From Flatland to Spaceland
Concepts for Interactive 3D Navigation in High Standard Atlases

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Abstract
"Moving from flatland to spaceland", this phrase aims at a development in atlas cartography, which represents a move from 2D maps to 3D representations. Navigation thus becomes a central feature of interaction. The concept of '3D thinking' in interactive atlas navigation results in user-friendly solutions, which allows for a smooth shift between 2D and 3D maps and for easy 3D navigation with no loss of orientation. 3D navigation includes processes of wayfinding and of motion. Starting with a simple camera model, we propose easy-to-use navigation modes for atlases. We also present a number of examples from the current test version of the «Atlas of Switzerland – interactive».

1 Introduction

From flatland to spaceland – what is the significance of this rather obscure message for atlas cartography? The idea of a new way of thinking spatially was first described in „Flatland", a novel written 1884 by Abbott (1950). The author describes a world in which people were used to see everything only in one or two dimensions. But one day they are getting in touch with extra-terrestrians from Spaceland, who are able to see, think and act in three dimensions. Acquiring and understanding this totally new concept, the flatlanders gain a lot of amplified sensations, particularly insight into spatial objects with their intrinsic characteristics.

The present situation in modern atlas cartography is quite similar: Interactive high standard atlases venturing into in many different fields, such as exploratory spatial data analysis, multimedia integration, vector and raster data visualization, and integration of time component by animation techniques. While those applications are mainly two-dimensional, atlas users increasingly are interested in solutions integrating topography and thematic layers including three-dimensional views and digital terrain or thematic models.

Navigation within maps and 3D views thus becomes a central and frequently crucial feature of interaction. The main goals of this article are:

- Introducing a general concept of *3D thinking* in atlas navigation
- Closing the gap in atlases between 2D (flatland) and 3D (spaceland)
- Providing easy access to effective navigation within a 3D environment.

The power of 3D visualization combined with well-designed atlas navigation tools will result in a greater range of visual and analytical data exploration keeping atlases competitive, and likely to attract new groups of users.

2 3D Thinking for Interactive Atlas Navigation

Technologically driven changes in digital cartography first of all means availability of new visual variables, new computational possibilities for representation and transformation, and increased levels of interaction between maps and users (Fisher et al. 1993).

From the point of view of modern atlas cartography this statement is still a matter of fact. In every one of the four main areas of atlas functionality – thematic navigation, spatial navigation, visualization, and analysis functions (Bär and Sieber 1997) – a great development potential is still ahead. The goal of atlas evolution on the level of these functionality groups is to smoothly increase overall complexity, which will result in ever more sophisticated forms of interaction and a dynamic user interface (Crawford 1990, Peterson 1996). In addition, high standard atlases need to emphasize the intensity of interaction, in order to become and stay competitive with other computer-based products. One of the most obvious and attractive fields where both of these goals – new forms or modes of interaction and the intensity of interaction – prevail, consists in the use and manipulation of the third spatial dimension.

But how can we make effective use of 3D (or rather 2.5D) in atlases? First of all, in order to reproduce a real "spaceland view" it is essential that atlas authors grasp a concept of three-dimensionality. This concept of 3D thinking should not only be preoccupied with genuine 3D data, but should also try to include all kinds of 2D data, functionality aspects and possible applications. Thus, the gap between the world of 2D maps and the so-called 3D maps (Häberling 2000) will be reduced.

Concerning the four areas of functionality mentioned above, spatial navigation certainly represents the key function, linking both worlds. 3D thinking for atlas navigation considers a 2D map as a continuous space, which is a priori multi-dimensional, and thereby open to 3D manipulations. Transitions between 2D and 3D maps are possible in both ways. 3D navigation in atlases is highly interactive but has to take into account some restrictions. This will be achieved by carefully watching the process of interaction design, in order to carry information straight to the user (Tilton and Karentz Andrews 1993). 3D thinking basically relies upon the same navigation concept for both 2D and 3D maps. One single set of shared navigation tools shall be applied to 2D and 3D representations, while an extended toolbox serves for accessing specific 3D manipulations. As a closed author-driven system, interactive atlases are well suited to consistently adhere to this concept.

Keeping in mind the underlying ideas of 3D thinking, two essential processes are focused upon in the following:

- Transitional process, shifting easily between a 2D and 3D representations
- Processes and methods for direct interactive navigation within a 3D map.

