Design Issues with 3D Maps and the Need for 3D Cartographic Design Principles

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Abstract

Design issues regarding the presentation of geographical information in a three-dimensional perspective are varied and complex. This paper looks at some of issues of 3D mapping stemming from its rapid development as a cartographic tool, its growing popularity and accessibility amongst users, and the 3D cartographic principles proposed to manage the design and presentation that are not covered by traditional cartographic principles.

Introduction

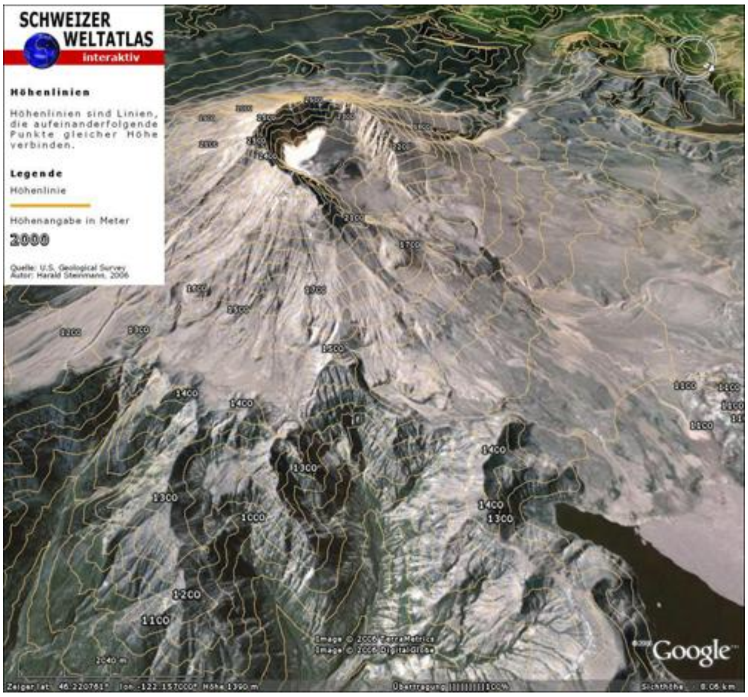
Multimedia cartography has been propelled forward by the rapid technological advances for the capture, manipulation and presentation of geographical data, with most map products now being developed digitally. The quality and accuracy of data capture, data storage & manipulation capabilities, as well as the advancements in software, mean that a cartographer now has the ability to digitally create spatially accurate, detailed and high resolution three-dimensional maps and visualizations. The advent of Digital terrain or elevation models make available the presentation of geographical data in three dimensional space, and allowing precise modelling of not only x and y locations, but the z height creating a three-dimensional landscape.

In the case of three-dimensional cartographic mapping, there are many different applications that have been designed for the creation of 3D maps and visualizations, and the development of standards and guidelines in regards to the technical aspects of such models.

3D maps can be done in several different ways, each way creating a different representation of the landscape. 3D maps can be photorealistic, where the landscape is created to match the exact landscape, using techniques of overlaying ortho-photography over a 3D model, or can be “symbolistic”, where the maps are generalized and symbols designed to show object locations and information.

A problem with 3D mapping is there are currently no adequate standards or design principles in place to guide cartographers in creating functional, user friendly 3D maps, or knowledge of the unskilled map readers requirements, as most of the research on 3D map use has been conducted on experts in map reading (SCHOBESBERGER, D. and PATTERSON, T., 2007). For issues regarding symbol recognition, depth perception (differences in scale), atmospheric conditions, seasonal variances, viewing azimuth and illumination settings are all currently up to the individual, and how best to display the information the map is trying to portray. While standard cartography design principles still apply to this newer form of geographical representation, we need to look past the technical aspects of 3D model creation and focus on the subtler aspects that can enhance a users understanding and comprehension of a landscape depicted in a three-dimensional view.

Below is an example of how a mountain can be taken from 2D topographic map with contours to a 3D perspective presentation to give the user a greater understanding of the landscape that the 2D map doesn’t offer.



