analyse der Eigenraumkomponenten der Strain-Rate-Tensoren in Fennoskandien (Statistical Analysis of the eigenspace components of the strain rate tensors in Fennoscandia)

MARIAN C: Charakterisierung, Identifikation und Analyse von Wiederholungsmustern und Resonanzen in CHAMP und GRACE-Satellitenbahnen (Characterization, identification and analysis of repitition samples and resonances in CHAMP and GRACE satellite orbits)

SCHNELLE S: Slepian-Funktionen für GRACE-Hydrologien (Slepian functions for GRACE-Hydrology)

Publications

Books

GRAFAREND E: Linear and nonlinear models - fixed effects, random effects and mixed models, 752 pp, Walter de Gruyter, Berlin - New York 2006

GRAFAREND E and F KRUMM: Map Projections - Cartographic Information Systems, 713 pp, Springer Verlag, Berlin 2006

Refereed Journal Publications

GÖTZELMANN M, W KELLER and T REUBELT: Gross error compensation for gravity field analysis based on kinematic orbit data. Journal of Geodesy 80 (2006) 184-198, DOI 10.1007/s00190-006-0061-9

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WANG J, W KELLER and M SHARIFI: Comparison of Availability of GALILEO, GPS and Combined GALILEO/GPS Navigation Systems. Artificial Satellites 41 (2006) 3-15

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Other Refereed Contributions

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BORKOWSKI A and W KELLER: An attempt to ALS-data filtering in wavelet domain. 8th Bilateral Geodetic Meeting Poland-Italy. Wroclaw (Poland), 22.-24.6.2006. (poster)

CAI J, H KOIVULA, E GRAFAREND and M POUTANEN: The statistical analysis of the eigenspace components of the strain rate tensor derived from FinnRef GPS measurements (1997-2004) in Fennoscandia, IAG Proceedings „VI Hotine-Marussi Symposium of Theoretical and Computational Geodesy“, 2006, accepted

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KLEMANN V, E IVINS, Z MARTINEC and D WOLF: The influence of a subducting slab on the uplift rate induced by glacial changes of Patagonia. Geophys. Res. Abstr., EGU General Assembly, 8, EGU06-A-04844.

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BAUR O and N SNEEUW: The Slepian approach revisited: dealing with the polar gap in satellite based geopotential recovery, (3rd International GOCE User Workshop, 6.-8.11.2006, Frascati, Italy), CD version, 6 pp, 2006

CHEN X, MG SIDERIS and M SNEEUW: Gravity Field Recovery from Spaceborne Gravimetry, (13th Astronautics Conference and 53rd Annual General Meeting: Canada’s Future in Space - Global Responsibilities and Opportunities, 25.-27.4.2006, Montreal), CD version, 11 pp

HINTZSCHE M: Vergleichswertverfahren, Lektion 4 des schriftlichen Management-Lehrgangs Marktorientierte Immobilienbewertung, EUROFORUM Verlag, Düsseldorf 2006

Guest Lectures and Lectures on special occasions

KUHN M, Dr. (Curtin University of Technology, Perth/Western Australia): Globale Meeresspiegel- und Erdschwerefeldänderungen aufgrund von schmelzenden Polkappen (12.1.)

LELGEMANN D, Prof. Dr. (Institut für Geodäsie und Geoinformationstechnik, TU Berlin): Hat theoretische Geodäsie noch eine Zukunft? (04.05.)

MORITZ H, Prof. Dr. (Physikalische Geodäsie, TU Graz, Österreich): Fraktale und ihre Anwendungen in der Geodäsie I-III (5.5., 8.5., 10.5.)

SCHRAMA E O, Prof. Dr. (Department of Earth Observation and Space Systems, Faculty of Aerospace Engineering, TU Delft): Do we understand temporal gravity from GRACE? (29.6.)

SIMONS FJ, Dr. (Department of Earth Sciences, University College London): A localization approach to measuring potential fields from noisy, incomplete data taken at an altitude (13.2.)

SNEEUW N, Prof. Dr. (Geodätisches Institut, Universität Stuttgart): Die Satellitengeodäsie als Tanzdisziplin? (Inaugural Speech, 3.2.)

SNEEUW N: Vermessung der Erde mit CHAMP, GRACE und GOCE, Kolloquium Institut für Raumfahrtsysteme (IRS), Universität Stuttgart, Germany (2.5.)

VARGA P, Prof. Dr. (GGKI Seismological Observatory Budapest): History of Seismology & „Seismological History“ (14.6.)

WEIGELT M, PhD student (Department of Geomatics, University of Calgary): Gravity field recovery at the University of Calgary (19.5.)

WEIGELT M, PhD student (Department of Geomatics, University of Calgary): First results from GRACE using the energy integral (19.6.)

XU C, Prof. Dr. (School of Geodesy and Geomatics, Wuhan University): Method and Application of Joint Inversion for Geodetic and Geophysical Data (16.11.)

Lectures at other universities

CAI J: I. The statistical analysis of geodetic deformation (velocity and strain rate) in Europe and Shanghai, II. Introduction of the Geodetic Study and Research in University Stuttgart. Tongji University, Shanghai, China, 26.9.2006

KELLER W: Non-terrestrial GPS applications. Helwan Institute for Astronomy and Geophysics, Cairo University, March 2006.

KELLER W: Deglaciation induced polar wander. Curtin University Perth, Department of Spatial Sciences, August 2006.

SNEEUW N: New Concepts in Satellite Geodesy. Tongji University, Shanghai, PR China, 5.6.2006

SNEEUW N: Satellite Geodesy: From Kepler to Formation Flight. Department of Geomatics Engineering, University of Calgary, Canada, 4.12.2006

Conference Presentations

AUSTEN G and W KELLER: On an ellipsoidal approach to the singularity-free gravity space theory. Poster presentation, VI Hotine-Marussi Symposium on Theoretical and Computational Geodesy, Wuhan, PR China, 29.5.-2.6.2006

BAUR O and G AUSTEN: Efficient Geopotential Recovery based on LSQR. 3rd HPC-Europa Transnational Acces Meeting, Barcelona, Spain, 14.-16.6.2006

BAUR O and J KUSCHE: Schwerefeldbestimmung mit LSQR. Geodätische Woche 2006, Munich, 10.-12.10.2006

BAUR O and N SNEEUW: Methodology and Use of Tensor Invariants for Satellite Gravity Gradiometry. Invited Paper, EGU General Assembly, Vienna, Austria, 2.-7.4.2006

BAUR O and N SNEEUW: Methodology and Use of Tensor Invariants for Satellite Gravity Gradiometry. EGU General Assembly 2006, Wien, 2.-7.4.2006

BAUR O and N SNEEUW: Schwerefeldprozessierung vermittels Slepian Funktionen. Project Meeting GOCE-GRAND II, Bonn, ITG, 17.-18.5.2006

BAUR O and N SNEEUW: Simulation von GOCE Beobachtungen über den polaren Gebieten. Projekt Meeting GOCE-GRAND II, Stuttgart, GIS, 30.11.-1.12.2006

BAUR O and N SNEEUW: Slepian Approach Revisited: New Studies to Overcome the Polar Gap. Geotechnologien II Status Seminar, Bonn, Universitätsclub, 18.-19.9.2006 (Poster)

BAUR O and N SNEEUW: The Slepian Approach Revisited: Dealing with the Polar Gap in Satellite Based Geopotential Recovery. 3rd GOCE User Workshop, Frascati, Italy, 6.-8.11.2006

BAUR O, G AUSTEN and J KUSCHE: LSQR based Geopotential Recovery. 1st International Symposium of the International Gravity Field Service (IGFS), Istanbul, Turkey, 28.8.-1.9.2006

BAUR O, G AUSTEN and W KELLER: Efficient Satellite Based Geopotential Recovery, High Performance Computing in Science and Engineering. The 9th Results and Review Workshop of the HLRS, Stuttgart, 19.-20.10.2006

CAI J and E GRAFAREND: Systematical analysis of the transformation between Gauss-Krueger-Coordinate/DHDN and UTM-Coordinate/ETRS89 in Baden-Württemberg with different estimation methods. IAG Symposium „Geodetic Reference Frames (GRF2006)“, Munich, Germany, 9.-14.10.2006

CAI J and E GRAFAREND: The inverse problem of strain analysis. Geodätische Woche 2006, Munich, Germany, 10.-12.10.2006

CAI J, C HU, E GRAFAREND and J WANG: The uniform Tykhonov-Phillips regularization (α-weighted S-homBLE) and its application in GPS rapid static positioning. VI Hotine-Marussi Symposium of Theoretical and Computational Geodesy: Challenge and Role of Modern Geodesy, Wuhan, China, 29.5.-2.6.2006

CAI J, H KOIVULA, E GRAFAREND and M POUTANEN: The statistical analysis of the eigenspace components of the strain rate tensor derived from FinnRef GPS measurements (1997-2004) in Fennoscandia. VI Hotine-Marussi Symposium of Theoretical and Computational Geodesy: Challenge and Role of Modern Geodesy, Wuhan, China, 29.5.-2.6.2006

DEVARAJU B, A BRAUN and N SNEEUW: Levelling Network Analysis for the Definition of Kinematic Vertical Datum in Canada. CGU Annual Scientific Meeting: Geospatial Processes, Banff, Canada, 14.-17.5.2006

DEVARAJU B, A BRAUN and N SNEEUW: Vertical crustal deformation analysis with the Canadian precise levelling network in Eastern Canada for the purpose of defining a kinematic vertical datum for Canada. 1st International Symposium of the International Gravity Field Service (IGFS 2006), Istanbul, Turkey, 28.8.-1.9.2006

FINN G and G GRAFAREND: The Ellipsoidal Disturbing Gravity Vector. 3rd General Assembly European Geosciences Union, Wien, 2.-7.4.2006

FINN G, E GRAFAREND and AA ARDALAN: Ellipsoidal Vertical Deflections: Global Test Computations. Geodätische Woche 2006, München, 10.-12.10.2006

GRAFAREND E: Ellipsoidal Gravity Disturbance: Global Test Computations. Geodätische Woche München, 11.10.2006

GRAFAREND E: Ellipsoidal Harmonics. Institut für Geoinformatik Stockholm / Schweden, 28.8.2006

KLEMANN V and D WOLF: A global database of sea-level indicators. (Poster). WRCP Workshop on Understanding Sea Level Rise and Variability, Paris, France, 6.-9.6.2006

KLEMANN V and D WOLF: Fuzzy logic as an alternative tool for the interpretation of sea-level indicators with respect to glacial-isostatic adjustment. (Poster). EGU General Assembly, Vienna, Austria, 4.4.2006

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KLEMANN V, E IVINS, Z MARTINEC and D WOLF: Einfluss einer subduzierenden Platte auf die durch glaziale Änderungen in Patagonien verursachte Hebungsbewegung. Geodynamik Workshop, Katlenburg-Lindau, 28.9.2006

