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Wheels of Geography: Interactive renewal of antique educational instruments

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Summary: Following the tradition of digital reconstruction and interactive exhibition of globes, Department of Cartography and Geoinformatics of ELTE has started a new renewal project focused on antique educational instruments preserved in the library of the Department. The term ‘wheels of Geography’ in the title refers to three of them. From a detailed analysis of their geographic content, we know they were prepared between the end of the 19th century and the mid 1930’s. Their purpose was to help understanding complex issues and related phenomena of geography at primary, secondary and university levels in education. Interactive forms of these wheels are collected to a web page named szertar.elte.hu where users can easily understand their methodology and content. This web page provides access to the applications, shows scanned images of the original objects and gives short descriptions on the content and usage. Web applications of these instruments are written in JavaScript, attributes of the databases are maintained with PHP and graphic visualization is based on SVG. Some details had to be slightly modified and geographic data needed to be updated. Today, web-based reconstructions of such objects are able to bring pupils and students closer to geographic topics. On the other hand, with digitalization, we are able to protect these objects from falling out of memory and to present them to the new generations. Breaking out from the library drawers, szertar.elte.hu ensures their way back to the students.

Introduction

Modeling spatial structure of the surrounding environment, regarding the Universe, the surface of Earth or the neighborhood around us, has a long history. Content and appearance of such models were evolved over centuries and, parallel with this process, demonstration aids have been developed for education, in optimally simplified forms considering cognitive characteristics of different age groups. As a result, today, it is unthinkable to teach Geography without globes and maps. It is also clear that tools that provide learning material in an alternative or in a less common way significantly increase the efficiency of teaching and understanding complex topics. Visualization in teaching Geography is particularly important because perception and interpretation of spatiality is almost impossible without globes, celestial spheres, maps, other 2D illustrations and 3D models. The library and map collection of the Department of Cartography and Geoinformatics of Eötvös Loránd University preserves several teaching materials for Geography from the first half of the 20th century. These objects are not in use any more as some parts of their content became out of date. Despite their primary task of demonstration, they got forgotten for a long time. But now, the continuously expanding set of digital tools offers the opportunity to recreate these old instruments according to modern visual and technical requirements. An essential part of the work is to update geographic names and data where it is needed. Interactive versions of the instruments described in this article are available on the website szertar.elte.hu (Figure 1). The name of the portal “szertár”

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refers to a common term in Hungarian schools used for typically small rooms where demonstration aids and class supplies are stored, especially for subjects of sciences.

Figure 1. Initial page of the web site of renewed educational instruments. The Hungarian word “szertár” denotes a kind of “room of class supplies”.

In the following chapters, we describe characteristics, usage and technical background of three teaching aids, namely a country guide, a sun pointer and a comparative time dial. These objects were prepared for students at different levels of the educational system therefore their scientific content and the complexity of their structure are optimized for different age groups. In this article, instruments are presented in chronological order of their publication. Their interactive versions are available in English and in Hungarian.

In the process of digital recreation, the most important aspects were to build a system where graphics and databases in the background are easy to edit, and we also intended to keep the characteristics of the original design. Interactivity of the web page is constructed in JavaScript client-side scripting language, database query functions are built in PHP server-side scripting language\(^1\), and images of the instruments are composed of SVG (Scalable Vector Graphics) graphic elements\(^2\). For the complete structure of the web page, see Figure 2. Web site editing and programming were done by Zsuzsanna Ungvári.

\(^1\) http://php.net/manual/en/
\(^2\) http://www.w3.org/Graphics/SVG/
A Comparative Time Dial

A **Comparative Time Dial** is used to determine differences in local time measured at two points on Earth. This specimen (Figure 3) is made of cardboard and consists of two parts. The upper, rotating disc shows the time in hours marked at every 30 minutes with a distinction between day and night. On the lower part, names of major towns, of some countries and regions from all over the World are linked to a circle divided by meridians. This circle of longitudes looks like a ribbon and runs around the dial. This instrument is easy to use: after selecting two places, we can see the difference of geographic longitudes (the distance) between them at the circle of longitudes. To determine local time for a certain moment, we need to set the base time at the first selected place by turning the dial to the right position and then we only need to read the local time at the second selected place. As time divisions on the dial are based on geographic longitudes, this instrument is not suitable for providing standard time.

