The Complexity Challenge to Creating Useful and Usable Geovisualization Tools

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The value of visualization (in particular, geovisualization) as an instrument for data exploration and analysis is widely recognized. In spite of this, the use of visualization tools by people different from the tool designers seems to be quite limited. It appears that data analysts, both novices and experts, are reluctant to use the tools and techniques created for them. We argue that user interface problems such as ill-organized menus, intricate GUI controls, and inadequate help may not be the only reason for this situation.

The problems we are concerned with seem to lie beyond the scope of the traditional usability research, which focuses on two major themes (Fuhrmann et al. 2005): user-centered design and evaluation of artifacts. In evaluation studies, the researchers ask the test participants to complete tasks that potential users of the system would want to accomplish and observe how the participants perform. The user-centered design approach means designing a tool or a system on the basis of an understanding of the potential users (in particular, their perceptual and cognitive processes and mental models) and their tasks.

It should be admitted that the established principles and methods of user-centered design and usability testing are not fully applicable in the domain of geovisualization. As Slocum et al. (2001) note, "a clear specification of tasks (and sometimes of users) is often not possible due to the exploratory and interactive nature of geovisualization" (p.71). Besides, the researchers in visualization and geovisualization usually strive at designing generic tools and techniques rather than address specific users or specific tasks. In this connection, Fuhrmann et al. (2005) try to persuade tool designers that they, nevertheless, should not operate at the "general user" level but sample different geo-domain users.

Despite of the problems, geovisualization researchers conduct a number of usability-related studies; see, for example, the dedicated chapter in (Dykes et al. 2005). What seems to be yet not in the scope of such studies is the design and evaluation of geovisualization toolkits (rather than separate tools) intended for broad user communities and various types of data and tasks.

When a geovisualization system is not created for a specific group of users wishing to explore specific data, it must be designed so as to be applicable to many different datasets and to cover the needs of many different users. The designer should anticipate the tasks the potential users would wish to perform and ensure that each task is properly supported. The striving to embrace a wide range of tasks and thereby enable comprehensive data exploration results in a growing complexity of the system, which makes it difficult to use. Although the complexity problem seems quite serious and directly related to usability of geovisualization tools, it has not yet got proper attention of the geovisualization researchers. We would like to motivate the researchers to think about these issues.

We ourselves started to think about the complexity issues in the course of a project where we cooperated and communicated with potential users of geovisualization tools. The project partners evaluated the geovisualization system CommonGIS and found it very complex and difficult to use. The evaluators had a feeling that the system includes too many different tools. While each individual tool is not too complex by itself, the multitude and variety of the tools result in the complexity of the system as a whole. At the same time, the evaluators could not say which of the tools were excessive. For each tool, they could imagine a situation when exactly this tool is necessary or serves in the best possible way. Hence, reducing the number of tools does not seem to be an adequate way to increase the usability of the system. Another problem we have revealed is that users often do not know how to approach a dataset even when they do know what tools exist and can operate each of them. When we demonstrated our partners how their own data could be explored by means of visualization, the partners often asked us, “How do you know what to do in each particular case and when to apply what technique?”

We believe that the problems that have been revealed are not specific for this particular project, or for this particular group of users, or for CommonGIS. The fundamental reason is that visual data exploration is by itself an intrinsically complex process. The analyst needs to look at data from various perspectives and at various scales, from “seeing the whole” to “attending to particulars” (Andrienko and Andrienko 2006). The analyst is also supposed to “see in relation”, i.e. make numerous comparisons. This inherent complexity is multiplied by the complexity of the data that is explored and analyzed. The complex, multi-dimensional structure and heterogeneous components of most contemporary datasets necessitate a combined use of multiple techniques and approaches. There is no single visualization capable to show “the whole”. The analyst has to decompose this whole into parts, examine these parts, and then try to synthesize the whole picture

from the partial views, analogous to reconstructing a complex three-dimensional shape from a set of projections and slices. Because of large data volumes, no visualization is simultaneously capable of providing an overall view and exposing various "particulars". Looking for "particulars" requires therefore different techniques than "seeing the whole".

Hence, the process of comprehensive data exploration is inherently complex, demanding of the human analyst, and requiring multiple tools and techniques. This means that even a perfect user interface and extreme ease of use of every technique separately and of several techniques jointly would not solve the complexity problem. Complexity remains in the necessity to remember which techniques are available and for what purposes and to what data each of them can be applied. Complexity also remains in the necessity to decompose a data exploration problem into subproblems and to understand how to do this properly and effectively in each particular case. Complexity is also involved in the need to merge fragmentary knowledge resulting from the application of multiple tools into a consistent conception of the data and underlying phenomena.

There is, apparently, a need to educate people to do data exploration and analysis with the use of visualization. It seems desirable that researchers in geovisualization and information visualization find appropriate ways to convey the necessary expertise to the users. We are afraid, however, that creating good educational materials for various user categories may be not enough. People may be overwhelmed by the multitude of aspects that must be cared of in order to explore and analyze a complex dataset properly.

The researchers should therefore try to find ways to alleviate the complexities involved in the process of data exploration and analysis. We propose the following questions to the geovisualization researchers for thinking and discussing.

1. "Ostensible simplicity": Is it possible to build a geovisualization system that is sufficiently powerful and flexible but appears light and simple to the user? Can the indispensable complexity of the system be concealed behind a well-designed user interface and intelligent behavior?

> **1A. "Sufficient minimum"**: An example of intelligent behavior is the system being capable to recognize which instruments make a minimum combination appropriate to analyze a specific data collection and simplify itself by hiding unnecessary tools and arranging the necessary ones in a way convenient for the user. Can (geo)visualization scientists develop an appropriate theoretical and methodological background for this?

1B. Automation: Is it possible to automate some of the data exploration operations, for example, by involving data mining or other computational techniques?

2. User guidance: Can geovisualization systems guide inexperienced users through the process of data exploration and analysis: help them to examine the structure of the data and decompose the problem, suggest right tools at right moments, attract attention to potentially important or "strange" things?

2A. Generic procedures: Can geovisualization researchers define generic procedures of data exploration, i.e. the reasonable sequences of steps and the tools and methods to be applied on each step?

2B. Helpful while not annoying: How to provide the guidance in such a way that the user could appreciate it and would not feel overwhelmed or annoyed?

3. "Incremental intelligence": Can geovisualization systems simplify and advance the work of experienced users, for example, by learning typical scenarios of data exploration and re-playing these scenarios when appropriate?

Besides the complexity problem, there are also other possible reasons for the low acceptance of (geo)visualization tools. Thus, data analysts do not only need tools that allow them to make discoveries and generate hypotheses but they also need the means to verify these discoveries and to test the hypotheses. Hence, exploratory tools should be linked with appropriate confirmatory techniques, and, for example, implemented as extensions to statistical packages.

One more challenge, which does not yet seem to be properly realized in the visualization research community, is related to the fact that observations and discoveries that people make in the course of visual data exploration cannot be conveniently captured for later recall and for communication to others. Primary results of using visual data displays are visual impressions, or mental images, which are hard to verbalize or express in any other form without referring to the displays from which they originate. The difficulty of recording and reporting the findings is a serious obstacle to wide recognition and use of visualization tools.

Hence, the problem of usability of (geo)visualization tools is complex and multi-faceted and requires systematic joint efforts of many researchers and tool designers to fully solve. The current scope of the usability-related research seems insufficient and needs to be extended.

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