3D Map Presentation – A Systematic Evaluation of Important Graphic Aspects

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1. The state of geo-data representation today

Today, the availability of digital geo-data is increasing rapidly throughout the world, a trend that undoubtedly will continue for the foreseeable future. Among the large geo-data sets available to cartographers are digital terrain models, as well as accurate topographic and thematic data sets about countless physical, social, and economic phenomena. In addition to their geographic coverage and thematic content, geo-data sets generally are available in vector and raster formats. To complement the growing availability of data, rapid development of computer technology during the last several decades permits cartographers to handle large high-resolution data sets more or less easily (Haeberling 1999). Maps and map-related representations, such as perspective representations, are now produced digitally (fig. 1). Digitally rendered work represents a significant advance over the pre-digital era when perspective representations were mainly sketched by hand and printed on paper, and physical 3D models were constructed from plaster and wood.

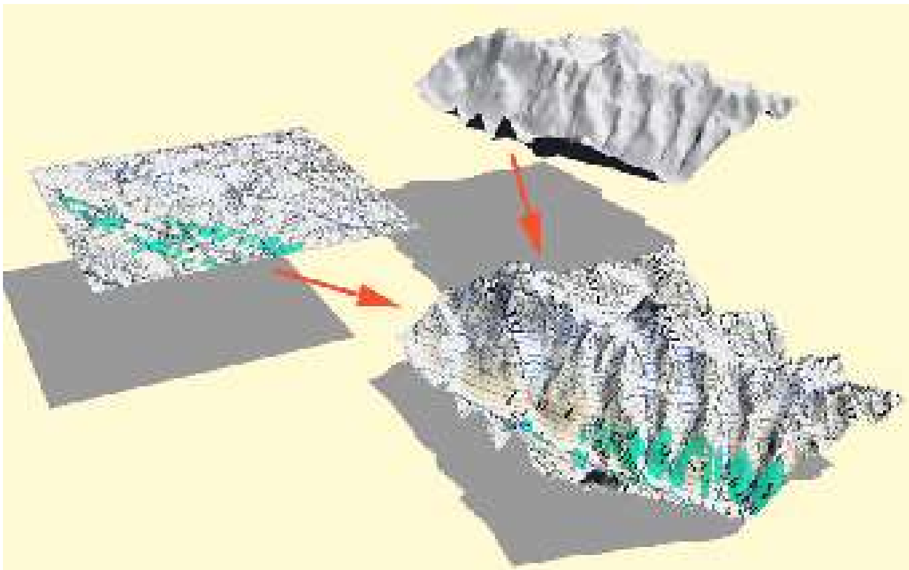

Figure 1: A simple perspective view model (front) made from a rasterised thematic data layer (middle left) and a digital terrain model DTM visualised in 3D (back). (All geo-data: © Federal Office of Topography, Wabern)

By harnessing geo-data and computer technology, cartographers can create entirely new kinds of perspective representations. These new perspective representations include images and animations presented on two-dimensional media, and true 3D representations that can only be visualised interactively using special equipment (fig. 2). In this paper I will discuss perspective views, the most basic variety of 3D representation.

Figure 2: Perspective view of the Lake of Constance, Switzerland created by draping an orthophoto onto a digital terrain model (Dobler 2001). (DTM: © Federal Office of Topography, Wabern; orthophoto: © Swissphoto)

2. "3D maps"

Computer generated perspective views, such as Lake Constance shown in Figure 2, are often simply referred to as “3D maps”. Although this term is not found in the cartographic literature, there are specific reasons why it should be used. “3D”, because we perceive the presented landscape with our human-perception system in a three-dimensional perspective way, even when the landscape is depicted on two-dimensional media. And, “maps”, because these products integrate and display spatially-arranged phenomena on the surface of a DTM in accordance with cartographic symbolisation and generalisation conventions. Nevertheless, although they possess cartographic characteristics, 3D maps should be considered a map-related representation, not a map in the classic sense.