Geographic names printed on the dial give an insight to the elements and focus of the curriculum of Geography in German schools of the period. Evidently, the majority of the 116 place names refer to big cities (eg London, Madras, Rio de Janeiro) and there are some archipelagoes (eg Azores, Cook Islands, Galapagos Islands) too, but large regions (eg Kamchatka Peninsula, Bering Strait, Lake Tanganyika) and states (eg New Guinea, Mexico, Cuba) are indicated as well.

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The time dial presented on the website was edited by J. Redtenbacher and was published by Freytag and Berndt in Vienna. Unfortunately, year of publishing is missing but it is possible to deduce a time interval of preparation from the analysis of the geographic names as some of them have been turned historic. One of them is “Christiania”. It refers to the capital of Norway that was originally called Oslo but it was renamed in 1624 in honor of Christian IV of Denmark. Until that year, large parts of the town got destroyed in fire several times and it was the Danish king who ordered and financed extensive reconstructions. Oslo was renamed again to its Norwegian name only in 1925. Another, easily dated example is “Neu Pommern” that refers to the largest island of the Bismarck Islands. From 1884 to 1914, this archipelago belonged to German New Guinea protectorate. Today, it makes part of Papua New Guinea and the main island is called New Britain. Among the names on the dial, we find “West-Australien” (Western Australia), separately, which territory became a member state of Australia in 1901. Another remarkable name is the one of the starting point of the longitude ribbon (0° longitude) that runs at London on this instrument. Since the International Meridian Conference held in 1884, the meridian running at the Greenwich Observatory (situated in London) has been considered as Prime Meridian. Similarly to the maps prepared during the transition period, Ferro Island, indicator of the former Prime Meridian is included, too. Based on the
data above, this comparative time dial was prepared between 1884 and 1901 but not later than 1914. (Figure 4)

*Interactive version of the Comparative Time Dial*

To use the Interactive Comparative Time Dial, users have to type first exact local time measured at the base point (or at the first place) and select the name of the place in the provided list of geographical names. A straight, red line indicates the initial position on the dial. Next step is to select the second place by clicking on the blue radio button next to its name in the same list and a blue line appears. Watching the dial, users can easily calculate or estimate local time difference and the difference of the longitudes between the two places (as it was the case with the original instrument) but a module in the software calculates exact local time difference and also the difference corrected according to time zones. This correction is generated with a function in PHP module “Date and time” that uses time zone data recorded for each location. All data are provided in an info box above the dial. It was necessary to slightly update the toponymy of the instrument (eg El Hierro, Oslo and New Britain instead of Ferro, Christiania and Neu Pommern respectively). (Figure 5 and Figure 6)

![Figure 4. Places indicated in the Comparative Time Dial (original in German, turn of 19th-20th centuries, J. Redtenbacher, Freytag & Berndt, 26.0 x 31.5 cm, Map Collection of the Department of Cartography and Geoinformatics, ELTE).](image)

![Figure 5. Data input panel to set the local time at the base location in the interactive Comparative Time Dial](image)
Figure 6. After selecting locations, users can read time difference between them. Base location is marked with a red line, and the second location is marked with a blue line. Example: What is the local time in Melbourne (blue) when it is 12:00 a.m. in Madrid (red)? It is 9:54 p.m.

Sun Pointer

In the first decade of the 20th century, Freytag & Berndt published a **Sun Pointer**, to calculate solar elevation angle, as part of their series of teaching aids. According to the German description on the verso, it was edited by W. Schmidt in 1902, and the Austrian Ministry of Culture and Education authorized it in higher education of geography teachers in 1909. Both in structure and design, Sun Pointer resembles the Comparative Time Dial. The base of the geographic content is a circle representing latitudes on which, a thin, rotating, transparent plastic element with divisions of months and hours is fixed. By adjusting correctly this plastic element, users can estimate the elevation of the Sun above the horizon at any place of the Earth because this calculation is independent of the geographic longitudes or of the time zones (*Figure 7*). The upper right quarter of the circle represents the Northern hemisphere, and the upper left quarter represents the Southern hemisphere.

On the plastic element, the central straight line is aimed to point at the latitude of the selected city (there is a short list of cities and their latitudes on both sides of the circle to help orientation). This central line also indicates the equinox; summer and winter solstice fall to the edges of the element. The elevation of the Sun during the day can be determined by looking at the numbered arcs on the central line. Numbers refer to the hours of the day. The straight lines, perpendicular to the arcs, show the position of the Sun during the year.