The implementation of both navigation processes is planned for the next version of the commercial product «Atlas of Switzerland – interactive».

3 Merging the Spatial Navigation of 2D and 3D Maps

3.1 A New 2D Map Navigation Space

When navigation is combined with 3D thinking, a 2D orthogonal map may be perceived as a special case of a 3D map. 2D maps thereby are gaining depth: common spatial navigation in atlases with its zooming and panning functions is now supplemented with rotation functions. This augmented interactive functionality (figure 1, left row), which is subject to some atlas-specific constraints, defines a new *2D map navigation space:*

- Zoom: Range according to map resolution (generalization) and data resolution. Amplified zooming (Brühlmeier 2000) is useful to switch from one data set to another in a close to seamless manner.
- Pan: Panning is unlimited; any point or area of interest in any zoom position can be accessed.

- Rotation: Tilting the map plane around the middle axis (elevation angle: 0°-90°). Full azimuth (0°-360°) rotating around a fixed center point is permitted. Roll needs to be avoided. Lettering of the map has to be kept on a separate layer. Rotation of the map (at least by the four cardinal points) is possible.

In this new 2D map navigation space, a fly-by situation is created, where navigation tools are no longer constrained to sliders, hand, and alphanumerical text fields or index. The scene is viewed from a camera position, using navigation metaphors like flight height and movement.

But how do we move from this still-flat 2D space map with its base maps and thematic layers towards a 3D space?

