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Editorial

Designing Geovisual Analytics Environments and Displays with Humans in Mind

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In this open-access Special Issue, we feature a set of publications under the theme "Human-Centered Geovisual Analytics and Visuospatial Display Design". As the title suggests, the scope of this collection is on human-centered questions regarding visual analytics software environments; and the design of visuospatial displays within and beyond these environments.

The essential building blocks of visual analytics (VA) are computers and humans [1]. Without computers (i.e., technology and quantitative methods such as those used in statistics and data science) VA simply would not exist. For decades now, it has been clear that computers are better than humans in processing large amounts of data, being capable of storing and quickly retrieving what is needed. Mechanisms such as parsing and filtering, automated pattern detection and machine learning, manual queries, and coordinated-view visualizations make visual analytics environments amazingly versatile and powerful [2]. The tools contained in VA environments assist us in spatial learning, discovery, and decision making [3,4]. It is important to remember that they can really only play an assistive role however, because tasks such as learning, interpreting patterns to make discoveries, and decision making are inherently qualitative. Often the goal is to make decisions based on observed patterns and anomalies. Such patterns and anomalies are much more likely to emerge (and if they are known to exist, they are better expressed) with visualizations than via numbers or tables alone [5].

When the goal is to learn, interpret visualizations, and make decisions, e.g., based on visual reasoning, humans are, and possibly always will be, better than computers [6,7]. Even though there are many individual and group differences in human performance in reading and interpreting visualizations [8–13], the success of humans in any of these listed tasks also highly depends on their design. It matters if the design of visuospatial displays (visualizations), interfaces, and interactions are well-considered or not [14,15]. However, despite individual and group differences based on human abilities or display design, unlike computers, we know that humans understand concepts beyond the 'limitations of the binary'. In varying degrees, we can comprehend and judge the relevance of details in a given context quickly both for themselves and others using our multiple senses. Thus, as definition of the visual analytics also clearly suggests [16], as much as we need the technology; it is just as important to leverage human abilities and respect their limitations.

One might argue that user experience is what 'makes or breaks' VA environments and visuospatial displays. If users feel comfortable and confident with a VA experience, find it helpful and easy to learn, and ideally even enjoy what they are doing, they are much more likely to continue using it, and to recommend it to others. Besides these desirability and functionality aspects of VA environments and displays, by examining visuospatial displays, interfaces, and user interactions in VA, we also have the potential to obtain important insights into human visuospatial perception and cognition [17,18]. In other words, human abilities, limitations, and attitudes are defining factors for adaptation of technological solutions, such as visuospatial displays used in VA software environments. That said, human-centered issues and associated solutions in developing and customizing VA experiences can be complex to understand, model, and, importantly, generalize from individual experiments [2]. Therefore, it is important that we continue asking new questions and answering old questions with fresh perspectives to advance and solidify our knowledge. In addition to fundamental knowledge, technical solutions that are informed by fundamental knowledge (e.g., on the perceptual and cognitive factors) are still rare, even though it is understood that they could benefit users.

With this Special Issue, we create a compendium of the state-of-the-art knowledge on human-centered approaches to creating and using visual analytics environments and of the design of the visuospatial displays that are of core importance in visual analytics processes. We have contributions that feature technical solutions informed by human-centered user research, experimental studies demonstrating new knowledge in human visuospatial information processing, spatial perception and cognition, and studies focusing on usability engineering. Specifically, this volume features seven publications that cover two broad categories within the scope of the Special Issue, the first of which focuses on new approaches for systems and analytics, and the second of which focuses on cognitive challenges and 3D representations. Below we summarize the contribution of each paper in relation to this Special Issue and in relation to each other in two sections.

New Approaches for Analytical Systems and Methods

One of the key strengths of visual analytics is that it can capture patterns and anomalies in data, including unstructured data such as text as input. Karimzadeh and MacEachren (2019) [19] take a visual analytics approach to a difficult problem that underlies geoparsing. In natural language processing (NLP), algorithms are validated using annotated corpora of text. When these texts contain geographic information, this information (usually in forms of natural language references to places) needs to be recognized and linked to toponyms in geographic gazetteers, and, through that, to coordinates which uniquely link the original references to a specific point on the surface of the Earth. This task is currently beyond the capability of computers alone and requires time consuming and tedious manual annotation by humans. Karimzadeh and MacEachren (2019) [19] thus offer a new bespoke and interactive visual analytics system, the GeoAnnotator, to speed up the process. The GeoAnnotator precomputes potential matches and then allows a multiuser collaborative approach to improve individual results. Its main purpose is geoparsing, but the algorithms can be further developed for other tasks related to recognition of patterns in spatial language. Further, the GeoAnnotator is provided as free and open source software (FOSS) at https://github.com/geovista/GeoTxt, thus the paper also supports open code provision and through it scientific reproducibility.

