International Journal of Digital Earth

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t777764757

Virtual representations of antique globes - new ways of touching the untouchable

F. Hruby [a]; A. Riedl [a]; H. Tomberger [a]

[a] Department of Geography and Regional Research, Cartography and Geoinformation, University of Vienna, Austria

Online Publication Date: 01 January 2008

To cite this Article Hruby, F., Riedl, A. and Tomberger, H.(2008)'Virtual representations of antique globes - new ways of touching the untouchable',International Journal of Digital Earth,1:1,107 — 118

To link to this Article: DOI: 10.1080/17538940701782635

URL: http://dx.doi.org/10.1080/17538940701782635

International Journal of Digital Earth
Vol. 1, No. 1, March 2008, 107–118

Virtual representations of antique globes – new ways of touching the untouchable

F. Hruby, A. Riedl* and H. Tomberger

Department of Geography and Regional Research, Cartography and Geoinformation, University of Vienna, Universitätsstrasse 7, 1010 Vienna, Austria

The starting point of this paper is the idea that a comprehensive understanding of the earth and its systems calls for consideration of bygone views of the world. Creating facsimiles of antique globes in the form of digital globes provides a new opportunity to make such bygone world views accessible to a wide scientific audience. However, up to now, little practical experience in applying digital technology on globes has been made. Considering these attempts by thorough synopsis, this article deduces a comprehensive approach on virtual representations of antique globes that can be described by the superordinate concept of *virtual representation*. This concept comprises facilities of data acquisition of the original globe, ways of visualising the digitised globe and its final cartographic preparation. Applications that arise from this procedure are exemplified through both virtual hyperglobes and tactile hyperglobes. New findings on a 16th century earth globe are encouraging results of the presented virtual representation approach, which may offer a sustainable visualisation platform of interdisciplinary research.

Keywords: 3D facsimile; digital globe; hyperglobe; 3D visualisation; digital restoration

1. Problem formulation: on untouchable times and untouchable objects

When we started preparing this paper for the 5th International Symposium on Digital Earth and the International Journal of Digital Earth, respectively, we found it interesting to have a closer look into the agenda of the Digital Earth partnership. What we have come upon, is the very ambitious aim of making the vast amounts of existent information ubiquitously available to better understand the earth and its systems. It seems to us that the topic of this text, i.e. the virtual representation of antique globes, is relevant to Digital Earth regarding two problematical aspects of handling with past-time data. These aspects concern the existence of evidence of bygone world views on the one hand and their communicable accessibility on the other.

We would like to illustrate the mentioned difficulties by means of a prominent example: In 1492 AD the part of the world that we currently call America had the – more or less – same geographical position as today. In view of our present knowledge, we state this as a matter of course. In fact, we are rather used to calculate our world view in millions of years up to the Pangaea supercontinent and

*Corresponding author. Email: andreas.riedl@univie.ac.at

ISSN 1753-8947 print/ISSN 1753-8955 online

DOI: 10.1080/17538940701782635
http://www.informaworld.com

even beyond it. Let us now take a look at European media anno 1492 to see what has been reported on America then. Take for example the earth globe of Martin Behaim of exactly that year – and what do we see there? Nothing . . . at least nothing of America. We could now easily explain that Columbus was just about to discover America for Europe, while Europe itself did not yet know about his discovery. Therefore, the content of Behaim's globe would be simply wrong. But this is not the only conclusion which we can draw from this example. Even though that view of the world of 1492 is incomplete and incorrect for us, it nevertheless has been a basis for real decisions and actions. For example, the attempt to seek a direct sea route from Europe to Asia, which finally resulted in the arrival at America can be explained on this basis. Thus, decisions that were based on misapprehension nevertheless continue to have an effect up to now.

As the Digital Earth program follows the aim to better understand the earth and its systems, it needs to include the practical relevance of bygone views of the world as well. Doing so, a problem becomes apparent, that can be – according to system-theoretically terminology – described as second-order-observation, i.e. an observation of an observation (Luhmann 2004): For example, current research methods allow looking back far in the past. Nevertheless, we have just little possibility to see, how people in the past have seen their environment and what decisions they have made on the basis of that sight. This information remains today widely untouchable and the more important it is to make accessible the little evidence that is left.