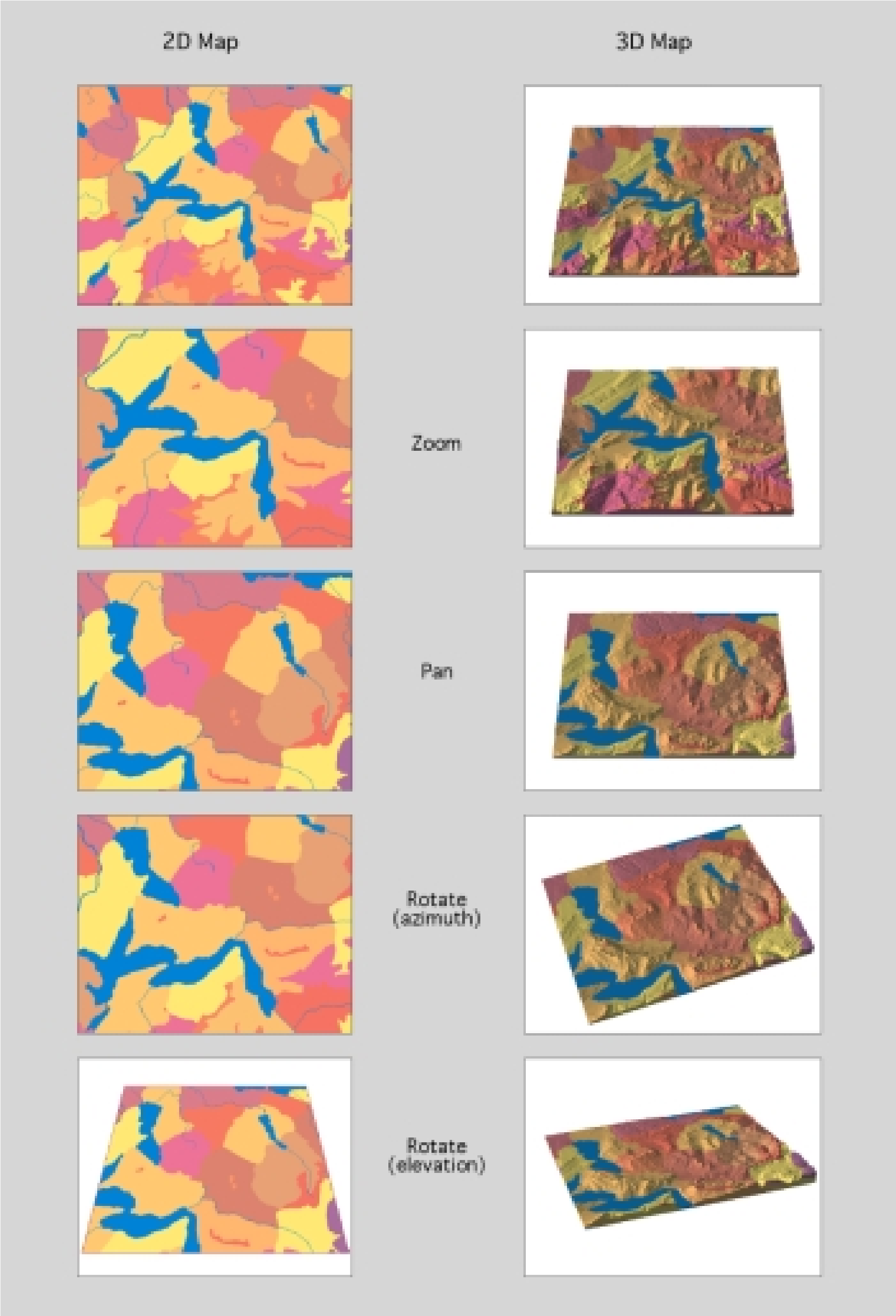

Figure 1. Shifting options between a 2D and a 3D map.

3.2 The Process of Transition

Transition from 2D to 3D is allowed at any starting position given by the 2D map's navigation space (figure 1). But it is most important to keep viewing conditions, e.g. the similarity of the map and the user's orientation in space (and other camera parameters) in a state of steadiness: the user must recognize in the 3D map his well-known 2D map enriched with 3D components.

A split-up of the process into several steps as described in chapter 3.3 is well suited to render this process of transition as clearly as possible. Transition may even be applied in a bi-directional way, shifting back from 3D to a 2D map. A mentally successful transition process leads to a more intense interaction and a better understanding of the thematic situation presented.

3.3 Transition Steps in the «Atlas of Switzerland – interactive»

The transition from two to three dimensions is starting from an orthogonal view of the 2D map. This map contains different base map layers in vector or raster format that may be switched on and off. One or two additional layers contain thematic information (c.f. regional biodiversity in figure 1). In order to interact with the same map content in a 3D setting, all of the thematic layers and a reduced set of base map layers must be overlaid upon the topographic 3D model. This substitution of the topographic 2D information (relief, contour lines) by a shaded 3D relief takes place within an orthogonal view. In order to avoid orientation problems, the orthogonal view of the 3D model is subject to the same viewing conditions and uses the same perimeter as the 2D map. At the same time, 3D navigation tools and the model's 3D information (georeferenced xyz-coordinates) are activated. The 3D map, basically a block diagram with parallel projection, is manipulated interactively around a fixed, centered rotation point, without viewing direction limitations. Zooming and panning is permitted, with certain restrictions due to data resolution and area limits. Another great advantage of 3D maps is that a number of shading effects may be achieved by changing the position of the light source (Atlas of Switzerland – interactive 2000). Switching back from such a manipulated 3D map to a 2D map means simply to choose the same theme in 2D from the menu panel. This action first of all brings the blockdiagram into an „upright" orthogonal position, since rotation of a 2D map is not yet implemented. 3D topography is then replaced by its 2D equivalent, and finally, the 2D interface is installed. As for now, this user-friendly switching automatism is only offered for themes that bear upon topography. Sure enough, merging 2D with 3D is an essential step towards applying 3D navigation to atlases.

4 3D Navigation

Hanson and Wernert (1997) define navigation "as the process of selecting a continuously-changing set of viewing parameters". As opposed to them, Bowman et al. (1999) divides navigation into "wayfinding (the cognitive decision-making process by which a movement is planned), and travel (the actual motion from the current location to the new location)". Merging both definitions we call the first navigation term *camera/user motion* – in the sense of "la caméra, c'est moi" – and then replace in the second definition *travel* by *motion.* Navigation is thus defined as the overall process of motion and wayfinding.

Since atlases are accessed by common desktop input devices (such as mouse and keyboard), some limitations have to be taken into account. A mouse handles two degrees of freedom and is used for quantitative input (may be used for the variable velocity). A keyboard deals with many degrees of freedom, particularly with qualitative input (i.e. a key either pressed or not).

4.1 Egocentric Navigation

When navigating through virtual space, we meet with countless possibilities and techniques. These may be grouped into exocentric navigation (object-centered, cf. *world-in-hand* metaphor) and egocentric navigation (*eyeball-in-hand metaphor*) (Ware and Osborne 1990). We are focusing on egocentric navigation, which implies moving a camera through the world either with a specific target in mind, or continuously.

