Designing Photo-Realistic and Abstract Mountain Maps for a 3D Mapping Study

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ABSTRACT

Design of contemporary 3D geovisualizations is mostly oriented to attractive photo-realistic visualizations in contradiction to theoretical fundamentals of cartographic science, which define abstraction and symbolization as the key facts of successful and efficient cartographic communication. The article summarizes the basic principles of both photo-realistic and abstract 3D representations, completed with simple draped maps. Those principles were applied during the creation of mountain 3D maps and geovisualizations of Pohorje highlands above Maribor, Slovenia. Created maps, incorporated into the interactive environment will be used for the research on the influence of levels of abstraction on cartographic communication in 3D maps amongst different map users.

Keywords

3D geovisualization – photo-realistic presentation – 3D map – cartographic abstraction

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 Such representations are no longer applicable only for specialists, since in the last few years realistic representations of the world around us have been widely used by the general public (Petrovič, 2007)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, and the upcoming 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, archeological 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 this 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 study will serve as framework to assess the transfer of contextual meaning to the map user on different types of mountain 3D maps. Based on Döllner (2007), Petrovič (2003), and other cartographers, we hypothesize that abstract 3D geovisualizations are more effective for cartographic communication than photo-realistic geovisualizations. The forthcoming user study will attempt to prove this hypothesis.

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

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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).

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.

THE DESIGN PROCESS FOR 3-D MAPS

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).

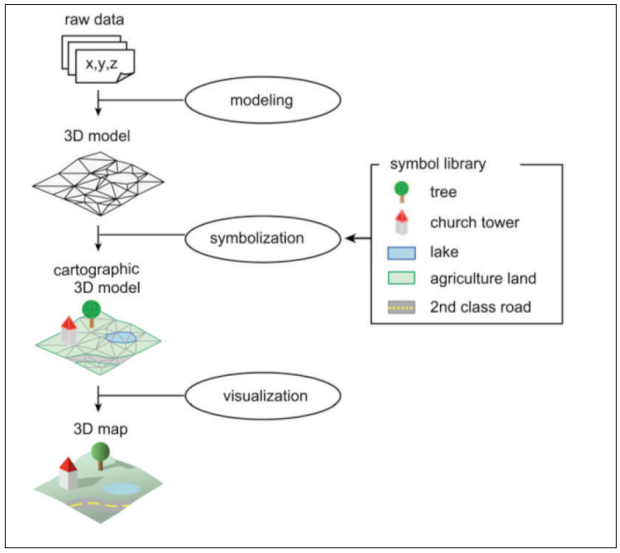

Figure 1. Workflow of the design process for 3D maps (Häberling, 2008)

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The first step of the design process is modeling the data to create a 3D model, where the most important factor for map appearance is building and scaling a DTM. In the symbolization process map objects get their graphical attributes, such as shape, size, color, lightness, texture and orientation, followed by the final step – visualization, where camera and lighting attributes are defined.

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." He divides the design aspects into three groups according to the design process: design aspects of modeling, symbolization, and visualization, where every design aspect involves bundles of graphic variables.

Bertin (1974) defined the graphic variables for 2D maps, and several authors (Buziek, 2002; Häberling, 2004; Petrovič 2001) attempted to do the same for 3D maps. The most complete review was done by Häberling (2004), where he defined more than 70 graphic variables and arranged them into three above-mentioned groups according to the design aspects.

On the basis of expert interviews regarding the defined graphic variables, he recommended 19 propositions for cartographic design principles for the design of 3D maps (Häberling, 2008), which we considered in the preparation of our abstract mountain 3D map.

CARTOGRAPHIC 3-D 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).

Generally, regarding the symbolization in 3D maps, we differentiate between three types of 3D maps. The simplest 3D maps are generated with a raster image overlay draped over the DTM. Slocum and others (2005) call such a perspective representation a "draped map". An overlaid raster image can be photo-realistic (e.g. orthophoto) – Figure 2, image 1a – or abstract

