Hyperglobes – The use of virtual reality globes in visualizing global phenomena

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Abstract

The roots of globe research in Austria date back to the early 1920s. Years of continuous scientific interest in the topic have lead to the fact that, at the end of the 20th century, Vienna ranks with the principal centres of globe research in Europe. While globe research, however, has concentrated on material (real) objects up to the late 1990s, the present study is the first to include immaterial (virtual) objects in its studies.

At the turn of the second millennium, information industry is in a state of change. One field of cartographic expressions has – although known to everyone - been neglected in this context up to the present: the presentation of spatial aspects in the form of globes. Therefore, the present situation (technological developments on the one hand, globalisation on the other) suggests an urgent need for in-depth research into the topic of the representation of global phenomena and processes with (hyper)globes. The application of digital technologies should permit to eliminate or at least to minimise the existing disadvantages of material globes, while at the same time advantages can be maintained. The resulting product is a Internet-ready Virtual Reality based globe (hyperglobe) which - just as other cartographic products - is primarily a carrier of knowledge, serving decorative purposes only secondarily. (This paper is based on my thesis[Riedl 2000])

Introduction

Until some few years back, scientific research on globes has essentially been limited to historic globes and to the development of new manufacturing processes (e.g. plastic globes). At the turn of the third Millennium, and especially under the influence of digital and multimedia techniques, the methods of visualization on globes should undergo a fundamental reconsideration. Just as the traditional map is subject to change, the enormous amount of presentation possibilities also gives additional momentum to globe visualization. Particularly animation, interactivity and virtual reality have a potential whose effect is still hard to estimate. Virtual Reality systems are the key technology for digital globes. Only VR gives cartographers the opportunity to implement a globe in a digital 3D environment in which the digital globe appears as real existing object to the user, just like an analogue/physical globe. It seems that the abundance of possibilities is limited by the creativity of cartographers only. With the new reproduction methods, the question of the usefulness of ”globe production” is no longer primarily determined by economic factors. In the digital era, the production of a globe theme is finally science-based, i.e. dependent on its globe worthiness (suitability for the visualization on a globe) rather than on economic factors.

How suitable is a theme for a VR-based globe?

Not every subject is suitable for a globe presentation. The evaluation of how appropriate a theme is for being presented on a virtual globe could generally be called the theme's ”globe-worthiness”. The globe-worthiness is - among other things – dependent on parameters which were discussed by George Jensch [1966], Werner Stams [1966], Wolfgang Pillewizer [1970], Karl-Heinz Meine [1978], and in particular Fritz Aurada [1978]. In view of the possibilities, offered by a virtual reality system, the globe-worthiness of a theme has to be re-analyzed. The parameters and criteria for the globe-worthiness of a hyperglobe are:

Freedom from distortion – relation to the shape (geometry) of the celestial body:
Fritz Aurada [1978] points out that the dependency of globe-worthy themes on the shape of the earth must be so high that the disadvantage of representation by a globe, i.e. the loss of complete overview, is counterbalanced. Thanks to the possibility of observing the digital globe from more than one position at the same time (multiple presentation), this problem is of minor importance for virtual globes. Nevertheless, the dependency of the theme or of the question to be solved on the shape of the celestial body is of central importance even for VR-based globes. The range of applications covers for example illustrating the earth's shape, showing the effects of the inclination of the earth's axis, tracing the great circle between two points, or visualizing dynamic phenomena (climatic topics, ocean-currents...).

In order to be globe-worthy, the theme has to meet at least one of the following conditions:

- The question to be solved shows a close relation to the celestial body's shape (e.g. geoid).
- Only by using distortion-free globe illustrations causal connections will be recognizable and can be interpreted perfectly.

Global availability of data:
The theme to be represented must be a worldwide phenomenon and require a global representation. The global availability of data is a basic condition, but it implies no globe-worthiness in itself. Depending on the theme, a "worldwide representation" can in exceptional cases also be meaningful when the representation is limited to sea areas or landmasses. In order to make their causal connection obvious, such topics are usually shown in combination with others (see capability of combination further below).

Representation on small scale – possibility of interpretation in spite of a great amount of generalization
Although virtual globes are - in principle - hardly subject to restrictions regarding the scale, representations on small scale with a great amount of generalization will nevertheless predominate. The themes shown must retain their expressiveness also under these circumstances. It is even possible that only by emphasizing single aspects in highly generalized themes global connections become visible.