In the next paper, Sarın and Uluğtekin (2019) [20] take an entirely different approach to finding and analyzing content in newspapers collections. The effort can be viewed as a manual annotation of a training set for a future machine learning algorithm. Authors document cartographic choices made by newspapers in communicating earthquake-related news in a historical period based on a manual collection, classification, and qualitative analysis. The objective of the work is to examine the role and the potential impact of newspaper maps and map-like contents to enhance spatial thinking abilities. Scanning the newspaper archives from 1928–2000 from eight major newspapers distributed throughout Turkey, a country with frequent earthquakes, authors first set up a geospatial database, coding the spatial and thematic features of map-like contents. The article describes the design of the database and the possible queries based on map title, type, purpose, scale, and elements such as text, location inside the newspaper, etc., that could be relevant in classifying maps. Sarın and Uluğtekin (2019) then perform a qualitative evaluation using a subset of earthquake-related news associated to destructive earthquakes in the period 1990–2000. This evaluation effort highlights the diversity of the quality of those maps based on criteria defined by the authors such as 'uninformative' or 'misinformative' and ranking of their visual complexity, legibility issues, etc. These criteria are then interpreted against the role of the newspapers, which were the main mechanisms to spread spatial information to citizens pre-Internet era. The study offers a unique look at the past and contains interesting observations for 'data journalism' in a specific context (earthquake news) and possibly a starting point for annotating visual materials in older news collections for historical insights. Further studies about usability perspectives could be elaborated based on this preliminary analysis of map-like contents in newspapers and extended to other topics and purposes in order to address the potential of maps in media.

Another map type that is used in popular media regularly is a weather map. Popelka et al. (2019) [21] examine the usability of five selected online weather maps in a comparative manner (DarkSky, In-Počasí, Windy, YR.no, and Wundermap), complemented with an eye movement analysis. Their selection of these five maps for a controlled lab study was informed by an online study. Based on 34 participants, the authors examined what they call "introductory", "dynamic", and "static" cases. Their evaluations based on quantitative statistics and think-aloud protocols show that depending on the design of the map, participants' map-reading strategies vary. Irrespective of design, a general observation is that participants omit the functions that are not explicit, and many advanced functions are lost. Specifically, if a menu only appeared after a click (expandable control panel), participants did not consult these until they exhausted the explicit and immediately available options. Authors observe that interactivity in itself did not pose a threat, but an interactive interface can contain too much information or too many options, and this is when it starts creating usability problems. Another observation in the paper based on the comparative analyses was that the visual search is quicker with static menus (where no interactivity was required). Essentially, we see in this study that the design decisions—whether on the display itself or the menu items—have significant impact on user strategies and success. These findings are in line with previous research and provide further evidence that design decisions are of critical importance in making interactive maps.

Cognition and 3D Representation

While studying specific map types (such as earthquake maps and weather maps) allow us to observe specific patterns for the studied "visualization families", there are certain considerations at a fundamental level that would potentially apply to all visuospatial displays. In "Why Shape Matters—On the Inherent Qualities of Geometric Shapes for Cartographic Representations", Klettner (2019) [22] characterizes the strategies users apply when evaluating and comparing basic geometric shapes (which are included in all visuospatial displays). Klettner's study seeks to dive one level deeper into the crucial visual variable of shape, to see whether or not it is possible to separate types of shapes into discriminable categories. In this paper, the results of an experiment with cartography students helps reveal how common shapes are conceptualized and can be grouped a few major clusters. In addition to exploring how users group common shapes, Klettner also reports on what can be learned from studying the retrospective verbal reports of participants who have completed this type of task. A key strength of this article is that we learn not only which groups users may assign shapes to, but we also learn why they chose those groups. The former may help us develop a better sense of the sub-levels within a common visual variable, and the latter can help us suggest the reasons for why those sub-levels work from the end-user perspective.

