Renáta Szabó*

Virtual visualization of a celestial globe

Keywords: celestial globe; cartographic heritage; virtual globe; constellations; 3D models

Summary: The Library of the Reformed College in Debrecen has a rare copy of a 300-year-old celestial globe. The globe was published in 1700 in Amsterdam. The publisher was the Valk family, though some sources say that the publisher was Hevelius. This paper explains this contradiction. This globe is an interesting cartographic product which is part of the cultural heritage and it has to be saved for the posterity. The solution offered by the latest technology is to transform the old cartographic product into a digital form, and then to publish it on the internet. This paper introduces the history of this special globe and describes the process of making its virtual copy.

The modern visualization of the globe needs two major steps: first, taking high resolution digital photos of the globe, then process the images using a special cartographic projection and software to represent the complete celestial globe in 3D on computer screen. The paper gives details on the transformation technique and the applied software, presents the cartographic values as well as analyzes the astronomical content of the globe, the names and positions of stars and constellations. The author compares the star positions of 1700 to the present positions and examines the accuracy of this old celestial globe.

About the globes

"A spherical structure on whose surface is depicted the geographical configurations of the earth (terrestrial globe), or the arrangement of the constellations (celestial globe)."[1] (Cartographical Innovations, 1982) The word "globe" comes from the Latin word globus, meaning sphere. There are two kinds of globes: terrestrial and celestial. The terrestrial globe is representing the earth. The celestial globe is "representing the heavens, the visible sky, and usually showing the positions of stars and the forms of the constellations."[1] (Cartographical Innovations, 1982)

The globosity of the Earth was formed by Greek astronomy in the 3rd century BC, and the earliest terrestrial globe turned up from this period. Greek-named Crates made the first globe in about 150 BC. Terrestrial globes from Antiquity or the Middle Ages did not survive, but a celestial globe remained from the Roman times. The Romans made a celestial globe known as the Farnese globe in 25 AD. It is a copy of a Greek sculpture made by the Romans, and now kept in the Naples Museum, Italy. Martin Behaim (1459–1507), a German geographer made the earliest terrestrial globe that survived. He made this globe in Nuremberg, Germany, in 1492. The German name of the globe was Erdapfel, which means earth apple.

Only few globes remained from those times and the bonded segments were damaged very easily, because they were made of wood or papier-maché. Globes were manufactured by sticking a printed paper map onto a sphere. There was more opportunity for the globes to survive if they were made from metal.

* Junior research fellow, HAS RCAES Geographical Institute [szabo.renata@csfk.mta.hu]

[1] Cartographical Innovations, 1982

The globe factory of Valk

Gerard Valk (1652–1726) had a publishing firm of maps and atlases together with Petrus Schenk (1675–1746). In 1687, their shop was in the Kalverstraat, in the centre of Amsterdam. Around 1700, they moved the shop on the Dam Square.
Petrus Schenk was married to Gerard's sister. Gerard's son and heritor, Leonard Valk (1675–1746) married Petrus's daughter, Maria (1688–1770) in 1710. In 1701, he requested and received from the States of Holland and West-Friesland a contract for making globes. Pieter Maasz Smit taught him on the art of globe. Pieter Maasz Smit was an instructor in navigation and mathematics. Gerard Valk's other teacher was Lotharius Zumbach de Coesfelt, a lecturer in astronomy at Leiden University.
The firm created terrestrial and celestial globes of 7.75, 15.5, 23, 31, 39 and 46 cm in diameter; further, a manual on the use of the globes was published in Dutch and in Latin. The cartographic content of the globes is accurate and up-to-date. A great number of new constellations were added to the celestial globes. The Valk firm made the globe by using the star atlas of Hevelius from 1690. All his celestial globes are called Uranographia following the title of the atlas of Hevelius. Gerard Valk published the manual of the globes in about 1700. The title of this book is 't Werkstellige der Sterrekonst (in English: The system of astronomy).
In 1711, Leonard Valk, who was Gerard's son, became a member of the bookseller's guild. Probably it was this time when he joined his father in the globe making business. Together they produced a number of new pairs of globes in different sizes. After Gerard's death (1726), the firm was continued by his widow, and after her death (1729) her son pursued the globe production. As he did not gain much success, he rented new but less expensive premises on the south side of the Rozengracht.
After Leonard Valk's death (1746), the firm was directed by his widow Maria Schenk, who sold it to her brother Petrus II Schenk (1693–1775). In the end of the eighteenth century, the factory came into the ownership of Cornelius Covens (1764–1825), a partner in the famous map publishing Covens & Mortier firm.
In the 1860's the publishing firm Covens & Mortier disappeared, "and globe production in the North Netherlands came to halt."[2] (Krogt, 1984)