Capability of combination
It is downright possible that a theme is not globe-worthy on its own, but does make sense in combination with another theme, thus to a certain extent combination is required. This is particularly true for themes whose content is limited either to the oceans or to the continents. The combined representation however makes hidden relationships visible and thus lets them become understandable. Simple interactions like the toggling on or off of single topics open the way for a broad variety of combinations.

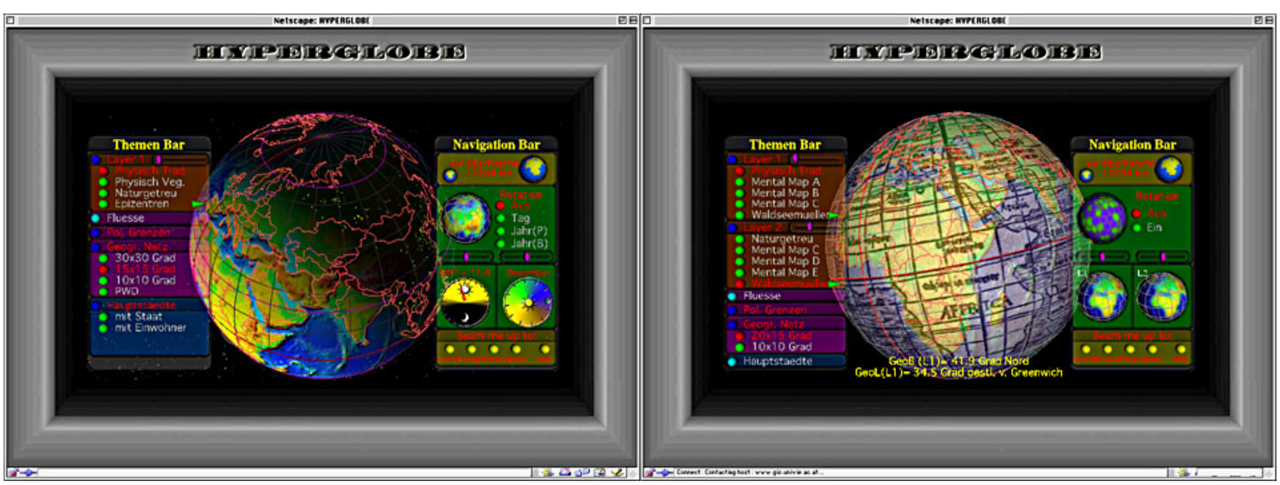

Fig. 1: Hyperglobe illustrating day and night (left) or studying historic globes (right) [www.gis.univie.ac.at/hyperglobe/html/]

The globe-worthiness of a theme - and thus the priority of a globe presentation over a map representation - is given when:

- The topic is tied to the shape (geometry) of the celestial body;
- Data are available globally;
- Greater legibility and a better interpretation are granted despite the small scale; and/or
- The combination of the topic with other themes represents a meaningful supplementation.

Particularly in the age of globalization (we are still at the point of its beginning), a global point of view is necessary to be able to better understand interweaving and interdependences. Virtual reality technologies permit the simultaneous illustration of different themes in a uncomplicated way. This stirs up the user's motivation to work with virtual reality based globes, and thus encourages the examination of global topics and their possible relationships.

Fig. 2: Hyperglobe illustrating epicenters, capital cities, solid of revolution (left) or GPS (right) [www.gis.univie.ac.at/hyperglobe/html/]

Which multimedia methods are suitable for VR-globes?

Due to the separation of display unit and data storage unit, various new geocommunication methods develop. These powerful presentation methods allow cartographers to implement dynamic information retrieval systems, whereby the active communication with the cartographic product and - in the case of hyperglobes - the interaction with a 3D-object in a virtual space become possible. This form of communication permits a completely new access to geographical information: The user can explore the world by experimenting with the globe in various ways.

Animating the virtual globe

As cartography in general moves towards dynamic visualization more and more, this will also have an impact on the globe presentation methods in particular. Animation as a form of time-dependent presentation adds an additional (fourth) dimension to the visualization of globes. When modeling a globe in VR-environments, cartographers more or less exclusively use a sphere as geometric base form (draped with materials/themes). Furthermore, at least one source of light and one camera/viewpoint are needed to make the globe visible.