Another important and complex variable in visuospatial display design is the level of visual realism and abstraction, e.g., [23–25]. Taking levels of realism as their main focus, Snopková et al. (2019) [26] examine the effectiveness of 36 participants in an indoor navigation task (specifically for evacuating under time pressure) using two- (n = 17) and three-dimensional (n = 19) displays. Participants navigated the physical environment after having been trained in a virtual environment (more realistic condition) and with more traditional two-dimensional floor plan (less realistic, or more abstract condition). Based on the efficiency (task completion time) and effectiveness (error rates in incorrect turns) of the participants in the two conditions as well as other measures such as mobile eye tracking measurements, participants' sketch drawings of their 'cognitive maps' (their recall of the route they took), structured interviews, and spatial abilities, authors conduct a rigorous analysis of participant performance comparatively in two conditions. They observe that both groups successfully complete the route, however, the group that learned their route in a virtual environment provide a richer (more detailed) mental map than the 'floor map group'. Authors surmise that the realistic details appear to help recall the details better and also aid in navigational decision making. Their findings provide a valuable additional contribution in comparing 2D and 3D displays as the contexts vary. Because this is a highly debated subject in information visualization community, and sometimes the understanding that 3D hurts performance [27] is generalized too far, new empirical evidence this paper offers allow more nuance in our understanding of the role of 2D and 3D in the context of navigation.

In a complementary study that concerns itself with 3D and spatial thinking, Carbonell-Carrera and Hess-Medler (2019) [28] switch the context to education and provide new empirical evidence on the subject. Authors examine how engineering students use 3D visuospatial displays over two workshops in seven tasks along with 18 exercises regarding relief interpretation based on topographic map assessment (TMA) test. Compared to the baseline topographic maps, the authors demonstrate that a 3D software environment improves operation as well as comprehension. Carbonell-Carrera and Hess-Medler (2019) [28] interpret their observations that an "easy to use" 3D software environment helps in developing better geospatial thinking and is useful in teaching and learning.

Jacquinod and Bonaccorsi (2019) [29] also examine 3D geovisualizations, yet in another context. Thanks to sociological theories and from a communication studies' perspective, this article analyzes the possibilities provided by 3D geovisualizations to risk managers and citizens, in the context of flood mitigation planning. A study has been conducted, based on 8 years (2009–2017) of action-research projects aiming at better understanding social uses of 3D geovisualizations in urban planning based on the co-production of 3D geovisualizations and the evaluation of their uses and benefits in practice regarding the risk. The main result of this study is the variety of roles that a given 3D geovisualization can play in a single situation, that could not be anticipated, but that they can be used to support exchanges of ideas and collaborative thinking, acting as a medium that facilitates the decision making. Nevertheless, a necessary appropriation of 3D geovisualizations by their users is claimed. A set of recommendations for 3D geovisualization design is provided, in particular regarding the balance between schematization and narration. An interesting part of the evaluation concerns the qualification of the level of engagement of the public (resonance, submersion, critical distance, reject). Benefiting from theoretical pluridisciplinary framework can offer the possibility to integrate into the design or evaluation of geovisualizations, human factors depending on the individuals using the devices [30].

Closing Remarks

Given the range of topics covered above, we believe this volume will be of relevance to geographic information scientists, visualization researchers, interaction designers, and anyone who makes maps and designs VA environments. Scientists working on visual and spatial cognition research may also find the studies presented in this compilation to be of interest. The examples provided in this volume make it clear that many questions remain unanswered regarding how best to design geovisual environments with users in mind. Specifically, the examples we have collected in this issue reveal that we need to more aggressively engage with big data and machine learning/artificial intelligence in the context of human-centered VA design. Visualization has the potential to serve as a bridging method between complex AI algorithms and end-users, but we currently know very little about how to design such systems.

We also note the need to focus on contexts in which problem spaces are complex, including vague and/or uncertain data elements, and those in which multiple interface paradigms may be applicable. For example, we see the potential for immersive environments and augmented reality systems in complex spatial problem solving contexts. At present we know relatively little about how such systems can or should be designed.

Finally, we see an opportunity to focus on analytical reasoning as a key area of research engagement to support a very wide range of new projects. The representation and interaction examples provided in this Special Issue prompt us to consider the ways in which we can leverage human capacities to reason and make decisions with spatial information, particularly in problem contexts where simple answers do not suffice and where multiple competing values must be weighed against each other.

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