Geodata visualization: a rich picture of the future

By Ron van Lammeren (email: ron.vanlammeren@wur.nl)

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Since a number of years we provide the course "*GIS for Society*". This course covers three challenging topics: geodata visualization, network analysis, and 'open' geodata. These three subjects have been chosen because today's citizens use these subjects on a daily basis via their smartphones in an integrated way. Numerous examples are the various Apps to navigate, monitor endurance sports performance, and monitor locations of friends and acquaintances. The most ultimate among these Apps offer a real-world gaming experience like the *augmented reality* game Pokémon Go. In our course we try to deal with the essences of each of the three subjects and from there their interrelationship.

The design of the course is strongly influenced by the story of Sui (1) which prepares for a next generation of geo-information applications with associated technology via the "emerging themes": *affective GIS, geogames, critical GIS, data type synthesis, map stories* and *geodesign*. If we currently take a look at the various *geo-data* driven Apps and developed and supplied various applications by the *geo-business*, we may picture that next generation.

This wealth of smart phone applications has not made offering essences within a course any easier. In the context of this article, I like to outline the framework by which we treat the essentials of geodata visualization in this course. This framework thus offers an opportunity to position the developments in this field that have taken place in recent decades, to link useful concepts to them and to specify the proposed geodata visualization.

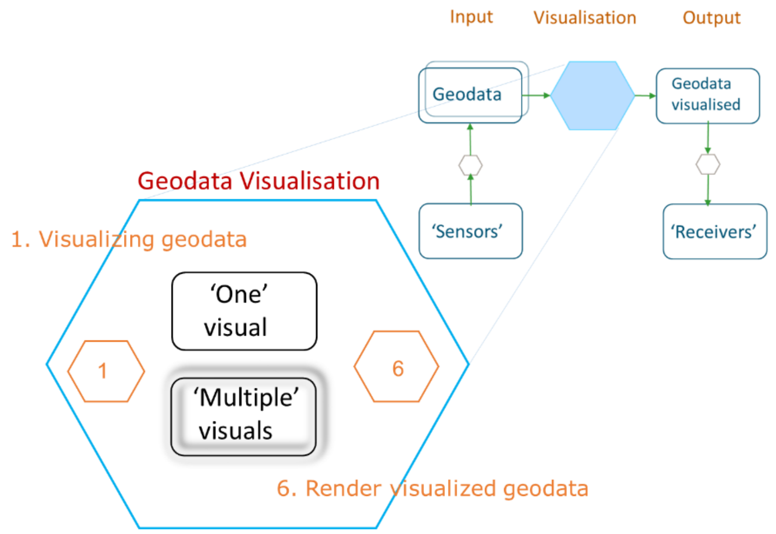

Figure 1 Geodata visualization: linking pin between 'sensors'

The starting point of this framework is the explicit separation within a geo-information system (GIS) between the geodata and its visualization. This framework is simple. There are geodata sources, from which geodata is extracted, processed and visualized. This visualization basically consists of two steps: converting the geodata (*visualizing - nr 1 in fig.1*) into a usable visualization (e.g. a thematic and/or a spatial reference) and rendering into a graphic product of it (*rendering - nr 6 in fig.1*). In the scientific literature we find beautiful studies on the creation of such cartographic products in which discussions about the representation of many variables via several univariate maps or one multivariate thematic map can crackle vigorously (*nr.2 in fig.2*). Chernoff's political color of Great Britain in 1973 is one of the highlights of that discussion. Knowledge of color systems, color harmony and *'gestalt'* theory is inevitable. Understanding map *layout* and various chart concepts is also a necessity in order to realize a readable cartographic product. In addition to these concepts, Bertin's theory (2, url1) plays the leading role in the translation of geodata into a graphical presentation.

