A knowledge base to classify and mix 3D rendering styles

Mickaël Brasebin, Sidonie Christophe, Élodie Buard, Florian Pelloie

IGN, COGIT 73 avenue de Paris 94 165 SAINT MANDE CEDEX Université Paris-EST

Abstract. In cartography, good practices are clearly established whereas they are not clearly defined for 3D (geographical) renderings. This article details some very first researches and an agenda that aims to provide a style knowledge database that offers possibilities to classify renderings according to graphical patterns. One application is to provide a method to generate relevant transition between two different styles to ease navigation in 3D geographical environment.

Keywords: 3D rendering, semiotics, style mixing, style knowledge base.

1.   Introduction

3D renderings are used and abused, notably for public consultation concerning urban projects. As 3D semiotics is not clearly defined (Häberling, 2008), the impact of graphic parameters (e.g. material color or light) of such renderings on public understanding and perception is not controlled. In cartographic domain, good practices based on a set of visual variables have been recommended by (Bertin, 1967) in order to ensure understandable cartographic messages. The aim of our work is to consider how these practices are modified and revisited in a 3D rendering process vs. a 2D one. The long-term purpose is to be able to formalize 3D practices to apply them on 3D renderings and thus to propose a conceptual framework for 3D semiotics.

In this contribution, we introduce an original generic method to assess categories of styles of 3D renderings in order to extract and specify some typical ones. We consider the style as the parametrization of the rendering, i.e. the assignment of graphic parameters to geographic feature to render. Our approach consists first in analyzing the styles of existing 3D renderings: we systematically analyze graphic parameters used to render each geographic feature (e.g. sidewalk, tree trunk, house roof or door) in a collection of 3D renderings. In this paper, our method is applied on urban projects highlighting one building. Then, four categories of styles are captured combin-

ing the level of detail (detailed representation vs non-detailed representation) and the level of photorealism (photorealistic representation (PR) vs non-photorealistic representation (NPR)). Each urban project is thus ranked into these categories, based on the analysis of the selected graphic parametrization of the rendering. Our approach then aims at navigating automatically in the research space delimited by the four proposed categories: this exploration is based on continuous transformations between renderings described into elementary modifications of graphic parameters. The paper ends by a discussion about further work and provides a research agenda on 3D semiotics.

2. Related works and purpose

This part refers to research works about knowledge bases on 2D and 3D representations, in particular how (photo-)realism is addressed in both paradigms. Finally we specify the purpose of the paper.

2.1. Knowledge base about *Graphic Semiology* (Visual Semiotics)

Graphic Semiology is a theoretical framework to manage a symbol (the *sign-vehicle*) and its meaning used to graphically represent an object or phenomenon of the real world. Mapmakers benefit from this framework to make efficient maps: seven visual variables -- size, value, hue, texture, orientation, shape, geographic coordinates – have been described by Bertin (1967), according to their capacity to organize/hierarchize information, i.e. perceptual properties – association, difference, and order. Other visual variables have been then proposed by various cartographers: color saturation and arrangement by Morrison (1974) and, clarity (fuzziness), resolution (of boundaries and images) and transparency by MacEachren (1995), amongst others. The purpose of research works about the validity of such a theoretical framework is to ensure that visual variables and related perceptual properties are suitable to represent such geographic information for a specific purpose. Several works have been focusing on the proposition of good practices to select visual variables, in particular colors, and to manage relations between them, in particular color contrasts and visual saliency (Brewer 1994, Fabrikant & Goldsberry, 2005, Klippel et al. 2009, Christophe 2011, etc.). Knowledge about the perception and the understanding of relations between graphic signs and relations between related meanings, leads researchers to better formalize the understanding and the usability of 2D representations (Cöltekin et al. 2009, Wilkening & Fabrikant 2011, Griffin & McQuoid 2012).

