

Visualising thematical spatial data by using the third dimension

Jukka Matthias Krisp¹, Stefan Fronzek²

¹ Helsinki University of Technology,
Department of Surveying, Cartography and Geoinformatics
PO Box 1200, FIN-02015 HUT, Finland
jukka.krisp@hut.fi

² Finnish Environment Institute
Research Department
Research Programme for Global Change
PL 140, 00251 Helsinki, Finland
stefan.fronzek@ymparisto.fi

Abstract. In this paper we examine the visualisation of multiple variables in thematic maps by using the third dimension. Three cases illustrate the potentials and limitations for three-dimensional visualisations of multivariate datasets. After examining these examples, we reflect what should be considered carefully when creating this kind of maps. Maps making use of the third dimension can help to visualise multivariate data and stress certain components of the information.

1 Introduction

Over the recent years various spatial datasets have been collected. This data can serve different purposes. In general, spatial data represents aspects of reality of for example land-use, constructions like housing or infrastructure. Using this data, we can create thematical data and relate spatial objects to each other. When used in a GIS environment, models can create various landscape scenarios and we are able to visualize them in two-dimensional, three-dimensional or even four-dimensional. If we want to visualise spatial data with more than one variable our task leads to the following question - Can we visualise thematic maps with existing spatial data by using the third dimension?

The use of a two-dimensional representation has generally been performed by delineating “objects in the plane” or “fields of observation” (Goodchild 1990), specifically the mapping of spatial extent (Raper 1992). In mathematics dimensions are defined as the number of directions to which an object distends. A line is one dimensional, because it only includes a length. An area has two dimensions - length and width. Types of two-dimensional spatial objects or fields and the operations, which can be carried out on them, are explained by Burrough (1986), Arnoff (1989) and Rhind and Mounsey (1991). Typical examples would be land parcels, coastlines or point clusters which are readily handled in a GIS with an X and Y coordinate

system. A body has three dimensions because it adds a height to the area. These dimensions are topological dimensions. Adding a fourth dimension like time would exceed these topological dimensions. Also a human being or an animal could be described as four dimensional, because it includes a length, width, height and distends in time. In general all spatial objects have a topological dimension. Data about these objects can include a timestamp and that enables us to visualize them including a fourth dimension.

Using three-dimensional visualisations is used mainly to explain measurements that have a third dimension in “real-appearance”. For example a digital elevation model (DEM) or heights of buildings are visualized three-dimensional. From crude symbols to exquisite shading, cartographers have long thought about the ideal way to show landforms on a flat map (Swanson 1999). The concept of three-dimensional thematic maps is not new, but we can find only very few examples. Generally these are three-dimensional illustrations using a single thematic variable. Numerous examples can be found in which an overlay image (e.g. a satellite image or an aerial photograph) is draped over a digital elevation model. Much of cartography’s familiarity with three-dimensional landscapes originates from the research and artistic achievements of Imhof (1981) and Harrison (1944). Their traditional works (panoramas, sculpted physical models and orthographic globes) are highly aesthetic, compelling readers to pause and explore spatial relationships within a landscape (Patterson 1999). The fundamentals to design “classic” three-dimensional visualisations, using greyscale DEMs, vertical exaggeration and illumination are explained by Raper (1989) and Petterson (1999) among others.

With this paper we would like to explore the possibilities and limitations of a three-dimensional visualisation for multivariate datasets. Our approach is to select cases of thematic maps that visualize variables by using the third dimension. These variables do not represent a real topographic height (e.g. a digital elevation model or the height of buildings) but they embody thematic data.

2 Cases of three-dimensional visualisations

To illustrate our approach we have selected three examples to show possibilities of visualising multivariate data. In these examples, one variable is shown as z value in the third dimension; a second variable is shown with different colour shading. Generally it is difficult to find thematic maps that visualise variables three-dimensional. We have selected these examples, because they demonstrate three-dimensional visualisations of a polygon layer (case 1), a combination of two regular raster datasets (case 2) and a combination of polygon and line layers (case 3). The third case illustrates one variable “usage” (for polygons and lines) that has two meanings. They represent landuse classes (like forest, fields, roads, etc.) and “ecological barriers” defined as obstacles to animal movement based on the landuse information. We intended to use the third dimension to include both of these aspects.