With these three basic objects (sphere, source of light, camera/viewpoint) as a starting point, the **animation of the system "hyperglobe"** is based on at least one of the following cases or on their combination:

- Animation of the globe’s body, e.g. rotation of the globe - for the illustration of the earth’s rotation, day and night, the time zones.
- Animation of the light source (illumination), e.g. rotation of the light source around the globe - for visualizing the seasons, for explaining tropic and arctic circles, polar day and polar night.
- Animation of the viewpoint, e.g. moving the camera around the globe – for the simulation of space flights.

In principle all of the objects and parameters determining a virtual globe can be animated by themselves or in combination. For example, the following combination of animations is thinkable: first, animation of the theme of the globe’s surface (lightning in the course of a year) and second, animation of the source of light (simulating the seasons) to illustrate the connections between the frequency of lightning and the position of the sun. Generally, however, the animation of the internal and external parameters of a virtual globe is the central point of attention. This concerns two areas:

- Animation of the shape of the globe’s body
- Animation of the optical appearance (overlaying theme).

As far as the **animation of the globe’s surface** theme is concerned, two forms of representation can basically be distinguished:

- 2+1-dimensional animation (animation on the flat plane or on the spherical surface; a2), e.g. continental drift, ice ages in the process of history, climatic change (temperature, precipitation, clouds...) over a longer period, vegetation in the course of a year, change of the ozone concentration, routes of migratory animals
- 3+1-dimensional animation (animation in space/volume; a3), e.g. morphing (see figure below).

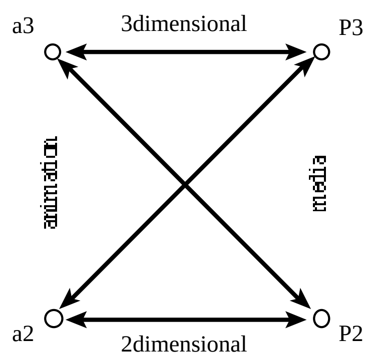

Fig. 3: Dimensions of animation and media for presentation

The **presentation** of the animation can take place via:

- two-dimensional medium (e.g. presentation as a movie; P2)
- three-dimensional medium (e.g. presentation in VR systems; P3).

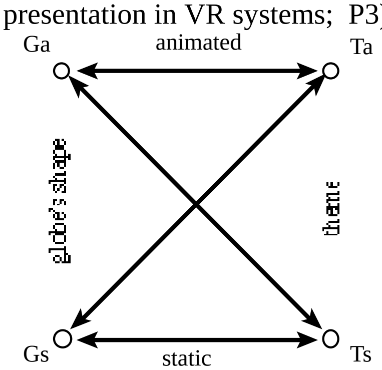

Fig. 4: Possible combinations of the globe's body and the theme (static or animated)

For digital globes, the types and representations of the animated phenomena as well as the presentation of the animation can be combined or fused. Most of the dynamic themes, for example, are prepared as an animated plane worldmap that is later transformed onto the globe body. The whole product is then stored and presented as an MPEG-movie. The result is a globe of the specification GsTaa2P2 (static globe body, with 2d-animation of the topic, presented by means of a 2d-medium). When the globe's body is animated, too, e.g. earth's rotation, then we speak of a GaTaa2P2-globe.

Morphing as a special form of animation illustrates the "conversion" of an original object into a target object in a continuous sequence by means of interpolated intermediate steps. Morphing would for instance be suitable for an illustration of the true shape of the earth or of the solid of revolution or for generating a relief globe with a freely selectable vertical exaggeration. Likewise, the flattening of the graticule in a plane map could be made understandable by means of morphing.

In view of the large variety of global themes with a dynamic nature, the application of animation is sometimes almost mandatory. Imagining satellite constellations with their orbital tracks, for instance, is much more difficult on the basis of a static representation than with an animated presentation.

Interactivity as the key to GOD (Globe on demand)

Although it has scarcely been noticed so far, interactivity as a means to give special impetus to globe representation has to be particularly mentioned. So far, the physical globe had the highest degree of interactivity of all cartographic products, but still the globe's theme had to be consumed as a non-changeable fact. There was just a one-way communication between globe and user. Contrary to this, a hyperglobe and its interaction features make it possible to receive feedback from the user, which can not be realized in a conventional/analogue way. The user can be involved directly and his individual requests can be integrated. This leads to a globe that – by means of selection options - represents information according to specific user needs. A "globe manufacturer" can include interactions in the hyperglobe, which puts the user into the position of controlling even the depth of the geometrical and thematical complexity. The result is – similar to map on demand – a globe on demand (GOD).

