THEMATIC MAPPING WITH CESIUM

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Abstract
The open source virtual globe API, Cesium is an excellent tool for creating various thematic visualizations on an interactive 3D globe model embedded into a web page. This API became particularly important since the deprecation of the popular Google Earth plugin. Cesium has a lot of features that can be utilized in thematic mapping: raster ground overlays, point placemarks, lines, polygons and 3D objects. Using its own data format, CZML, it is also possible to define time-dependent features: any kind of numeric values can be interpolated over time such as coordinates, size, height, rotation or colour components, which gives the opportunity to create various spatio-temporal visualizations. This paper introduces the most important features of this API along with their possible use in thematic visualization as well as their limitations. The author also developed a QGIS plugin that helps generating various thematic visualizations in CZML format.

Keywords: Cesium API, Thematic mapping, CZML

INTRODUCTION

Virtual globes and geobrowsers are nowadays very popular media for thematic mapping. As an interactive, moving, rotatable-zoomable "gadget" is always good at raising attention, their primary use is in the fields of decision support and popularising, disseminating information. Several papers are available on the topic, focusing either on the technical possibilities, the possible visualization methods or discussing the justifiable uses of these visualization methods.

Regarding the technical background, most of the solutions based on Google Earth or its – already deprecated – plugin, and using the KML file format for defining thematic content (e.g. Sandvik 2008). Others (e. g. Tiede, Lang 2010) used ArcGIS Explorer, ArcGlobe or NASA World Wind for visualizing data, although in some cases also using KML format.

With the emerging new technologies, WebGL and HTML5, several JavaScript-based virtual globe libraries, APIs (Application Programming Interfaces) were developed to facilitate displaying 3D interactive globe models on web pages without the use of any plugins. Such a library is OpenWebGlobe, created by Swiss researchers (Christen, Nebiker, Loesch 2012) or WebGL Earth JavaScript API, which originally was a bachelor thesis (Sloup 2011) and is currently maintained by Klokan Technologies. Although these two products are also useful in some cases, due to their limitations (discussed e.g. in Gede 2015a) it is advisable to use another library, the Cesium API (Cozzi 2013). Cesium offers much wider functionality, rich documentation and a very active developer community ensuring that most questions are answered quickly in developer forums.

In a few special cases it is more advisable to create a "standalone" 3D thematic globe model instead of using one of the aforementioned APIs. This usually occurs when the globe has a special, non-spherical shape, e. g. the detachable structural-morphological Earth model showing cross-section of the Earth in (Gede 2015a). If the goal is publishing the globe on the web, the best choice is X3DOM, a JavaScript library which enables embedding declarative 3D content (X3D code) directly into HTML (Fraunhofer 2014). Using X3DOM, the 3D content becomes an integrated part of the Document Object Model (DOM), making it possible even to alter the 3D content run-time.

As for the thematic content of the globe, the possibilities of 3D visualisation are virtually unlimited – there are much more possible visual variables than in the case of 2D maps. This does not mean, however, that one should overwhelm the globe with data – placing too many objects to the globe or using too many visual variables simultaneously may result in information loss (Gede 2015b). In daily practice, however, most thematic globes use only one of the three most common visualization methods: choropleths, 3D prism maps and graduated 3D symbols.

Globes are not necessarily the best choice for thematic maps. Harrower (2009) even claims that there is no need to use virtual globes for thematic visualizations at all, as reading planar maps is faster and more efficient. A master thesis at the University of Kansas (White 2012) evaluated the effectiveness of thematic maps on virtual globes. The results indicate that planar thematic maps are more effective in information transmission than thematic globes.

These studies suggest that globes are not a good choice for thematic mapping, but one should not forget that there are much more ways of visualizing information than the most commonly used choropleths, prisms and graduated symbols; and that the nature and extent of the data should always influence the choice of visualization method. There are at least two important factors that make it reasonable to use globes instead of flat maps. First, let's think about traditional globes, and their role compared to planar maps. Although it is usually easier to read information from a paper map, globes have advantage when it is important to emphasize the seamless and/or the spherical nature of the Earth surface. This is the reason of the existence of traditional thematic globes as well, depicting usually some global natural phenomena, like the Earth's tectonics, or climate zones etc. Then, there are cases when the attractiveness of an interactive, three dimensional object is taking preference. This is particularly important nowadays when people are overwhelmed with information, which makes it hard to raise their attention.