2.2. Practices about abstraction & realism in 2D/3D representations

Hoarau (2015) defines the notion of abstraction as a simplification of the perception of the real world. Mc Cloud (1994) distinguishes the simplification of visual variables and the simplification by the removal of some relevant details. The issue of abstraction is in the middle of the 2D map design process, and may be semantical, geometrical and graphical. The issue of (photo-)realism, a longtime ago mainly related to image processing and 3D representations, is now a new challenge again to take advantage of abstraction and photorealism in 2D representations, instead of opposing them. For instance, Patterson (2002) suggests texturing empty areas of topographic maps in order to make maps more expressive; Jenny et al. (2012) uses graphic rendering tools in order to make maps more natural; Hoarau et al. (2013, 2015) provide rendering techniques based on color, transparency and natural and procedural textures to co-visualize vector data and ortho-photographies. Raposo & Brewer (2011, 2013) compare topographic map designs using orthoimage backgrounds in order to identify preferred design methods and propose a symbol specification suitable to swing from map to ortho-image. Several research works use orthophotographies as realist information sources for realist characteristics retrieval and application in realist representations (Crombez et al. 2013, Lafarge et al. 2010).

A high level of photorealism and high level of detail have been the main challenge for 3D rendering, in order to obtain high visualization quality (Drettakis et al. 2007). An opposite view is to consider that photorealism techniques do not offer optimal solutions for understandable visualizations, e.g. too low contrasts, visual noise, imprecise objects boundaries, etc. (Semmo et al. 2010). Kostelnick & McDermott (2011) evaluate the relevancy to use photorealism (photos or virtual reality in 3D) to represent risks according their dangerousness. Zanola et al. (2009) aim at determining the influence of realism level in 3D representations on the confidence in data quality a user may have. Expressive rendering allow stylizing 3D models in order to attempt aesthetic purposes or more efficient renderings (Döllner 2007, Willats & Durand 2010, Cunzi et al 2003, etc.) and thus to inject some semantical, geometrical and graphical abstractions. Döllner *et al.* (2006) identify three relevant styles to render a 3D urban model (photorealist, informative and illustrative), integrated by (Semmo *et al.* 2012) in a continuum of representations.

Semmo *et al.* (2012) also propose to use parametrization of rendering methods to make progressive transitions between various levels of abstraction and various strategies to distribute the level of abstraction in the representation according to the distance from the image center or the saliency of rendered objects. Hoarau et al. (2015) propose various symbol specification

methods to interpolate colors and textures between orthoimagery and vector data (vector & raster styles mixing). Style mixing has been also used to manipulate several styles of 3D models (Talton and al, 2012) or websites (Kumer and al, 2013).

2.3. Purpose

We consider that the substantial knowledge base we benefit for 2D representations could be transferred to 3D representations. Formally, models of style and legend have been provided for 2D representations, but not considered through the 3D perspective. Parametrization of rendering engines for 3D representations have not been formalized as styles relying on graphic parameters, useful to control the resulting renderings. Figure 1 specifies these relations between concepts: a *Style* is composed by assignments of values of *Graphic Parameters* to *Named Feature*; the *Rendering Engine* uses the specification of a *Style* to render the related *Geographic Features*.
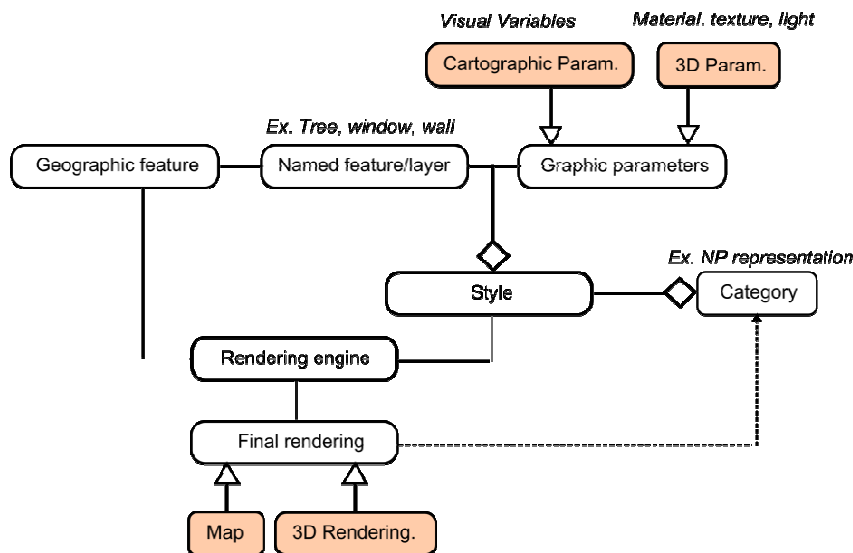