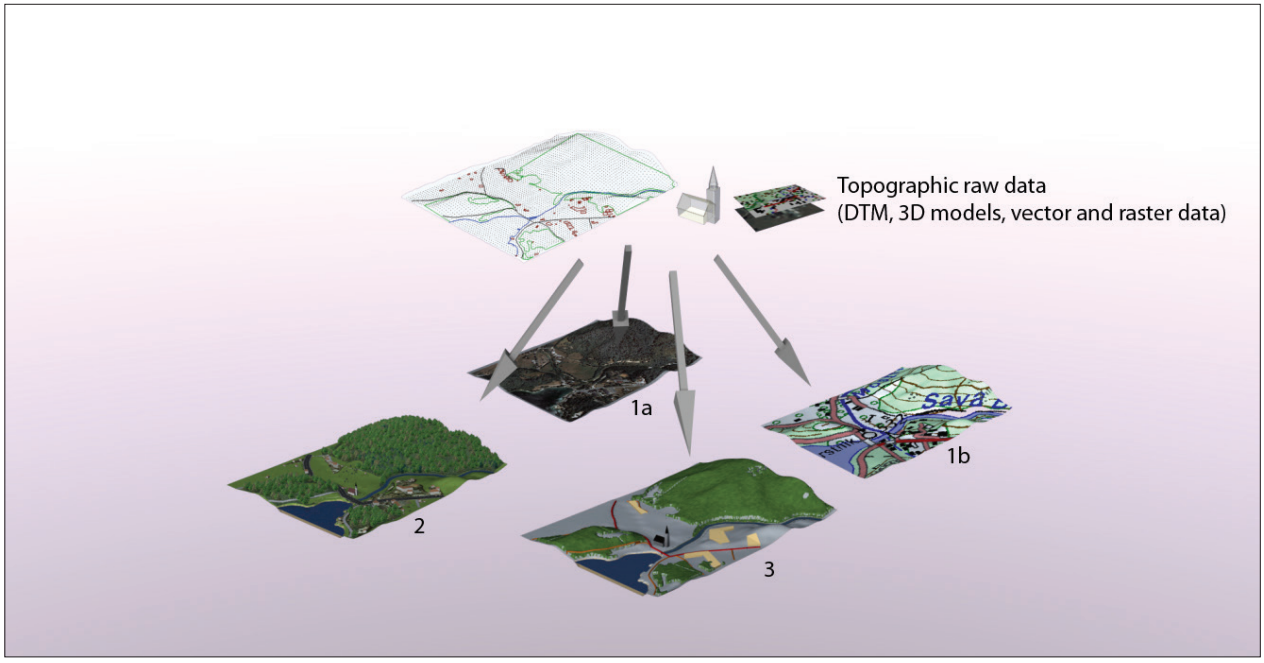

Figure 2. Different types of the symbolization of the data 3D model

(e.g. topographic 2D map) – Figure 2, image 1b. 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 2. 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 correct perception of the information contained in a cartographic 3D model – Figure 2, image 3. 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.

For the purpose of the forthcoming study three different cartographic 3D models were designed, from which four different geovisualizations were created. Digital elevation model was the basic data set, which was overlaid with various vector and raster data. For two simplest visualizations the DTM was overlaid with raster images (orthophoto and topographic map). The focus of the study is on designing abstract and photo-realistic 3D geovisualizations in terms of creating effective cartographic communication in mountain maps.

Mountain maps must enable users to examine the whole mountain path and estimate the difficulty of it. Therefore, our test geovisualizations represent a regional area of the path. For such a regional view we created an abstract and a photo-realistic 3D geovisualization. An abstract visualization contains only the significant details needed for the correct perception regarding its purpose. On the contrary, the photo-realistic visualization requires a large number of details to achieve a convincing photo-realistic appearance.

Draped Map

The basis of each 3D map is the DTM, which 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 abstract 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).

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).

