Designing Interactive Environment for Examination of 3D Maps for a Mountain Map Study

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Abstract. The article describes the study that was undertaken with the belief that abstract visualization of mountain 3D map would be more effective for the majority of map uses. On the other hand, photo-realism seems to be more attractive. The article summarizes the basic principles of both photo-realistic and abstract 3D representations, completed with simple draped maps. To support the study mountain 3D maps and geovisualizations of Pohorje highlands above Maribor, Slovenia were created. They were incorporated into the interactive environment that will be used for the research on the influence of levels of abstraction on cartographic communication in 3D maps amongst different map users. The interactive questionnaire to support the research as prepared, too and is briefly presented in the article.

Keywords: 3D geovisualization, 3D mountain map, photo-realistic presentation, cartographic abstraction, user questionnaire

1. Introduction

The trend of today's 3D geovisualizations is to employ the latest computer technology to create very realistic representations of the real world. Such representations are no longer applicable only for specialists, since in the last few years realistic representations of the world around us have been widely used by the general public (Petrovič 2007) - Google Earth, Bing Maps Bird's-eye views, Apple 3D Maps. The number of such tools is increasing, since the modern remote sensing technology (satellite imagery, laser scanning, stereo photography) enables quick and easy creation of realistic mapping applications. These visualization tools provide natural looking representations that are easy to understand also for non-experienced users, therefore they are very suitable for various purposes such as landscape planning, archaeological reconstruction and architectural construction, but also for general 'discovering' of the Earth's surface.

However, it is argued by cartographic science that abstract 3D geovisualizations are more convenient for clear, understandable cartographic communication for the majority of map uses. In our study different design issues regarding photo-realistic and abstract geovisualizations are considered and used in the creation of mountain 3D geovisualizations.

The focus of this paper is primarily on the design issues and the creation of mountain 3D maps for a forthcoming user study on interactive 3D maps. The goal was to gather the latest cartographic findings on the design of 3D maps and use it for creating the various cartographic 3D models of Pohorje highlands near the city of Maribor. All cartographic models were visualized in the similar manner and assembled in the interactive application, which enables cartographic experts the direct evaluation of different 3D cartographic representations. Furthermore, these representations will be used in a comprehensive study regarding the correct perception of the information contained in cartographic 3D models.

The abstract 3D maps presented in this paper were designed according to the proposed design principles by Häberling (2008) and Petrovič (2003) and the techniques for representing building groups, vegetation areas and landmark buildings proposed by Glander and Döllner (2007). In creating the photo-realistic geovisualizations we followed the guidelines set by the theory of virtual reality and computer graphics. In order to consider the whole spectrum of 3D geovisualization design aspects, we also created two simple 3D maps, where two different raster maps (a topographic 2D map and an orthophoto) were draped over the Digital Terrain Model (DTM).

2. Mountain 3D Map

Mountaineers and other frequent map users employ their knowledge of map reading for effective acquisition of information from traditional (2D) topographic maps. On mountain maps they can very easily estimate the difficulty levels of mountain paths, approximate their length, height differences and the time needed to complete them. However, the less skilled users are unable to read maps in such sophisticated manner and extrapolate the needed data. Traditional mountain maps are sufficient for them to perform basic horizontal orientation in track network, while they can neglect other topographic content. The relief on mountain maps is usually presented by a combination of contours, spot heights and hills-shading. However, many people are unable to read heights and are unable to obtain the information of the vertical character of a selected route from the map (Petrovič 2001). For them, 3D maps are more appropriate as they enable a direct perception of the vertical character of the depicted area.

In the last decade 3D maps have become increasingly frequent in various fields and for different purposes. The reason for this is, above all, the evolution of the digital and automatic techniques for map creation, which enable quick and non-expensive creation of attractive 3D maps also to non-expert map makers. Indeed, such 3D maps are often of very low informational value, because their makers lack the cartographic knowledge. Moreover, the cartographic design principles, which have not yet been established, differ depending on: the type of map, the purpose and the conditions of use, as well as the user's knowledge and experience.