Steinmann 2006 cited in Haeberling & Jenny 2004

Popularity of 3D maps

As computer technology and storage of data has improved enormously over the past few decades which allows the creation of high-resolution, aesthetically pleasing and often dynamic and interactive map products (Haeberling, 2002)(Bandrova, 2005). For this reason, it is expected that 3D images will dominate the visual landscape of mapping (Zlatanova & Bandrova, 1998).

Perspective view representations (as opposed to orthogonal view), are more commonly known as three-dimensional or 3D maps, are one such product that can be created, using varied 3D modelling platforms and software to manage and transform spatial data, to display standard location information and adding the extra dimension of height (Petrovic, 2003).

A wider range of users, from young students to highly skilled specialists in various sciences and practices have better understanding due to the realism displayed in 3d mapping (BANDROVA, T., 2005).

When viewed from a perspective, geographic information delivered in 3d can enhance the users understanding of the spatial relationships between features by being a more realistic view and more similar to natural landscapes, simplifying the information and creating a less abstract view of the world than a traditional map (HAEBERLING, C., 2004). Also, height information no longer needs to be derived from contour lines or shading, so there is less confusion for the user trying to decipher the heights (Buchroithner, 2002 as cited in (CARTWRIGHT, W. et al., 2007)).

3D modelling and mapping are being used by an ever increasing and varied range of consumers, for such purposes as diverse as city planning and architecture, design and advertising, utility management (e.g. Sydney Underground), transportation and tourist maps (see figure 2 below). The 3D offers opportunities for data analysis not available on 2D representations (BANDROVA, T., 2005)

Fig 2 - 3D Tourist map from OnionMaps.com

When comparing cost effectiveness of 3D maps to 2D maps for hikers on trails in Zion National Park, Schobesberger and Patterson (2007) found 3D maps allow a person to more accurately ascertain their position on the landscape, and were better interpreted by younger people and people who did not have English as their first language, giving the impression that the 3D maps create easier understanding of the landscape.

Design Issues in 3D Mapping

There are three processes that are common to all maps, reduction (determining scale), selection and abstraction of features, and symbolisation (ELMES, G., 2005) and this is taken further for 3D maps by Haeberling (2002), who adds visualisation and modelling of the raw data via a Digital Terrain Model (DTM).

Cartographic principles for classical mapping (2D) were created many years ago as a foundation for successful map creation (HAEBERLING, C., 2002)utilizing Bertin's visual variables (as cited in Haeberling, 2002), that suggest what elements a map should contain, what should be left out, and how features should be generalized to display relevant information to the user in a clear and efficient manner(PETROVIC, D., 2003).

With the advancements in technology causing 3D maps to develop at a rapid rate, there has been little time for determining guidelines for the design of and presentation of 3D maps. While many papers have been written about the technology and creation of 3D mapping products, no official design principles exist for 3D representations (HAEBERLING, C., 2004, PETROVIC, D., 2003, HAEBERLING, C., 2002).

While orientation is no longer really an issue for a 3D map, other factors can have a major affect on the way a 3D presentation is perceived, with recognition of symbology, annotations and 3D objects for the user being an issue. Other issues that can affect the usefulness of a 3D map are different levels of detail and abstraction, depth perception and a constantly changing scale.

3D maps can be created in several different ways and depending on the level of detail, this will cause an inconsistent image, and problems with generalization and symbology can occur. This is made more difficult due to the continuously changing scale (Bandrova, 2005).

Symbols are what differentiate a map from a model, providing the user with the required information, and according to a survey of 15 Bulgarian firms in the fields of GIS, geodesy and cartography, are a very important cartographic issue (SLATANOVA, S. and BANDROVA, T., 1998).

This observation and the lack of formally defined 3D symbol systems lead Bandrova to develop theory for creation of a symbol system that would standardize similar objects (e.g. street light) across a town, country, region or globally into a generic 3D cartographic symbol representation (BANDROVA, T., 2005).

When comparing 2D maps to 3D maps, a survey of map users hiking in Zion National Park found that although users found 3D maps better for understanding distances, topography and the environment, they had less recall of place names then they did with 2D topographic maps, suggesting that the symbology may have been inadequate (SCHOBESBERGER, D. and PATTERSON, T., 2007).