The celestial globe

The copy of the examined celestial globe is in the Library of the Reformed College, Debrecen. The globe was registered in the catalogue of the Library in the beginning of the 18th century. The condition of this celestial globe is excellent. It was restored in 1995–1996 in the National Széchényi Library in Budapest.

[2] Krogt, 1984

Figure 1. The Valk's celestial globe in Debrecen.

The globe was published in Amsterdam by the Valk family, though some sources say that the publisher was Hevelius. The Valk firm made the globe by using the star atlas of Hevelius from 1690. The epoch of the celestial globe refers to 1700. He published several other celestial globes, all with the title of *Uranographia,* which was originated from the title of the atlas of Hevelius.
The globe is 31 cm in diameter and is made of papier-maché, a composite material. This consists of paper pieces or pulps, sometimes reinforced with textiles, bound with some adhesive material. The sphere is covered with a plaster coating and two sets of 12 half gores, clipped at the ecliptical latitude of 70°, and two polar calottes. The gores are copper-engraved, hand-coloured (stars in gold), and varnished. The sphere is mounted in a graduated brass meridian ring. The hour circle is missing from the North and South Pole of the globe. The stand is wooden and there are four legs. Nothing supported the meridian ring. In other copy, the meridian ring is held up by a circular base-plate with a central pillar.
The title is below Cetus constellation: "Uranographia/ Caelum omne hic Complectens,/ Illa pro ut aucta,/ et ad annum 1700 Completum,/ MAGNO ab HEVELIO/ Correcta est;/ ita, ejus ex Prototypis,/ sua noviter haec Ectypa/ veris Astronomiae culturibus/ exhibet et consecrate/ GERARDUS VALK/ Amstelaedamensis/Cum Privilegio."[3] (Krogt, 1984)

[3] Krogt, 1984

Figure 2. The title field.

This title in English is: "Uranographia, comprising the whole sky, as it was augmented and corrected for the year 1700 by the great Hevelius. Thus from his prototypes Gerard Valk of Amsterdam offers and dedicates these new engravings to true devotees of astronomy. With privilege."[3] (Krogt, 1984)

The globe's coordinates are on the circles of latitude and parallels to the ecliptic. Every 5° is written both in latitude and parallels. The equator is labelled: Æquator. The ecliptic is provided by the symbol of the signs of the zodiac. (Zodiac is a circle of twelve 30° divisions of celestial longitude. The twelve constellations are named: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces). The five major circles of latitude are written: the Circulus Arcticus (Arctic Circle), the Tropicus Cancri (Tropic of Cancer), the Equator, the Tropicus Capricorni (Tropic of Capricorn) and the Circulus Antarcticus (Antarctic Circle). The solstitial colures are drawn but not labelled. (The solstitial colure is the meridian of the celestial sphere which passes through the poles and two solstices [the first point of Cancer and the first point of Capricorn].) Below Sagittarius, there is a magnitude table with a symbol of the Sun. The Milky Way (Via Lactea and Galaxia) and the Magellanic Clouds (Nubec:Minor and Nubec:Major) are labelled.

