MOUNTAIN CARTOGRAPHY: STATE-OF-THE-ART AND CURRENT ISSUES

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ABSTRACT

The main intention of the paper is to cover the evaluation of the cartographic modelling and visualisation demands of the user community with respect to broad range of spatial, mountain-related applications, and to assess new user groups and their demands. It is obvious that the different branches require specific techniques and technologies. Furthermore, the analysis and output of the results will no longer be limited to paper maps, but also to new devices like screen displays and Personal Digital Assistants (PDA) and multimedia applications such as web-maps or CD-ROM-based map applications. Following this assessment, a basic infrastructure (adaptable toolbox) allowing the processing of such thematic data will be proposed, with emphasis on the cartographic visualisation, interaction and publication. Furthermore, the paper proposes and shows existing demonstrator applications from different fields of applications proving the ease of adaptation of the above infrastructure. The paper is intended to serve as a description of the state-of-the-art of mountain cartography and as a new base for discussion of future terms of reference for the ICA Commission on Mountain Cartography.

1. WHY MOUNTAIN CARTOGRAPHY?

The social and economic importance of mountain regions has been increasing in the last few years. 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. 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 important demand for economic, societal, cultural and scientific action in mountainous areas in Europe during this century.

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 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.

2. THE ICA COMMISSION ON MOUNTAIN CARTOGRAPHY

During the 19th International Cartographic Conference in Ottawa in 1999, a new ICA Commission on Mountain Cartography was established in order to meet the new demands in this domain.

The Commission defined the following terms of reference that have been accepted by the ICA General Assembly:

- Definition of the scope of subjects of high mountain cartography
- Promotion of mountain cartography
- Providing a platform to promote the exchange of ideas and scientific collaboration between scientists in mountain cartography and related fields
- Compilation of web-based compendium
- Collection of mountain cartography specific and related links

- Collection of bibliographic references
- Status of national mountain cartography activities (federal agencies, private companies, etc.)
- Promotion of joint research projects with other organisations and ICA commissions

The commission has organised three very successful workshops so far, which showed the broadness of the thematic spectrum of mountain cartography. The papers have been published for the Silvretta 98 workshop by Kriz (1998), for the Rudolfshütte 2000 workshop by Buchroithner (2001) and for the Mt Hood 2002 workshop on the web-site [wwwICAHood, 2002]. More information about the commission and its activities can be found on the official web-site http://www.karto.ethz.ch/ica-cmc/

3. MODELLING AND VISUALISATION DEMANDS FOR CARTOGRAPHIC, MOUNTAIN-RELATED APPLICATIONS

The following, incomplete list after [wwwCIPRA] gives an impression of the thematic variety which are related to mountain environments:

- Agenda 21
- Alpine cities
- Alpine convention
- Bio-diversity
- Change of cultural landscape
- Energy
- Fauna
- Flora
- Health
- Hydrology
- Land use planning
- Landscape
- Migration
- Mountain agriculture
- Mountain forest
- Natural Hazards
- Nature protection
- NGO involvement
- Protection of species
- Regional development
- Ski resorts
- Societal and Cultural cohesion
- Soil protection
- Sustainable development
- Tourism and leisure
- Traffic
- Waste disposal

This list shows that today's demands on cartographic support in mountain themes go much farther than topographical maps. In this chapter, these demands will therefore be categorised by topographic/technological and thematic means. The chapter is based on a more detailed description which can be found in (Häberling/Hurni, 2002)

3.1 From classic to personalised topographic mountain maps

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 be 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 fig. 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.