2.1 Case 1

An example by Swanson (1999) shows the centre-pivot irrigation systems sighted in the counties of Nebraska between 1972 and 1988. This is one example of multiple variables (administrative area, centre-pivot irrigation systems sighted), which are represented over time by using the third dimension. It uses a three-dimensional prism map to illustrate the number of centre-pivot irrigation systems sighted in different administrative areas, which are represented by different colours.

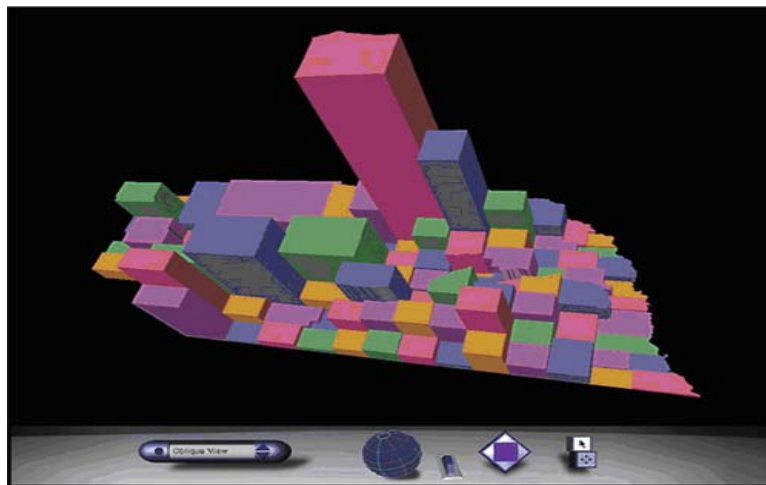


Illustration. 1. The animating prism map as it appears in a Web browser using the Cosmo VRML plug-in. It shows the centre-pivot irrigation systems sighted in the counties of Nebraska between 1972 and 1988

The intension of the author in this case was to show the technical aspect of distributing three-dimensional maps by using Virtual Reality Markup Language (VRML) code. The distribution for this kind of maps is still a problem. To make screenshots and distribute them undervalues the possibilities for this kind of maps and includes risks. In this case certain blocks get hidden behind others and the information is lost.

2.2 Case 2

A second example is the combination of two datasets acquired from the Baltic Drainage Basin Project (BDBP). It is a multi-disciplinary research project under the EU 1991-1994 Environment Research Programme. It was developed as joint effort between the Beijer Institute, Stockholm, Department of Systems Ecology, Stockholm University and UNEP/GRID-Arendal. The data provided by the BDBP is free of charge¹. We have selected two datasets for the southern part of Finland. They consist of a grid (1 km x 1 km square pixel) with cells containing information about land cover and a second grid with the same cell size holding information about population

¹ The data can be downloaded at: <http://www.grida.no/baltic/htmls/arcinfo.htm>

density. The land cover has been classified into water, coniferous forest, deciduous forest and build-up areas. To visualise these to variables we used the third dimension to show the population information and different colours for the land cover areas.

