THE EFFECT OF REALISM ON THE CONFIDENCE IN SPATIAL DATA QUALITY IN STEREOSCOPIC 3D DISPLAYS

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Abstract. This paper reports on an empirical study investigating whether novice users infer higher spatial data quality from more realistic looking (static) displays depicted with a stereoscopic 3D viewing system. Thirty participants were presented with large 3D views including natural and built features at three levels of realism (photorealistic, CAD-style, and sketch-style renderings). They were asked to rate the 3D view types in their confidence of being credible spatial representations of their real-world referents. Participants' confidence ratings were significantly highest for photorealistic displays, followed by CAD-style, and lastly sketch-style renderings. This study provides new insights into the effects of photorealism for spatial data depiction, and the potential influence graphic fidelity might have on people's beliefs in the quality of the underlying spatial data.

1 Introduction

Photorealism has been one of the major driving forces in computer graphics research since its beginnings in the 1960s (Durand 2002; Strothotte & Schlechtweg 2002). The attraction to graphic realism extends well beyond the computer graphics community. Significant improvements in computer technology have resulted in a wide dissemination of spatial data to a non-expert audience through interactive globe viewers such as, Google Earth, or NASA World Wind that simulate reality with high fidelity. Photorealistic displays are frequently lauded for their near-effortless comprehensibility and ease of use for non-experts. In environmental planning for example, it is commonly argued that realistic depictions of landscapes are "the easiest form of visualization for the public to associate with and understand" whereas more abstract displays are believed to be better suited for an expert audience with the appropriate domain knowledge (Bishop & Lange, 2005: 28–29). However, more realistic visual renderings of spatial data do not necessarily mean that the underlying data are closer to reality. Furthermore, precise and crisp looking digital displays are not necessarily more accurate or more true to reality than a hand-drawn sketch. Smallman & St. John (2005) argue that users and designers alike are often susceptible to *naïve realism*, in other words they place too much faith into realistic displays.

In contrast, cartographers have long been aware of the necessity of presenting an abstract view of the infinitely complex world in the form of 2D maps, and several authors from the geovisualization and cartography community have advocated the use of more abstract 3D views for more efficient inference making (Döllner 2007; Döllner & Buchholz 2005; Häberling 2003; Häberling, Bär & Hurni 2008). For example, in an empirical study Plesa & Cartwright (2008) found that users prefer non-photorealistic 3D maps for mobile navigation devices, because of their enhanced clarity and better usability. Hegarty, Smallman and colleagues demonstrated in several user studies that realistic displays are often confusing users and consequently lead to poor task performance (Canham, Hegarty & Smallman 2007; Hegarty, Smallman & Stull 2008; Smallman & Hegarty 2007). Interestingly, these authors have also noted that novice users and people with low spatial ability tend to favor realism more than experienced users. The quality and "ease of use" of computer-generated photorealistic images is often judged by how closely the display resembles a photograph (Gooch & Gooch 2001). Is then a trend towards more realism in spatial data depictions (e.g., globe viewers) perhaps inadvertently conveying the impression of more certainty in the data to novice users?

