THE PROJECTION ASPECTS OF DIGITISING GLOBES

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Abstract

The recently opened Virtual Globes Museum publishes three dimensional virtual models of old globes on the Internet. The main purpose of the museum is to preserve these artifacts of old cartographers and at the same time to make them available for anyone who wants to study their content without the risk of making any harm to them.

There are two types of models in the Museum: a spherical object with the surface of a globe as texture defined in VRML, and a KML „globe layer" which can be viewed by Google Earth. There are several steps of processing to get these different models from the source materials of the globes, in which projection transformations are also involved to a certain extent.

This paper presents the projection-theorical background of the process. The first chapter introduces the Virtual Globes Museum project itself; then the possible source materials are presented: unmounted prints or photo series of the globes. Another part shows the projections used for globe prints (Cassini and Azimuthal Equidistant) and the projection of a globe photo (Vertical Near-Side Perspective). As the latter has several parameters to be determined, the method of calculating the projectional parameters is also presented. The exact definition of the projections of images is needed for the georeferencing process.

The next part presents the two different 3D models and the steps of creating the appropriate material for them. Digital projection transformations are always a part of this process as the models need images in different projections from the ones the sources are in. What is more, there is an intermediate format, in which the partial images are assembled into one. The KML models need a series of images in Plate Carrée or in Equidistant Cylindrical projection, while the VRML models require two different types of images: two polar caps in Azimuthal Equidistant projection and four images in Plate Carrée for the remaining equatorial areas. Each model has its advantages and disadvantages. VRML models need relatively big system resources and the texture sizes are limited, while KML models have a visualization problem in the polar regions, which is caused by the texture mapping method of Google Earth.

In the discussion chapter various issues are discussed. For instance, the sources of different errors and how to manage them, the accuracy of georeferencing, and the possibilities of dealing with special globes such as those with different prime meridian or non-spherical globes like the detachable geophysical Earth-model.

Finally, the paper describes the most common problems which can occur during the process of globe digitalizing: the insufficient number of control points in specific areas caused either by a big title field overlaying the grid or simply by missing grid lines, which is quite usual on polar caps and on celestial globes. The possible ways of solving this issue are also shown.

Keywords: *projections, virtual globes, KML, VRML, 3D models*

Introduction

The Virtual Globes Museum has been opened to the public (Márton 2008; Márton & Gede 2008) after following research of globes at the Department of Cartography and Geoinformatics.

The project aims at the following goals:

1. Developing a method of 3D globe model production from globe prints or by using photographs
2. Founding the Virtual Globes Museum (Márton ed. 2008) – a virtual exhibition on the Internet open to the public – based on the globes of the Cartographia Enterprise (Márton 1988; Kovács & Márton 1989)
3. Developing and presenting the method of digital virtual globe restoration in order to free the restoration process from any risk
4. Producing new (thematic) globes (Márton 1975)

There are several other virtual globe projects. For instance, János Balázs had made a digital version from Waldseemüller's globe (Török & Balázs 2008), but the content is not the original: only the coastlines were redrawn by graphic software and some names were put onto it. The result is an animation, which does not let the user interact.

Another project is Andreas Riedl's "hyperglobe" (Riedl 2000, 2003). This shows several ways of globe visualization. With Florian Hruby and Irmgard Plank they created the digital copy of Mercator's globe using photographs (Hruby et al 2006). Although the processing method was quite similar to the one described here later, there are some differences: they georeferenced smaller areas and used different software for it. They also examined alternative display technologies for better visualization (Hruby et al 2005).

In the Virtual Globes Museum project several globes are shown in their current, real state. There is a searchable background database, which contains detailed datasheets for each globe. The models are fully interactive, and visitors can spin the globes around, zoom in and out.

