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Interactive computer-aided learning of landslide identification and monitoring process

Apprentissage par logiciel interactif des processus d'identification et d'auscultation des glissements de terrain

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ABSTRACT
Within a large multidisciplinary project, a well-structured and interactive knowledge database was developed aimed at providing MS and PhD students with a comprehensive and well-illustrated information on all natural hazards and risks. In particular it develops methods to plan investigation works and interpret landslide field data and monitoring results so as to establish the mechanisms of the studied landslides. The main aspects of this teaching tool accessible through internet are presented as well as the tests allowing a self-evaluation of the knowledge acquired by the students.

RÉSUMÉ
Dans le cadre d'un grand projet multidisciplinaire, une base de données et de connaissances bien structurée et interactive a été développée dans le but de mettre à la disposition des étudiants de masters et des doctorants une large information, bien illustrée, sur tous les dangers naturels et les risques. En particulier, cet outil pédagogique développe des méthodes pour planifier des travaux de reconnaissance et interpréter les relevés de terrain et les résultats d'auscultation sur les glissements, de façon à établir leur mécanisme. Les principaux aspects de cet outil pédagogique accessible par internet sont présentés, ainsi que les tests permettant une auto-évaluation des connaissances acquises par les étudiants.

1 INTRODUCTION

The integrated management of natural hazards and risks represents an ever increasing complex task that implies a large number of specialists. No appropriate prevention or protection action can be carried out if the evolution of the phenomena, their mechanism, their interactions and the potential impacts are not well understood by the scientists as well as by the managers. Such a management must be based therefore on a clear perception of the integral risk process that implies scientific knowledge, but also economic, social and environmental reference data.

In order to educate and train students that may be qualified in one field, but are non-specialists in all the other domains, a project called NAHRIS, or Dealing with Natural Hazards and Risks, was developed within the organization called Swiss Virtual Campus, supported by the Swiss University Conference, the Swiss Office for Education and Science and the ETH Board. The main partners of this comprehensive e-learning project are all members of the Natural Hazards Competence Centre (CENAT) which gathers the major universities and institutes of technology of Switzerland that are active in this field, namely :
- Swiss Federal Institute of Technology of Lausanne (EPFL)
- Swiss Federal Institute of Technology of Zurich (ETHZ)
- Institute of forest, snow and landscape studies, in Birmensdorf (WSL) and Davos (SLF)
- University of Zurich, Department of Geography
- University of Bern, Department of Geography
- University of Fribourg, Department of Geography

Moreover, some institutions and private consultants contributed to provide information in specific fields.

Thus a large organization and a complex computer-based system was set up in order to develop a network aimed at educating and teaching in the inter- and trans-disciplinary field of natural hazards and risks, as well as their extension to society problems.

2 CONCEPT OF THE NAHRIS E-LEARNING TOOL

The development of the NAHRIS Swiss Virtual Campus is based on a parallel structure including six initially independent modules (Figure 1). It covers the whole range of the required subjects, namely the aspects of hydrological and meteorological hazards, geological and tectonical hazards, vulnerability and integral natural risk management, plus a presentation module as an overview and guide on the virtual campus, and a learning module on basic knowledge and tools. Each module proposes a series of learning units (LU) which can be explored by the students in about 45 minutes, a large additional effort being expected to fully acquire the knowledge (pdf files are provided) and to pass the final auto-evaluation test.

The LUs of modules 2 and 3 related to a certain type of hazard are structured in a logical sequence, starting with a description of the processes and principles, as well as of the triggering events. Then they focus on methods of process investigation, monitoring and analysis (see § 4), as well as on assessment of magnitude / intensity and probability. The relationships between different processes and the elaboration of scenarios are finally developed before hazard mapping techniques at different levels are detailed, and case studies are presented.

The module 4 on vulnerability displays a slightly different structure, focusing first on definitions, framework and vulnerability assessment for different hazards; then a separate presentation is adopted for the built environment on one hand, the natural environment on the other hand. The economic aspects of vulnerability are commented, before a presentation of the possible vulnerability reduction measures. Finally, the module 5 on risk management details the risk analysis tools, the criteria for risk appraisal and assessment and concludes by developing concepts of mitigation, preparedness and disaster management (Heinimann, 1999).

