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Cartographic continuum rendering based on color and texture interpolation to enhance photo-realism perception

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ABSTRACT

Graphic interfaces of geoportals allow visualizing and overlaying various (visually) heterogeneous geographical data, often by image blending: vector data, maps, aerial imagery, Digital Terrain Model, etc. Map design and geo-visualization may benefit from methods and tools to hybrid, i.e. visually integrate, heterogeneous geographical data and cartographic representations. In this paper, we aim at designing continuous hybrid visualizations between ortho-imagery and symbolized vector data, in order to control a particular visual property, i.e. the photo-realism perception. The natural appearance (colors, textures) and various texture effects are used to drive the control the photo-realism level of the visualization: color and texture interpolation blocks have been developed. We present a global design method that allows to manipulate the behavior of those interpolation blocks on each type of geographical layer, in various ways, in order to provide various cartographic continua.
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1. Introduction

The increasing diversity of geographical data provides a wide range of representations of the real world. Users are already able to access and visualize heterogeneous data such as topographic vector databases, ortho-images, DTMs, Lidar point clouds, thematic raster data (weather, pollution, population density, etc.). When considering to visualize them together, visual heterogeneity appears and may prevent users from reading and understanding the represented territory. Human computer interaction research proposes a wide range of co-visualization tools such as magnifiers, lenses, swipes, or enslaved views (Pindat et al., 2012; Karnik et al., 2009; Lobo et al., 2015). Nevertheless providing *hybrid visualizations* would allow merging and visually integrating heterogeneous data in the same visualization: in particular, those visualizations would allow to control abstraction and photo-realism levels.

Our long-term research issue is to address the problem of suitable and comprehensive graphic representations of geographical spaces while taking advantage of existing representations to better fit users' needs and preferences. Ortho-images have been used for a long time as backgrounds to overlay vector data or thematic information (Bildirici et al., 1999; Donnay, 2000; Albertz and Lehmann, 2005; Bianchin, 2007). Their relevancy to possibly better support some cartographic tasks than abstract representations has been experimented (Wilkening and Fabrikant, 2011; Raposo and Brewer, 2011; Boér et al., 2013; Cöltekin et al., 2015).

We assume that topographic map design could be improved by *mixing relevant visual properties coming from maps and ortho-images*, and by *controlling the level of photo-realism*. Even if map designers suggest ways to integrate ortho-imagery backgrounds or to blend heterogeneous data together (Raposo and Brewer, 2013; Hoarau et al., 2013; Murphy, 2015), few research focus on providing methods to continuously browse the cartographic space delimited by the data to hybrid, driven by the photo-realism level.

In this paper, we aim at designing continuous hybrid visualizations between symbolized vector data and a related ortho-image, while providing controls on the photo-realism level. Our global approach relies on the interpolation of visual properties coming from both representations of both continuum ends. Our proposition is based on:

- An extraction of colors and the handling of texture effects coming from the imagery, to be faced to colors of symbolized vector data, as relevant visual properties to reduce or enhance the perceived photo-realism (*natural appearance*).
- The interpolation of color and texture with the help of elementary blocks, in order to smoothly navigate between visual properties of each geographical layer (*color and texture interpolation*).

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- A global design method to manage the behavior of those interpolation blocks for each considered geographical layer, and thus make possible cartographic continua between vector data and an ortho-image (*global design method*).

In the following, Section 2 provides the related work. In Section 3, we detail our approach to control the interpolation blocks to enhance the level of photo-realism in a cartographic continuum. Then, we precise the main components of this framework, natural appearance extraction in Section 4 and color and texture interpolation in Section 5. Section 6 illustrates the genericity of our global method by providing the design method to manipulate the interpolation blocks, according to the set of input vector data, in order to make a cartographic continuum to an ortho-image.

2. Related work

The availability of heterogeneous geographical data raises new map design issues and invites map designers to revisit theoretical cartography principles. The introduction of ortho-imagery background especially encourages map design, computer graphics and image rendering scientists to make their rendering techniques converge to *control abstraction and photo-realism levels in geovisualization tools*. Issues of *renderings methods and parametrization of the visual properties to control abstract and photo-realist cartographic styles* are at stake.

The efficiency of various data and representations to fit to users' needs and tasks, has been evaluated by visual experimentation. In particular, the photo-realism in maps is evaluated regarding its capacity to support some users' tasks. Users might prefer more realistic looking maps, whereas they do not necessarily perform better with them (Wilkening and Fabrikant, 2011). Correlations between the performance of some cartographic tasks and the abstraction/realism levels of the given representations have been experimented and observed (Hoarau, 2012; Bernabé-Poveda and Çöltekin, 2014; Cöltekin et al., 2015). Therefore, the need for geovisualizations with different levels of abstraction and realism regarding every-day cartographic tasks has been clearly claimed (Boér et al., 2013).