These star names are written on the globe:

- Achernar (in Cygnus),
- Archermar (Eri),
- Alamac,
- Aldebaran: is located in the zodiac constellation of Taurus,
- Algenib (Per): is a name of Gamma Pegasi and Alpha Persei,
- Algol: is in the constellation Perseus,
- Antares: is the brightest star of Scorpio,
- Arcturus: is in the constellation of Boötes,
- Canopus: is in the constellation of Carina,
- Capella: star is part of the constellation of Auriga,
- Castor: it is a star in the constellation of Gemini,
- Cauda Cygni,

- Dubbe,
- Lucida Arietis,
- Lucida Lyra,
- Marcab,
- Mirach: Beta Andromeda is a star in the northern constellation of Andromeda; its traditional name is Mirach,
- Pollux: is a star in the northern constellation of Gemini,
- Procyon: is a star in the constellation of Canis Minor,
- Propus,
- Regel,
- Scheat (Aqr): Beta Pegasi in the constellation Pegasus; its traditional name is Scheat,
- Scheat (Peg),
- Schedir: it is a star in the constellation Cassiopeia,
- Spica Virgins,
- Syrius: it is in the constellation of Canis Major,
- Vindemiatrix: it is member of Virgo.

There are some copies of this globe around the world. There are copies in Netherlands:

- Utrecht, Universiteitsmuseum (1700, 1st edition)
- Amsterdam, Rijksmuseum (1700, 2nd edition) 'Nederlands Scheepvaart Museum'
- Amsterdam, Rijksmuseum (Nederlandse Geschiedenis)
- Amsterdam, Rijksmuseum 'Nederlands Scheepvaart Museum' [17(5)0]
- Amsterdam, Artis Bibliotheek (1750)
- Amsterdam, private collection
- Eijsden, Kasteel Eijsden

There are copies in Austria, too:

- in the National Library,
- in private collection in Styria,
- another globe in private collection in Vienna.

In the National Maritime Museum in Oxford there is also a duplicate. In the Königliches Museum of Kassel the diameter of celestial globe is 30 cm. In the Mathematische Salon of Dresden there is a celestial globe, its diameter is 30 cm. In the Germanisches Nationalmuseum of Nuremberg a well-preserved pair of the Valk globes is found, they are dated in 1700 and their diameters are 31 cm. The Hispanic Society of America owns some pairs of the Valk globes, too. One of the pair of Valk globes (celestial) has a diameter of about 30 cm. In the celestial globe, the author and date legend are placed near the constellation "Cetus". This is "Uranographia Coelum omne hic Complectens, illa pro ut aucta, et ad annum 1750 Completum Magno ab Hevelio correcta est; ita ejus ex Prototypis, sua noviter haec Ectypa veris Astronomiae culturibus exhibit et consecrant GER. et LEON. Valk, Amstelaedamenses. Cum Privilegio." "Star-Map comprising the entire heavens according as it has been corrected to the end of the year 1750 by the Great Hevelius; so from his prototype Gerhard and Leonard Valk present and dedicate these their own recent copies to the true lovers of astronomy. With Privilege."[4] (Stevenson, 1921) Near the constellation of "Hydra" there is a legend: "Monitum Novis hisce Sphaeris Novissimus. Ex praescripto Lotharii Zum-Bach Med. Doct. unus, et alter additus Horizon: Quorum Is, qui huic Caelesti singularis, Praeter Communes atque Bissextilem, Ut exactior, Luminarium indigetur Locus ad Meridianum

[4] Stevenson, 1921

Amstelodamens. Plus quam per Ducantos. Annos Suis Mensium Dielbus Appositas Lunae Syzygias, Mediô Tempore Medias, Ingeniosa Methodō et eruit, et exhibet."

Figure 3. The legend.