Nevertheless, today, the following sources and ways of representations of map and map-related data are offered as standard product, e.g. by National Mapping Authorities:

- Vector data: Most mapping agencies are in the process of vectorising their topographic map data. Usually, data can be obtained in topologic GIS data format, some cartographically symbolised data sets can also be used for desktop publishing (DTP) applications.
- Raster data: Most European mapping agencies offer their National Map Series also as digital raster maps. Unfortunately, they are usually only colour-separated
- Aerial orthophotos: Since the early seventies, the use of orthophotos as base image for mountain maps is growing (Brunner, 1988). Analogous images still play an important role as basic recording method. The aerial images are then rectified differentially and represent geo-referenced orthogonal projections.
- Satellite images can also be used as ortho-rectified base images in mountain cartography. Due to their lower resolution compared to aerial orthophotos older satellite images could hardly be used for detailed representations of mountainous phenomena. However, new sensors such as IKONOS provide a resolution comparable to small scale aerial images.

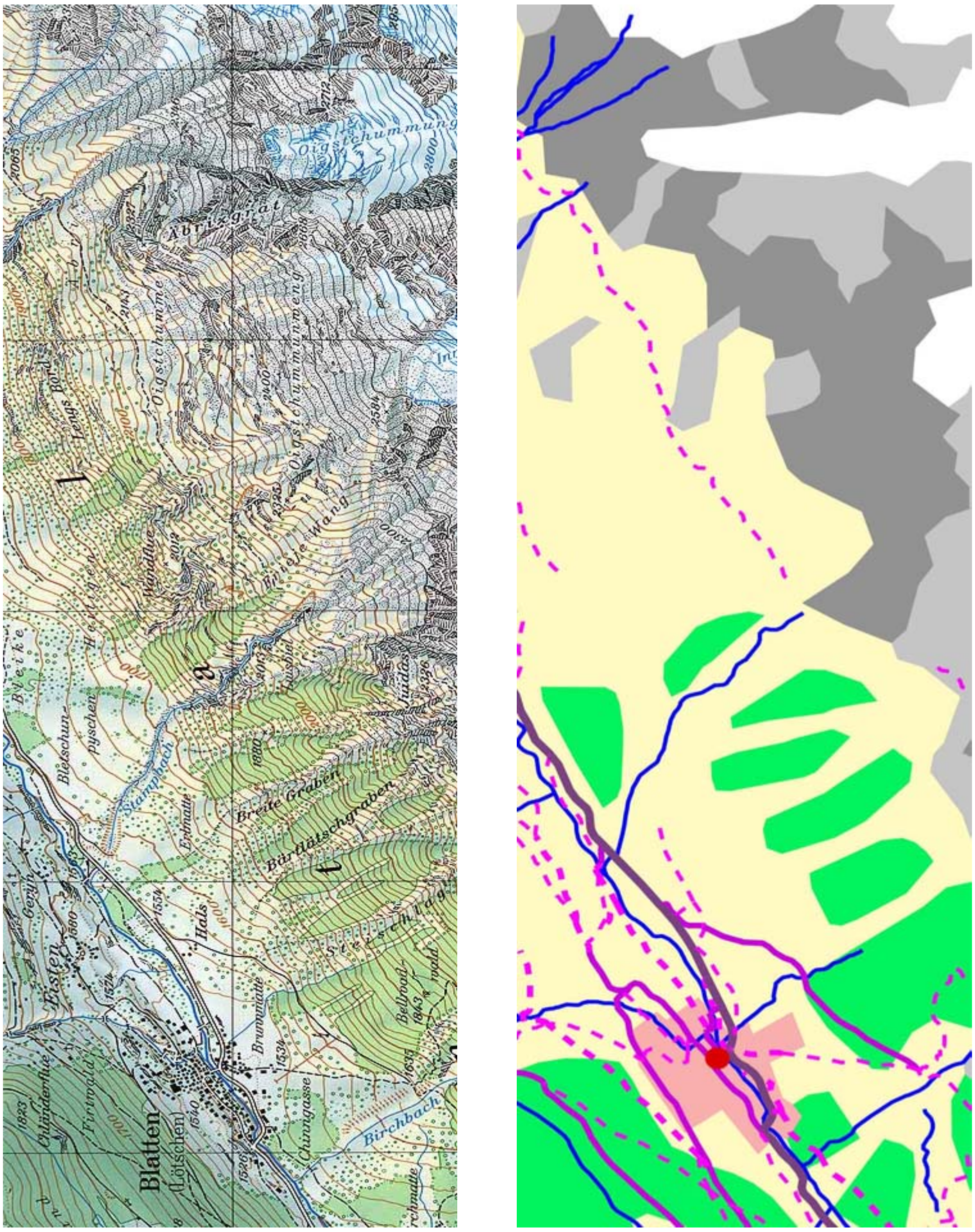


Figure 1. Map extract of Mt. Bietschhorn area in Switzerland. Classical topographic map 1:25’000 (left) and vector data set 1:25'000 (situation) and 1:200'000 (land use) provided by the Swiss Federal Office of Topography (right). The hardly accessible areas such as cliffs and scree contain significantly less information in the vector data set. © Swisstopo, Wabern, Switzerland

Other representations:

- Map-related representations (in German: ‘‘Kartenverwandte Darstellungen’’): Besides the classic orthogonally projected maps, perspective views, which allow a more natural view, are used in mountain cartography. This leads to a large variety of different types of map-related representations, such as panoramas and block diagrams.
- GIS maps (‘‘synthesis maps’’). More recent, but less spectacular applications are printed mountain maps, which are based on data resources from GIS and other databases. However, there is still considerable lack of homogenised vector base data, not only in less developed areas but even in the Alps (Fig. 1).