KLEMANN V, E IVINS, Z MARTINEC and D WOLF: The influence of a subducting slab on the uplift rate induced by glacial changes of Patagonia. EGU General Assembly, Vienna, Austria, 5.4.2006

KLEMANN V, E IVINS, Z MARTINEC and D WOLF: The influence of a subducting slab on the prediction of present-day lithospheric and asthenospheric motions induced by glacial changes in Patagonia. 11. Geodätische Woche/Intergeo, München, 12.10.2006

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MÄKINEN J, A ENGFELDT, BG HARSSON, H RUOTSALAINEN, G STRYKOWSKI, T OJA and D WOLF: The Fennoscandian land uplift gravity lines 1966-2005. General Assembly of the NKG, Copenhagen, Denmark, Programme Overview and Abstracts, p. 32., 1.6.2006

MARTINEC Z, V KLEMANN and D WOLF: Development and validation of a three-dimensional viscoelastic lithosphere and mantle model for reducing GRACE-gravity data (VILMA). Geotechnologies Status Seminar „Observation of System Earth from Space“, Bonn, 19.9.2006

RAIZNER C, M WEIGELT AND MG SIDERIS: On the accelerometer calibration on board GRACE. Astro 2006 - 13th Canadian Astronautics Conference and 53rd Annual General Meeting, Montreal, Canada 2006

SASGEN I, R MULVANEY, V KLEMANN and D WOLF: Glacial-isostatic adjustment and sea-level change near Berkner Island, Antarctica. (Poster). EGU General Assembly, Vienna, Austria, 6.4.2006

SCHUH WD, H ALKHATIB, C BOXHAMMER, B KARGOLL, CH SIEMES, O BAUR and N SNEEUW: Numerical Challenges for GOCE Data Analysis. Geotechnologien II Status Seminar, Bonn, Universitätsclub, 18.-19.9.2006

SNEEUW N: Novel modeling approaches in Dynamic Satellite Geodesy. Turkish-German Joint Geodetic Days, Berlin, 29.-3.3.2006

WEIGELT M, M EL-HABIBY, MG SIDERIS and N SNEEUW: Comparison and combination of CHAMP and GRACE data for gravity field analysis. Canadian Geophysical Union Annual Meeting, Banff, Canada 2006

WEIGELT M, MG SIDERIS and N SNEEUW: Combination of CHAMP and GRACE data for Gravity Field Analysis. 1st International Symposium of the International Gravity Field Service (IGFS), Istanbul, Turkey, 28.8.-1.9.2006

WEIGELT M, MG SIDERIS and N SNEEUW: Combination of CHAMP and GRACE satellite data for Earth monitoring. 8th GEOIDE Annual Scientific Conference, Banff, Canada 2006

WEIGELT M, MG SIDERIS and N SNEEUW: Comparison and combination of CHAMP and GRACE data for gravity field analysis. CGU Annual Scientific Meeting: Geospatial Processes, Banff, Kanada, 14.-17.5.2006

WEIGELT M, MG SIDERIS and N SNEEUW: GRACE gravity field recovery using differential gravimetry. 1st International Symposium of the International Gravity Field Service (IGFS 2006), Istanbul, Turkey, 28.8.-1.9.2006

WEIGELT M, MG SIDERIS and N SNEEUW: Gravity Field Recovery from satellite-to-satellite tracking missions. Astro 2006 - 13th Canadian Astronautics Conference and 53rd Annual General Meeting, Montreal, Canada 2006

WEIGELT M, MG SIDERIS and N SNEEUW: High-latitude local gravity field recovery from CHAMP with least-squares collocation. European Geosciences Union, General Assembly 2006, Vienna, Austria 2006

WEIGELT M: Combination of satellite-to-satellite tracking mission data for global gravity field recovery. 3rd Faculty of Engineering Graduate Student Conference, Calgary, Canada 2006

WEIGELT M: Space Gravimetry Contributions to Earth Monitoring. 8th GEOIDE Annual Scientific Conference, Banff, Canada 2006

WOLF D and J HAGEDOORN: Glacial isostasy and sea level: forward and inverse problems. Modelling Meeting Section 1.5., GFZ Potsdam, 28.3.2005

WOLF D and V KLEMANN: Glacial isostasy and sea level: the data. Modelling Meeting Section 1.5., GFZ Potsdam, 28.3.2005

XU C, MG SIDERIS and N SNEEUW: Gravity Field Recovery from Spaceborne Gravimetry. 13th Astronautics Conference and 53rd Annual General Meeting: Canada’s Future in Space - Global Responsibilities and Opportunities, Montréal, Kanada, 25.-27.4.2006

XU C, N SNEEUW and MG SIDERIS: The Torus Approach in Spaceborne Gravimetry. VI Hotine-Marussi Symposium 2006, Wuhan, China, 29.5.-2.6.2006

XUE Y and N SNEEUW: Ein stabiler Algorithmus zur Berechnung von Legendre-Funktionen hohen Grades, Geodätische Woche München, 11.-12.10.2006 (Poster)

Research Stays

GRAFAREND E: Finnish Geodetic Institute, Masala, Finnland, 5.8.-20.8.2006

GRAFAREND E: Kungl. Tekniska Högskolan, Institutionen för Geodesie, Stockholm, Schweden, 21.8.-2.9.2006

KELLER W: Helwan Institute for Astronomy and Geophysics, Cairo University, Ägypten, 3.3.-11.3.2006

KELLER W: Agricultural Department University Wroclaw, Polen, 3.4.-10.4.2006

KELLER W: Curtin University Perth. Department of Spatial Sciences, Perth, Australien, 20.7.-29.8.2006

KRUMM F: Geodetic and Geophysical Research Institute, Seismological Observatory, Budapest, Hungary, 2.-6.10.2006

SNEEUW N: PPP-Exchange-Program with China, Tongji University Shanghai, China, 2.-7.6.2006

Lecture Notes

GRAFAREND E and F. KRUMM
Map Projections, 300 pages
(http://www.uni-stuttgart.de/gi/education/kapro/kp_komplett.pdf)

HAUG G
Grundstücksbewertung I, 28 pages
(http://www.uni-stuttgart.de/gi/education/Grundstu/Vorlesung_I.pdf)
Grundstücksbewertung II, 11 pages
(http://www.uni-stuttgart.de/gi/education/Grundstu/Vorlesung_II.pdf)

KELLER W
Foundations of Satellite Geodesy, 51 pages
(http://gipc41.gis.uni-stuttgart.de/)
Observation Techniques in Satellite Geodesy, 80 pages
(http://gipc41.gis.uni-stuttgart.de/SATGEO/SCRIPT/ObsTech1.pdf)
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Geodetic Coordinate Systems, 80 pages
(http://gipc41.gis.uni-stuttgart.de/GKS/SCRIPT/GKS.pdf)
Satellite Geodesy, 51 pages
(http://gipc41.gis.uni-stuttgart.de/SATGEO/SCRIPT/satgeodesy.pdf)
Wavelet Applications in Geodesy and Geodynamics, 134 pages
(http://www.uni-stuttgart.de/iag)

SCHÖNHERR H
Amtliches Vermessungswesen und Liegenschaftskataster, 60 pages
(http://www.uni-stuttgart.de/gi/education/Lieka/script_herbst2006.pdf)

SNEEUW N
Physical Geodesy, 137 pages
(http://www.uni-stuttgart.de/gi/education/erdmessung/LNErdm.pdf)
Dynamic Satellite Geodesy (Preliminary), 90 pages
(http://www.uni-stuttgart.de/gi/education/analytic_orbit/lnABkSat.pdf)

WOLF D
Continuum Mechanics in Geophysics and Geodesy: Fundamental Principles, 100 pages
(http://www.uni-stuttgart.de/gi/research/schriftenreihe/report2003_2.pdf)

Participation in Conferences, Meetings and Workshops

AUSTEN G

VI Hotine-Marussi Symposium on Theoretical and Computational Geodesy, Wuhan, PR China, 29.5.-2.6.2006

BAUR O

EGU General Assembly, Vienna, Austria, 2.-7.4.2006
Project Meeting GOCE-GRAND II, Bonn, ITG, 17.-18.5.2006
3rd HPC-Europa Transnational Access Meeting, Barcelona, Spain, 14.-16.6.2006
1st International Symposium of the International Gravity Field Service (IGFS), Istanbul, Turkey, 28.8.-1.9.2006
Status Seminar GEOTECHNOLOGIEN II, Bonn, Universitätsclub, 18.-19.9.2006
Geodätische Woche 2006, Munich, 10.-12.10.2006
High Performance Computing in Science and Engineering - the 9th Results and Review Workshop of the HLRS, Stuttgart, 19.-20.10.2006
Project Meeting GOCE-GRAND II, Stuttgart, GIS, 30.11.-1.12.2006

CAI J

VI Hotine-Marussi Symposium of Theoretical and Computational Geodesy: Challenge and Role of Modern Geodesy, Wuhan, China, 29.5.-2.6.2006
Geodätische Woche 2006, Munich, Germany, 10.-12.10.2006
Intergeo 2006, Munich, Germany, 10.-12.10.2006
IAG Symposium „Geodetic Reference Frames (GRF2006)“, Munich, Germany, 9.-14.10.2006

FINN G

European Geosciences Union (EGU) General Assembly, Wien, 2.-7.4.2006
Geodätische Woche 2006, Munich, 10.-12.10.2006

GRAFAREND E

European Geosciences Union (EGU) General Assembly, Wien, 2.-7.4. 2006
Geodätisches Kolloquium der Universität Bonn anlässlich des 60. Geburtstages von Prof. Dr.-Ing. W. Förstner, Bonn, 18.5.06
Geodätische Woche 2006, Munich, 10.-12.10.2006
Jahrestagung der Deutschen Geodätischen Kommission (DGK), 22.-23.11.2006

KELLER W

VI Hotine-Marussi Symposium on Theoretical and Computational Geodesy, Wuhan, PR China, 29.5.-2.6.2006
Geodätische Woche 2006, Munich, 10.-12.10.2006

SCHLESINGER R

Geodätische Woche 2006, Munich, 10.-12.10.2006

SNEEUW N

Turkish Geodetic Days / Berlin, 29.-31.3.2006
GUTS Progress Meeting / Kopenhagen, 24.3.2006
Hotine-Marussi / Wuhan, 29.5.-5.6.2006
DVW-Beiratssitzung, Rüdesheim, 23.-24.6.2006
IGFS (International Gravity Field Service) / Istanbul, 28.8.-1.9.2006
Statusseminar GEOTECHNOLOGIEN „Erkundung des Systems Erde“ Bonn, 18.-19.9.2006
INTERGEO/Geodätische Woche / Munich, 9.-13.10.2006
GOCE User Workshop / Frascati, Italy, 6.-8.11.2006
Jahrestagung German Geodetic Commission (DGK), Munich, 22.-23.11.2006