Figure 1. Modeling of the notion of style as rendering parameterization

We thus address the issue of being able to define and specify visual variables for 3D, such as visual variables and related properties we have for 2D: those so-called *Graphic Parameters* could be used to make various styles, specifying the rendering methods to use. The aim of this article is to present our current advances and agenda about the specification of 3D styles in the context of 3D rendering. This is a preliminary work of ongoing researches. A first step is to be able to propose *Categories* of *Styles*, and typical values for the related set of *Graphic Parameters* (see Figure 1).

The section 3 describes our global approach. In section 4, we present our future work and research agenda about 3D styles and the opportunity to provide 3D semiotics framework.

3.   Global approach

In section 3.1, we propose and apply a method based on the study of 3D renderings of urban projects, in order to produce a knowledge base that describes the styles. From this base of knowledge, we propose several style categories and extract typical graphic parameters (section 3.2). In order to illustrate our work, we propose to study two classes of categories according to the level of photorealism and the level of detail. An immediate use of this base of knowledge is presented in section 3.3 and aims to mix two different styles in order to provide continuous transitions between them.

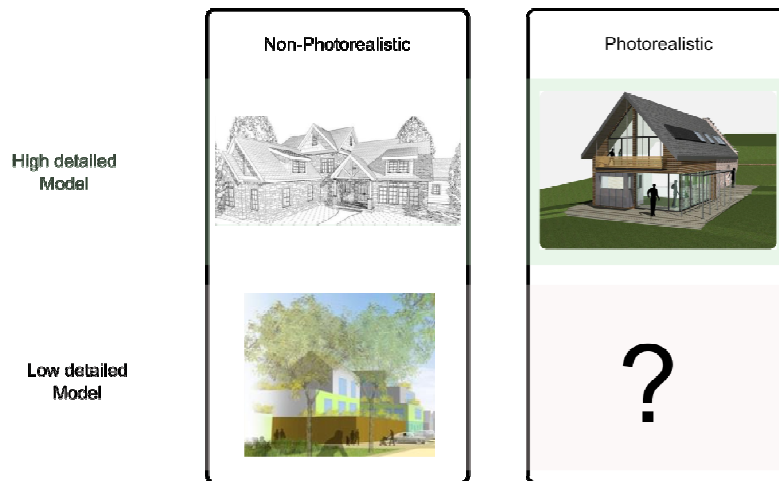### 3.1. Evaluation of a set of existing styles

Figure 2. 4 categories for 3D urban projects classification.

The aim of this task consists in analyzing different renderings of urban projects in order to extract the different graphic parameters that participate to the style of the rendering. In order to illustrate this very first work, 3D renderings studied are presentation of future urban project and focus is set on single presented building. Other geographic features are not considered. This task can be decomposed into the following three steps. The global process is illustrated in figure 3 on a detailed non-photorealistic rendering.
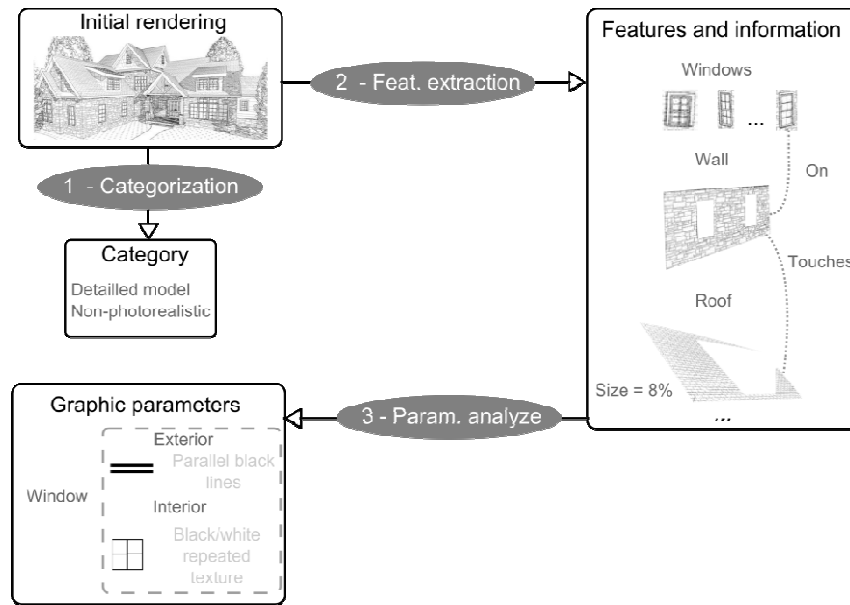
Figure 3. Style evaluation task illustrated with a building rendering.