3. Design process

Before analysing the many graphic cues and resources that influence the look of 3D maps, we should first examine the design process. By doing so, we will have a better understanding of how to apply these cues and resources in the design of 3D maps. We will also understand how they affect overall representation, and how they interact effectively with other graphic cues and resources (fig. 3).

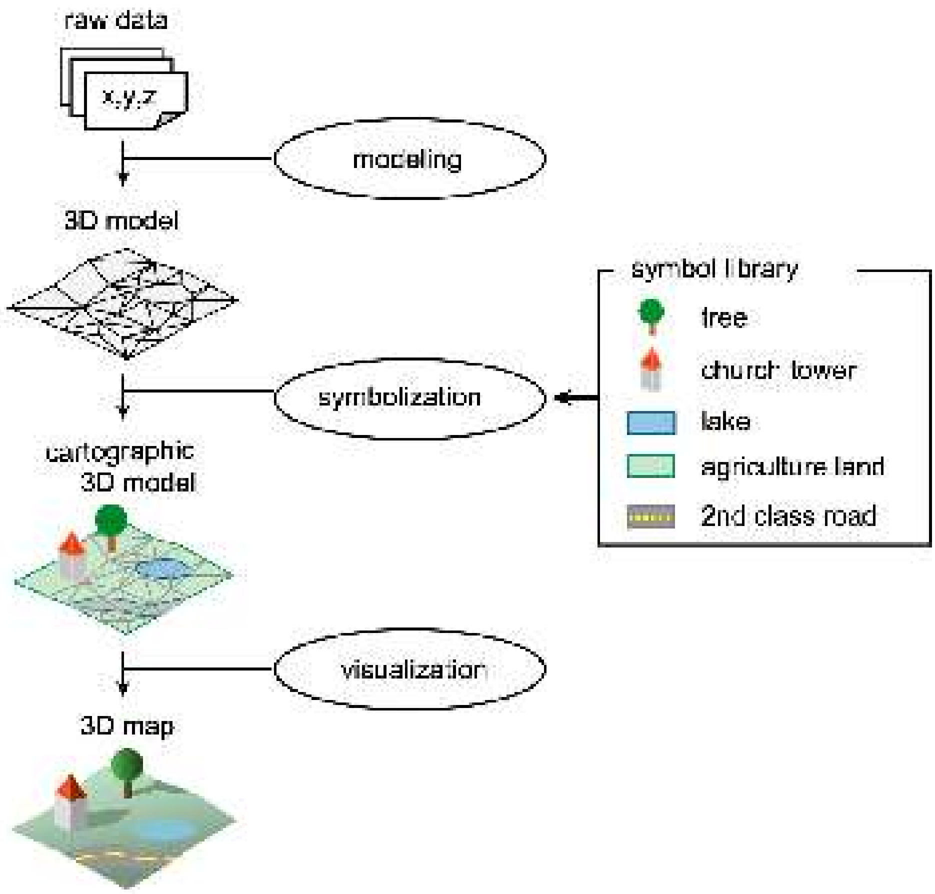

Figure 3: Schematic design process for 3D maps (Terribilini 2001).

The first step of the design process is data modelling. The original data are analysed, and, depending on the circumstances, converted to another format and file structure, upon which subsequent 3D map design processes depend. The geometric and semantic aspects of the objects in the data are reshaped, aggregated, and/or classified in the format required with the specific software used for designing and producing 3D maps.

Symbolisation is the next step. This step involves determining the graphic appearance of the DTM section as well as topographic and thematic objects. In other words, we define the legend for the 3D map. It must be noted that a physical image has not yet been created at this stage of the design process.

The last step is visualisation. Parameters are chosen for creating the image and completing the scenery that will become the final 3D map.