In the inner part of the circle, daytime is indicated with white color, civil and astronomical twilights are grey and night time is black. During astronomical twilight, the center of the Sun is between 12 and 18 degrees below the horizon, therefore stars are visible in the sky, still there is some light.⁶

To determine the Sun’s elevation in the Interactive Sun Pointer, users are asked to enter the latitude of the area and the exact time in question (month, day, hour and minute). These data can be entered manually or automatically. In the latter case, GeoLocation API\(^7\), a free JavaScript module, is activated. In addition to the Sun elevation, the Interactive Sun Pointer provides the direction of the Sun and the sunrise and sunset times, too. When determining these data, time lag and geographic length of the selected area are also taken into the calculations with equations\(^8\) published by NOAA.

In the following, equations\(^9\) that were used in the calculations are explained. In general, $\phi$ and $\Lambda$ indicate the latitude and longitude of the observer’s location on Earth. The date determines the day of the year (n). Hour angle ($\omega$) is calculated from time data (hour / h and minute / m). For example, the solar hour angle is -90° at 6 a. m. and 0° at 12 a. m. The solar time is corrected with the time offset of the time zones. The variable named $\Delta t_{GMT}$ marks the difference from the Greenwich Mean Time.

\[
\text{lst}m = 15 \cdot \Delta t_{GMT}
\]

\[
\beta = \frac{360}{365} \cdot (n - 81)
\]

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\(^7\) http://dev.w3.org/geo/api/spec-source.html
\(^8\) https://www.esrl.noaa.gov/gmd/grad/solcalc/solareqns.PDF
The equation of time (EoT) describes the discrepancy between two types of solar time (mean solar time and theoretical solar time).

\[ EoT = 9.87 \cdot \sin 2\beta - 7.53 \cdot \cos \beta - 1.5 \cdot \sin \beta \]

Time correction factor is:

\[ tc = 4 \cdot (A - lst) + EoT \]

Sidereal time is a timekeeping system where a time scale that is based on Earth's rate of rotation measured relative to the fixed stars rather than the Sun. Therefore, the local sidereal time (lst) is

\[ lst = \frac{h + m}{60} + \frac{tc}{60} \]

Hour angle (\(\omega\)) of a point is the angle between the planes of the Earth's axis and of the zenith (meridian plane).

\[ \omega = 15 \cdot (lst - 12) \]

The \(\delta\) is the current declination of the Sun.

\[ \sin \delta = \sin \beta \cdot \sin 23.45^\circ \]

E gives the elevation of the Sun above or under the horizon:

\[ E = \sin^{-1}(\sin \delta \cdot \sin \Phi + \cos \delta \cdot \cos \Phi \cdot \cos \omega) \]

Solar azimuth angle (A) is:

\[ A = \cos^{-1}\left(\frac{\sin \delta \cdot \cos \Phi - \cos \delta \cdot \sin \Phi \cdot \cos \omega}{\cos E}\right), \text{ if } h < 12 \]

\[ \text{else } A = 180 + (180 - \cos^{-1}\left(\frac{\sin \delta \cdot \cos \Phi - \cos \delta \cdot \sin \Phi \cdot \cos \omega}{\cos E}\right)) \]

The time of the sunrise (SR) is

\[ SR = \frac{12 - 1}{15} \cdot \cos^{-1}(-1 \cdot \tan \Phi \cdot \tan \delta) - \frac{tc}{60} \]

and the time of the sunset (SS)

\[ SS = \frac{12 + 1}{15} \cdot \cos^{-1}(-1 \cdot \tan \Phi \cdot \tan \delta) - \frac{tc}{60} \]

Figure 8 shows the example of calculating the elevation of the Sun at noon, 16 March in Budapest. As the geographical latitude of Budapest is 47°, the middle element has to be rotated as the central straight-line points at 47 degrees on the outer (black and white) circle. Find 16 March on the arc with names of the moths, and slide your eye to the arc of 12 (this is indicated with the shorter arrow). The height of the crossing point of these two lines (indicated with red circle) has to be projected to
the vertical axis of the circle (this is indicated with the longer, horizontal arrow). To determine the current sun elevation of the example, we have to use divisions of sun elevation that are indicated in degrees in the inner part of the circle (dashed horizontal pink line). In the original Sun Pointer, 0°, 5°, 10°, 30° and 60° degrees are indicated with straight, horizontal lines.

![Sun pointer](image)

Figure 8. In Interactive Sun Pointer, elevation of the Sun in Budapest (47° 27' 35.5482'' N; 19° 3' 27.2239'' E) on 16 March, at Noon is 38.8°. The vertical red line helps the user to determine the value.