As a very first step (1 - *Categorization*), four categories of style are used: photorealistic / non-photorealistic and detailed / non-detailed rendering (Figure 2). As a free classification, each rendering is assigned to a category of style based on its overall visual aspect.

In a second step (2 - *Feature Extraction*), for each rendering, each elementary geographic feature (i.e. for buildings windows, wall, chimney, etc.) is extracted from the 3D rendering. Contextual information is added to each geographic feature in order to traduce its visual impact on the overall visual aspect of the rendering, i.e. size of the object, overlapping relationship with other features, etc. For instance, very small windows would be less visually salient than walls all around, except if their symbol specifications are highly contrasted.

The last step (3 - *Parameter Analysis*) consists in extracting graphical parameters applied on the geographic features extracted in the previous step. To do that, we can use existing formalizations of style, i.e. Styled Layer Descriptor (SLD) and Symbol Encoding (SE) OGC norms. SLD has been extended to offer capacities to describe expressive renderings for 2D artistic stylization (see Christophe et al. 2015) or to describe graphic 3D parameters applied on a scene in a SLD 3D proposition (Neubauer & Zipf, 2007). Those extensions of SLD offer the possibility to integrate specific processes provided by computer graphics algorithms. According to our long term purpose, in order to be able to describe more specifically each category of style, and finally each style, some other 3D graphic parameters have to be specified such as light direction or shadowing.

Our purpose now is to link graphic parameters and category of styles.

3.2. Analyze of the knowledge base

Once evaluation bases produced on a set of various renderings, the analysis task (described in figure 4) aims to highlight patterns that contribute to classify a style in a category. These patterns are extracted from information captured in the previous step. We define pattern as an association of information whose presence or absence contributes to classify a style in a category. A pattern can be composed by:

- **Inherent characteristics of used graphic parameters**: pencil like lines increase the probability of a style to be non-photorealistic (level of stylization);
- **Association between graphic parameters and a feature**: non cartographic colors applied to a feature (red for vegetation) are generally applied on artistic / non photorealistic representation (level of conventions);
- **Contrast between representations of related features:** same representation on touching features may tend to decrease the level of detail of a representation (level of contrasts).
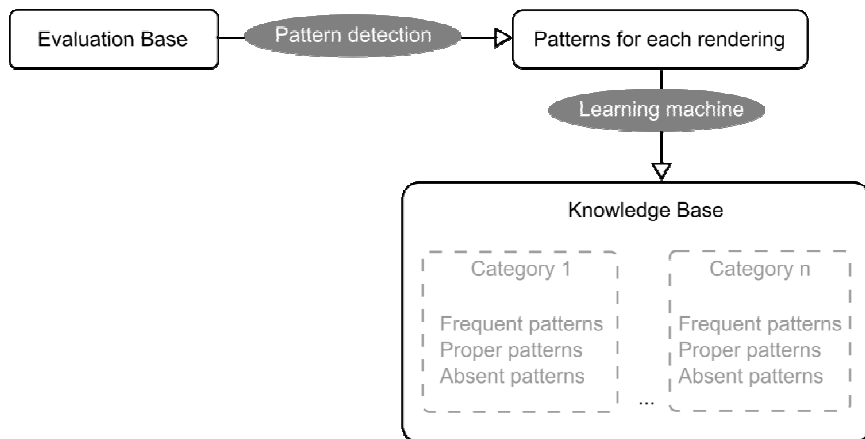

Figure 4. Production of a knowledge base from the evaluations.

By analyzing these different patterns in each category, it is possible to detect patterns that are frequent, proper or absent from a category and store this information in knowledge base. This information can be used on others renderings in order to classify them automatically in a category and to enrich the knowledge base of new patterns. In this paper, we propose to exploit this knowledge base in order to mix styles.