Map design research have addressed the design problem of visually merging an ortho-image background with an abstract topographic map for a long time ago. Nevertheless, *legibility issues* are still at stake, implying issues in *graphic semiotics* (Bertin, 1983), mostly on colors, color contrasts, and size of objects, but also in rendering techniques to variously blend geographical layers (Porter and Duff, 1984). The adaptation of toponyms regarding orthoimagery background colors and contrasts has been explored (Bildirici et al., 1999; Albertz and Lehmann, 2005). The unique use of the transparency to blend topographic map and orthoimages, in most of geoportals, implies a visual scramble of the information and is thus insufficient to help hybrid those data (Hoarau, 2012). In such a context, researchers suggest specific symbolization methods that take into account orthoimagery background. Raposo and Brewer (2013) provide guidelines to symbolize roads and rivers with a survival symbolization regarding background toggle between topographic map and orthoimagery backgrounds. Hoarau et al. (2013) propose a locally adaptive symbolisation of road casing that take into account orthoimagery colors around considered road features. At the contrary, Murphy (2015) provides imagery processing methods to make features salient in the imagery background regarding an overlaid vector data.

Researchers in computer graphics, expressive rendering or geovisualization aim at *exploring photorealistic and non-photorealistic rendering techniques* to control the style of their visualizations (Brasebin et al., 2015; Masse and Christophe, 2015; Christophe et al., 2016). In geovisualization, this issue intends to increase the realism of maps, based on photorealism or non-photorealism techniques, in order to make them more realist, expressive and thus efficient. Features natural appearance is used as an inspiration source by several map designers. For instance, natural color maps are investigated (Patterson and Kelso, 2004), relief realism is based on its enhancement by illumination (Patterson, 2002) and by natural texturing (Jenny and Jenny, 2012). Map designers also explore the potential of texturing rendering techniques coming from graphic computers, by synthetic vectorial textures (Loi et al., 2013; Jenny et al., 2014), by watercolorization on oblique views (Jenny et al., 2015); water surfaces are rendered by realist textures (Patterson, 2002), animated textures (Yu et al., 2011), by expressive renderings (Semmo et al., 2013).

The concept of *continuum* has been defined as 'a series of pictures, iteratively reduced in representation from its referent', based on photographs, drawings, sketches, etc.: precisely, images of greater realism help to solve the homogeneity problem (distinguishing objects in the same class), whereas images of reduced or distilled detail facilitate object hypotheses (distinguishing between classes of objects) (Medley and Haddad, 2011). Based on this definition, several research works aim at controlling the photo-realism and abstraction levels of a cartographic representation in so-called *cartographic continuum*. In order to make progressive transitions between various levels of abstraction, the parameterization of rendering methods is explored through various strategies to distribute the level of abstraction in the representation (Semmo et al., 2012, 2013; Semmo and Döllner, 2014): according to the distance from the image center or the saliency of rendered objects (Semmo et al., 2012), river rendering according to more or less cartographic styles (Semmo et al., 2013), more or less complex textures according to scene depth and expected abstraction level (Semmo and Döllner, 2014). Metrics are also used to describe the level of detail in order to make discrete scales of this level of detail (Biljecki et al., 2014). Another lead consists in using techniques to capture the visual attention of the users. For instance, an image is decomposed into a zone of interest (focus zone) and its periphery in the visual field (context zone): irrelevant details are perceptually removed based on a model of the foveal vision (Bektas and Çöltekin, 2012; Bektas et al., 2015). Another example consists in generating masks according to relevant geographical objects and scene depth and highlight specific objects as soon as the users perceive them (Trapp et al., 2011).

3. Approach: controlling color and texture interpolations between vector data and ortho-image

Previous research invites us to consider the user control of the level of photo-realism of their geovisualization in order to adapt their representations to the tasks they have to achieve. We need tools and methods to browse the cartographic representation space. In particular, continuous transitions between representations are required in order to make a cartographic continuum, helping users to find the more suitable representation they need.

We propose a global design method to make various cartographic continua between two types of representation, by interpolating their graphic parameters. In order to manage these continuous transitions, we consider *the level of photo-realism as a main visual and perceptual property to control*. Continuous transitions are based on interpolations guided by crossing points selected according to salient visual properties. Current trends in *natural* map design invite us to focus on the natural visual properties coming from ortho-imagery, i.e. natural colors and textures, in order to convey orthophoto-realism. Color is a powerful visual variable conveying realism perception, when conventionally used

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