Processing source materials

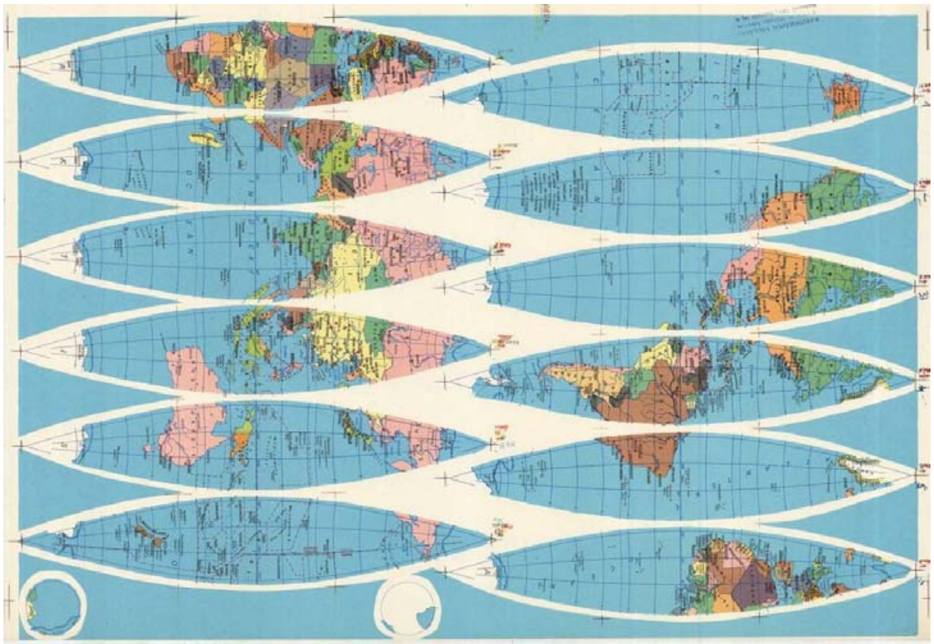

Figure 1: Globe print

The first step of making a digital globe is to select the sources material. The best material is a set of unmounted globe prints (Figure 1). Unfortunately, there are several occassions when no any of these prints are available, especially when processing manuscript or illuminated globes. In this case a photo series has to be taken.

The globe prints usually consist of a series of globe segments (gores) and two polar caps. K. Wagner recommends Cassini's projection for gores (Wagner, 1962). Although the gores of old globes didn't have an exact projectional background, the Cassini's fits them adequately. This is the transverse form of the equidistant cylindrical projection. The central meridian of the projection always matches one of the globe segments. The segments are usually 30° wide (sometimes 20° for larger globes and in some cases 40° for tiny ones). The most precise cartographers even modified this projection in empirical way to minimize the distortion caused by the paper stretching during mounting the segments. These modifications however are not so big that they would influence the processing method.

The polar cap prints are in the Azimuthal Equidistant (or Postel) projection and usually stretch to the latitude of 80°.

The Global Mapper software is used to georeference the scanned prints. The intersections of grid lines are used as control points.

The processing method of photos is more difficult. The first problem is the projection. If we treat a globe photo as a map, its projection is the so-called Tilted Perspective (Snyder 1987), which is not known by any GIS programs. However, if the globe's centre is on the optical axis, it is the simpler Vertical Near-Side Perspective projection. But knowing the projection's name is far not enough as it has several parameters: the longitude and latitude of its central point and the relative height of the perspective point. In order to solve this problem, I developed a program which uses the Downhill Simplex method (also called Nelder-Mead method) (Nelder & Mead 1965) to find the optimum of these values using the given control points, which are again the intersections of grid lines and – for sky globes – some stars whose coordinates can be determined.

This program uses the Global Mapper's control point files (with extension .gcp) as input and creates a projection description file (.prj) as output. The user can refine the search as long as the average error at the control points sinks below the desired limit. This limit depends on the scanning resolution, and should be less than the width of the globe's grid lines. The main causes of errors are the improper positioning of the camera (the globe's center is not on the optical axis), the deformations of the globe's surface (it is not exactly a sphere) and the positional errors of the globe content itself.