There is still not enough knowledge about the user's requirements of 3d maps. As with most cartographic products, it is imperative that the user's needs, skills and perceptions are understood, and cartographic principles are derived from that understanding. 3D map users' perceptions and behaviours are largely unknown, and this must be rectified to enable the cartographer to develop a successful 3D visualisation (Bandrova, 2005).

One other issue that can affect design issues is data quality and accuracy. Obviously x and y coordinates aren't going to change a great deal, but with minor shifts in terrain elevations the height of an object above the datum may change considerably, making the data inaccurate at the least and obsolete in some instances (DOBSON, M., 2009).

Issues such as viewing angles and illumination are especially prominent in a map such as the Sydney Underground (see figure 3 below).

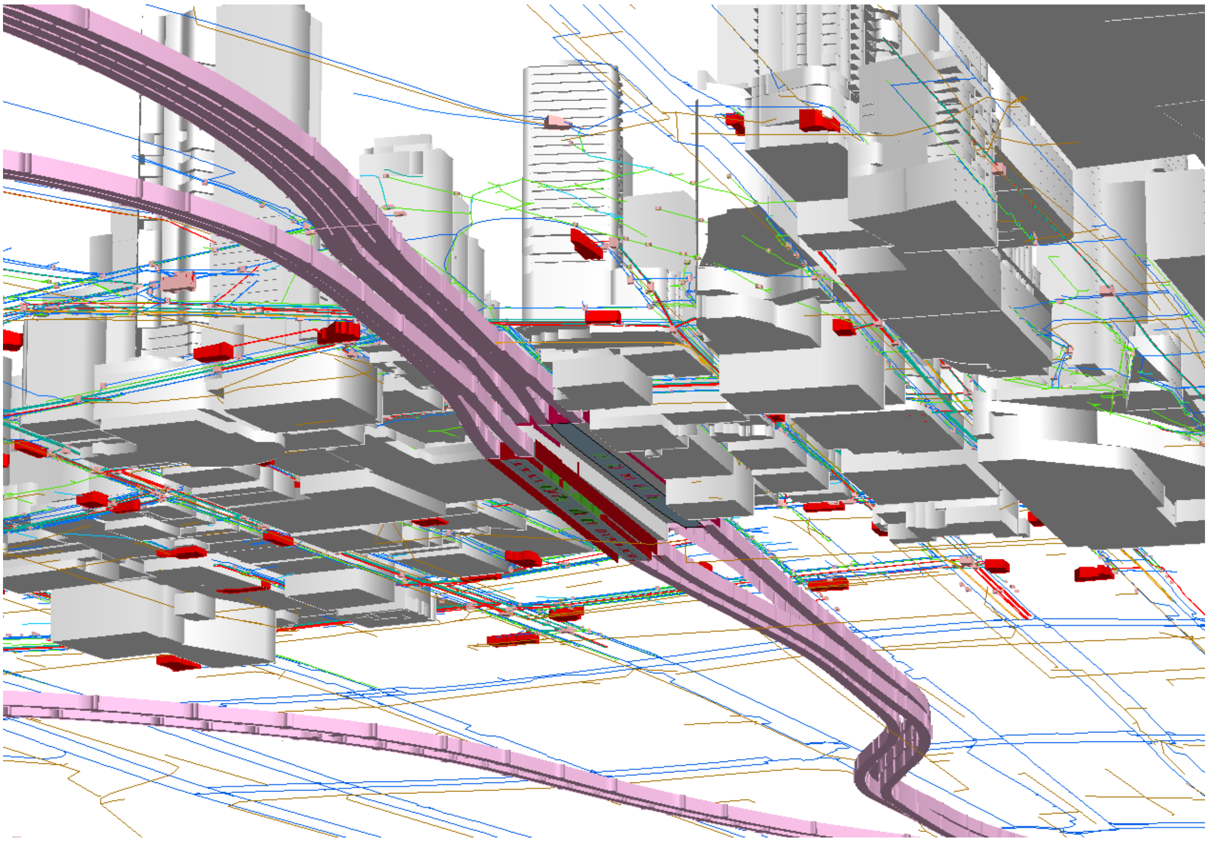


Fig 3 – Snapshot of the Sydney Underground 3d mapping project (Dobson, 2009)

Design Processes Improved with Design Principles for 3D maps

3D mapping lends itself to user oriented cartography, with the visualisation in a perceptive view removing some of the obstacles faced by standard map users, increasing the range of potential users who benefit from the similarities in the map and the natural landscape (Bandrova 2005).