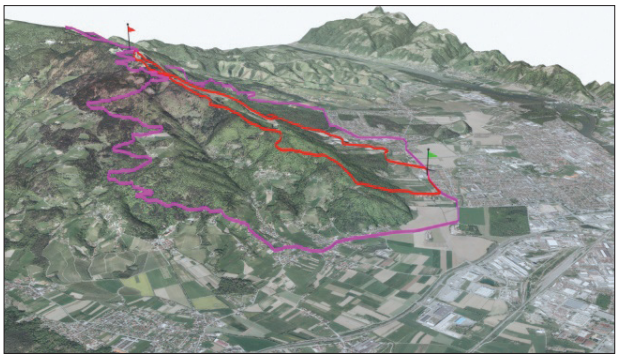

Figure 3a. Draped map; orthophoto overlay overlay

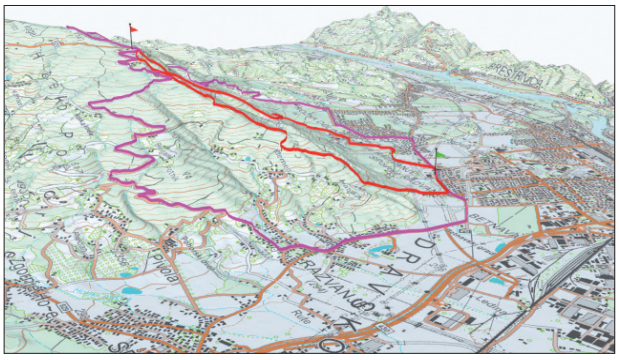

Figure 3b: Topographic 2D map overlay

Photo-realistic Cartographic 3D Model

The most technically demanding cartographic 3D model to create is the photo-realistic one. It requires a large number of details in terms of shape and color to achieve impressive photo-realistic appearance of the 3D map. The photo-realistic 3D model has to include enough geometrical and graphical details to prevent an unconvincing visual result from a perception's and an observer's point of view (Döllner, 2007). The aim of the photo-realistic 3D model is to provide sufficient

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details for visualization, which replicates photographs as close as possible and adds spatial 3D effects. When such model is visualized in an interactive environment, it becomes possible to observe and explore geographical objects and phenomena of the world as if the map user were actually there.

Figure 4. Designing of photo-realistic 3D map content; ski slope (left) and road infrastructure (right).

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 phenomena. The 3D models were designed to imitate corresponding real objects. Additional realism was achieved with shading and atmospheric effects.

Abstract Cartographic 3D Model

Cartographic generalization and cartographic abstraction are key features of the abstract 3D map. Principles of generalization and abstraction ensure that the cartographic communication in 3D maps is efficient in terms of clear and understandable transfer of contextual meaning to the map user.

According to the 3D map definition by Petrovič (2003), this type of 3D cartographic representation is the most appropriate to be termed a map. Requirements for a 3D landscape representation to be called a map are (Petrovič, 2003):

