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Book of abstracts

measuring the changes

13th FIG Symposium on Deformation Measurement and Analysis

4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering

LNEC • LISBON • PORTUGAL • 2008 May 12-15

Welcome address

The Symposium "Measuring the Changes", organized by LNEC (National Laboratory for Civil Engineering of Portugal), combines the 13th FIG (International Federation of Surveyors) Symposium on Deformation Measurements and Analysis with the 4th IAG (International Association of Geodesy) Symposium on Geodesy for Geotechnical and Structural Engineering.

Besides LNEC, the Local Organizing Committee was greatly supported by Ordem dos Engenheiros (Association of the Portuguese Engineers) and SPUIAGG (Portuguese Section of the International Unions of Astronomy and Geodesy and Geophysics), who represent Portugal in FIG and IAG, respectively, and guarantee the involvement of the Portuguese technical and scientific communities in this event.

A considerable number of abstracts, dealing with a wide spectrum of themes, have been submitted for presentation in the Symposium. Thanks are due to the colleagues who submitted abstracts and to the members of the Scientific Committee for having kindly accepted to perform this important and time consuming task, certainly contributing for the quality and reconnaissance at international level of "Measuring the Changes".

This volume contains the texts of the abstracts grouped by sessions, an overview of the symposium organizational aspects, the sessions' time schedule and references to the sponsors and exhibitors, institutional and private. We thank all the sponsors and exhibitors as well for their generous support.

The Local Organizing Committee is certain that the Symposium will be a successful one, bringing new ideas and advances in the theoretical and practical fields, and that it constitutes a step forward in the technical and scientific domains embraced by the theme "Measuring the Changes". Finally, we wish all the participants a warm and pleasant stay in Lisbon.

Maria João Henriques
João Agria Torres
José Nuno Lima
Manuela Vasconcelos
Rui Manuel Fernandes

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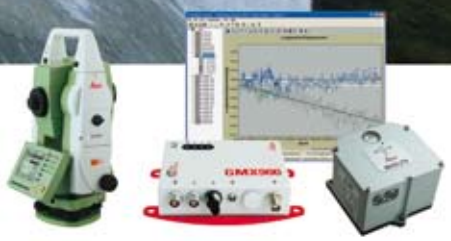

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At-A-Glance Symposium Programme

	Monday 12		Tuesday 13		Wednesday 14		Thursday 15
8:00	**Registration**						TECHNICAL VISIT *Alqueva* Dam (departure 08:00)
8:30							
9:00	Opening Ceremony keynote speeches		MST1	GDF1	MST3	MOD3	
9:30							
10:00							
10:30	coffee break		coffee break		coffee break		
11:00	MTT	EGMT	MOD2	GDF2	LSS	GNSS2	
11:30							
12:00							
12:30	lunch		lunch		lunch		
13:00							
13:30							
14:00	MOD1	GNSS1	RDR1	MST2	EQP2	MOD4	
14:30							
15:00							
15:30	coffee break		coffee break		coffee break		
16:00	EQP1		PST1		PST2		
16:30			RDR2		Closing Ceremony		
17:00					Meeting WG6.4TF5 "Fibre Optic Sensors"		
17:30	Tools for Measuring the Changes: the Exhibitor's session		Social Dinner				
18:00							
18:30							
19:00	Ice breaker party						
19:30							
20:00							
20:30							
21:00							
21:30							

Sessions code

MOD	Modelling
EGMT	Engineering geodesy for multi-technique local survey ties
MTT	Multitechniques
GNSS	GNSS
EQP	Equipment
MST	Monitoring of structures
GDF	Geodeformations
RDR	Radar
LSS	Laserscanning
PST	Poster Session

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ACTIVITY OF THE FIG WORKING GROUP 6.1 ON DEFORMATION MEASUREMENTS – PROGRESS REPORT 2006-2008

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Abstract: International symposia organized by FIG Working Group 6.1 provide international forum for the exchange of information on developments of new techniques and methods for monitoring and analysis of structural and ground deformation. International Task Forces are established to solve specific problems that are identified by researchers and users of the new methods and techniques. Currently, the following Task Forces are active:

Task Force 6.1.3: Optimal Use of Interferometric Synthetic Aperture Radar (InSAR);

Task Force 6.1.4: Monitoring and Analysis of Cyclic Deformations and Structural Vibrations;

Task Force 6.1.5: Remote Engineering Surveys with Terrestrial Laser Scanning techniques;

Task Force 6.1.6: Geodetic Engineering in Crustal Deformation Studies;

Task Force 6.1.7: Continuum Mechanics as a Support for deformation Monitoring.

A summary of progress reports submitted by the Task Forces is presented.

Key words: monitoring techniques, INSAR, laser scanners, continuum mechanics, FEM, crustal deformations, cyclic deformation,

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GEODESY & ENGINEERING –DEFORMATION STUDIES AT LARGE SCALES FROM A GEODETIC VIEWPOINT

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Abstract: Geodesy is the foundations of Surveying and Mapping. Yet Geodesy is also a critical geoscience discipline. Geodesy's contributions to global change studies, crustal dynamics, seismological and volcanic research, sea level rise and ocean circulation, mass transport in the atmosphere, oceans and solid earth, are well known and increasingly important. The International Association of Geodesy (IAG) has developed a new component of its activities known as the Global Geodetic Observing System (GGOS). GGOS unifies the work of the various IAG Services (the IGS, IVS, ILRS, IDS, etc) and the Commissions. However GGOS is not just about global scale observing and analysis systems, there will also be local components. Deformation due to ground subsidence, coastline erosion, landslide hazards, building structural monitoring, etc., using a range of technologies, is hence an important part of GGOS. In addition, increasing development of GNSS technologies and methodologies promise improved positioning performance for all users, including geodesy and precise deformation applications. One important initiative is the establishment of real time products and services from the Internationa GNSS Service (IGS). Many of these developments in modern geodesy will impact on sister disciplines represented by the FIG. This paper will discuss developments in the IAG, and within geodesy in general, and relate them to the work of FIG Working Group 6.1 and IAG Sub-Commission 4.2.

Key words: Geodesy, IGS, IAG, GGOS, GNSS, deformation.

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DEFORMATION MONITORING THROUGH MULTI-PLATFORM INTEGRATION

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Abstract: GPS, Tilt and InSAR measurement technologies all have shortcomings that limit their application in deformation monitoring projects. Proper integration of all three measurement types allows many of these shortcomings to be mitigated and provides stable, high accuracy and high precision measurements of ground surface and structure motion.

The performance regime of each technology is well established. GPS is ideal where absolute measurements are needed, where all three axes of motion are of interest, and when long term accuracy of results is a key requirement. InSAR is especially applicable where large areas need to be covered, ground instrumentation is prohibitively expensive, and deformation rates fall within its lower, yet respectable, resolution limits. Tilt is the only technology capable of both medium and very high precision measurements of the earth surface or structures.

Each of these technologies has several weaknesses that must be addressed for their successful and accurate deployment. For example, GPS sites are relatively expensive and require open sky. Tilt becomes impractical for monitoring areas larger than several square kilometers and loses its precision advantage over long periods of time. Since tilt measures the gradient of the deformation, instrument layout requires special attention and may compromise results if not implemented correctly. InSAR provides line of sight measurements rather than the full motion vector and is often limited in accuracy by variable atmospheric and ground conditions.

Integrating the different technologies, by using data from one set of tools to constrain the analysis of another, takes advantages of their respective strengths while partially cancelling the weaknesses. The result is a more robust and accurate monitoring system that can meet design goals previously unattainable or attainable only at very high cost. The paper outlines the integration methods and provides examples of these systems using real data. Finally, an automated system is introduced that performs data quality control and presents the results in an easy to understand format.

Key words: GPS, Tiltmeter, Tilt, InSAR, Integration, Deformation Monitoring

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DESIGN AND ANALYSIS OF MULTI-SENSOR DEFORMATION DETECTION SYSTEMS

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Abstract: Recent world-wide catastrophic failures of civil and natural structures dramatically increase the demand for fully automated, reliable, and continuous monitoring of structural and ground deformation. To satisfy the requirements, an optimal combination of geodetic and geotechnical/structural instrumentation is sought in the development of multi-sensor deformation detection systems. The design of the systems must be based on the integrated analysis in which geometrical analysis is combined with deterministic modelling and prediction of deformations. Geodetic robotic total stations, GNSS techniques augmented by pseudo-satellites, and micro-machined sensors based on the micro-electromechanical systems (MEMS) technology, are the main components of multi-sensor systems being developed at the Canadian Centre for Geodetic Engineering. Deformation Detection System software suite for fully automated data acquisition and data processing supports the systems. The design and physical interpretation of the integrated monitoring surveys are based on the finite element method.

Key words: deformation monitoring, FEM, deterministic modelling, multi-sensor systems

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COMBINED TECHNIQUES FOR THE STABILITY CONTROL OF HISTORICAL STRUCTURES

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Abstract: The demand for high-definition surveys within cultural heritage-related projects represents one of the main factors which promoted the use of laser scanning technology. By measuring millions of points within relatively short time periods, terrestrial laser scanners allows to derive complete and very detailed 3D models of real objects from acquired point clouds. These features drew in recent years the interest of surveyors, engineers, architects and archaeologists towards the laser scanning technique as an invaluable surveying mean for 3D modeling of sites and artifacts of cultural heritage. A wide variety of objects, e.g., small pieces of pottery, statues, buildings, and large areas of archaeological sites, have been scanned and modeled for various purposes like preservation, reconstruction, study, and museum exhibitions. However, the use of TLS systems for stability control is still a research field not much investigated.
In the view of insight investigation on this topic, a three-years project has been established in order to evaluate the use of multiple surveying techniques for the stability control of a complex historical structure. To this aim, terrestrial laser scanning (TLS), total station (TS), deflectometers and photogrammetry are being employed for a first test on the Anatomy Theatre, one of the oldest, most important and best-known historical "medical" buildings. Located inside the *Palazzo del Bo'*, the building seat of the University of Padua, the Theatre was built in 1594 as first permanent structure of its kind and substituted for the temporary theatres which were set up when necessary. The main goal of this work is to verify the stability over the time of this kind of structure, given the inherent organic decay of the wooden parts.
So far four consecutive surveys of the Theatre have been carried out with a Leica laser scanner (HDS 3000) and a Leica Total Station. In the first one the historical structure has been fully measured in order to derive a complete 3D model suited for FEM analysis; then, according to a six months time span, three further surveys were performed for stability check.
In this paper we present the results obtained from the repeated surveys and highlight issues and difficulties related to the laser scanning of an unusual geometry such as the one provided by the Anatomy Theatre of the University of Padua.

Key words: stability control, terrestrial laser scanning, 3D modeling

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DAM MONITORING USING COMBINED TERRESTRIAL IMAGING SYSTEMS

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Abstract: Thousands of registered large concrete and embankment dams have now more than five decades of operation and age related problems. Structural safety condition assessment is the main aim of dam monitoring activities and a concern for authorities. Laser scanners combined with digital calibrated reflex cameras provide accurate and very dense 3D numerical models as well as spatially continuous high-resolution RGB information of the objects under study. These combined terrestrial imaging systems (CTIS) provide a huge amount of geometric and radiometric well structured data in a short period of time. A 3D scanning company, Artescan, and a research organization (LNEC, Laboratório Nacional de Engenharia Civil, in Portugal) have been, since 2003, developing positional monitoring methodologies for embankment dams and assisted visual inspection methodologies for concrete dams. Interesting results have been achieved in what concerns positional accuracy, system reliability and cost-effectiveness of this approach to enhance dam monitoring capabilities. This paper presents different examples of the developed methodologies as applied to dam monitoring.

Key words: Structural safety assessment, monitoring, laser scanning, digital calibrated cameras, combined terrestrial imaging systems, visual inspection, positional accuracy, reliability.

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POINT ATTITUDE DETERMINATION USING INCLINOMETER AND GPS FOR HIGH RISE BUILDING MONITORING PROJECTS

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Abstract: Traditionally structural response of high-rise building due to severe conditions has been measured using accelerometers only.

The new generation of dual axis digital inclinometer and a loose integration with GPS-RTK receiver can bring a better answer for those who are interested in monitoring such structure.

An inclinometer provides an absolute dual-axis inclination measurements referring to the main gravity vertical. GPS-RTK offers direct relative displacement measurements for dynamic monitoring, but it has its own limitations. The measurement accuracy can be affected by multi-path and are influenced directly by the satellite constellation geometry. Moreover the altitude delivered by GPS needs to be expressed in an orthometric reference frame.

In this paper a new technique will be described that uses the correlation signals directly detected from a GPS-RTK receiver and an high accurate inclinometer to produce an optimal unbiased estimation of the point attitude (dx, dy, dz, roll,pitch and azimuth) variation.

The methodology consists of Fast Fourier Transform (FFT), a filtering technique, and velocity linear trend estimation from both GPS and inclinometer measurements.

Several types of datasets have been tested from equipment deployed on high-rise towers and the results will be presented.

Because of redundancy within the loosely integrated GPS-RTK and inclinometer system, the authors opinion is that a much more robust quality assurance in monitoring structural deformation for high-rise building can be achieved paving the way for new applications as well.

Key words: high-rise building, monitoring, point attitude, inclinometer, GPS.

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IMPORTANCE OF LOCAL TIES FOR THE ITRF

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Abstract: The key-element of the construction of the International Terrestrial Reference Frame (ITRF) is the availability of co-location sites where two or more space geodesy instruments are operating and where differential coordinates (local ties) between the measuring reference points of these instruments are determined. The very existence of the ITRF relies on the availability and quality of local ties in co-location sites as well as the number and distribution of these sites over the globe. In this presentation we review the current status of co-location sites of the 4 techniques contributing to the ITRF: VLBI, SLR, GPS and DORIS. After recalling the usage of local ties in the ITRF combination, we will evaluate the impact of their errors on the ITRF quality and reliability as well as on its datum definition and mainly its physical parameters, namely the origin and the scale. Based on the results of the ITRF2005 combination and other analysis, we will isolate co-location site where discrepancies between terrestrial surveys and space geodesy estimates are significant.

Key words: Reference Frames, Combination, Local Survey, ITRF

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CHALLENGES OF INTER-TECHNIQUE TIE SURVEYS – AN ENGINEERING PERSPECTIVE

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Abstract: The determination of terrestrial and celestial reference frames is based on the combination of space-geodetic techniques such as Very Long Baseline Interferometry (VLBI), the Global Positioning System (GPS) and Satellite Laser Ranging (SLR). Today, impressive results for the determination of the site coordinates are already reached globally in the range of a few millimetres. For the inter-technique combination, collocation sites are maintained which provide at least two different space-geodetic techniques. The actual connection of the respective techniques is based on local surveys which is a typical task of engineering geodesy. In order to provide highly precise and reliable local ties, both scientific and technical issues have to be treated considering the available surveying technology.
The goal of this paper is to show both the possibilities and challenges of inter-technique tie determination from an engineering viewpoint. The presentation is divided into three parts. First, the state of the art of local tie surveys is discussed. Some shortcomings of the present-day strategies are indicated. Second, the relevant sensors and systems are presented including high-end instrumentation such as laser trackers and laser scanners. Third, a more comprehensive dynamical monitoring approach is outlined and discussed regarding instrumentation and data analysis which can provide high-quality local tie products.

Key words: Reference frames, local ties, engineering geodesy, metrology

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INDIRECT DETERMINATION OF THE INVARIANT REFERENCE POINT (IVP) OF SLR AND VLBI OBSERVING SYSTEMS

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Abstract: The integrity and strengths of multi-technique terrestrial reference frames such as ITRF2005 depend on the precisely measured and expressed local tie connections between space geodetic observing systems at co-located observatories. Australia has several geodetic observatories, which together host the full variety of space geodetic techniques, including GPS, GLONASS, DORIS, SLR and VLBI. The observational reference point of large geodetic observing systems, such as SLR and VLBI, are generally inaccessible. Therefore, Geoscience Australia developed an indirect measurement approach, using terrestrial observations, to precisely determine the invariant reference point (IVP) of SLR and VLBI telescopes. The indirect IVP determination technique involves a rigorous process of three-dimensional circle fitting to the coordinates of targets observed on the structure during rotational sequences about each of the systems' independent axes (e.g. azimuth and elevation). Geoscience Australia routinely measures millimetre accurate connections between survey monuments and geodetic observing systems at co-located observatories across Australia. The IVP derivation technique continues to be refined, looking to account for further un-modelled systematic errors.

Key words: local tie, indirect method, invariant point (IVP), SLR, VLBI

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TERRESTRIAL SURVEYING APPLIED TO LARGE VLBI TELESCOPES AND ECCENTRICITY VECTORS MONITORING

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Abstract: Large VLBI telescopes undergo gravitational deformations which affect both geodetic and astronomic observations as well as the real reference point (RP) position (i.e. the reference point which is directly linked to and determined by the physics of the VLBI observations). As a consequence, the accuracy of eccentricity vectors determined with high precision terrestrial observations strictly depends on the possibility of univocally define the geodetic instrument's RP to be surveyed and estimated: technique dependent effects (e.g. gravitational and thermal deformations for VLBI, phase centre variations for GPS, etc) bias RP positions and weaken and corrupt the information contained in the eccentricity. The impact on combined geodetic products is remarkable; a proper definition of space geodetic instruments' RP must therefore account for possible biases that modify its theoretical position. Whether the problem must be directly addressed by each technique-specific Service is still an open issue. Indirect approaches based on high precision terrestrial observations have proved to be additional, accurate and independent tools for determining and monitoring the eccentricities at co-location sites. Nevertheless, a deeper and rigorous investigation on RP location's variations is at least as important and it is nowadays fundamental for each space geodetic instrument.
To this respect, we are presenting the investigations on VLBI telescope's RP position that were carried out at Medicina and Noto (Italy) on the 32 m antennas: trilateration, triangulation and laser scanning observations were applied and combined to monitor the gravitational deformations which affect the telescope's structure and to derive an elevation dependent correction function for radio signal path.

Key words: local tie, indirect method, terrestrial observations, reference point, laser scanning

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AN EVALUATION OF METHODS FOR THE IDENTIFICATION OF VARIANCE CHANGES IN DEFORMATION ANALYSIS

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Abstract: An important aim of structural deformation analysis is to obtain parameters for the reaction strength and delay of the monitored structure, based on continuous observations of the deformation and the acting loads. This task is performed using specific tools of time series analysis. The used functions assume the stationarity up to the 2nd order of the observed phenomena. As a consequence the parameters are estimated from the entire available data set. However, the analysis of the structures' deformation behaviour due to loads exhibiting an irregular pattern, i.e., traffic or wind, requires a more thorough consideration of this assumption. Its violation may lead to biased estimations of the parameters.

