THREE-DIMENSIONAL MOUNTAIN MAP

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ABSTRACT

Development of computer technology has brought many advantages in cartography. On one hand it gives possibilities of producing traditional paper two-dimensional (2D) maps, panoramic views and other types of maps faster and more accurate. On the other hand technology development offers the production of new landscape presentations which can supplement and partly substitute traditional maps. Interactive and multimedia dynamic three-dimensional (3D) cartographic models enable the users to select the view and the sort of information they want to see. Applicability of 3D maps depends on the cartographers' ability to present all relevant data as user friendly, easily understood and complete as possible.

In my article basic principles which should be considered in designing of interactive multimedia 3D mountain maps are described.

Key words: mountain maps, three-dimensional cartographic models, map design

INTRODUCTION

In the last years mountain cartography has become one of the most attractive fields of cartography. Living standard has been increasing, people are oriented to a more healthy way of life with closer connection to the nature and all these facts have caused that more and more people spend their time in mountain regions, walking paths and climbing peaks. This phenomenon is especially significant for the Alpine region. A lot of people go to the mountains on their own, they also use the paths which were years ago accessible exclusively in the company of skilled mountain guides. The season of mountain visiting has been extended from a few summer months over the whole year, whenever weather and snow condition are suitable.

A lot of people are encouraged to visit an unknown city without a city map or plan, it is also possible to drive and follow roads without using a road map. But, we can hardly imagine a mountaineer who is visiting an unknown mountain area without using a mountain map. This is the reason that more and more mountain maps and the other types of mountain area presentations have been requested on the market. Cartographers have answered such users' wishes by an increased mountain map production. Typical

mountain maps are quite detailed large or medium scale topographic maps with accented mountain information, such as mountain tracks, mountain huts or ski-mountaineering routes (Figure 1). Usually additional information as texts or pictures is added at the back side of the map or in a separate brochure.

Figure 1: Insert from the mountain map

This is a very efficient way to satisfy different users' profiles. Skilled mountaineers, who are familiar with reading maps have a possibility to read detailed topographic information. This is very important in bad weather conditions or in moving outside marked routes. On the other hand mountain data on mountain maps are usually very accented. So less skilled users have no problems in using only presentation of mountain tracks for basic horizontal orientation in track network, while they can neglect other topographic content. On mountain maps relief is usually presented by a combination of contours, spot heights and hills-shading. However, a lot of people are unable to read heights and so they can't get the information of the vertical character of a selected route. For them, additional mountain presentations, like ridge maps, panoramic views or profiles are available (Figure 2).
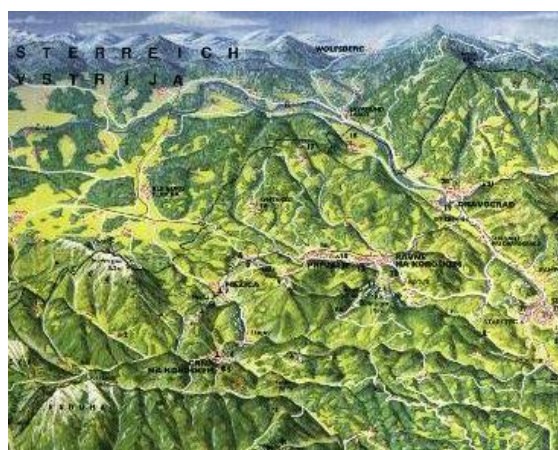