If, considering all these factors, the best choice is a thematic visualisation on a virtual globe, the solutions and tools introduced in the following sections may help to create it.

FEATURES OF CESIUM API FOR THEMATIC MAPS

Using Cesium, only a few lines of JavaScript code is required to embed an interactive virtual globe into an HTML page. This is described in detail in the Cesium API documentation (Analytical Graphics 2016), especially in its tutorial section. Once having a virtual globe on our website, various types of thematic visualizations can be added to this globe several ways:

Raster overlays

In a number of cases it is enough to drape a raster overlay to the globe. Using this solution we can use all the traditional cartographic visualization methods (e. g. point density, choropleths, isolines) but it is important to take the distortions into account while editing the map: the raster overlay have to be in equirectangular projection, therefore distances in east-west direction will be reduced significantly on higher latitudes. The compilation of equirectangular maps suitable for use on virtual globes is explained in details in (Hargitai, Gede 2009 and Gede 2015b).

The raster overlay can be added as a single image (which is the advisable solution for smaller resolution images) or as tiled image, either through a TMS service or in a KMZ file.

Vector data

Points, polylines and polygons can be added either directly from JavaScript (which is preferable when there are only a few features to add), or using KML/KMZ or CZML files.

KML (or KMZ) is the native format of Google Earth (Google 2016). These files can be added with a few lines of code. This is particularly useful when the thematic content in KMZ format had already been prepared for some other purpose and we would like to use the same material on Cesium. As KML is widely supported by most GIS applications, it is very easy to produce data in this format. When using KML/KMZ, one should keep in mind that not all features of KML is supported by Cesium. Basic geometry types have full support, as well as ground overlays, but for example context-sensitive styles or zoom-dependent visualization using Regions and LODs has not been implemented yet.

The most widely usable format is Cesium Language (CZML). Similarly to KML/KMZ, adding CZML files to the globe is also very simple. The disadvantage of CZML is that it is not yet supported by any of the popular GIS software, but with a bit of programming skills these files can be easily produced.

KML and CZML data can be added from remote URLs as well, provided the remote server supports cross-origin resource sharing (CORS) (W3C 2014).

Special features provided by CZML format

CZML is a JSON-based format, therefore documents in this format can be parsed directly by JavaScript. The content of a CZML document is one single JSON array, containing objects called *packets*. Each packet represents an object on the globe, except the first one, which contains the document version. The detailed documentation can be found on the

Internet (Analytical Graphic 2015), here only those features are introduced that are important for creating thematic visualisations.