Antique globes are among this rare evidence as there is documented proof that globes played an important role in science and practice in the past. For instance, in the 17th and 18th century terrestrial and celestial globes were part of the standard equipment on Dutch ships and used as viewing and demonstration devices in teaching navigation (Davids 1987). However, most of these old globes have been lost wherefore the remaining objects are now of high cultural and material value. As a consequence, they are just provided with limited accessibility, if any, kept safe in vitrines or under archives' lock and key. Thus, in many cases they remain untouchable as well. Creating facsimiles of antique globes in the form of digital globes provides a new opportunity to get out of this dilemma. How an untouchable original can be transferred into a virtual representation and therewith to a ubiquitous Digital Earth data pool, i.e. how the untouchable can be made touchable shall be argued in the following chapters.

2. Digitalisation of the original globe

The first and decisive move on the way to a virtual representation is the digitalisation of the original data. Various techniques are available to capture both the globe's surface and its inner construction. Methods to look inside the globe are the use of X-rays, tomo- or ultrasonography, which can be very useful for purposes of restoration. For the intention of this article, i.e. the virtual representation of the cartographical content of antique globes, their impact is just secondary, wherefore they will remain unaccounted for the further discussion. However, the interested reader is invited to look up more detailed information in Tomberger (2007). Returning to the former techniques concerning the surface and its content, we can distinguish in chronological order between two groups: close range photogrammetry or three-dimensional (3D) scanners.

2.1 Close range photogrammetry

Techniques of close range photogrammetry have been applied on globes already in 1978 by Kraus and Vozikis (1978), using the digitally controlled differential rectification. Initially they have been aiming at an exact representation of a globe in the plane. In addition, the photogrammetrical measurement allows a precise description of the globe's shape and deformations respectively to ease tasks of restoration and documentation. The realisation of the reversed procedure – i.e. the (re-)production of a globe based on these rectified images – had to wait until 1992 on the occasion of the 500th anniversary of the introductory mentioned Behaim globe. Although the method of Kraus and Vozikis offers a high-precision data acquisition of shape and content, it could not prevail for the digitalisation of antique globes up to now. One reason may be the small size of this market; another cause may be the extraordinary expense. Apart from software development, several man-days are necessary for each globe and, owing to the high investment costs for the hardware (approximately 150 000 euros), these techniques are only available to a few specialised institutes. Furthermore, they often require a transport of the original globe which may be refused by the owners for safety reasons. Detailed information on this method of close range photogrammetry is published in Kraus *et al.* (1992).

Another approach availing photogrammetric techniques has been developed in 2004/2005 within the scope of a spatially and conceptually reorganisation of the worldwide only Globe Museum, which is part of the Austrian National Library in Vienna. Aim was the virtual representation of the earth globe of Gerard Mercator of 1541 which is a centrepiece of this collection. From the part of the Globe Museum it has not been intended to neither transfer the globe outside the museum nor give direct access to external researchers. These criteria had to be considered regarding the design of the method. Therefore, it had been decided to photograph the Mercator earth globe with a digital camera in the photo studios of the Austrian National Library. In order to assure high resolution and little distortion while taking the pictures, the whole globe was photographed in 432 single shots, each of them showing a sector of 10° latitude $\times 15^\circ$ longitude. Afterwards each photo with its own coordinate system was transformed to a reference system via photogrammetric software tools to obtain an equidistant cylindrical projection. Owing to the use of commercially available equipment, the costs of the hardware are clearly reduced in comparison with the former technique. Another advantage of this method may arise from the fact that no transfer of the globe is necessary. Furthermore, the whole photographing process can be delegated to internal stuff. Further information on this approach is presented in Hruby *et al.* (2006).

