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Geovisual analytics: human factors

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EDITORIAL

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This special issue is the Part II of a two-volume special issue comprising of a series of papers documenting the state-of-the-art research in geovisual analytics. Part I consisted of four papers and *focused* on *design and implementation issues in geovisual analytics*. Here, with an additional four papers focused on the *human factors in geovisual analytics,* we present Part II.

Visual analytics aims at combining the strengths of machines and humans (Keim et al. 2010). In the light of this definition, studying *human factors* is essential in understanding what we can truly achieve using visual analytics and how we can optimize software systems and visualization design to human strengths and limitations (Tory and Möller 2004). In the Part I of the series *Special Issue on Geovisual Analytics: Design and Implementation* edited by Pettit et al. (2015), Cartwright (2015) collects expert interpretations to build a definition of the word map and distinguish it from other representations, because for tasks such as qualitatively defining and interpreting a concept, we need human input. Similarly, to understand which processes should be left to machines and which to humans; how well geovisual analytics concepts and tools are understood and utilized by their users; what are their limitations; we need to understand human experience with these systems.

This special issue puts together research articles in which various components of geovisual analytics environments are evaluated through user-centered approaches. Some take an efficiency and effectiveness (performance) approach, while some others take perceptual and cognitive approach to human factors in visual analytics; offering insights into how humans interact with geospatial products. For example, MacArdle, Tahir, and Bertolotto (2014) study mouse trajectories that we leave behind when we interact with a digital geospatial product. If we have different levels of expertise, do we use the computer mouse differently? If yes, why should this be the case? Such knowledge can be powerful in providing real-time (and effective) help to users when they need it, and can help developing better interaction designs, thus making Digital Earth displays more usable and useful. Tackling another important aspect of human experience with Digital Earth-related visualization environments, Bleisch and Dykes (2014) offer a comparative view of human performance with 2D and 3D displays in a desktop-based virtual reality environment. The study contributes incrementally to our (scarce) knowledge as to whether such realistic 3D representations work for people and if yes how well they work, and for which task. Further in this special issue, Bernabé Poveda and Çöltekin (2014) study a perceptual issue in relation to interpreting 3D forms on satellite images through an online user study, providing us with new knowledge on the well-known *terrain reversal effect.* This is an illusion that can have undesired consequences in Digital Earth applications and other use of satellite images and shaded relief maps. When shadow is the dominant depth cue in such visualizations and shadows are not where they are supposed to be, the scene interpretation becomes ambiguous or even reversed: we see convex shapes as concave and *vice versa*. Can we really trust what we see? This paper demonstrates how prevalent this interesting phenomenon is, and briefly discusses the proposed solutions. Last but not least, on another front where 3D visualizations and satellite imagery are used in combination for visual analysis, Ghosh and Lohani (2014) report their user-centered LiDAR (Light Detection and Ranging) visualization environment and the iterative process of developing this environment based on user-feedback.

These four papers, when complied, give us a multi-faceted coverage of philosophical, methodological and cognitive/perceptual perspectives on human factors involved in geovisual analytics in connection with the Digital Earth. Below you will find an individual summary of each paper.

The first paper in this special issue (McArdle, Tahir, and Bertolotto 2014) offers an interesting investigation on interpreting people's map-use patterns through an empirical study. As a user interacts with a web map using a mouse as a pointing tool, invisible trajectories are generated. By examining the spatial features on the map where the mouse cursor was placed, the user's interests and experience can be detected. The investigation involves a spatiotemporal clustering technique to group mouse trajectories with similar behavioral properties. Based on a controlled user study with 27 participants (each executing 10 tasks), McArdle, Tahir and Bertolotto validate their approach. Their results reveal that it is possible to identify experienced and novice users of web mapping environments, *i.e.*, experts and non-experts use the computer mouse differently. This investigation is of significance to provide personalized map interfaces to users and provide appropriate interventions for completing spatial tasks in geovisual analytics. This study not only provide us with insights in group differences when geospatial tasks are executed and helps with building more usable and useful Digital Earth applications, but also describe a visual analytics implementation in which others can identify expert users from novice users through behavior identification using mouse trajectories.