- Enhanced image maps: Orthophoto and satellite images data can be integrated as ‘‘base map’’ similar to digital topographic maps.
- Animations: Animated scenes in 2D mode can easily be created using temporal scientific data covering mountainous areas in combination with topographic data or image data.
- Perspective views and 3D mountain maps. DEMs enable the presentation of landscape sections as digital perspective views with the help of specialised modelling and rendering software (Häberling, 1999; Petrovic, 2001).

- Other 3D representations: Recently, new approaches using real 3D techniques have been applied in different scientific, non-commercial mountain-related projects, such as display techniques like holography or anaglyph stereoscopic images (Schenkel, 2000).
- Personalised mountain maps: In the future, a broad variety of mountain maps will be accessible by the user by means of new media technology. The user will choose the preferred data layers and will add own topographic or textual layers.

3.2 Thematic mountain cartography

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 cartographic, mountain-related applications:

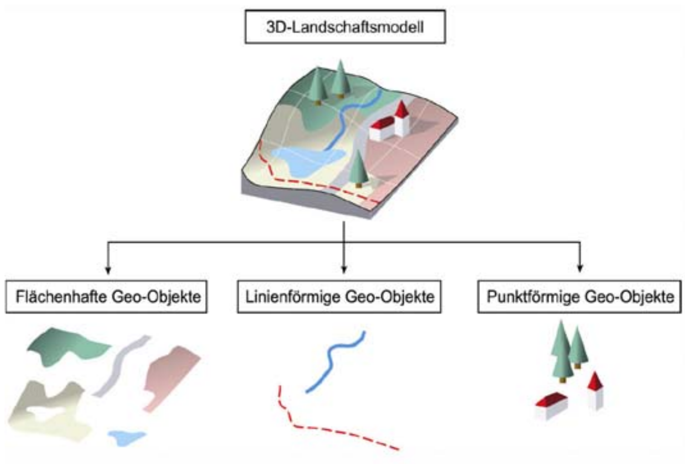
Topics	**Phenomena (structures, processes)**
Topographic relief representations	Heights: Represented by contour lines, spot heights, networks, hill-shading, (cliff representation)
Extent and surface	Geology, geomorphology, glaciology, permafrost, hydrology, climate
Dynamic processes	Glacier development,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

A selected set of examples covering a variety of thematic applications in mountain cartography using different technologies and media will be shown in chapter 5.

4. A TOOLBOX FOR PROCESSING CARTOGRAPHIC MOUNTAIN DATA

This chapter deals with the proposal for an interactive toolbox able to carry out a broad range of cartographic functions. The focus is laid on interactive mountain maps. Such an overall system does not yet exist but single components have already been developed. Some of them will be presented in chapter 5.