Within this study we combined the findings from the various researches dealing with the issues of 3D map design in order to create an attractive, expressive, informative and comprehensible mountain 3D map. The designed 3D map can be compared to the photo-realistic 3D geovisualization created according to the theory of virtual and computer graphics. Furthermore, two draped maps of the same area were also produced. All of the above-mentioned mountain 3D geovisualizations are presented within an interactive environment in which the user can choose the best viewpoint and zoom extent to effectively interpret the scene.

This interactive environment will also serve for the future study that will include actual map users to better determine advantages and disadvantages of each type of mountain 3D map for cartographic communication. Also, the study will be the first to address the photo-realistic 3D geovisualization in terms of efficiency for cartographic communication. The evaluation of the research will be based on the questionnaire – a quantitative method of research with a series questions regarding different cognitive tasks. The aim is to evaluate the influence of different levels of abstraction in 3D representations for cartographic communication.

3. The Design Process of Mountain 3D Map

The main map-creation process and the workflow of the design process for 3D maps was defined by Terribilini (2001) and upgraded by Häberling (2004). The process is composed of three steps: the process of modeling, symbolization and the process of visualization (*Figure 1*), from which we focused on the symbolization process that results in the creation of the cartographic 3D model. The entire process is iterative, therefore, we need to address and understand also the other two processes. *Figure 1* shows the workflow of the design process for 3D maps as defined by Häberling (2008) on the basis of Terribilini (2001).

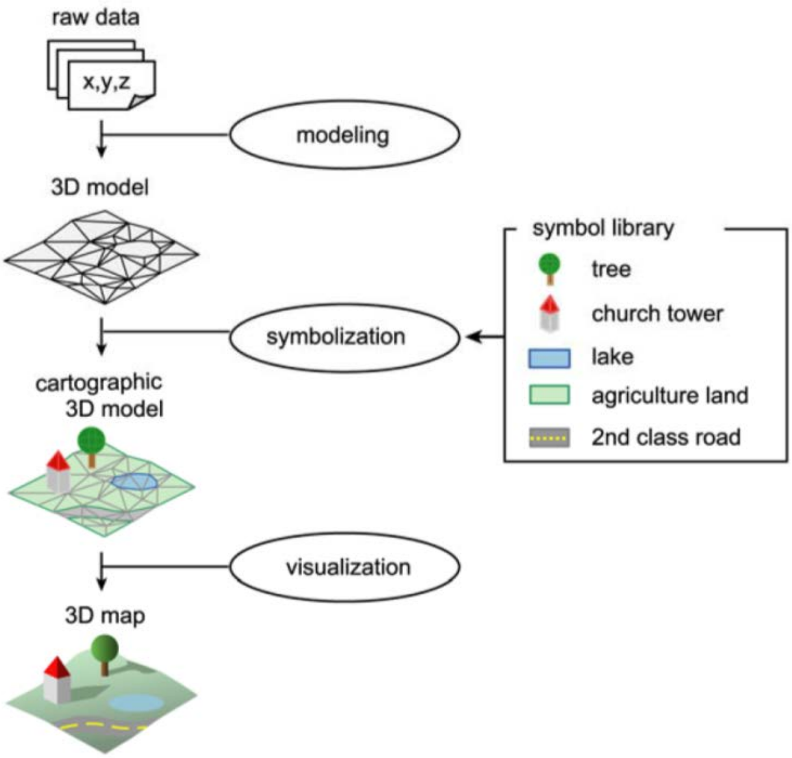


Figure 1: Workflow of the design process for 3D maps (Häberling 2008).

The basis of each 3D map is the DTM, which can be covered with an image overlay. The raster image can be a topographic map, orthophoto or a satellite image. More sophisticated 3D maps are created by combining vector and raster topographic data, designed according to the desired level of abstraction. The photo-realistic 3D geovisualization closely imitates real world phenomena while the abstract one represents a landscape with abstract and generalized shapes and objects.