WEIGELT M

EGU General Assembly, Vienna, Austria, 2.-7.4.2006
13th Canadian Astronautics Conference and 53rd Annual General Meeting, Montreal, Canada, 25.-27.4.2006
3rd Faculty of Engineering Graduate Student Conference, Calgary, Canada, 3.-4.5.2006
CGU Annual Meeting, Banff, Canada, 14.-17.5.2006
8th GEOIDE Annual Scientific Conference, Banff, Canada, 31.5.-2.6.2006
1st International Symposium of the International Gravity Field Service (IGFS), Istanbul, Turkey, 28.8.-1.9.2006

WOLF D

WRCP Workshop on Understanding Sea Level Rise and Variability, Paris, France, 6.-9.6.2006
11. Geodätische Woche/Intergeo, München, 10.-12.10.2006
AGU Fall Meeting 2006, San Francisco, California, 11.-15.12.2006

University Service

FINN G
Member Faculty of Aerospace Engineering and Geodesy, Universität Stuttgart
Member Advisory Council of High Performance Computing Center

GRAFAREND E
Member Faculty of Aerospace Engineering and Geodesy, Universität Stuttgart
Member Faculty of Civil and Environmental Engineering, Universität Stuttgart (kooptiert)
Member Faculty of Mathematics and Physics, Universität Stuttgart (kooptiert)

KELLER W
Member Promotionsausschuss der Universität Stuttgart
Member Studienkommission Geodäsie und Geoinformatik an der Universität Stuttgart
Member erweiterter Fakultätsrat der Fakultät für Bau- und Umweltingenieurwissenschaften an der Universität Stuttgart

KRUMM F
Member Studienkommission Geodäsie und Geoinformatik an der Universität Stuttgart

SNEEUW N
Associate Dean (Academic) Geodäsie und Geoinformatik and Geoengine
Member Examining Board of the Faculty of Aerospace Engineering and Geodesy
Chair Studienkommission Geodäsie und Geoinformatik an der Universität Stuttgart
Member Search Committee Flugzeugastronomie und Extraterrestrische Raumfahrtmissionen

Professional Service (National)

GRAFAREND E
Member Scientific Board of the German Geodetic Commission (DGK)
Emeritus member German Geodetic Commission (DGK)

HINTZSCHE M
Member Gesellschaft für Immobilienwirtschaftliche Forschung (gif)
Member 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

KELLER W
Member Society of Industrial and Applied Mathematics
Member Deutscher Mathematiker Verein

SNEEUW N
Member German Geodetic Commission (DGK)
Chair DGK-working group „Theoretische Geodäsie"
Member DGK-working group „Neue Satellitenmissionen"
Chair AK7 (working group 7), „Experimentelle, Angewandte und Theoretische Geodäsie", within DVW (Gesellschaft für Geodäsie, GeoInformation und LandManagement)
Member Search Committee Juniorprofessur ESPACE, Munich

Professional Service (International)

FINN G
Member IAG Special Study Group „Spatial and Temporal Gravity Field and Geoid Modeling"

GRAFAREND E
Member Royal Astronomical Society, Great Britain
Corresponding Member Österreichische Geodätische Kommission (ÖGK)
Member Flat Earth Society

SNEEUW N
Corresponding member Joint Working Group (JWG) between International Gravity Field Service (IGFS) and the IAG Commission 2
Member Editorial board of Studia Geophysica et Geodaetica
Member Editorial board of Journal of Geodesy
Fellow International Association of Geodesy (IAG)
Chair IAG intercommission working group „Satellite Gravity Theory"

WOLF D
Chair IAG Inter-Commission Committee for Theory (ICCT) Working Group „Dynamic Theories of Deformation and Gravity Fields"
Fellow International Association of Geodesy (IAG)

Courses - Lecture/Lab/Seminar

Geometric Data Processing (Keller)	1/1/0
Adjustment I, II (Sneeuw)	2/1/0
Coordinates and Reference Systems (Keller, Krumm)	1/1/0
Geodesy and Geodynamics (Sneeuw)	2/1/0
Measurement Techniques of Physical Geodesy (Sneeuw)	2/1/0
Modeling and Data Analysis in the Field of Physical Geodesy (Engels)	2/1/0
Foundations of Satellite Geodesy (Keller)	1/1/0
Observation Techniques and Evaluation Procedures of Satellite Geodesy (Keller)	1/1/0
Dynamic Satellite Geodesy (Keller)	1/1/0
Map Projections (Krumm)	1/1/0
Mathematical Geodesy (Krumm)	2/2/0
Official Surveying and Real Estate Regulation (Schönherr)	2/0/0
Real-Estate/Property Valuation I, II (Haug)	2/1/0
Geodetic Seminar I,II (Keller, Sneeuw)	0/0/4
Integrated Field Work Geodesy and Geoinformatics (Keller, Sneeuw)	10 days
Gravity Field Modeling (Keller)	2/1/0
Analytic Orbit Computation of Artificial Satellites (Sneeuw)	2/1/0
Orbit Determination and Analysis of Artificial Satellites (Keller)	2/1/0
Geodetic Reference Systems (ICRS-ITRS) for Satellite Geodesy and Aerospace (Krumm, Richter)	2/1/0
Advanced Mathematics (Keller)	3/2/0
Statistical Inference (Sneeuw)	2/1/0
Satellite Geodesy (Keller)	2/1/0

Institute of Navigation

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Prof. Dr.-Ing. A. Kleusberg

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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
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/Navigation Systems
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

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 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 Environment al 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

Unmanned Aerial Vehicles

The utilization of autonomously flying unmanned aerial vehicles (UAVs) for various types of applications is an important issue in the field of aviation. The scope of UAVs includes remote sensing for ecological purposes, traffic monitoring, supervisions of safety critical objects and military reconnaissance as well as the provision of services, e.g. in the field of telecommunication. In comparison to military UAVs, civil application scenarios require higher safety standards for the complete system. Essential for this project is the formulation of all required technologies (entering national airspace system, integrated system platform, safety and redundancy aspects, accreditation issues, etc.). For the evaluation of the research and development work various kinds of unmanned aerial test vehicles (so-called demonstrators, class of $<$ 25 kg and visual flight) as well as a manned light aircraft are available to the project cooperation (fig. 1-2). This interdisciplinary research project contributes to enhance the competence of the Faculty Aerospace Engineering and Geodesy as well as the appropriate industry of Baden-Württemberg in the field of unmanned aerial vehicles.

Figure 1: Unmanned demonstrator „Adler“ (IRS, Universität Stuttgart)

Figure 2: Manned light aircraft „DA40 Diamond Star“ (ILS, Universität Stuttgart)

The research work at the INS includes the layout and demonstration of a low-cost, minimized, lightweight and airworthy sensor technology for an integrated navigation and flight guidance system comprising the formulation of a reliable real-time processing algorithm based on an extended Kalman filter. Fundamental in this context are off-the-shelf sensors based on micro-electromechanical systems (MEMS) and GPS.

Research in satellite navigation and inertial sensor technology has been done for many years at the INS. The equipment available at the INS ranges from the very low-cost sector up to highly integrated high-end measurement systems. Among others, those systems are utilized for the determination of position and orientation of vehicles (e.g. car, aircraft) and also serve as a reference for the evaluation of other measurement systems of lower accuracy. Since 2004 the research work has been expanded to include investigations and further developments of MEMS and special laboratory equipment has been acquired to allow for the analyses of the stability and accuracy of sensors. This work is also supported by student research projects and diploma theses.

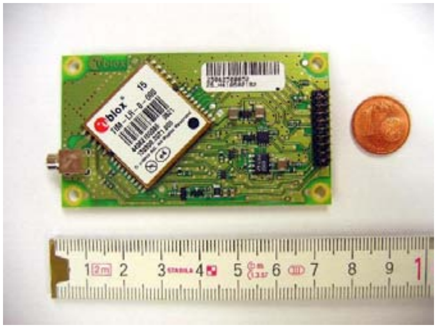


Figure 3: μ-blox GPS receiver board (INS, Universität Stuttgart)

Figure 4: Tri-axial navigation unit MMQ-G (INS, Universität Stuttgart)

For the UAV related research a highly integrated navigation unit MMQ-G (Systron Inc.) was acquired which is suitable to support 3D flight navigation of UAVs due to its size, mass, power requirement and performance parameters. The MMQ-G unit comprises a tri-axial inertial measurement unit (IMU), a GPS receiver and a micro-processor including real-time software for processing position and orientation angles of a moving vehicle. Among other things, this unit will support the development of an airworthy navigation platform. For further information see http://www.ifb.uni-stuttgart.de/uav/

Simulation of a realistic flight trajectory and associated IMU raw data

A particular research project at the INS deals with the development of new algorithms for the integration of GPS and IMU measurements. In this context it has proven to be essential to work with raw measurement data whose error behaviour is known. Since real sensor data usually have unknown and unwanted error components, such data with predictable error behaviour can be obtained only through simulation.

Furthermore in the future it will be necessary to evaluate the performance of the developed integration procedures in relation to existing methods. To draw conclusions about the accuraties of differerent algorithms it is important to know „true solution“, being the source of the simulated measurement data.

For these two reasons there was a need to simulate IMU raw data and the corresponding flight geometry in an adequate way. At first some very simple scenarios were modelled, e.g. stand phases, elevators and straight line flights with constant airspeed. Thereafter more complex flight geometries should be designed - similar to a real flight.

Since the research in sensor integration at the INS is targeted to the typical applications of airborne sensor positioning (photogrammetry, Laser scanning), the geometry of the simulated flight path should correspond to typical flight path encountered in such applications. Therefore the geometry of a real flown trajectory provided a good basis for the data simulation. The reference trajectory was recorded in a flight campaign in the year 2002 above the urban area of Dessau. For simulation purposes exactly one curve of the real flight path was reconstructed (see the left part of figure 1).

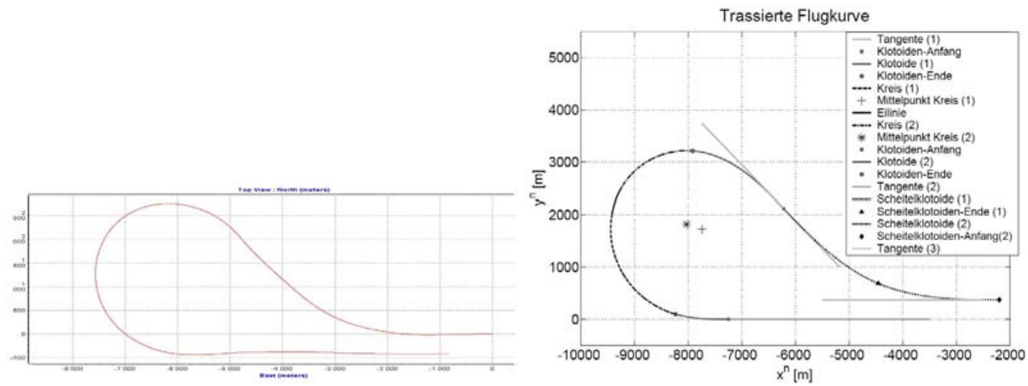


Figure 1: left: Trassierungsvorlage = Geometrie einer realen Flugkurve; right: trassierte Fluggeometrie

For the analytical reconstruction of this curve three tangents $t1$, $t2$ and $t3$ were drawn to the graphical sketch of the real curve. The tangents $t1$ und $t3$ represent the straight lines and are parallel to each other. The criterion of parallelism was of high importance as to avoid difficulties in the subsequent composition of the single parts. The tangent $t2$ was added to the curve arbitrarily. After the predefinition of an initial value for the first clothoid on the tangent $t1$ we were able to construct a sequence of clothoid-circle-clothoid-circle-clothoid between the tangents $t1$ and $t2$. Subsequently a symmetric apex clothoid was traced out between the tangents $t2$ and $t3$, as can be seen on the right side of figure 1. The attachment of straight line elements to the curve and further extension of the flight path by equal curves (only in different orientations) yielded to an entire flight trajectory, see figure 2.