Both of the above mentioned methods have in common to result in a tessellation of single pictures. Therefore, they need to be merged to one complete overlay and corrected radiometrically as well if necessary in a further step. Moreover, the application of a photogrammetric approach on globes implicates the transformation of a 3D object into a two-dimensional (2D) dataset in the form of a map. This (2D-) map serves as overlay for the virtual (3D-) representation so that we can describe the whole procedure as 3D $\rightarrow$ 2D $\rightarrow$ 3D – facsimilation, where the map just forms an intermediate step. This time-consuming intermediate step loses his necessity using systems of 3D $\rightarrow$ 3D-data acquisition, summarised under the term '3D-scanners'. The next section shall give an accordant overview.

2.2 3D-scanners

3D-scanners meanwhile are available in various technical designs, serving different application areas. Since practical experience about the applicability of this technology on globes is rare, the authors have been testing several systems for their utilisability (Tomberger, forthcoming 2007). The conclusion of this benchmark is that 3D-scanners already allow to create a high-precision 3D-model of a globe, whereby the duration of the data recording shortens from a couple of days with photogrammetric methods to just a few hours. A weak point on the other hand is the less detailed acquisition of colour information of the globe's surface, which means a grave shortcoming for the purpose of representation.

Overcoming these obstacles, next generations of 3D-scanners can be expected to provide an ideal digitalisation tool for antique globes that is not just working quickly and precisely, but mobile and inexpensive as well. Further advantages with regard to the price will result from automations that the use of 3D-scanners may offer. Therefore, automation will probably be a precondition to extensive digitalisation projects which could give room for development of the research potential that is inherent in antique globes, i.e. in bygone views of the world. Then the creation of a map as an intermediate step to the final virtual representation could lose its current necessity.

3. From globe to hyperglobe

If the digitalisation of the original globe has been completed, various technical possibilities are open to the virtual representation, wherefore Figure 1, offers an accordant structure. From the preceding steps we have attained a digital image.

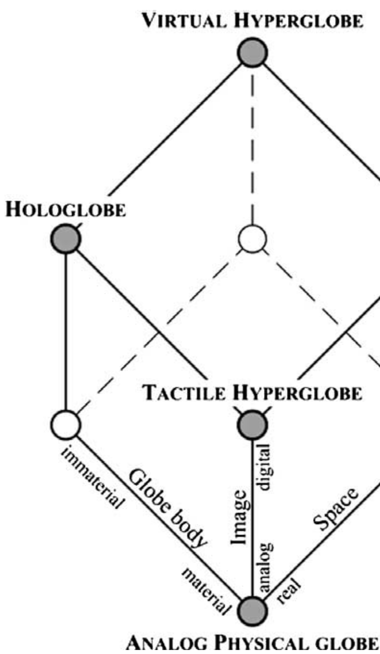

Figure 1. Typology of globes (Riedl 2006; slightly modified).

According to Figure 1, three types of digital globes are available, namely virtual hyperglobes, tactile hyperglobes and hologlobes (Riedl 2000). The application of each of them results in a digital facsimile, if it builds on digitised data of an antique globe. We will characterise these three types of hyperglobes in a chronological order below.

3.1 Virtual hyperglobes

Virtual hyperglobes result from a visualisation of the digital image on an immaterial globe body in virtual space. According to this definition virtual hyperglobes are presentable on currently common computer screens. On this account, they are representing the most popular type of digital globes for the moment. However, they fail at representing the original 3D-globe in an adequate 3D-form, because their underlying 3D-data model always has to be mapped onto the (2D-) display.

3.2 Tactile hyperglobes

Tactile hyperglobes result from a visualisation of the digital image on a material globe body in real space. According to this definition, tactile hyperglobes are only presentable on spherical screens which form a special type of real-3D-visualisation systems. Depending on the projection of the image on the screen, two main approaches can be distinguished at present, namely internal-projecting systems from external-projecting systems. The former are projecting the image either mirror based (e.g.: Magic Planet®) or lens based (e.g.: OmniGlobe®), while the projection device is outside of the screen in case of the latter. Contrary to virtual hyperglobes, tactile hyperglobes have not yet reached the stadium of mass production, not least because of high costs and (still) limited display resolution. But they allow representing the original 3D-globe in an adequate 3D-form, as the shape of the screen corresponds to the original globe's shape.