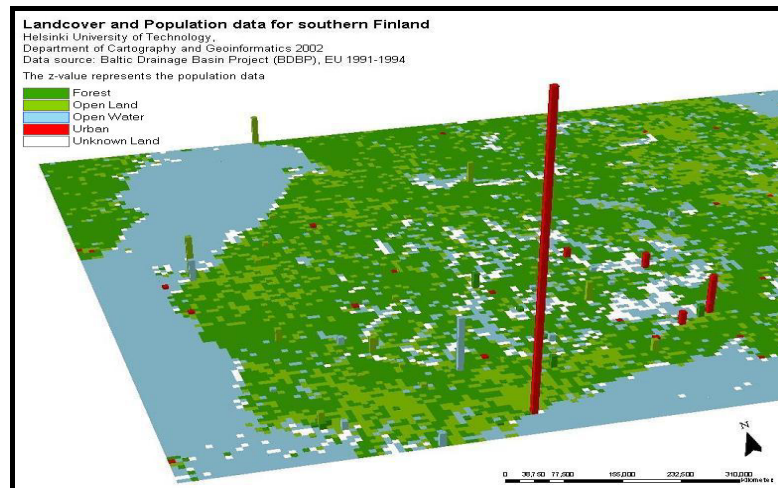


Illustration 2: Landcover and Population density in southern Finland in 1994

We choose this as an example of a thematic map using two variables. The map indicates a very high population density in the grid cells of Helsinki, while the rest of southern Finland remains sparsely populated. The information in the two datasets (both from the BDBP data) does not fit together logically. For example, when visualising the data together the grid cell in the city of Tampere (North-West of Helsinki) indicates a high population in the water (light blue). Since the city is build between two lakes this might be the correct classification for this grid cell, but contains a logical error since people do not live inside a water area. These errors are difficult to spot, because they do not influence the data properties. This represents a general problem in combining raster datasets to visualise multiple variables. Even datasets from the same source, that are in the same data format, projection and coordinate system, which are generally intended to be used in data combinations, contain logical errors.

2.3 Case 3

The third case is showing a map for the Finnish city of Jyväskylä with ecological barrier in different visualisations. Ecological barriers indicate the barricade effect on animal movement for different land cover types. The concept of ecological barriers has been described by Väre (2002). In this study the “land use polygons” and “line data” have two meanings. They represent “real objects” (like forest or roads) and “ecological barriers” and “ecological barriers” defined as obstacles to animal movement based on the landuse information. By using the third dimension we can visualize both of these aspects in the same time without overloading the map and we are able to stress the barrier information.

Illustration 3 shows the two-dimensional map of Jyväskylä from the Institute of Cartography and Geoinformatics 2002 using data provided by the city of Jyväskylä (2001). Colours are selected freely as a suggestion for a map design. The numbers in the map indicate the barrier effect value of every specific polygon and line. The values are taken from a research about the ecological barrier effect by Krisp (2002). No other annotation has been added to this map.



Illustration 3.: Two-dimensional map of Jyväskylä, Finland including the ecological barriers effect as values

The following illustration 4 visualises as well both of these variables (the visitors map and the ecological barrier effect). In this case barrier values are used as z-values to give the model a third dimension. The illumination is set with the azimuth to the North West (315 degrees) and the altitude of 30 degrees to provide a sufficient shadow for all objects.



Illustration 4: Three-dimensional map using an ecological barrier assessment as z values

In illustration 5 the perception of the barriers is stressed by using the different colours. We used the same classification for the colours as we did for the z values. To change the colour settings can help to stress the ecological barrier effect that is intended in this map. The range of the colours is set from green indicating low barriers to yellow to red for high barrier values. Polygons and lines with the same barrier value have the same colour.



Illustration 5: Three-dimensional using an ecological barrier assessment as z values with the same barrier classification for a colour range from green-yellow-red

Modelling barrier effects three-dimensional can help to identify ecological corridors, networks or bottlenecks that might be underestimated in the two-dimensional visualisation. In addition to that it can help to provide appealing visualisations that can be understood easily, to encourage the public to participate in the development processes. Thereby it can also be used to integrate this subject within the planning procedures for new infrastructures.

The barrier values can change over time, which can give this model a fourth dimension. For example the barrier value of a lake can change over different seasons. In Finland lakes are frozen during the wintertime, so they have a low barrier effect on animal movement. To visualize this change over time we can create a series of models and visualize them over time creating in an animation. In addition to their ecological barrier value every spatial object has an influence value that depends on its impact on other spatial objects. To measure and visualize this value as a potential fifth dimension could be investigated in further research. These models can be useful for creating “What if” scenarios that can help us to predict changes in the research area, for example the impact of a new road on its environment concerning the movement of animals. Thematical relationships of these objects interact and influence each other. In some cases we might be able to measure this influence. For example, the modelling of ecological networks shows that certain spatial objects have a very strong impact in the movement of animals, while others are less important. This “influence” also can change over time. An object distends in topological dimensions (length, width,

height), time and “influence” in a defined spatial area. It is a more artificial variable that can be measured only by “soft” indicators, but according to the mathematical definition the “influence” can be described as a fifth dimension. To model the influence of each spatial object on its environment is a challenge for cartographic representations.