The present paper deals with methods for the identification of variance changes in the recorded time series. Based on the detected changes one can adapt the estimation model by introducing different system parameters corresponding to each segment of the time series with homogeneous variance. The assessed identification methods use different approaches. The first one uses a statistical test, with a test value based on the cumulative sum of squares. In the second method the configuration of the change-points is estimated.

In order to avoid influences due to changes of the mean, the time series are first decomposed using a Wavelet-Transform. The variance homogeneity of individual spectral components of time series is analysed at the level of the wavelet coefficients.

First, the theoretic concepts of the two methods are introduced. The second part is dedicated to the assessment of the performance of these methods based on simulated signals and on real data recorded at a wind energy plant and a vertical lift bridge.

Key words: variance homogeneity, change points, deformation analysis

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AUTOMATED ANALYSIS AND EVALUATION OF TECHNICAL SURVEYING PROCESSES WITH KNOWLEDGE-BASED SYSTEMS

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Abstract: In this paper the application of knowledge-based systems for the analysis and evaluation of geodetic measurements is described. The first part gives a nontechnical overview over existing software products like GeoFit and current research activities (e.g. TUNCONSTRUCT, KASIP) with special focuses on tunneling and natural disaster management. The second part of the paper describes a case study from technical surveying in detail: the knowledge-based evaluation of the quality of free stationing on construction sites (e.g. tunnel sites). One main goal of the knowledge-based approach is to automate the time consuming daily process of manually checking lots of datasets by human experts. The paper shows the development of the knowledge-based system ranging from knowledge acquisition over knowledge analysis and representation up to the software prototype. A practical example is presented which indicates the capability of the system even to reproduce the often intuitive ratings of human experts.

Key words: Technical surveying, free stationing, knowledge-based system, quality assessment

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BAYESIAN ESTIMATION IN DAM MONITORING NETWORKS

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Abstract: A Bayesian estimator with informative prior distributions (a multi-normal and an inverted gamma distribution), adequate to displacement estimation at dam monitoring networks, is presented. The hyper-parameters of the prior distributions are obtained by Bayesian empirical methods with non-informative priors. The performances of the Bayes estimator and the classical generalized lest squares estimator are compared using two measurements of the horizontal monitoring network of a concrete gravity dam: the Penha Garcia dam (Portugal). In order to test the robustness of the two estimators, gross errors are added to one of the measured horizontal directions: the Bayes estimator proves to be significantly more robust than the generalized least squares estimator.

Key words: Bayes estimator, hyper-parameter, informative prior.

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COMPARISON OF MONTE CARLO AND FUZZY TECHNIQUES IN UNCERTAINTY MODELLING

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Abstract: The standard reference in uncertainty modelling in engineering and mathematical science is the "Guide to the Expression of Uncertainty in Measurement (GUM)". GUM groups the occurring uncertain quantities into "Type A" and "Type B". Uncertainties of "Type A" are determined with the classical statistical methods, while "Type B" is subject to other uncertainties like experience with and knowledge about an instrument. GUM proposes to describe both types of uncertainty with random quantities. For this reason, all occurring uncertainties can be treated in a stochastic framework using variances and covariances. Our comparative study focuses on the description and on the propagation of the uncertainties of "Type B".

Monte Carlo Techniques provide a powerful tool to take into consideration, that the uncertain quantities of "Type B" are not normal distributed, only. They allow computing variances, covariances and confidence regions for the parameters of interest with respect to triangular, trapezoidal, uniform and normal distributions in analogy to the guidelines of GUM.

But in the last years new mathematical techniques were introduced as an alternative evaluation to handle with uncertainties of "Type B". This allows to distinguish between "Type A" and "Type B" uncertainties within the propagation process of the uncertainties to the parameters of interest. Whereas the uncertainties of "Type A" are modelled in a stochastic framework, the uncertainties of "Type B" were treated with interval and fuzzy techniques.

In this study both approaches shall be critical analyzed and compared to each other. The applied procedure is outlined showing both, the theory and a numerical example for the evaluation of uncertainties in an application for laserscanning.

Key words: Monte Carlo Techniques, Fuzzy Techniques, GUM

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COMPARATIVE TESTING AND ANALYSIS OF RTS VERSUS GPS FOR STRUCTURAL MONITORING USING CALIBRATION MEASUREMENTS UPON SINUSOIDAL EXCITATION

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Abstract: In the past, conventional and satellite surveying methods have been used to monitor the dynamic behavior of oscillating engineering structures. However, only very recently, a thorough examination of their capabilities and limitations in terms of positioning quality measures has been attempted.

This paper presents an experimentally based approach to the study and cross-examination of the modal characteristics of GPS and Robotic Total Stations (RTS) used for structural monitoring applications. Dynamic deformations of a fully controlled sinusoidal form were produced using an oscillating source, on which an on purpose built metallic brace adapter attached to hold the reflector and the GPS antenna. The GPS and RTS were set to record data at sampling rates up to 20 Hz and 6 Hz respectively. A total of 100 sets of experiments were performed to simulate the harmonic motions of known amplitude and frequency values ranging from ±1 cm to ±5 cm and from 0.1 Hz to 2 Hz respectively, which cover the dominant frequency spectrum of most major flexible structures.

Data spectral analysis techniques were employed to compute the parameters (frequency, amplitude) of motion of the oscillating prism and the GPS antenna using the recorded positions. Data analysis was based on two processing methodologies. Under the first scenario, the nominal signal is considered unknown, and therefore, the residuals between the observed signal and its least squares estimates reflect the precision of the measuring sensors. The second scenario simulates a natural system with known motion parameters. In this case, is assessed the ability of the sensors to reproduce the nominal (original) signal.

Key words: GPS, RTS, Dynamic Deformation, Monitoring, Flexible structures

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STRUCTURAL DEFORMATION MONITORING ANALYSIS USING GEODETIC TECHNIQUES AFTER THE EARTHQUAKE AT BOLU PASS OF TRANSPORT EUROPEAN MOTORWAY

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Abstract: The Bolu viaduct I, viaduct II and the tunnel are a part of the Bolu mountain project that is located in the north central Turkey. The project which is a part of the Transport European Motorway (TEM) aims to improve the transportation conditions in the western part of Bolu.
The crustal movements that come out as a result of earthquakes are the main cause of the deformations in engineering structures. Turkey has a long history about the earthquakes, because one of the most active faults, the North Anatolian Fault (NAF), is crossing over Turkey. Especially in 1999, the earthquakes that happened because of the movements in the NAF cause damages on many engineering structures.
The earthquake that happened in 12th November 1999, cause serious damage to the Bolu viaducts and tunnel which were under construction. The damaged viaduct, viaduct I was nearly complete and the the viaduct II was in its foundation construction stage when the second earthquake (12th November earthquake) struck Turkey.
The aim of this study is to investigate the deformations (rotation, bending and torsion), occurred on structures (especially the viaduct I) of the Bolu pass of 114 km long Ankara-İstanbul motorway, after 17th August Marmara and 12th November Düzce earthquakes.

Key words: earthquake, deformation, viaduct.

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DEVELOPMENTS TOWARDS A LOW-COST GNSS BASED SENSOR NETWORK FOR THE MONITORING OF LANDSLIDES

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Abstract: Great advances in the recognition of landslides have been made in the last few years. Exclusive integrated monitoring systems with early warning capabilities are available, but for economical reasons they are not used on broad scale. At the same time the worldwide number of localities with an urgent need for monitoring is rising noticeably. The GNSS monitoring system under development aims to fill this gap. The challenge is to have a flexible GNSS low-cost equipment available which records movements on the surface of the slide slope. Finally, this component can be seen only as a part of a combined system and should be used parallel together with other measuring devices. Here the concept of a wireless sensor networks is incorporated in the ideas. In particular the following characteristics were stated for the system's design:

- application of low-cost GNSS sensor technology;
- WLAN-Communication between the sensor knots (wireless data transmission on site);
- autonomous power supply of the sensor knots in the field;
- flexibility of the analysis through options of near real time processing;
- possibilities for remote maintenance and request of the system;
- separation between data recording and evaluation (a so-called "dual system");
- possibility of inco-operation of existing (proofed, powerful) program tools;
- open system to integrate other sensors resp. to be adapted to other sensors.

The developed GNSS monitoring system bases on the evaluation of phase measurements over a certain time interval. These data are automatically analysed in an appended processing and then be available for further evaluations (especially the time series analysis). With the expected movement rates and necessary advance warning times, this understanding of "near real time" normally represents no restriction to the intended use in a early warning system. Some further details of the system's hard- and software and some gained results so far will be depicted. The system is already in use in two research projects in the alpine region.

Key words: Monitoring Instrumentation and Techniques, GNSS, Sensor Networks

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ANALYSIS OF DEFORMATIONS IN THE AUSTRIAN REFERENCE NETWORK

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Abstract: The Austrian federal reference network has a very long tradition. Due to historical measurement methods, instruments, network design and other influencing factors (e.g. difficult measurement conditions in mountainous regions), deformations occurred in the development of the reference network. Nowadays, GNSS measurements allow for establishing homogeneous networks, even for larger regions. When performing GNSS measurements the main drawback is the calculation of parameters to transform the ITRF coordinates into the local datum. Due to the historical development, the deformations in the official reference network can be regarded as local systematic effects, which cannot be covered by regional transformation parameters.
A comparison of points, which are determined or known in both systems, can detect these deformations. The GNSS data for the comparison was measured within the setup of several regional GNSS permanent station networks in Austria. The aim of the study is to find groups of points with a similar behaviour of deformations. The resulting local deformation patterns within the federal network can help to improve the accuracy within the transformation process by overlaying the regional transformation parameters with local polynomial corrections, compensating the deformations of the official network. This can lead to accuracies in the horizontal component of 2 – 3 cm for the transformed points instead of up to 10 cm without a compensation of the deformations.

Key words: GNSS, deformations, federal network.

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NAVD88 ORTHOMETRIC HEIGHT DETERMINATION UTILIZING THE CALIFORNIA REAL TIME GPS NETWORK AND VARIED OCCUPATION TIME INTERVALS

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Abstract: The California Spatial Reference Center (CSRC), in collaboration with the Scripps Orbit and Permanent Array Center (SOPAC) at University of California, San Diego, has completed numerous height modernization projects following the standards and specifications defined for the National Height Modernization Program, by the National Geodetic Survey. The continued demand for height modernization survey data, combined with advances in GPS processing and wireless data communication, led to the subject project utilizing the capability of the California Real-time Network (CRTN). This continuous GPS (CGPS) network utilizes real-time 1Hz data streams flowing through the SOPAC archive from more than 80-stations in southern California.

The precursor to this project included testing the application of modern real-time GNSS surveying methods to high-precision geodesy, and to obtain critical data needed to analyze a proposed accuracy model for the national geoid. These purposes were accomplished by collecting data to establish GPS-derived North American Vertical Datum of 1988 (NAVD88) orthometric heights on about 46 passive stations (National Geodetic Survey (NGS) first order benchmarks) in Southern California. This observation campaign was also part of a demonstration to test the viability of using the CRTN for National Height Modernization surveys. The GPS observations were collected in 2 five-hour sessions while connected to the CRTN server through a PDA cellular phone with the Geodetics RTD Rover software. Observations and 1 Hz positions were computed instantaneously (once per second) and stored at the server using Inverse Instantaneous Network RTKTM procedure, and streamed to the PDA. Single-epoch position statistics were computed at the server and running statistics were computed on the PDA.

From this prior campaign we found that using the CRTN to collect and adjust the 3D solutions (but specifically the height component), the final result was actually determined in much shorter time intervals than the specified 5 hours. This second project was designed to determine whether we could define new specifications (specifically shorter occupation times) for achieving orthometric heights in a more economical process. A timelier and economically feasible method is needed for quick and accurate height recovery after seismic events in southern California. This paper discusses our findings.

Key words: height modernization; GPS real time network; vertical height recovery

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OVERVIEW OF FIBRE OPTIC SENSING APPLICATIONS TO STRUCTURAL HEALTH MONITORING

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Abstract: Fibre optic sensors have proven to be ideal transducers for structural monitoring. Being durable, stable and insensitive to external perturbations, they are particularly interesting for the long-term health assessment of civil and geotechnical structures.

Many different fibre optic sensor technologies exist and offer a wide range of performances and suitability for different applications. The most widely used sensing techniques include point sensors (Fibre Bragg Gratings and Fabry-Perot interferometers), long-gauge sensors (SOFO) and distributed sensors (Raman and Brillouin scattering sensors).

These sensing technologies are now widely used in routine application for health monitoring of structures such as bridges, buildings, monuments, tunnels, dams, dykes, pipelines, landslides and many others.

This contribution reviews these systems and technologies and presents some significant application examples, in particular to Bridges, Buildings, Geostructures and Pipelines.

Key words: fibre optic sensors, structural health monitoring.

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AUSCULTATION AND MONITORING IN REAL TIME

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Abstract: The auscultation project was created for execution of the work necessary for the high speed train (AVE) to enter in the railway station Sants in the city of Barcelona, Spain.

This location, a priori, made the execution of work extremely difficult. That is why the auscultation and monitoring project needed to be performed.

The points which raised particularly serious difficulties as described in what follows:

1) the location of the station
2) the location of the prisms
3) obstructed field of vision
4) frequency of the trains (600 per day)
5) the weather
6) the temperature gradient
7) communications,

etc. etc..

Key words: monitoring, real time, total station, tunnel

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3-DEMON MONITORING PLATFORM: EXAMPLES OF APPLICATIONS IN STRUCTURAL AND GEOTECHNICAL MONITORING PROJECTS

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Abstract: The 3DeMoN (3-Dimentional Deformation Monitoring Network) monitoring platform integrates conventional monitoring devices and sensors (e.g. GPS receivers, Laser distance meters, Dataloggers, etc.) with lowest power semiconductors, wireless communication, advanced database systems and Internet, with the aim to provide a unified management and view of remote monitoring data. The open hardware and software architecture of the system allows expanding its applicability to many domains, requiring the remote management of a network of different data acquisition devices.

This contribution presents the monitoring platform as well as some relevant monitoring projects where the 3DeMoN system was successfully applied. In particular landslide monitoring applications as well as roof deflection monitoring in buildings will be presented.

Key words: GPS, laser distance meter, landslides monitoring, structural monitoring.

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GAMMA'S PORTABLE RADAR INTERFEROMETER

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Abstract: Satellite interferometry has been used extensively for ground-motion monitoring with good success. In the case of landslides, for example, space-borne SAR interferometry has a good potential to get an overview on the slope stability. Furthermore, relatively slow, temporally uniform movements can be quantitatively monitored from space. The results achieved caught the interest of wider potential user communities. The assessment of user requirements showed, nevertheless, that some user needs were clearly not met. The role of a space-borne INSAR as an element in a landslide or rock fall warning system is constrained by the specific space-borne SAR imaging geometry, the typical multiple-week repeat-interval, and uncertainties in the data availability. Most of these limitations can be overcome with a terrestrial system. Major advantages of a terrestrial system are that it can be used more specifically to monitor landslides, rock falls, or infrastructure. Measurements are taken at intervals as required and not as dictated by an orbital configuration. The information is readily available and not dependent on satellite downlink and distribution networks. With this in mind GAMMA developed a ground-based radar interferometer. Unlike other comparable instruments it does not use a synthetic aperture to attain a good azimuth resolution, but it is a real aperture radar with 2 meter long antennas. The antennas are mounted on a tripod. An image is taken line by line while rotating the antennas around a vertical axis.
Phase differences between successive images acquired from the same viewpoint are used to determine line-of-sight displacements. The instrument operates at Ku-Band at a wavelength of 17.4 mm, and has a measurement sensitivity better than 1 mm. Phase differences between simultaneous acquisitions by the two receiving antennas are used to calculate the precise look angle relative to the baseline, permitting derivation of the surface topography. Adjusting the baseline is used to tune the height sensitivity versus phase unwrapping complexity.
The instrument is portable and can be operated from battery if necessary. The installation effort is relatively small and individual measurements can be taken in less than 15 minutes. Typically, multiple measurements are taken to reduce the errors related to heterogeneous atmospheric path delays. Furthermore, the measurement interval must be long enough so that the movement of interest results in line-of-sight displacements larger than 1 mm. In the case of faster moving targets as the Tessina landslide or the Rhone glacier the velocity field and the surface topography could be measured in a single day.
The focus of our contribution is on the presentation of the design, measurement principles and characteristics of GAMMA's novel Portable Radar Interferometer.

Key words: Ground-based Radar Interferometer, deformation measurements, topographic measurements, instrument design and characteristics.

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TOPOGRAPHIC MONITORING OF A WATER TANK IN THE WIDENING WORKS OF EIXO NORTE-SUL HIGHWAY IN LISBON

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Abstract: A monitoring necessity for a water tank in Lisbon originated in the widening work of the Eixo Norte-Sul highway, which involved excavation near the tank. The water tank is a 83 m × 43 m, 7 m-high (with only 1 m above ground level) structure with two independent cells, built in different phases, separated by a corridor which gives access to both cells.
According to the project programme and scope, the excavation works would be followed by the construction of two supporting walls, in order to stabilize the embankment and the tank.
As the excavation could affect the tank's safety and the water supply service, the owner (EPAL – Empresa Portuguesa de Águas Livres) and the employer (EP – Estradas de Portugal) agreed on the installation of a topographic monitoring system.
The installed system, operating since April 2005, is composed of horizontal and vertical displacement determination sub-systems. Used equipment includes a TCA2003 total station and a NA2002 optical level. The least square method was used in the adjustments of the observations to compute displacements. The system was complemented with geotechnical instruments, such as tiltmeters, inclinometers and fissurometers.
This paper describes the processes in the topographic monitoring of the water tank, and stresses the importance of the installed system. The use of the sub-system for vertical displacement determination as a warning system is also focused. Due to the complexity of the works and an unexpected behaviour of the structure, the integration of the results of the topographic monitoring with the geotechnical instruments was critical in the analysis, understanding and validation of the results.
Finally we conclude that topographic monitoring can be used as an important decision tool to avoid possibly large financial losses and assure the continuity of the water supply service.

Key words: topographic monitoring.

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MONITORING PLANIMETRIC DISPLACEMENTS IN CONCRETE DAMS

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Abstract: Structural safety control of concrete dams is based in the analysis of the response of structure, characterized by the evolution of several variables representative of its behaviour. Among these variables are absolute and relative displacements of points of the structure and of the foundation, uplift and flow rates in the foundation, and deformations and stresses in the concrete.

In particular, the analysis of the displacements is very important, because they reflect the structural global behaviour of the dam. Therefore, monitoring plans of concrete dams usually consider the measurement of displacements of points of the structure and of its foundation.

In the more important concrete dams, displacements measurement involves the simultaneous use of different methods, such as rockmeters, pendulums and applied geodesy. For the measurement of planimetric displacements, two methods have long been applied: one uses pendulums, placed inside the structure; the other makes use of applied geodesy.