Figure 2: Insert from a panoramic view of a mountain area

THREE-DIMENSIONAL CARTOGRAPHIC MODEL

Computer technology offers a possibility of producing a three-dimensional cartographic model, also called a 3D map as a new approach in landscape presentation. There are many definitions of the 3D map and 3D models. One of them (Bandrova, 1998) says, that a 3D map is a computer made, mathematically constructed high realistic presentation of a landscape together with the natural and artificial objects and phenomena. In analogous cartographic technology there were no differences between the cartographic model and the map itself. The cartographic model offers users direct recognition of contents and it presents a direct communication medium between the cartographer and the user. The cartographic model is fixed (static) and the user can perform only some limited changes in it. In computer technology the cartographic model is a digitally written record of spatial data and it is not possible to use it directly either for recognition or for communication purposes. But, the user can influence the model by changing its properties and make it applicable in the following ways: visualisation with various symbol sets, selection of elements and objects which will be visualised, spatial transformations, scale generalization, reambulation and adding new data, including new users oriented functions, format changing and more. Besides, these computer made cartographic models offer many new additional possibilities of use: simulations of moving in real time, simulations of placing new objects on landscape, dynamic phenomena analyses, etc. Digital cartographic models can contain many more data than the analogous ones. Additional data as specification tables, attributes, topological relations, pictures, movies and sound can be added to individual objects and elements. Data can be more heterogeneous, all the data needn't have the same accuracy, complexity, detainees or depth. There is no theoretical limitation of the size of the area presented in model, but there are some practical limitations such as amount of digital data.

A cartographic model generally has no scale, all contents are stored in real units, e.g. kilometres. Each object is defined in real space with horizontal and vertical coordinates. But we consider the scale in digital models in the meaning of geometric accuracy, complexity, detailness and level of generalization. Regarding this we have to define the scale range in which model can be visualised and presented.

There are many possibilities of use of the 3D cartographic model:
- visualisation as a static or dynamic presentation by user's demand,
- spatial analyses,
- connection to different spatial datasets and
- map measurement tasks, calculated from original data without using special equipment or methods that brings mistakes and inaccuracy.

Of course, we can also find some weaknesses of 3D models:
- we need proper computer and SW,
- we are faced with HW limitations (disk space, communication speed in web applications),
- both the cartographer and the users have to be familiar with computers and
- format transformation often leads to the data loss.

3D cartographic model can be represented as a real 3D, pseudo 3D or 2D presentation (Schenkel, 2000). Real 3D and pseudo 3D visualisation technologies base mostly on human's physiological cues of 3D determination, while 2D technologies use people's psychological cues. Real 3D and pseudo 3D presentation technologies have limitations: they can be used only under special conditions or they require additional equipment. For mountaineering they can be used for basic preparation and planning, while they are not usable in the terrain conditions. Users would need paper version of 3D model presentation. They can make it by printing on printer and such presentation have to be designed similar to traditional perspective or ordinary 2D map.

DESIGNING OF MODEL

Designing of a digital cartographic model depends on the expected use and users' needs. This is even more important for mountain map then for the other types of maps. Model contents can be divided into three groups: main content, secondary content and additional content.

Main content consists of objects and phenomena that have the essential importance for the users. The first of all there is relief presentation, which is the fundamental part of every 3D model. Relief is determined as a space surface, defined as a triangular mesh (TIN) or rectangular mesh (GRID). On mountain maps relief is very important. The model should be dense and detailed enough because users can be interested in each single detail which can influence the passage. All peaks must have exact heights, so they have to be included into terrain model. The nature of terrain and possibility of different complex make TIN model more suitable as GRID. A problem in terrain presentation is area limitation. In conditions of good visibility in mountain areas users can often look much longer over the limits of our model. In visualization end of model shouldn't be presented as a sharp edge. The most efficient solution is animation of atmosphere fog which limits distance of clear picture.

In the group of main content we have to include all the objects which are important to users. On mountain maps these should be as follows:
- mountain paths and tracks network,
- peaks and saddles, that have significant importance to mountaineers,
- refuges, mountain huts and other objects, where it is possible to eat, find logging or to supply,
- cable and rack railways,
- objects and phenomena of special interests as a nature or cultural–historical points of interest,
- observation towers and other sightseeing points,
- ski courses and background skiing tracks,
- roads, tracks and railways, which serve as an access to starting points and also
- important public objects, like health centres, the police.