The final graphical appearance of the 3D map depends on the so-called design aspects and graphic variables. According to Häberling (2008) “design aspects are groups of parameters that exert different effects on the position or appearance of objects within the map.

3.1. Cartographic 3D Model

The cartographic 3D model is created from the 3D data model in the process of symbolization. Once the 3D data model is built, the map maker needs to reach a decision about the final appearance of the map, which is closely related to the cartographic generalization and the abstraction of map objects. The graphical appearance of the thematic content (including shape, degree of generalization, degree of abstraction, and graphic attributes of map objects) is defined in the symbolization process, where map objects get their graphical attributes, such as shape, size, color, lightness, texture and orientation (Häberling 2008).

A cartographic 3D model can be simple, containing only DTM and an overlay image, or it can contain all essential elements of the landscape model in three dimensions. The simplest 3D maps are generated with a raster image overlay draped over the DTM. Slocum and others (2005) call a perspective representation of such a cartographic model a »draped map«. An overlaid raster image can be photo-realistic (e.g. orthophoto) – *Figure 2, image d* – or abstract (e.g. topographic 2D map) – *Figure 2, image c.* More advanced cartographic 3D models contain all essential elements of the landscape model in three dimensions. The second type of 3D maps is designed to appear as similar to the real world as possible and is referred to as a photo-realistic 3D geovisualization or photo-realistic 3D map – *Figure 2, image f.* They allow users to observe the representation exactly in the same manner as they observe reality (Petrovič 2003). However, in terms of cartographic communication the third type of 3D maps, named the abstract 3D map, seems the most suitable for a efficient perception of the information contained in a cartographic 3D model – *Figure 2, image e.* The latter maps are also termed non-photo-realistic 3D maps. However, as stated by Döllner (2007), the expression non-photo-realistic is not satisfying because neither the notion of realism nor its complement, non-photo-realism, is clearly defined. Also the prefix 'non' indicates a negativeness, which a cartographic abstract 3D map is certainly not. Therefore, the expression ‘abstract 3D map’ seems more appropriate.

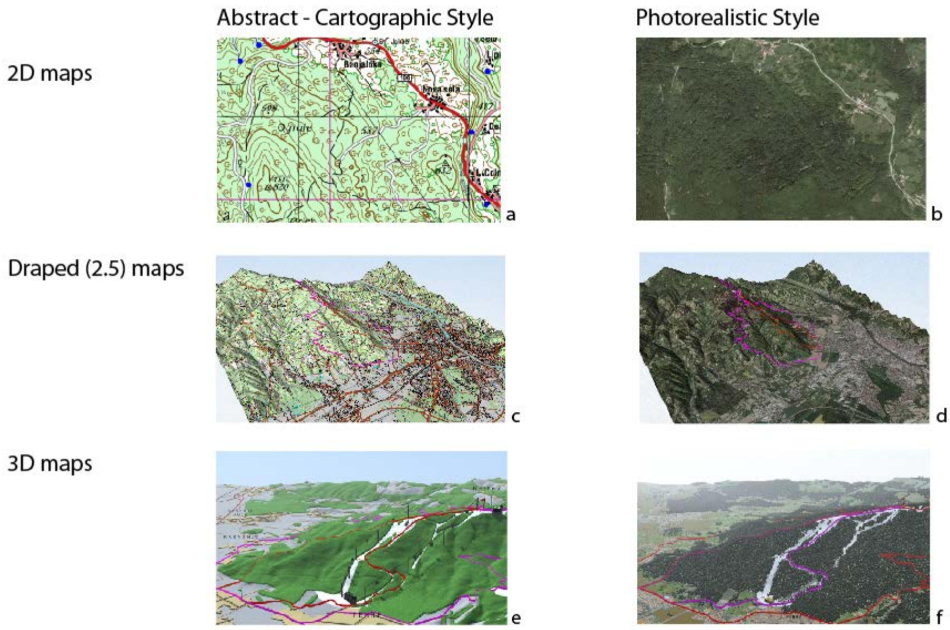


Figure 2: Cartographic and photo-realistic style of maps.