In the whole simulation process firstly the geometry was designed in a two dimensional coordinate system as described above. This step was followed up by the modelling of the observation time. That means the positions and velocities had to get a time allocation. In this context a presetting of a sampling rate (e.g. 200Hz) and the definition of a flight velocity (e.g. 75m/s) had to be done. Furthermore for this purpose the dependent parameters (arc lengths in the clothoids and in the straight lines; angle increments in the circles) had to be scaled adequately.

For each of thepredetermined observation epochs velocities and accelerations were calculated from the positions, after the positions had been transformed to an earth fixed three dimensional coordinate system. Starting from the tangent unit vector on the flight path also the attitude angles *heading* and *pitch* were determined. The third attitude angle roll was modelled independent of the geometry of the trajectory (in a pure mathematical manner, not in respect to flight dynamics). For that reason a model for the roll angle had to be introduced. In the simplest case the roll angle could be set to zero for the whole flight. This approach wouldn't be realistic but could be implemented very easily. For more realistic conditions the roll anle change within the clothoid was described by a cosine function. Cosine fuction sections from 0 to π respectively from π to 2π were used since their slopes were zero at the beginning and the end of the function. Thus the derivations became continuously differentiable.

In a final step the simulated accelerometer and gyro measurements were calculated with the use of the derivative of the attitude angles. The entire trajectory can be seen in figure 2.

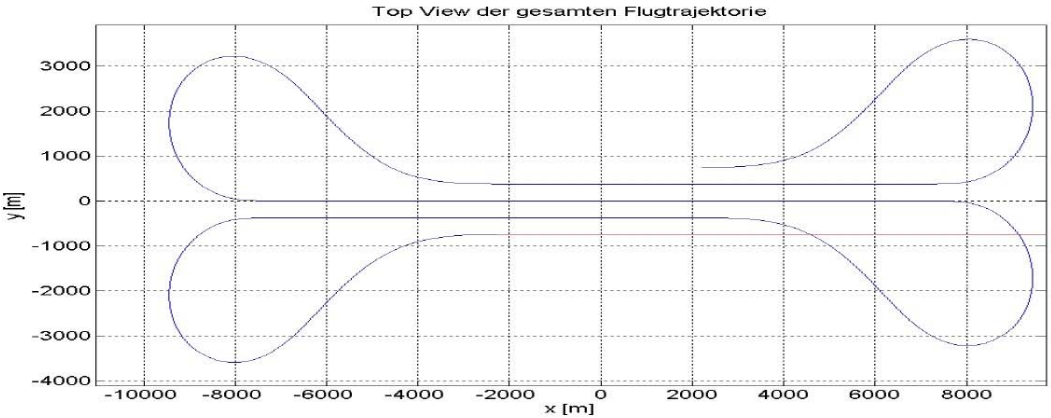


Figure 2: Geometry of the simulated flight path

Remote sensing - PROJECT MONAT-X

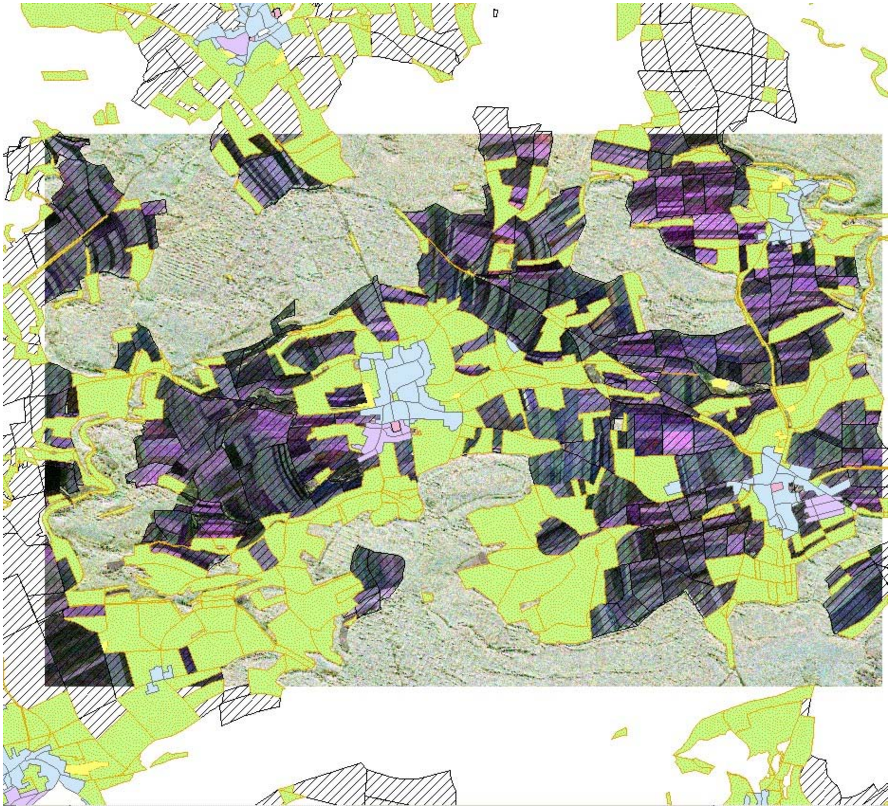
The TerraSAR-X Satellite, developed in Germany, will be available in 2007. TerraSAR-X will provide high resolution radar remote sensing data that allow an accurate determination of landuse by automatic remote sensing methods. The geometric resolution up to 1 m and the 11 day repetition rate together with the data acquisition independent from weather conditions and cloud coverage allow the TerraSAR sensor to be an ideal tool for the monitoring of the earth surface.

The Institute of Navigation has performed first investigations of the potential of the future TerraSAR-X data in cooperation with the remote sensing company ILV (Ingenieurbüro für Luftbildauswertung und Vermessung) in the framework of 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).

The Landesvermessungsamt Baden-Württemberg (LV-BaWü), responsible for the ATKIS topographic information system of Baden Württemberg has shown great interest for the development of a cost effective method for the ATKIS-updating based on TerraSAR remote sensing data. The INS in close cooperation with LV and ILV has therefore submitted the proposal of a project named MONAT-X (High accurate **Mon**itoring of Land Use and Updating of the **AT**KIS Topographic and Cartographic Information System using TerraSAR-**X** Data) to DLR. MONAT-X suggests an innovative method for updating of the ATKIS topographic and cartographic information system. The methods used for the ATKIS data acquisition so far (aerial Photogrammetry) are very expensive due to the required manpower. The LV-BaWü is therefore interested in modern computer based methods using radar remote sensing data, if these could provide the required information more cost effective.

The ATKIS-update is foreseen to be performed in two steps. The first step is the monitoring of ATKIS object classes and the detection of possible changes of object classes: The comparison of TerraSAR data taken at the same vegetation time period of two consecutive years will be used to detect those areas, where a change of ATKIS classes is likely to have taken place in between. The second step is the updating of the existing ATKIS-database with the classification results of a segment based classification using multi-temporal high resolution TerraSAR image products. This step is foreseen to be performed only for those areas, where a change of ATKIS classes has been detected in the initial monitoring step.

The MONAT-X Proposal has been accepted by DLR. DLR will provide a total number of 40 TerraSAR image products test areas located in Baden Württemberg. The acquisition of these data is foreseen to take place during the main vegetation periods between 2007 and 2009.



RADAR IMAGE AND ATKIS VECTOR OVERLAY

Publications and Presentations

Breidenbach, J., Koch, B., Kändler, G., Kleusberg, A.: „Vergleich von LIDAR- und Radardaten zur Ermittlung von Baumhöhen für Waldinventuren“, Proc. Workshop on 3D Remote Sensing in Forestry, Vienna, Feb. 2006.

Chen, S., Thiel, K.-H., Kleusberg, A.: „Modular RF Front End with AD Converter and Software Receiver for GPS/GNSS Signal Analysis“, Proc. CERGAL 2006, Braunschweig, April 2006.

Wehr, A., Schiele, O., Kleusberg, A.: „CW-Laser-Scanning State-of-the-Art at INS and Future Multispectral Sensors“, Proc. Fifth International Symposium Turkish-German Joint Geodetic Days, Berlin, March 2006

Schiele, O., Wehr, A., Kleusberg, A.: „CW-Laser-Scanning State-of-the-Art at INS and Future Multispectral Sensors“, Photogrammetric Workshop Lidar for Aerial and Terrestrial Applications, Istanbul, 7-8-9 November 2006

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

Education (Lecture / Practice / Training / Seminar)

Navigation and Remote Sensing (Kleusberg)	2/1/0/0
Electronics and Electrical Engineering (Wehr)	2/1/0/0
Satellite Measurement Engineering (Kleusberg)	2/1/0/0
Aircraft Navigation (Schöller, Wehr)	2/0/0/0
Parameter Estimation Technics in Dynamic Systems (Kleusberg)	2/1/0/0
Navigation I (Kleusberg)	2/2/0/0
Inertial Navigation (Kleusberg)	2/2/0/0
Remote Sensing I (Thiel)	2/2/0/0
Remote Sensing II (Smiatek)	1/1/0/0
Satellite Programs in Remote Sensing, Communication and Navigation I (Liebig)	2/0/0/0
Satellite Programs in Remote Sensing, Communication and Navigation II (Liebig)	2/0/0/0
Radar Measurement Methods I (Braun)	2/0/0/0
Radar Measurement Methods II (Braun)	2/1/0/0
Navigation II (Kleusberg)	2/2/0/0

Integrated Positioning and Navigation (Kleusberg)	2/1/0/0
Interplanetary Trajectories (Kleusberg)	1/1/0/0
Practical Course in Navigation (Schöller)	0/0/2/0
Geodetic Seminar I, II (Fritsch, Sneeuw, Keller, Kleusberg, Möhlenbrink)	0/0/0/4

Institute for Photogrammetry

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Head of Institute

Prof. Dr.-Ing. Dieter Fritsch
Deputy: PD. Dr.-Ing. habil. Norbert Haala
Secretary: Martina Kroma
Emeritus: Prof. i.R. Dr. mult. Fritz Ackermann

Research Groups at the ifp:

Geoinformatics

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

Photogrammetry and Remote Sensing

Head: Dr.-Ing. Michael Cramer	GPS/INS-Integration
Dipl.-Geogr. Timo Balz	SAR Image Analysis
Dipl.-Ing. Susanne Becker	Resolution Enhancement
Dipl.-Ing.(FH) Markus Englich	Sensor Laboratory
Dipl.-Ing.(FH) Werner Schneider	Digital Photogrammetry Laboratory

Terrestrial Positioning Systems and Computer Vision

Head: Dr.-Ing. Jan Böhm	Spatial Segmentation and Object Recognition
M.Sc.Eng. Yahya Alshawabkeh	Heritage Documentation

External teaching staff

Prof. Volker Schäfer, Ltd. Verm. Dir., Wirtschaftsministerium Baden-Württemberg
Dipl.-Ing. Sabine Urbanke, Landesvermessungsamt Baden-Württemberg

Research Projects

Geoinformatics

Semantic Generalisation of Spatial Data

Photorealistic visualisations are very common, although they are not always the most adequate tools to communicate spatial information. Architects and designers often produce sketch like hard-copy outputs to make their objects appear more alive or to express the preliminary status of their designs. Recent works on interactive visualisations of 3D city models explore non-photorealistic techniques that imitate this style so that spatial situations are easier to perceive and comprehend. Such techniques, however, rely on information about the characteristic edges that best reflect the global shape of a building. This is basically what results from a cartographic simplification.

