WHAT MAKES CARTOGRAPHY INTERESTING FOR MOUNTAIN RESEARCHERS?

TOWARDS AN INTEGRATED CARTOGRAPHIC MOUNTAIN INFORMATION SYSTEM (MIS)

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Abstract: *The first intention of the proposed paper is to evaluate the cartographic modelling and visualisation demands of the user community with respect to broad range of spatial, mountain-related applications. It is obvious that the different branches require specific techniques and technologies and that the printed map plays only a minor role and is replaced by distributed information systems with a multifunctional interface. Following this assessment, a basic infrastructure (adaptable toolbox) allowing the processing of such thematic data will be presented, with emphasis on the cartographic visualisation, interaction and publication. The toolbox will be demonstrated by an application developed at the Institute of Cartography of ETH Zurich. This Internet-based Metadata Information System allows access to datasets about potential multi-hazards and multi-risks in an Alpine valley in Switzerland. This development could finally lead to the establishment of integrated Mountain Information Systems (MIS).*

Note: Chapters 1,2,3,4, and 6, describing the conceptual aspects of MIS, are mainly based on an existing paper (Hurni et al, 2003) whereas the description of the HAZMET tool is an original contribution.

INTRODUCTION

The social and economic importance of mountain regions has been increasing in the last few years. A decrease in agriculture and a growing use of alpine areas as leisure parks can be observed in the service societies of Europe, North America and Japan. In Central and South-eastern Europe, the Alpine and other mountainous countries play a major role for transit traffic between Northern and Southern Europe and partly Eastern Europe. In third world countries the population pressure leads to a more intensive settlement and economic harnessing of mountain regions. Finally, the number of natural hazards with devastating consequences for man is increasing in all of these areas due to this pressure and partially due to climatic influences. Altogether, the combination of these developments will create an increased demand for economic, societal, cultural and scientific action in mountainous areas during this century.

THE ROLE OF CARTOGRAPHY IN MOUNTAIN RESEARCH

Today's demands on cartographic support in mountain themes go much farther than topographical maps. Together with the growing importance of mountain areas, the demand for adequate cartographic base data with respect to its contents, application, graphic design and the media is therefore also increasing. Especially the analysis and visualisation of a large spectrum of new themes requires new cartographic methods and approaches which go beyond classic topographic and thematic cartography. In this domain, cartographic research stands only at its beginnings. The degree of automation of major production steps can still be increased significantly. Today's Geographical Information Systems (GIS) still lack cartographically adequate and sophisticated visualisation functions. Therefore the development of specialised tools – especially for difficult visualisation tasks of mountainous terrain – is a foremost task of cartographic application developers.

CARTOGRAPHIC BASE DATA FOR MOUNTAIN RESEARCH APPLICATIONS

Currently, also due to the reasons mentioned in the first chapter, there is a demand for a new kind of topographic base-maps including novel data models as well as cartographic representation methods and media which allow flexible, standardised and user-centred access, analysis, visualisation and publishing of mountain-related themes. In today's fast living societies, the immediate and easy access to processed data and the interaction is of paramount importance. To solve the current and future problems in mountainous areas, mountain cartography and derived spatial methods will provide an important contribution.

Classic topographic maps are considered to be multipurpose maps by definition. First of all established for military purposes throughout the 19th and early 20th century, their scope of thematic applications has widened since. Nevertheless, the maps were mainly used in 2-dimensional form as paper base-maps to be combined with thematic information. The digitisation of those maps which began in the seventies and eighties of the 20th century led to a raster or vector-based, CAD-like representation of the same content or even to substantially thinned-out information (e. g. cliff areas, see *Figure 1*), using rather unsophisticated data models like object-layers or Triangulated Irregular Networks (TIN). Especially for modelling, analysis and visualisation of mountainous environments, those models are not sufficient.

