Discussion paper submitted to the ICA Commission on Visualization and Virtual Environments
Pre-Conference Workshop on Geovisualization on the Web, Beijing, China, Aug. 3-4, 2001.


# Building Task-Ontologies for GeoVisualization

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## Abstract

This short position paper proposes a task-ontological approach to geovisualization. Two recently identified challenges in geovisualization research justify such an endeavor, particularly for the web-enabled domain: (1) the need for developing task-driven tools to facilitate problem solving and knowledge sharing amongst heterogeneous user communities, and (2) the lack of sound evaluation procedures to assess the usability of geovisualization tools.

## Background

Scientific Visualization, Information Visualization and Geovisualization have produced a wide array of visual forms and interaction mechanisms to depict and explore abstract, multidimensional datasets. Taking advantage of the Internet many cutting-edge visualization tools and products are now even made accessible to an exponentially growing, diverse user community distributed over computer networks. The potential the Internet has to offer for sharing large data sets, visualization tools and graphic methods seems to be limitless. As Sowa (2000) suggests, "The Internet is a giant semiotic system", and it is this system's potential for collaboration that makes it so attractive to just do 'about anything graphic' on the Web. However, this semiotic system is only useful for knowledge sharing if the meaning encapsulated in the signs can be effectively communicated to all collaborators in the knowledge discovery process. Although the flexibility and power of visualization tools may well be augmented by networked information technology, the GeoVis community needs to particularly focus their attention on two of the recently formulated geovisualization research challenges, to take full advantage of Web-enabled visualization. These two research foci will be highlighted below.

## The need for developing task-centric visualization tools

The goal of any scientific visualization approach is to extract knowledge buried in data sets for the problem at hand, and facilitate decision making in problem solving tasks. Successful visualization tools are applications that provide users with the necessary visual support to accomplish problem-solving and decision-making goals. Therefore, interaction mechanisms embedded in the user interface should enable users to make the appropriate representation choices based on their information need. However, most of the current visualization approaches and tools are data-driven not problem-driven, thus lack support for effectively generating task-based knowledge representations.

Sharing graphic tools and visualization methods over a network requires that meaning embedded in them should be made explicit to facilitate unambiguous communication and collaboration amongst a heterogeneous user community. Missing transparent semantics and explicit mapping rules for the semiotic transformation are particularly problematic when moving towards distributed GeoVis services on the Web. While the current modularization trend will allow to more efficiently share individual visualization components over a network and potentially increase visualization flexibility, it bears also the danger of unnecessarily fragmenting the knowledge discovery process. For example, as with a visual component builder environment such as GeoVista Studio, users will need to know how and which components should be plugged together. If a layout is already provided, they will need to understand the logic behind the module connections to be able to adapt the visualization component to their needs. Increased process complexity due to fragmentation may even require a more comprehensive procedural knowledge for visualization. This effect will have to be addressed thoroughly, particularly if tools are made available to non-expert users in an uncontrolled, distributed environment. The success of web-enabled visualization tools is dependent on sound task-driven system design principles. A task-centric perspective is also necessary for identifying and applying appropriate usability evaluation procedures.

## The need for sound usability evaluation procedures

A pervasive theme among the current geovisualization research challenges (MacEachren and Kraak, 2001) is the difficulty to effectively evaluate visualization tools. Slocum et al. (2001) suggest that one of the key usability evaluation problems is the lack of clear task specifications (and sometimes user base) when dealing with exploratory visualization tools used for solving ill-structured problems (p. 63). The increased flexibility of Web-enabled visualization tools such as Descartes (Andrienko and Andrienko, 1998) and GeoVista Studio (Gahegan et al, 2000) for example, makes this research challenge even more prominent.

## Rationale for a task ontological approach to visualization

Considering the 'universality claim' of Internet tools, it begs the question if one can formulate domain independent visualization tasks that are generic enough to be effectively shared amongst a heterogeneous user community. If such tasks exist, can generic semiotic transformation principles be identified to map tasks onto the appropriate cognitive image schema, to effective graphic display types, as well as to graphic interaction mechanisms for efficient knowledge discovery?