3.3 Hologlobes

Hologlobes result from a visualisation of the digital image on (i.e. in form of) an immaterial globe body in real space. In comparison with virtual and tactile hyperglobes, hologlobes are still in an early stage of development, which currently does not allow for feasible solutions concerning globes, e.g. in the face of satisfying colour reproduction. Some interesting prototypical approaches (e.g. Felix-3D or Perspecta Display) are presented in Schratt and Riedl (2005).

4. Tasks of cartographic preparation

All of the various ways of data acquisition and data visualisation that were presented earlier result in a digital facsimile, but not in a virtual representation of antique globes that serves cartographic requirements completely. An important factor that makes an old globe especially interesting is its discrepancy with our current view of the world. This discrepancy may be obvious in some cases (e.g. concerning the absence of the American continent), but mostly requires additional cartographic preparation, wherefore three different tasks can be distinguished (Hruby and Plank 2006).

First task of cartographic preparation is to make contents comparable. This can be achieved via superimposing up-to-date geodata in terms of multiple overlays that contain distinctive features like coastlines or rivers as well as toponyms. Such basis allows for discovering both geographical vacancies and incorrect topographical proportions. Furthermore, the option arises to provide historical toponyms (e.g.: Hybernia) together with their current correspondent (e.g.: Ireland).

Second task of cartographic preparation is to make contents clear. In many cases, the cartographic content of antique globes will be hardly readable or even unreadable owing to abrasion or damages. Using graphics software can help to restore globes based on their digital facsimile by increasing contrasts or refreshing colours. Moreover, as antique globes usually have been produced based on printed 2D-gores, alternative sources of the original globe's content may be available. Such gores sometimes are remaining in uncoloured or reprinted form, offering an alternatively overlay. By means of these even mentioned options blind spots on old globes can be illuminated digitally.

Third task of cartographic preparation is to scrutinise contents. The originality of antique objects is not always to be taken for granted. For instance, most of old globes were coloured after their final sale, sometimes after years of storage and occasional damage. Due to that fact a cartographically untrained colourist may have painted improperly and therefore created geographical mistakes. Likewise it is conceivable that such errors occurred during later restorational works. Discovering these kinds of inconsistencies requires superimposed alternative sources of the original content as mentioned before. The availability of further digitised cartographic representations of the same age or of a subsequent era can ease verification tasks as well. Investigations of the earth globe of Gerard Mercator (Hruby and Plank 2006) exemplify these possibilities (see also chapter 6.2).

All three aforementioned tasks of cartographic preparation enable us to confront a bygone view of the world with a current one, so that differences can be qualified and quantified as well. These potentials already point at the final move, which is necessary to virtually represent an antique globe in an adequate form. This means the step forward to interactivity, which is already implicit in those selectively superimposed overlays we have spoken to afore. Furthermore, this interactive aspect is inherent to every globe *per se*, as the globe cannot be acquired at a glance and therefore needs to be rotated; also measuring on a globe calls for an interactive access. Hence, interactivity in a broad cartographical sense shall be subject of the next section.

5. Interactivity

According to Riedl (2000), we can combine cartographic demands of interactivity with three interrelated interaction complexes concerning tasks of navigation, adaption and information. These complexes determine the functions which shall be provided to every user and therefore are to be integrated to the virtual representation as follows.

Navigation presumes orientation and can be carried out in space, time and topic. Regarding globes navigation comprises flexible rotation (=spatial navigation), diachronic visualisation of various, but at least two different world views (=temporal navigation) and adjustable representation of varying themes, e.g. coastlines, cities or toponyms (= thematic navigation). In addition, orienting details such as overview map, timeline or legend help the user to assess the navigational situation.

Adaption of the visual appearance partly results from the above mentioned navigation measures wherefore we can speak of secondary interactions in this case. For instance, various superimposed themes (= thematic navigation) will have an effect on the appearance as well as zooming in on a certain detail of the contents.

Information includes two connected aspects, namely integration and retrieval. For example we can apply hyperlinks to varying locations on the virtual representation of a globe, which is a form of data integration. But the same hyperlinks can be activated by other users to gain information, which then is a form of data retrieval. Depending on the concrete aim of an application, one of these two aspects may prevail. Also among this interaction complex are help and cartometric functionalities (e.g. the measurement of position, distance or area).