A schematic framework has been established for the presentation and structure of the LUs in order to insure a coherent display of the knowledge database. Moreover, numerous links are

Module 0 **Overview / Guide**	**Module 1** **Basic Knowledge and Tools**	**Module 2** **Hydrological and Meteorological Hazards**	**Module 3** **Geological and Tectonical Hazards**	**Module 4** **Vulnerability**	**Module 5** **Integral Natural Risk Management**
⇓	⇓	⇓	⇓	⇓	⇓
Topic Groups	**Topic Groups**	**Topic Groups**	**Topic Groups**	**Topic Groups**	**Topic Groups**
0.1 Principles of distance learning	1.1 Data acquisition	Processes Module 2 - precipitation - storm - hail - forest fire - floods - avalanches - torrents/debris flow 2.1/3.1 Process types and principles	Processes Module 3 - earthquake - landslide - rockfall - mudflow - subsidence	4.1 Definition of vulnerability	5.1 Framework System, structure and position of integral risk management
0.2 Pedagogical objectives	1.2 Data handling, modeling and administration	2.2/3.2 Triggers / triggering events		4.2 Vulnerability assessment	5.2 Risk analysis
0.3 Communication	1.3 Data analysis	2.3 / 3.3 Methods of process investigation		4.3 Vulnerability of the built environment	5.3 Risk appraisal, assessment and valuation
0.4 Concept of the NAHRIS project	1.4 Data presentation	2.4 / 3.4 Methods of process analysis - Investigation / measurement / monitoring - Slope stability analysis - Process modeling		4.4 Vulnerability of the natural environment	5.4 Risk prevention and preparation for disaster
0.5 Guide - Basic questions to the SVC NAHRIS - Modules 1 - 5 - Definitions - Terminology - Bibliography	1.5 Laws	2.5 / 3.5 Magnitude and frequency; process probability		4.5 Economical aspects of vulnerability	5.5 Disaster / event management
0.6 *Entry test*		2.6 / 3.6 Process monitoring		4.6 Vulnerability reduction measures	5.6 Case studies
		2.7 / 3.7 Relationship and interrelationship between different processes / Scenarios			
		2.8 / 3.8 Hazard mapping on different levels			

Figure 1. Simplified presentation of the parallel structure of the modules forming the NAHRIS virtual campus. The main groups of learning units (LUs) are shown, but they are not all listed in this chart. During the elaboration process, some adjustments and changes have been introduced.

provided within the structure of the module, in order to help connecting the different related concepts and favoring a trans-disciplinary approach of the major steps in the hazard and risk assessment. For each module a close collaboration has been set up between the authors of the various LUs, coming from different institutions, so that the content and the style of the LUs appear relatively homogeneous.

At the end of the NAHRIS project, some 85 completed LUs have been implemented in the virtual campus by the six main partners which include contributions from some 25 laboratories. The organization of such a complex work could be carried out setting up a steering committee for the general management and strategic options, a management committee to lead the planning and detailed elaboration of the modules, and a technical realization team to ensure the solution of the logistical questions. Moreover six module leaders have coordinated the detailed content and the interactions between the concerned LUs.

3 DEVELOPMENT ARCHITECTURE OF NAHRIS

In order to allow a progressive elaboration of the LUs, implying modifications to the draft documents, proofing and control of their formal presentation, as well as the development of connections and the homogenization of the proofed LUs, before their availability on an open platform, the required hardware architecture has been based on the operation of three servers (Figure 2). The BSCW server supplies the authoring environment for the development of the LUs by the authors and their processing by the technical realization team. The CVS server insures a development environment for all the modules and their approved LUs. After a final implementation, the e-learning platform will be accessible from outside through the WebCT server on which future modifications can only be brought by the technical realization team.