4. Graphic aspects

4.1 General considerations about graphic aspects

For generating 3D maps, there are a great number of input cues that influence the map creation process (Kraak 1988). Taken together these cues are known as "graphic aspects" (or "design aspects"). The different kinds of maps and map creation steps require many graphic aspects to be distinguished by cartographers. Graphic aspects are groups of parameters that exert different effects on the arrangement or appearance of the objects within the map. With them, it is possible to design and control all map features, including how features should appear in the perspective view. Every graphic aspect includes one or more graphic variables. A starting point for understanding graphic variables is Bertin's "visual variables" for graphics and maps (Bertin 1998). For this discussion, however, it is necessary to enlarge Bertin's list to include sub-

variables within variables. A graphic variable is a design factor, which directly affects a focussed map object in a unidimensional way.
Similar to the design process of 3D maps, all graphic aspects need to be divided into similar groups. But before doing this we will first examine the different object types, followed by an examination of their graphic aspects.

4.2 Graphic aspects of modelling

Before analysing the first step in the creation process, we must first be aware of the three types of objects the map model is based on:

- DTM objects are normally rectangular sections of a large data set. This data set describes the earth's surface numerically by a huge amount of terrain points.
- Topographic objects may be classic vector objects, external 3D objects, or mostly raster objects, such as textures. Not only single objects, but also object groups with a specific characteristic in their appearance and, perhaps, behaviour. They are the result of aggregation within the modelling process.
- Orientating objects are already defined features that assist the map user with extracting geo-information from the map. They complete the model of a 3D map. For example, co-ordinate lines or labelling objects are absolutely necessary to express the accurate geo-positioning and the notations of map objects.

Regarding the geometric shape of objects, the user has some possibilities to determine the original outlines of the objects in different manners. Simplification of the shape can be accomplished by eliminating vertices or creating polylines instead of curves, or by determining the object’s shape for later application of a level-of-detail mechanism. Positioning concerns include whether the object will obey its geo-referenced position or its referenced position in relation to neighbouring objects. Thematic objects need to be adjusted to facilitate harmonious data classifications. The semantics of objects is yet another consideration in the modelling process. Changing thematic attributes or spatio-temporal dependencies, typically done in an attributes table, connects all objects to the appropriate data base.

4.3 Graphic aspects of symbolisation

The best method for determining the appearance of objects within a 3D map can be found within the group of graphic aspects for symbolisation. It is comparable to the map legend creation process on classic (2D) maps. Groups of graphic aspects include:

- Aspects for object positioning.
- Aspects strongly affecting the graphic appearance within the map.
- Aspects responsible for controlling the interactive behaviour of objects, including the behaviour between single objects and groups.
- Aspects determining the appearance of orientation features by selecting graphic attributes.

In general, there are millions of possible setting combinations in each group. And every variation within the full range of characteristic has its own effect. The reader will quickly recognise that the first two aspect groups (object position and graphical appearance) match Bertin's list of visual variables.

Position: One of the most important characteristics for geo-related representations is the exact position on earth of every object, including the geographic extent of the landscape being digitally represented. Positioning information could be represented in form of numeric or graphical co-ordinates, either in geographical co-ordinates (latitude/longitude) or a country-specific reference system. In the future, all geo-data must also contain absolute or relative height position for 3D representational purposes. Because 3D terrain occasionally occludes other objects, resetting some position parameters of objects or object groups may be necessary for optimal viewing within the 3D scene.

Shape: The graphic aspect of shape determines the impact of abstraction, generalisation, and the degree of homogeneity within the entire 3D scene.

Size: Choosing the proportional parameters of an object changes the character of the object itself. For example, by simply adjusting vertical exaggeration, a landscape can be made to appear flat or dramatically mountainous (fig. 4).

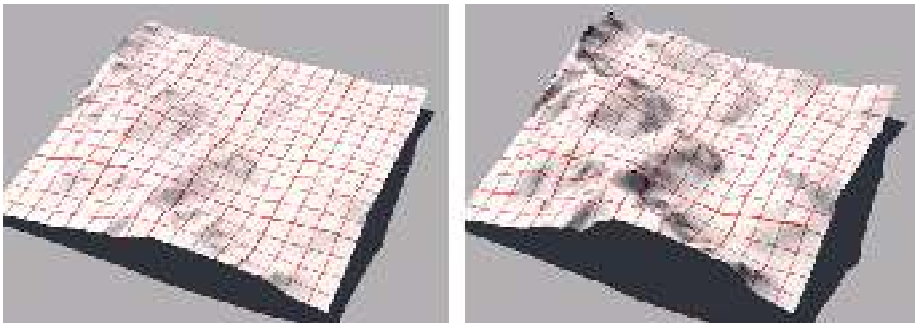

Figure 4: DTM modelled with vertical exaggeration factors: 100% (left) and 200% (right).