To sum up the preceding sections, we can now define a virtual representation of an antique globe (according to the motto: touching the untouchable) in the following way. *A virtual representation of an antique globe is based on a geometrically precise acquisition and digitalisation of the antique globe's surface, whose subsequent projection on a real or virtual globe body produces a digital facsimile in terms of a hyperglobe. The historical characteristic of this facsimile has to be explained to the user by means of the three cartographic tasks and the three cartographic interaction complexes.* We would like to reflect this definition in the light of current practice.

6. Virtual representations of antique globes – the status quo

6.1 An overview of digitised antique globes

The number of antique globes that have been digitalised up to now is small. Corresponding results solely represent the type of the virtual hyperglobe, whose hard- and software standards offer the widest area of application at the moment. One of the first exponents of a virtual hyperglobe was a replica of the Behaim globe at the beginning of the 1990s (Klimpfinger 1993). This application already covered some of the aforesaid features of interactivity and cartographic preparation. For instance, you can make measurements on the digital facsimile or superimpose present coastline data (Dorffner 1996). Further to mention is a digital facsimile of the Karl-Theodor globe of the Heidelberg University Library made within the scope of the restoration of the original globe of 1751 (Jäger and Krömker 2004). This project confines itself to build a digital facsimile without the intention of further cartographic preparation. A common characteristic with both aforementioned globes is the Virtual Reality Modelling Language (VRML) based model to create a sphere. Downsampled versions of both objects are presented online (see references for URLs). Another common factor is that these two examples do not seem to have been the exclusive focus of a research project. In contrast, the virtual representation of the earth globe of Gerard Mercator of 1541 has been an essential part of the new multimedia Globe Museum of the Austrian National Library. Decided aim was to make the Mercator globe touchable for a wide audience in form of a virtual

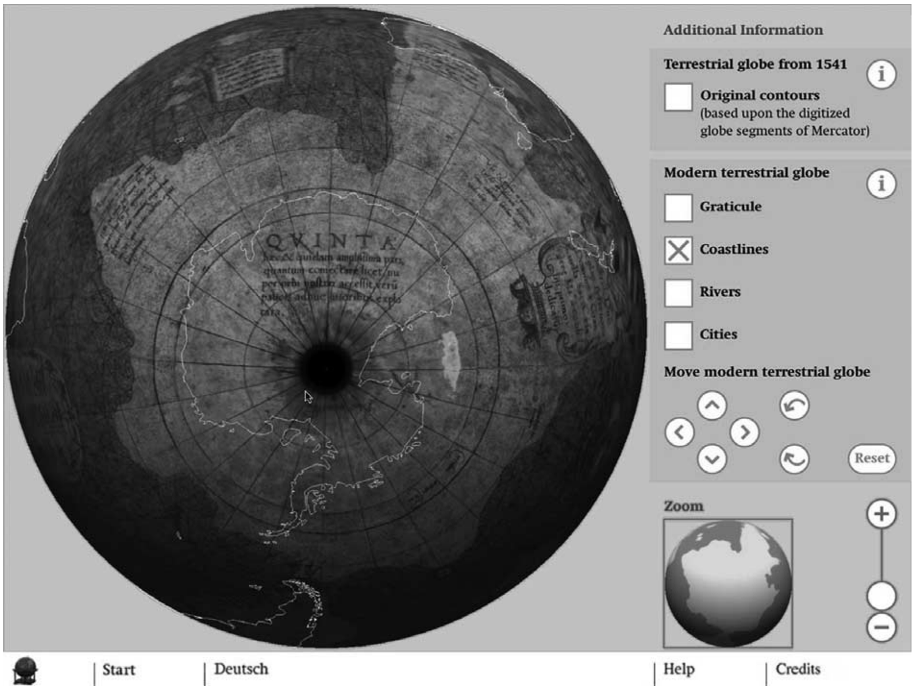

Figure 2. The virtual representation of the earth globe of Gerard Mercator (1541) – scene on a display screen. Note: you can see the imaginary south continent Terra Australis while the current coastlines are superimposed in white colour.

hyperglobe. While the digitalisation of the original has been done as described in section 2, Figure 2 shows the final application. This virtual representation in the Shockwave3d data format is accessible in the Globe Museum via touchscreen.