Cartographers are used to designing maps with the guidelines provided by cartographic design principles, convention and rules (Haeberling, 2004). Maps have been made for many years before principles were developed, and have been made for many years since, and suggest the most efficient way to produce a map that best meets the user's needs. Comparatively, the concept of 3D mapping is still in its infancy, and as such there are no equivalent principles for this type of representation (Haeberling, 2004).

Haeberling (2004) suggests that along with traditional guidelines for visual variables, when designing 3D maps a cartographer must also consider additional aspects like perspective view, illumination, structure of three-dimensional space and possible effects for enhancement. Design variables within these aspects need to be used knowingly, and limited variables should be provided as a guide for the designer.

3D modelling software, such as Google Sketch UP, are now freely available to non-cartographers who may use the software for developing maps as well as regular 3D images (see figure 4 below). Users may not be aware of the elements that can transform a map from being a good visualisation to a practical and useful application, and having guidelines included in the software may assist them in better design of images and maps.

The Special Interest Group 3D (SIG 3D) have developed a standard for 3d models, called CityGML, that builds on the GML3 standard. It is a language designed for the storage, representation and transfer of 3D geographic information in complex and three-dimensional geo-referenced models and determines geometric and appearance information. Object's appearance, textures and relationships between objects all predetermined and standardised (KOLBE, T. H., 2007). The elements that make 3D maps an effective communication tool, such as symbology and perception, are still very much up to the individual.

Fig 4. 3D townscape developed in Google Sketch UP (ATTILI, W., 2005)

Suggestions for Design Principles

Assisting the cartographer in 3d map design is the optimal outcome and there are still too many new design possibilities that shouldn't be restricted by too stringent principles (Haeberling 2004).

Separately in 2004, both Petrovic (with Masera) and Haeberling have conducted research into the needs of users of 3D cartographic presentations to determine different aspects of the visualisation, and to establish a theory for the development of cartographic design principles for 3D mapping.

Ealrier in 1998, Slatanova and Bandrova conducted their own research on the use of symbols in 3D models, determining that symbology was required to add guiding information such as place names, landmarks and public information (BANDROVA, T., 2001). Below are the steps that Bandrova developed.

1) **The symbols should be similar to the real objects, which are represented in 3D map.**
2) **Minimum polygons should be used when a new symbol is built.**
3) **The symbols should be created in their real dimensions.**
4) **The symbols are designed for different purposes depending on user's needs.**

Petrovic and Masera concentrated on the effectiveness of 3D maps in delivering information, such as distances between objects, orientation, feature recognition and symbology, and compared it to user's experiences with a topographical map of the same area.

Most of the respondents identified as regular map users (95% used maps in spare, 57% for work), with more than half of those were mountaineers as a recreational activity. As a result, most stated that topographic maps at the 1:25,000 scale were their favourite, followed by mountain maps and road maps. As expected, they preferred the 3D model that had the topographic map overlayed for measuring distances and was familiar to them, but they preferred the 3D symbolic map for recognition of objects over the other two maps, even though they were used to symbology on the 2D topographic map. Petrovic and Masera state that their research shows that cartographers can't always follow the opinions of map users to design their maps, they need to be able to teach users about new map methods and representations and their uses.

Haeberling's research focused on the design aspects of the map, concentrating on the two main aspects of 3D design, abstraction and dimension. Within each step of the 3 stage design process of modelling, symbolisation, then visualisation, Haeberling assembled an inventory of design variables relevant to the concepts of 3D maps.

The results of the trial has lead to Haeberling developing a set of cartographic design principles for 3D mapping that focus on the three stages of design, i.e. modelling, symbolization and visualisation.