"Notice. To these our spheres, in accord with the directions of Lothar Zum-Bach, Doctor of Medicine, there has been added one very recent, and also a second horizon; of these two the one which belongs to the celestial globe has in addition the common and bissextile years, in order that the location of the stars may the more exactly be discovered; it both works out and exhibits by an ingenious method, according to the meridian of Amsterdam, over a space of more than two hundred years the syzygies of the moon placed opposite their proper days of the month, the middle ones being in the middle time."[5] (Stevenson, 1921) These globes are well preserved, and the colours are in original condition.

There is some globe in auction web pages. One of them was found on Christie's auction web page. The diameter of this globe is 31 cm. It was published in circa 1803. On the cartouche is: *URANOGRAPHIA CAELUM Sive GLOBUS CAELESTIS à Gerardo Valk olimaere excusus nunc secundum norissimas observationes, ac multo emendiator editus à CORNELIO COVENS Calcographe 1803.*

[5] Stevenson, 1921

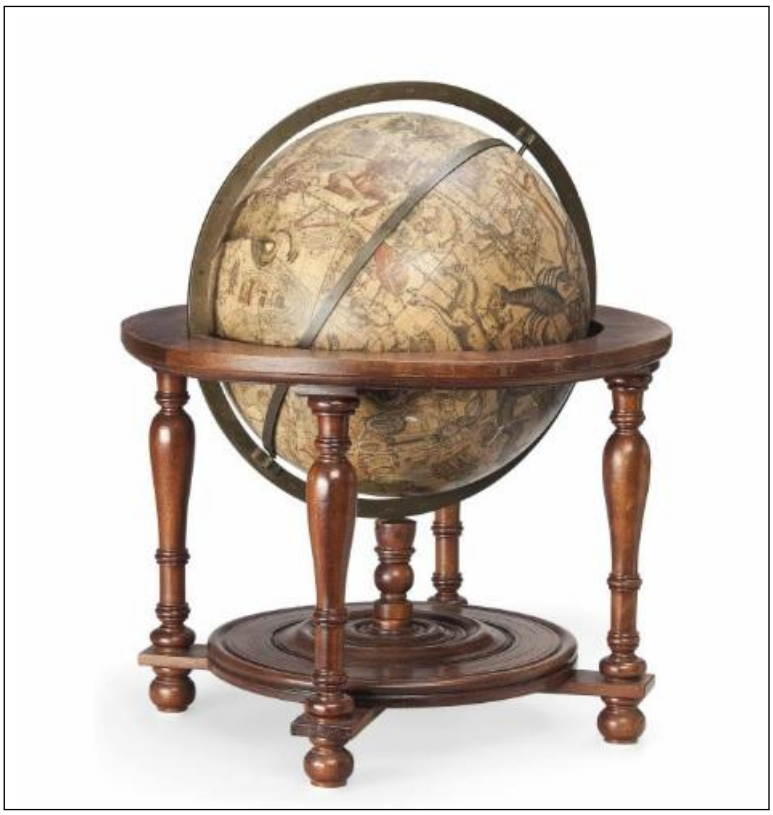

Figure 4. The globe on an auction web page.

Compilation of the virtual globe

The old globe needs restoration from time to time. We have the chance to present this globe in original condition with the help of computer science. By taking photos of the surface of the globe it can be protected and presented in the same form as it was made. This is a cheap and quite simple solution to preserve the globe.

This globe appears in the Virtual Globe Museum of my university. This museum has been available since 2007. The Virtual Globes Museum aimed at presenting the globe in its original condition. There is a unique website (http://vgm.elte.hu) where people can see the realistic steerable-zoomable models of old globes.

The website of the Virtual Globes Museum uses X3DOM. "X3DOM is an experimental open source framework and runtime to integrate HTML5 and declarative 3D content."[6] (Fraunhofer, 2011) It is used to create 3D scenes in web pages. It is based on standard browser technology, such as HTML5 and WebGL. The browsers do not need any plugin to display X3DOM scenes.