The second paper (Bleisch and Dykes 2014) provides observations and findings from two empirical studies where the authors measure performance (efficiency and effectiveness) as well as insights that the users reported (which they term insight plausibility), and their confidence levels and complexity ratings as they worked with 2D and 3D visualizations. This study, therefore, contributes to the debate whether there are certain advantages to using 3D visualizations in comparison to 2D. The answer is, so far, 'it depends'. In some cases, 3D can harm performance (Borkin et al. 2011; Hegarty et al. 2009), but in this case, performance differences are not many, nor very high. The paper suggests that 3D visualizations or 2D representations may be more (or less) useful for particular data-sets and contexts in geovisual analytics. While more empirical studies are needed in this area, Bleisch and Dykes (2014) provide us with very interesting and relevant clues (and further questions) regarding how to choose 2D *and/or* 3D displays wisely in relation the task at hand.

The next paper (Bernabé Poveda and Çöltekin 2014) also offers a user study about 3D visualizations; however, they tackle the issue from a perceptual standpoint. In 3D (geographic, or other) visualizations, people may experience a visual illusion termed *relief inversion* (Imhof 1967), *false topographic perception phenomenon* (FTPP; Saraf et al. 1996), or *terrain reversal effect* (Zhou, Zhang, and Gao 2006). This illusion leads to an inversion of the relief; as such, mountains appear as valleys, craters appear as hillocks, and *vice versa*. The effect can lead to critical mistakes in interpreting the terrain. The effect can be observed in remotely sensed Earth imagery as well as lunar surface images (Saraf et al. 1996; Wu, Li, and Gao 2013). Bernabé Poveda and Çöltekin (2014) provide a systematic investigation of the terrain reversal effect in satellite imagery through a two-stage *online* user experiment with 535 participants. The findings demonstrate that the illusion is acutely present. This paper also cautions us that in an interactive environment where people can rotate the display, severe perceptual problems might be introduced. Better understanding of the problem and its solutions are required to relieve this phenomenon in geovisual analytics and satellite imagery used in Digital Earth applications.

The last paper in this issue (Ghosh and Lohani 2014) offers another user study on 3D visualizations, with a focus on finding computationally and perceptually optimum ways to visualize large point clouds combined with aerial photography (or satellite imagery). They describe their proposed 'visualization pipelines' to *analyse* how fast the LiDAR data can be processed and how well depth differences and 3D features can be identified with LiDAR point clouds. LiDAR technology and the collected point cloud data have been widely used in various applications since the late 1990s. Conventional ways of using LiDAR data for visualization or mapping purposes require the process of classification or feature specific segmentation, which is usually time-consuming. This paper presents several heuristic approaches for visualizing LiDAR dataset without carrying out a segmentation process of the point cloud (therefore, speeding up the process). Results indicate that the heuristic-based method receives user ratings that are almost equivalent to the manually classified and reconstructed LiDAR data-set for the purposes of visualization. The approaches are evaluated through a user study in which 67 participants rate how well they can perceive depth, the display quality and quality of other objects displayed on the scene. The work described in this paper will definitely interest LiDAR data processing and visualization community.

Concluding remarks

In this special issue, we provide a set of new knowledge and findings about human factors from various viewpoints. It is important to note that conducting properly set up user studies without confounding variables or without priming the users can be a difficult task, thus it is important to think carefully what kind of finding one can generalize from a single user study. We also note that in 'standard' visual analytics literature, there is a focus on 2D (and there are good reasons for this); however, empirical studies on 3D visualizations are rare to this day, and we believe there should be more of them. With this special issue, we provide the reader with several new and interesting findings that can lead to a more informed use and design of 3D visualizations; and hopefully an awareness of some of the human factors when designing Digital Earth displays. Digital Earth displays, by their original intention, are realistic displays and may suffer from information overload (Coltekin and Reichenbacher 2011). As designers of scientific visualizations, we should be aware of our users' limitations and strengths as, for example, expertise in a domain can lead to different strategies and better performance (Çöltekin, Fabrikant, and Lacayo 2010) or spatial abilities between people may differ strongly (Hegarty and Waller 2005).

We believe you will enjoy reading these interesting papers, taking you on a brief journey on a lively scientific debate; and we are convinced that you will learn a great deal about human factors in geovisual analytics in connection to the Digital Earth.

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