The first step in the establishment of the toolbox will 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 must be developed. Preliminarily and technically spoken, the implemented model might for instance be based on a modified TIN model, added by topological object-oriented components. and applied methods. Figures 2 and 3 show one possibility of such a topological model: An object-enriched TIN-structure, i.e. TIN meshes are attributed due to the thematic content of the overlying objects. If the objects are more detailed than the original TIN meshes, the structure is refined. This model is mainly suited for area objects. Such a description is primarily used for system internal purposes, i. e. to support the development of the tools and to ensure the compatibility (input/output) with existing data sources.



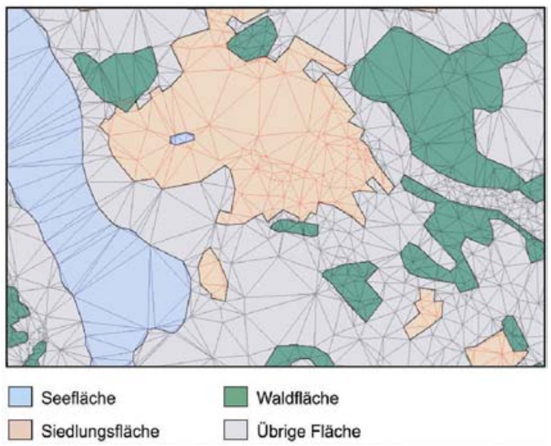


Figure 2. Object-oriented data model (left), object-enriched TIN-model (right). After Terribilini (2001).

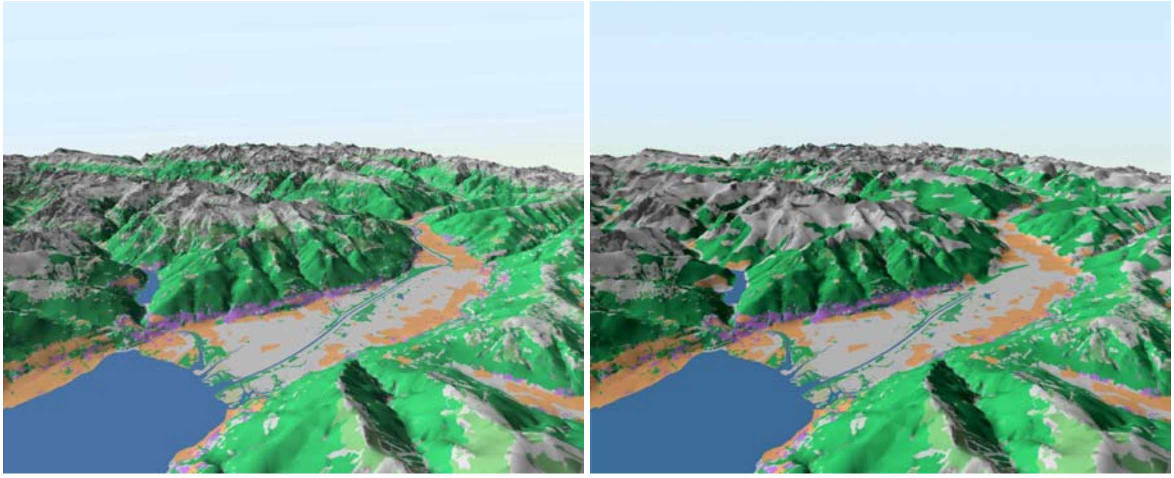


Figure 3. Symbolised (abstracted) visualisation of mountainous area in Southern Switzerland without (top) and with (bottom) level-of-detail techniques: Degree of details is higher in foreground than in background. The rendering is based on the object-enriched TIN-models shown in Fig. 2. After Terribilini (2001). DEM and area data © Swisstopo, Wabern, Switzerland

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 word in brackets indicate the type of activity):

- Data import and export modules compatible with national and international geo-data standards:
- 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 (Fig. 4) (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 (Fig. 5). (display)