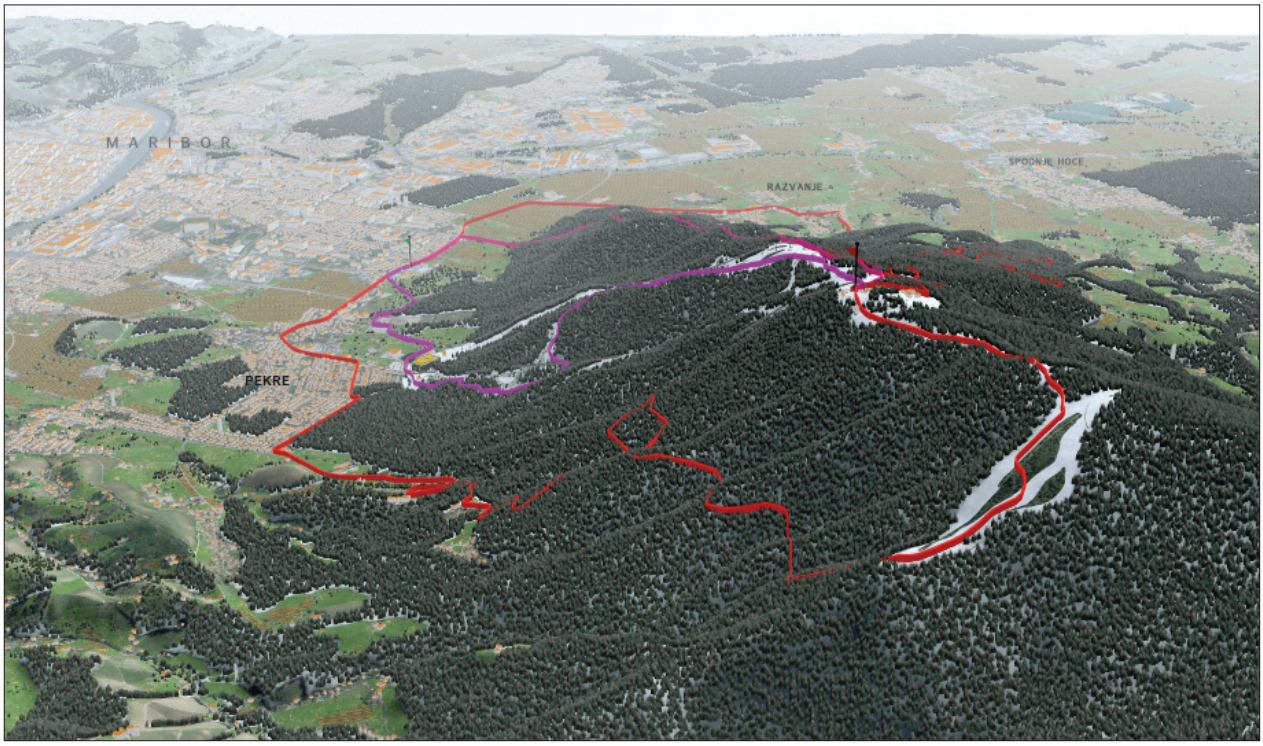

Figure 5. Photo-realistic 3D geovisualization.

- every presented object is defined with its geographical position in a selected coordinate system and this position has to be accessible to the user
- objects and phenomena are projected from Earth's surface to the selected (usually plane) coordinate system according to exact cartographic projections that assure deformations in regulation sizes
- cartographic symbols as "an alphabet" of the map archive the communication and the information transfer between the cartographer and user
- cartographic generalization principles that define the level of map detainees

However, most currently available 3D spatial representations are often called a 3D map, although, they do not follow the cartographic language.

In order to create an expressive, clear and aesthetic 3D map the cartographic theory of various cartographers was followed. We created an abstract 3D map that was based on Häberling's Proposed Cartographic Design Principles for 3D Maps (2008). In the symbolization process we considered Petrovič's study Cartographic Design in 3D maps (2003). The cartographic 3D model was extended with Glander's and Döllner's (2007) techniques for:

Figure 6. Abstract 3D map.

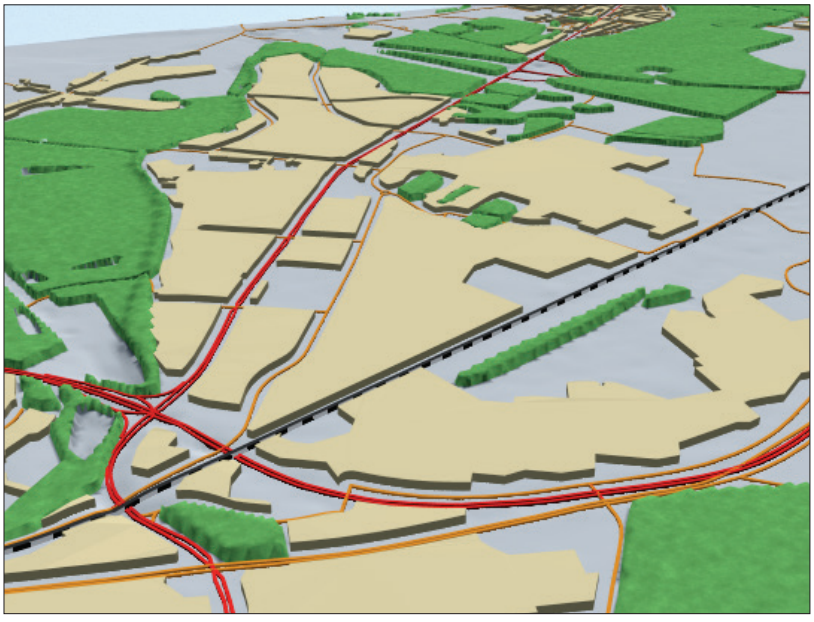

Figure 7. Designing the abstract 3D map

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- Generalization of 3D building groups
- Vegetation block model with coarse edge-line and coarse surface
- Cut-out of cell polygons

Map content in abstract 3D map 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. Forest areas were additionally painted with structural patterns. Users' subjective impression of the vertical character of the terrain is emphasized with a vertical exaggeration factor of 1.5 (the same vertical exaggeration was used for all cartographic 3D models within this study). The 3D symbols were designed in the abstract appearance in a neutral color.