Objects of main content should be presented accented, clearly visible and distinctive. A lot of authors suggest, that they should appear as similar to the real ones. But here we

can come into conflict. If we want that 3D model presentation retains communication function of 2D maps we have to include symbolization system. Some objects are too similar in reality and they do not "jump" from the surroundings as they should according to their importance to the users. The other reason is the need of using different levels of detail in different observation distance in perspective view. There are also technical reasons: a symbol needs less memory space than a real 3D object, dynamic presentations can be faster and visibility of a symbol in limited resolution (screen or paper print from printer) is better. Users are familiar with contemporary 2D maps and symbols on 3D maps should follow those on 2D maps. They shouldn't be too geometric because such signs don't attract users' attention (Rojc, 1986).

On principle we should decide for a combined solution, where an object in high level of detail is presented as a model of reality, while in lower levels of detail we use symbols, designed as similar to 2D map symbols as possible. But we will soon come into conflict with objects, where 2D map symbols are distinctively different from real objects. A typical feature is a building, presented as a black rectangle or some other black symbol on 2D maps, while in reality and also in panoramic views it is presented as a white box with a red roof (Figure 3).

Figure 3: Difference between building presentations on 2D map and in panoramic view

The same problem is roads. In reality they are grey and usually not very distinctive from surroundings, while on 2D maps they are very distinctive and often filled with clearly seen attractive colour.

Users are often interested in additional information on the above listed objects of main content. They should be accessible by choosing (click) the concrete object and stored in the model as the additional content.

In the group of **secondary content** we can find objects and phenomena which give the complete impression of landscape, but they don't have any significant importance for users. Land cover, hydrology, less important buildings and other structures, administrative boundaries could be recognised as secondary content. They should be presented by quite simplified and unaccented symbols which lead to less complex and faster vizualization. Reality can be very effectively replaced by fractals, e.g. as the presentation of forest or rock area. With increased observation distance presentation of secondary content can be efficiently presented as a colour surface covering DTM.

The last group, called **additional content** consists of data which are not regular part of presentations. Additional content is presented exclusively on users demand. In fact it is

an addition explanation or illustration of particular objects of main content. It can be just a record of horizontal and vertical position of an object or a complete and huge detailed description of it. Several types are possible: written text, speaking, or even both which leads a much more efficient memorizing process; hyperlink, picture, movie, specific voice. The advantage of content organized this way is that even a very huge amount of additional content data have no influence on vizualization speed.

USERS' POINT OF VIEW
The main possibility which 3D mountain map should serve to users is presentation by users selection of viewpoint and a viewing direction. Probably, a mountaineer as a typical 3D mountain maps user should prepare appropriate view on the screen, print it on paper using printer and then take this paper with him to the terrain. That means, all relevant and important information, including additional content data have to be printed on paper. Such requirement doesn't meet basic principles in 3D maps use and presentations and we have to adapt it for the specific mountaineers' use. Several special requirements can be expected:

a) Map measurements
Map measurement methods, which serve to define coordinates, height, distance, slope, direction, bearing or visibility on 2D maps are not acceptable in the perspective views. Scale is not constant and some data are hidden. Distance measurement is possible only if distance is perpendicular to view direction, but in general measurements are impossible. When we use 3D map in a computer this isn't a problem, because computer algorithms can calculate the requested data. A possible solution can be the presentation of grids (coordinate lines) for easier horizontal position determination and the presentation of contours for height determination. These options should be available on demand.

b) Special views
While talking about 3D map visualization we usually have perspective views in our minds. But, since users are mostly familiar with ground plan maps (vertical views), it can be expected, that users would prefer vertical view from 3D model. This view should be as similar to the contemporary 2D maps as possible. One solution is using of raster image of "old" 2D map, draped over the DTM, which would be usable also for views, near to vertical. The other possibility is a special symbol set for vertical and almost vertical views.