Uncertainty is an inherent part of the entire spatial data processing chain from data acquisition to transformation, and finally visualization (Pang, Wittenbrink & Lodha 1997). Various methods have been proposed to visualize uncertainty (MacEachren et al. 2005). For example, McGranaghan (1993) suggested photorealism as denotation of higher data quality and MacEachren (1995: 437) proposed "clarity" or rather the lack of it as a visual metaphor for uncertainty. The visual variable clarity is composed of the variables crispness, resolution, and transparency. Applied to 3D views, the distinctiveness of a feature's edges (i.e., its crispness) might be systematically modified to express spatial data uncertainty. For example, fuzzy edges simulating a hand-drawn sketch of a building in a city model might communicate to viewers that this building has not gone beyond the initial planning stage. In an empirical study Schumann et al. (1996) could demonstrate that sketch-style, non-photorealistic, computer-based 3D views are significantly preferred over shaded displays or CAD-like renderings when architects present first drafts to clients, because they appear to be less finished. Sketch-style views were found to encourage more discussions about potential modifications to the plan than the other display types. Zuk, Carpendale, and Glanzman (2005) modified the level of realism as a visual cue for the degree of temporal uncertainty in 3D archeological reconstructions. They used photorealistic 3D views and wire frame models to communicate the reliability of the dating method of a given archeological monument. An empirical study carried out by Boughman and colleagues (Boughman 2005; Fabrikant & Boughman 2006) revealed that 2D maps with varying degrees of realism do significantly influence people's confidence ratings about data quality. However participants' response pattern is quite complex and confidence ratings vary not only by level of realism, but also by cartometric map task (e.g., question type). Despite various attempts to formalize uncertainty visualizations (for a recent in-depth review see MacEachren et al. 2005 and Zuk 2008) less has been done to empirically evaluate whether the proposed methods work, or whether the theoretical perspectives lead to supportable hypotheses (MacEachren et al. 2005: 151). This is in particular true for 3D visualization (Johnson & Sanderson 2003). Building upon the above mentioned work by Boughman and colleagues, in this study we extend it to the realm of 3D visualization. Boughman (2005) hypothesized (but did not experimentally test) that natural features which tend to have complex, irregular shapes are perceived differently than built features with their mostly geometric and regular shapes. Empirical studies that looked into how people categorize photographs might support this hypothesis. For example, Rogowitz et al. (1998) could demonstrate that people sort photographs according to two main dimensions: natural versus built environment, and whether the pictures contained humans or not.

In this study we aim to empirically assess how static large-screen stereoscopic 3D views with varying levels of realism affect people's belief in the veracity of the underlying spatial data. The leading research question of our study is: Do novice users infer higher data quality from more realistic looking displays compared to less realistic ones? Specifically, we empirically investigate the following research hypotheses: (1) The more photorealistic a 3D view, the higher the confidence of novice users in the veracity of the underlying data; (2) confidence ratings depend on the depicted feature type; (3) confidence rating depend on the data quality assessment task.

2 Method

In a controlled two by three by three (feature type × display type × question type) factorial within-subject experiment we asked novice participants to evaluate the veracity of spatial data depicted on static large-screen stereoscopic 3D views, such as shown in Figure 1. We hypothesize that users' confidence ratings increase with the level of visual realism shown in the 3D views. To investigate this relationship we developed eighteen 3D scenes with varying levels of realism (first independent variable; three levels: photorealistic, technical and sketch-style rendering, see Figure 2). Based on related work reviewed earlier we predict that peoples' confidence ratings will not only vary depending on the depicted feature type (second independent variable; two levels: natural vs. built features, see Figure 1), but also on the data quality type considered for the task (third independent variable; three levels: a feature's location, its size, and attribute type), defined according to Thomson et al.'s uncertainty typology (2005). The typology incorporates the established data quality measures from the USGS Spatial Data Transfer Standard. We contend that the confidence ratings are a suitable proxy for "naïve understanding of spatial data quality".

Participants. Thirty participants (12 female and 18 male) were recruited from the undergraduate and graduate student body at the Geography Department of the University of Zurich. We also invited people outside of academia to participate in the study. On average, participants were 25.8 years old, reported to have normal or corrected-to-normal vision, and no one indicated to have impaired stereo vision. The participants were judged to be a good sample of the desired novice user population, as they have low to average prior knowledge of geographic information science, geographic information visualization, computer graphics, including 3D visualizations, and graphic design. All participants volunteered for the study, and were not compensated for their participation.