Once the source is georeferenced, it has to be reprojected to some cylindrical projection. The reason of this is that the content of different segments or photos has to be assembled into one big image; as the geographical quadrangles become flat rectangles in these projections, it will be easy to assemble them.

Among the many cylindrical projections I use the Plate Carrée. The reasons are that it is the simplest, and it can be used without any modifications for KML files.

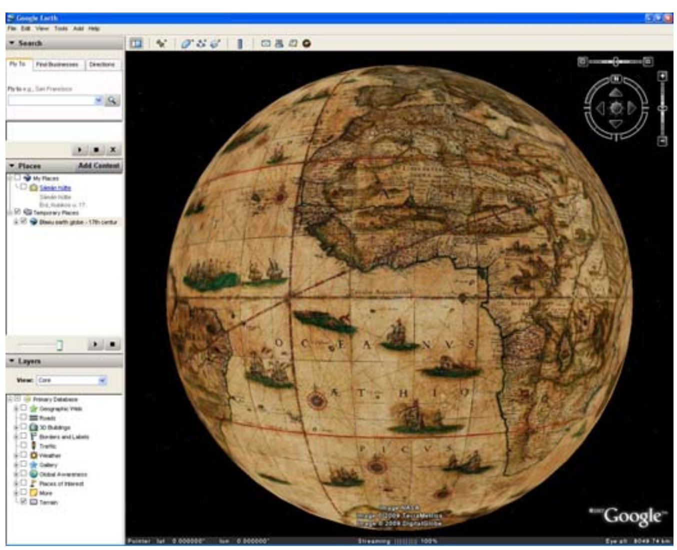

Figure 2: The 68 cm diameter globe of Blaeu in Google Earth

The KML globe

There is a possibility to add the digitized globe to Google Earth as a new layer (Figure 2). The Plate Carrée map has to be divided into parts no bigger than 2048*2048 pixels, because Google Earth reduces the resolution of larger images. A KML file containing these also has to be generated. For the higher latitudes it is advisable to use Equirectangular projection with a true scale latitude matching the image's lowest latitude as this image needs less space. Another option is using Plate Carrée with different horizontal and vertical sampling spaces (the rate of vertical spacing to horizontal is $\cos \varphi$, where φ is the lowest latitude of the image), which produces the same result.

The VRML globe

The obvious method of 3D visualizing is the using of VRML (Virtual Reality Modeling Language) (Carey & Bell 1997). The easiest option is the built-in Sphere shape with the Plate Carrée map as texture. This solution however, is far from being perfect. The Sphere shape is realized with a polyhedron and its edges do not match the gridlines. This results in zigzagging lines, mostly at higher latitudes (Figure 3). Another problem is that VRML browsers do not support texture images larger than 2048*2048 pixels. This means less than 100 dpi equatorial resolution at a 16 cm diameter globe, which makes it impossible to reproduce all the details.

Figure 3: The interference between the edges of the polyhedron representing the sphere and the grid lines

To solve both problems I defined a new shape which consists of six surfaces. The edges match the ten-degree grid lines so the grid no longer crosses the shape edges. The six surfaces allow higher resolution as all surfaces have their own textures. Two of them are round the poles above the ±50° latitude; the rest four divide the remaining area to equal parts (Figures 4 and 5). The ideal bound would be ±45° but as most of the globes do not have such latitude lines, the border of the surfaces would be visible.