Probably the most widely used thematic mapping method is choropleth. In CZML (and usually in most GIS software) choropleths are realised by polygons free from gaps and overlaps. Polygons can be filled with uniform colours, hatches or even images. Polygons can be extruded and/or raised above the ground as well as. A great advantage of Cesium that (unlike in Google Earth) elevated polygons still follow the curvature of the sphere, therefore they won't intersect the surface (Figure 1).
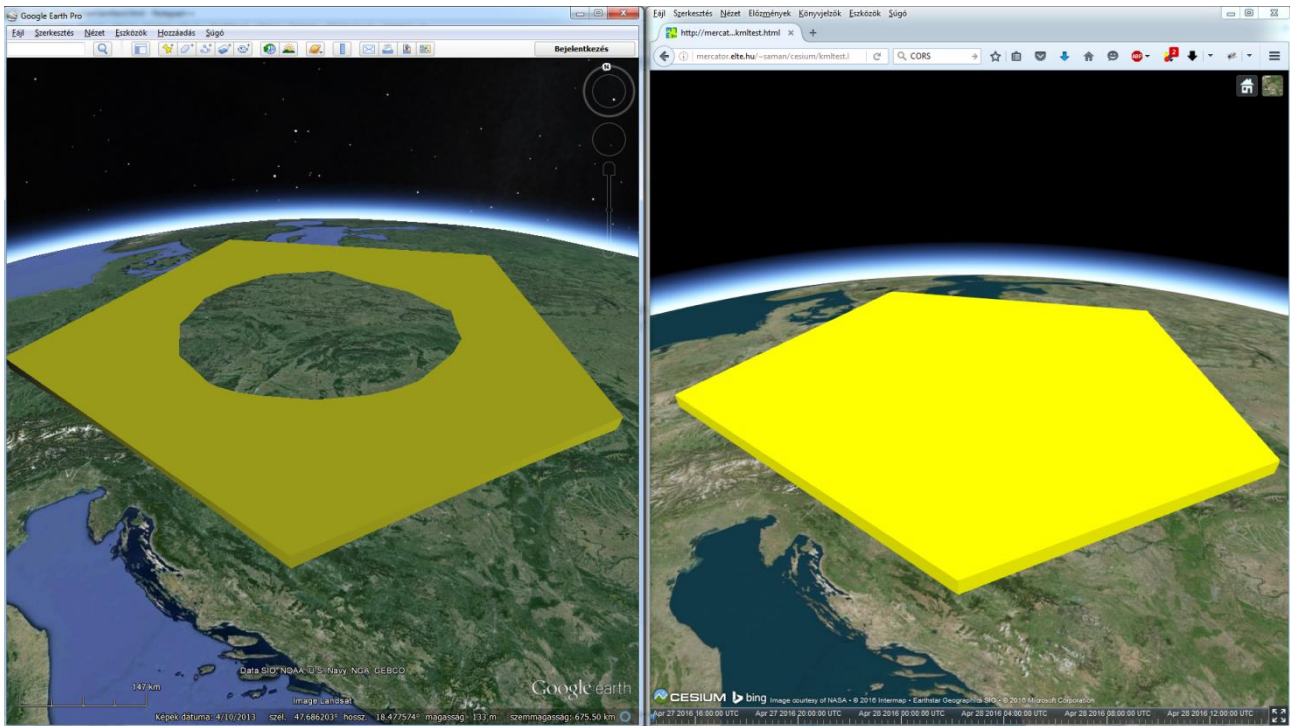
Figure 1. While raised polygons may cut into the surface in Google Earth (left), they follow the curvature of the sphere in Cesium (right).
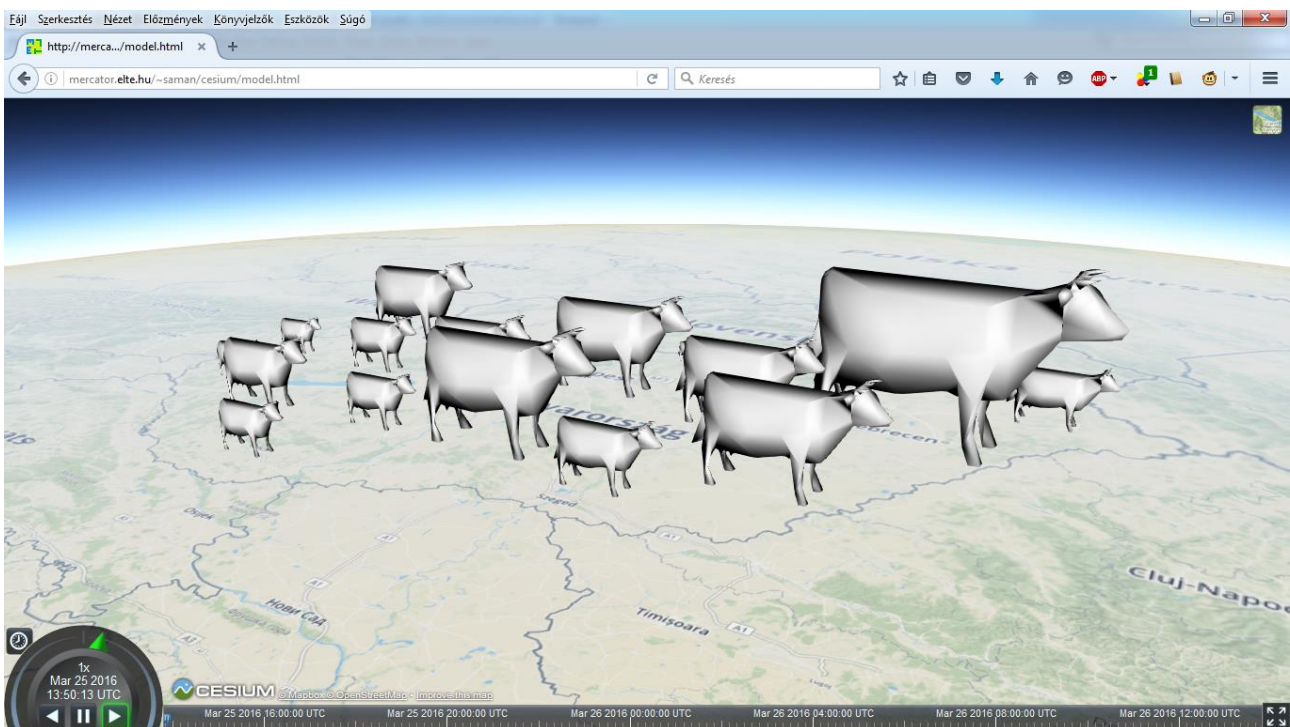