To look at a 3D map model, Häberling (2008) recommends an average inclination angle of about 45°. Lower inclination angle leads to covering background objects; if the inclination angle is too steep, the vertical character of the terrain is hard to perceive. Since the forthcoming study will employ the interactive environment where the 3D map can be viewed from different azimuth angles, the problem of low inclination angle is negligible. Flat inclination angle (of about 30°) was used for all our 3D maps.

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

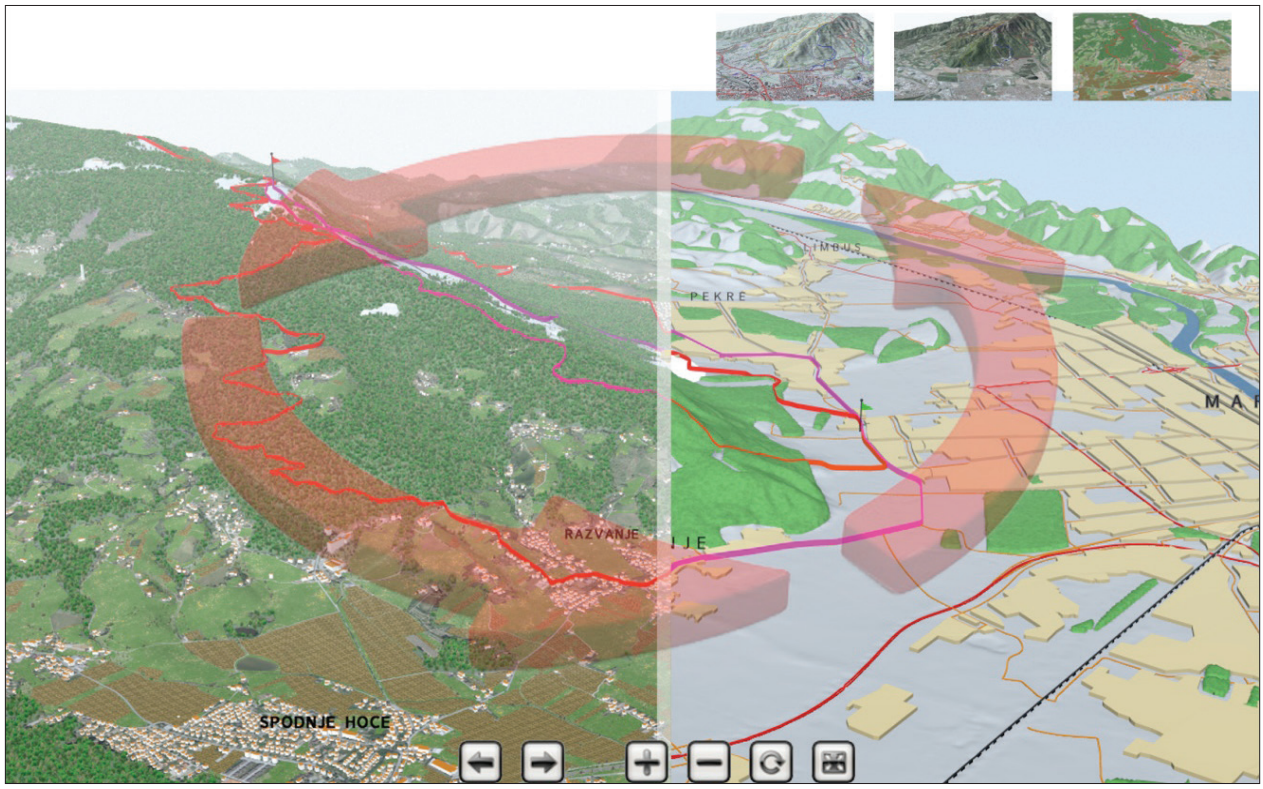

Figure 8. Application for the evaluation of created 3D maps.

where the user can select the azimuth of viewpoint and zoom extent. These two options provide the abovementioned feeling of free rotation and navigation.

FUTURE WORK

The study will be broadened with the research on the influence of levels of abstraction on cartographic communication in 3D maps amongst different map users.

The focus of the research is to determine the response of 3D map users to different levels of abstraction. The aim is to determine advantages and disadvantages of different types of maps that are presented in this paper. In addition, the study will upgrade the design principles, as it will be the first comprehensive study to include a representative sample of map users.

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