Another field of application for 3D city models are location based services or context-aware applications. Their users rely heavily on a location- or situation-dependent presentation of the information that is most relevant to their current task. To be useful anywhere at all times, such systems run on mobile devices like digital personal assistants (PDA) or mobile phones. As their screen size and resolution will always be a limiting factor, a geometric simplification of 3D objects is necessary to guarantee the graphical minimum feature size required by maps or map-like presentations. Otherwise the high line density makes it impossible to recognize important aspects of the building object.

Because it is not reasonable to collect and store data for all requested levels of detail, an automatic process is necessary that transforms 3D building models towards more simplified shapes. A simplification of solitary objects under these spatial constraints is one of the elemental operators of cartographic generalisation. For this task, a new generalisation algorithm was developed which is based on cell decomposition. From a derived set of planes that approximate the façade surfaces of the building, a subdivision of space is generated in order to form 2.5D cells. This intermediate result can also be thought of as a ground plan generalisation with additional information about the height discontinuities of the building roof.

The generalization of the roof follows in a two steps approach: first the simplified roof structure is reconstructed for each cell to form a set of parameterized 3D primitives which are then glued together in the second step to form the final building model. The cell decomposition approach has also been evaluated for the use in a 3D building reconstruction process based on aerial laser scanning data. The interpretation results look promising so far and further research follows this direction. Simplification is only one out of several generalisation operators. Another operator is typification, which is the replacement of a number of equally shaped objects by a lower number while maintaining the object arrangement. This can e.g. be utilised for repetitive roof types like shed, saw tooth and parallel roof in order to generate fewer roof elements in the generalised model.

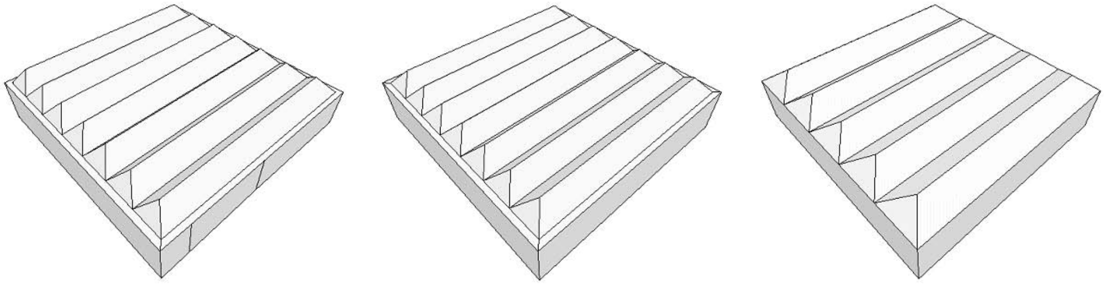


Figure 1: Original building model with parallel roof (left), generalised model with same (middle) and fewer (right) roof elements.

Creating a spatial integration schema for global, context-aware applications

The world of spatial data is still split into individual database islands that have different thematic focuses, like e.g. topographic, cadastral, environmental or traffic related databases. Some are only available for certain geographical regions, e.g. for a city, a federal state or a country. Rarely, spatial data are overstepping administrative boundaries without difficulties. Hence, a joint use of the separate data islands is often not feasible. This is a big disadvantage regarding the use of GIS in today’s decision processes. Having realized this obvious drawback, many organizations and institutions are currently aiming at the development of spatial data infrastructures that allow an integrated use of data comming from heterogeneous sources or different regions, at least within a certain application domain. One of the main problems is the lack of a common data schema - which we call spatial integration schema here - that can provide a basis for data integration.

On the other side, a new application domain has emerged in research and industry: so-called context-aware applications adapt their behavior - i.e. presentation, information selection or action - depending on the situation of their users or the physical world. They are known under various terms: location-based services use the user’s position to determine relevant information in his environment. Navigation systems direct cars or pedestrians through traffic networks. The vision of ubiquitous computing (also known as pervasive computing or ambient intelligence) covers disappearing systems that support the user in a natural way wherever he is. Current applications of that field use sensor technology and smart environments for supporting elderly people at home, office workers or industrial manufacturing. There are context-based communication applications like GeoCast that allow sending a message to all users in a geographical area. With context-aware tagging, the user or provider can leave virtual information in the world that can be read by others. Even games are developed in that domain: so called mixed-reality games or serious games use the physical world as game board for new kinds of entertainment and education.

Common to all these applications is their need for context information that can be used to derive the user's current location. Depending on the application, such a context model contains various kinds of information. An analysis of different applications shows that their needs for data are overlapping. Common data types in context models are:

- ▷ geographical context: digital map data (up to 4D). Physical objects like buildings, streets, rooms; points of interest (POIs) like sightseeing objects, landmarks, etc.
- ▷ technical context: available devices, sensors, communication networks, infrastructure
- ▷ information context: digital information that is relevant to the current place or location: web sites, documents, notes, game objects
- ▷ mobile objects: objects that move, like people, vehicles or pets

As a consequence of these overlapping requirements for data, we can reduce the effort of creating and maintaining context models by sharing them between applications. The goal of the Nexus project is to support all kinds of context-aware applications through an open platform that efficiently manages large-scale context models. The platform is realized as a federation between so-called context servers that store local context-models. This allows for autonomous data providers that keep control of their context data.

Fig. 2 depicts the vision of a global context model. So-called context servers store local context models. This can be the floor plan of a building, a digital map of a city, the positions of clients of a mobile phone provider or any other selection of context data as mentioned in the introduction. We assume that each context server has only data for a certain geographical region and of certain object types. Most of the data objects have some spatial part.

A global context model that integrates these local models would be of great benefit for context-aware applications: it disburdens them from the tedious tasks of discovering context servers, finding out about their query capabilities, binding to their communication protocol, sending information requests and integrating the (probably very heterogeneous) results. The alternative for applications would be to use only a limited, fixed set of well known context servers, and ignoring large parts of available context data. To achieve this goal, we develop a federation platform that provides applications a single interface and an integrated view on the context data. One important problem that has to be solved is to find an integration schema that facilitates this task.

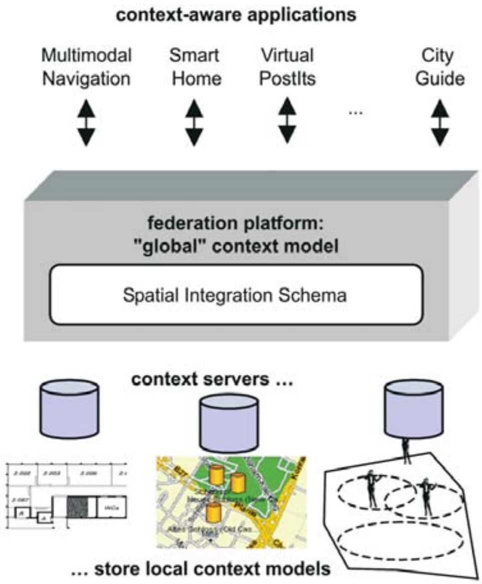


Figure 2: A global, federated context model.

Photogrammetry and Remote Sensing

Digital Airborne Camera Calibration and Validation in Europe

With the growing use of digital airborne imagers in daily operational data collection and processing the need for the development of guidelines and procedures for quality assurance and quality control is obvious. Several national and international organizations are dealing with those topics, where the focus is laid on the calibration, validation and certification of the new sensors.

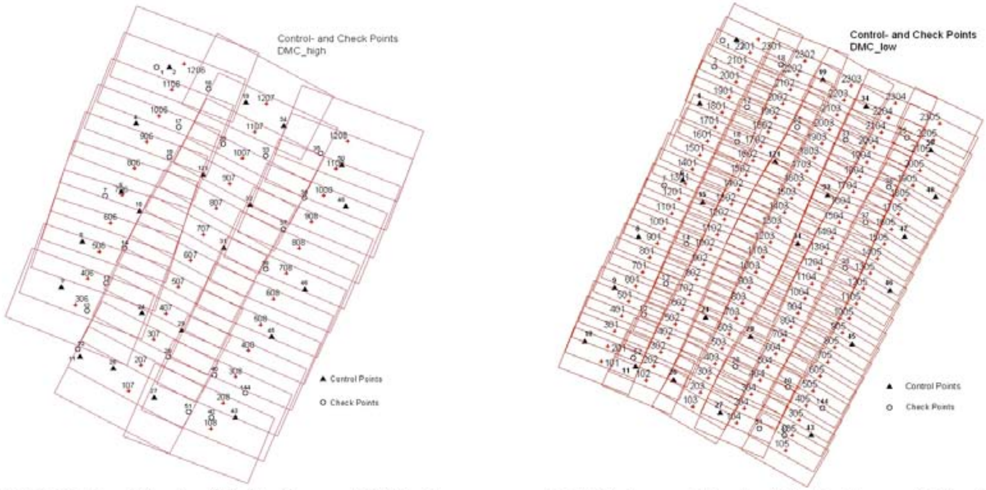
In Europe the topic of digital camera calibration and validation has extensively addressed in a project headed by the Institute for Photogrammetry (ifp) and initiated from the European Spatial Data Research organisation (EuroSDR, www.eurosdr.net). This project was designed as a network of experts from academia, authorities like national mapping and cadastre and industry, including the main digital airborne camera suppliers. Main objective of this initiative is to share the individual knowledge and expertise on the complex field of digital camera calibration and validation. Started end of 2004, the activities in year 2006 were mainly focused on the empirical analysis of airborne sensor data from well-controlled photogrammetric test flights. Data from the three main digital large format photogrammetric systems, namely the Intergraph ZI DMC camera, the Microsoft/Vexcel UltracamD and Leica ADS40 sensor, has been distributed to all interested network members. All of them evaluated mostly one of those flights and tried to obtain optimal performance from the given data. Afterwards, different evaluations and versions were returned to the pilot centre, where the absolute quality of the results was checked by an independent check point analysis.