Mountain maps require attractive and understandable presentations of terrain and natural phenomena. Mountaineers traditionally use 2D topographic maps where landscape elements are presented in a generalized and a symbolized manner. Also, in 3D representations photo-realistic visualizations may provide an effective way to transmit information to the map user.

In order to compare different level of abstraction in a mountain 3D map we created simple cartographic model – for draped maps and two advanced cartographic 3D models: an abstract and a photo-realistic one. Both include the same DTM, other objects such as vegetation and buildings are designed in a contrary fashion.

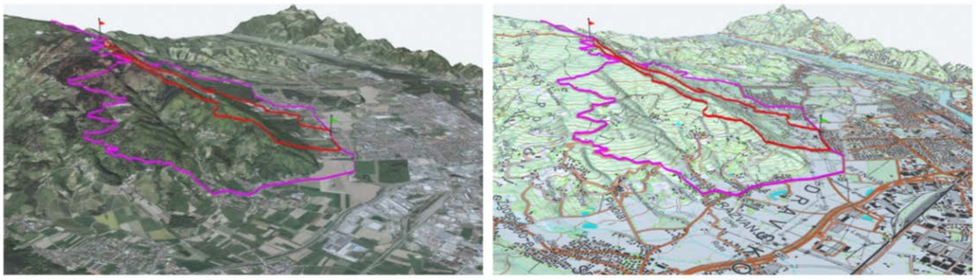
The photo-realistic 3D model and the corresponding photo-realistic 3D map were produced using the software Visual Nature Studio© (3D Nature). The representation of the content should be very similar to the real appearance of the presented objects and geographic phenomena. The 3D models were designed to imitate corresponding real objects. Additional realism was achieved with shading and atmospheric effects.

Map content in abstract 3D model was designed according to the various design principles. Linear and area map objects were symbolized to allow a familiar and easy-to-interpret 3D map. Urban and forest areas were generalized and represented in a good color contrast to the terrain.

User's subjective impression of the vertical character of the terrain is emphasized with a vertical exaggeration factor of 1.5 within cartographic 3D models.

3.2. Draped Map

The basic DTM can be created with a triangulated irregular network (TIN) or with a regular square grid. As we overlay the DTM with a raster 2D image we get a useful simple 3D representation of geographic phenomena. A high resolution raster image is needed to assure that the raster structure is not noticeable on the 3D map. A raster image can be photo-realistic (e.g. orthophoto) or abstract (e.g. topographic 2D map). The latter ensures better recognition of map objects and phenomena because it represents the map elements with symbols and it employs cartographic generalization. On the contrary, the photo-realistic image overlay represents an up-to-date situation in the moment when the images were taken (Petrovič 2007).



(a) (b)

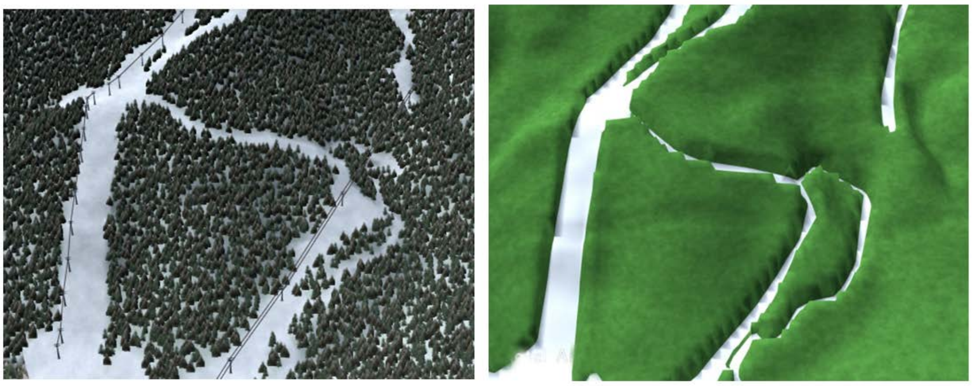
Figure 3: Draped map: orthophoto overlay (a) and topographic 2D map overlay (b).