These monitoring methods are complementary, and coexist in many Portuguese large concrete dams since the 1940's. Pendulums have the advantage of being more precise and, nowadays, can easily be included in automatic data acquisition systems. Geodetic methods can give information not only on the dam but also on the foundation and surrounding terrain. Because they are more expensive, geodetic campaigns are much less frequent, but are very important for the validation of the pendulums readings.

In this paper a comparison between these two methods is made using the monitoring data of some Portuguese concrete dams and some considerations about the LNEC experience on their use are presented.

Key words: Concrete dam monitoring, applied Geodesy, planimetric displacement.

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COMPARISON BETWEEN GEODETIC TECHNOLOGY AND PLUMB LINES IN MONITORING OF DISPLACEMENTS ON ITAIPU DAM

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Abstract: ITAIPU is the World largest dam regarding energy production and the second in power installation. ITAIPU hydro-electrical power plant is situated in the Southwest of Brazil on the Paraná River, which forms the border with Paraguay. The generation of electrical energy began in 1981. One of the aspects for the evaluation of dams' safety is the displacement of its structures, which has to be monitored and analyzed in different ways. In this case, different techniques and methods, appropriate for the different types of the structures, have to be applied. At ITAIPU Dam the measurements of displacement are performed by plumb lines and also by geodetic observations using a high precision Total Station based on a network of 7 stable pillars downstream the dam. A total of 20 object points are visualized. Polytechnic School of the University of São Paulo (EPUSP) through its Laboratory of Topography and Geodesy (LTG), Department of Transportation Engineering - PTR, has addressed the attention recently to use GPS as an alternative for monitoring the pillars and the dam. The purpose of this paper is to describe the methodology used to process the GPS observations and to present the displacements in some object points where GPS and plumb lines readings are coincident.

Key words: Monitoring of dams, geodetic methods, plumb lines, GPS.

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MONITORING AND DEFORMATION ASPECTS OF LARGE CONCRETE FACE ROCKFILL DAMS

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Abstract: Safety of Concrete Face Rockfill Dams (CFRDs) depends on the proper design, construction, and monitoring of actual behaviour during the construction and during the operation of the structure. Geotechnical and geodetic monitoring may provide information on the state of deformation and provide a warning system in case of an abnormal behaviour of the dam. CFRDs undergo deformations during their construction and during a reservoir filling. During construction, the rockfill settles and compacts until the end-of-construction stage. During impounding, the rockfill deforms under the water pressure. The upstream concrete face deforms as a result of the rockfill deformation. The displacements of the concrete face during the reservoir filling should not exceed the maximum allowed values in order to maintain the structural integrity of the concrete face. Due to the uncertainty of the model parameters, careful monitoring of the dam and its surroundings are required in order to verify and enhance the model. The paper presents a study using monitoring results and FEM analysis of behaviour of the Shibuya Dam in P. R. China, the tallest (233 m) concrete face rockfill dam in the world.

Key words: concrete face rockfill dam, deformation analysis, finite element method, monitoring.

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MONITORING AND DEFORMATION ANALYSIS OF ROCK BLOCKS

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Abstract: Mass movements of sandstone rock blocks in the Table Mountains National Park (SW Poland) generate threat for intensive tourist activity there.

In the 70'ties of the 20th Century a monitoring and measurement system has been set up for monitoring and quantitative assessment of this phenomenon. In the result of long-term satellite GPS and geodetic (Total Station, precise levelling) surveys and relative measurements with crack gauges spatial displacement vectors have been determined for points located on these rock blocks as well as their relative movements calculated.

These results have been used to calculate deformation parameters (translation, rotation, shear strain) of the analysed rock blocks.

This research has been described on the example of the most mobile part of the Szczeliniec Massif in the largest rock crack "Piekielko"(Little Hell).

Key words: deformation, mass movements, monitoring and measurement system

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DETECTION OF LANDSLIDE PRONE AREAS ON THE BASIS OF GEOLOGICAL, GEOMORPHOLOGICAL INVESTIGATIONS, A CASE STUDY

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Abstract: Relationships between regional tectonics, subsurface structures and mass movements were investigated on the high loess bank of the river Danube at Dunaföldvár based on remote sensing data, gravity and tilt measurements. The geological and morpho-tectonic situations of the test site were examined by evaluation of LANDSAT ETM, ENVISAT, ERS and SRTM data. On the basis of C-band SRTM data, recorded during the 11 day Shuttle Radar Topographic Mission in February 2000, morphometric maps (e.g.: hillshade, slope, aspect) were derived. SRTM data, representing the radar reflective surface such as vegetation, man-made features or bare earth are available at a horizontal spatial resolution of 90 meters (averaged from 30 by 30 meters) at vertical increments of 1 metre. For image processing the ENVI software and ArcGIS 9.1 by ESRI including ArcHydro tools were used. The basement structure under the high loess bank and its surroundings were revealed by gravimetric measurements. Our tilt measurement results indicate that the movements are the consequence of erosion and undercutting caused by the Danube which led to slow loss of the base support of the high loess bank. The Danube's course at Dunaföldvár was pre-determined by tectonic events in addition to subsequent undercutting which suggested that the detected surface movements are indirectly related to the regional tectonics.

Key words: geology, geomorphology, gravimetry, high bank, landslide, remote sensing.

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USE OF GEOID, LEVELING AND GPS FOR VERTICAL DEFORMATION MONITORING

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Abstract: Faial island on the Azores archipelago have been the subject of several tectonic-volcanic events as the Capelinhos eruption and more recently the 1998 M_w6.1 Pico-Faial earthquake. For this reason, from 1937 to 2006 several geodetic surveys have been performed including relative and absolute gravity measurements, azimuthal and zenithal observations and more recently, GPS observations. A high precision geoid model has been recently developed for Azores area with an estimated accuracy ranging from 2 to 4 cm on Faial. This geoid model was used to integrate into a common vertical reference the old trigonometric heights and the most recent GPS height data. Therefore, the vertical deformation time series on some geodetic vertices of Faial, over more than 60 years and 8 surveys, was assessed. On the first period 1937-1987 it was verified a subsidence on the west side of the island with a maximum of 1.7 m at Faja vertice and a maximum uplift of 1.5m on the north caldera. The coseismic vertical deformation due to the 1998 earthquake was evaluated showing the subsidence of 0.13 m on the summit caldera. In the following period, 1998-2006 an uplift of the volcanic edifice was determined with a maximum value of 0.061m on the summit. The estimated vertical deformation is the result of persistent tectonic and volcanic activity on Faial and surrounding area confirmed by intense seismic activity, although irregular in time, registered in this period. In this paper, the usefulness of an accurate geoid model to integrate old geodetic data with GPS data is evaluated and the resulting vertical deformation time series accuracy assessed from independent geodetic data.

Key words: vertical monitoring, geoid, GPS, Faial.

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DERIVATION OF ENGINEERING-RELEVANT DEFORMATION PARAMETERS FROM REPEATED SURVEYS OF SURFACE-LIKE CONSTRUCTIONS

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Abstract: The deformation of a surface-like construction is a complicated problem in the deformation analysis of Riemannian manifolds. The relevant mathematical theory and a relatively simple solution algorithm are developed, which allow the computation of invariant deformation parameters from coordinate displacements of isolated control points. The computed parameters are the dilatation and maximum shear strain at each surface point as well as variations in curvatures related to the surface bending. The required interpolation of coordinate displacements over the whole surface is realized by either finite element methods or by stochastic interpolation, i.e. prediction where displacements are modeled as spatially correlated random variables.

Key words: engineering deformation, shear strain, dilatation.

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AN INNOVATIVE MATHEMATICAL SOLUTION FOR A TIME-EFFICIENT IVS REFERENCE POINT DETERMINATION

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Abstract: The perfecting of the local ties between different observation methods (GPS, VLBI, etc.) improves the quality of the ITRF considerably. The IVS reference point of a VLBI radiotelescope is defined as the intersection between the azimuth and elevation axis or, if they do not intersect, the intersection of the right angle projection from the elevation axis onto the azimuth axis. In the past, these axes have been estimated by fitting 3d-circles, e.g. [Eschelbach, 2002] or [Dawson et al., 2006]. The data acquisition for the determination of the circles requires that the telescope has to be moved into clearly defined positions, so that the basic station process (data gathering for the intrinsic telescope task) is disturbed.

In this paper we present an alternative mathematical model, which computes the reference point without circle fitting. This algorithm does not need observations from predefined telescope positions and therefore the station´s downtime can be reduced. The parameter estimation of this non-linear-problem is realized in two steps. At first we are using the Levenberg-Marquardt-Algorithm for a pre-evaluation to find stable approximate values [Madsen et al., 2004], which we use for the main least-square-model in a second step.

Key words: local tie, reference point determination, mathematical model.

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PRACTICAL ADVANTAGES OF USING THE MECHANICS OF CONTINUUM TO ANALYSE DEFORMATIONS OBTAINED FROM GEODETIC SURVEY

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Abstract: The paper demonstrates why applying of the theory of continuum is useful to deformation analyses obtained from repeated positional survey in geodesy. The mechanics of continuum may be applied as basis of communication during the multidisciplinar approach to geodetic and geotechnic monitoring. It serves also as a technological and scientific communication basis between geodesists and specialists of other professions as geotechnics, geophysics, building engineers etc.

The independency of resulting deformation parameters to applied coordinate frame is shown, too. It is not necessary to try to find any conditions of placing the survey network in the coordinate system but the calculation should be adjusted as free network. Then errors originated from erroneous pre-requisites about stability of some selected points that are taken during normal calculation as stable (in the stable part of such location) will be completely eliminated. When compared to the sole listening of displacements this procedure enables to present deformation parameters in much more objective way and serves as a tool to demonstrate the relatively geodynamical trends of the territory in question.

Key words: deformation analysis, displacement vectors, mechanics of continuum

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INVESTIGATION OF DYNAMIC THERMAL EFFECTS WITH NON-PARAMETRIC AND PARAMETRIC DEFORMATION MODELS

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Abstract: The Viennese theatre "Etablissement Ronacher" was founded in 1871 and is one of the oldest theatres in Vienna. Since 1987 the listed building is integrated in the "Vereinigte Bühnen Wien" cooperation and serves for the presentation of musicals. Increasing numbers of spectators and the necessity for modernisation of the infrastructure require a complete rehabilitation which started in 2006 and will be approximately finished in spring 2008. The stability control of the theatre demands a permanent geodetic monitoring for the whole construction process. Especially the theatre ceiling over the audience hall is affected by significant mechanical and thermal loads.
The first part of the paper contains a short description of construction process, permanent monitoring system for the ceiling (based on tacheometer measurements) and the strategy for automated alerting via e-mail or SMS. It is shown that the monitoring system is able to detect displacements with min. 2-3/10 mm in real-time. Its reliability is only limited by occasional energy blackouts caused by the construction company.
The second part of the paper deals with the investigation of the displacements in selected material points. A special focus is set on the quantification of thermal effects caused by changes of the temperature gradient between roof truss and auditorium. It is shown that as well non-parametric models (e.g. Neural Networks, Fuzzy Methods etc.) as parametric models (e.g. analogous spring-damp-systems identified by Kalman-filtering) are suitable to quantify and predict the deformation behaviour. Advantages and disadvantages of the different applications are discussed.

Key words: Theatre ceiling, monitoring, thermal deformations, non- and parametric models

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INVESTIGATION OF DIFFERENT POSSIBLE AGENCIES CAUSING LANDSLIDES ON THE HIGH LOESS BANK OF THE RIVER DANUBE AT DUNAFÖLDVÁR, HUNGARY

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Abstract: There are high, steep loess banks along the River Danube in Hungary. Landslides, on this area, cause a lot of damages resulting in severe human casualties, property losses and environmental degradation. Monitoring the surface displacements of a slope and other geophysical, geological, hydrological, meteorological, etc. phenomena by a multi-sensor measurement system can provide valuable information about the causes of abrupt slope movements and can serve as a basis for development of a knowledge-based, early warning system.
Dunaföldvár is a small town which is partly situated on the high loess bank of the River Danube and a lot of houses are built also at the foot of the steep bank. A number of landslides caused damages here. That was the reason for establishment of a test area in this town to investigate the connections between different effects and movements of the high bank. A network of points for GPS, field gravimetric measurements, precise levelling was established and yearly repeated GPS and levelling measurements have been carried out since 2001. The gravimetric measurements were executed two times first in 2003 than in 2005. Two biaxial borehole tiltmeters were installed on the test area. One was placed on the top and the other at the foot of the high bank. The tiltmeters have been operating since June, 2002. A vertical borehole extensometer was also installed for monitoring the vertical movements of the high bank. The water level of the Danube, the precipitation and the temperature were also recorded.
The results of the measurements carried out between 2002 and 2006 showed that the test site is in "rest" between abrupt landslides. The horizontal displacements of the geodetic benchmarks measured by GPS are within the error range of this technique. The precise levelling showed a very small characteristic tilt in south direction but the tilt values were also in the confidence interval of 95% probability level. The continuous tilt measurements showed a permanent SSW tilting with a rate of 50.6 μrad/year at the top and a SSE tilt with a rate of 3μrad/year at the foot of the high bank. These tilts are of tectonic origin according to our investigations. The continuous tilt measurements showed also that the high frequency variations of the water level of the Danube have no influence on the high bank movements. Only the very high and slow, long-lasting changes in the water level cause observable tilt changes. The influence of the precipitation was also investigated.

Key words: high bank, landslides, precipitation, tectonics, vertical extensometer, water level.

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MONITORING OF A LARGE SLIDE AND SLOPE RECLAMATION IN A FORMER OPEN-PIT MINE

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Abstract: The unstable area has been observed since 2003 with use of coupled geotechnical and geodetic monitoring. A long anchored pile wall built in 2007 to stabilise the upper part of the area. In the lower part a huge stabilisation embankment on the internal waste dump is under construction. The existing monitoring was extended in 2007 in order to prove efficiency of remedial measures and decreasing rate of slope movements. The embankment is instrumented and monitored with respect to its construction phases. According to our information, this method of prolonging geotechnical measurement lines in a rising embankment will be used for the first time in the Czech Republic. All the gathered results will be used for reverse analysis through a numeric model, which will be calibrated and updated with use of the last measured data, including oriented stress measurements in the subsoil.

Key words: monitoring, numeric analysis, slope stability, reclamation.

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DEFORMATION MONITORING AT AN INDUSTRIAL SITE USING COMBINED DGPS AND TOTAL STATION DATA

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Abstract: A large deformation monitoring network has been observed in three epochs. Heterogeneous data were collected on two unstable slopes near a cooling water pond for a large coal-fired electric power generation plant. The heterogeneous data consist of horizontal directions, horizontal distances and trigonometric height differences derived from total station observations and azimuths, distances and ellipsoidal height differences derived from DGPS observations. A separate network adjustment is performed for each epoch to integrate the heterogeneous data and obtain local coordinates of all stations. Then, a Multi-Parameter Transformation is applied to compare coordinates between epochs. In the MPT method, a three-dimensional similarity transformation (three rotations, three translations, and a scale factor) is used to relate observations or derived observations (e.g. coordinates) from different measurement epochs. A global best fit will yield three-dimensional differences of all stations between measurement epochs. Statistical Verification of these differences allows us to distinguish between apparent movements due to random observation errors and actual deformations. Furthermore, a priori knowledge of the unknown transformation parameters can be utilized to strengthen the solution.

In the paper, the integration of heterogeneous data will be described. However, the focus will be on the mathematical model applied to determine the three-dimensional movements from the coordinates of each epoch. Results (transformation parameters and movements of the stations) will be presented for the analyses of all three epochs.

Key words: deformation monitoring, heterogeneous data, Multi-Parameter-Transformation

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QUANTITATIVE ASSESSMENT ON THE INFLUENCE OF RAINFALL ON KUTLUGUN LANDSLIDE

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Abstract: Seasonal heavy rainfall is the most active meteorological factor that can be threatens the stability of landslides. In this paper, on the basis of the rainfall-related behavior of the Kutlugün landslide by analyzing the precisely and periodically observed 3D GPS data, a method was developed to quantitatively assess the effect of rainfall on Kutlugün landslide. This paper describes mathematical and statistical structure of the model regarding intensive rainfall being the most important one of the causative forces for translational slide. The model includes computations of 3D displacements, and the rainfall effect parameter that shows the geometric reflection of the effect of rainfall on point movements. Defining and calculating causative relationship analyzed the relationship between the rainfall and rainfall-induced 3D displacements of landslides. Finally, acceleration effects of intensive rainfall on the Kutlugün landslide were investigated. Results indicated that rainfall-induced 3D displacements of Kutlugün landslide show good correlation with the effective rainfall.

Key words: Kutlugün landslide, translational slide, rainfall-induced 3D displacements, Kalman-Filter

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SUBSIDENCE AND UPLIFT AT WASSENBERG, GERMANY DUE TO COAL MINING USING PERSISTENT SCATTERER INTERFEROMETRY

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Abstract: The town of Wassenberg is situated in western Germany close to the border with the Netherlands. Black coal mining activity in this area (district of Erkelenz) started in 1914 and stopped in 1997. Until 1997, this caused subsidence of up to 3 meters in the period 1953-1997. When mining operations ceased, the drainage of the mine also stopped causing ground water to invade the empty space. Once it reached the lower bound of the overburden, this resulted in surface uplift. In particular, the strongest movement was detected during 2001 to 2004, with an estimate of 8 to 9 cm uplift. The geophysical structure of the region made the uplift to be discontinuous in space. In fact, Wassenberg is crossed by the Meinweg fault creating a natural limit to the mining subsidence and consecutive uplifting. The goal of this paper is to present results of the study and analysis of this land movement using Persistent Scatterer Interferometry, PSI. The employed time series started in 1992 and continued until 2007, covering both periods of subsidence and uplift. The data were acquired by the satellites ERS1/2 and Envisat.

Key words: InSAR, Persistent Scatterer Interferometry, deformation, coal mining

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PS-INSAR MEASUREMENT OF GROUND SUBSIDENCE IN GRANADA AREA (BETIC CORDILLERA, SPAIN)

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Abstract: Differential SAR interferometry (DInSAR) is an alternative technique to obtain measurements of the surface displacement providing better spatial resolution and comparable accuracy while being less time consuming than conventional surveying methods. However, spatial and temporal decorrelation and atmospheric signal contributions in repeat-pass SAR interferometry often hamper the accurate measurement of surface displacements in SAR interferograms. The Persistent Scatterer Interferometry (PSI) technique, developed at Delft Technical University (The Netherlands) and based on the POLIMI Permanent Scatterer Interferometry technique, allow us to measure deformation with uncertainties of one millimeter per year, interpreting time-series of interferometric phases at coherent point scatterers. In the framework of two CAT-1 ESA projects, in this paper, we analyse two time-series of 32 ERS-1/2 and 22 ENVISAT ASAR acquisitions of the Granada basin, located at the central sector of the Betic Cordillera (southern Spain), covering the period from 1992 to 2005. This is the first time that the PSI technique is applied to derive displacement information in this southern Iberia region. This technique is very useful for the analysis of subsidence in urban areas, where angular structures produce efficient reflectors that dominate the background scattering. After this first data processing, several subsidence areas have been detected in the southern part of Granada city and nearby villages. At the moment, some investigations are being carried out in order to find the relationship between the detected deformation and the tectonic deformation present in the area.