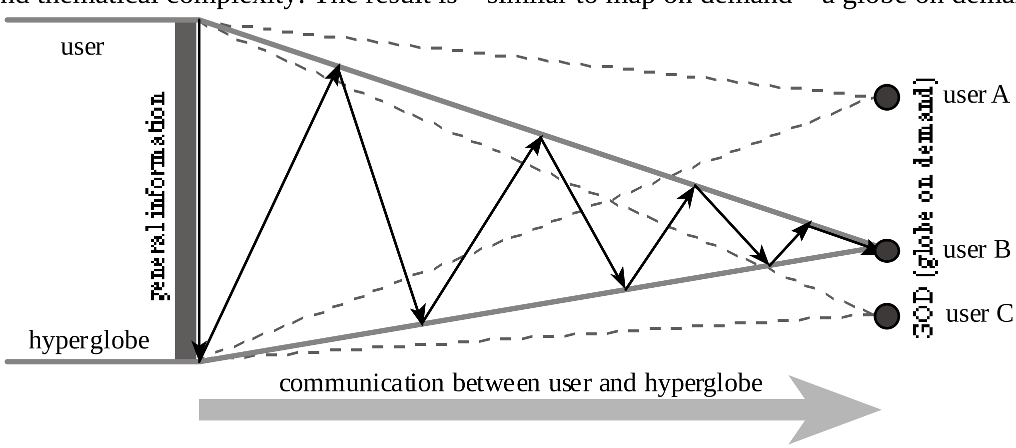

Fig. 5: The hyperglobe as GOD (globe on demand)

The following interactions (sorted by categories) are conceivable:

Orientation and navigation

- Spatial:

    - Stationary: Free rotation of the globe as a whole or independent manipulation of different theme layers.
    - Mobile: Free movement of the user in the virtual space surrounding the globe.
- Temporal: Adjustment possibilities for the time of the day, the season, the calendar.
- Thematic:
    - Different information densities: Moving closer or zooming leads to a larger scale and less generalized globe pictures, LOD technique.
    - Different information levels: Accessing themes via hierarchical menu.
- Adaptive representation of information:
    - Connected with orientation: Several display objects (as part of an extended legend) are required for indicating location in space and time. These are an overview globe (particularly when using a high zoom level), a graphical ”globe scale”, a time indicator corresponding to the topic, and a coordinate display.
    - Connected with interpretation: The activated legend must adapt itself automatically to the visualized theme. Likewise the lettering must be aligned to correspond to the user's movements.

Influence on the appearance

- Globe scale dependant:
    - Free selection of the globe scale.
    - Zoom only within a scale range depending upon the theme.
    - Free selection of the vertical exaggeration within certain values.
- Theme-based:
    - Switch between different thematic layers.
    - Make certain objects (groups of objects) of a topic able to be switched on/off.
    - Additional overlays for certain themes.
- Via graphic and dynamic parameters:
    - Modify the graphic variables of objects, e.g. color of the graticule.
    - Control animation speed.
- Varying the classification.

Information query and integration

- Help system for explanations and guidance to using the hyperglobe.
- Queries with following screen-centered representation of important areas and locations.
- Links to in-depth information (e.g. to country-, capital city web pages) via symbols
- Cartometric functions (e.g. display of the geographic coordinates, distance measurement, route measurement, area measurement, rhumb line).
- Selection of and emphasis on objects.
- Add user specific attributes or information (e.g. travel routes, place of residence, GPS data).

Conclusion

The paper dealt with the manifold possibilities arising from the symbiosis of globes, interactivity, multimedia and Internet technology in a virtual reality environment. The main advantages of virtual globes over physical globes are summarized as being:

- Questions about the earth’s shape are easier to solve – ellipsoid and geoid;
- Questions which can not be solved with maps can be visualized in a more illustrative way (e. g. the earth’s inclination, presenting dynamic phenomena, space travel and satellite-technology);
- Some issues are solved faster (e.g. interactive cartometry);
- New fields of use (investigating historic globes on a virtual model, 3-dimensional geoid visualization, real-time presentations); and
- Economic advantages (no printing house needed and subsequent savings in salaries and operating costs)

A hyperglobe offers the potential for providing a tool that could act as knowledge transmitter for anyone, everywhere and at any time. Therefore hyperglobes are a viable replacement for physical globes.

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