3 Results - General settings for a three-dimensional map

When constructing three-dimensional visualisations, it is important to carefully choose the 3D settings. Most GIS software tools, for example ESRI®'s ArcGIS including the 3D analyst extension (that contains the ArcScene module), offer extensive possibilities to change these models. We point out the following settings that should be considered carefully when creating visualisations using the third dimension.

- **The view of a three-dimensional map**

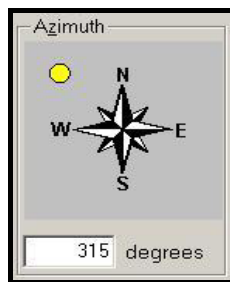
The view is the position from the point the user is looking at the three-dimensional map. In a three-dimensional model, the user can control its position by changing pitch and roll values. That enables the user to navigate through the model. If the three-dimensional map is presented on paper or as a screenshot, the position is fixed. In this case it is crucial to find an optimal viewing position to make use of the three-dimensional component. The optimal viewpoint should center the part of the map that contains the information of interest for the user.
- **The extent**

Rising or reducing the extent of a three-dimensional map can be a useful way to remove inappropriate information. A smaller extent of the map might also save computing power and increase rendering performance.
- **The vertical exaggeration**

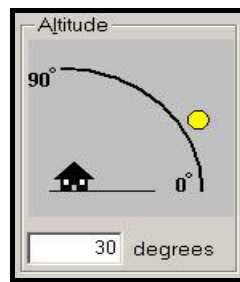
The vertical exaggeration can be used to emphasize the variable that is visualized in the third dimension. This is useful in creating visualisations where the extent does not vary significantly. A limit can be used to flatten surfaces or features that have extreme vertical variations. As shown in case 2, the population in Finland concentrates in the Helsinki area, while other areas seem to be sparsely populated. In this case it might help to flatten the vertical exaggeration. Then the population significance of the Helsinki area could be decreased. Generally the vertical exaggeration is applied to all objects in a map in the same way, i.e. all objects are increased or decreased in their vertical dimension. By choosing an inappropriate vertical exaggeration for prism maps, certain blocks can be hidden behind others and the information is lost as shown in Case 1. Small administrative areas are hidden behind large blocks. To reduce the vertical exaggeration would make all areas visible.
- **The illumination (including azimuth and altitude)**

Additionally we are able to set the azimuth and altitude of the light source, as well as the amount of contrast, used in rendering the illumination of the scene. As shown in illustration 6, the azimuth is the angular direction of the

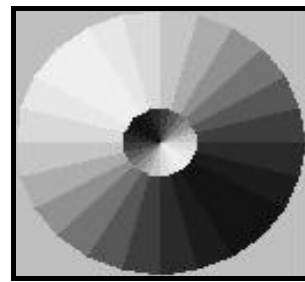
sun, measured from north in clockwise degrees from 0 to 360. An azimuth of 90 is due east. Commonly the default azimuth is North-West (315 degrees). The altitude is the slope or angle of the illumination source above the horizon. The units are in degrees, from 0 (on the horizon) to 90 degrees (overhead). Normally the default is 45 degrees. Generally the illumination properties for three-dimensional maps apply to all of the objects (including extruded polygon and line features) that are presented in the visualisation.



The illumination source is set to the North West (315 degrees)



The illumination source has an altitude of 30 degrees to provide a sufficient shadow for all objects



Preview result of the sample settings (azimuth 315, altitude 30)

Illustration 6. Sample of properties for the Illumination settings in a three-dimensional scene

What are the advantages or disadvantages of using the third dimension in visualisation? To visualise two variables in a two-dimensional map (e.g. by hatching) one can easily reach its limits. Unlike a two-dimensional map a three-dimensional map can include two raster grids at the same time and they can be displayed in one map (as shown in case 2). By doing this, the map can include more information. In addition to that the three-dimensional map might be more interesting for certain target groups. Nevertheless there is the risk of overloading the map. Users might not be used to look at three-dimensional maps and the brain has to process the height and the perspective as additional parameters. According to Schlosser (2002) the use of the third dimension in thematic maps would be something completely different. Nearly everyone has seen a "normal" two-dimensional thematic map (e.g. presenting crime-rates, health or market potentials). Three-dimensional maps get more attention because they are different.