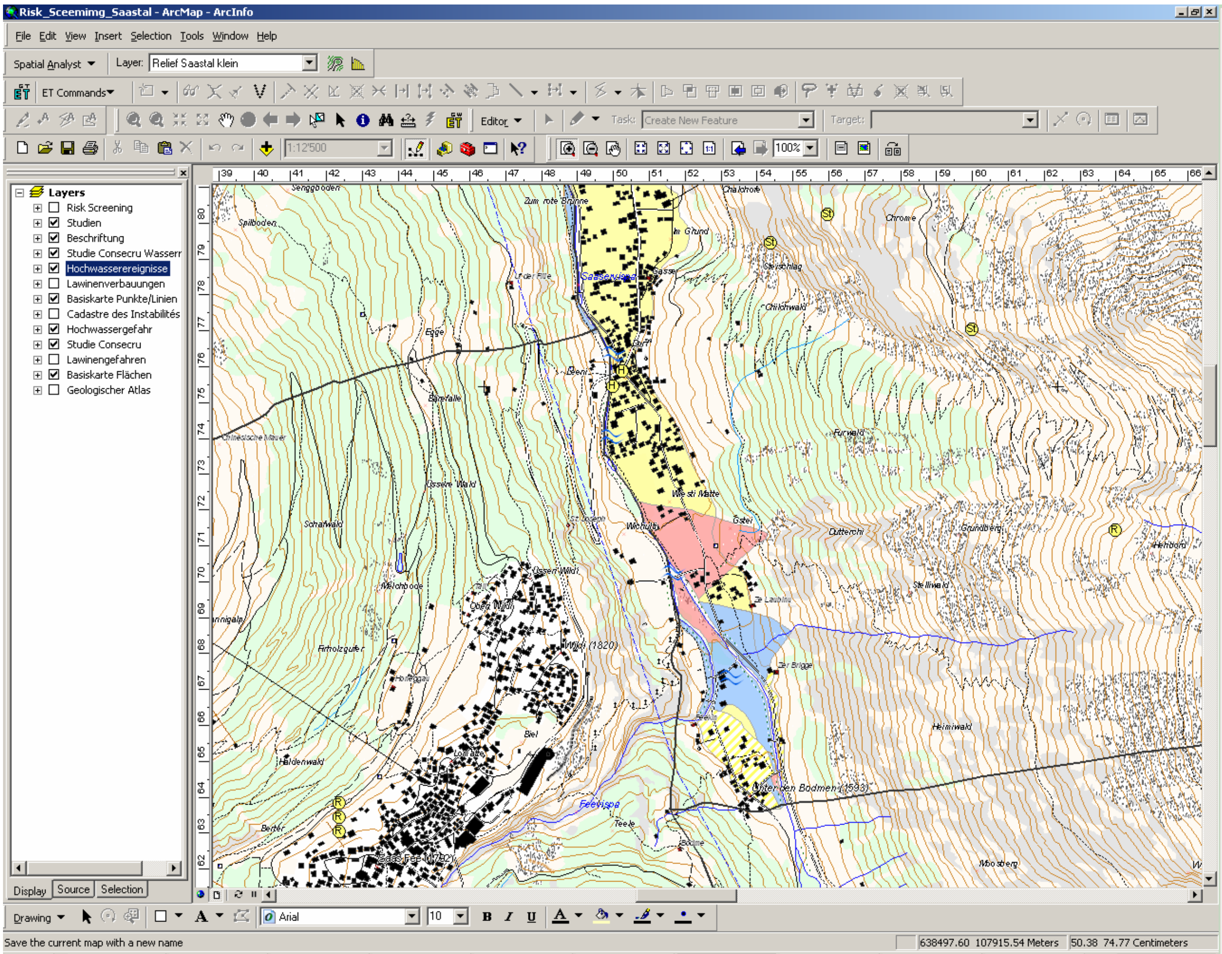

Figure 1: Map extract of the Saas Fee – Saas Grund area in Switzerland.
Vectorised National Map 1:25'000 (Product VECTOR25), © Swisstopo

Today, applications of mountain cartography are not only restricted to large mountainous areas like the Alps but one deals also with phenomena related to smaller areas, such as volcanic islands or coastal areas. Within this discipline, numerous thematic topics can be listed. The following – incomplete – list gives an impression of the large extent of cartographically treatable, mountain-related topics, features, phenomena and processes (*Table 1*).

Topics	Phenomena (structures, processes)
Topographic relief representations	Heights: Represented by contour lines, spot heights, networks, hill-shading, (cliff representation)
Extent and surface	Geology, geomorphology, glaciology, permafrost, hydrology, climate
Dynamic processes	Glacier development, avalanches, debris flows, landscape change, vegetation development, weather
Anthropogenic influences	Settlement, economic structures, (mountain agriculture, tourism), leisure use (activities, infrastructure), traffic, environmental emissions (harmful substances, noise), culture (languages, customs)

Table 1: Thematic cartographic, mountain-related applications

CARTOGRAPHY AS A VALUE-ADDING TOOL IN MOUNTAIN INFORMATION SYSTEMS

In this chapter an interactive toolbox able to carry out a broad range of cartographic functions is proposed s part of an interactive Mountain Information System (MIS). Such an overall system does not yet exist but single components have already been developed. One of them will be presented in chapter 5. *Figure 2* shows a schema representing the cartographic toolbox of such a MIS. The first step in the establishment of the toolbox would be the development of a digital multipurpose data model for topographic and thematic applications, based on a new "mountain cartography ontology". Within this ontology, basic definition of objects and their relation and interaction should be developed.