Figure 2 illustrates the integration of the three interaction complexes to one graphical user interface (GUI) that allows for superimposing current data (graticule, coast lines, rivers, cities). This complies with the first task of cartographic preparation, namely to make contents diachronically comparable. Furthermore, you can superimpose printed gores that have been reedited by the Royal Library of Belgium in 1875. This conforms to the second and third task of cartographic preparation that is to make contents clear and to scrutinise them. Figure 3 shows how readability and explanatory power increase when these printed gores are added.

6.2 New knowledge by means of virtual representations of antique globes

As explained previously, an important task of cartographic preparation is to scrutinise contents. How this task may lead to new knowledge can been exemplified by means of the aforementioned earth globe of Gerard Mercator. Figure 3 has already shown the increase of readability by superimposing printed gores. But doing so not only brought out the subjacent content. Instead of that, surprising discrepancies appeared which put the globe's own history and originality in a new light. The representation of the island of Cyprus gives a good example of these discrepancies.

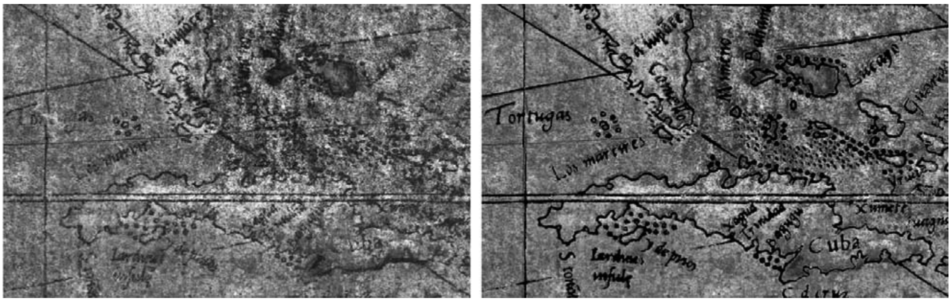

Figure 3. Detail (Cuba, Florida) of the virtual representation of the Mercator globe. Note: left picture: the original globe of 1541 showing sign of wear; right picture: printed gores of 1875 are superimposed on the original globe of 1541, which effects increasing readability of toponyms and other content.

Figure 4 shows on the left-hand side the island of Cyprus on the globe of 1541, while the same situation on the printed gores of 1875 can be seen in the middle scene. If we now view the superimposition of these two sources on the right hand side of Figure 4, it becomes clear that Cyprus is portrayed in mainland on the globe of 1541; likewise, southwards, the estuary mouth of the Nile. These inconsistencies were unknown until Mercator's earth globe has been made accessible and touchable by its virtual representation. Even without an exhaustive analysis of the whole globe further discrepancies have been noticed, e.g. in the area of the English Channel or Denmark. While possible explanation of this particular case already has been named in section 4, we would like to draw further conclusions on the potential of hyperglobes on a more abstract level subsequently.

The findings we have just mentioned resulted from a synthesis of two different data origins. Currently, such synthesis is limited since just a few antique globes are available digitally. Hence, developing an extensive database seems to be worthwhile to strengthen the scientific potential of virtual representations. This database of bygone world views could include various objects from various ages, globes as well as maps, which would be retrievable corresponding to a particular problem. In accordance with MacEachren's approach of multiple representation of geodata (MacEachren 2004), such database could offer different perspectives on past-time knowledge to facilitate analysis of spatio-temporal relationships. Ideally, antique

Figure 4. Detail (Cyprus) of the virtual representation of the Mercator globe. Note: left picture: the original globe of 1541; middle picture: printed, uncoloured gores of 1875; right picture: superimposing printed gores of 1875 on the original globe of 1541 disclosed that Cyprus is portrayed in mainland on the globe of 1541.

globes are not only to be stored as digital image data, but retrievable at different levels of data detail as well. This may contain the separate acquisition of all the toponymic data for example.