Key words: InSAR, Persistent Scatterer Interferometry, Granada, subsidence, deformation

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PSINSAR DETECTION OF GROUND MOTION IN THE LISBON REGION

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Abstract: We present evidence of ground motion detected in and around Lisbon with Radar Interferometry (Permanent Scatterers Technique - PSInSAR). The work was done in the scope of GMES Terrafirma project, and two datasets of PSI data were used, with different orbital tracks. The first, provided by Tele Rilevamento Europa, is a standard TRE's PSINSAR processing chain H1 map of the Lisbon area. It covers the period from 1992 to 2003 and uses 55 Synthetic Aperture Radar Scenes from the ESA satellites ERS1/2 (orbital track 452, descending pass). The second set of data spans the period 1992-2006 and was provided by Altamira Information: it consists of (1) a standard SPN H1 product map of the area to the South of Lisbon, and (2) the result of running the SPN medium resolution processor for the Lisbon area and northwards. The Altamira maps were produced using 100 SAR scenes from both ERS1/2 and ENVISAT satellites (orbital track 223, descending pass). The delivered psinsar maps give, for the spanned period, the mean velocity (in the line of sight of the satellite) and velocity time series for over 500.000 points in the area. The psinsar maps were interpolated, detrended, contrast-enhanced, and compared with mapped geological features, soil classes, aeromagnetic and gravimetric data. In-situ CGPS and levelling data were integrated to validate the technique. At a regional scale, the results show a correlation between deep geological features inferred from geophysical techniques and psi-derived velocity patterns. At a more local scale, the main results are the detection of an area of ground subsidence (~6Km2) in the centre of Lisbon, and of another area affected by slope movement in the north of Lisbon, close to the main highway.

Key words: Radar Interferometry, Permanent Scatterers, Lisbon, ground motion.

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USING SMALL BASELINE INTERFEROMETRIC SAR TO MAP NONLINEAR GROUND MOTION IN NORTHERN TIBET

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Abstract: Interferometric SAR (InSAR) techniques utilize the phase differences in complex (magnitude and phase) Synthetic Aperture Radar (SAR) images acquired in similar geometric conditions, but at two different epochs, to measure the component of the surface displacement (i.e. range changes) in the radar line of sight to the satellite with sub-centimetre precision and tens-of metres horizontal spatial resolution over a large region (e.g. 100 km × 100 km). With its global coverage and all-weather imaging capability, InSAR has been already revolutionizing our ability to image the Earth's surface and the evolution of its shape over time, which in turn has led to many new insights into geophysical and engineering processes, such as volcanoes, earthquakes, landslides and mining activity. In this study, we used Small Baseline (SB) InSAR time series technique to map ground motion in Northern Tibet using ENVISAT images acquired during the period between 2003 and 2007. In order to minimise the effects of baseline decorrelation, a subset of possible pairs with perpendicular baseline (i.e. orbital separation) less than 400 m was chosen in the SB InSAR time series analysis. Preliminary results reveal a nonlinear ground motion spreading over a 4.5 km × 2.7 km region: the studying area was relatively stable during the period 2003 to the middle of 2004, whilst it has exhibited an uplift of about 7 cm since the middle of 2004.

Key words: InSAR, small baseline, time series, nonlinear, ground motion.

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CONTRIBUTION OF THE APPLIED GEODESY TO THE PREVENTION OF ACCIDENTS AND TO THE REHABILITATION OF FILL STRUCTURES

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Abstract: The wide range of materials used in the construction of embankments leads to highly differentiated structural behaviours and sometimes to accidents. Therefore, namely in higher hazard works, such as dams, it is necessary to periodically assess their safety.

That assessment is done by site visits, to perform visual inspections, and the reading of certain quantities. Those variables are not to exceed certain values, which are related with the behaviour models predicted in the design.

Applied Geodesy plays a significant part in the measurement of surface displacements. The visual inspections are a complement to the data obtained in those measurements, as zones of differential settlements, deviation, fissures, cracks, etc.

This paper presents the contribution of the Applied Geodesy to detect the causes of accident in two embankment structures, as well as to the decisions adopted for their rehabilitation.

Key words: Applied Geodesy, embankment dam, fill structure, displacement, accident, rehabilitation.

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HORIZONTAL DEFLECTION ANALYSIS OF A LARGE EARTHEN DAM BY MEANS OF GEODETIC AND GEOTECHNICAL METHODS

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Abstract: Earthfill dams are subject to external loads that induce deformations to the structure and the foundations. The self-weight of a dam and the reservoir water pressure are primarily responsible for the increase of stresses within the dam body, which in time result in horizontal and vertical displacements, mostly of a permanent character. In this gradually evolving process, the dam geometry characteristics, the type of materials and their geotechnical properties play a key role in the geometrical changes in concern. Current techniques which are used to study the dynamic behavior of dams are based on statistical analysis of recorded displacements, as well as on predicted deformations derived from numerical modeling of physical parameters, such as external loads and construction element features.

The paper compares actually measured horizontal deformations resulted from a continuous geodetic monitoring record of the dam behaviour with a numerical back analysis. The geodetic data originate from a continuous, long-standing (> 25 years) monitoring program of the dam and the surrounding area. The geotechnical modelling of the dam is implemented using *Z_Soil*® software, which adheres to the finite element method. Numerical simulation was carried out in two-dimensional plane-strain conditions. The computed stresses and displacements refer to certain stages (construction, filling and operation) in the lifetime of the dam, whereas, in this study, emphasis is given on horizontal displacements. Comparisons of the computed deformations from the FEM analysis with those obtained from the geodetic monitoring record for a large number of control points established on the dam body revealed a very good agreement. These findings are of great importance considering that in the long-standing history of the dam different monitoring techniques (terrestrial and satellite) were implemented, the observation schemes varied and a large number of observers were involved.

Key words: dam deformations, finite element method, geodetic monitoring

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DAM CREST SETTLEMENT, RESERVOIR LEVEL FLUCTUATIONS AND RAINFALL: EVIDENCE FOR A CAUSATIVE RELATIONSHIP FOR THE KREMASTA DAM GREECE

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Abstract: Crest settlements of the Kremasta Dam (Greece), one of the highest (160.3m high) earthfill dams in Europe, were analysed in combination with the elevation of the reservoir level and the rainfall height for the period 1966 – 2003. Using an analytical approach based on the optimization of the correlation coefficient and a high-pass filter (threshold correlation) we determined critical values of three parameters (reservoir level, rate of increase of the reservoir level and rainfall) which, if all at the same time exceeded, the rate of the settlements of the crest is increased significantly. This result is important, especially in view of plans for increase of the reservoir level to the design value, a task never accomplished since the construction of the dam in 1965 because of the threat of increased leakage already approaching safety limits.

Key words: Kremasta, earthfill, dam, crest, settlements, reservoir, rainfall, threshold correlation

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SLOPE STABILITY MONITORING USING SPACE-BORNE REPEAT-PASS SAR INTERFEROMETRY

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Abstract: Over the last years slope stability monitoring with space-borne interferometric SAR techniques reached some maturity. For many alpine slopes the knowledge on the stability is quite minimal. Consequently, a novel method potentially providing such information is well received even if there are limitations to its applicability. This even more so, as space-borne SAR interferometry benefits from the already existing SAR data archives covering more than 15 years. The two main categories of results generated are "land slide surveys", i.e. products which are primarily used to identify unknown slope instabilities and to get information on the activity of known land-slides and "landslide monitoring", intended to get quantitative information on the movements of specific landslides.

Based on examples potential and limitations of SAR interferometric techniques, including differential interferometry (DINSAR) and Persistent Scatterer Interferometry (PSI) will be discussed. Landslide survey and monitoring results obtained over different parts of Switzerland will be presented. In some cases the results could be validated with auxiliary information and in other cases an independent interferometric analysis conducted using alternative data over the same area gave additional confidence in the result.

Considering the high costs related to landslide mapping, and in particular the difficulties in the detection of the active, slow, and dormant parts of landslide, especially over urban areas, the use of a SAR interferometry based approach can positively impact on the hazard mitigation activities of local and regional authorities. As a next step the monitoring of the actual movements using SAR interferometric techniques could be implemented in the risk management.

Key words: Differential SAR Interferometry, Persistent Scatterer Interferometry, land motion, landslides inventory, deformation monitoring.

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GPS/INS/PL/TLS INTEGRATION SUPPORTING NAVIGATION OF GEOPHYSICAL SENSORS FOR UNEXPLODED ORDNANCE DETECTION AND DISCRIMINATION

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Abstract: Reliable and precise navigation technology is essential for robust detection and discrimination of unexploded ordnance (UXO) in a wide range of field conditions. The detection and remediation of munitions and explosives-of-concern (MEC) is one of the Department of Defense (DoD) most pressing environmental problems. The MEC characterization and remediation using current technologies is often unreliable, due mainly to the inability of current technology to detect all MEC and to discriminate between MEC and non-hazardous items, which is mainly due to the lack of precise relative navigation in the area. Thus, the goal of the research presented here is to design and implement a high-accuracy navigation device based on multi-sensor integration, that can address the stringent requirements of a man-portable geophysical mapping/imaging system in open and impeded environments, to lower the cost of remediation by improving the geolocation accuracy of MEC discrimination and thus, eliminating the excavation of non-hazardous objects.

The proposed design of the system is based on the "quadruple-integration" of GPS, IMU, terrestrial RF system – pseudolite (PL), and terrestrial laser scanning (TLS) to support high-accuracy navigation for a non-contact mapping system in various environments. The proposed design integrates PL and GPS signals together with INS and TLS measurements to deliver an optimal multi-sensor positioning solution in a tight integration model that will not interfere with magnetic and electromagnetic geophysical sensors. The key novel component of the proposed multi-sensor system is a terrestrial laser scanner that can provide very high positioning accuracy in a local frame, and thus can support a GPS/INS/PL-based navigation system to achieve both absolute and relative high positioning accuracy in impeded environments. The proposed fundamental positioning concept is hierarchical, with three main levels of positioning:

- Absolute or global positioning in open areas (primarily using GPS/IMU integration).
- Relative medium-range positioning under canopies or other obstructions will be accomplished with the PL/IMU technology.
- Relative short-range positioning, where extremely high relative positioning accuracy is required, will be realized by employing TLS technology in a local reference frame.

This paper will address the concept design of the system, the algorithmic approach to sensor integration with a special emphasis on TLS integration with GSP/IMU/PL, and the preliminary performance assessment based on simulations and real data.

Key words: multi-sensor integration, georegistration and monitoring instrumentation

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MEASURED SETTLEMENTS OF THE PESNICA HIGH EMBANKMENT

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Abstract: As a part of the National Motorway Construction Programme, a large number of high embankments founded on soft soil have been built in Slovenia. One of them, the Pesnica high embankment, is located on the motorway section Šentilj - Pesnica, close to the city of Maribor. The height of the embankment varies between 6 and 8 m. The embankment had to be built on very compressible subsoil, with a low bearing capacity and low permeability, so it was necessary, in the design, to provide adequate measures to increase the stability and the consolidation rate of this subsoil.
A system for geotechnical monitoring of the embankment and the subsoil beneath it, whose aim was to monitor the performance of the embankment, was established. Two methods were used to obtain settlement profiles at various locations along the embankment. As well as conventional settlement plates, which were installed at numerous transverse profiles along the embankment, two measuring tubes were installed at two of the embankment cross-sections in order to be able to measure settlements using a hydrostatic profile gauge (HPG).
The results of a comparison of settlement development at two different profiles where the HPG was used are presented. It can be seen that the development of soil settlement at the two selected profiles was very different, which is the consequence of the heterogeneity and different compressibility of the soil beneath the embankment. It was also shown that the values of the settlements measured by HPG were very similar to those observed on the settlement plates, which were located very close to the measuring tubes.
The use of a measuring tube and a HPG, which does not interfere with the construction works, has proved to be an excellent practical solution. In this case the results consist of not just a single settlement (as in the case when a settlement plate is used), but every time a measurement is made a complete settlement profile is obtained.

Key words: geotechnics, field measurements, settlements, embankments.

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FOUR DIMENSIONAL MONITORING OF DEFORMATION AS DEDUCED FROM REPEATED GPS CAMPAIGNS

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Abstract: Recent development of GPS performance enables us to apply four dimensional monitoring of ground deformation or any other engineering structure with precision of ~3 mm in horizontal positioning and ~10 mm in vertical determination. We demonstrate two examples of deformation deduced from repeated GPS campaigns. The one is the ground subsidence monitoring inside Kawasaki city in Japan, and the other is the subsidence of viaduct along the high speed railway during construction work in Taiwan. Both of these two cases, we performed out continuous GPS observation more than 12 hours by dual frequency receiver. The observed data are analyzed both with aid of Bernese Ver4.2 and Gamit Ver10.1 software. Finally three dimensional positioning are deduced referring to the IGS stations located in and around the respective countries.

Repeated GPS campaigns had been performed during February ~March every year from 2003 to 2007 inside Kawasaki city, Kanagawa Prefecture in Japan, in order to realize practical GPS/Leveling employing the latest geoid model. Traditional precise leveling was also repeated. We can compare two kinds of results of orthometric height change; one is obtained from GPS and the other from leveling. We recognize that discrepancies among these two do not exceed over15mm/year. Also we deduce horizontal displacement vector and find significant trend of northward movement at some bench marks which are distributed on the ground of past remarkable subsidence.

The Taiwan High Speed Railway of 350km length was constructed by the Taiwan High Speed Rail Corporation. We carried out various kinds of requested surveys, and paid much attention on the ground subsidence along the rail way. The repeated GPS campaigns were carried out to investigate viaduct deformation caused by the ground subsidence in March and September, 2004, respectively. We find viaduct subsidence of 10cm/year at the most that is the same trend obtained from repeated precise leveling performed on the viaduct, and also horizontal movement of 2~3cm directed westward on the viaduct during the respective period. This fact is confirmed from the results obtained by application of two kinds of software Bernese Ver4.2 and Gamit Ver10.1 though we have some small discrepancies among them.

Key words: campaigns, four-dimensional monitoring, ground deformation.

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DAM DEFORMATION ANALYSIS USING THE PARTIAL LEAST-SQUARES METHOD

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Abstract: Main problem in data analysis is a construction of mathematical models relating environmental variables and patterns of deformation. In case of the dam environmental variables are temperature, water level in a reservoir, etc. The most commonly used method of data analysis is statistical modelling of the data. The partial least-squares regression (PLSR) is a statistical method which finds a linear model describing some predicted variables in terms of other observable variables. The partial least-squares regression (PLSR) is a multivariate statistical algorithm, which can overcome some of the shortcomings of other approaches, for instance, the multiple correlation among independent variables. PLSR methodology is presented on the example of an earth dam located in central China. A three dimensional deformation analysis for a single point on the dam is performed. The analysis consists of a data fitting, deformation prediction, and contribution analysis of individual factors. The presented in the paper research shows that PLSR results are more reliable and have the better integrity than the other methods.

Key words: dam deformation monitoring, data analysis, partial least-squares regression, prediction.

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MONITORING STATIC DEFORMATION OF THE BULK DAM IN THE EAST SLOVAKIA

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Abstract: Deformations on buildings and structures due to own weight, water pressure, inner temperature, contraction, atmospheric temperature and earth consolidation occur. Especially, it is necessary to embark on monitoring and analysing of deformation effects and movements of any sizeable dams and water basins and so to prevent of their prospective catastrophic effects into environment.

The paper is centred on stability of the rock-fill dam of the water basin Pod Bukovcom near Košice in the East Slovak Region. The purposes of the dam are to supply industrial water for cooling up of metallurgical blast furnace equipment of company U.S. Steel Košice in case of its emergency. Actual stray terrestrial geodetic and GPS measurements were not construed on a level of terms of present scientific analyse in deformation surveys. Results and analyses of geodetic measurements on the rock-fill dam will be undergone by to test-statistics, the model of stability or prospective movement of the rock-fill dam with time prediction.

The paper outputs are incorporated into GIS and information system of U.S. Steel Košice.

Key words: Rock-fill dam, deformation survey, test-statistics, GIS, GPS observations, terrestrial geodetic measurements.

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STUDY OF LAND SUBSIDENCE AND GROUND FISSURE ACTIVITIES IN XI'AN CITY WITH INSAR

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Abstract: Land subsidence and ground fissure activities have been a serious geo-hazard in Xi'an city, China. The land subsidence started in the 1960s and has affected a large area in the city. The ground fissures associated with the land subsidence have caused damages to a large number of buildings, bridges and other structures. Differential SAR interferometry (DInSAR) technique is applied to monitor the phenomena of land subsidence since 1992. Special interferogram filtering and phase unwrapping algorithms are used in processing the data. Leveling and GPS measurements are used to validate and calibrate the InSAR results. Three main subsidence stages during 1992 to 2006 are revealed based on the DInSAR results. High correlation with uncontrolled ground water withdrawal and city development can be seen from the results.

Key words: Land subsidence, ground fissures, DInSAR, GPS, city development

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GPS NETWORK FOR LOCAL DEFORMATION MONITORING IN THE ATLAS MOUNTAINS OF MOROCCO

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Abstract: The Atlas Mountains of Morocco have been the target of several geophysical studies: gravity, refraction and MT surveys carried out during the 80's and 90's have helped to establish some of the main characteristics of this intracontinental orogen, such as its overall structure and modest crustal thickness. Later studies, based on structural geology, higher resolution gravity surveying and multidisciplinary potential field modelling indicated that the High Atlas crust is too thin to support its topography and that a mantle contribution is required. An astenospheric upwelling, which triggered the Eocene-to-recent Atlas magmatic activity was then proposed as the main cause of its topography. Crustal thickness happens to be the key to establish the position of the lithosphere-astenosphere boundary and therefore, to asses the real contribution of the mantle to the topography and accordingly the actual uplift. In the frame of a multidisciplinary project covering the described issues, a non-permanent GPS network have been established around the Ouarzazate Basin and surveyed for the first time in September 2007. This network is aimed to control the recent vertical and horizontal movements that affect the area in an attempt to constrain the current deformation rates in the Atlas system.