Colours and brightness: Cartographers are able to choose the colour and brightness of every object with thousands of variations (fig. 5). Today, thanks to sophisticated software, map aesthetics are no longer dependant on the manual skills of the map's author – although good design sense remains an essential prerequisite.

Figure 5: A panorama of the Säntis mountains, Switzerland, created from coloured hypsometric tints applied to a DTM (Atlas of Switzerland 2000).

Textures and patterns: Again, thanks to digital technology, today's cartographers have a wide variety of textures and patterns to choose from in designing the surface of objects. Textures and patterns can be created by simply draping raster images on the objects, or they can be produced using sophisticated computer techniques such as bump mapping or fractalising (fig. 6).

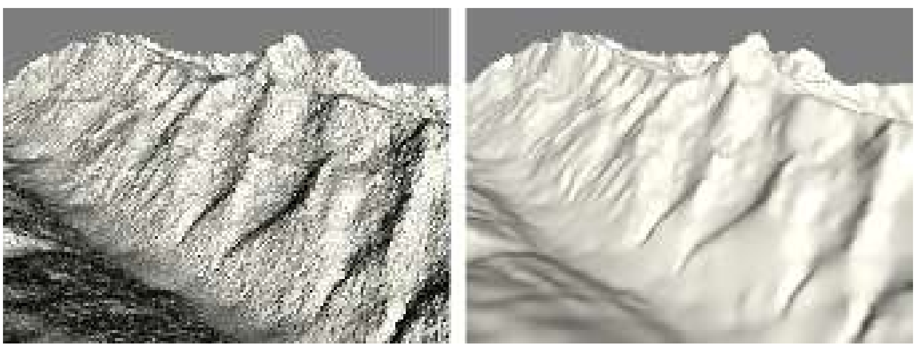

Figure 6: DTM modelled with different surface structure: high fractal depth (left), smoothed (right).

Orientation: This aspect is the only classic visual variable from Bertin's list. Orientation has minimal importance in the design process of 3D maps, particularly when choosing the orientation aspect of objects and patterns. Because innumerable orientation possibilities exist for viewing a 3D map – determined by adjusting camera parameters in a 3D application – orientation can not be considered a differentiating variable.

Special graphic aspects: The graphic appearance of many objects can be designed with special graphic aspects. These effects are easily created with most of the modern software, although Bertin did not take them into account in his discussions. Among the possible applications, map objects can be given transparent surfaces, which allows objects on the map surface to be seen through overlying elements (fig. 7).