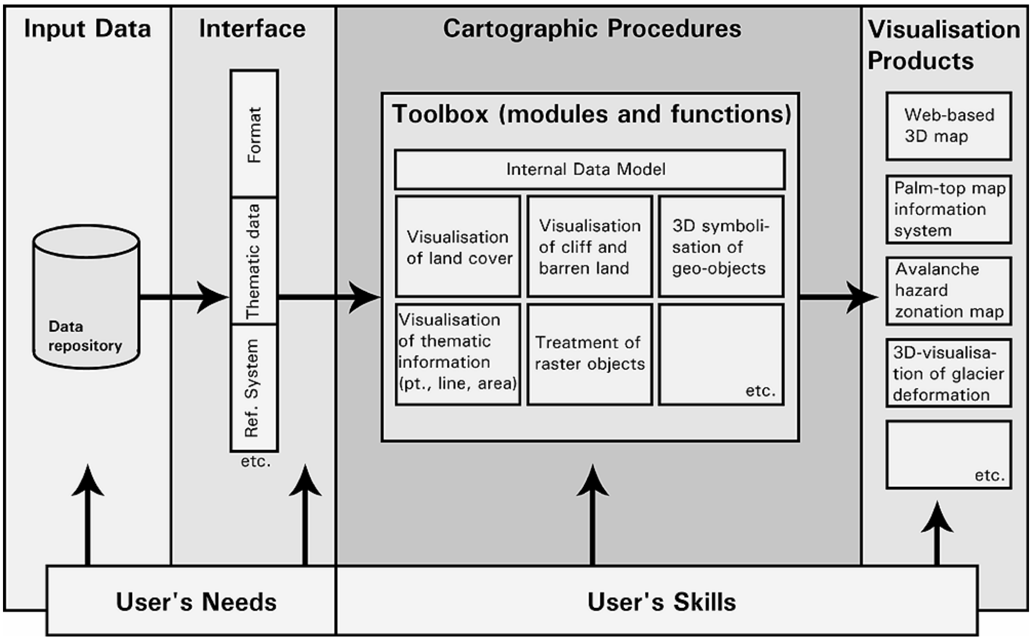

Figure 2: Cartographic toolbox within a MIS

The second step would be the development of a toolbox for cartographic mountain visualisation in 2D and 3D, based on the "mountain cartography ontology". The intention is not to propose a monolithic, closed program solution, but open, modular and distributed software components which can be accessed on the Internet and can be combined upon user's needs. Data structuring, administration and storage should take place on standard databases with added GIS functionality. It is not planned to "re-develop" a sophisticated Geographic Information

System, but rather to build on existing (open-source) modules and to concentrate on the mountain-specific needs and aspects. The following functions should be included (the words in brackets indicate the type of activity):

- Data import and export modules compatible with national and international geo-data standards (input module)
- Interface to existing geo-data standards, allowing the conversion into the multipurpose data format as well as the enrichment with additional attributive information, e.g. relations between objects, etc. (input module)
- Base maps: resolution, format, GIS compatibility (mapping)
- Combination with thematic data (overlay)
- Reference systems (transformation)
- Visualisation methods (display)
- Modelling and visualisation of mountain-specific features, representation in 2D (paper, screen) and 3D mode
- Land cover, hydrography (mapping)
- Cliffs, scree and barren land, analytical shading (cartographic visualisation)
- Thematic (abstract) information, based on thematic survey (mapping)
- Symbolised (abstract) vs. photo-realistic visualisation (display)
- Automated derivation of .classic. topographic paper maps from above data. (display)
- Definition and implementation of functionality of a possible 3-dimensional topographic map, allowing the combination with thematic and interactive analysis of thematic map layers (combined activity)
- Guidelines for map visualisation and use for the mobile user: Portability on portable, palmtop, and augmented reality displays (display)