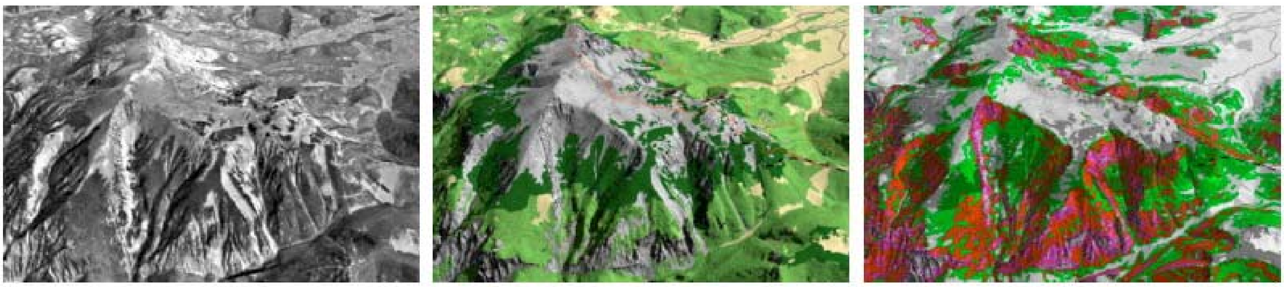


Figure 4. Visualisation of Mt. Schneeberg near Vienna, Austria: Photorealistic visualisation using orthophoto draped over landscape (top). Symbolised visualisation of land cover and touristic infrastructure (centre). Overlay with slope and aspect information (bottom). Source: Karel Kriz, University of Vienna

The following graphics shows the major components of such an integrated mountain visualisation system. The core functions are concentrated in the toolbox which is based on the internal data model and allows to process suitable input data (Fig. 5).