An ontological approach seems appropriate to help address aforementioned research questions. Several definitions of ontology exist in the literature, depending on the academic background of the authors (e.g. philosophy, computer science, artificial intelligence, knowledge engineering etc.). The knowledge engineering community defines ontologies as "agreements about shared conceptualizations" (Gruber, in: Uschold and Gruninger, 1996). Ontologies can be further classified into domain ontologies and method (task) ontologies with mapping rules between them (Guarino, 1997). The goal of ontological engineering is to make conceptualizations of domain knowledge more transparent to a user community. By doing so knowledge sharing and knowledge reuse is facilitated. Knowledge reuse relates to adapting existing ontologies to new domains. Knowledge reuse simplifies and shortens the domain conceptualization process, thus makes communication more efficient.

An ontological approach to visualization seems particularly adequate for formalizing semantic and semiotic transformation components of web-enabled geovisualization. Three sets of related ontological issues can be identified: (1) The explicit structuring of the visualization domain (e.g. identification of a visualization taxonomy and its representational building blocks), (2) the identification of generic visualization goals and their respective visualization sub-tasks and (3) the identification of semiotic mapping rules between domain (including primitives) and its related tasks.

Summarizing, the research questions proposed for discussion at this workshop are as follows:

(1) can we create a geovisualization domain ontology?

(2) can we identify a visualization taxonomy of graphic primitives that match cognitive image schema?
(3) can we identify generic visualization goals and their related task primitives?
(4) can we identify mappings between the visualization domain ontology, the cognitive domain, the task ontology, and the visual primitives?

and on a more technical level:

(4) How can we take advantage of emerging machine readable formats (e.g. XML, GML and related standards) to encapsulate the semantics of the domain, the mappings between domain, tasks and visualization primitives for embedding visualization task ontologies in GeoVis software tools?

The next sections outlines briefly existing task analytical approaches the may be relevant starting points to tackle above research questions.

## Related Work

Task analytical methods are not new and there exists a wealth of literature in psychology, cognitive science, information science and human computer interaction that document this area of research. Task analysis has gained new importance in the human computer interaction community to evaluate the usability of graphical user interfaces and computer tools (Lewis, 1990). For example Activity Theory goes back to work of Russian psychologists in the 1920-ies, but has more recently been adapted for usability evaluation approaches in computer mediated environments (Leontev, 1978; Nardi, 1996). Activity theory is a formative evaluation approach and its goal is to hierarchically structure goal directed human actions on computer objects. Task analysis is typically a top-down, decompositional approach with the goal of identifying a hierarchical taxonomy of goals and sub-goals that are in turn composed of procedures, actions and objects (Sutcliffe, 1997).

Examples of top-down task analytical techniques exist specifically for knowledge-based visualization approaches, mainly developed by researchers in computer science and human computer interaction. For geovisualization particularly the works of Wehrend and Lewis (1990), Casner (1991), Knapp (1995), and Zhou and Feiner (1997, 1998) are noteworthy. Zhou and Feiner's research includes many explicit geographic data examples, although the researchers are outside of GIScience. Knapp's (1995) work explicitly addresses GeoVisualization within GISystems.

## Recent developments

Ontological approaches have also found their way into the GIScience community, due to the increasing efforts in GIScience to develop and deploy distributed GIServices. The University Consortium for Geographic Information Science (UCGIS) has recently identified *Ontological Foundations for Geographic Information Science* as an emerging theme in GIScience research (Mark, 2000). In geovisualization, Andrienko and Andrienko (1999) have begun to develop a task-based, semantic mapping approach linked to Bertin's semiotic variables system (Bertin, 1999).

## Closing Remarks

The time seems to be ripe for the cartographic community to embrace and consolidate ontological approaches in their research and tool development endeavors. Additional research efforts are needed to move from data-driven approaches to problem-centric geovisualization. As briefly sketched above, many components for a task-ontological approach to geovisualization are already in place, and these provide a solid basis for a task-centric development framework.

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