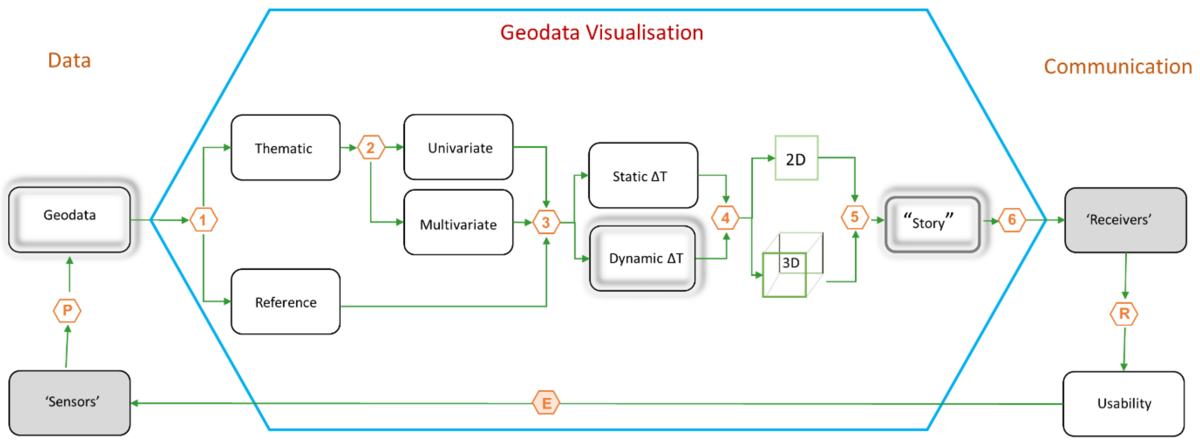

Figure 2 Geodata visualization framework

As soon as the inhibitions on the acquisition of geodata disappeared due to, among other things, the high-frequency supply of geodata via various 'sensors' (from satellite-linked, automated observations to those of human emotions via social media) and free access to public data, the study of time-space dynamics received more attention. This attention had a similarity in geodata visualization and was recognizable in the geodata visualization definition of Kraak and MacEachren (3).
Time-space dynamics on the map provides insights into the development of spatial objects and spatial themes. Delta T has thus entered the world of geodata visualization. We now distinguish two options to visualize this dynamics. The cartographic product that consists out of either one or more 'static' maps or an animation in which several map images (*frames*) show changes over time.

In our revised geodata visualization framework (*no. 3 in fig.2*) this means that the processing of geodata into a graphical product includes a new step, which focuses on visualizing the dynamics: stepwise change based on presenting specific time units or on the difference between significant periods. Depending on the geometric data primitives (e.g. *vector* or *tessellated*), other graphic attributes can be used, such as *blinkers*, *halos* and *moves*. In recent years, various studies have been devoted to the visualization of spatial dynamics and the use of 'dynamic' graphic attributes as initiated by Blok (4) and Andrienko et al. (5).
The use of animation again highlighted the specific conditions of interacting with a visualization because the world of animation brought us the options of stopping, pausing, fast forwarding and rewinding. The aforementioned definition of Kraak and MacEachren (3) also implicitly refers to the role of interaction with the image. For the time being, we consciously keep the interaction out of the picture of the geodata visualization framework as presented in this text, but we do refer to the work of Roth (6). Incidentally, the role of various interaction options has created an interesting new separation between image and interaction with the image.

The next essence in our framework concerns the spatial dimension of visualization: two (2D) or three-dimensional (3D) visualization of the geodata. This always raises the following questions: "what is 3D and why 3D?" The last question can only be answered if we place our information and knowledge questions in the context of a spatial thinking model, for example, an allocative or egocentric with corresponding usage requirements. I'll leave that placement out of this story as well.

Spatial thinking, however, is primarily nourished by our visual perception system, which in principle provides a stereographic experience. In the discussion about what 3D is, we use a transformation model (fig. 3) that shows the relationship between geodata, data visualization and perception of *rendering* via a specific presentation medium (e.g. *desktop, touch screen, oculus rift and hololense*). The transformation scheme refers, among other things, to a stereographic experience of the third dimension (via *shutter glasses, Google cardboard VR* or *Microsoft hololense, for* example) and to a monographic experience (via a standard screen or projection surface of a single *beamer*), interpreted by using *depth cues*. A *depth cue* appeals to our perspective experience of reality by using perspective lines that connect front, middle and background scenes.