Figure 2. Scaled 3D models for displaying quantitative data

For displaying geolocated quantitative data we can also use scaled 3D symbols (Figure 2; similar visualisations can be found e. g. in Zsoldi 2011). In Cesium (and CZML), 3D models have to be in *glTF* (GL Transmission Format). If we are not able to produce models in this format, there is a free on-line converter at *http://cesiumjs.org/convertmodel.html*.

Maybe the most important feature of CZML is that any numeric value can be interpolated through time. When displaying such data, the time-dependant value (e. g. the colour, height, position of elements) changes with time (Cesium provides a "time slider" for setting time).

GENERATING CZML CONTENT IN QGIS

Unfortunately, most GIS software products do not support data export in CZML format. To help this situation, the author developed a QGIS plugin (available for download at *https://github.com/samanbey/czml_generator*), which facilitates the creation of (at the time of writing this paper) three different visualisation types in CZML.

After copying the plugin to the Python plugin folder of QGIS, it can be added to the program in Plugin Manager, and will appear in the *Plugins/CZML Generator* menu.

Using the "Prism Map" menu item we can create 3D prisms (elevated choropleth) from any polygon layer. In the dialog box (Figure 3) we can select the layer and the attribute field, as well as the colours for the lowest and the highest value of the chosen attribute (the values in between get interpolated colours). The prism heights can be linear, square root or logarithmic function of the attribute; a vertical exaggeration factor can also be defined. The plugin can also create an HTML format legend if the appropriate checkbox is set. The legend settings appear in an additional dialog box.
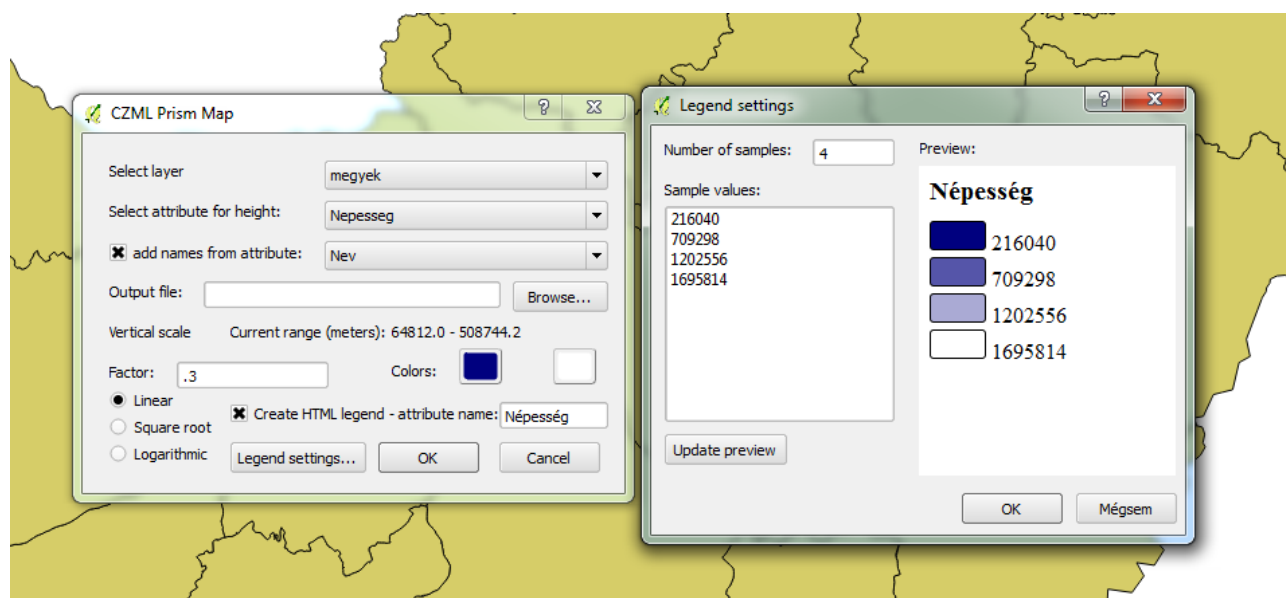