Key words: crustal deformation, active tectonic, GPS network, Atlas mountains

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STABILITY OF HISTORICAL BUILDINGS

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Abstract: The main objective of the project "Stability of historical buildings" supported by the Czech Science Fund is to develop a methodology of complex stability analysis of historical buildings. The analysis is based both on archive search started before the year 2000 and visual inspections. Different sets of long-term measurements as surveying, structural monitoring and geotechnical measurements are performed to gather input data for assessment of the technical state of buildings and their interaction with the subsoil. The project is executed in the Prague Castle area, a part of the Czech cultural heritage, because of different structures selected for application and verification of the developed methodology, as well as previous activities of the team members there.

The project will be described in brief and the ways of instrumentation, monitoring and its results will be discussed. Combination of line-wise subsoil deformation measurement together with sensitive geodetical methods and GPS applications are used for assessment of long-term structural behaviour followed by structural numeric modelling.

Key words: monitoring, differential settlement, tilting,

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MONITORING THE DEFLECTIONS OF LARGE SUSPENSION BRIDGES IN THE UK BY GPS

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Abstract: The use of GPS for monitoring the deflections of large suspension bridges in the UK has been under research at the University of Nottingham and Brunel University for over a decade. The following paper details the main outputs from this work, focusing on the ability of GPS to measure the deflections to the order of a few millimetres, as well as measuring the fundamental frequencies of the bridges.

Key words: GPS, deflection monitoring.

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CONCEPT FOR RISK ASSESSMENT AND MONITORING OF THE UPPER BIO BIO REGION IN CENTRAL CHILE STRUCTURES

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Abstract: Two major dams have recently been constructed for power supply within a tectonically active area in central Chile. These dams (Ralco and Pange) are filled by the river Bio Bio, which gives the complete region its name. This area has been affected recently by a M=6.1 earthquake in Dec 31, 2006, located at 10 km below Ralco's dam, and is related to either the Liquinnofqui fault zone or by induced seismicity. It has been affected also by increased activity of the Callaqui volcano (at 12 resp. 20 km distance) since 1992. Furthermore, heavy rainfall in the past years caused severe flooding, affecting the towns and cities along the rivers course including the capital of the region.

The main objective of this project is to make risk assessment, based on a detailed GIS-supported documentation and analysis of the existing situation in terms of historic records of events, structural geology, surface structure (topography), existing vegetation and the hydrological regime. Here optical remote sensing data will be used extensively.

Parallel the actual ground displacements will be monitored by advanced DInSAR techniques, using TerraSAR-X radar data, rigorously combined with time series of GPS-observations. Additional information will be collected from seismometer records, water level observations and rain fall measurements. In addition, a permanent monitoring of the dams, mainly based on total stations, has to be set-up. This more local system will be an integral part of the outer monitoring system.

Based on all this information the identification of triggering parameters for surface deformations and damages should be possible. As final step a non-parametric model, based on Fuzzy and/or KNN techniques, will be developed, where the known information is used to describe the behaviour of this complex system and – hopefully - to define critical situations.

By this approach a first version of an early warning system for this area could be established.

Key words: risk assessment, natural hazard, InSAR and GPS, integrated monitoring.

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STUDY OF A LONG-TERM BEHAVIOR OF LARGE EARTH DAM COMBINING MONITORING AND FINITE ELEMENT ANALYSIS RESULTS

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Abstract: Sensitive structures such as large earth dams require continuous and real time information on their stability, particularly when they are located in tectonically active zones. The results from automated monitoring surveys, when compared with the predicted regular behavior of the structures, give information on the effects of seismic disturbances and may trigger a warning alarm if irregular behavior exceeding a threshold value is detected. Deformations of an earth or rockfill dam start occurring during the construction of the dam. After the construction of the dam is completed, the considerable movements of the crest and the body of the dam can develop during the first filling of the reservoir. Later, the rate of deformations decreases in time, with the exception of variations associated with the periodic variations of the level of the reservoir and, in seismic zones, with the tectonic activity. The dams located in the seismically active areas are built with the material, which allow for a dam to be more adaptable to the changes of loading conditions. The deformation process can be simulated using, for example, the finite element method. Due to the uncertainty of the model parameters, careful monitoring of the dam and its surroundings are required in order to verify and enhance the model. This paper presents an analysis of long term deformations of West Dam of Diamond Valley Lake (DVL) Project in California, U.S.A.

Key words: large earth dam, deformation analysis, finite element method, monitoring.

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GEODETIC MONITORING OF THE THERA (SANTORINI) CALDERA

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Abstract: The Santorini (Thera) volcano caldera in the southern Aegean, is part of a well developed volcanic system, partly submerged and famous for the eruption which buried the prehistoric town of Akrotiri about 3500 yrs ago. This volcanic system is very active and small-scale eruptions occurred till the 20th century.

Since 1985 there have been efforts at a systematic surveillance of the volcano using geodetic techniques in order to identify periods of tectonomagmatic unrest, pour some light in the mechanism of deformation and even predict future eruptions.

Analysis of a geodetic, EDM radial monitoring network revealed a small-scale (up to 10cm length changes and up to $2*10^{-5}$ strain) non-uniform inflation of the north part of the caldera between 1994-2003. Between 1985-1988 centimeter-scale vertical movements were also observed along a leveling traverse following a zone of recent magmatic and hydrothermal activity in the Nea Kammeni Islet, at the central part of the caldera, and especially close to a site where an up to 60-70cm transient coastal uplift occurred in 1996, as is inferred from non-instrumental data.

In late-spring 2006, with UNAVCO field support, a network 18 GPS stations has been established. Most stations coincide with triangulation stations and cover the whole of the non-submerged part of the caldera. In addition, continuous GPS recording stations have also been established in the northern part of the caldera. Preliminary analysis of the latter revealed no significant coordinate changes, most-likely indicating that for the moment the volcano is in a state of dormancy.

Key words: Volcano, Thera, geodetic surveillance, EDM, GPS stations

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HORIZONTAL MOVEMENTS OF THE TECTONIC UNITS OF EUROPE BASED ON DATA OF EPN SERVICE

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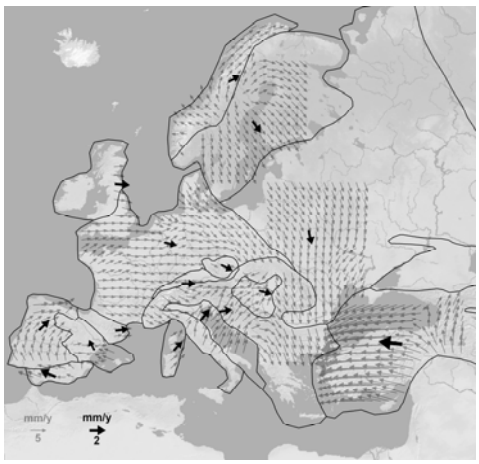
Abstract: Contemporary geodynamic investigations on a global and regional scale are being realized by network of permanent GNSS stations distributed all over the Earth. The Continental EPN (EUREF Permanent Network) is a European network of 200 permanent stations and the main assignment of EPN is the maintenance of ETRF89. One from many available products as part of project "EPN Coordinate Time Series Analysis Special Project" are components of the velocity vectors of EPN stations. The analysis, interpretation and visualization of motion velocity vectors of permanent stations can be used for different interdisciplinary research, especially for locally geodynamic investigations. The main aim of the elaboration was to find a correlation between velocity fields of EPN stations and the tectonics of Europe. Based on the geological maps, major tectonic structures have been distinguished. For each unit the continuous velocity field has been developed by means of kriging's method of interpolation. Moreover, to establish the areas of homogenous changes, the k-means method of cluster analysis technique was used. One of the research stages was to find the answer to the question about possibility to determine average velocity vector of motion for each tectonic unit, which will be illustrating mobility of the whole tectonic structure.



Key words: tectonics of Europe, EUREF Permanent Network, geodynamic researches, cluster analysis, horizontal movements.

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AN INTEGRATED MONITORING SYSTEM FOR THE MONUMENTAL WALLS OF AMELIA

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Abstract: The ancient town of Amelia (Umbria, central Italy) is surrounded by monumental walls built by Italic civilization between VI and IV century BC. The walls of Amelia have an exceptional historical and architectonic interest due to their particular construction made of very large limestone blocks cut in polygonal shape, assembled with no cement. Recently, a part of the walls has been interested by serious structural problems culminating in a local collapse. Consequently, a series of restoration actions have been undertaken by the regional authorities, and the walls have been put under control. In this frame, the Department of Civil and Environmental Engineering of the Perugia University (DICA) has designed and set up an integrated monitoring system for the Amelia walls involving various techniques (GPS, high accuracy total stations, close-range photogrammetry, laser scanning, deformation sensors), which is now starting to operate. The system is designed to employ such different techniques and sensors in synergy, taking advantage by the different features of each one. The work analyses the design of the integrated multi-sensor system, the selection criteria of instruments and sensors, the setting up of the system and the expected results.

Key words: historical buildings, deformations, multi-sensor monitoring.

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RECOVERY OF SENSOR PLATFORM TRAJECTORY FROM LIDAR DATA USING REFERENCE SURFACES

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Abstract: Even though terrain-based navigation has been used for years to navigate airborne platforms, a continuous exchange of precise geolocation information between the imaging and navigation modules to improve the overall error calibration is a novel idea, which should significantly increase the system's fault tolerance in a variety of situations, including terrestrial systems. Presently, the navigation solutions are predominantly based on a GPS or integrated GPS/IMU systems, supporting typically a single imaging sensor, with no feedback between the sensory data processing filters. Most of the research in terrain-based navigation proposes the use of optical measurements from airborne imagery, although the concept of exploring LiDAR-based terrain navigation is also reported. Recent technological advances in imaging sensors improved the potential for obtaining feedback from image data for navigation, as in general higher spatial sampling and positioning accuracy can be achieved.

This paper is concerned with obtaining navigation data from LiDAR and presents a trajectory recovery method based on LiDAR data using reference terrain surface models. Under normal circumstances, the coordinates of LiDAR points are calculated from position and attitude, provided by the GPS/INS navigation solution, boresight parameters between navigation and imaging sensors, scan angles and laser range measurements. If GPS signals are lost, the coordinates of LiDAR points can be still computed using an INS-only solution; obviously, with growing errors in time. If reference surface data exists, it can be used for recovering the LiDAR sensor trajectory as long as the INS drift is under a certain threshold. This task is similar to surface matching, except 1) the quality of one dataset is strongly location-dependent, and 2) by using the primary laser data and reference surface, the sensor trajectory is estimated. To assess the performance of the proposed method both simulated and actual LiDAR data was used and an analysis on the feasibility of the method is provided.

Key words: terrain-based navigation, LiDAR (airborne laser scanning), surface matching, multi-sensor integration.

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STRUCTURAL DEFORMATION OF THE HIGH-SPEED LINE (HSL) INFRASTRUCTURE IN THE NETHERLANDS; OBSERVATIONS USING SATELLITE RADAR INTERFEROMETRY

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Abstract: HSL Zuid (High-Speed Line South) is a dedicated 125 km high-speed rail line, forming part of a new route between Antwerp, Belgium and Amsterdam. Construction began in 2000, and major engineering projects include the new 7.2km Leiderdorp-Hazerswoude tunnel under the Groene Hart (Green Heart) open country between the country's four largest cities, Amsterdam, Rotterdam, Den Haag and Utrecht. North of this tunnel, a section of the line near Rijpwetering, containing the sharpest curve on the entire route, experienced significant structural deformation during the construction stage due to ground instability, and 800 m of the line had to be rebuilt. Local in situ surveys show that up to 15 mm of horizontal deformation occurred after 2003. Here we investigate whether local deformation of this kind can be observed by satellite radar interferometry, using a fine-tuned processing approach dedicated for this application. We report on the procedure followed, on the constraints in the parameter estimation and the obtained level of precision and reliability. The combination of a forward model to simulate radar observations from in situ measured displacements and an inverse model using the satellite data to estimate the displacements will be presented.

Key words: InSAR, Persistent Scatterer Interferometry, structural deformation, infrastructure

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EXPERIMENTAL STUDIES ON MONITORING GROUND DEFORMATIONS WITH CORNER REFLECTOR INSAR

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Abstract: Six corner reflectors (CR) installed on a hillside slope and on reclaimed land in Hong Kong are used as point targets in our interferometric synthetic aperture radar (InSAR) experiments to study ground motions related to the landslide and ground settlement. Eight ESA ENVISAT SAR images spanning from February 2006 to May 2007 are used in the study. The Least-square AMBiguity Decorrelation Adjustment method (LAMBDA) that was originally developed for phase ambiguity resolution in GPS positioning is used for phase unwrapping in processing the InSAR data. The zenith tropospheric delays determined with 12 continuous GPS stations in Hong Kong are used in the study to determine and correct for the tropospheric delays to the InSAR measurements. Both linear and periodic deformation models are tested in the study. The study demonstrates that the CRInSAR method provides accurate results in monitoring ground motions.

Key words: InSAR, corner reflector InSAR, ground motions

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MONITORING DEFORMATION OF WATER DEFENSE STRUCTURES USING SATELLITE RADAR INTERFEROMETRY

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Abstract: The majority of the Dutch population is living on land reclaimed from the sea, below the high water levels of the sea, large rivers and lakes. Seventy percent of the gross national product is earned in these vulnerable areas. Therefore, the safety of the water defense systems (WDS) is of paramount importance to sustain Dutch society. Failure can have catastrophic humanitarian and socio-economic consequences. The primary water defense systems form a protection against flooding from the sea, the main rivers, and the large lakes, for which failure would have dramatic consequences. Monitoring the status of WDS is particularly difficult, partly because of their large extent: 17000 km in the Netherlands. Inspection methods rely largely on expert observers, who perform yearly manual (visual) inspections, a method that has been unchanged since the centuries. Consequently, such observations are infrequent, subjective and qualitative. Here we show that satellite radar interferometry, using a new methodology derived from earlier results on persistent scatterer interferometry, is able to detect more than 90% of the primary water barriers around the main open waters of the Netherlands; the Waddenzee and the IJsselmeer. The results show that it is possible to derive millimeter scale deformation and to assess whether the outer dike structure remains intact after strong storms.

Key words:

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MEASURING DEFORMATION AND TOPOGRAPHY WITH A PORTABLE RADAR INTERFEROMETER

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Abstract: After a short description of GAMMA's novel portable radar interferometer we report the results of surface topography and ground-motion measurements over the Rhone glacier in Switzerland and the Tessina landslide in Italy.
The Terrestrial Interferometric Radar was deployed overlooking the Rhone Glacier in September and October 2007 for a series of measurements to evaluate the feasibility of using a ground-based real-aperture interferometric radar for remote sensing of glaciers. Comparisons of the phase between successive images acquired from the same viewpoint were used to determine displacements on the order of a fraction of a wavelength. In the case of this Ku-band instrument, operating at a wavelength of 17.4 mm, the measurement sensitivity is better than 1mm. Multiple images of the Rhone glacier where acquired over a 6 hour period. Interferometric post-processing of these data yielded LOS velocity estimates on the order of 4 mm/hr (35 m/year). The interferograms have good coherence even over several hours. We also acquired simultaneous interferometric image pairs with a vertical baseline of 25 cm. We derived the surface topography from the interferometric phase by calculating the precise angle of the LOS relative to the baseline. Rapid simultaneous acquisition of the image pair eliminates interferometric decorrelation due to surface change and phase errors due to tropospheric variability and ground motion. Our results are in good agreement with the topographic maps and photogrammetric data.
Another set of measurements was taken at the Tessina landslide in Northern Italy. Small parts of this landslide moved so rapidly that distinct signs of the deformation were already evident after 15 minutes. Multiple measurements were taken throughout the day to map and monitor the movement. Over the short intervals considered the coherence was high except for the forested parts where the vegetation decorrelated the signal. The effect of the relatively strong atmospheric path delay distortions could be significantly reduced by stacking the individual observations. Overall the instrument showed a very satisfactory potential.

Key words: Ground-based Radar Interferometer, deformation measurements, topographic measurements, landslides, glacier motion, glacier volume change.

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EXTRACTION OF DEFORMATION SIGNALS OF A SLOPE WITH KALMAN FILTERING TECHNIQUE

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Abstract: This paper discusses the methodology to extract deformation signals from the monitoring measurements of a slope with Kalman filtering technique. A first order Markoff process is used as the dynamic model to describe displacement rate of a monitoring point. The method was used to process the measurements of a steep slope at a hydropower station in south-west China. The results show that the accuracy of derived deformation parameters is significantly improved.

Key words: Kalman filtering; deformation analysis; slope.

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OPTIMAL DESIGN OF DEFORMATION MONITORING NETWORKS BY USING PSO ALGORITHM

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Abstract: Geodetic deformation monitoring networks has to be sufficient in terms of precision, reliability and strength, sensitivity and cost. Hence, before monumenting and gathering survey data, a geodetic network must be designed to meet some quality criteria. Mathematically, optimal design of a geodetic network implies minimizing or maximizing a target function that denotes the quality of the network. Classically, a network can be optimized using the trial and error method and analytical methods such as linear programming, quadratic programming or some optimization problems can be solved by generalized or iterative generalized inverses. Optimization problems may also be solved by intelligent optimization techniques such as genetic algorithms, simulated annealing and particle swarm intelligence (PSO) algorithm.

In this paper, we dealt with optimization problem of geodetic networks. A GPS network was optimized by using PSO algorithm in the sense that it will satisfy good precision and high reliability requirements. According to our results, PSO algorithm can be used as a tool for optimizing a geodetic network.

Keywords: GPS network - optimization - PSO algorithm - network quality criteria - artificial intelligence - swarm intelligence.

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SMOOTHING GNSS TIME SERIES WITH ASYMMETRIC MOVING AVERAGES

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Abstract: There is an increasing trend to apply GNSS continuous observation of short baselines to the monitoring of engineering works, such as bridges and dams, for their structural analysis and safety control. In the case of large dams, one important application of the GNSS continuous observation is the establishment of early warning systems that demand accurate, frequently updated information and where the analysis of the baseline time series, in order to separate signal from noise is mandatory. The paper presents a study on the performance of linear filters of the asymmetric moving average (AMA) type to smooth baseline time series. The transfer function of the AMA is adopted as a smoothing criterion to define an adequate order for the AMA, in face of the spectral density function of the baseline time series. One series of measurements of a short test baseline (325 m), materialized in the campus of the National Laboratory for Civil Engineering, is used as an example of the proposed strategy.

Key words: Moving average, Noise, Signal, Spectral density.