We took a series of photos of the surface of the globe. There are some criteria that we had to take into account when the photos were taken. For instance, the optical axis of the camera had to be focused to the centre of the sphere; the work place had to be antiglare. Altogether, 109 pictures were taken of the surface of the globe. The photos cover areas of 20*30°. This part of the globe had to be antiglare. The next step was the georeferencing, which was made by Global Mapper software. The projection of the photos is the Tilted Perspective projection, which most of the programs may not know. "But if the globe's centre is on the optical axis then it is Near-

[6] Fraunhofer, 2011

side Perspective projection."[7] (Gede, 2009) If the parameters are determined (the geographic coordinates of projection centre and height of camera), Mátyás Gede "developed a little program which uses the simplex algorithm to find these values using the given control points which are the intersections of grid lines."[8] (Gede, 2009)

The digital projection transformation was also made in Global Mapper. The projection adjustment is Geographic (Latitude/Longitude). The next task was cutting out the usable area of the pictures and then assembling the pieces. This software was used for the projection transformation and for assembling the pieces too.

X3D supports the usage of textures of the surface. An image of the world was given in Equirectangular projection as a texture in X3D, and the steerable globe appeared on the computer screen when the code was opened with an internet browser.

Position analysis of stars

The astronomer of ancient times thought that every planet was placed on a big sphere, and the Earth was in the middle of this sphere. The Earth rotates west to east, but the celestial sphere including the planets seems to rotate east to west. Only two points do not move: they are marked by the axis of rotation of the Earth. The celestial globe is divided in two parts (hemispheres) by the equator. Before the telescope, people could observe the Sun, the Moon, five planets and around 5000 stars in the sky. The stars are in one of the 88 constellations and they do not move relatively to each other. The shape of constellations is steady (at least for us it does not change noticeably).

Edmond Halley (1656–1742) was the first who found out in 1718 that the position of one of the constellations was different from the one of the ancient time. This is because of the proper motion of stars. This means that the stars change their position. This movement can be perceived on secular or millennia time scale.

The right ascension and declination are coordinates used in astronomy. The right ascension is one of the coordinates of the second equatorial coordinate system. It is measured counter clockwise along the celestial equator from the vernal equinox until the meridian passing through the given celestial body, from the perspective of the north celestial pole. The other celestial coordinate is the declination. Declination means the height of the point above the celestial equator and it is expressed in degrees.

A simple method to compare the position of stars is to georeference and transform the celestial globe map into a geographic projection, and compare this picture to a star map. The method is presented on the example of the Big Dipper. The seven brightest stars of Ursa Major are made up of Big Dipper. However, this method is not precise.The failures were caused by the contemporary unpunctual measurements, small distortions and inaccuracies in the digital processing, also the relative position of the stars has changed over the past 300 years.