**Country Guide for Pupils**

The third piece of the collection is a *Wheel of Europe*, a country guide for children, published by Kosmos in Stuttgart (*Figure 9*). This is the simplest structure in this series, built up with two, rotatable cardboard disks. The lower and larger one contains various data on 34 European countries that are seen through little “windows” of the upper one by rotating the disk to the right position, i.e. when the red arrow points at the country name in question. Geographic and statistical information are organized in eleven data classes: country name and flag, government type, total population of the state, name and population of the capital, name and length of the main river, name and height of the highest mountain, total area in km², population density in persons per km² and an identification number with which we can find the country in the small scale, supplementary map. This map is rather sketchy, shows only the country borders with identification numbers instead of country names. Toponymy is reduced only on names of largest water bodies (Atlantic Ocean, North Sea, Mediterranean Sea and the Black Sea). There is no indication of the year of publishing but the geographic content suggests that this piece was prepared in the 1930’s (see *Table 1*). Contrary to the first two instruments, that were prepared to complete secondary and higher education of Geography, Wheel of Europe was used in primary schools.
<table>
<thead>
<tr>
<th>Name on the Wheel</th>
<th>Actual name</th>
<th>From (initial year)</th>
<th>To (final year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free City of Danzig</td>
<td>Gdansk, Poland</td>
<td>1920</td>
<td>1939</td>
</tr>
<tr>
<td>Kingdom of Yugoslavia (Seven successor states)</td>
<td></td>
<td>1929</td>
<td>1941</td>
</tr>
<tr>
<td>Kowno (as capital of Lithuania)</td>
<td>Kaunas</td>
<td>1922</td>
<td>1939</td>
</tr>
<tr>
<td>Finland</td>
<td>Finland</td>
<td>1917</td>
<td>present</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>Czech Republic and Slovakia</td>
<td>1918</td>
<td>1992</td>
</tr>
<tr>
<td>Kingdom of Hungary</td>
<td>Hungary</td>
<td>1001</td>
<td>1946</td>
</tr>
<tr>
<td>European Russia (part of the Soviet Union)</td>
<td>Russia</td>
<td>1922</td>
<td>1991</td>
</tr>
</tbody>
</table>

Table 1. Overlapping time intervals of geographic names in the Wheel of Europe help to determine the period of publication (between 1929 and 1939).

Interactive version of the Country Guide

In the Interactive Wheel of Europe, users only have to click on the name in the ribbon of the countries and the wheel automatically “turns” and shows the same data types that are presented in the antique tool. At the same time, the selected country is highlighted with red color in the little index map (Figure 10). Operation of this application is based on a simple database of the modern countries of Europe.¹⁰

Figure 9. Wheel of Europe (in German, Kosmos Verlag, Stuttgart, diameter: 24.8 cm. Map Collection of the Department of Cartography and Geoinformatics, ELTE)

¹⁰ Actual data are taken from Családi világatlasz (Family World Atlas) 2007 and from Wikipedia
Figure 10. In Interactive Wheel of Europe, users receive updated data on the European countries.

**Conclusions**

In the mental process of understanding complex issues of Geography, visual aids have always had a great role as they facilitate cognitive creation of spatial arrangement of geographic objects and phenomena in some cases, and they help to understand correlations of different disciplines in some other cases. Today, a controversial situation is emerging with the widespread use of digital technologies, which is particularly noticeable among younger age-groups. On one hand, general demand for digital, interactive (and playful), high-quality content is constantly increasing, and the knowledge disclosed this way is clearly appreciated. On the other hand, acceptance and appreciation of contents (and even the objects themselves) in the "analogue world" are eroded and are often considered "obsolete", "outdated" or "outworn". Classroom experience shows that students’ interest in analogue devices can be aroused but this is a cumbersome task in comparison to the digital versions. Digital reconstructions of old teaching aids are in accordance with expectations of the generations that are socialized in digital environment, so they facilitate understanding the use and the content of the original tools, this way transferring the substance of each topic. Thus, these special, but undeservedly forgotten objects can fulfill their original duties in a new form.

**References**


Equations for calculations:


GeoLocation API: http://dev.w3.org/geo/api/spec-source.html


PHP official documentation: http://php.net/manual/en/

Solar equations by NOAA: https://www.esrl.noaa.gov/gmd/grad/solcalc/solareqns.PDF

SVG official documentation: http://www.w3.org/Graphics/SVG/


Time zones and astronomical concepts: https://www.timeanddate.com