OVERVIEW OF A COUPLED GEOINFORMATION AND SIMULATION SYSTEM FOR THE EARLY WARNING OF LANDSLIDES

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ABSTRACT:

In this paper a coupled geoinformation and simulation system for early warning is proposed. This allows for a detailed investigation of landslides within the simulation system and the user-friendly analysis of the results in the geoinformation system (GIS). The paper provides an overview of the coupled system.

1. INTRODUCTION

During the last decades a lot of research work has been done in the field of the prediction of landslide occurrence and in the development of early warning systems of landslides (e.g. Zan et al., 2002; Lee and Ho, 2009). Nevertheless, the understanding of the hazard and the forecasting of critical events are still particularly weak points of the early warning chain. For landslide hazards this especially requires a precise predictability and an exact determination of exposure of slopes.

In order to advance research in the field of early warning systems of landslides the joint project “Development of suitable Information Systems for Early Warning Systems” was launched. The project aims at the development of components of an information system for the early recognition of landslides, their prototypical implementation and evaluation (Breunig et al. 2009.). One subproject of the joint project addresses the coupling of complex finite element simulations with geo information systems (Ortlieb et al., 2009a; Trauner and Boley, 2009). In the project numerical simulations are set-up to calculate the stability of slopes and to improve the understanding of the causes of slope instability and triggers of ground failure. This allows for the evaluation of instable slopes and their imminent danger for humans and infrastructures. Because of the complex procedure of performing a simulation and the bulky simulation results such numerical simulations are mostly used by experts and scientists. For disaster prevention and management they are currently not available in practice, but would obviously be very helpful. The interconnection of the simulation with the GIS enables a broader use of such a complex system as the handling of it becomes more intuitive and user-friendly and GIS methods can be used to prepare the input data as well as to make the bulky results usable.

2. OVERVIEW OF THE COUPLED SYSTEM

Complex simulations are computationally intensive and may be, in case of a rapidly required decision for early warning, too time consuming. Therefore two main operational modes of the coupled system have been identified: the use as decision support system for prevention or reaction to a hazardous event, which requires very fast results and the use as learning system for better understanding and prognosis of landslide movements. The decision support system is primarily used by decision makers (which could be laymen from local authorities or from emergency management) for identification of the areas at risk. The learning system mode, which is provided for experts (e.g. geologist, geotechnical engineers …), additionally supports the assessment and further GIS based analysis of the simulation results (Ortlieb et al., 2009a).

The interconnection between the simulation system and the GIS is schematically depicted in figure 1. First, the required input data for the analysis is selected and prepared. These parameters describe basically the geometry and the subsoil structure of the slope and several boundary conditions. The transfer of the input data is controlled by the GIS. Within the simulation system the finite element modelling of the slope and the simulation of the slope failure formation is executed (Trauner and Boley, 2009).

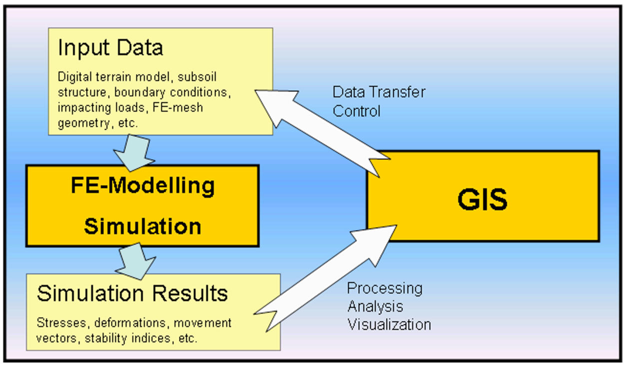

Figure 1. Architecture of the coupled system

The result of the simulation is a bulky field of vectors (e.g. deformation vectors in our test case) which are transferred to the GIS for preparation, analysis and visualization.

In figure 2 the results of a 3D simulation is shown. The problem is that the simulation results are too complex and confusing to be presented as a base for decision support. Therefore methodologies are needed, which allows for a user-friendly preparation and visualization, to support users in the decision support and in the learning system, respectively.

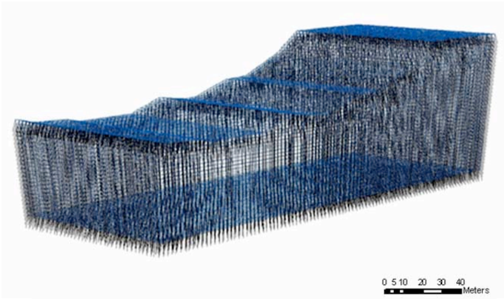

Figure 2. Visualized 3D simulation results

In order to process these bulky data first, the slope has to be divided in an area where deformations occurred during the simulation and in areas with no or minor deformations. In figure 3 (above) a section through the sliding body is shown. Compared to figure 2 here the deformation vectors of different sizes can be distinguished, but no conclusion can be made, if the slope has to be categorized as landslide susceptible or not. Therefore a methodology is needed, which allows for the clustering of the complex simulation results. In a first step the deformation vectors can be divided according to their length and their deformation direction into classes. Afterwards clusters can be detected, which include deformation vectors, which belong to the same deformation class, to the same direction class and are spatially adjacent. After the aggregation of the deformation vectors in the clusters the area of validity is determined. For a better visualization the detected deformation areas are classified in deformation areas with small (green), moderate (yellow) and large deformation (red) (see Figure 3 below). The result of this method can be presented to the responsible decision-maker for decision support (Ortlieb et al. 2009b).

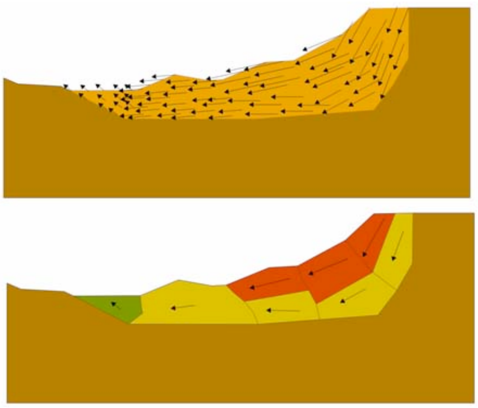

Figure 3. Above: Deformation vectors for a 2D section of the sliding body. Below: Aggregated deformation vectors with areas of validity

Besides the processing of the data to produce more user-friendly diagrams, much more GIS methods can be used to support the decision-making process. For example, the simulation results can be intersected with available digital topographical data to determine the potential endangered infrastructure (e.g. buildings and streets). By linking the simulation results with such additional data, a decisional base for preventive measures, emergency and risk management is provided. This information can then be used to support the user in the decision-making process, whether to issue an early warning or not.

3. CONCLUSION

In this paper an overview of a coupled simulation and geoinformation system has been given. At the moment the coupled simulation is tested for a study area in an unstable part of the hillsides in the Isar valley in the south of Munich (Baumann, 1988). Future research related to the GIS part will be focused on further methods, which allow for a user-friendly preparation of the complex simulation results to provide a reliable tool for early warning purposes.

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