3.3. Mixing between styles

As we obtain four categories of style in which we can add existing 3D renderings, it could be challenging to be able to pass from a category to another: this transformation requires controlling the graphic parameters all along the interpolation between two styles. Mixing styles can be used in order to provide smooth transitions during transformation of a rendering from a style 1 to a style 2 or to integrate new geographic features with preservation of the style category of a rendering. In our context, mixing style is possible by using information modeled in our evaluation database. It is thus possible to apply elementary modifications to iteratively transform a style into another one. Such modifications include value changes for graphical parameters (i.e. color interpolation, for instance hue modification) or substitution of graphic parameters (i.e. symbol interpolation, for instance switch between tint area and a photorealistic texture) (See Hoarau et al. 2015).

Nevertheless, in order to make transitions between two styles, several ways are possible according to the order of application of elementary modifications. It provides an important variety of transitions but also non-desired intermediate styles. In order to guide this transition process, information from our knowledge database can be used in order to classify the style during each step of the transformation process. It is thus possible to know the category of the intermediate style and constraints it (by applying relevant modifications) to stay in a wished category. It is so possible to provide relevant and smooth style transition.

4. Future work and agenda

This research work tends to provide a global system whose architecture is presented in figure 5 and is based on concepts mentioned in previous sections.

In order to provide the system with categorized rendering styles, it is necessary to annotate an initial set of renderings with terms defining their styles. As this categorization is subjective, this step needs **contributors** to manually put descriptors on a map to classify it (Bucher et al. 2010), or to freely classify maps, as a kind of card-sorting (Christophe 2012). Initial set of renderings can be provided by system manager or by contributors themselves according to the final use of the system (i.e. high photorealistic urban project representation or symbolic cartography for forestry). The interest for contributors is to participate to produce a semiotic database production (named evaluation database).
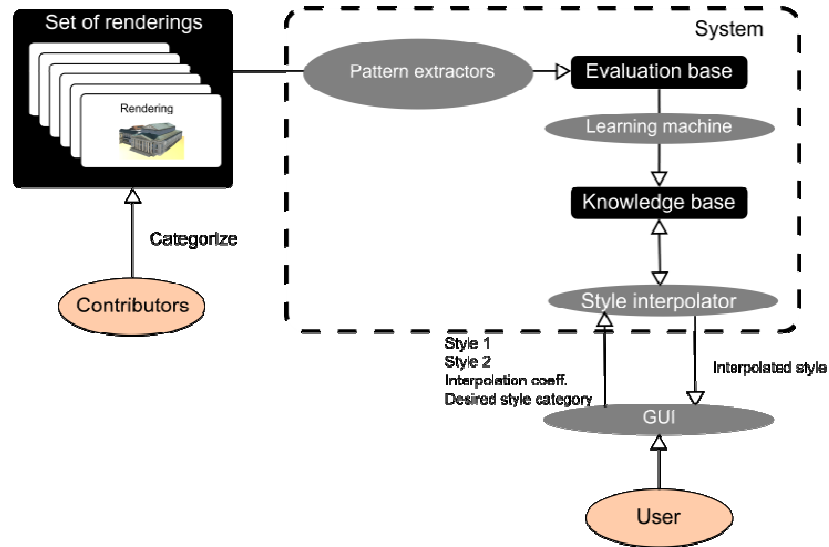
Figure 5. Production of a knowledge base from the evaluations.

When a significant set of renderings is annotated, patterns are extracted to provide the **evaluation base** (evocated in section 3.1). **Patterns extraction** aims to associate a set of patterns (as we describe above) to each annotated rendering. For a first operational system, we aim to do this step manually. It can be realized by expert contributors as it requires skills in order to determine and to put information in a predetermined model. In a second step, some future works include the automated detection of graphic parameters from a given rendering, the integration of constraints to preserve between graphic parameters and geographic features and the derivation of a style for a given use. Some first research in this domain tends to detect material characteristics from 3D renderings (Coubard, 2011). The result is to automatically detect graphic parameters associated to features or to features relations by image analyze. Once this database is produced, users and contributors can query it to get a desired style according to represented geographic features or required graphical processes.