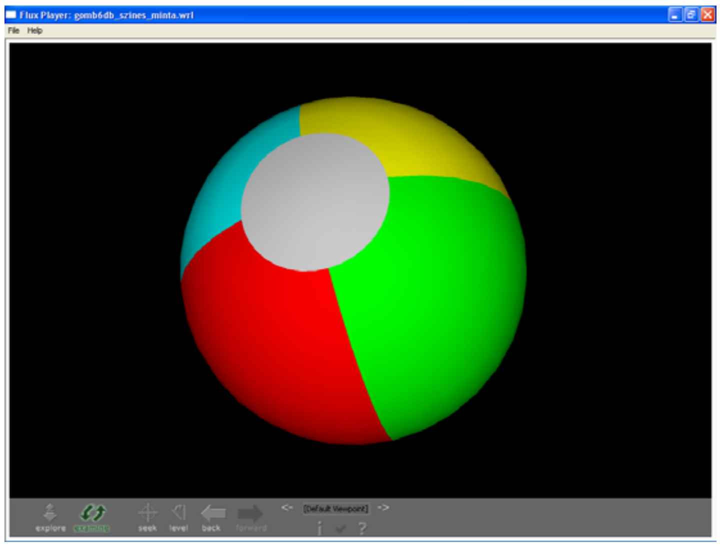

Figure 4: The self-defined sphere built up of six surfaces (here with boundary latitudes of 70°)

Figure 5: Virtual globe on the self-defined sphere

The equatorial regions use again Plate Carrée for textures but the maps of the polar caps are in Azimuthal Equidistant (Postel) projection. The best way of creating these maps is to use the original polar caps (if they are available), and to re-project the Plate Carrée map to get the remaining areas.

Discussion

The accuracy of georeferencing a globe photo depends on the distance of the globe centre from the optical axis. The greater the distance, the smaller area of the photo can be used. The criteria I used to determine this area was that the exact place of the geographic grid lines on the georeferenced image must be within the original grid line. As these lines on the photos are usually 2–3 pixels wide, this is the maximum error of the georeference. Of course it means different values in geographic coordinates according to the different globe diameters.

A frequent problem is the appearance of Moiré effect (interference between the printing rasters and the sampling grid, see Figure 6). The phenomenon appears usually after re-projecting the globe segments from Cassini's projection to Platte Carrée. To avoid this problem, it is advisable to apply a Moiré filter on the scanned prints before processing. It is usually made by Corel PhotoPaint or Adobe PhotoShop.

It is possible to represent special globes with non-spherical shape in VRML, e. g. the detachable geophysical Earth-model of Cartographia (Hajdu & Márton 1986; Hajdu & Márton & Bardócz 1988; see Figure 7). When defining this shape, special texture-mapping rules are applied to fit the images correctly to their place.

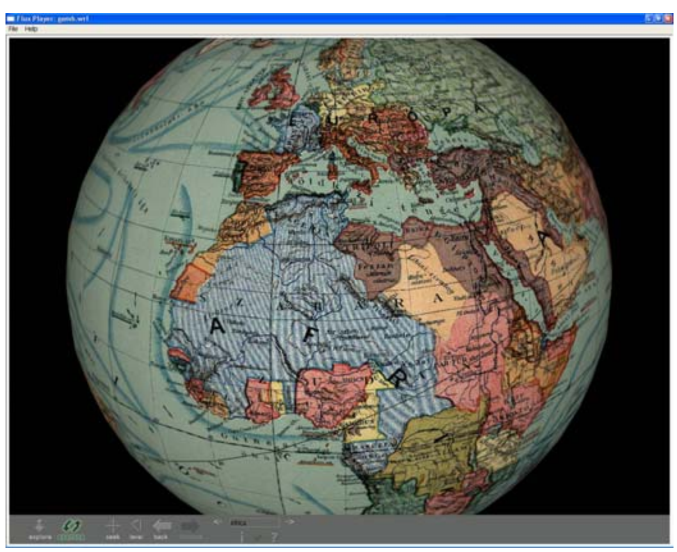

Figure 6: Moiré effect appearing due to and interference of the sampling grid and the printing raster