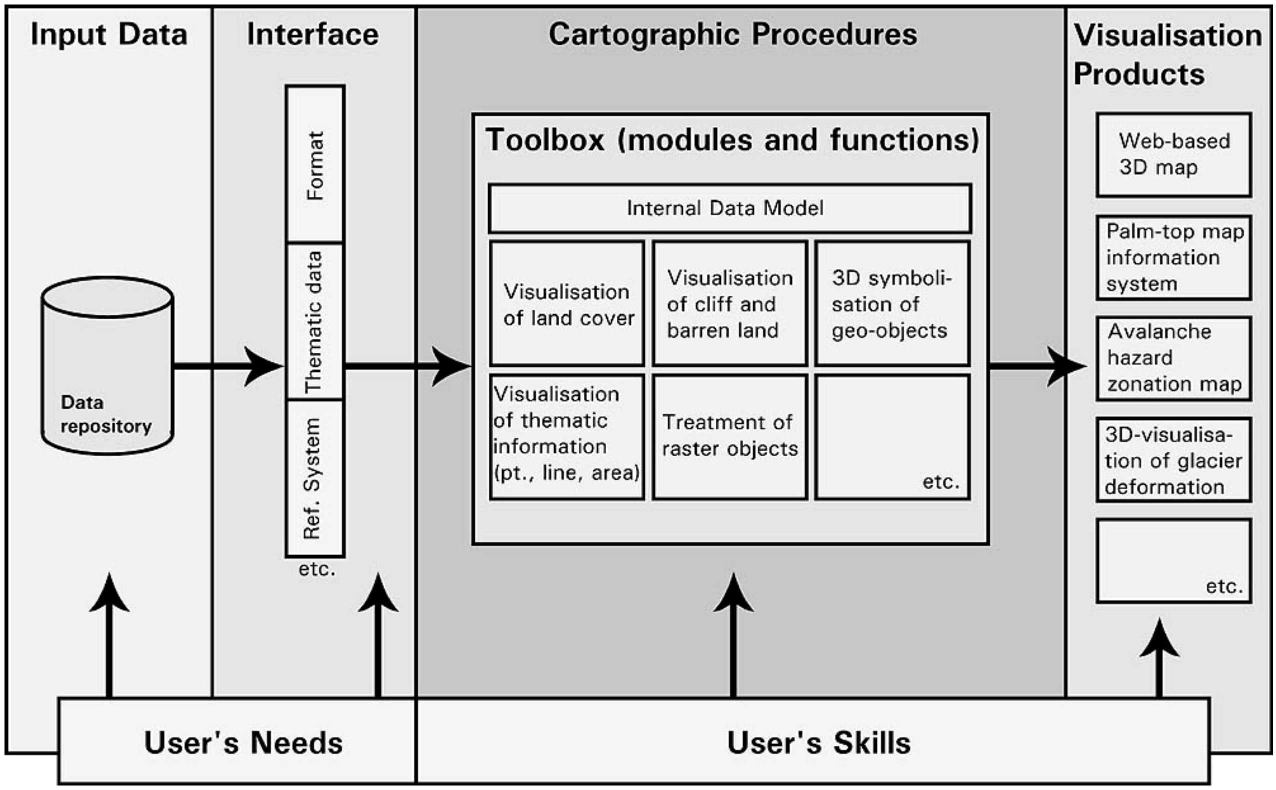


Figure 5. Components of a Cartographic Mountain Information and Visualisation System

5. TWO SELECTED EXAMPLES

5.1 Internet presentation of the Mount Hood area (Oregon/USA)

In the framework of a diploma thesis at the Institute of Cartography of ETH Zurich, an Internet presentation covering the Mount Hood area (Oregon/USA) shows current possibilities of integrating terrain, remote sensing, vector and other digital map data (Dobler, 2002). An orthophoto (USGS 7.5-min Digital Orthophoto Quads DOQ 1:24 000) and several thematic raster data layers (precipitation, geology from USGS geo-spatial data sets 1:500 000) were combined. Additionally, extracts of digital raster maps from different publishing houses with scales ranging from 1:24000 to 1:100 000 were integrated to enable an easier orientation. Then, all the raster data files were individually draped over a section of the USGS 7.5-min DEM (10-m ground resolution), using the 3D visualisation software World Construction Set 4. In the same way, additional vector data covering infrastructure and land-use were added to the textured topographic model (vector data: USGS 15-min Digital Line Graphs DLG 1:100 000). The vector elements were symbolised and labelled directly in the three-dimensional cartographic model using the same software. Within this model, images were rendered to create perspective views, panoramas and frame-by-frame flythrough-movies. All cartographic representations created in this framework are shown on a special web-site. Visitors of this portal can get a virtual overview of this attractive touristic mountain area (Fig. 6). The base data sets used in this project differed considerably regarding data type, digital format and thematic content. Nevertheless, the work showed that even an innovative and integrative cartographic visualisation system can be based on low cost technology. [wwwHood]

5.2 Touristic 3D-information system

Between 1991 and 1995, a large mapping project was carried out at the Institute of Cartography of ETH Zurich in close collaboration with the Institute of Mineralogy and Petrography. The topography and the geological features of Methana, a volcanic peninsula in Greece which covers an area of 55 km^2, were entirely surveyed and mapped at the scale of 1:25’000. In a dissertation (Hurni, 1995) based on this work, the techniques and requirements for the digital production of these map types were systematically examined and exemplary workflows were presented. The aim at that time was to produce an analogous paper my by entirely digital means which has the same geometric and graphical quality as conventionally produced maps. This goal was met and the related technologies are today broadly used in digital map production.