Significant information between graphical patterns and style categories is extracted with a learning machine from the evaluation base (such as used in (Talton, 2012)) to make a **knowledge base** in order to indicate frequent, proper and absent patterns. An assessment of the quality of modeled knowledge is an important step to make it operational. As this knowledge base can be used to categorize renderings; this task can be led by categorizing extra renderings in order to determine the abilities of this knowledge database to classify these renderings.

The **style interpolator** aims to mix two different. It determines the differences between the two styles by the list of necessary elementary operations to transform style 1 to style 2 and provides a path to transform one style to others. A path is a sequence of intermediate renderings (from style 1 to style 2) for which an intermediate rendering can be transformed to the following one by applying one or several operators from the list. In order to determine the most interesting path, the knowledge base assesses the category of

all possible intermediate styles and the interpolator chooses the waypoints according to some external constraints (i.e. to limit the number of categories changes or to avoid certain categories). These constraints are provided by the designer of the final GUI. Some experiments must be led in order to determine the possible constraints and the best methods to provide relevant paths.

On this GUI, **users** access to a slider to navigate between styles according to waypoints determined by the style interpolator. A last research work is to assess for a given task how this style interpolation can help users realizing this task and to provide some methods to keep smooth transitions between two intermediate styles in order to detect if users are lost during style changes.

5. Conclusion

In this paper, we present our preliminary works about modeling 3D style knowledge and its exploitation for providing styles mixing. We provide a research agenda that leads us to consider the design of a 3D style evaluation database, its processing to extract knowledge for style categorization, and the conception of a style interpolator and related users experimentations.

Over time, we wish to propose a unified framework that allows to describe both cartographic and 3D graphic parameters and to control them with a unique base of knowledge in order to apply good practices.

In the long term, we aim to create methods to automatically change styles (3D or even 2D) according to the context of users and purposes. For that, we could apply and study other types of cartographic practices, not only based on visual variables, but concerning for instance: identification of thematic relationships between geographic features, rules to preserve readability of neighbor features using color, shape or style contrasts or adding thematic qualitative or quantitative information. As for the users, our objective is to provide them tools to create 3D renderings with a specific style and relevant to their objectives.

Acknowledgment

References

Bertin J (1967) Semiology of Graphics: Diagrams, Networks, Maps. University of Wisconsin Press, 1983 (first published in French in 1967, translated to English by Berg W.J. in 1983).

Brewer C.A. (1994). *Visualization in modern cartography*, chapter 7 - Color use guidelines for mapping and visualization, pages 123-147. A.M. Mac Eachren and D.R.F. Taylor, Elsevier Science, Tarrytown, NY.

Christophe S. (2011). Creative colours specification based on knowledge (COLor-LEGend system). *Cartographic Journal, The*, 48(2):138-145.

Christophe S. (2012). Cartographic styles between traditional and original (towards a cartographic style model). In *proceedings of AutoCarto Conference 2012, 16-18 September, Columbus, Ohio, USA*.

Christophe S., Hoarau C., Boulanger L., Turbet J., Vanderhaeghe, D. (2015) Automatic rendering of a Cassini style, 27th International Cartographic Conference (ICC'15), Rio de Janeiro, Brasil. (abstract accepted)

Cöltekin A., Garlandini S., Hei, B., and Fabrikant S. I. (2009). Evaluating the effectiveness of interactive map interface designs: a case study with eye movement analysis. *Cartography and Geographic Information Science (CaGIS)*, 36(1):5-17.

Coubard F., Brédif M., Paparoditis N., Briottet X. (2011) Reflectance estimation from urban terrestrial images: Validation of a symbolic ray-tracing method on synthetic data. PIA11, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences (IAPRS), vol. 38 (3/W22) pp. 71-76.

Crombez N., Caron G., Mouaddib, E. M. (2013). Colorisation photo-réaliste de nuages de points 3D. *In Orasis, Congrès des jeunes chercheurs en vision par ordinateur*, Cluny, France.

Cunzi, M., Thollot, J., Paris, S., Debunne, G., Gascuel, J.-D., Durand, F., (2003.) Dynamic canvas for Non-Photorealistic walkthroughs. In: Graphics Interface. pp. 121-130.