HAZMET: A METADATA VISUAL SEARCH TOOL

The “HazNETH” Project

HazNETH (the Research Network on Natural Hazards at ETH Zurich) provides a platform for trans-disciplinary projects focusing on hazard assessment and mitigation. A declared mandate is to develop cross-boundary avenues to explore the causal relation between different processes as well as their combined effects on our natural and social environment, and to develop tools capable of handling together phenomena acting at different time and spatial scales, varying from several tens of metres (e.g. in geotechnics) to several hundred kilometres (meteorology and tectonics), and from few seconds (earthquakes) to tens of thousand of years (crustal deformation and earthquake preparation). HazNETH attempts to respond to the increasing need for advanced research and integral risk management solutions in Switzerland. (HazNETH, 2005)

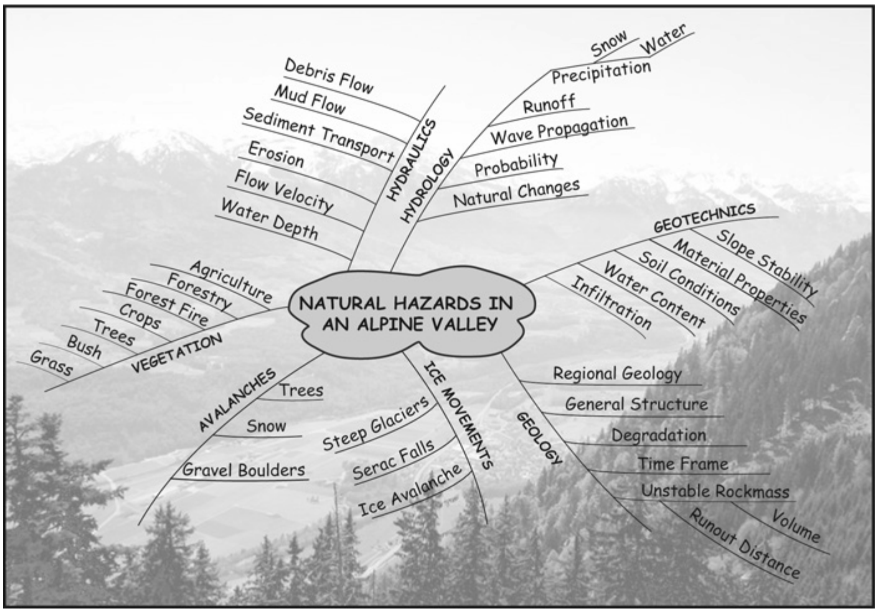

Figure 3: Different phenomena acting as natural hazards in an alpine valley

Natural hazards in an alpine valley

Natural hazards can be defined as extreme naturally occurring events which pose a potential threat to people and their welfare. The threat to humans includes injury, loss of life, disease and stress, while the threat to human's welfare can include property damage, economic loss or pollution. These extreme events occur in closed time spans of seconds or weeks and arise from the normal physical processes operating in the Earth's interior, at its surface, or within its enclosing atmosphere.

Switzerland is exposed to a wide variety of natural hazards especially happening in its alpine valleys. Recent events, which included floods, debris flows and slope instabilities, or the avalanches in February 1999 lead to substantial loss of life and damage to property, infrastructure, cultural heritage and environment. An overview of the different phenomena acting as natural hazards in an alpine valley is presented in Figure 3.

The HazNETH database concept

A structured database with accurate procedures for data search and retrieval provides the basis for developing interdisciplinary applications in the field of natural hazards (Gogu et al, 2005). The central idea is to create an accessible management system not only for the data needed in the research of natural hazards but also for the knowledge (models) and the research results (hazard, vulnerability and risk maps and studies).

The HazNETH database concept was created having in mind two major characteristics: modularity and extensibility. These characteristics work well with each other. By using a modular architecture, the database extensibility is assured. The database can be extended anytime by adding new modules without causing architectural modifications.

The HazNETH database is modular on both horizontally and vertically. Horizontally, the database is divided in three major frames: the initial/processed data frame, the hazard data frame and the hazard management frame. In a vertical section, each of these three frames possesses more modules, each module comprising a specific set of entities and relations with a specific purpose. Unifying components like catalogues and geocoding (toponymy) entities are linking the frames and modules together and create a basis for accurate and fast data search and retrieval.