Materials. Built feature stimuli are based on a detailed, photorealistically textured 3D city model of Chemnitz, Germany. We chose a set of buildings representing an urban scene with commercial and residential buildings, as shown in Figure 1a. Natural feature stimuli (see Figure 1b) are derived from fan palm-tree models created with the open source procedural modeling engine Arbaro 1.9.8 that implements Weber & Pen's (1995) tree rendering algorithm. The modification of the levels of realism (i.e., photorealistic, technical, and sketch-style renderings) and the final assembly of the 3D views were carried out in Google SketchUp Pro 6.

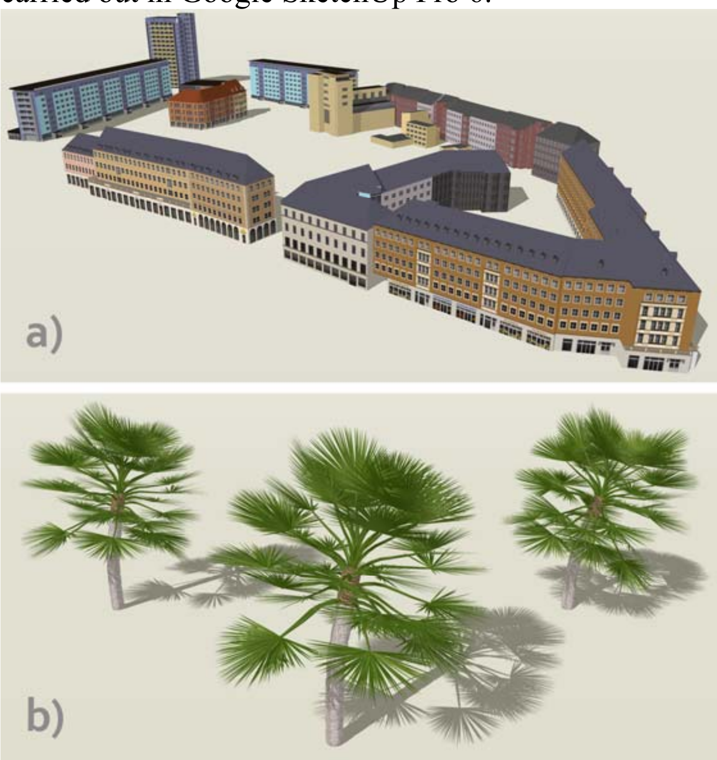

Figure 1. Test displays showing photorealistic (a) *built* and (b) *natural* features.

For the "*photorealistic*" views detailed photographic textures were applied to the 3D models, as shown in Figure 2a. The "*technical*" views feature solid shading and crisp, straight black lines as edge-enhancement akin to CAD-like, technical drawings (see Figure 2b). Solid shading was also employed for the "*sketch-style*" displays as can be seen in Figure 2c. For these displays we chose fuzzy and irregularly curved black lines as edge-enhancement to convey the look and feel of a hand-drawn sketch. To increase the number of trials, additional test displays were created in Adobe Photoshop by flipping scenes along the z-axis. Aside from the varying levels of realism all other visualization parameters were held constant for all stimuli—most notably, camera settings (angle of view and field of view, vantage point, etc.), view perspective (i.e. isometric projection), background, atmospheric effects (i.e. no fog or haze), as well as shadows and illumination. Aside from these graphic changes the underlying geometric model was not modified for all three display types. Stereo image pairs of the scenes were generated with a plug-in that adds stereo support to SketchUp. All stimuli were assembled and rescaled to fit the stereo display system's native screen resolution. The size of the stimuli was either 1280×673 pixels for displays with only one level of realism, or 649×1024 pixels for views showing all three realism levels jointly.