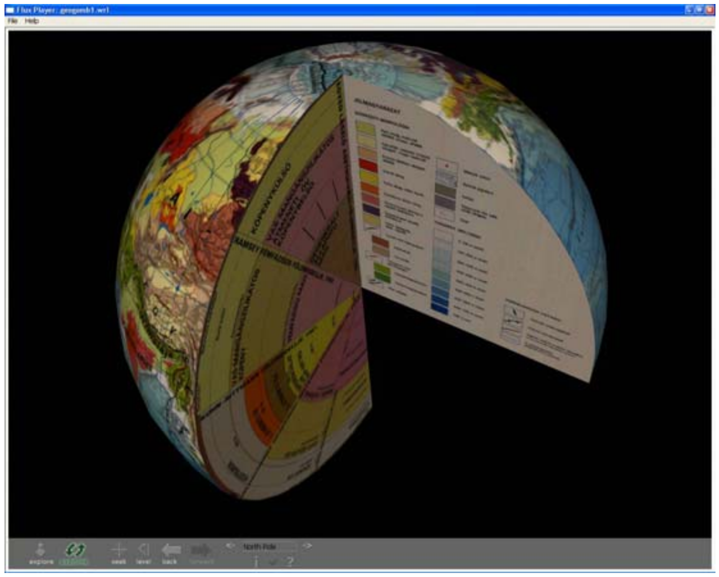

Figure 7: The geophysical Earth-model in the virtual space

The KML globe layers for Google Earth has a great disadvantage: the visualization problem of polar regions (Figure 8). As it is a peculiarity of the software itself, the only way to avoid this is the using of VRML models, when the polar regions are important.

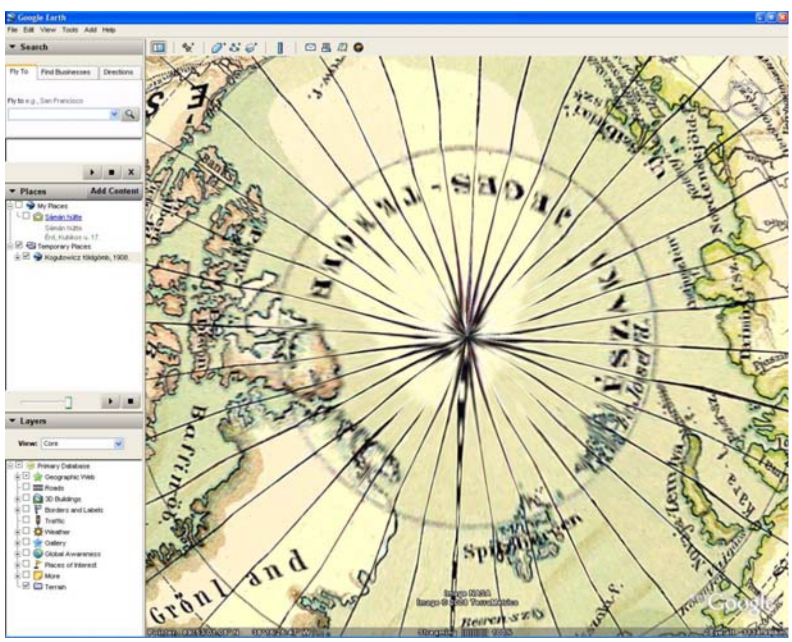

Figure 8: The visualization problem of polar regions in Google Earth

Some of the older globes have different prime meridian from Greenwich. The best method to deal with this problem is to georeference the sources as if they had used Greenwich; then to re-project them from Platte Carrée to Equirectangular projection using the negative longitude of the original prime meridian as "Central Meridian" parameter before the bitmap exportation. For example, this parameter should be 17.67° for the most common Ferro (also called Hiero) Prime Meridian.

Conclusions

Although one might think that there is no need of using projections when mapping a globe's surface to a virtual sphere as their shapes are identical, the technical steps of this process involve a lot of projection theoretical issues. To avoid major distortions during the creation of virtual globes, one has to pay attention at each step.

After processing more than 20 items of the Virtual Globes Museum, the most common problems were the following:

There are printed sheets where a big title field or cartouche hides some of the grid lines. If this field spreads to two or more segments, some offset error can occur due to the lack of control points at the adjacent edges of the neighbouring sheets. It is advisable to measure the coordinates of some easily identifiable points, e. g. lines crossing these edges, and use them as GCP's.