Targeted egocentric navigation includes the following basic functions:

- Select from: discrete selection of the target (e.g. in a list of viewpoints)
- Go to: direct selection of the target in 3D space
- Look at: direct selection of a new direction; the position remains the same.

These basic functions may be combined with three movement modes (Russo Dos Santos et al. 2000):

- Jump: the user jumps directly to the new target. Lacking landmarks, the user may get lost in space, especially if opting *Select from*.
- Interpolated: an animated interpolated flight between the current and target position. If both viewpoint and direction change, the flight may become unpredictable.
- Path: the user follows a metaphor-based path like traffic systems or terrain shapes/elements. Reasonable paths are often lacking in geo-data.

In contrast, *unlimited egocentric navigation* (flying) is based on a camera model, which usually offers six or more degrees of freedom. Viewing a simple perspective camera model (figure 2) you are able to distinguish:

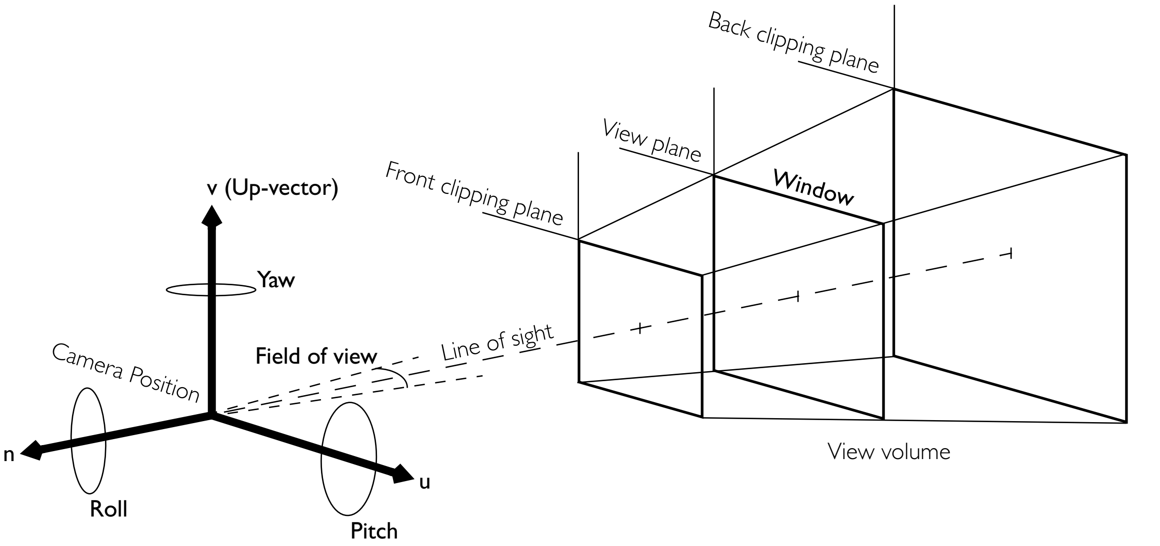

Figure 2. A simple perspective camera model with seven degrees of freedom.

- Translations into all the three directions of the camera coordinate system (n, u, v)
- Rotations around all the three axes of the camera coordinate system (yaw, pitch, roll)
- Field of view.

A number of user-friendly navigation modes may be defined in terms of the above camera model parameters:

- Pan: combining translations in u and v direction
- Zoom: modifying the field of view within a useful range
- Move: combining translation in n direction and yaw. Translation in v direction (like an "elevator") is a useful extension.
- Look around: combining yaw and pitch.

The combination of pitch and yaw (*look around*) results in a rolling effect and leads to an important outcome. Awareness of the vertical direction (Murta 1995) is a central issue concerning the user's spatial orientation. With regard to geo-data, a stable, horizontal horizon serves this purpose. Undesirable rolls may be corrected by modifying the orientation of the view plane (Huber 1999).

4.2 Interactivity and Continuity in 3D Navigation

3D navigation may either be *given* or *interactive, discrete* or *continuous.* The potential and the drawbacks of these four terms are as follows:

Navigation in the given sense (animation) is only useful, if the presented scenes have a clear purpose and are easily interpreted. Interpretation is supported by a good base map design, by adapted thematic overlay, additional visual cues (landmarks, labels) and adapted speed. This makes good sense if e.g. following a road or a railway track; the user can thus concentrate on the surroundings and on phenomena along this given path.