This last server is installed at the Institute of Geography of the University of Zurich. It is accessible through internet after requiring a password from CENAT (see addresses at the end of the paper).

4 ILLUSTRATION OF TWO LUs RELATED TO LANDSLIDE INVESTIGATION

Among all the different subjects presented in the LUs, a very limited part of the NAHRIS Virtual Campus has been selected here in order to display the possibilities of such a tool, concerning the development of landslide investigation and monitoring. This step is taken from LUs 3.3 and 3.4, included in Module 3 (Figure 1). It presents the required hydrogeological investigations and monitoring plans aiming at determining some of the essential parameters that will have to be introduced in the modeling, namely groundwater conditions and location of the slip surface.

Figure 3 illustrates the learning principles which are developed throughout this module, namely information acquisition, analysis and decision. It concerns the LU devoted to the methods of process investigation.

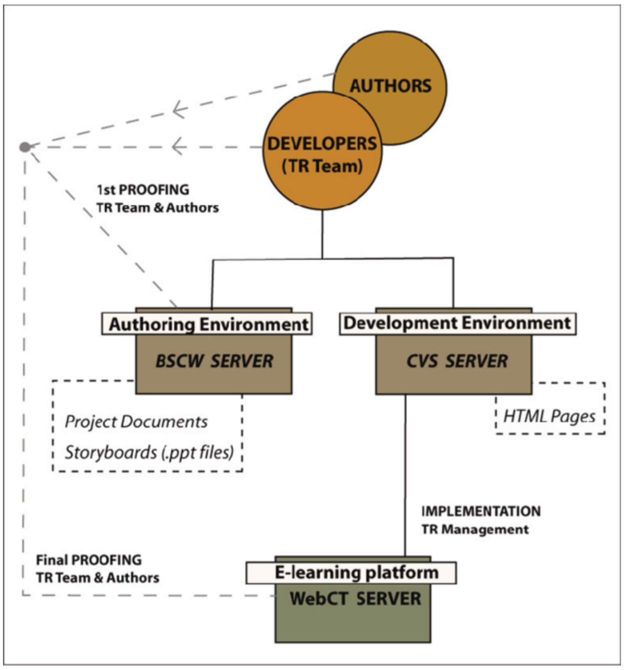

Figure 2. Development architecture of the e-learning tool NAHRIS

In this particular case, the objective consists in driving the user to think about the hydrogeological system associated with a deep landslide. The question to be answered is thus “How many aquifers can be identified ?”

First, the learning system provides the user with an initial source of information (Figure 3, top):

- the section of a synclinal structure composed of three geological units, i.e. a high permeable limestone at the bottom, an intermediate low permeable flysch and marl unit and a superficial flysch unit acting as the sliding mass.
- piezometric levels observed in five shallow-depth pits (A to E) and their interpolated watertable line.

With this initial information, the user should identify the major geological features and point out the incomplete nature of the given piezometric information. He should thus be naturally driven to ask for deeper piezometric data by interactively starting the drilling process (by clicking on the drilling machines).

Then the learning system will provide the user with a continuous evolution of water levels with depth when drilling at each point (Figure 3, bottom). Sudden artesian effects associated to the flysch unit followed by a loss of water in the unsaturated zone of the limestone aquifer can thus be clearly and dynamically demonstrated (e.g. at borehole B). Maximum drilling depth (i.e. maximum piezometric information) is fixed for each borehole by the learning system, so as to demonstrate the relevant piezometric effects.