A database or digital archive of antique globes and maps as outlined above, accessible by means of virtual representations, should be of particular interest to numerous scientific disciplines: Genus proximum, of course, is the object of all kinds of historical research; linguistics, to give another example, is highly interested in historical toponyms to explain current linguistical phenomena, e.g. diphthongisation. A ubiquitous Digital Earth data pool may provide an appropriated framework for such a database of bygone world views, accessible everywhere and every time.

7. Prospects

It seems that the two aforementioned VRML-examples of digital facsimiles are not developed further at the moment. However, the Department of Geography and Regional Research (IfGR) at the University of Vienna, which has been responsible for the virtual representation of the Mercator globe, is working on further research into digital globes as medium for geocommunication. This ambition requires us to take the next level of digital globes, i.e. the development of tactile hyperglobes. Virtual hyperglobes – although most popular for the moment – are restricted to represent 3D-reality on common computer screens actually in 2D. But the main advantage of a globe, compared with any 2D-visualisation form, is its ability to conceptualise and to represent global spatial relationships (e.g. relative distances and areas, angles) without considerable distortions. Tactile hyperglobes make this possible in an adequate form.

According to section 3.2, the appropriate visualisation systems are only on the cusp of feasible solutions for a mass market. Nevertheless, they already allow us to explore their geocommunicational potentials. The IfGR is currently working with a 1.5 m diameter tactile hyperglobe. Research needs to be done, on the one hand, in matters of input, as spherical displays raise various special problems concerning e.g. software development, data projection on a sphere or navigation tasks; regarding 3D-progamming we are using the open source Object-Oriented Graphics Rendering Engine (OGRE) at the moment. On the other hand, questions arise in reference to the output, concerning the communicative potentials of tactile hyperglobes as a new platform of knowledge transfer. Empirical analysis has to be done in this respect. Figure 5 illustrates the tactile hyperglobe as a projection screen of bygone and present views of the world.

Figure 5 foreshadows how satisfying virtual representations of antique globes may look like: reproductions of a sphere on sphere – investigable and touchable. One of the main current issues for a widespread application of these potentials is the high expense of digitalisation and representation devices. Thus, the development of digital facsimiles and digital globes in general reproduces the development of analogue globes from status symbol to everyday object. Not until digital globes are everyday's objects they may play a decisive role within the scope of Digital Earth, namely to form a visualisation platform for vast amounts of information to better understand the Earth and its systems.

Figure 5. Visualisation of bygone world views and current geodata. Note: bygone world views left picture: Cornelius de Jode; end of the 16th century and current geodata (right picture: surface air temperature on Earth; end of the 20th century) on a tactile hyperglobe at the IfGR.

References

Behaim globe (VRML) [online]. Source: Available from: http://www.ipf.tuwien.ac.at/teaching/vrml/behaim/behaim.html [Accessed 10 November 2007]

Davids, C.A., 1987. The use of globes on ships of the Dutch East-India Company. *Globe studies*, 35–37, 69–77.

Dorffner, L., 1996. Der digitale Behaim-Globus – Visualisierung und Vermessung des historischen Originals. *Cartographica helvetica*, 14, 20–24.

Hruby, F., Plank, I. and Riedl, A., 2006. Cartographic heritage as shared experience in virtual space: A digital representation of the earth globe of Gerard Mercator (1541). *e_Perimetron*, **1** (2), 88–98. Available from: http://www.e-perimetron.org/ [Accessed 10 November 2007].

Hruby, F. and Plank, I., 2006. Mercator reloaded – den Erdglobus von 1541 virtuell entdecken. *In*: K. Kriz, W. Cartwright, A. Pucher and M. Kinberger, eds. *Cartography as a communication medium,* (Vienna: University of Vienna, Department of Geography and Regional Research, Cartography and Geoinformation), (=Wiener Schriften zur Geographie und Kartographie, Vol. 17) pp. 201–208.

