Current developments in deformation analysis

Monday, 07.04.2025, 10:50 - 12:20, Room Tulla

W. Niemeier

50 Years of Deformation Monitoring - What has been achieved?

In 1975 the “1st International Symposium on Deformation Measurements with Geodetic Methods” took place in Krokow, Poland, organised by FIG. I had the pleasure to attend this meeting and most of the subsequent symposia in this series.
In this paper I’ll give a – personally biased - overview on the advances in the field of geodetic deformation studies from 1975 till today. There is an impressive progress in sensor technology as well as data capture and data analysis, as in 1975 modern systems, e.g. GNSS, Lasercanning or UAVs, are not at all visible at the horizon. The same is valid for data preprocessing and analysis: Automated data storage devices or online processing as well as advanced computational methods including AI applications were unknown. In the area of deformation modelling several advances can be reported, but challenging tasks still remain.
Some remarks regarding competence and acceptance of our profession finalize the paper.

Keywords: Progress in sensor technology, Advanced analysis methods, Deformation modelling

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H. Kutterer, M. Even, A. Seidel, J. Weisgerber

Bridging the scales - Earth observation infrastructure and geodetic deformation monitoring

Geodetic deformation monitoring has been a topic of high geodetic interest and productivity since decades. Main fields of application are structural monitoring and geodynamic monitoring. Over the years, outstanding progress has been achieved on the one hand in terms of geodetic instrumentation including and exploiting new sensor technologies and on the other hand in terms of geodetic modelling and analysis. During the last two decades, Earth observation infrastructure (such as, e.g., Global Navigation Satellite Systems (GNSS) or the European Remote Sensing System Copernicus) have become increasingly available. Such infrastructures are operated on a long-term sustainable basis, and their data and products are provided

based on an open data policy. This allows to merge previously independent approaches for structural and geodynamic monitoring, geodetic networks and point clouds as well as local and regional scales and short-term and long-term temporal resolution. In this presentation, these developments are addressed emphasizing the opportunities, needs and challenges with respect to a fully integrated geodetic monitoring that bridges scales and disciplines. Examples of geodetic monitoring are presented which are derived from recent projects of the Geodetic Earth Systems Science group of the Geodetic Institute of the Karlsruhe Institute of Technology with a focus on the integration on GNSS and Radar Interferometry.

Keywords: Earth observation, GNSS, PSInSAR, Integrated approaches

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J. Stähle, A. Volovikova, S. Freitag, A. Stark

Artificial Intelligence-Based Deformation Analysis for Damage Identification in Structural Health Monitoring

This paper investigates damage quantification through artificial neural networks. A feedforward neural network (FNN) and a convolutional neural network (CNN) is trained based on synthetic vibration displacements of a reinforced single-span concrete beam. The damage extent is modeled by crack patterns, which differ in crack lengths and number of cracks. Different levels of accuracy in the damage quantification are analyzed by investigating various classes of damage extents. The inputs of the CNN are vibration displacements whereas damage indicators are used for the FNN. High classification accuracies are obtained for both networks, which shows the benefit of artificial intelligence-based Structural Health Monitoring (SHM).

Keywords: Structural Health Monitoring, Damage quantification, Damage indicator, Artificial neural network

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K. Karsznia, E. Świerczyńska, K. Książek, W. Odziemczyk

Development of an expert system for the deformation monitoring of historical sites using Artificial Intelligence (AI)

Historic buildings are invaluable national heritage assets that require diligent conservation. To ensure their preservation, regular surveying and physical deformation measurements are essential. These measures provide continuous or periodic data supporting conservation efforts. Additionally, non-invasive photogrammetric techniques offer valuable insights. Industry data, such as geological, mining, meteorological information, and satellite imagery, provide substantial context for understanding the Earth's surface and its impact on historic structures. Structural monitoring is typically conducted using total stations. A key challenge lies in effectively integrating and validating data from these diverse sources. Combining these data allows for developing artificial intelligence (AI)-based approaches, specifically applying machine learning (ML) models. These models can then be verified against monitoring results to identify and address potential overfitting issues. This research presents an expert system developed to automate the monitoring of historic buildings. The system leverages a methodology that incorporates various measurement techniques and ML models. A case study focusing on one representative object of the Coal Basin Museum in Będzin - The Mieroszewski Palace, Silesian region, Poland, demonstrates the application of this approach. The object encompasses unique challenges, necessitating the use of specific measurement technologies. This research, conducted between 2022 and 2024, highlights the successful integration and application of modern measurement methods in developing fully automated structural monitoring systems.

Keywords: Historical objects, Deformation Monitoring, Data integration, Automation, Model building