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PROCESSING METHODOLOGY FOR THE COMPUTATION OF AFREF SOLUTIONS

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Abstract: The goal of this manuscript is to describe the methodologies and steps used to produce the first realization of the AFREF (African Reference Frame) solution, called AFREF08. AFREF is an effort carried out by the international community, in particular the African countries, to establish a continental reference system as a basis for national reference networks.
AFREF08 is being realized by simultaneously compute accurate positions of an extended set of GNSS (Global Navigation Satellite Systems) distributed by the entire African continent. The positions are referred to the latest realization of ITRS (International Terrestrial Reference System), ITRF2005, by aligning the continental solution into this global frame at a defined epoch.
The solution for the AFREF network needs to be fixed to a certain epoch in order to be the backbone system that will allow every country to realize its national system fully and directly consistent with the national realizations produced by the neighbouring countries. To respect the dynamics due to the existence of several tectonic blocks, AFREF08 is fixed to the Nubia plate and the differential motions with respect to this block for stations located in different plates have been accurately modelled.
We discuss here the theoretical issues involved and the results obtained, which are based on the combination of two individual solutions produced using two different software packages.

Key words: AFREF, Reference Frames, Tectonic Plates

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GNSS RTK NOISE REDUCTION IN POSITION DOMAIN USING CAUSAL FIR FILTERING FOR GEOTECHNICAL AND STRUCTURAL ENGINEERING APPLICATIONS

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ABSTRACT. There is no doubt that GPS/GNSS has introduced a disruptive change in the way we are handling structural monitoring operations. Short range GPS/GNSS positioning can today rivals in term of precision with the traditional geodetic technology based on Total Stations.

While today the GNSS receivers can process the observation at highest rate such 20 Hz than before, it has all been a concern to reduce the result noise inherent of the observations contaminated by atmosphere turbulence, inaccurate orbits information etc, and to take advantage of most data we can collect to do so.

Applying an appropriated causal Finite Impulse Response filter directly on the position domain (coordinates) guarantees a noise reduction of around 35%. On the same time the characteristic of the sample distribution is tested to ensure the filter can be reset in case of even small and abrupt changes.

After comparing the merit of a conventional Kalman filter with the performance of a causal FIR filter, Leica Geosystems has opted and decided to implement such filter in both his Leica GNSS Spider positioning software and in the Leica GNSS QC software.

The author will review the characteristic of the filter implementation, the different parameters that can be set and the resulting performances on different projects using dual frequency GNSS receivers and the new single frequency Leica GMX901 receiver in real time as well as in near real time or post-processing mode. The results obtained show remarkable performances in noise attenuation and therefore open the way to give more credit to the use of GNSS technology for geotechnical and structural engineering application as well.

Key words: GPS, GNSS, reference Station network, deformation monitoring, geotechnical and structural monitoring, Leica GNSS Spider, RTCM, RTK, FIR, filtering, smoothing, data snooping.

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MODELLING THE BEHAVIOUR OF A LARGE SPAN GLULAM BEAM OF ATLÂNTICO PAVILLION

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Astract: Atlântico Pavilion, designed for the world fair Expo'98 in Lisbon, is a multi-purpose hall created to receive an audience up to 16,500 people. It is a remarkable structure. From the outside it resembles a futuristic spaceship. But it is the inner timber roof structure which turns it in one of the most emblematic buildings of its kind.

The Pavilion has one of the largest glued laminated timber (glulam) structures in the world, with arches from 52 to 115 m in span. This structure supports the arched roof and it is fixed to the concrete foundations by means of pinned joints.

Since 2000 the National Laboratory for Civil Engineering is responsible for following up the glulam structure. The monitoring includes: periodic visual inspections, continuous measurements of moisture content of the timber and of standard environmental conditions relevant to the structure, and the determination of horizontal and vertical displacements by geodetic surveying methods.

Vertical displacements of one of the beams, function of the influence of several parameters, are modelled. The model is calibrated using data from the last measurements campaigns. The paper describes the Pavilion glulam structure, the monitoring system and presents the results as well as the numerical solution of a linear model (using Matlab) for estimation of vertical displacements.

Key words: geodetic monitoring, vertical displacement, glulam structure, model.

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EVALUATION OF THE CONVENTIONAL SURVEYING EQUIPMENT APPLIED TO DEFORMATION ANALYSIS OF HERITAGE BUILDINGS. A CASE STUDY: THE TOWER OF SANTA MARÍA LA BLANCA CHURCH IN AGONCILLO (LA RIOJA, SPAIN)

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Abstract: A typical feature of heritage buildings' is their fragility which is displayed by means of several pathologies such as wall sloping, convexities or cracks. Although there are some model projects on monitoring, they are usually enclosed in big restoration works whose budgets are ample enough to accommodate the cost. Except for these cases, most of the churches, palaces or castles which makes up our vast heritage, have to share the limited funds assigned to their maintenance where the geodetic analysis are just a luxury it can not afford.
In this paper, it is reported a case study carried out at Santa María la Blanca church (Agoncillo, Spain) which shows significant deformations. For two years, a number of field campaigns are being observed exclusively with conventional surveying equipment and benchmarks.
Of course, it is not intended to perform a thorough monitoring but to answer the questions whether the building is stable and the scale of the possible movements. In order to accomplish this aim, it is proposed to study the tridimensional movements from their horizontal representation and the restriction to angular observations which are the most easily controllables.
The main goal is to define a low-cost method useful as a tool for preliminary diagnosis and to permit optimizing the cases in which it resorts to detailed geodetic studies or consolidation works.

Key words: heritage, deformation analysis, low-cost.

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ESTIMATION OF THE VERTICAL DEFORMATIONS OF THE STYLOBATE OF ANCIENT TEMPLES – THE CASE OF THESEION

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Abstract: In this paper a method is presented for the estimation of the vertical deformations of the stylobate of ancient temples. Following the determination of the settlements of the stylobate of the temple of Ifaistos (Theseion) is presented as a case study.

The surface of the stylobate – the upper surface of the temple's crepis- is a curved one with different transversal and longitudinal gradients. Its original shape can be derived from the uneven heights of the columns' lowermost drums. Since these drums are not affected by distortional features through out the centuries, their heights, if measured accurately, can be used for the determination of the original shape of the temple's stylobate. Using least squares techniques the best fitting surface can be determined, using as observations in the adjustments the measured heights if the drums. Finally the deformations of the stylobate can be estimated from the comparison between the estimated best fit surface and the nowadays profiles of the stylobate, determined by precise leveling.

The deformations of the Theseion stylobate are presented as a case study. The original curved profiles of the four sides of the stylobate of the Theseion are approximated by two different curves (circle and a parabola), the best fitting line is estimated. and the settlements of the temple's stylobate are determined..

Key words: Original geometry of ancient structures, deformations.

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MONITORING OF TALL BUILDING'S DYNAMIC BEHAVIOUR USING PRECISION INCLINATION SENSORS

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Abstract: The observations made on the engineering structures like dams, bridges, viaducts and high buildings provide to determine whether the structure was built in accordance with the project or not and whether it behaves reliably or not. In the light of this information, new information that should be considered in the assumptions used in the project can be obtained and some parameters can change. The dynamic parameters like wind, temperature, earthquake loads especially acting on the tall buildings cause the structure move in the horizontal direction.

A high precision inclination sensor, a GPS site and an anemometer were installed in order to observe the dynamic behaviors of the 30-storey high Rixos Hotel building in the horizontal direction. The floors of the building are formed from a lobby, a clerestory, 4 basement floors, an equipment floor and 26 floors with hotel rooms. The biaxial inclination sensors namely Leica Nivel 220 were installed at the 21st and 26th floors on one of the shear-nucleus. The GPS site was located at a place on the roof from which the satellite view would be maximum and the behavior of the building would be reflected at best, and the Young Anemometer was installed at a most dominating place on the roof in order to measure the velocity and the direction of the wind. The horizontal movements of the building, the velocity and the direction of the wind are still continuously observed using the biaxial inclination sensor and the anemometer.

In this paper, there were given information about the installation plan of inclination sensor, anemometer and RTK-GPS point that were installed to determine the dynamic behaviors of the building. We dealt with monitoring strategy of tall building by using inclination sensor and RTK-GPS, the data-acquisition periods, comparison of two monitoring system and the purposes of the study. In addition, we explained dynamic systems and system identification procedure related to deformation monitoring.

Key words: Monitoring of deformations-inclination sensor-system identification-tall building

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METROPOLITANO DE LISBOA - TERREIRO DO PAÇO TUNNEL: EXTENSION OF THE BLUE LINE LISBON UNDERGROUND; GEODETIC MONITORING OF AN ACCIDENT SITE

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Abstract: During the construction of the Terreiro do Paço Underground Station in 2001, as part of the Blue Line expansion project, an accident occurred in the main Blue Line tunnel, at a curve executed partly in the silt bed of the Tagus river in front of the Praça do Comércio square.The consequential damages include some loss of correct longitudinal and transverse configuration of the tunnel rings in the curved part of the main tunnel. Remedial works were carried out, starting in 2005, under the engineering design and supervision of TEC – Holland.

This presentation describes the geodetic solutions implemented by SPGO, Lda, for continuously monitoring the remedial and post-remedial works and induced displacements, in which four Leica TCA2003 robotic total stations were set up inside the tunnel, distributed from one end to the other end of the curved part of the main tunnel.

For this specific purpose, the curved part of the tunnel was divided into two "cantilever" independent parts, each controlled by two total stations. The "rigid" extremes of each "cantilever" are the two outer ends of the curved and damaged parts of the main tunnel. Two special and common points in the middle of the tunnel, in the free ends of each "cantilever", are measured by both the internal and dependent total stations, in each observation cycle.

The commercial GeoMos software, from Leica Geosystems, was applied for controlling all the parameters of the continuous, cycle after cycle, measurements. However, before implementation of the whole physical and logical geodetic system, some additional non--commercial routines were discussed previously with Leica Geosystems software developing team, concerning their approval and final agreement for the logical and physical principles described above. After this, the special routines were designed in Switzerland and, finally, tested on site by the Leica Geosystems software developers.

The presentation describes the logical functioning principles of the implemented geodetic system, the raw data transfer to the engineering designers in Holland, the general analysis of booth "cantilever" object point and on site measured displacements and the often manually performed adjustments, using Epoch Suite software.

Key words: Monitoring, Automatic monitoring, GeoMos, Terreiro do Paço, Lisbon Underground, Epoch Suite, SPGO, Leica Geosystems

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DETERMINING DISPLACEMENTS ON TUNNEL BY GEODETIC AND 3D FINITE ELEMENT METHODS

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Abstract: Temporary and permanent effects occur on major engineering buildings and their environments such as dam, bridge, tunnel, viaduct and tower. These effects generally occur because of the physical properties of the land, the weight of the building, active external burden and other similar effects. This results in deformation on both buildings and their environments. The observation of the deformation on engineering buildings is necessary in terms of socio-economic perspective because of the high costs of the buildings and the importance of their usage.

In this study, an attempt was made to determine the deformations occurred on Arhavi Tunnel, constructed on Eastern Black Sea Coastal State Highway, by using geodetic measures and 3D Finite Element Method (3D-FEM). The results from both models were compared and interpreted. The directions and the values of the tunnel deformations determined by both models seem to be the same and compatible with each other. Comparing both results had done more realistic assessments.

Key words: Tunnel deformation, Finite Element Method (FEM), Geodetic method

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CHECKING OF CRANE RAILS BY TERRESTRIAL LASER SCANNING TECHNOLOGY

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Abstract: Measuring crane rails is one of important applications in the engineering geodesy. At present, crane rails are most frequently measured with using theodolites, levelling instruments and total stations. Another possibility for measuring crane rails is using terrestrial laser scanning. Technology of the terrestrial laser scanning offers several advantages in comparison with commonly used processes. One of the most significant advantages is fast data collection and high density of the detailed points measured on the crane rails. Although this technology does not achieve such accuracy for the individual points as when using the exact classical procedures, the final accuracy of this method can be fully compared with the other methods thanks to the point density and knowledge of shape of the measured crane rails. The paper presents experimental using of the laser scanning technology for the static check of the crane rail placed in the engine room of the water power plant in Gabčíkovo (the Slovak Republic) with the Leica HDS 3000. The measured data are processed in the PointClouder software by means of fitting geometric primitives. Accuracy of the final data is judged by the accuracy analysis and also by comparison with the results of the classical method. The results are compared with the allowable deviation stated in the ISO 12488-1 norm and the STN 73 5130 state norm. Relevant precautionary measures for rectification of the crane rails are taken on the basis of this comparison.

Key words: terrestrial laser scanner, accuracy, geometric parameters of crane rail,

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MONITORING OF LOCK CHAMBER DYNAMIC DEFORMATION

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Abstract: Measuring deformations is an important part of geodetic works during carrying out and supervising of various engineering projects. Most used methods currently used for measuring deformations are methods using the total stations and GNSS technologies. An interesting possibility in the area of measuring deformations is the laser scanning technology. This technology does not reach such accuracy for the individual points as in case of the exact total stations or of the long-term GNSS observation but it overruns this drawback in measuring speed, point density and complexity of surface record. This technology can be even used for monitoring of dynamics processes because of its very high measuring speed.

Experimental using of the laser scanning technology for monitoring of areal dynamic deformations of the lower lock chamber with huge size 37.00 x 21.95 meter is presented in the paper. The process of lock chamber filling and emptying is monitored by the laser scanning system Leica HDS 3000. Various interpretations of acquired data are considered and the data accuracy is analyzed. The results are compared with the results of electronic measuring system which is placed in the inner area of the lock chamber door. The electronic system measures relative deformation at 56 points.

Key words: deformations, accuracy, laser scanning, lock chamber, digital terrain model.

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USE OF A POINT CLOUD CO-REGISTRATION ALGORITHM FOR DEFORMATION MEASURING

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Abstract: During last few years the use of Terrestrial Laser Scanner has increased notably in different application fields, like architecture, geology and geodesy. This paper will be focused in the use of TLS data for deformation measurement and monitoring purposes which concerns both engineering geology and geodesy. The authors will propose a new approach for deformation measurement which fully takes advantage of the TLS data characteristics. The procedure is based on the point cloud matching algorithm Least Square 3D Surface Matching proposed by Gruen and Akca (ISPRS Journal, 2005, 59, 151-174). The paper will be focused on a combined use of both Surface and Curve Matching for improve the matching results and as a consequence the deformation measurement precision.

The paper will start with a brief summary of the state of the art. Then the authors will describe the proposed procedure. The last part of the work will be focused on experimental results (validation exercise) and will be followed by conclusions.

Key words: Terrestrial Laser Scanner, Point Cloud Matching, Deformation measurement, precision, curve matching.

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DEFORMATION MONITORING BASED ON TERRESTRIAL LASER SCANNER POINT CLOUD REGISTRATION

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Abstract: Deflection monitoring of structures requires spatial measurement techniques that are have reliable, accurate, low-cost and easy to installation. While a number of techniques possess these characteristics, many require the use of targets which may be disadvantageous in some circumstances, especially when the structure is inaccessible to operators. Terrestrial laser scanning has already been recognised as a useful technique for deformation detection and monitoring. However, general practice for deformation monitoring with laser scanners still requires use of targets. A methodology for measuring structural deformation, based on the acquisition of two terrestrial laser point clouds from a deforming object without the use of targets, has been developed and presented in this paper. At different data collection epochs, the position and orientation of the acquired scans are not the same. Therefore, the two point clouds should be transformed to a global reference system to enable comparison and hence extraction of deformation information. For this purpose, a number of stationary control points located in the surrounding area of the object are used. These points are identified automatically on photographs taken during laser scanner data acquisition from a high resolution CCD camera mounted on the scanner device. The position and orientation of the camera relative to the reference system of the laser scanner are estimated through appropriate calibration in a high accuracy control field. Since there is no one-to-one correspondence between the pixels of the photograph and the relevant point cloud, the position of a pixel on the object surface is estimated by interpolation. In this way, pixel coordinates are related to object X,Y,Z coordinates and control points identified on the photographs can be transformed to object points on the relevant point clouds. Using these control points, the parameters of a rigid body transformation relating both point clouds can be estimated. The comparison of the two point clouds is then possible by transforming the second point cloud to the reference system of the first point cloud. The paper also describes the application of the above methodology in laboratory experiments for the monitoring of deformations of cultural heritage structures under stress caused by controlled motion. The laboratory experiments have been performed on a model of an ancient temple which undergoes controlled stress by an earthquake table. The results of these experiments are presented.

Key words: terrestrial laser scanning, deformation, point cloud registration

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DEFORMATION ANALYSIS WITH 3D LASER SCANNING

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Abstract: Modeling of deformation processes and deriving characteristic parameters from measurements are one of the main tasks of engineering surveying. The currently used deformation models are based on a discretization of the relevant object by point marks. The positions of these marks are determined at definite times. Positional changes are evaluated in order to derive deformations.
Prerequisite for this procedure is the existence of marks on the object which can be aimed at. If such points are not available they have to be created using targets.
In addition it has to be known in advance where deformations might appear before measuring the first epoch. If deformation appears in regions which where not observed these deformations are not detectable.
In the paper a technology is described which uses terrestrial laser scanning for observing deformation objects.
Instead of points, object inherent planes and their positional changes are derived and used as observations. Point targets on the object are neither necessary for the transformation of scanner stations nor for the deformation analysis itself. The scanner stations can be chosen arbitrarily and they don't have to be identical between the epochs.
Also a priori knowledge of where deformations have to be expected is redundant. Deformations are detected where they appear.
The analytical procedure is structured in the steps: Plane detection and plane matching, interconnected transformation of the scanner station within the individual epochs and inter-epochal matching based on statistical significance.
The plane detection procedure works automatically, separately for each individual scan. The process is controlled by stochastic parameters which are derived from the accuracy of the point cloud of the scanner. The stochastic parameters determine the degree of abstraction of the plane detection process. Dependent on the project conditions the matching is performed in a fully automated or semi automated way. Result of the matching process is information about topological identities between planes of different scans. The individual scans are transformed into a unique datum by an interconnected transformation based on identical planes. The comparison between epochs is based on the same model of matching and interconnected transformation.

Key words: Terrestrial Laser scanning for engineering survey, site surveying, data processing, deformation analysis

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IDENTIFICATION OF MULTIPLE OSCILLATION FREQUENCIES WITH GPS, BASED ON EXPERIMENTAL EVIDENCE AND ANALYSIS IN THE FREQUENCY AND THE TIME DOMAIN

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Abstract: A serious limitation in the use of GPS in the monitoring of important structures like bridges, and especially in the identification of their modal frequencies, is whether this geodetic sensor can identify more than one modal frequencies. In order to contribute in the solution of this problem, we made a large number of experiments with a linear oscillator of predetermined characteristics and with three degrees of freedom and max displacements up to 3.4cm. A GPS receiver was mounted on the sliding mass most remote from the generator and was recording in kinematic mode simultaneously with another receiver in nearby, stable position, both sampling at 20Hz rate.
Experiments were made with different excitation frequencies, up to 4Hz, either constant or linearly increasing from 0.05 to 4Hz. Recorded displacements were analyzed in both the frequency and the time domain using least-squares and wavelet- based software, suitable the spectral analysis of short and non-equi-spaced time series.
In the steady part of the oscillations with constant excitation frequencies, computed frequencies were practically equal with the input ones. For the transient part of the oscillations, excitation frequencies as well as modal frequencies were accurately identified, but the amplitude of the latter was smaller, as expected. However, in the case of very small oscillation amplitudes, high (>2Hz) modal frequencies differ by up to 6% from the real values. These results are very promising for they were obtained from signals a few seconds long and with very small amplitude.
The conclusion is therefore that GPS can identify multiple frequencies, including transient and modal ones in normal structures, especially in flexible ones in which the oscillation amplitude is larger than those tested and leads to a higher signal-to noise value.