[7] Gede, 2009
[8] Gede, 2009

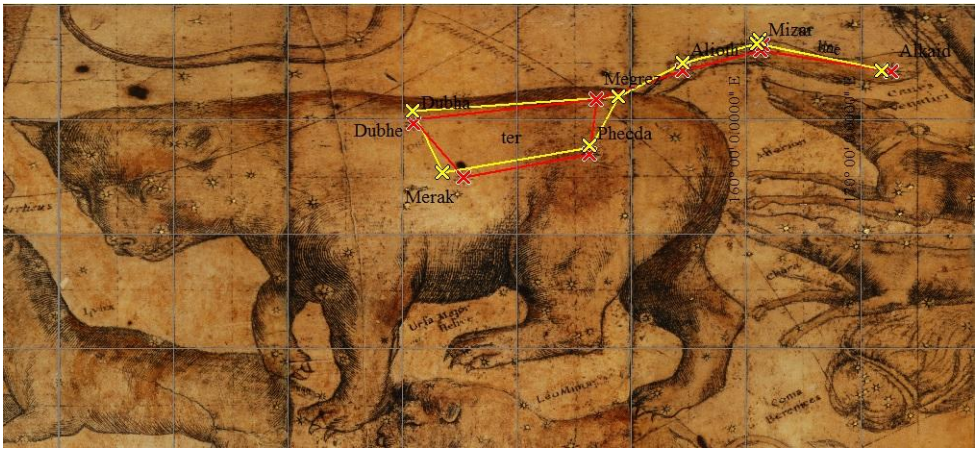

Figure 5. Red line is meaning the Big Dipper on Valk's globe, the yellow line is representing the modern position of Big Dipper

Conclusion

In the cultural history of mankind, the production of the earth and celestial sphere has always meant the synthesis of science and art. The spheres represent the Earth and Universe, and they model the known world. Through these spheres the development of the geographical and astronomical knowledge is traced. This is why studying the old globes are very important.
The Valk's celestial sphere is already saved for the future generations. It is transformed into digital form and published on the internet. This globe is found in the Virtual Globes Museum, where there are many earth and celestial globes, and luckily these numbers increase.

Acknowledgement

The author thanks György Danku for his help to find sources for the Valk's globe.

References

Allmayer-Beck, P. E. (1997). Modelle der Welt: Erd- und Himmelsgloben, 352.

Barcza, J. (ed.) (1988). A Debreceni Református Kollégium története, 406.

Dekker, E. (1999). Globes at Greenwich, *A Catalogue of the globes and Armillary Spheres in the National Maritime Museum, Greenwich,* 509-515.

Fraunhofer (2011). X3DOM Documentation. Fraunhofer IGD, VCST.

https://x3dom.readthedocs.org/en/1.3.0/ Accessed 25 July 2014

Gede, M. (2009). Publishing globes on the internet. *Acta Geodaetica et Geophysica Hungarica* 44 (1): 141-148.

Gede, M., Ungvári, Zs. and Zentai, L. (2013). Virtual Globes Museum 2.0 – Adding the Power

of Community.
http://www.icc2013.org/_contxt/_medien/_upload/_proceeding/174_proceeding.pdf

Klinghammer, I. (1998). A föld- és éggömbök története

Krogt, P. (1984). Old globes in the Netherlands, 25-26., 220-254.

Restás-Göndör, A. (2010). Régi csillagtérképek pontossági analízise.
http://lazarus.elte.hu/hun/digkonyv/szakdolg/bsc/2010-restas-gondor.pdf

Accessed 27 July 2014

Stevenson, E. L. (1921). Terrestrial and celestial globes, *Their history and construction including a consideration of their value as aids in the study of geography and astronomy*

Tooley, R. V. (1999). Tooley's dictionary of mapmakers

Web sites:

http://doc.x3dom.org/
Official x3dom documentation, Accessed 27 July 2014

http://pvs.kcc.hawaii.edu/ike/hookele/celestial_sphere.html
The celestial sphere, Accessed 27 July 2014

http://regi.oszk.hu/hun/szakmai/restaurator/restaurator_globuszok_hu.htm *The restored globes in the National Széchényi Library,* Accessed 27 July 2014
http://www.astro.wisc.edu/~dolan/constellations/constellations/Ursa_Major.html
The Constellations and their Stars, Accessed 27 July 2014

http://www.berksastronomy.org/starcharts.htm
Celestial cartography, Accessed 27 July 2014

http://www.christies.com/lotfinder/lot/a-12-inch-dutch-celestial-globe-covens-after-5723258-details.aspx#top Accessed 27 July 2014

http://www.ianridpath.com/startales/hevelius.htm
Hevelius, Accessed 27 July 2014

http://www.konkoly.hu/~kovari/CSILLAGASZAT/tananyag/CSILLAGASZAT/04_01.html
Orientation in the sky, Accessed 27 July 2014

http://www.madehow.com/Volume-4/Globe.html
Globe Accessed 27 July 2014