Jäger, W. and Krömker, S., 2004. Map projection versus image processing – the role of mathematics in the restoration process. *In*: W. Jäger, S. Krömker and E. Wolgast, eds. *Der Heidelberger Karl-Theodor-Globus von 1751 bis 2000*. Berlin, Heidelberg, New York: Springer, 69–100.

Karl-Theodor globe (VRML). Available from: http://www.iwr.uni-heidelberg.de/groups/ngg/Globus1751/Virtuell/index.html [Accessed 10 November 2007].

Klimpfinger, H., 1993. *Visualisierung von Oberflächen und Oberflächenveränderungen mit dem Softwarepaket IDL*. Thesis, Vienna University of Technology, Vienna.

Kraus, K. and Vozikis, E., 1978. Die Verebnung von Globen mit Hilfe der Differentialumbildung. *Globe studies*, 25–27, 55–61.

Kraus, K., Tschannerl, J., Halmer, A., and Rottensteiner, F., 1992. Die Bearbeitung des Behaim-Globus mit photogrammetrischen Methoden. *Globe studies*, 40/41, 9–19.

Luhmann, N., 2004. *Einführung in die Systemtheorie*. Heidelberg: Carl Auer.

MacEachren, A.M., 2004. *How maps work: representation, visualization, and design*. New York, London: The Guilford Press.

Riedl, A., 2000, *Virtuelle Globen in der Geovisualisierung. In* I. Kretschmer and K. Kriz, eds. Vienna: University of Vienna, Department of Geography and Regional Research, Cartography and Geoinformation, (=Wiener Schriften zur Geographie und Kartographie, vol. 13).

Riedl, A., 2006. Digital globes. *In*: W. Cartwright, M.P. Peterson and G. Gartner, eds. *Multimedia cartography.* Berlin, Heidelberg, New York: Springer, 255–266.

Schratt, A. and Riedl, A. 2005. The potential of three-dimensional display technologies for the visualisation of geo-virtual environments. In *Proceedings of the 22. ICA Cartographic Conference, A Coruña, Spain,* 2005.

Tomberger, H., 2007. Digitising of Antique globes – a summary of the latest technologies. *Globe studies,* 53. Vienna, 176–188.

About the authors

Florian Hruby, born 1978, studied cartography at the University of Vienna, Department of Geography and Regional Research, Cartography and Geoinformation (IfGR). He has been a teaching assistant at the IfGR and project associate in the project: *Multimedia Globemuseum* (MUGL). He has acquired some international experience by participating during a three-month assistantship in the SICATUR-project (Sistema Cartográfico Turístico de la Costa de Jalisco) at the Department of Geography in the University of Guadalajara, Mexico. After finishing his diploma thesis concerning the topics of cartosemiotics and three-dimensional modelling, he started working on a PhD degree on the topic: 'Communicational Potential of Digital Globes.' He is a corresponding member of the Commission on Theoretical Cartography of the International Cartographic Association (ICA).

Andreas Riedl, born 1965, studied cartography at the University of Vienna, Department of Geography and Regional Research, Cartography and Geoinformation (IfGR). He carried out research work at the Simon Fraser University in Vancouver, Canada and participated in the development of courses for multimedia-Computer Based Training, at the International Institute for Geo-Information Science and Earth Observation in Enschede, Nederlands. Since 1997, he has been assistant professor at the IfGR. His scientific priorities are the integration of multimedia techniques (3D visualisation, web-mapping, virtual worlds) into geocommunication with a special focus on the development and potential of digital globes. He is a board member of the Austrian Geographic Society and corresponding member of the Commission on Visualisation and Virtual Environments of the International Cartographic Association (ICA).

Harald Tomberger, born 1974, studied cartography at the University of Vienna, Department of Geography and Regional Research, Cartography and Geoinformation (IfGR). He has been a teaching assistant at the IfGR and project associate in the project: *Multimedia Globemuseum* (MUGL). His masters thesis *Computer-aided methods for the examination of antique globes* dealt with hard- and software techniques regarding the digitalisation and analysis of analogue globes and has been awarded by the Austrian Cartographic society. He is a member of the International Coronelli Society for the Study of Globes.