For the purpose of this study, we created two draped maps, one overlaid with the 1: 50,000-scale topographic 2D map (*Figure 3b*), and another with a color orthophoto image ground pixel size of 0.5m (*Figure 3a*).

3.3. 3D Vegetation modeling

Photo-realistic vegetation needs to be detailed, three-dimensional and must not differ from the photography photography at the specific scale. Thus, the vegetation for the mountain 3D representations can be presented with images of plants that are dispersed within the area. The software calculates the plant distribution for a given area to produce homogeneous parts in the landscape. *Figure 4a* shows the representation of a forest in a photo-realistic mountain 3D map.

Vegetation in abstract 3D maps is based on vector land use data. Areas of homogeneous vegetation are painted with associative color/texture and extruded above the terrain. The result is a clean, associative and generalized representation of vegetation (*Figure 4b*).



(a) (b)

Figure 4: Forest modeling in photo-realistic and abstract mountain 3D map.

3.4. Modeling of urban environment

Urban areas in photo-realistic mountain 3D maps are represented with buildings, acquired from building footprints (cadastral data) and height attributes. Such a representation is suitable only for depicting larger areas, where textured facades are not necessary for a convincing result.

In mountain 3D maps buildings are not a key element and be replaced with simple, uniform cell blocks. The technique we used was proposed by Glander and Döllner (2009), where individual buildings can be substituted by a cell block built by surrounding streets.

(a) (b)

Figure 5: Urban area in photo-realistic and abstract mountain 3D map.

4. Methodology of the Research

Our research was designed to evaluate the influence of different levels of abstraction in 3D representations for cartographic communication. We used different design issues regarding photo-realistic and abstract geovisualizations in the creation of four different types of a Mountain 3D map (Maribor – Pohorje). Different geovisualizations are presented within an interactive environment that is embedded in an online questionnaire. Participants with different backgrounds in working with 3D maps are invited to participate in this study. The sample consists of non-experienced map users, experienced 2D map users, and experienced 3D map users.

Based on a research, performed by Petrovič and Mašera (2006), we hypothesize that more experienced users prefer draped topographic maps and abstract 3D maps as they are familiar with generalized and symbolized 2D maps. Less experienced users presumably prefer photo-realistic landscape visualizations. On the other hand, we hypothesize that all users perform efficiently and more effectively in map use-tasks on abstract 3D maps.

To test our hypotheses we use quantitative method of research – an online questionnaire which consists of 3 parts. After the first part of the questionnaire (demography and user experience), participants are confronted with all types of 3D maps and asked to evaluate the aesthetics and readability of different types on a Likert scale of 1 to 5. In addition, they are asked to specify their preferences to use a certain map for the following purposes:

- examination of the landscapes and exploring new places,
- navigation and route planning,
- professional use.

In the third part of the questionnaire the users are asked to interact with the 3D maps and perform a set of map-use tasks. Questions regarding those tasks will help us identify the usability of different types of maps with SEE methodology, defined by the ISO 9241 - 11 standard. The above mentioned methodology serves to assess the ease of use of the product or system. The category of usability consists of three subcategories: effectiveness, efficiency and satisfaction. Effectiveness refers to whether or not a task is successfully completed, efficiency refers to how quickly the tasks are completed, and satisfaction refers to a user's attitude towards or preferences for the system (Coletkin et al. 2010). In the third part of the questionnaire each participant interacts with two (out of four) types of 3D maps. Maps and questions (map-use tasks) are randomly selected for each participant in order to avoid the transfer of skills the users gained in completing the tasks on the first map.

Before we started the questionnaire, a pilot study was conducted to expose problem areas of the interactive environment and of the online questionnaire. Users with different experiences were included in this phase to get a representative sample (experts, students of geodesy, non-skilled users). The main goal of the pilot study was to eliminate basic flaws and improve and upgrade questionnaire.

