Coupling Simulations of Landslides with Geoinformation Systems for Decision Support and Early Warning

Eva Ortlieb[1], Stephan Mäs[1], Wolfgang Reinhardt[1], Franz-Xaver Trauner[2]

[1]Geoinformatics Research Group (AGIS), University of the Bundeswehr Munich, D-85577 Neubiberg
{eva.ortlieb, stephan.maes, wolfgang.reinhardt}@unibw.de
[2]Institute for Soil Mechanics and Foundation Engineering, University of the Bundeswehr Munich, D-85577 Neubiberg
{franz-xaver.trauner}@unibw.de

INTRODUCTION

„Early warning systems include a chain of concerns, namely: understanding and mapping the hazard; monitoring and forecasting impending events; processing and disseminating understandable warnings to political authorities and the population, and undertaking appropriate and timely actions in response to the warnings“ (NDMA, 2008). Although over the past years the evaluation of natural danger has been nationally and internationally identified as an important task, the understanding of the hazard and the forecasting of impending events are particularly critical points of the early warning chain. In this paper we present a new and challenging approach to improve these critical points. A three-dimensional finite element (FE) simulation model of slopes coupled with a geographical information system (GIS) is suggested to improve the early warning.

Due to their complexity simulation systems (SIMS) are mostly used by experts. For disaster prevention and management such tools are currently not available, but would obviously be very helpful. A numerical simulation requires detailed input information, therewith the configuration of the input data is very complex and usually not sufficiently supported by the SIMS. On the other side outputs of the SIMS are extensive and difficult to interpret. For a broader use of SIMS their handling should be more intuitive and user-friendly. GIS provide a good basis for setting up the inputs of a numerical simulation, analyzing and integrating the outputs and finally support a decision.

COUPLING SIMULATION SYSTEMS AND GEOINFORMATION SYSTEMS

Only little research has been accomplished regarding interactive linking or interfacing of GIS and SIMS. Application of standard interfaces (e.g. High Level Architecture, OGC Standards) for interlinking the mentioned systems has hardly been researched. Some efforts to support interoperability among simulation models and GIS have been made in (Bernard and Krüger, 2000; Bernard, 2000 and Schulze et al., 2002). Since this work has already been done at the beginning of this century and it has been undertaken under different boundary conditions, this issue has to be investigated with regard to the interconnection of our SIMS with the GIS anew. The interconnection between SIMS and GIS is schematically shown in figure 1.

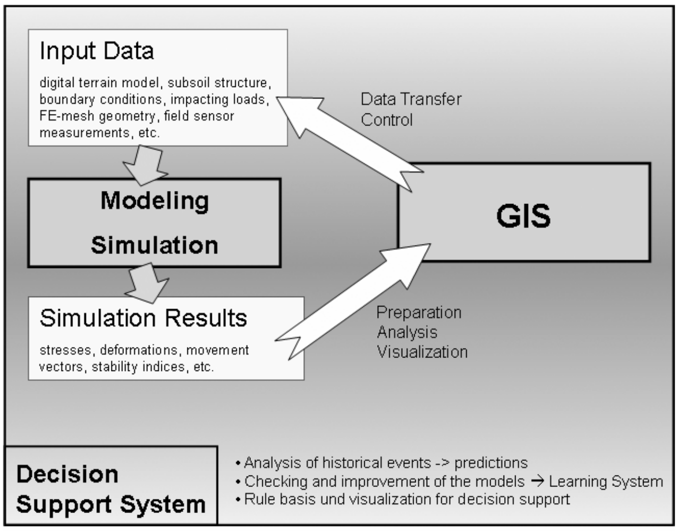

Figure 1: Interconnection between SIMS and GIS

The process starts with the selection and definition of the required input data. The transfer of the input data to the SIMS is controlled by the GIS and should enable for an automated data flow. For the FE simulation model of slopes the following types of input data have been identified:

- A digital terrain model (DTM),
- a three-dimensional model of the subsoil structure (geology),
- boundary conditions and impacting loads,
- appropriate constitutive equations to define the material behavior,
- the FE-mesh geometry and
- field sensor measurements.

The DTM defines the geometry of the upper model boundary of the slope and is required for the generation of the FE-model. Further, a three-dimensional model of the subsoil structure has to be available to define the stratification, which gives information about the distribution of different soil types. For the characterization of the deformation behavior of the slope, the mechanical properties have to be described for all observed materials by appropriate constitutive equations. Another input parameter is the mesh geometry, which is needed for the FE-modeling of the slope.

Within the SIMS the focus is put on numerical analyses to investigate and assess the stability of slopes. Applying different loads and exogenous scenarios, the prediction of the system behavior can be achieved on basis of geotechnically and mechanically well-founded models. Compared to the approach of statistical models, the employment of physically founded models enables to take the causes and triggers of landslides into direct consideration (Trauner et al., 2008).

Results of the simulation are basically stresses and deformations which are transferred to the GIS for visualization and assessment. Furthermore, stability indices and movement vectors can be calculated from the simulation results to assess the slope stability, future system behaviour and potential risk scenario to support the decision of the user whether to issue an early warning or not.

OUTLOOK

In future work suitable methods have to be developed to present the results of the SIMS – which represents the risk - to the decision maker. Further the simulation results have to be linked with decision rules in order to support the decision making process of the user, whether to issue an early warning or not. Therefore, existing methods and techniques have to be analyzed and adapted and new methods have to be developed.

ACKNOWLEDGEMENTS

The funding of the research project "Development of suitable information systems for early warning systems" (Breunig et al., 2007) by the German Ministry of Education and Research (BMBF) under grant no. 03G0645A et al. within the framework of the GEOTECHNOLOGIEN initiative (http://www.geotechnologien.de) is gratefully acknowledged. The responsibility for the contents of this publication is by the authors. This is publication no. GEOTECH-301 of the R&D-Programme GEOTECHNOLOGIEN.

BIBLIOGRAPHY

Bernard, L. (2000): Integration von dynamischen Atmosphärenmodellen auf Basis interoperabler objektorientierter Komponenten. Phd Thesis, Institut für Geoinformatik, Westfälische Wilhelms-Universität Münster.

Bernard, L. and Krüger, T. (2000): Integration of GIS and Spatio-Temporal Simulation Models: Interoperable Components for different Simulation Strategies. Transactions in GIS 4, pp. 197-215.

Breunig, M., Reinhardt, W., Ortlieb, E., Mäs, S., Boley, C., Trauner, F.-X., Wiesel, J., Richter, D., Abecker A., Gallus, D. and Kazakos, W. (2007): Development of suitable information systems for early warning systems. In: GEOTECHNOLOGIEN Science Report No. 10: Early Warning Systems in Earth Management, Kick-Off-Meeting 10 October 2007.

NDMA (2008): National Disaster Management Authority. Terminology of disaster risk reduction. http://www.ndma.gov.pk/publications.html.

Schulze, T., Wytzisk, A., Simonis, I. and Raape, U. (2002): Distributed spatio-temporal modeling and simulation. In: Proceedings of the 2002 Winter Simulation Conference, edited by E. Yücesan, C.-H. Chen, J.L. Snowdon and J. M. Charnes, pp. 696-703.

Trauner, F.-X., Meyer, F., Boley, C. and Ortlieb, E. (2008): Neue innovative Methoden zur Frühwarnung auf Basis von gekoppelten Informations- und Simulationssystemen am Beispiel gravitativer Massenbewegungen. Tagungsband 6. Kolloquium "Bauen in Boden und Fels", Technische Akademie, Esslingen.