Bivariate maps show two variables at once and enable us to visually analyse correlations e.g. between income distribution and crime incidence (Schlosser 2002). In cases like the visualisation of barrier effects (case 3) the perspective view of a three-dimensional map can assist to create a view closer to "reality", i.e. the abstract meaning of the thematic variable as a barrier is visually translated into heights and thus helps the user to interpret and understand it better.

However, a perspective view distorts angles and lengths in the map. That makes it difficult to use the map for measurements. An interactive software tool can enable the user to e.g. change the viewpoint and explore the data from different angles. Paper presentations for these maps are problematic. The printed form might cause confusion

to users, which could have difficulties to understand the perspective view. Presenting this map in digital format, either online or offline, offers users the possibility to interactively explore the map. In this case users can change the settings of the view. This makes it easier to investigate the representation.

The examples (cases 1 to 3 above) show possible applications of multivariable three-dimensional maps. Further potential applications include two-variable datasets that 1) are valid in the same spatial and temporal scales, and 2) whose combination offers the possibility to explore relationships and thus induces an additional meaning compared with analysing each variable separately. The two variables to be explored can either have a cause-and-effect relationship or they could represent two different aspects of a phenomenon. An example for the latter might be a climate map showing the annual mean temperature in different colours and the annual precipitation as the z value in the third dimension. An example for two variables having a cause-and-effect relationship is emissions of nitrogen oxide (NO_x) from combustion processes and nitrogen depositions; a three-dimensional map could show the emissions in different colours and the depositions in third dimension.

4 Conclusion

Generally three-dimensional maps offer the possibility to visualise the data in a different way, but the information included remains the same as in a two-dimensional map. The use of the third dimension can aid the visualisation of spatial datasets consisting of two thematic variables and allows comparing them more directly. It can also help to stress certain components of the information. Selecting and intensifying of specific parts of the information is especially important in the creation of thematic maps. Using the third dimension, with appealing colour combinations, has this effect. It might result in a confusing three-dimensional map that can be misunderstood or even not understood at all. When used in a proper way, the method can result in attractive visualisations that stress the message of the map for the user. In this case the message in these visualisations can be understood easily.

References

- 1 Aronoff W.H., GIS: a management prespective, Ottawa 1989
- 2 Burrough P.A., Principals of geographical information systems for land resources assessment, Oxford 1986
- 3 Cartwright W., Peterson P., Gartner G., Multimedia Cartography, Berlin 1999
- 4 Goodchild M.F., Geographical data modelling, Proceedings GIS Design Models Meeting, Leicester 1990

- 5 Harrison R.E., Look at the world, The fortune atlas for world strategy, p.1-67, New York 1944
- 6 Imhof E., Cartographic Relief Presentation, p. 173-185, Berlin, New York 1982
- 7 Kennelly P.J., Creating three-dimensional displays with ArcScene, ArcUser magazine 01-03, 2003
- 8 Krisp J., Three-dimensional visualisation of ecological barriers, submitted article to the Finnish journal of surveying science, Helsinki 2002
- 9 Patterson, T., Designing 3D Landscapes, in Multimedia Cartography, Berlin 1999
- 10 Raper, J.F., Three-dimensional applications in GIS, London 1989
- 11 Raper J.F., Key 3D modelling concepts for geoscientific analysis, in Raper - Three dimensional applications in GIS, p. 215-232, London 1989
- 12 Rhind D.W, Mounsey H.M., Understanding GIS, London 1991
- 13 Schlosser J., Presentation at the MapInfo User Group 2002
- 14 Swanson, J., The Cartographic Possibilities of VRML, in Multimedia Cartography, Berlin 1999
- 15 Turner, K. Three dimensional modelling with Geoscientific Information Systems, Proceedings of the NATO Advanced Research workshop in three dimensional modelling, Santa Barbara 1989
- 16 Väre S., The ecological network and the built up areas in fourteen towns in Finland – The application for master plan to notice ecological functioning of nature in land use planning, Greenscom conference 2000