The initial/processed data frame contains modules dedicated to the storage and management of the datasets required in the research of natural hazards. Fifteen data modules were identified according to the HazNETH partners as required initial data: Topography, Digital Elevation Model, Remote Imagery, Geological information, Soil, Biosphere and Environmental Data (Ground covering), Meteorology, Hydrology, Boreholes, Geophysics, Seismicity, Hazard Observation Systems, Multimedia Datasets and others.

The hazard data frame is dedicated to hazard data storage, management and retrieval according to researcher's needs. This frame contains structured hazard modules that represent the basis for application development and research. The hazard management frame contains several modules dedicated to damage prevention, control and response. This frame addresses more aspects regarding the damage management. Some of the modules in this frame like protective measures (both existent and planned) are also important for the research in the field of natural hazards. The protective measures entity describes certain attributes as their type, coordinates, geometry and construction date and they are also connected with a maintenance table that records the maintenance motives. The natural hazard events and scenarios may trigger additional projects with the purpose of building new protective measures. These projects are managed in an protective measures projects entity that besides the associated geometry also records some projects characteristics like its price, who proposed the project, who is financing the project, who is executing the projects, if it is already approved or not, etc.

The database frames are unified by catalogue and geocoding components. This approach allows a better management of the huge amount of information that the database can store and also a faster and intuitive information visualization, search and retrieval. Catalogues were created for initial data, hazard maps, hazard studies and hazard models. The catalogues provide support for queries by Name, Title, Type, Hazard and Location. Further on, between these catalogues relations were created in order to record any available correlations and correspondences between them. In this way it is possible to virtually follow the entire process of producing natural hazard studies and hazard maps starting from specific initial datasets. On the other way around, by selecting a hazard map, it can be retrieved information about the associated hazard study, the models used to compute the hazard map, and also about the initial/processed data that the authors used in order to create the final result.

Different studies and projects in the field of natural hazards may not finalize with georeferenced results or maps. In this cases we define a general X,Y pair of coordinates to georeference the study and additionally we link the study with a place name or a perimeter. The database catalogues support also integrated hazard research in which more natural hazards are considered in the same time and combined. Because every study, cadastre data or hazard map it's linked with a hazard_id, integrated hazards can be defined also as a new hazard type and thus stored in the database. In addition every hazard map has a "hazard combination" relationship that allows results from such analysis to be integrated in the database and easily retrieved and visualized when needed.

The geocoding component increases the capabilities of the catalogues by providing the translation of the (local) names into geographical coordinates. In this way, a search by location can be accomplished by providing the name of the place of interest. The catalogue and geocoding components represent the basis for developing important web services like a map service, a catalogue service and a gazetteer service. All of these services can be easily integrated in a web application dedicated to data visualization, search and retrieval.

The metadata visual search tool

Prototype description

To maximize the efficiency a step-wise implementation of the database is foreseen. In the first step, only the catalogue and geocoding components can be implemented and populated in the database. In this way the available datasets are identified and described by metadata. The metadata is then stored in the database catalogues. This approach allows the users to search, visualize and retrieve all the necessary information about the available HazNETH datasets and gives the necessary time needed for data acquisition and database population.

The populated catalogue and geocoding database entities will provide a basis for developing a metadata search and retrieval tool. The metadata search and retrieval tool could then implement different queries for all the attribute fields and combination of attributes presented the catalogue tables. For example it is possible to implement searches by Title, Source, Authors, Location and much more. This tool will take the user keywords, will search the database and finally will deliver the results to the visualization interface.

The visualization interface is a client side application that will allow the visual browsing of the metadata repository and of certain datasets. In addition to the metadata browsing, the user is able to visualize topographic data and certain natural hazard data that is already available. However the main purpose of the visualization interface is to display the query results, both in form of a list and in the map.

The SVG technology is the best option of implementing the visualization interface. SVG is an open standard for the representation of two-dimensional vector graphics, text and images. It supports scripting, enables the implementation of interactive interfaces and it can communicate with databases using web standards. A prototype of the application can be seen in Figure 4.