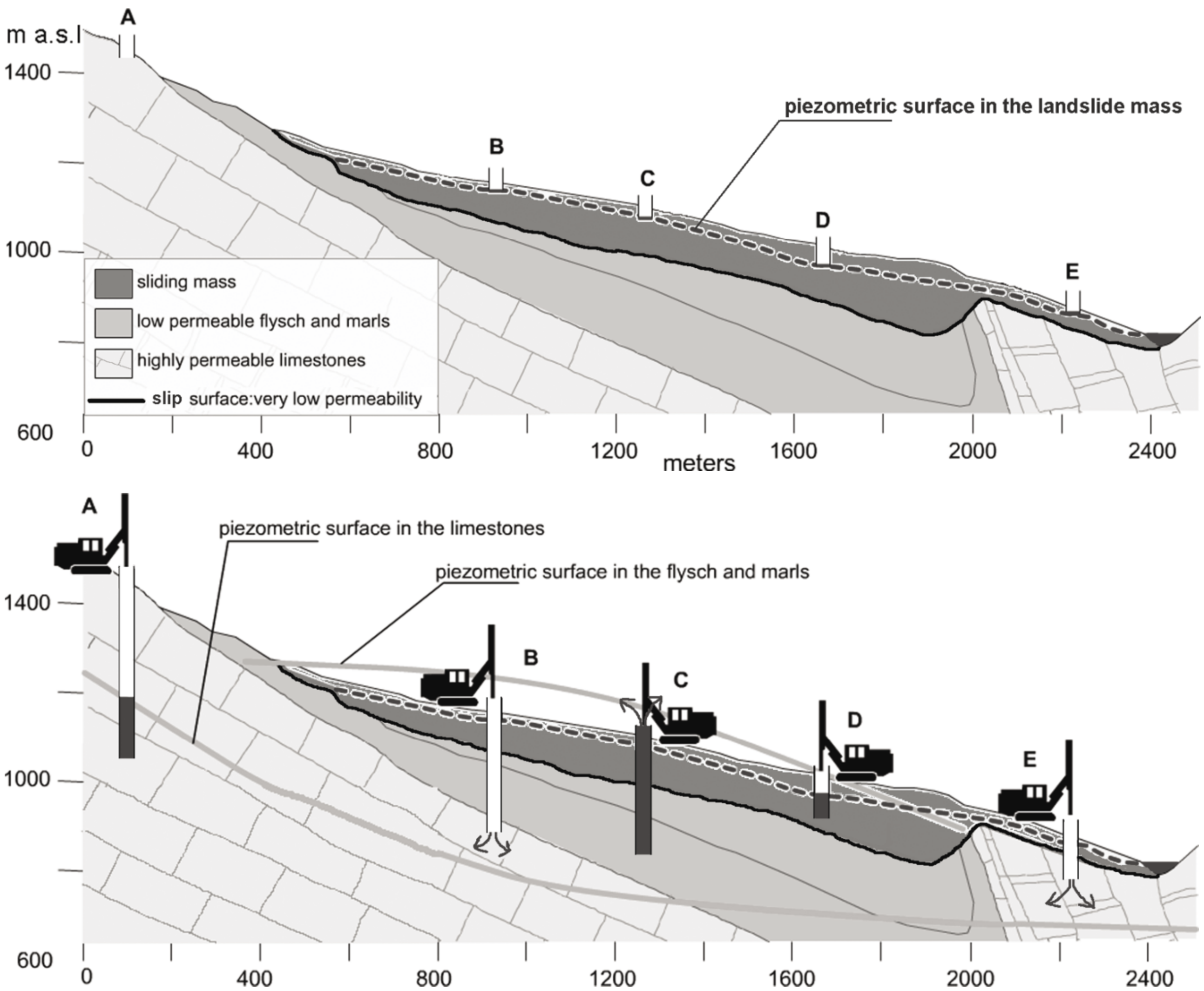

Figure 3. Snapshots of the initial (top) and final (bottom) geological and hydrogeological information provided to the user by the learning system. (Drawn from LU 3.3, hydrogeological investigation)

At this step, the user should be able to deduce a conceptual model of the groundwater flow from the overall information and to predict the piezometric behavior for each hydrogeological unit. He should consequently be able to select the number of aquifer units from the five types proposed.

Finally, the learning system will immediately validate, or invalidate, the given answer by a status (wrong/right) and by showing the piezometric lines corresponding to the two deeper geological units, as indicated in Figure 3, bottom.