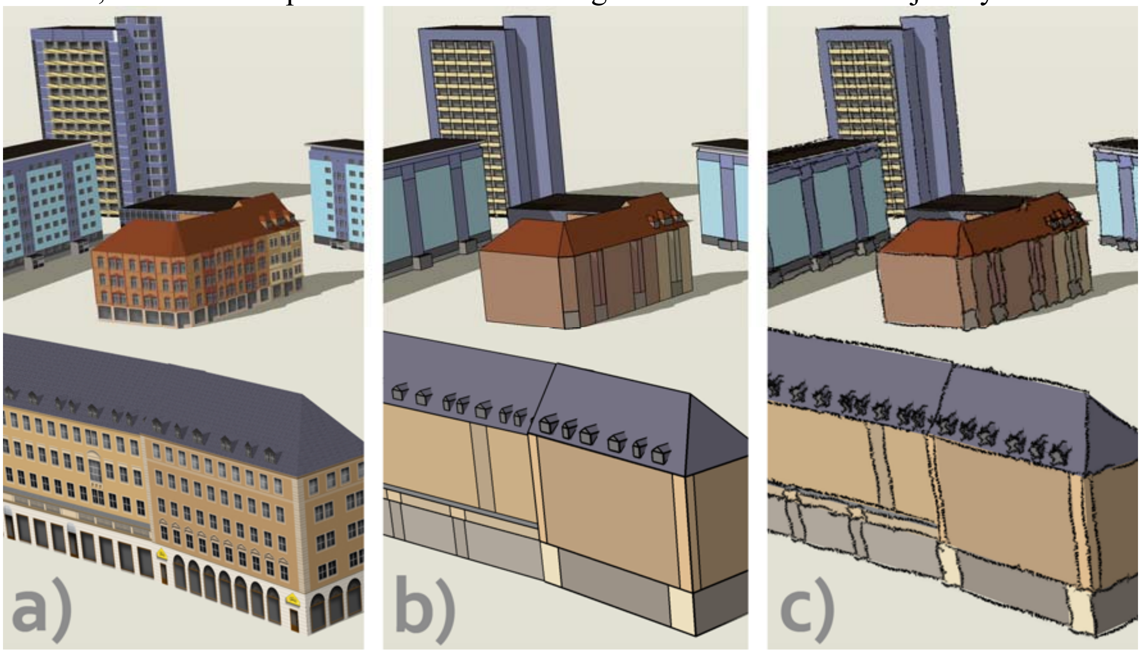

Figure 2. Details of (a) *photorealistic*, (b) *technical*, and (c) *sketch-style* displays of built features.

Apparatus. The experiment took place in a windowless room, dedicated to run experiments with a *GeoWall*, a large-screen stereoscopic display system. This passive stereo system achieves the stereo effect through linear polarization (Johnson et al. 2006). Our GeoWall[1] system uses a Cyviz Viz3D stereo projection unit comprising two DLP projectors and a stereo converter. Images are projected onto a polarization-preserving rear-projection screen measuring 120 inches diagonally and resulting in a maximum image size of 2.4×1.8 meters. The test was administered on a Dell Precision Workstation 390 with a nVidia Quadro FX3500 256 MB graphics card and Windows XP as operating system. To view the displays in stereo, participants wear linearly polarized 3D glasses. All stimuli were displayed full screen with StereoPhoto Maker 3.2x at the

[1] More details on: http://www.geo.uzh.ch/en/units/giscience-giva/services/3d-visualization-lab/

system's native screen resolution of 1280×1024, using the software's shutter glass mode. Participants were seated at a table three meters away from the screen.

Procedure. At the beginning of each test session participants were welcomed to the lab and asked to sit at the table in front of the GeoWall screen. After they had read the test instructions and signed a consent form lights were switched off and the first stimulus was displayed. During the first part of the test session participants were asked to study and describe the stereoscopic 3D views for each feature type individually, shown at one level of realism. Following the description task, participants were asked to rate the stimuli on a Likert scale ranging from one (no confidence) to five (complete confidence) regarding the perceived veracity of the 3D views, based on a data quality characteristic. For example, for the data quality type question "size" they were asked: "*How confident are you that the view accurately shows the height of the buildings?*". Stimuli in this part of the test session consisted of a composite of vertically arranged displays including all three levels of realism. The sequences of the realism levels and the data quality type questions were randomized to avoid any potential order effect. Additionally, half of the participants were first presented with the built feature stimuli, and the other half with the natural feature stimuli. Participants were also asked to explain their ratings. After completing the stereoscopic view portion of the experiment participants filled-in a background questionnaire and were thanked for their participation.