Key words: GPS, monitoring, multi-degree of freedom oscillation, frequency, spectral analysis, time domain analysis

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DETECTION OF DEFORMATIONS AND OUTLIERS IN REAL-TIME GPS MEASURMENTS BY KALMAN FILTER MODEL WITH SHAPING FILTER

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Abstract: Landslide hazard is one of the most important natural hazards. In order to reduce any loss of lives and economic damages it is necessary to develop an early warning system for landslides. It is a challenging and complex topic to develop an early warning system for landslides because the landslide hazard is caused by mutual interaction of various factors. To develop the deformation monitoring and the analysis model are one of the most significant parts providing an important basis for identifying a landslide. GPS is a useful tool to obtain the real-time observations of landslides. The main task of the GPS real-time series analysis is to separate the measurement deviations from the observations and to detect the point deformation epochs with less time delay.
As we know, Kalman filter is a key tool to process the real-time deformation series but it requires white noise. Because the GPS observations with a high sampling rate are correlated, the kalman filter model with a shaping filter is applied. In order to monitor and control the quality of the GPS observation series, a new method of simultaneously detecting deformations and outliers is put forward. The deformation and outlier have similarities as well as differences so that they can be detected and distinguished simultaneously. How to determine the state vector value when outlier and deformation occur is discussed in detail in this paper. An application to the GPS static and kinematic time series demonstrates that the method proposed can detect the deformation epochs with less time delay. This method is suitable for analysing the time series and making the right decision when deformations occur.

Key words: kalman filter outliers deformation detection

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MONITORING THE DEFORMATIONS OF A MOTORWAY VIADUCT USING KINEMATIC GPS

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Abstract: The use of GPS for monitoring the deformations and deflections of large suspended bridges has been shown to be a viable tool. The following paper details initial trials carried out by the researchers in the UK, investigating the use of GPS to measure the long term deformations and short term deflections of a viaduct carrying six lanes of motorway. The paper outlines the configuration of a number of receivers placed on the structure, as well as provisional results, showing the feasibility of GPS for such monitoring.

Key words: GPS, deflection monitoring, deformation monitoring.

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HOW FAR COULD GPS GO IN MONITORING STRUCTURAL RESPONSE TO WIND EVENTS?

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Abstract: Two techniques have been applied increasingly in recent years for monitoring the response of tall buildings to wind: the traditional accelerometer and GPS. The focus of this paper is to study how the two sensors perform relative to each other, and in particular the value of GPS measurements in improving wind effect modelling. The test site is a 192m high office tower in downtown Sydney (with a height of 222m to the tip of the spire). It is 45 levels above ground and has 20m of underground levels, and was completed at the end of 2004.

Accelerometers and anemometers have been installed on the tower since 2005, and in 2006 GPS was added to the monitoring system. Data from three reference stations in the SydNET GPS CORS network have been analysed together with data from the GPS rover on the tower, forming baselines of 1.5km, 5km and 20km in length. A large wind event was captured by the system on the 7th September 2006. The analysis will focus on the dynamic response to wind events derived from displacement measured using three GPS reference stations, how to validate GPS-derived dynamic response with accelerometer measurements, and how to separate the static and quasi-static components from the GPS measurements. The full picture of structural response to wind will be established by combining the static and quasi-static components with the validated dynamic component, which will be compared to wind effect modelling. Wind response of the structural mass motion will be modelled with measured wind speed and direction data from the anemometers by means of a frequency-dependent transfer function.

It has been demonstrated that the dynamic response obtained from both GPS and accelerometers agree well with each other. The full-scale structural fundamental mode is the 0.25Hz for the NS direction and 0.29Hz for the EW direction, with a first tortional frequency of 0.41Hz. It is encouraging that results using the GPS reference station 20km away from the rover also captured the 0.25Hz signal very clearly. Such information offers structural engineers the opportunity to refine their FEM analysis and develop models more representive of the real structure.

Key words: structural deformation, GPS, accelerometer, wind effect modelling.

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DEFORMATION MONITORING USING A NEW KIND OF OPTICAL 3D MEASUREMENT SYSTEM: COMPONENTS AND PERSPECTIVES

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Abstract: High accuracy 3D representation and monitoring of objects is an increasing field both in science and industrial applications. Up to now many tasks like monitoring of building deformations or displacements were solved by means of artificial targets on the objects of interest. Meanwhile mature optical 3D measurement techniques are available. Such image-based systems can perform their measurements even without targeting. They use the texture on the object surface to find "interesting points" which can replace the artificial targets. Example for a monitoring task is the stability control during the whole construction process of engineering buildings like bridges, high-rise buildings, dams, etc. This paper gives an overview of a new type of optical 3D measurement system and its components. It uses learning-based object recognition techniques to search for relevant areas to collect robust interest point candidates to be long-term tracked to provide a deformation database. The task of deformation analysis is on one hand based on a traditional geodetic deformation analysis process and on the other hand on a new developed procedure called deformation assessment. The main goal of this development is to measure, analyse and interpret object deformations by means of a highly automated process. We focus on key functional components, development stage and perspectives of the developed system.

Key words: Image-Based Measurement System, Deformation Analysis, Image-Assisted Total Station, Knowledge-Based System, Learning.

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MONITORING A DEEP-SEATED MASS MOVEMENT USING A LARGE STRAIN ROSETTE

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Abstract: The monitoring results of the landslide Gradenbach, Austria by GPS suggest that the motion of the deep-seated mass movement is not uniform but rather intermittent, i.e., periods of accelerated motions are followed by quiescent periods. However, GPS surveys are not sufficiently precise to allow for a detailed study of this pattern of motions. Therefore, we are developing a strain rosette for in-situ measurements of local distance changes. It consists of three embedded extensometers with a separation in orientation of 120°. The sensors are long gauge (5 m) fibre optical interferometers of SOFO type (low coherence interferometer) yielding a precision of 2 μm for length changes. The same sensors can be used for dynamic measurements with a precision of about 0.05 μm with sampling rates of 1 kHz. The concept and design of the strain rosette are presented as well as the results obtained at a test installation. First results of the strain rosette embedded in the landslide mass highlight the capability of this new measurement system under field conditions.

Key words: large fiber optic strain rosette, monitoring of landslide

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FUSION OF GEODETIC AND MEMS SENSORS FOR INTEGRATED MONITORING AND ANALYSIS OF DEFORMATIONS

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Abstract: Automated shape-measuring arrays of micro-machined sensors based on micro-electromechanical systems (MEMS) technology are capable of three-dimensional deformation measurements with sub-centimetre accuracy over several hundred metres. The MEMS sensors are placed either in boreholes in ground deformation studies or along walls and other structural elements. Due to their low cost and high accuracy, MEMS sensors successfully replace conventional electro-mechanical geotechnical instruments in many applications in geotechnical, mining, and structural engineering. The fusion of MEMS sensors with automated geodetic positioning instruments (e.g. GPS, robotic total stations) supplies information on both relative deformation and absolute displacements with reference to a selected coordinate system. Thus the fusion of the two technologies supplies all the information needed for the determination of the strain field and rigid body movements of the deformable object. This paper illustrates some installation details and field data from autonomous shape-sensing arrays using hundreds of MEMS sensors. Recent data from autonomous and fully automated GPS measurements and installation details of large-scale autonomous surveying equipment are also presented. All of these systems can take advantage of wireless communication methods integrated with internet delivery. A simple fusion of MEMS and GPS data is shown for a laboratory setup, and concepts for more complex combinations of field equipment and field data are proposed.

Key words: integrated monitoring, MEMS sensors, deformation analysis.

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NEW DIGITAL CRACK-MONITORING SYSTEM FOR OBJECTIVE DOCUMENTATION OF THE WIDTH OF CRACKS IN CONCRETE STRUCTURES

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Abstract: The width of cracks is one of the major sources of information for civil engineers for stability assessment and damage detection of concrete structures. Up to now only very simple devices are used for this task, where the main shortage is lack of real documentation and the subjective estimation of the width value.

During the past years a completely new instrument was developed for this task based on digital image processing. By constant illumination and stable camera parameters the crack is documented objectively and with high precision.

More complex is the processing software, where two approaches are realised: A modified fly-fisher algorithm to follow the crack progress and measure the width in numerous cross sections and a correlative concept, which allows to determine a combined value for the width.

For documentation of numerous cracks at real structures the location of these cracks have to be determined as well. For this georeferencing task classical geodetic approaches as well as modern concepts are going to be applied.

Within this presentation the basic concepts of the new instrument, the underlying algorithms of the software solution and practical examples are presented.

Key words: optical measuring device, crack monitoring, digital image processing.

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THE CONCEPT OF NETWORK ROBUSTNESS BASED ON STRAIN ANALOGY AS SEEN IN THE LIGHT OF CONTINUUM MECHANICS

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Abstract: . The Vaniček concept of network robustness to observation gross errors, being a merger of the reliability and strain analysis, is investigated with respect to basic assumptions and the resulting requirements of continuum mechanics. The main objective of the study is to precisely determine to what extent the strain analogy can be applied to robustness analysis of geodetic networks and to provide explanations throwing some more light on this analogy. The following aspects are considered:

- structure of a network and nature of geodetic observations as non-material links between the network nodes;
- the influence of the reference conditions upon propagation of the effects of observation gross error through a network (free networks, tied-up networks);
- methods of finding the elements of the strain tensor;
- practical usefulness of the robustness indices in evaluation of the network's quality.

The theoretical considerations are illustrated with simple numerical examples.

Key words: network robustness, observation gross errors, continuum mechanics, displacement field, strain tensor.

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SPLIT ESTIMATION OF PARAMETERS IN FUNCTIONAL GEODETIC MODELS

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Abstract: The method of estimation presented in the paper is based on the assumption that every measurement result can be a realization of one from two different, random variables (differing each other in expected values). Supposing it, the functional model $\mathbf{v} = \mathbf{x} - \mathbf{AX}$ is split into two competitive ones $\mathbf{v}_\alpha = \mathbf{x} - \mathbf{AX}_\alpha$ and $\mathbf{v}_\beta = \mathbf{x} - \mathbf{AX}_\beta$, that concern the same vector of observation $\mathbf{x}$ ($\mathbf{A}$ is a common coefficient matrix, $\mathbf{v}_\alpha$ and $\mathbf{v}_\beta$ are competitive residual vectors, $\mathbf{X}_\alpha$ and $\mathbf{X}_\beta$ - competitive parameter vectors, respectively).

The proposed estimation process is based on the principle of crossing (mutual) weighting of competitive residuals $v_{\alpha i}$ and $v_{\beta i}$ (concerning the same observation x_i). That important rule is realized with such convex weigh functions $w_\alpha(v_\beta)$ and $w_\beta(v_\alpha)$ that (for $\delta_v = v_\beta - v_\alpha$): $\sup_{|v_\beta| \le \delta_v} w_\alpha(v_\beta) \Leftrightarrow \min_{v_\alpha} w_\beta(v_\alpha)$ and $\sup_{|v_\alpha| \le \delta_v} w_\beta(v_\alpha) \Leftrightarrow \min_{v_\beta} w_\varepsilon(v_\beta)$. According to the above principle and referring to *M*-estimation theory, the following optimisation problem: $\min_{\mathbf{x}_\alpha} \sum_i v_{\alpha i}^2 w_\alpha(v_{\beta i})$, $\min_{\mathbf{x}_\beta} \sum_i v_{\beta i}^2 w_\beta(v_{\alpha i})$, was formulated and solved in the paper.

The proposed method is essential extension of *M*-estimation class. However, its practical applications are not restricted to robust estimation of parameter $\mathbf{X}$ ($\hat{\mathbf{X}}_\alpha$ estimator) extended with estimator $\hat{\mathbf{X}}_\beta$ that concerns outliers. The presented method can be also applied to a joint adjustment of two observation sets measured in two, different epochs. Differences between competitive estimates $\hat{\mathbf{X}}_\alpha$ and $\hat{\mathbf{X}}_\beta$ indicate displacements of network points. The paper presents some basic, numerical examples that illustrate principles of the split estimation in functional geodetic models.

Key words: *M*-estimation, split estimation.

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GEODETIC APPLICATION OF R-ESTIMATION: LEVELLING NETWORK EXAMPLES

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Abstract: The paper presents geodetic application of R-estimation. Proposed method concerns estimation of differences between parameters of two, functional models. Such estimation seems very useful in many geodetic problems e.g. when observations are disturbed with gross errors or when differences mentioned are displacements of geodetic network points. The paper presents general solutions of R-estimation but it focuses special attention on its geodetic applications. In particular, it concerns levelling networks. The proposed estimation method, thanks to its properties, can be applied, for example, to monitoring of reference mark stability. The paper presents particular solution of such problem, based on R-estimation principle. Theoretical derivations and analysis are illustrated with some numerical examples.

Key words: R-estimation, levelling network, reference mark stability.

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COMPARING A UNIVARIATE TIME SERIES APPROACH WITH NEURAL NETWORKS TO PREDICT DEFORMATION OF SOIL MASS

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Abstract: The deforming soil mass of two major lignite mines in Greece is being monitored by conventional underground and surface methods, namely, inclinometers, total station surveying using control targets and differential GPS. While the inclinometer data can indicate the early stages of the landslide process, they provide little information about regressive and progressive movements of the soil mass under consideration. Thus, the effective monitoring of mine benches is based solely on surveying data. This paper describes two different approaches for the detailed analysis of data to predict the deformation rate of the soil mass. In the first approach, univariate time series analysis is used to transform the deformation rate of each survey target into an appropriate ARIMA model. The stochastic function that is generated follows the process which created the underlying data. Thus, the short term prediction of future deformation rates is quite feasible. The main limitation of this approach is the white noise which is generated when dealing with low deformation rates. The second approach is implemented through neural networks. Two types of networks, a feed forward and a recurrent network are described. After their basic training procedure, both networks are able to map the inputs (relative distance of total station to surveying targets, date and time of measurement) to the output, i.e. the deformation rate of a series of characteristic survey targets. The latter approach has an advantage over the former, as it's able to analyze the low deformation rate data that cannot be handled by time series approaches. However, the processing performed over the data sets is not totally controlled as in the time series case. Both approaches are implemented through in-house developed open source software, which is capable of running on all major operating systems. The paper, finally, presents results from both processing approaches using real data from the lignite mines.

Key words: prediction, deformations, time series, neural networks, open source software .

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THE CONCEPTION OF MONITORING THE SUPERFICIAL DEFORMATION LOCATED ON THE UNSTABLE FOUNDATION WITH THE USAGE OF GPS TECHNOLOGY

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Abstract: The deformation measurement, including the Earth surface deformation, is present problem in the modern engineering geodesy. The monitoring of deformation located on the unstable foundation and assigned in unstable reference system is especially important problem. The unstable foundation is defined as surface that can be influenced by movements together with the engineering objects located on it. The problem of deformation assigning is still present because a lot of building investments are situated at city centres, next to existing buildings. The earth works aiming at creation of for example underground multi-storey car parks, can cause the movements of area surrounding the building area (including the local reference system) and at the same time can influence on the existing buildings causing the strains and mutual displacements.

In this paper the conception of monitoring Earth surface deformation located on the unstable foundation with usage of GPS technology is presented. The formulas solving the problem including the accuracy analysis defined by the covariance matrix were derived. The empirical tests were made. The interpretation of interesting results coming from the tests encourages to conduct further and more detailed theoretical and empirical analyses.

Key words: superficial deformation, unstable reference system, GPS, adjustment.

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GROUND RUPTURES AND SEISMIC FAULTING AT DEPTH: THE CASE OF THE KALAMATA, GREECE, 1986 EARTHQUAKES

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Abstract: The 1986, Ms=5.8 Kalamata (S. Greece) earthquake was one of the most destructive but least studied earthquakes in Greece is the last 30 years. Based on the limited available seismological data and certain discontinuous minor ground ruptures, this event was assigned to a normal fault cutting through to the surface and correlating with a major range-front fault.
A refinement of this fault model was attempted on the basis of an elastic dislocation analysis of pre-seismic and post-seismic leveling data. These data reveal that the 1986 earthquake reflects reactivation of a segmented, blind normal fault, part of a major broad left-stepping fault zone associated with several earthquakes during the last 200 years; a result consistent with seismological evidence (clustered aftershocks, absence of very shallow aftershocks and waveform complexities). Widespread minor surface ruptures associated with the 1986 earthquake are not regarded as tectonic, shear fractures, but as extensional (secondary) fractures produced by the very strong ground motion produced by this earthquake in intensively pre-fractured rocks, while seismic accelerations were amplified in high gradient slopes (topography effect).
Still, the differences between these models are small, and some years ago would have been dismissed as noise in the data used.

Key words: earthquake, Kalamata, fault model, levelling data, elastic dislocation analysis

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APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM IN DEFORMATION STUDIES OF FORMER COAL MINING GROUNDS

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Abstract: Geographical Information Systems (GIS) are used in ground surface deformation studies on a growing scale because of their potential to handle, manage and process vast amounts of various spatial and non-spatial (attributive) data. Geo-information system for former underground hard coal mines in the Walbrzych area located in SW Poland has been developed in the Institute of Mining Engineering at the Wroclaw University of Technology in Poland. All the mining operations in this coal basin were, almost simultaneously, shut down in the late 90'ties of the 20th Century because of complicated geological and mining conditions. Long-term coal mining caused significant deformations of the ground surface and damage to buildings and infrastructure there. The present-day state of ground surface deformations associated with subsequent liquidation of abandoned underground mine workings and deterioration of old, shallow, mining voids is unknown.
The GIS has been developed to perform several functions. Firstly, store and manage available data including: geological, mining, geodetic, topographical, spatial development and other information. Secondly, perform spatial and temporal analyses and aid interpretations of subsidence studies results. The system's database has been designed to accommodate input datasets coming from many sources and in various data formats. Its structure has been described and the main GIS functions applied, such as data correlation, geo-processing or graphical (including 3D) visualisations, have been demonstrated. Results of initial studies realised with the aid of GIS concern the final stages of coal extraction (1980's and 1990's) in two out of four mines located in the centre of the basin (the City of Walbrzych). Using digitalised information and basing on the results of periodic national and local (performed by mining services) levelling surveys, analyses of mining induced ground surface deformations in heterogeneous geological environment have been carried out. These results show direct relationship, in space and time, between subsidence and method of coal extraction used. In addition probable influence of tectonic faults on ground behaviour has been found. This must be, however, confirmed by further studies on larger sets of geodetic data. In the paper results of example analyses have been given and applications of GIS in interpretation and visualisation of these results have also been presented. Further research plans focus on performing satellite GPS observations and acquiring SAR images as sources of information to study deformation of the whole basin after the end of coal extraction.