Haeberling's Proposed Cartographic Design Principles for 3D Maps

The following outlines the cartographic design principles for 3D mapping proposed by Christian Haeberling following his research. He has suggested 19 design principles, looking at not only his results but other research done by Petrovic & Masera, Jobst and Buziek (HAEBERLING, C. et al., 2008)

The 19 principles have been broken down into more specific categories that relate to the different design aspects in the 3D map design process. These principles are all designed in regards to the 3 stage design process mentioned earlier, with a large focus on the symbolization of objects.

What's good about Haeberling's principles is that they suggest guidelines for successful symbol production which is an area of 3D mapping that has had little development and no defined system for symbol creation in 3D mapping. As Bandrova (2001) stated as yet there are no suitable guidelines in place for 3D symbol design but an urgent need for 3D symbols.

As well as proper symbols for successful design of 3D maps, the other visual elements play a very important role for effective communication of landscape and terrain to the map user, and 3D mapping has been around for many years without the establishment of 3D cartographic design principles.

3D Mapping Without Principles

Although there are many issues relating to the design of 3d cartographic mapping products, especially making a generic convention that can relate to all aspects of 3d mapping and modelling, there have been a number of very successful applications of 3d mapping that have not relied on defined principles. Classic examples of 3D maps that have been created without Haeberling's principles (created since the 1960's) are the ski resort maps that depict the mountains and ski runs in a 3D perspective. These maps have been developed over the years in a number of ways, firstly by painting or illustrating the images, using topographic maps and aerial photos for thematic and elevation data, and later with the advent of DTM's and computer rendering (TAIT, A., 2008).

It is interesting to note that these maps seem to follow the principles proposed by Haeberling for 3D maps, as in the example of James Niehues below (figure 5), showing the haze for depth, azimuth angle, hill shading (shadows) from a consistent source of illumination. Many of these map makers, from the pioneers like Hal Shelton, through to Bill Brown and James Niehues, already apply these type of principles to their landscapes.

Fig. 5 James Niehues 3D panoramic vision of Crystal Mountain (NIEHUES, J., 2009)

Bernhard and Stefan developed their website for Cartographers to develop their skills and knowledge about relief depiction in mapping that teach these techniques so therefore have created their own set of rules for 3D design. The rules cover design topics that have been covered by Haeberling's principles, but the major difference between the two sets of guidelines are that Haeberling details the symbolization aspects of 3D map objects.

Roger Smith, working for Geographx, developed a 3D dynamic map of New Zealand's backcountry, an area known as paradise, using software they developed.

Fig x. 3D Virtual Model of Paradise, NZ (permission requested)(SMITH, R., 2008)

While it looks obvious from these images that there is a general understanding of the principles surrounding 3D map visualization, these images were created by dedicated cartographers who have been trained and developed their skills over time. The principles that Haeberling is proposing are more to do with developing cartographic theory in this regard, and to create guidelines for future map makers that are not so skilled, as the shift toward user-developed maps becomes greater.

Conclusion

As 3D maps can be created to different levels of detail, and different accuracies and generalizations, there needs to be some guidelines or principles that give the cartographer a base from which to develop their map. 3D mapping lends itself to very artistic and creative designs, and without guidelines can get very confusing and miss the main point of the map, which is to convey geographical information.

All mapping relies on understanding the requirements of the end user and the objectives of the person or company who commissioned the map as to what they want the map to display, as well as following established cartographic rules that define good map creation.

The guidelines that have been shown here will go toward helping the professional develop successful 3D maps and do highlight the need for more study to be done on the user requirements of such maps.

As far as the creation and design of 3D presentations, there are already guidelines, techniques and standards developed that influence effective design in regards to rendering, illumination, exaggeration / abstraction, generalization and viewing azimuths.

Symbology is the bigger issue in regards to 3D mapping as shown by the studies on users, both industry experienced and regular users that recognize the importance of successful communication of information to the reader, and not just an impressive representation of the landscape.

3D cartographic design principles are still in their preliminary stages, with a lot more research needed into their effectiveness and appropriateness for the 3D cartographic community and the map users. With many unskilled map makers having access to mapping and modelling software it will be a difficult process to establish guidelines for fundamental map design aspects, but at least for trained cartographers it will give them a better understanding of the techniques and requirements for this branch of mapping.

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