With *interactive navigation*, the user feels free to explore the 3D world. This causes some implications for both map authors and users. The information rendered available by the author must be ready for interpretation, and configured for the whole geographic area, not only for some points of interest. Useful and easy-to-understand constrained navigation modes have to be offered. The user is probably confronted with a bulk of information; it is his responsibility to filter and correctly interpret it and not to "get lost in space". Nevertheless, most users clearly prefer interactive navigation, because most of them want to freely explore a given data set.

Discrete navigation offers visualization techniques with a high resolution of the 3D models. It is dedicated to focusing upon areas of special interest or upon specific points of information within a given theme.

Continuous navigation due to technical limitations uses a lower resolution of the 3D model, but offers a new spatial experience by moving steadily or with varying speed through 3D space.

A combination characteristics results in four groups:

- given – discrete: e.g. Select from in movement mode Jump; index tool with predefined panoramas in the «Atlas of Switzerland – interactive»
- given – continuous: e.g. Select from in movement mode Interpolated; animation, movie.
- interactive – discrete: e.g. targeted navigation like Go to and Look at in movement mode Jump; 2D panorama navigation tool
- interactive – continuous: unlimited navigation (flying), and more or less Go to and Look at interpolated.

5 Interactive-Continuous 3D Navigation in Atlases

The average user of multimedia atlases has limited experience in 3D navigation and limited equipment. A user-friendly navigation therefore should be easy to get acquainted with by mere intuition. Restrictions safeguard a safe and stable orientation in space, by avoiding disorientation and "lost-in-space" situations.

In order to achieve these goals constrained navigation will be used. As discussed above the camera's degrees of freedom may be reduced and usefully combined. (e.g. *Move, Look around*). Additionally to camera dependent constraints model dependent constraints results in a steady navigation. Constrains include limiting navigation space:

- Camera position stays within model area boundaries.
- Factors like image resolution (geometry, texture, screen resolution) and cartographic features determine reasonable minimal and maximal height over terrain and preserve the user from collisions.

Velocity may either be constant, model dependent (e.g. height over terrain) or explicitly selected (discrete, continuous range); range is limited by reasonable values. Reasonable values lie between "ennui" and "overextend" of the user.

In the "Move" mode the camera moves in a plain. A modified model-dependent version called "Walk" substitutes the plain with a camera model field (Hanson and Wernert 1997). A simple model field for geo-data is defined by a fixed height over ground. A more sophisticated version uses a smoothed model field where the distance to the model is maximum over downs and minimum over mountains. Until now we have assumed that the camera is looking straight ahead. In the "Walk" mode the line of sight may be slightly modified, similar to the smoothed field. If the camera is rather close to the ground over downs it is directed somewhat upwards and in the opposite case slightly downwards.

The most promising modes integrating interactive navigation in the «Atlas of Switzerland – interactive» version 2 are:

- Targeted navigation: “Go to” and “Look at” interpolated by clicking on a point of the model
- Overview: continuous “Move” (highly over ground), and “Pan”
- To show details: any version of “Walk”
- On the spot: “Look around”

Figure 3. Series of pictures from a real time “walk” through a mountain valley (made with Geo3D; Huber 1999).

6 Conclusions, Trends and Future Developments

Integration of 3D navigation in high standard atlases for 2D and 3D themes seems an attractive and most promising way for atlases to remain competitive. Spatial navigation is described and executed in terms of camera parameters rather than by map- or model-oriented notions. Thus it is possible to create a fly-by situation for 2D maps, where navigation is only limited by map perimeter and resolution. The same set of basic navigation tools is used for 2D and 3D maps.

Taking into account that average users of multimedia atlases have limited experience in 3D navigation different modes of targeted and interactive-continuous navigation suit atlases best. Various modifications of the "Walk" mode are particularly promising.

A broad field of research and development is on the advance, starting from design questions with regard to user interface and navigation tools. The presentation or visualization of spatial data in 3D is also of great relevance: What kind of map object symbolization should be applied, with respect to different interactive navigation modes? Additional investigations are due into the field of information retrieval. The issue is to obtain a 3D exploratory environment with query and analysis functionality. Finally, we can imagine a move from 2.5D atlases towards real 3D (volume) for topographic and thematic features.

From flatland to spaceland – certainly one of the most promising ways to improve high standard atlases.

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