Key words: GIS, spatial analyses, deformation, mining grounds

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INTRODUCTION AND ANALYSIS OF COMMONLY USED NON-PARAMETRIC MODELS OF DAM DEFORMATION IN CHINA

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Abstract: Dam deformation analysis is an important part of dam safety monitoring. Generally dynamic models of dam deformation analysis include: parametric models and non-parametric models. In China, large amount of research activities in data analysis is in developing new non-parametric models such as stepwise regression (SR), partial least-squares (PLS) regression, artificial neural network (ANN), time series (TS), and grey system (GS). The methods have been applied in dam deformation analysis, and have showed good results in modelling and predicting deformation. The principles and merits of above listed non-parametric methods are discussed.

Key words: deformation analysis, non-parametric model, dam monitoring..

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SPECIAL MARKING OF 3D NETWORKS' POINTS FOR THE MONITORING OF MODERN CONSTRUCTIONS

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Abstract: In order to monitor deformations of modern constructions a local 3D network was usually being established at the surrounding area of the construction. The centering error of the used instruments and targets is a random error, which causes significant errors in the determination of the x, y, z coordinates of the network's points.
In order to assure precise centering for both the instrument and the targets, not only for the accessible but also for the inaccessible points a prototype way of marking the network's points is being implied.
A special semi-permanent portable metallic stand (photo 1) is manufactured for marking the accessible points. This stand provides forced instrument centering. It is light enough to carry it, it accelerates and facilitates the centering and leveling of the instrument as well as it eliminates the time needed for the measurements.
The stand is described in details and the laboratory checks in order to certificate the suitability of its use and the provided accuracy are being analyzed.
For the inaccessible points special targets of industrial geodesy were used. The targets were put in permanent attachments (photo 2), which were also manufactured.
Useful conclusions were drawn when using these special markings for a 3D network, which was established for the monitoring of a new football stadium.
Two measurement phases were carried out.
The first one with the stadium being empty and the second one when it was crowded (about 32000 people) during a significant football game.


Photo 1


Photo 2

Key words: centering, point marking, geodetic control networks, monitoring modern constructions.

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APPLICATION OF DEFORMATION ANALYSIS AND ITS NEW POSSIBILITIES

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Abstract: The XML Web Application to on-line calculation of deformations derived from repeated geodetic plane survey using Internet is described in this paper. Parameters of deformation field (strain tensors, total dilatation) in quadratic network, covering the whole result obtained at individual points of the network in question are derived and described. Vectors of displacement from repeated - and in several phases observed - results obtained at individual points of this network are given as input values. The calculation is based on the theory of mechanics of continuum and its basic prerequisite is the homogeneity of the tested territory in question.

Using proper calculation method to obtain the right interpretation of results is not the only one important thing, but its representation form as well. And this fact is also given in this paper. Deformation analysis uses Web Map Services (WMS) as its graphic representation of calculated results in the GIS format. Such services enable forming on-line of defined thematic maps in Internet viewer shown in its viewer from data obtained from servers with WMS by user. Thus no geographic data are needed by user to create GIS of his own.

Results may be reproduced and observed on a digital terrain model. This makes better evaluation and analysis possible and takes spatial relation of given terrain in consideration, too. The application includes export of results to a series of formats to further using, e.g. as the KML format to Google Earth programme.

Several programmes applied to practical processing of repeated geodetic surveys indicate possibility of reproduction and demonstrate chances of mechanics of continuum to deformation analyses. Such application is at disposal to be registered as on-line calculation using Internet to all interested persons.

Key words: deformation analysis, undermined localities, XML, WMS, displacement vectors, digital terrain model

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REDUCTION OF THE DIMENSIONALITY OF HYPERSPECTRAL DATA FOR THE CLASSIFICATION OF AGRICULTURAL SCENES

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Abstract: Recent advances in sensor technology opened new possibilities for remote sensing. For example, the appearance of sensor higher spatial and spectral resolution. In terms of spectral resolution, the number of available bands increased significantly, resulting in hyperspectral sensors. Hyperspectral remote sensing images are characterized by the division of the electromagnetic spectrum in a great number of narrow spectral bands, which enable greater detail of spectral variation of targets. High dimensionality demands special attention in the classification process. The main problem caused by the increase of the dimensionality is the reduction of the efficiency of the classifiers. This problem is known as the Hughes phenomenon. The occurrence of the Hughes phenomenon is caused by the exaggerated increase of the dimensions of the variance covariance matrix (increase of the dimensionality), compared to the limited number of available training samples. As a result, recent approaches focus reduction of the dimensionality. In this paper, a method of feature selection from hyperspectral images is presented. The proposed method, based in the use of the Genetic Algorithms, is evaluated with a AVIRIS data set and the results are compared to the results of other algorithms (Sequential Forward Selection and Sequential Backward Selection), recognized as techniques for reduction of dimensionality. A Genetic Algorithm can be described as a global search technique for optimization purposes inspired by the natural evolutionary process. The experiments show that Genetic Algorithms based reduction method can be used to reduce the dimensionality within image classification in remote sensing.

Key words: Hyperspectral Image; Reduction of the Dimensionality; Genetic Algorithms.

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INTEGRATED SOFTWARE FOR LOCAL GEODETIC MONITORING

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Abstract: The present paper describes a complete software package for local geodetic monitoring applications. The last five years Laboratory of Geodesy & Geomatics has been developing this software based to theoretical and practical knowledge of major engineering projects. The modules of the package refer to simple topographical problems, geodetic networks analysis, general deformation monitoring and special tunnel monitoring. The software attempts to present a reliable, automated and user-friendly answer to everyday needs for monitoring of structures and landslides geometry, mainly during construction. The key object of this paper is the integrated confrontation of the problem, starting from the planning of the geodetic control networks and ending with processing and managing of data and development user-friendly results, having always in mind a multi-discipline users group.

Key words: software, local deformation monitoring, engineering geodesy.

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DEEP, SUB-SURFACE DEFORMATION MEASUREMENTS OBTAINED USING COMBINED GEOMECHANICAL MODELING AND INVERSION TECHNIQUES WITH SURFACE MICRO-DEFORMATION MEASUREMENTS

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Abstract: The use of micro-deformation measurements (movements on the order of 10e-6 meters or 0.01 millimeters) to monitor production, waterflooding, steamflooding, and waste injections in oilfields has grown extensively over the past decade. A revolution in the sensitivity, accuracy, and cost of micro-deformation measurements has not only produced the ability to report smaller and more accurate numbers. We may now also combine these high sensitivity deformation measurements with advanced analytical techniques and geomechanical models into a whole new class of sub-surface source characterization tools.

This paper describes the successful combination of micro-deformation observations with inversion-based analytical techniques to back-calculate remote, sub-surface deformation parameters. These calculations are based solely upon the characteristics of the deformation field, generated at depth, and propagated through the earth. This deformation field is precisely characterized at the surface with a strategically deployed array of high-resolution tiltmeters. These tilt responses are then fed into a combined geomechanical model/inversion routine to locate and characterize the deformation sources at depth. The inversion approach, simulation runs, and a recent successful application in an oilfield environment are presented and discussed.

Key words: Tilt, Tiltmeters, Deformation Monitoring, Inversion, Source Mechanics

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SOFTWARE TO OPTIMIZE SURVEYING NETWORKS

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Abstract: This paper shows the implementation of a software using the language Java, to apply the concepts of optimization of surveying monitoring networks and to propitiate the user the interaction possibility with the program, in way to optimize a two dimensional surveying network according to the analysis of the criteria of precision, in that it should look for the minimum variance for each point of the network and reliability criteria to evaluate the number of redundancy and with this the influence of the blunders in the adjusted parameters. The software is capable to perform the adjustment of the observations using least squares method of groups of horizontal coordinates, distances, azimuths and angular observations. It optimizes through the change of observations of the network, with increment of observations or if it is the case reduction of these.
The concept of reliability of a surveying network is related to the capacity that this has to detect blunders such small as possible. And this can be evaluated through the numbers of redundancies. The sum of the partial redundancies of the observations of a surveying network indicates the degree of freedom of the network. Therefore each added redundant observation increases in a unit the sum of the partial redundancies, independent of the observation. In this work is intended to apply the idea of the more homogeneous the values of the partial redundancies, more reliable the network is considered. In other words, it is looked for to minimize F, such that $F = (Rmm)^2$ is minimum. Through that minimization of the sum of the squares of the partial redundancies a better distribution of values is sought reducing the amount of unreliable observations.
It was obtained software capable to improve a surveying network suggesting observations to improve the precision and the redundancy of the parameters and observations of the network. The software uses the least squares method using the approach of observation equation. In the aspect of the reliability it uses the concept of redundancy matrix. To each change of the observations of the network the precision and redundancy of the parameters are recomputed, warning whenever some essential observation in the computation of the network be excluded. Some tests have been done and it evidenced that the software reached its objective.

Key words: optimization, redundancy number, network

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A WEB-BASED SYSTEM FOR DEFORMATION MONITORING

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Abstract: In late 2006, a new three-year NSERC (Natural Sciences and Engineering Research Council of Canada) CRD (Collaborative Research and Development) project on "Intelligent Structural Monitoring" was begun in the Department of Geomatics Engineering, Schulich School of Engineering at the University of Calgary. This research project is a collaboration of industry and university partners. The industry partners are Sarpi Ltd. (Dr. Robert Radovanovic, NSERC CRD Co-Investigator) and Terramatic Technologies Inc. (Bill Lovse, NSERC CRD Co-Investigator). The university partners are Dr. Bill Teskey (Principal Investigator), Dr. Naser El-Sheimy (Co-Investigator), and Axel Ebeling (Project Manager). The first objective of the "Intelligent Structural Monitoring" NSERC CRD Project is to develop new, more efficient, and more reliable methods for deformation monitoring. The second objective is to develop a web-based system for deformation monitoring.

This paper will deal with the development and application of the web-based system for deformation monitoring. In Summer 2007, the first version of the web-based system was ready for launch. The system allows for on-site analysis of original and repeated observations, with these observations coming from total stations, precise levelling equipment, GPS/GNSS satellite receivers, terrestrial laser scanners, or other sensors. From the analysis of these observations, three-dimensional movements can be determined. Testing of the system was carried out in Fall 2007 after original and repeated observations were available from the Turtle Mountain / Frank Slide Deformation Monitoring Project.

Key words: web-based system, deformation monitoring

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ARTIFICIAL INTELLIGENCE METHODS IN DEFORMATION ANALYSIS

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Abstract: In the paper application of selected artificial intelligence methods in analysis of ground surface deformations are presented. These methods have been used to classify sub-regions taking into consideration displacements vectors of discrete points of the object, geological, geotechnical and ground water conditions and other potential factors influencing deformations of the ground surface. Examples of artificial intelligence methods used for predicting displacements have also been shown. Two variants of the displacement-potential cause of displacement relation models have been developed, one for the whole area under study and separate models for selected (designated) sub-regions. In the article results of computations using artificial intelligence methods and methods traditionally used in deformation analysis have been compared. The research object described, is the area of Wroclaw city located in the Middle Odra Fault Zone in SW Poland.

Key words: deformations, artificial intelligence methods

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TESTING: AN APPLICATION FOR MOTORIZED TACHEOMETERS

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Abstract: The measurement of the observables is affected by observation errors, which arise from several causes, such as the measurement equipment, the operative methods, the atmospheric conditions, and the operator's skill. Experience has shown that developing observing procedures and performing tests to control the errors during or right after the measurements is not only a reasonable procedure to minimize the effect of the errors but might also have a high economic impact.

The tacheometer (i.e., total station) Leica TCA2003, with automatic target recognition (ATR), has an ATR accuracy that can reach levels similar to manual pointing. For this reason, in some of the high precision geodetic monitoring systems, were angle and distances are measured, TCA2003, along with the onboard software *Monitoring*, can be applied. This software, also from Leica, was designed to perform repeated automatic measurements to predefined points. But, after the first campaign, it became obvious that the lack of control on the data was leading to longer measurement periods because these had to be repeated several times, only way to be able to, latter, reject those measurements that clearly include errors. To avoid long periods of observations and the uncertainty on the quality of the data, it would be important to include the control of errors during the measurements.

TCA2003 belongs to the Leica instruments family that can be loaded with software applications developed by the user, according to his needs. This paper presents an application called *Testing*, developed using the programming language GeoBASIC from Leica. Although it has some similarities with the application *Monitoring*, the onboard software *Testing* has some very unique properties since it can perform tests in real time, to validate the data measured, and alerts the observer whenever it detects an error, allowing the user to undertake the most adequate procedure. The paper describes the limitations of software *Monitoring*, when applied in very specific applications, the solution used to surpass the shortcomings - the development of a new onboard software, *Testing* – and the main features of this one.

Key words: Tacheometer, Leica TCA2003, application, measurement.

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LOW COST MOBILE MAPPING SYSTEM FOR URBAN SURVEYS

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Abstract: This article describes a low cost terrestrial Mobile Mapping System (MMS), developed at the University of Porto, that can be used in a wide range of urban GIS data acquisition (like traffic signs, infrastructures inventory, publicity, road marks, etc.), as well as in highway or railway inventory. It incorporates a direct geo-referencing system with a single frequency GPS receiver board and two progressive CCD colour video cameras with 640x480 resolution as remote sensors. The image acquisition system works independently so it can be used with any direct georeferencing system. The system allows for the association of a position and attitude to each digital frame captured by the video cameras. Several calibration steps have to be overcome before the system is prepared to do the survey operations, namely camera calibration, relative orientation between cameras and determination of rotation and coordinate offset between vehicle and cameras reference frames. Procedures were developed in order to guarantee the perfect synchronization between direct geo-referencing data and image data. A user friendly software tool was created to allow for an easy object coordinate extraction either in auto mode, where the conjugate coordinates are obtained using image correlation techniques, or in manual mode. Tools for efficient integration with previously existent databases and communication with other GIS platforms were developed as well. Several surveying experiments are described in the paper. The videogrammetry system implemented is a low cost system that can achieve accuracy, in relative positioning, of a few decimetres. The overall accuracy depends mainly on the direct georeferencing system used.

Key words: Mobile Mapping System, Digital Photogrammetry, Correlation, Camera Calibration, etc.

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ESTABLISHMENT OF THE GHANA'S GEODETIC REFERENCE NETWORK

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Abstract: The first phase of a nationwide Geodetic Reference Network covering about forty percent of Ghana has been completed. This included the establishment of three permanent stations out of which one is to function as an IGS/AFREF station. The network included, in addition to the three permanent stations, eighteen other stations, well distributed in and around the Golden Triangle of Ghana, which serve as points of departure for the user community. This demand-driven project under the Land Administration Project of Ghana introduces the adoption of the International Terrestrial Reference Frame (ITRF) in replacement of the War Office Ellipsoid and the Clarke 1880 Ellipsoid which have been used over the years. The concurrent running of the two ellipsoids sometimes created confusion in the mapping system and it is therefore relieving to adopt the ITRF system. The situation necessitated the computation of the Transformation Parameters from the two old systems into the new geocentric coordinate system.

This paper explains how the geocentric coordinates of the stations were calculated and adjusted using GTCE and NEADS, modules of the PrePos GNSS Suite, a scientific software developed at the Institute of Geodesy and Navigation (IfEN) of the University FAF-Munich in Germany. The DITON module of the PrePos GNSS Suite was used to determine the Transformation Parameters as well.

Key words: Geocentric coordinates, Transformation Parameters, Reference Network.

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REAL TIME AND POST-PROCESSING MONITORING SOLUTIONS WITH THE NEW LEICA GMX901 L1 GPS RECEIVER

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Abstract: With the promises of new GNSS constellations such as GALILEO and BEIDOU, the whole GNSS industry is now mobilizing to release multi-frequency, multi-constellation GNSS receivers and antenna.

On the other hands the responsible of monitoring projects are looking for affordable low cost GPS L1 receiver but with still high accuracy performances. It has been requested many time by the professional of such projects to have for a given budget as much sensors they can. Multi-switch antenna based receiver solution has been a trial to reduce the cost of an installation based on GNSS monitoring with the inconvenient that the results are not synchronised in time and the communication link between the antennas and the multi-switch device restricted to short ranges.

Leica Geosystems AG Switzerland has released a new low cost L1 GPS equipment with antenna and receiver integrated into a smart mount. The Leica GNSS Spider software handled already only L1 measurement processing in both real-time and post-processing mode.

The authors will introduce the characteristics of this new equipment as well as the results obtained on a monitoring project hold in the area of a South African open pit mine where the Leica GMX901 has been engaged for a trial. Performances in Real Time and in Post-Processing will be presented to justify the large potential of this new solution.

For large project area and for sub-tropical regions where the ionosphere tends to restrict the range of the baselines, a network of dual frequency GNSS receivers can be used as a frame where a large number of single L1 GPS receivers can benefit of the ionosphere and troposphere mitigation deduced by the network solution. Leica GNSS Spider software has now also implemented that possibility and the authors will elaborate on that new feature with some practical examples.

Key words: GPS L1, deformation monitoring, GPS Network, processing, filtering

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USE OF GPS BASED DRIFTERS IN THE STUDY OF COASTAL CURRENTS

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Abstract: One of the goals of project NICC is the spatial analysis of the Northwest Iberian Coastal Current. With that purpose, dedicated satellite based drifters were deployed with the possibility to acquire information about its trajectory and velocity and transmit it via GSM.
In order to evaluate also the estuarine/ocean interaction, those drifters were lunched inside the Douro estuary and monitored on their track all the way to the ocean.
The drifter design allowed one to guarantee that the main driving effect is the current although also the wind and other meteorological conditions should be taken into account when analysing the trajectories.
Several experiments were done, in different tide conditions, and under different runoff forcing. The results obtained allow us to conclude that the local surface current pattern, derived from the drifters monitoring, is compatible with the information obtained with an ADCP moored in the neighbourhood on the inner shelf.
The analysis of the free trajectories of the drifters in the different campaigns allowed us to draw some conclusions about the characteristics of the estuarine flow, the effects of bathymetry and the transitions between inner and mid shelf.
The use of the drifters has shown to be appropriate for the definition of the Coastal Current Field. The velocities and evolutionary patterns revealed were in agreement with the observation from the fixed ADCP station.

Key words: Coastal currents, drifters, estuarine flow, GPS, ADCP.

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