Since all the flight data was recorded in photogrammetric test ranges providing a quite large number of signalized control and check point information the overall absolute geometric accuracy could be estimated from check point differences. Each sensor was flown in two different flying heights, in some cases additional GPS or GPS/inertial trajectory information was available (Fig. 3). Those block configurations are straight forward to estimate the influence of additional self-calibration parameters within the photogrammetric orientation process. Thus, the analysis of influences of variable self calibration parameter sets on the final object point performance was one of the main objectives during this empirical testing.

So far 13 individual participants have provided their results back to the pilot centre and were included in the absolute accuracy analysis. In almost all cases the two different flying heights were treated as separate blocks and additional parameters were introduced to compensate for remaining systematic effects in the imagery. Mathematical polynomial corrections or physical relevant parameters have been applied mostly. Two participants introduced sensor specific corrections, explicitly developed for the individual camera layout to take care of the system related camera geometry. In general the additional parameters are mainly of influence on the vertical accuracy increase.

Exemplarily some results from the DMC test data are given (Fig. 4). The images were taken in the test field Frederikstad / Norway with a ground sampling distance of approximately 18cm. Four different participants returned several versions using different software for tie point transfer (like LPS, Match-AT, PhotoMod, ISAT), different bundle adjustments (BLUH, Match-AT, PhotoMod, IS Photo-T) and different additional parameter sets. Although each participant used the same input images and control points, the obtained absolute accuracy behaves different. Especially in vertical component larger variations are obvious. This is due to the different mathematical models used and the individual performance of manual and automatic image point measurements.

The almost mandatory use of additional parameters for all of the three distributed data sets is the most important finding of this extensive analysis. In case of the frame based multi-head camera configurations non negligible remaining systematic effects are present in the images which might be due to the use of multiple sensors heads puzzling the large format images. The major role of self-calibration was shown and underlined. Quite interesting to note that very recently two of the three main system suppliers have already established special task forces within their companies to explore and solve for the reasons of the remaining systematic errors in the images. These manufacturer initiatives were surly pushed by the results from investigations as they were done within the EuroSDR network. If all this will finally lead to a „more accurate and user friendly“ workflow in digital airborne imaging all of those investigations were of great success!



DMC high altitude flight (hg = 1800m) DMC low altitude flight (hg = 950m)

Figure 3: The DMC test flight configurations Frederikstad.

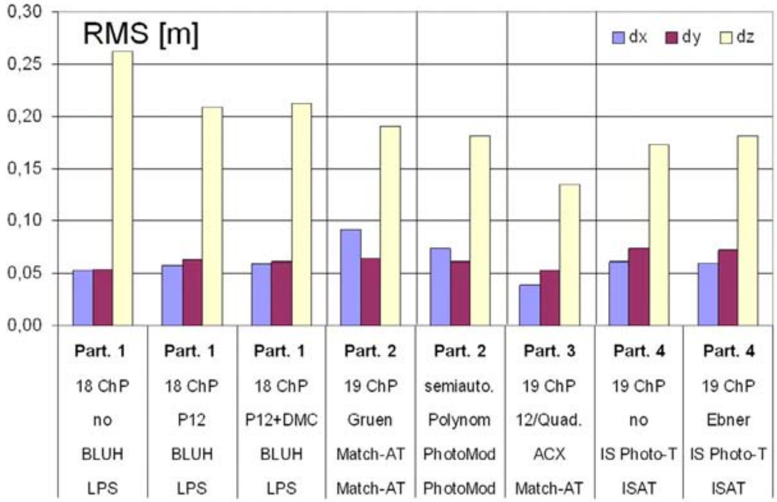


Figure 4: Absolute Accuracy RMS from check point analysis (19 check points max.), DMC test flight Frederikstad, Ground sampling distance approx. 18cm, flying height 1800m.

Facade refinement by terrestrial LIDAR

Urban models extracted from aerial data are sufficient for a number of applications. However, some tasks like the generation of realistic visualisations from pedestrian viewpoints require an increased quality and amount of detail for the respective 3D building models. This can be achieved by terrestrial images mapped against the facades of the buildings. This substitution of geometric modelling by real world imagery is only feasible to a certain degree. Thus, for a number of applications a geometric refinement of the building facades will be necessary. As an example, protrusions at balconies and ledges, or indentations at windows will disturb the visual impression if oblique views are generated. As it will be demonstrated by the integration of window objects, our approach based on cell decomposition is also well suited for such a geometric refinement of an existing 3D model.

Facade refinement requires additional 3D information obtained from terrestrial data sources. Many applications use terrestrial images for the detection of facade structures like windows and doors. Our approach is based on densely sampled point clouds from terrestrial laser scanning. In order to provide full coverage of the scene and to avoid occlusion due to other objects, the point clouds are usually collected from different viewpoints. During pre-processing, the scans referring to different coordinate systems are coregistered and geocoded. For this purpose, an approximate direct georeferencing is combined with an automatic alignment to existing 3D models. Afterwards, both the building models and the 3D point cloud are available in a common reference frame. The selection of the relevant measurement points for each facade is therefore reduced to a simple buffer operation. Fig. 5 (left) exemplarily shows the LIDAR points collected by a HDS 3000 scanner at an approximate spacing of 4 cm. The transformation of the point cloud to a local coordinate system defined by the facade plane simplifies further processing since 2D and 2.5D algorithms can be used.

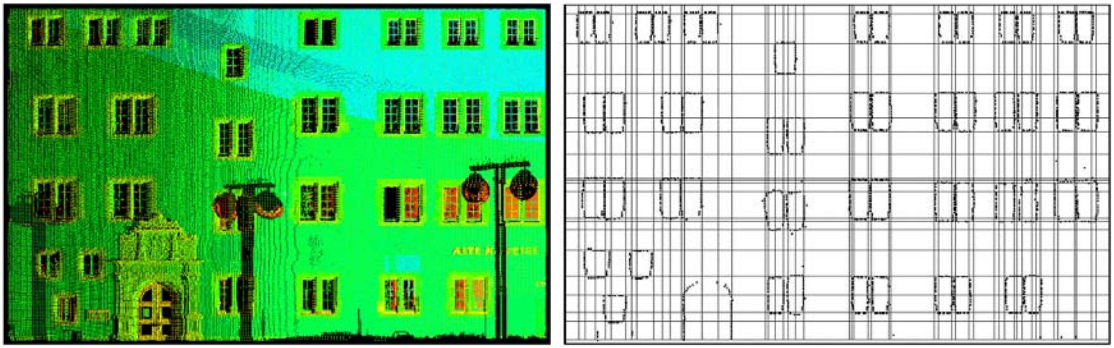


Figure 5: 3D point cloud for facade refinement (left), detected edge points and window lines (right).

The reconstruction of the facade geometry is based on the segmentation of a 3D building model with planar facades into 3D cells. Each 3D cell represents either a homogeneous part of the facade or a window area. After the elimination of the window cells, the remaining facade cells are glued together to form the refined 3D facade model. The planar delimiters of the 3D cells are constructed from the 3D points that were measured at the window borders. These points are identified by a segmentation process.

Generally, laser scanners collect only few measurements on the facade at window areas. This is due to specular reflections of the LIDAR pulses on the glass or points that refer to the inner part of the building and were therefore cut off in the pre-processing step. Thus, our point cloud segmentation algorithm assumes the windows to be areas with few point measurements that also lie behind the facade plane. For instance, the edge points of a left window border are detected if no neighbor measurements to their right side can be found in a pre-defined search radius at the facade plane. In principle, such no data areas can also be the result of occlusions. However, if the facade was measured from different viewpoints, these occlusions can be avoided in most cases. Fig. 5 (right) shows the detected edge points which are used to derive the window borders depicted as horizontal and vertical lines. Each boundary line defines a partition plane that is perpendicular to the building facade. An additional partition plane is estimated from the 3D points measured at the crossbars of the windows. It is parallel to the building facade and describes the window depth. These planes are used to intersect the coarse building model resulting in a set of small 3D cells.

In a next step, the generated 3D cells have to be classified in building and non-building cells. For this purpose, a „point-availability-map“ is used. It is a binary image with low resolution where each pixel defines a grid element in the facade. Black pixels (facade pixels) are grid elements where LIDAR points are available, white pixels (window pixels) represent raster elements with no 3D points. Based on this binary map, the 3D cells can be classified as building cells if the ratio between facade and window pixels exceeds a pre-defined threshold. If the ratio is below a certain value, then the 3D cell is assumed to be a non-building cell. The result of the classification is given in Fig. 6, where building and non-building cells are depicted in grey and white, respectively.

Most of the 3D cells can be classified reliably. Nevertheless, the result may be uncertain especially at window borders or in areas with little point coverage (see the black cells in Fig. 6 (left)). The final classification of these uncertain cells uses neighborhood relationships and constraints concerning the simplicity of the resulting window objects. Thus, window cells are combined to convex window objects and the alignment as well as the size of proximate windows is ensured. Fig. 6 (right) shows the result of the final classification. Further refinements are possible by integrating additional facade cells. For example, if only one vertical window border can be detected between two closely neighbored windows, the reconstruction result will be one big window instead of two small ones. To overcome this problem all reconstructed windows are by default separated into two smaller cells by an additional facade cell. In a next step, this configuration is tested. It will be kept if there are 3D point measurements at the position of the new facade cell. Fig. 7 depicts the final result of the facade reconstruction from terrestrial LIDAR. As it can be seen from the round-headed door of the building, not only polyhedral cells, but also curved primitives can be integrated in the reconstruction process.

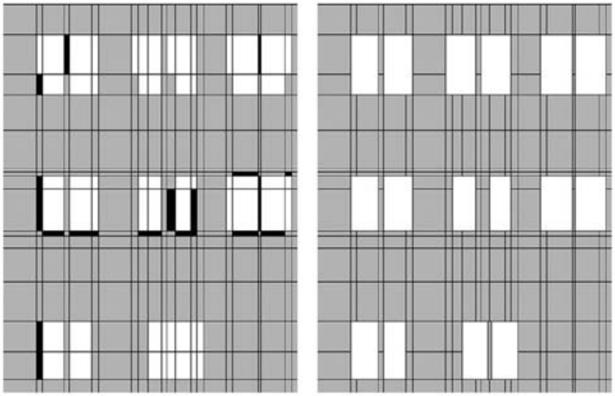


Figure 6: Classified 3D cells before (left) and after enhancement (right).