Figure 3. The Prism Map function of the plugin

The resulting CZML file can be opened using the sample HTML viewer accompanying the plugin (located in the folder *sampleViewer*), after changing the CZML (and the legend, if created) file name in the code at the appropriate places (marked by comments). The map, created from the sample data also attached to the plugin can be seen on Figure 4.
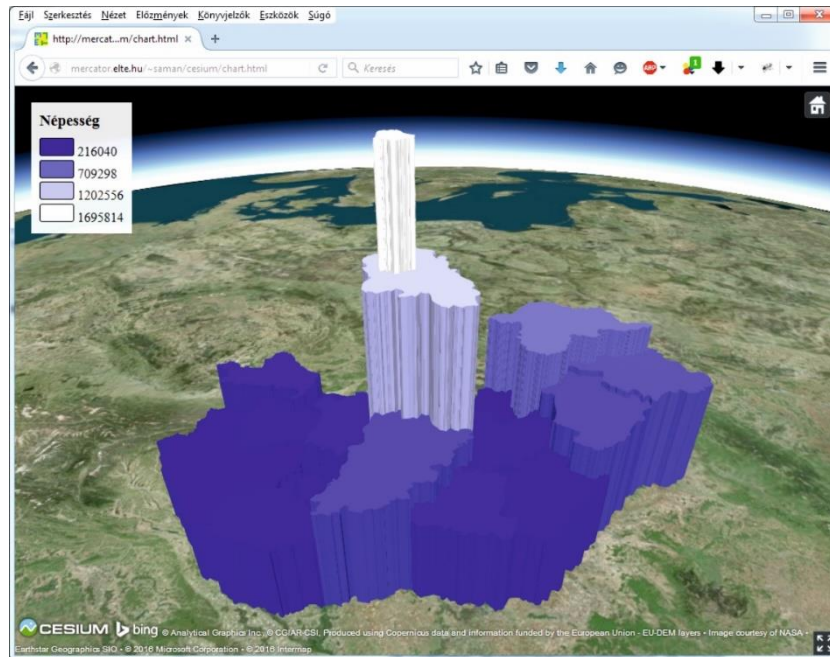
Figure 4. Prism map created by the plugin visualized in Cesium.