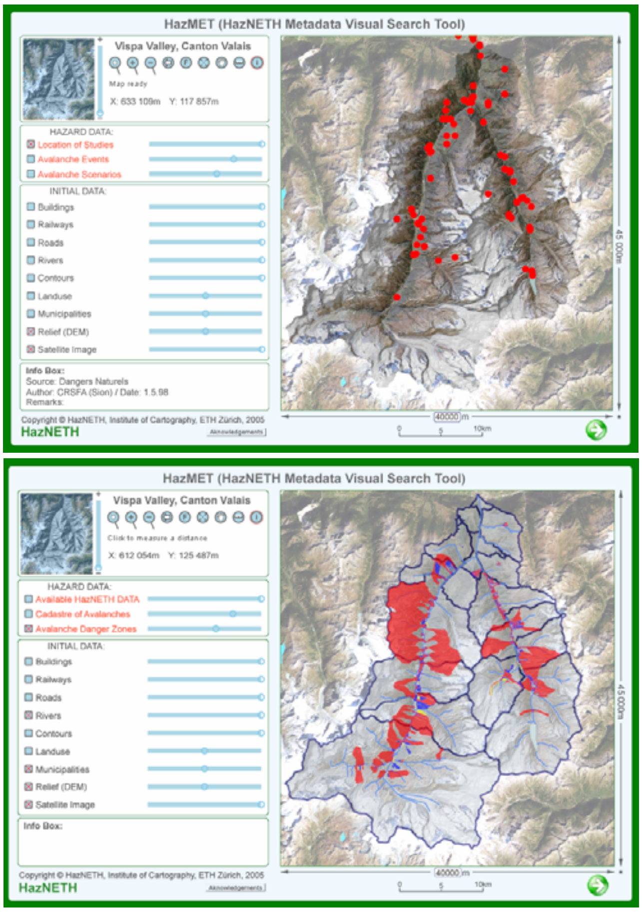

Figure 4: Prototype of the metadata visual search tool

Technology

The metadata visual search tool is developed using SVG (Scalable Vector Graphics). This technology is an XML-based W3C (World Wide Web Consortium) standard that integrates vector and raster graphics, multimedia, text, animations and scripting. The vector graphics presentation combined with dynamic content manipulation is particularly interesting for cartographic purposes and interactive web mapping. JavaScript enables the manipulation of the document content thus allowing the development of interactive applications. Elements in the SVG applications are receptive to mouse and keyboard interactions that may trigger one or more JavaScript functions.

The on-demand map generation is enabled by accessing cartographic data with different degrees of generalization from a multi-scale database. The vector data used for the analysis and for drawing the map is stored in a PostgreSQL database using the spatial extension PostGIS. As the user interacts with the learning platform, the JavaScript functions request the necessary layers from the database and then insert the new geometries in the map. On the server, PHP scripts create, execute and process SQL queries producing SVG geometry fragments. PHP, in combination with PostGIS functions, is responsible for the correct selection, symbolization and generalization of the requested cartographic data (Williams, 2005).

CONCLUSIONS

The development of geo-technologies will make further progress. Public and private geo-data sets including remote sensing data will be extended to entirely cover of small and large territories. Visualisation and data management software will be improved. The main revolution in this domain will be the shifting towards flexible, user-centred and portable information, analysis and visualisation systems. Thus, for the cartographic community, there are many challenges left – also in the field of mountain cartography. For mountain-related projects (e.g. avalanche survey, climate monitoring), it will be necessary to import data directly into analysis systems, to process the data according to the appropriate methods, to produce cartographic representations and to re-import the resulting information into the database.

REFERENCES

Gogu, Radu C.; Dietrich, Volker J.; Jenny, Bernhard; Schwandner, Florian M. and Lorenz Hurni: A geo-spatial data management system for potentially active volcanoes. Computers & Geosciences 32 (1), 29–41

HazNETH (2005): Website Network for Natural Hazards at ETH Zurich (HazNETH): www.hazneth.ethz.ch

Hurni, Lorenz; Häberling, Christian and Karel Kriz (2003): Mountain Cartography – State-of-the-art and current issues. Proceedings of the 21st Cartographic Conference, Durban, South Africa, 1333-1342 (CD-ROM)

Williams, Juliana (2005): Interactive Hiking Map of Yosemite National Park, Proceedings of the 22nd International Cartographic Conference, A Coruña (CD-ROM)

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Ionut Iosifescu-Enescu graduated in geodesy (2003) and spatial information systems (2004) at the Technical University of Civil Engineering Bucharest. During his one year research scholarship at ETH Zurich (2004-2005) he deepened his knowledge in Web Cartography and GIS. He developed SVG-based web mapping and e-learning applications as well as database models for natural hazards management. Since end 2005 he is a PhD candidate at the Institute of Cartography, ETH Zurich. The focus of his current research lies in cartographic web services, cartographic ontologies and geospatial standards.