Döllner J. Baumann K., Buchholz H. (2006). Virtual 3d city models as foundation of complex urban information spaces. *In* Schrenk, M., editeur : *11th international conference on Urban Planning and Spatial Development in the Information Society (REAL CORP)*, pages 107–112. CORP – Competence Center of Urban and Regional Planning.

Drettakis G., Roussou M., Reche A., Tsingos N. (2007). Design and evaluation of a Real-World virtual environment for architecture and urban planning. Presence: Teleoperators & Virtual Environments, MIT Press.

Fabrikant S.I., Goldsberry K. (2005). Thematic relevance and perceptual salience of dynamic geovisualization displays. In *Proceedings, 22th ICA/ACI International Cartographic Conference, A Coruña, Spain, Jul. 9-16, 2005. (refereed extended abstract)*.

Griffin A.L., McQuoid J. 2012, At the intersection of maps and emotion: The challenge of spatially representing experience, *Kartographische Nachrichten*, 62(6), 291-299.

Hoarau C., Christophe S. and Mustière S. (2015) Sliding from imagery realism to topographic abstraction, 27th International Cartographic Conference (ICC'15), Rio de Janeiro, Brasil.

Hoarau C., Christophe S., Mustière S. (2013) *Mixing, blending, merging or scrambling topographic maps and orthoimagery in geovisualization?*, In proceedings of the 26th International Cartographic Conference (ICC 2013), 25-30 August, Dresden, Germany.

Jenny H., Jenny B., Cron J. (2012). Exploring transition textures for pseudo-natural maps. *In* Jekel, T., Car, A., Strobl, J. et Griesebner, G., editeurs : *GI_Forum 2012 : Geovisualization, Society and Learning*, pages 130–139. Wichmann.

Klippel A., Hardisty F., Li R., Weaver, C. (2009). Color enhanced star plot glyphs. can salient shape characteristics be overcome? *Cartographica*, 44(3):217-232.

Kumar R., Satyanarayan A., Torres C., Lim M., Ahmad S., Klemmer, S., Talton, J., (2013) Webzeitgeist: Design Mining the Web. Proceedings of the 31st Annual ACM SIGCHI Conference on Human Factors in Computing Systems, April

Lafarge F., Gimel'Farb G., Descombes X. (2010). Geometric feature extraction by a multimarked point process. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 32(9):1597–1609.

McCloud S. (1994). *Understanding Comics*. A Kitchen Sink book. HarperCollins.

MacEachren A. M. (1995). *How Maps Work : Representation, Visualization, and Design*. The Guilford Press, 2nd ed. edition edition.

Neubauer S., Zipf A. (2007) Suggestions for extending the OGC styled layer descriptor (SLD) specification into 3D. In: Towards Visualization Rules for 3D City Models, Urban Data Management Symposium. UDMS.

Patterson T. (2002) Getting real : Reflecting on the new look of national park service maps. *Cartographic Perspectives*, 0(43).

Raposo P., Brewer C. A. (2011). Comparison of topographic map designs for overlay on orthoimage backgrounds. *In 25th International Cartographic Conference*.

Raposo P., Brewer C. (2013). Guidelines for Consistently Readable Topographic Vectors and Labels with Toggling Backgrounds. *In 26th International Cartographic Conference*.

Semmo A., Kyprianidis J., Döllner, J. (2010). Automated image-based abstraction of aerial images. *In* Painho, M., Santos, M. Y. et Pundt, H., editeurs : *Geospatial Thinking*, volume 0 de *Lecture Notes in Geoinformation and Cartography*, pages 359–378. Springer Berlin Heidelberg.

Talton J, Yang L., Kumar R., Lim M. Goodman N., Měch R. (2012) Learning Design Patterns with Bayesian Grammar Induction. Proceedings of the 31st Annual ACM SIGCHI Conference on Human Factors in Computing Systems.

Wilkening J., Fabrikant S.I. (2011). How do decision time and realism affect map-based decision making? In Egenhofer, editor, *10th International Conference, COSIT*, pages 1-19.

Zanola S., Fabrikant S. I., Cöltekin A. (2009). The effect of realism on the confidence in spatial data quality in stereoscopic 3D displays. *In 24th International Cartographic Conference.*