When having time series data, one can also use the function "Prism Map with time". Its dialog box is similar to the previous one except that more than one attribute of the selected vector layer can be used. A timestamp has to be chosen for each attribute (Figure 5).
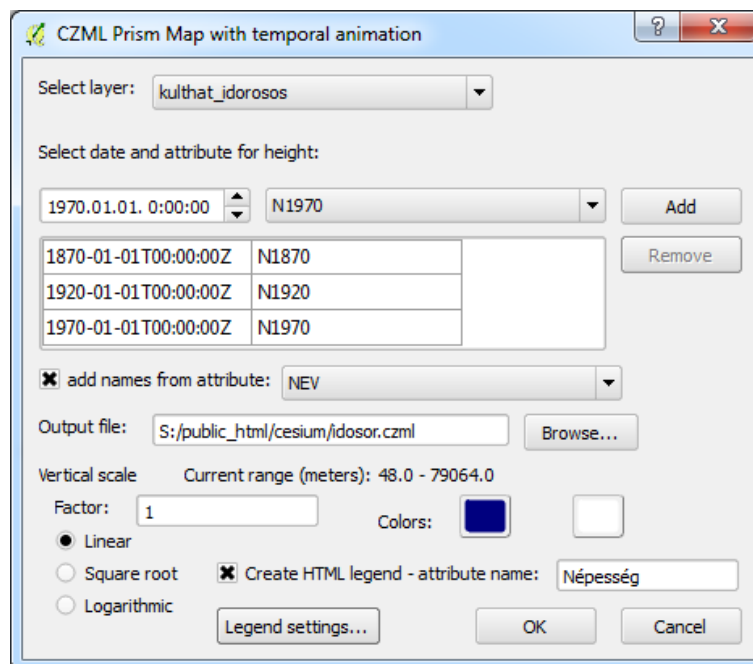

Figure 5. Using CZML Generator plugin with time series data.

When visualizing time series data, we have to set the *animation* and the *timeLine* options to true at the Cesium.Viewer constructor. These settings make the time slider and the other necessary controls visible in the viewer (Figure 6).
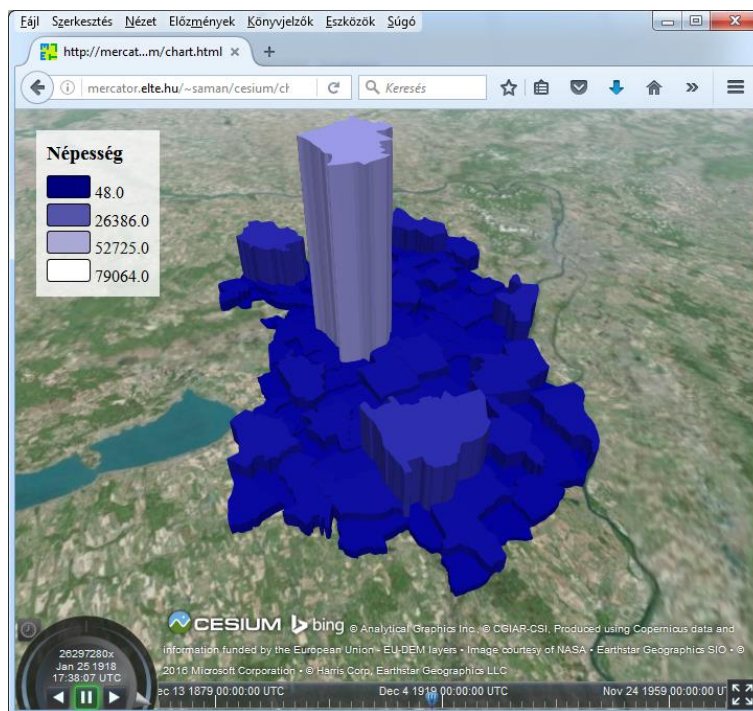
Figure 6. The time controls of Cesium (at the bottom of the screen) come in handy when visualizing time series data.

The function "Scaled models with time" creates a CZML file containing 3D models with sizes corresponding the selected attribute value (like on Figure 1). Settings are similar to the previous function but here also the URL of a 3D model has to be given. It is advisable to use relative URL. A sample model (*cow.glb*) can be found in the folder *sampleViewer*.

FURTHER PLANS

This paper gives only a brief introduction to the possible uses of Cesium in the field of thematic mapping. The CZML Generator plugin is still under development; the author's aim to add several new functions, covering many fields of 3D thematic visualization.

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BIOGRAPHY

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