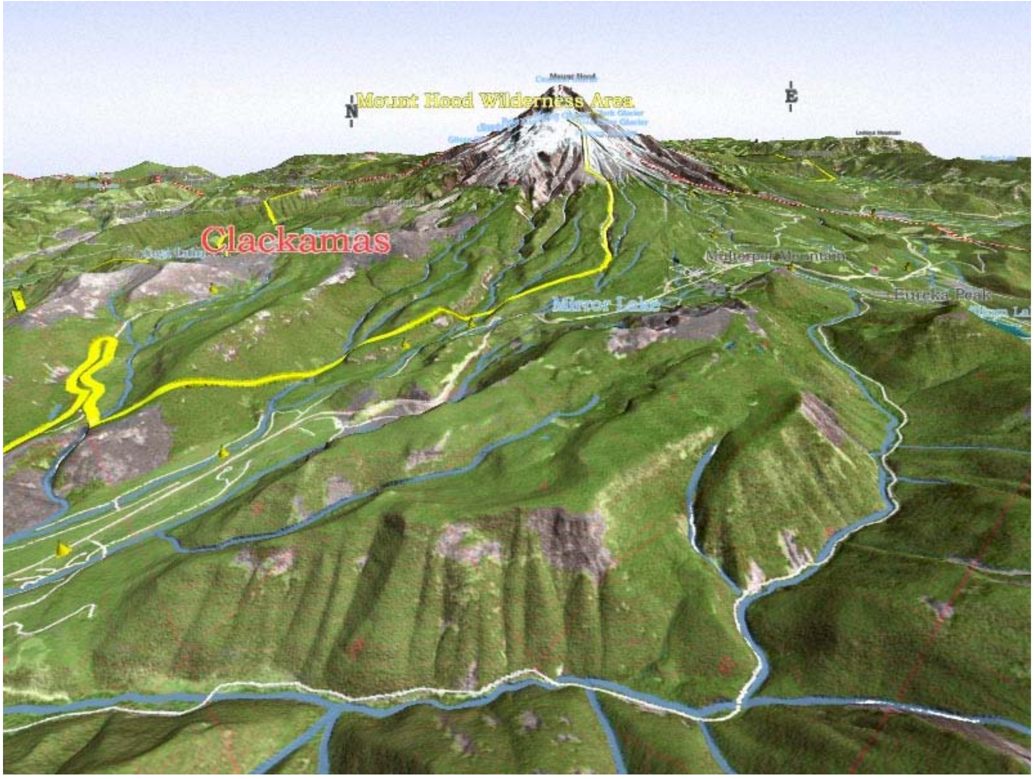


Figure 6. 3D-visualisation of Mt. Hood/Oregon/USA: DEM overlayed with topographic map elements, orthophoto, vector linework and labels. See [wwwHood].

The same vector-based map data set was later used for further projects: First of all, the data has been converted into a three-dimensional model using VRML technology. The data however has to be thinned out due to performance limitations. Land-use polygons have been draped over the terrain, as well as line elements. Point objects (mainly touristic sites like churches and hotels) were converted into three-dimensional pictorial objects and were placed on the terrain. The data set now allows a virtual flythrough of the Methana area and a direct query of the clickable objects. (Mundle, 1999, Fig. 7).

Figure 7. Web-based 3D map for a tourist information system of Methana Peninsula, Greece. ETH Zurich.

A further project of the University of Vienna used the Methana map data in raster form. After geo-referencing and transformation into the WGS system, the data was imported into the PDA-software OZI Explorer [wwwOZI]. In combination with a GPS card, the system allows exact positioning and display on a virtual map (Fig. 8). In the future, a combination of such 2D, 3D and location based services will be a major challenge.