The polar cap prints sometimes do not have any grid except the boundary latitude circle. Before georeferencing such prints the globe segments have to be processed first, and the adjacent area (e. g. a ten degree wide ring adjacent to the polar cap) has to be re-projected to Azimuthal Equidistant projection. This image can be used then to find common control points (usually intersections of the latitude circle and coastlines).

Blaeu's celestial globe unfortunately does not have a proper geographic grid thereon. There are only a few lines: the tropics, polar circles, the prime meridian, the Equator and the Ecliptic. There are some additional lines also: the edges of the globe segments, which are equivalent to the 30 degree meridian lines of the celestial coordinate system. I calculated the coordinates for the intersections of all these lines, and I used them as control points. There were areas however, where much more points were needed. I used some easily recognizable stars there.

References

(all URLs reviewed at 26 November, 2008.)

Carey, R., Bell, G., 1997. The Annotated VRML97 Reference Manual [internet] *http://www.cs.vu.nl/~eliens/documents/vrml/reference/BOOK.HTM*

Google, 2008. KML Documentation [internet] *http://code.google.com/apis/kml/documentation/*

Hajdu, L. & Márton, M. [ed.] 1986. 40 cm átmérőjű szétszedhető szerkezeti morfológiai Főld-modell. *Cartographia – Tanért, Budapest, 1986*

Hajdu, L. & Márton, M. & Bardócz, L-né 1988. 40 cm diameter detachable structural morphological Earth model. *Cartographia – Tanért, Budapest, 1988*

Hruby, F. & Plank, I. & Riedl, A., 2005. Potential of Virtual 3D-Facsimiles – Exemplified by the Earth Globe of Gerard Mercator (1541). *In: Proceedings, 22nd ICA Cartographic Conference, 2005. A Coruña, Spain.*

Hruby, F. & Plank, I. & Riedl, A., 2006. Cartographic heritage as shared experience in virtual space: A digital representation of the earth globe of Gerard Mercator (1541) [on-line] *http://www.e-perimetron.org/Vol_1_2/Hruby_etal/Hruby_et_al.pdf*

Kovács, P. & Márton, M., 1989. Globes of the Cartographia
in: Csáti Ernő ed.: Hungarian Cartographical Studies (pp.: 61–69)
Hungarian National Committee, Internat. Cartogr. Assoc., Budapest

Márton, M., 1975. Geofizikai földgömbök szerkesztése (Diplomamunka – Final Essay)
ELTE Térképtudományi Tanszék, Budapest

Márton, M., 1988. A Kartográfiai Vállalat földgömbjei
Geodézia és Kartográfia, 1988/1, pp.: 42–48.

Márton, M., 2008. Megnyílt a Virtuális Glóbuszok Múzeuma
Térinformatika-Online, 9 May 2008.
http://terinformatika-online.hu/index.php?option=com_content&task=view&id=217&Itemid=46

Márton, M. ed., 2008. *Virtual Globes Museum* [internet]
http://terkeptar.elte.hu/vgm

Márton, M. & Gede, M. & Zentai, L., 2008. Föld- (és ég-) gömbök 3D-s előállítása – Virtuális Földgömbök Múzeuma és digitális virtuális restaurálás
Geodézia és Kartográfia, 2008/1–2. pp. 36–42.

Nelder, J. A. & Mead, R., 1965. A simplex method for function minimization.
Computer Journal, 7:308–313. Oxford

Riedl, A., 2000. Virtuelle Globen in der Geovisualisierung. In: *Wiener Schriften zur Geographie und Kartographie* 13. Vienna: 158.

Riedl, A., 2003. Hyperglobe – alpha test site [internet]
http://hal.gis.univie.ac.at/hyperglobe/html/home/index_hg.html

Snyder, J. P., 1987. Map Projections – A Working Manual. *USGS Professional Paper 1395. Washington, 1987.*

Török, Zs. & Balázs, J., 2008. Waldseemüller újratöltve
A Földgömb, 2008/1, pp. 82–84., Budapest

Wagner, K., 1962. Kartographische Netzentwürfe. *pp. 155-156.*
Bibliographisches Institut, Mannheim 1962.