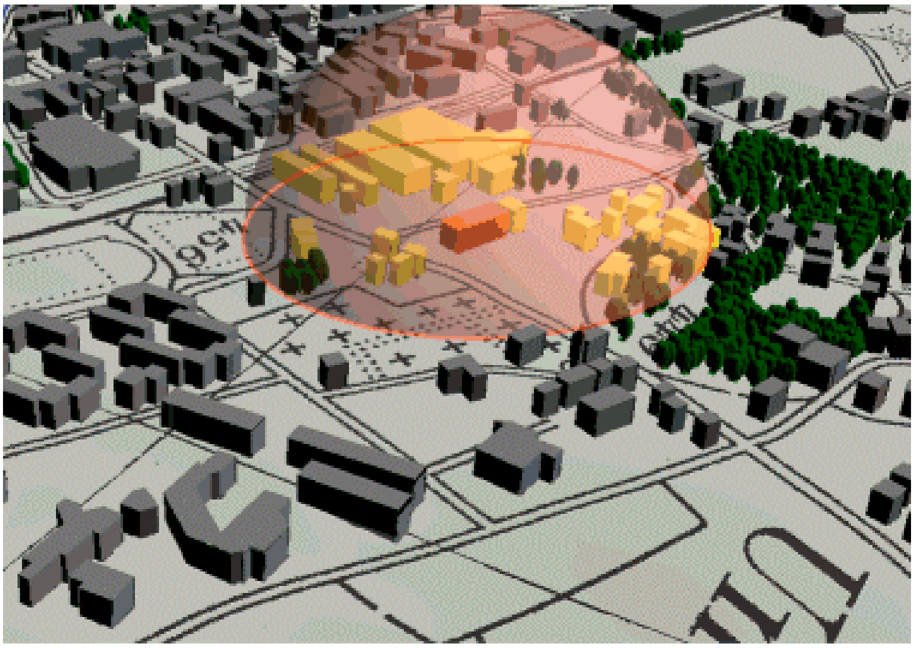

Figure 7: Example of a transparent surface put over a city model, complemented with special effects in colours (Pfund 2002).

In another possible application, for use with contours and other lines, all line characteristics – thickness, style, pattern, and amount of smoothing – can be chosen in advance. This technique gives cartographers enormous variety to represent linear or contoured objects (fig. 8).

Figure 8: A portion of the "Mount Hood Visualization" showing differing graphical styles applied to linear vector objects (Dobler 2002).

Object animations and movements: In interactive and animated map scenes, objects can be modelled and defined by changing graphic or positional attributes. Objects can also easily be created by changing their size or shape. Or they can be determined with changing colours or textures when selected or clicked on screen. Interactive map design is more a question of computer programming and less a methodological or cartographic focus. Only with the advent of modern computer technology, map objects can be set in motion easily. Not only are simple displacements from point-to-point feasible, but other movements such as rotation, which serve to attract the user's complete attention are possible. Finally, fly-by and walk-through actions that show animated objects in 3D maps now can be made with little difficulty. Computer technology enables object attributes to be changed or objects set in motion in innovative ways.

Orientation features

Another category of graphic aspects are orientation features, which we also define by their graphic appearance in the symbolisation process (fig. 9). Orientation features include:

- **Labelling and co-ordinates.** The cartographer must decide the type and special appearance of the labelled objects, and it is necessary to determine how we introduce a co-ordinate reference system. Co-ordinates could be displayed in billboards, or with additional numerical notes in information boxes.
- **Scale information.** Information about scale is essential to the map reader. This information can be conveyed by a graphical scale bar or by using subtle measuring tools.

Figure 9: A topographic 3D map of the Greifensee area, Switzerland containing orientation features – labels, compass points, and co-ordinate lines. (All geo-data: © Federal Office of Topography, Wabern)

4.4 Aspects of the visualisation process

Parallel to important considerations for computer hardware and software applications, diverse aspects concerning the final representation of the 3D map model on a desired media must be decided.

Model viewing in general

The cartographer must first choose a procedure for representing a three-dimensional map model on a two-dimensional plane. The choice of the projection method is essential for the generation process of 3D maps. All characteristics and mathematical procedures of the central projection, including parallel projection (cavalier perspective, isometric view) or intermediary projections (e.g., progressive central perspective), must be considered. With the choice of the perspective, the computer methods are mostly given.

Model structuring

Together with the choice of projection laws, the cartographer must decide the level-of-detail in a 3D model, which is inversely related to computer processing speed (fig. 10). An implemented mechanism significantly affects the efficiency of the rendering procedures for on-screen display or final image creation.