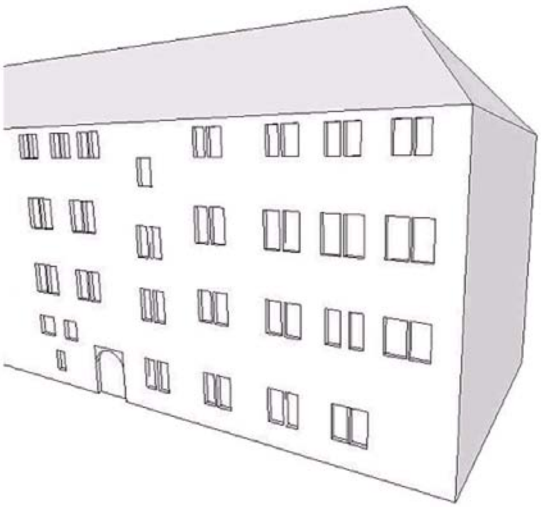


Figure 7: Reconstructed 3D building model with refined facade.

Using general-purpose computation on graphics processing units for remote sensing applications

The fast development in computational power of modern GPUs and their wide availability, led to the growing interest in general-purpose computation on graphics processing units (GPGPU). The performance and especially the performance growth of modern GPUs is tremendous.

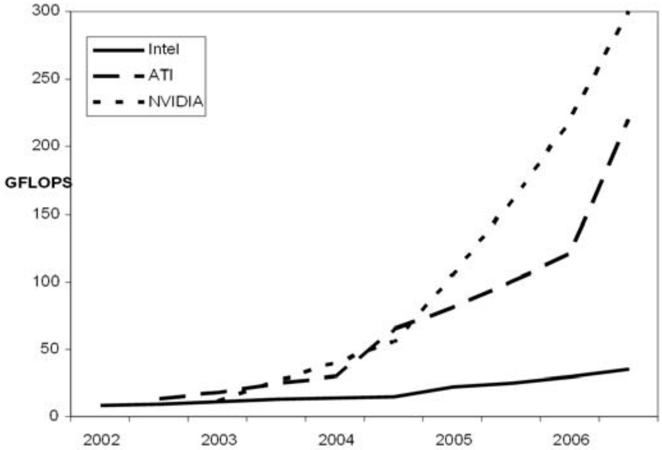


Figure 8: CPU performance comparison (Owens et al, 2007).

Beside applications in image processing, photogrammetry and computer vision, GPU computation can also be used in remote sensing. SAR images, for example, are not easy to understand and to interpret. For this purpose SAR simulators are important tools. They usually apply the ray tracing approach. Real-time applications, like interactive visualisation, in general use the rasterization method. Rasterization is less complex to calculate and is therefore faster. The real-time SAR simulator SARViz, which uses rasterization, is implemented on programmable graphics processing units.

Beside SAR, LIDAR also can benefit from GPU processing. LIDAR data is delivered as point data, but usually triangulated surfaces are analysed. The triangulation of this data is a time consuming process. Standard tools are often not able to triangulate the data in an acceptable time or are, due to the amount of points, not able to triangulate the data at all. GPUs are designed to process large amounts of triangles, although older cards are limited by the video memory. This can be used for hardware supported triangulation of LIDAR point data.

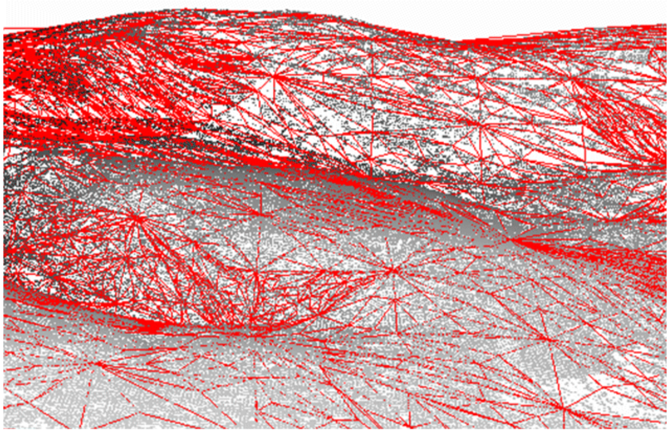


Figure 9: Triangulated LIDAR points.

Terrestrial Positioning Systems and Computer Vision

Camera Tracking from Point-Based Environment Models

Localization is an important problem studied in many fields of research. Applications are wide spread and can range from pedestrian self-localization, augmented reality and autonomous robotics to object recognition under camera motion. Many approaches addressing the problem have been proposed. Some use direct orientation sensor such as inertial measurement units (IMUs) and GPS systems to determine orientation and position, others use a combination of a variety of sensors, such as ranging, imaging and orientation sensors.

In the field of computer vision the problem is often confined to the problem of determining position and orientation, or orientation in short, from the information given by an imaging sensor, i.e. a camera, alone. The most prominent approaches today are for one structure from motion (SfM), which puts the emphasis on the problem of deriving a representation of the scene and the actual localization is more of a by-product. Another well known approach is simultaneous localization and mapping (SLAM), or more specific visual SLAM (VSLAM), which emphasizes more the localization problem. In their core these approaches use some variation of relative orientation and stereo matching algorithms to derive orientation and scene structure. These approaches are particularly suitable when the system is supposed to work in an unknown environment with no or limited information on the scene. In such cases pure local orientation relative to an arbitrary starting point is sufficient.

In contrast to these approaches we propose to separate the acquisition of the three-dimensional scene structure from the on-line orientation procedure. We propose a point-based environment model (PEM) to represent the absolute coordinate frame in which the motion is being estimated.

The motivation for this approach is based on the expectation, that dense point clouds of large building complexes, industrial facilities and urban areas will become widely available in the next few years. The main drive behind the acquisition of such data is from the computer-aided facility management (CAFM) industry, preservation authorities and safety agencies. The main enabling factor is the recent wide spread availability of reliable sensor systems and service companies. Once this data has been acquired it can serve multiple purposes, our proposed application being only one in many. For testing purposes the experiments were set up in an office environment. The scanner is placed in the middle of the room. A single scan captures the full room, with little occlusions. The resolution on the surfaces was chosen to 5 mm on average. The point cloud consists of over 1.5 million points, which were acquired in about 15 minutes. In addition to the x, y and z coordinates, the scanner also records the intensity of the reflected laser pulse. An overview of the collected point cloud can be seen in Fig. 10 on top.

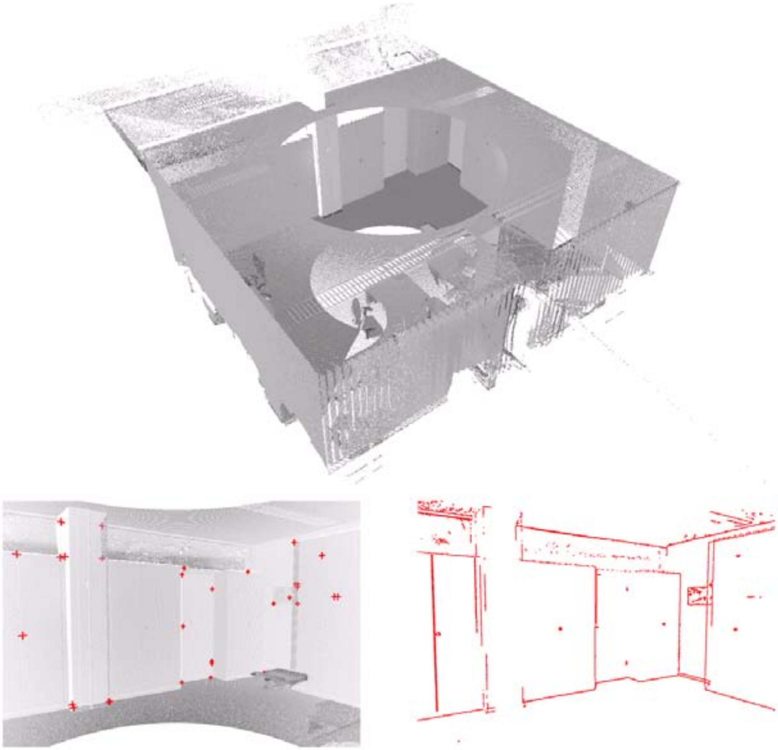


Figure 10: The point cloud data acquired by our laser scanner. The top figure shows an overview of the full scan of an office. The bottom left figure shows a part of the scan with automatically extracted feature points. The bottom right figure shows a reduced point cloud which contains only edge points.

Fig. 11 finally shows a set of three images from a sequence of 500 frames. The images are not consecutive but are several frames apart. The left column shows the projection of three-dimensional feature points and the search areas for the image template matching. The right column of Fig. 11 shows the projection of three-dimensional edge points. This serves as a visual test for the correctness of the tracking and the estimation of the orientation by resection. The optimal alignment of extracted laser edge points to the edges in the image indicates successful orientation of the camera.

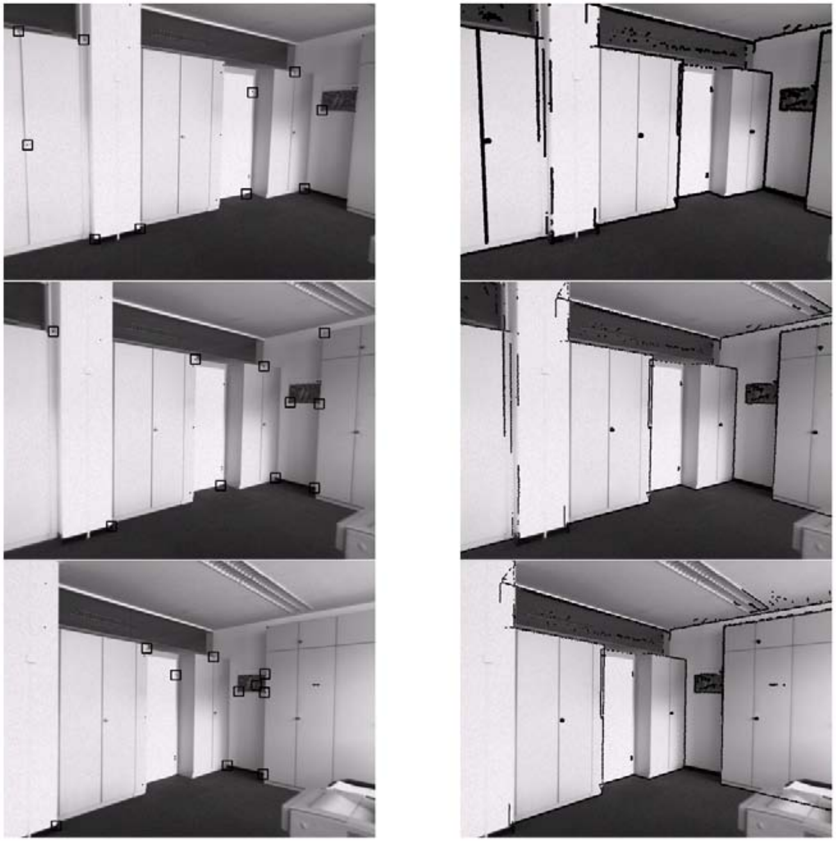


Figure 11: Three frames out of a sequence of 500 frames taken from an office environment. The three frames show a pan motion from left to right. The order of the sequence is from top to bottom. The left column shows the projected feature points, which were extracted from the laser range data. The features selected for tracking are marked with a box. The right column shows the projection of the edge points extracted from the laser data onto the images.