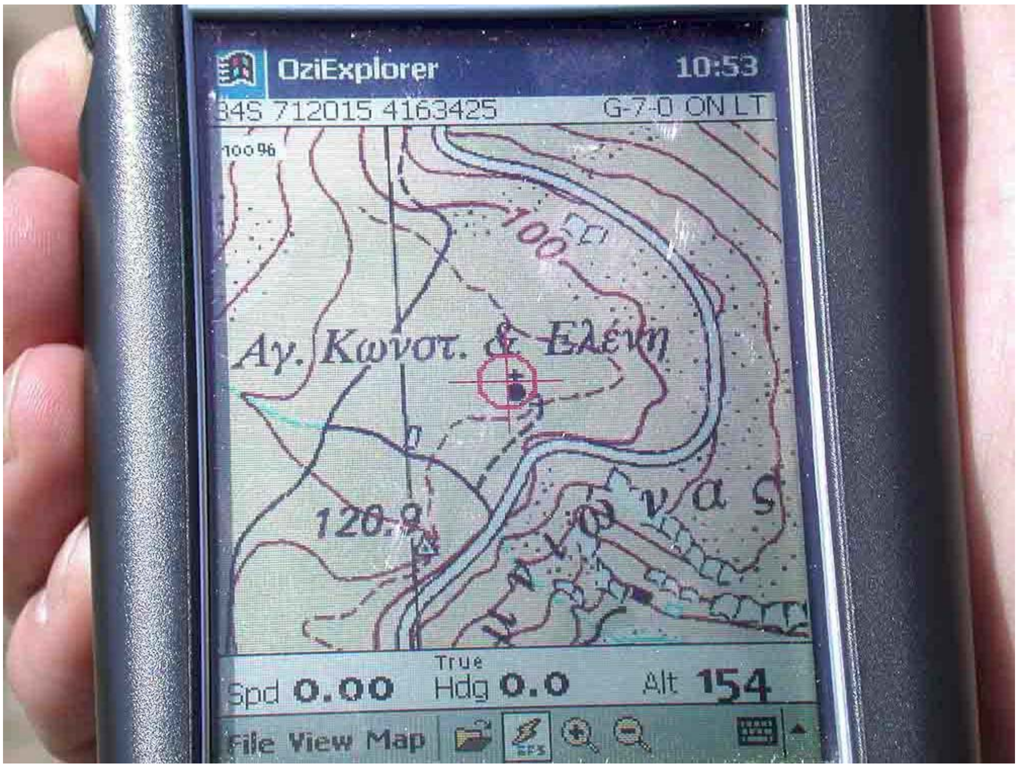


Figure 8. PDA map display with map extract of Methana Peninsula, Greece. ETH Zurich.

6. OUTLOOK

In the next few years, 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 are permanently being improved. The main revolution in this domain will be the shifting towards improved, 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 individual localisation purposes with new portable devices, the supply and distribution of object-oriented, symbolised and easy-to-use geo-data and maps will take a decisive role. For enhanced interactivity, new modelling standards and graphic principles have to be derived and formulated. For other mountain-related science projects (e.g. avalanche survey, climate monitoring), it will be necessary to import their 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. Finally, the challenge to develop algorithms for automatic symbolisation and display of mountainous features (cliffs, debris) and dynamic spatio-temporal processes (glacier movement, timberline shifting) is continuing.

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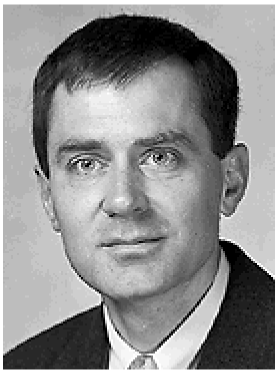
Biography



Lorenz Hurni has been Associate Professor of Cartography and director of the Institute of Cartography at the ETH Zurich since November 1, 1996. He is managing editor-in-chief of the "Atlas of Switzerland", the Swiss National Atlas.

Born in 1963. From 1983-1988 he studied geodesy at ETHZ. As assistant at the Institute of Cartography, he implemented a digital cartographic information system for teaching and research purposes. In connection with his doctoral thesis, he developed the first program for automatic generation of cartographic cliff drawing. In 1994 he took up a position at the Federal Office of Topography in Wabern. As project leader for computer-assisted cartography, he worked mainly on the implementation of an interactive graphic system for the digital processing of national maps.

The emphasis of Hurni's research lies in cartographic data models and tools for the production of printed and multimedia maps. Currently he is directing a project which will lead to a multimedia version of the "Atlas of Switzerland". He is chairman of the "Working Group on High Mountain Cartography" of the German Society of Cartography (DGfK) and chairman of the "Commission on on Mountain Cartography" as well as member of the "Commission Map Production", both of the International Cartographic Association (ICA).