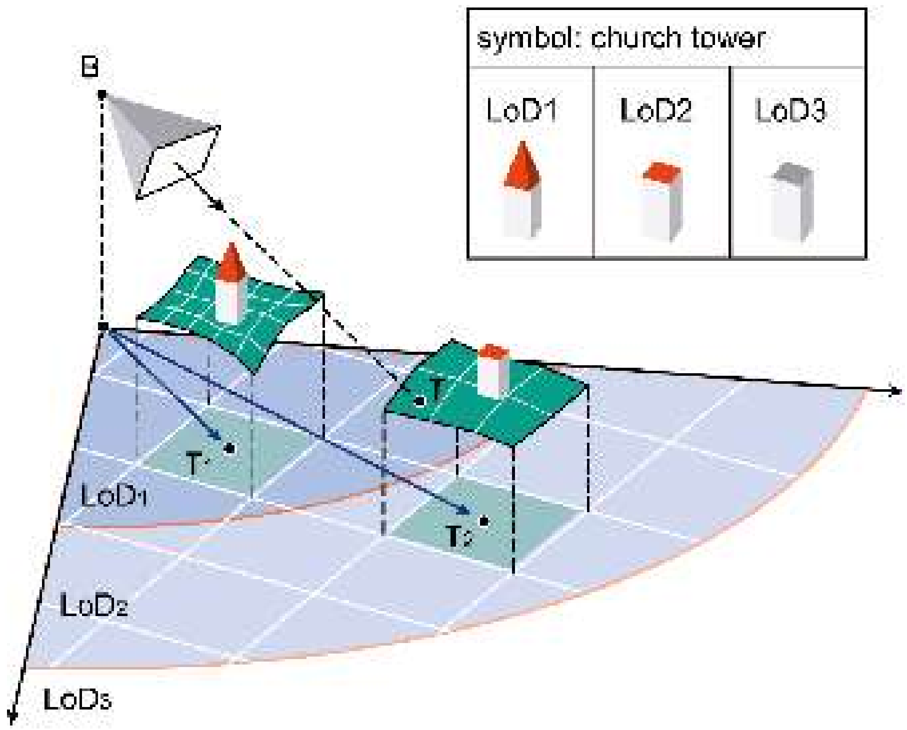

Figure 10: Level-of-detail concept depending on the camera distance (Terribilini 2001).

Camera settings

In the visualisation process, options or values for the static or moving camera are specified via the input dialogs of the software. Important graphic aspects include the settings for the camera position and the camera geometry. The actual position is determined by the two plane spatial co-ordinates, x and y, and the height, z. If these values are given in geographical co-ordinates or in a reference specific system for the model, the resulting position depends on the visualisation system used by the software. Important: for every 3D representation, the complete set of co-ordinate values must be known to create useful views.

To specify camera geometry, it is necessary to fix the viewing direction as horizontal component, the viewing angle (tilt angle) as vertical component, and, of course, the field of view. To complete the geometry elements, we also need to know the position of the target point – in the central perspective mode – and the potential rotation angle along the pitch axis. Finally, although it is not a true camera parameter, usually a magnification factor can be chosen to frame an enlarged portion of the map for rendering.

To move the camera, special dynamic variables need to be considered – for example, the ground speed for positioning or the acceleration and deceleration components of the movement. These settings are important for creating movies and other animations that depict 3D maps.

Lighting and illumination

Lighting and illumination aspect groups offer a large numbers of variations, especially for the representation of scenery (fig. 11). The type of lighting must be chosen very carefully because of the overall impact on all integrated objects. Whether a model is illuminated with direct light (similar to that of the sun), ambient light, or artificial light (using directional light, spot lights, or reflected light), the effects are entirely different. And, like camera geometry, the light geometry, consisting of position, angle, and direction variables, is an important consideration. The horizontal direction and wave angle of the light beams also influence illumination within the entire map scene. As for bundled light beams, the angle of the cone enables more naturalistic cast shadows of objects in the final rendered image.

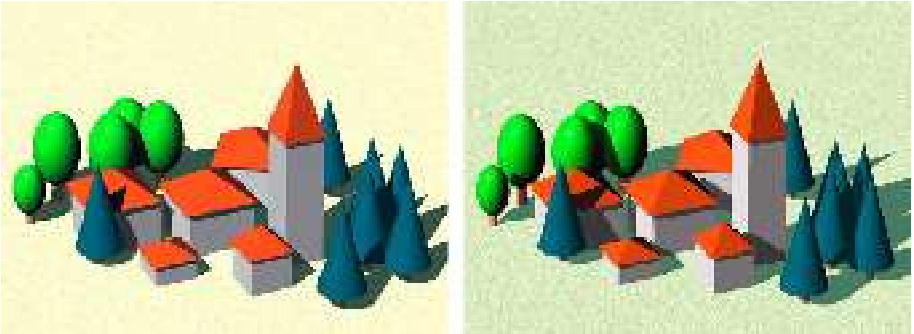

Figure 11: Different effects of light geometry and intensity in a 3D model scene: steeper light incidence and white light (left), flatter light incidence and more yellow light (right).