From Point Samples to Surfaces

Terrestrial laser scanners deliver a dense point-wise sampling of an object's surface. For many applications a surface-like reconstruction is required. The most typical example is the visualization of the scanned data. Traditional approaches use meshing algorithms to reconstruct and triangulate the surface represented by the points. Especially in cultural heritage, where complex objects with delicate structures are recorded in highly detailed scans, this process is not without problems. Often long and tedious manual clean-up procedures are required to achieve satisfactory results. We have applied an alternative approach which is called point splatting. We have developed an algorithm to compute a suitable surfel representation directly from the raw laser scanner data. This results in a speedy and fully automated procedure for surface reconstruction. The Panagia Kera, a 13th century church in Kritsa near Agios Nikolaos on the island of Crete, was chosen as a suitable example for testing the approach.

While triangular meshes have proved to be a flexible and effective surface representation they might become inefficient when the number of vertices becomes very large. When the number of triangles exceeds the number of pixels on the screen, most triangles cover less than a pixel and the rasterization of the triangles becomes extremely expensive. We can easily follow this argument when we observe that currently a typical computer screen has just over a million pixels and even a simple dataset as the one used in our experiment exceeds this number. Laser-scanning projects of over 100 million points are not unusual.

To overcome this limitation of triangular meshes point-based methods have been proposed, which represent the surface by a point-wise sampling, where each point also stores the normal vector of the surface at this point. Point-based geometry provides all typical processing needs, such as editing, filtering and texturing. It becomes evident that this form of representation is ideally suited for datasets which were acquired with a sensor in a point-wise fashion such as terrestrial laserscanners. For the rendering of a point-based representation surfels are used as rendering primitives also referred to as point splats. Each point is associated with a disk perpendicular to the normal vector and with a radius just large enough to cover the space to the neighboring points. This idea is visualized in Fig. 12, where a part of the point cloud is render with point splats, which have a reduced radius, so we can see the individual disks.

We propose a new method to use the topology given by the physical scanning process as the initial neighborhood information to compute both the normal vector and the radius for each point splat. Since we use the scanning topology we do not have to dynamically compute neighborhood information and thus we do not need to build expensive search structures such as a kd-tree. All operations become linear with respect to the number of input pixels. As we only use a small number of points for each operation the method can also be implemented very memory efficient. The result on the full point cloud consisting of 2.2 million points is shown below.

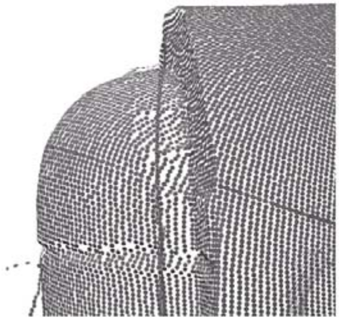


Figure 12: Detail of the model showing point splats with reduced radius.

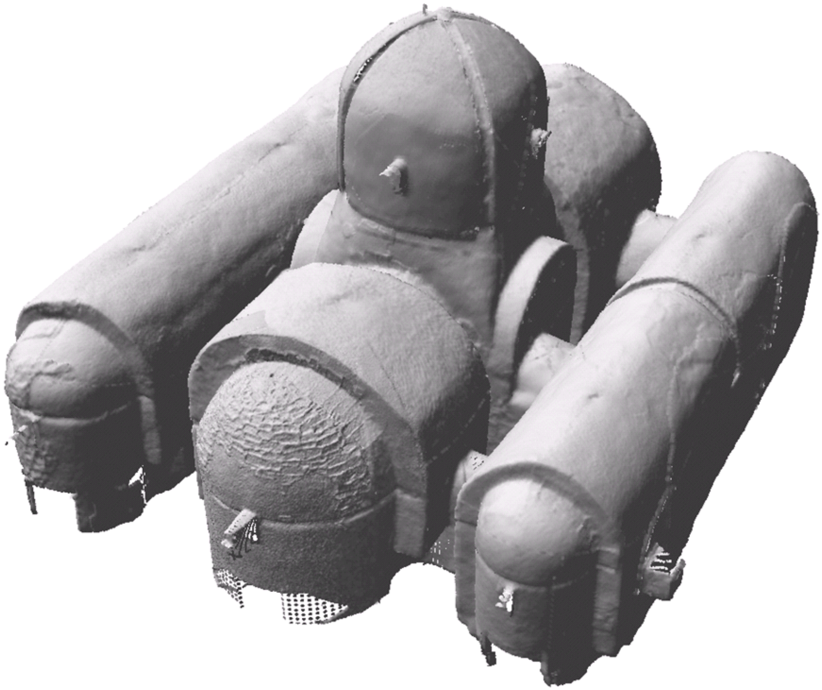


Figure 13: The full dataset of the interior converted to point splats and visualized using PointShop3D in high-quality software-rendering mode.

Automated edge extraction for the registration of intensity images to range data

Cultural heritage applications frequently require data collection by terrestrial laser scanning for very complex structures. In addition to geometric data collection, texture mapping is particular important in the area of cultural heritage to have more complete documentation. Photo-realistic texturing can for example add information about the structure condition, which is not present in the 3D model such as decay of the material. Additionally, color image information is also indispensable for features like frescos and mosaics. For this reason, some commercial 3D systems already provide model-registered color texture by capturing the RGB values of each LIDAR point using a camera already integrated in the system. However, these images frequently are not sufficient for high quality texturing, which is desired for documentation, since the ideal conditions for taking the images may not coincide with those for laser scanning. Therefore it is useful to acquire geometry and texture by two independent processes and allow for an image collection at optimal position and time for texturing.

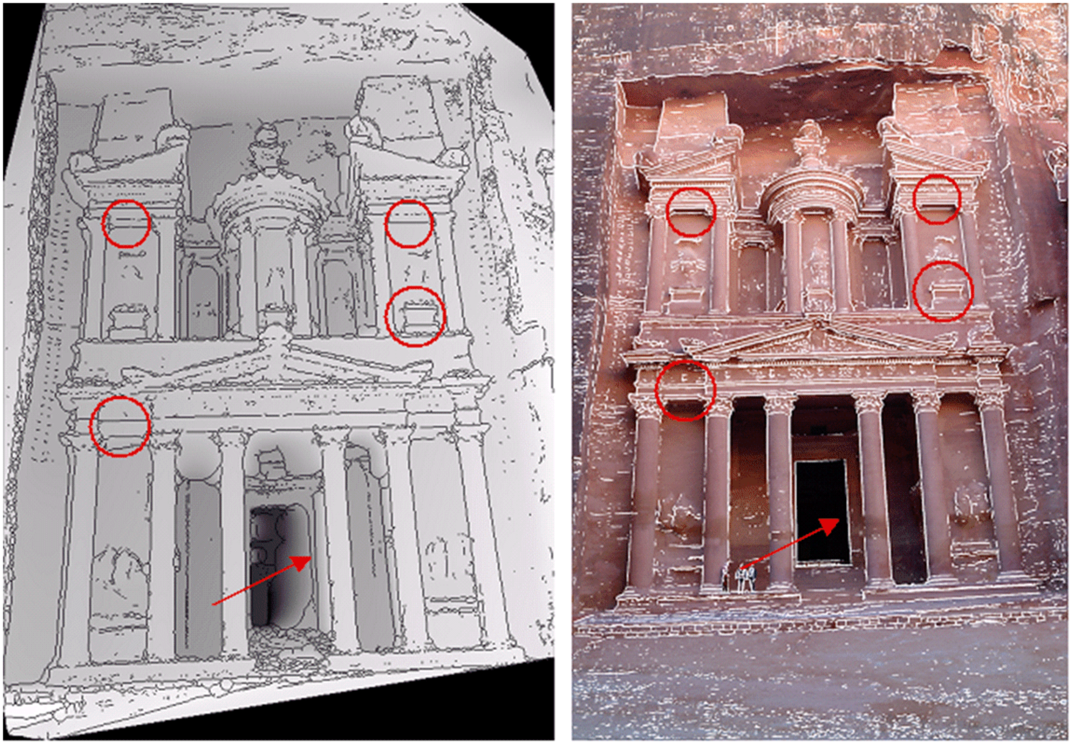


Figure 14: Corresponding registration features.

The quality of the registration process, which aligns the laser scanner data with the imagery, is a crucial factor for the texturing processing. This registration can be performed when corresponding coordinates are available in both systems. Since the accurate detection and measurement of point correspondences can be difficult, especially within point clouds from laser scanning, lines are measured as corresponding elements. We have presented and discussed an efficient edge detection algorithm that can detect the line features in both range and intensity images. In the proposed algorithm the distinguished points, which will comprise the edges, depend on the spatial analysis of the numerical description of the mean curvature values. Although the central task of the proposed edge detection algorithm is to reliable detect and locate edge points, a rich description of edge points give the ability to reliably detecting and characterizing the edge types as a crease and step edges, and then go further to classify the crease edges as concave or convex types. The algorithm was initially proposed for range image segmentation and has been extended to segment the intensity images with some improvements. The algorithm is illustrated on a dataset of the Al-Khasneh monument in Petra, Jordan. Fig. 14 shows the extracted edges and highlights corresponding line features, which are used for registration.

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Blumrich, F.: Experimentelle Bestimmung der Auflösungsgrenze des HDS 3000. Betreuer: J. Böhm.

Activities in National and International Organizations

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Member Advisary Board Finnish Geodetic Institute
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Haala, N.: Co-Chair ISPRS WG III/4 - Automatic Image Interpretation for City-Modelling

Walter, V.: Nationaler Berichterstatter für die ISPRS Kommission IV

Education - Lectures/Exercises/Training/Seminars

Adjustment theory and Statistical Inference I, II (Fritsch, Becker)	4/2/0/0
Aerotriangulation and Stereoplotting (Cramer)	2/1/0/0
Close Range Photogrammetry (Böhm)	2/1/0/0
Databases and Geoinformation Systems (Walter)	2/1/0/0
Digital Terrain Models (Haala)	1/1/0/0
Digital Image Processing (Haala)	2/1/0/0
Digital Signal Processing (Fritsch, Böhm)	2/1/0/0
Geodetic Seminar I, II (Fritsch, Sneeuw, Keller, Kleusberg, Möhlenbrink)	0/0/0/4
Geoinformatics I (Fritsch, Walter)	2/1/0/0
Geoinformatics II (Walter)	2/1/0/0
Introductory Readings to Photogrammetry (Cramer)	2/0/0/0
Image Acquisition and Monoplotting (Cramer)	2/1/0/0
Practical Training in GIS (Walter)	0/0/4/0
Urban Planning (Schäfer)	1/0/0/0
Pattern Recognition and Image Based Geodata Collection (Haala)	2/1/0/0
Photogrammetry and GIS (Cramer)	2/1/0/0
Advanced Projects in Photogrammetry and GIS (Böhm, Cramer, Haala, Walter)	1/2/0/0
Animation and Visualisation of Geodata (Haala, Kada)	1/1/0/0
Cartography (Urbanke)	1/0/0/0