c) Presentation, depending on time
In mountain area weather conditions, especially snow is very important in landscape forming. A Several-metres-high blanket of snow changes character and forms of landscape. Moving possibility, visibility and also usage of objects (e.g. closed mountain huts) is completely different in different seasons. We can recognize tree typical periods. The first period is late autumn and winter. Snow covers the landscape from low areas and rises evenly to higher regions. Vegetation is poor, temperatures are low, the sun is

low and shadows are long. The second typical period is spring and early summer with a high blanket of snow in high mountain areas, while in valleys we are faced to vegetation growth and high rivers with speed stream. The third typical period is late summer and early autumn, with snow only on glaciers and permanent snowfields. This is the situation, regularly presented on each contemporary 2D maps, but in reality valid for at most 2 months a year. That's why 3D mountain maps should offer at least three different presentations according to the season. An additional option is a full 4D model, where visualization would consider natural and artificial changes over the last years or illumination of landscape according to hour and date. I doubt that this enormous work could be economically acceptable.

d) Limited resolution
We have to consider technical limitation of resolution which printer can supply while printing on paper. Limitations are minimal sizes of text, number of colours, thickness of lines. It is almost clear that every additional data have to be printed separately from the main view.

FUTURE WORK
The above described principles have to be tested on a prototype model. We decided to make a 3D mountain map of Kamnisko-Savinjske Alps, a small mountain ridge in the north part of Slovenia, with heights up to 2500 metres. Besides high mountains this region area covers also foothills and a plain with towns which are most common start points for mountaineers. Figure 4 presents the area of prototype model.

Figure 4: Area, chosen for the prototype 3D mountain map

The basis for our prototype 3D mountain map is topographic data in digital form. The surface was generated from vectorised contours with equidistance of 10 metres and characteristic height points (peaks, saddles, depressions). All other objects are in vector form, placed on the surface as areas or 3D objects. A detailed description of objects is organised as additional content. The map model is still in development and results will be presented at the author's internet home page. We would like to include as many principles described in this article as possible. The aim of the described prototype 3D map is to find out the principles of the 3D mountain maps design. Good 3D map has to satisfy main theoretical requirements for cartographic presentation and also gives advantages to map readers corresponding to traditional 2D maps. Besides the user's point of view we are also trying to predict economical reasonableness of 3D mountain maps.

CONCLUSION

Mountain maps in traditional paper form are very usable and will still be used for several years in the future. But, technology development like multimedia and interactivity give a chance to find new cartographic representation of mountain regions which would become a very usable products in the future. Designing of prototype models and analyses of users opinions on such models will help to design widely used and economically successful 3D mountain maps.

References

1. Haeberling, C., 1999. Symbolization in topographic 3D-maps: conceptual aspects for user oriented design. Proceedings of the 19th ICA International Cartographic Conference, Ottawa.
2. Bandrova, T., 1998. Cartographic Modelling of the Real World. Proceedings of E-mail Seminar of Cartography, Volume 1, University of Architecture, Civil Engineering and Geodesy, Sofija.
3. Buziek, G., 1999. Dynamic Elements in Cartography. In book Cartwright et al. (ed.), Multimedia Cartography, Springer, Berlin.
4. Ormeling, F., 2000. Paradigm Change in Cartography and its Effects. Proceedings of E-mail Seminar of Cartography 1999-2000, Volume 2, University of Architecture, Civil Engineering and Geodesy, Sofija.
5. Petrovič, D., 2000. How to present mountain tracks? Proceedings of the International ICA Workshop on High Mountain Cartography 2000, Rudolfshuette, Austria.
6. Rojc, B., 1986. Contribution to investigation on map content perception (in Slovene). Dissertation, Faculty of architecture, civil engineering and geodesy, University of Ljubljana.
7. Schenkel, R., 2000. A Cartographic Systematisation of 3D Display Technologies. Proceedings of the International ICA Workshop on High Mountain Cartography 2000, Rudolfshuette, Austria.
8. Terribilini, A., 1999. Maps in transition: development of interactive vector-based topographic 3D-maps. Proceedings of the 19th ICA International Cartographic Conference, Ottawa.