At the end of this case-oriented exercise, the user should be more concerned with the determination of hydrogeological boundary conditions in the investigation of landslide and should be naturally driven to learning units devoted to the monitoring of landslides and the coupling between groundwater and landslide processes (Turner and Schuster, 1996).

In a following LU entitled process monitoring, a presentation of the different techniques available to determine the landslide movements is provided, including animations of the different sets of results as they vary with time (Dunnicliff, 1988). Figure 4 illustrates e.g. the meaning of inclinometer readings to describe the movement of a slide; as the mass shown in the right sketch progressively moves, the inclinometer pipe is bent at the level of the slip surface and the corresponding displacement curves with depth drawn from real inclinometer data appear on the graph on the left in a sequential way.

A special accent is given to the operating conditions of the monitoring devices and their reliability, so as to help the user to determine which are the most appropriate solutions in a specific context.

As for all LUs, the presentation ends up by a simple quiz in order to help the user checking its capacity to acquire the main principles developed with respect to the monitoring. For technical reasons, the self-evaluation test mainly requires yes/no answers or the selection of a given equipment for a specific situation, but it is not possible here to develop more sophisticated answers. For some case oriented units (e.g the one concerning the process investigation methods), the final self-evaluation test is replaced by short questions distributed along the LU. All questions need to be solved correctly before accessing to the next LU.

5 CONCLUSIONS AND PERSPECTIVES

This computer-aided learning tool is unique and can be seen as a precursor. Its development was facing two major challenges : (i) to propose a new multi-disciplinary approach of the natural risk management and (ii) to address the promising educational domain of e-learning.

The production of such a large interactive knowledge database implying many contributions from experts and specialists also represents a major challenge, especially as the theme of natural hazards and risks implies theoretical as well as technological and practical aspects. It often appears to the specialists of one domain that the subject is developed in an oversimplified way, but in the other domains, the non specialists will find a very interesting and comprehensive overview of the major problems and their interactions with other themes. A main advantage lies in the open and well structured access to a large amount of information that can be easily reached.

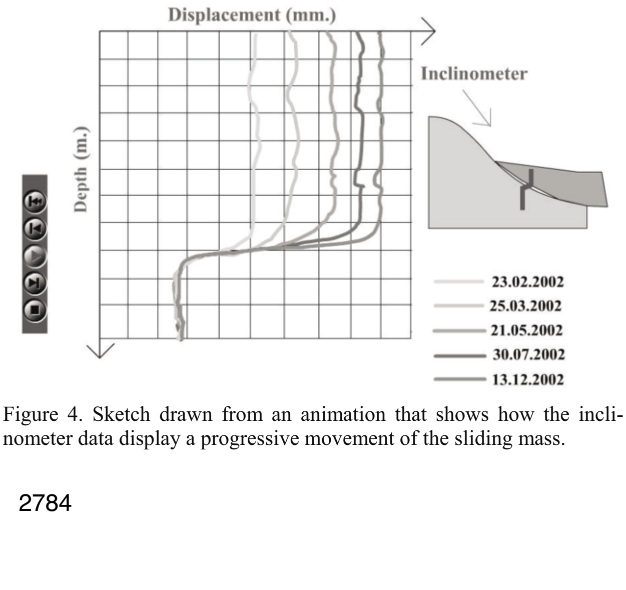

Figure 4. Sketch drawn from an animation that shows how the inclinometer data display a progressive movement of the sliding mass.

The drawbacks that can be mentioned are related to the somehow excessive use of animations that are required in this type of product, but are not always appropriate to express the complexity of the real phenomena. On the other hand, they are time consuming and do not always provide a better understanding of the process.

It is foreseen in the next stage to improve the links between the different modules and to complete some LUs based on the observations received by the users who will progressively test this e-learning tool. The representativeness of all provided data and case studies will have to be checked so as to ensure that the lessons drawn from this virtual campus on natural hazards and risks are really significant worldwide.

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Web site of SVC NAHRIS :
http://www.cenat.ch/index.php?navID=688&userhash=9979353&lID=6

Web site to see the animations shown in Fig. 3 and 4 :
http://lms.epfl.ch/