3 Results

Figure 3 below summarizes participants' average confidence ratings on the Likert scale from 1 (no confidence) to 5 (complete confidence) depending on the display's level of realism (PR = photorealistic, NPRt = technical, NPRs = sketch-style). On average, people's confidence in the photorealistic views is highest (M=4.02, SD=.50), followed by the technical depictions (M=3.45, SD=.54), and lastly the sketch-style renderings (M=3.00, SD=.61).

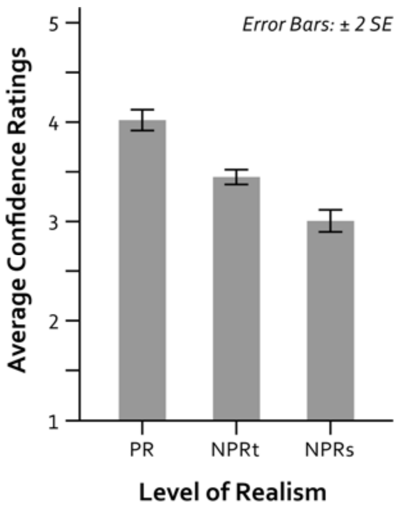

Figure 3. Participants' average confidence ratings.

A repeated measures ANOVA confirmed a significant overall effect for the independent variable realism, $F(2,58) = 71.89$, $p < .05$, partial $\eta^2 = .71$. A subsequent pairwise comparison with a Bonferroni correction to maintain $\alpha = .05$ showed that the data quality of a 3D view is indeed rated significantly highest when a photorealistic display is used. The technical views received the second highest ratings, which are in turn rated significantly higher than thirdly, the sketch-style renderings. We have not completed data analysis regarding the variables feature type and question type and hope to report respective results in a future paper.

4 Discussion

Replicating results by Fabrikant & Boughman (2006) on 2D maps, the results of this study suggests that varying levels of realism in 3D perspective views does indeed influence people's confidence in the credibility of the spatial data depictions. Specifically, the more realistic the stereoscopic 3D display, the higher participants' confidence ratings. These findings add a novel wrinkle to a phenomenon Smallman & St. John (2005) have coined *naïve realism*, i.e., novice users' misplaced faith in the utility of realism, even though a more realistic display can even significantly hinder task performance. Not only do novice users tend to favor realistic displays for various inference making tasks (Canham, Hegarty & Smallman 2007; Hegarty, Smallman & Stull 2008; Smallman & Hegarty 2007), but also more realistic looking displays seem to instill greater confidence in data quality. Based on our empirical results, we can indeed recommend the use of realism as a visual variable to convey data quality, as was proposed by McGranaghan (1993) over 15 years ago. Our results also suggest the effectiveness of MacEachren's (1995) visual variable "clarity" for systematically matching realism levels with degrees of data quality.

5 Conclusions

This paper reports on an empirical study investigating whether novice users infer higher spatial data quality from more realistic looking static, large-screen stereoscopic 3D views. Participants' confidence in the veracity of the depicted spatial data was significantly highest for photorealistic displays, followed by CAD-like, technical views, and lastly sketch-like renderings. This evidence suggests that gradations of photorealism (or varying levels of feature fidelity) in depictions involving human-made and natural features could be employed as an effective visual variable in situations that involve communicating different levels of data quality. At this stage of the research it is not yet clear whether confidence ratings depend on feature type and the type of data quality. We intend to provide answers to these questions in a follow-up publication. We hope that the current findings will help increase the awareness of under researched perceptual factors in 3D visualization and design that might influence people's understanding of spatial data. Systematic control of visual effects by the display designer will in turn lead to more effective communication of inherent spatial data quality and uncertainty in visuo-spatial displays.

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