Shading and shadows

As mentioned earlier, shading aspects give life to a 3D map. Landscape cognition is strongly influenced by the interaction between lighting and shading. Without the combined effects of light and shadow, and the intermediate shades between these extremes, the 3D scene would not be perceived as virtual landscape. When making detailed views, minor shadows cast by objects and the terrain could have great beneficial impact (fig. 12). The effective appearance of shading in the rendered image depends on different mathematical algorithms. And like the aspect group of lighting, different grades of intensity and sharpness can be used to create more informative and intuitive representations.

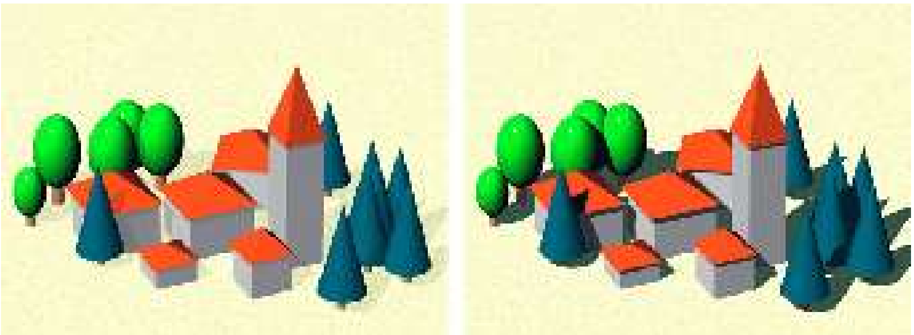

Figure 12: Different effects of shadow modelling in a 3D model scene: cast shadow intensity 10% (left), cast shadow intensity 100% (right).

Atmospheric and environmental effects

The last group of graphic aspects, atmospheric and environmental effects, allows for simulation of atmospheric and environmental effects in 3D visualisations (fig. 13). These effects give us a bridge to perceive 3D maps in a more naturalistic depiction, rather than as an abstracted map representation (Terribilini 2001).

Figure 13: Section of a topographic 3D map of the Ticino Mountains, Switzerland with integrated atmospheric sky and haze effects (Terribilini 2001).

5. Conclusions and future developments

For the authors of 3D maps, a large variety of graphic aspects exist. And, as in the generation process for 3D maps, we can distinguish different groups of graphic aspects. Graphic aspects of modelling define the basic object structures and semantics in the data base. Graphic aspects of symbolisation designate the appearance of objects in form, colour, line-style, and other visual characteristics. Finally, the graphic aspects of visualisation arrange all the settings for the final display of the 3D map scene on different output media (fig. 14). With each graphic aspect, a large number of variables can be differentiated. A specific variable represents a unidimensional input with two or more possibilities of variations. Every aspect with its variables and sub-variables has a different impact on the 3D map. If or how much we consider the single aspect is dependant on the use and the content of the map.

Figure 14: Topographic 3D map out of the Internet application "Mount Hood Visualization" (http://www.karto.ethz.ch/dobler/mthood/) (Dobler 2002).

Unfortunately, for map makers today, cartographic theory and principles about 3D map design are almost nonexistant. To create informative and sophisticated 3D maps, design guidelines should be formulated based on cartographic principles and research. Using these guidelines as a starting point, map authors can organise their conceptual thoughts and even drafts for 3D maps. However, the guidelines should not stipulate strict design rules. Every 3D map is unique. The design aesthetics of the map author should not be limited unduly. The aim of 3D map design guidelines is to give cartographers additional stimuli to generate informative and useful representations, ultimately benefiting the map user.

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