5. Interactive Environment for Examination of 3D Maps

The ability to navigate through virtual space is one of the most important features of mountain 3D maps. The map should not be static to permit the correct perception of the topographic data and the user should at least have an option to select a viewpoint and a zoom extent.

For this purpose the interactive environment was created, based on QuickTime VR technology, which gives the user a feeling of free rotation of the 3D map. In order to achieve that, camera trajectory was set to follow the horizontal circumference above the cartographic 3D model, where the target of a viewpoint is always at the same spot, usually found in the middle of the model.

The height of the camera trajectory was set to 3000 m above sea level, camera field of view to 40° and the target viewpoint of the camera in the middle of the cartographic 3D model, at the foothill of a mountain.

With such camera settings there were 120 panoramic images rendered at intervals of 3° of azimuth. The rendered images were combined using the QuickTime VR technology to create a simple 3D map viewer where the user can select the azimuth of viewpoint and zoom extent. These two options provide the above-mentioned feeling of free rotation and navigation.

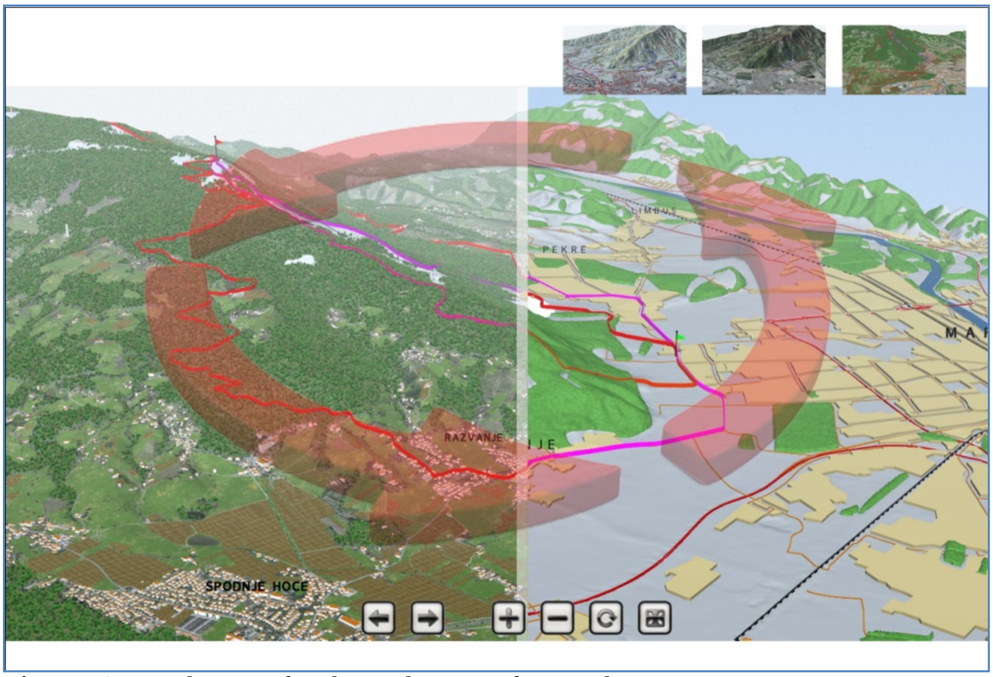


Figure 6: Application for the evaluation of created 3D maps.

6. Conclusion

The main goal of our study is the usability evaluation of levels of abstraction in different 3D geovisualizations. This paper reports only part of the study, namely creation and design issues of four different mountain 3D maps that were employed in user testing. Methodology of the exploratory study is presented as well.

Furthermore, the study is broadened with different visualizations of a city of Prague as an example of urban environment, with intention of establishing an overall view of the influence of levels of abstraction on cartographic communication in 3D maps.

Our study was undertaken with the belief that abstract visualization of 3D map would be more effective for the majority of map uses. On the other hand, photo-realism seems to be more attractive. We also plan to analyze effectiveness and efficiency of maps and user preferences regarding participant's experiences.

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