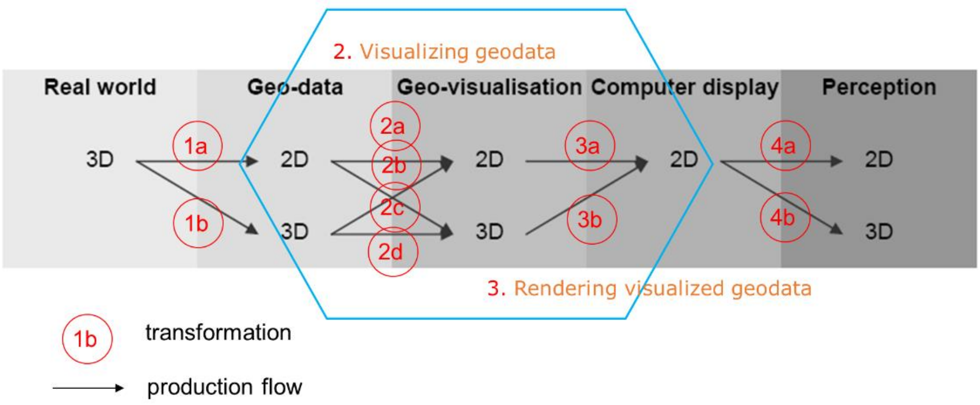

Figure 3 2D/3D geodata visualization transformation

The transformation model shows that the transition of geodata into a graphic product offers many editing options. Understanding such options we add another essential step to the framework (*No. 4 in Fig.2)*. In the course this step is explained and practiced by a 'peep box' metaphor to give insight into the construction of a 3D visualization (*3D scene*) from the various geodata sets, graphical attributes and visualized geodata. The relationship between all components in that construction does require dedicated explanation. Some examples of this explanation discuss the desired spatial 3D detail (*level of detail*), the *extrusion* of point-, line- and plane primitives (vector features) in 3D objects, the *texture mapping* of these *extruded* primitives, the placement of 3D-CAD models in such georeferenced 3D scenes, and the inclusion of dynamic visualizations via, for example, a layer animation or object movement via a route (*flight path*). The *rendering of* such a digital 'peep box' also requires attention to specific views to which camera parameters (*Field of View settings*) can be set, as well as the route of the camera, and the settings that determine shadow and light effects based on the time of day at specific longitude and latitude.

The last essence that is included in the geodata visualization framework concerns the story that the user of the visualization undergoes. In a short period of time the term *storymap has been* embraced and in many projects communication takes place via this form of visualization. The essence of a *storymap* is linked to the theory of *storytelling*. From the framework we refer to the *narrative* theory of Freytag (7) and the relationship between the *narrative* and the presentation of the story (*representation)* as introduced by Potteiger et al. (8). When making games, films and documentaries, among other things, these are important concepts. The storyline (*script*) is elaborated in a visual presentation that is mostly audio supported in which story scenes based on views, sequence, duration and frequency of visualizations are described (*storyboard*). It is therefore essentially a montage of within the storyline usable geodata visualization formats that have been dealt with earlier in the frame. The use of narrative theory is another step in the framework (*no. 5 in Fig.2*). For the implementation of elements from storytelling theory, we refer to the various techniques used in the video and film industry (*camera degree rule, framing, sequence, voice over*).

Once the presentation of the storyline has been *rendered using* various geodata visualizations, the visualization is available, in practice called *storymap* or *map movie*. The television series *Britain from Above* (url2) and look-a-likes as *Nederland van Boven* (url3) shows appealing examples of such geodata based stories. However the story goes on. In the summer of 2019 Niantic Inc. has launched a 3D, dynamic *augmented reality* application called *Harry Potter's wizard unite* (url4) offering various storylines to be discovered by playing this game. They have realized this by integrating the essences of the presented visualization framework in an attractive way and providing it with various forms of interaction. As indicated earlier, this framework description does not yet consider interaction in relation to the six steps presented.

This article provides an overview of the essentials of geodata visualization using a framework that we currently use in academic education. We use this to treat the various components step-by-step by step by referring to theoretical concepts and their application through the use of various software components from desktop to client-server (*3 tier architecture)*. The framework also illustrates the developments in geodata visualization and specifies research and application questions. In addition, this development from Bertin to Niantic offers a clear view of the necessary knowledge and skills integration and thus paints a rich picture of the future for the visualization of geodata.

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