

The Science and Practice of Cartographic Interaction

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Objective: The research reported here contributes to cartographic theory on interactive mapping in two ways. A review of secondary sources from disciplines related to Cartography and GIS first was completed to understand the current *state of science* on cartographic interaction, revealing a guiding theoretical framework for a scientific approach to interactive cartography comprising six fundamental research questions. This background review was complemented by a set of semi-structured interviews with twenty-one power users of interactive maps or map-based systems, designed to capture the current *state of practice* on cartographic interaction across a number of application domains, generating insights into each of the six open questions on cartographic interaction.

Background: The current pace of innovation in interactive and web-based mapping technology is spectacular, and the possibility and pervasiveness of interactivity has transformed the way in which many maps are produced and consumed. Despite this remarkable pace—or perhaps because of it—there have been relatively few efforts to understand how interactive maps should be designed and used. This research directly contributes to this gap, treating the topic of cartographic interaction as a complement to cartographic representation, the traditional topic of inquiry within the field of Cartography. In this research context, *cartographic interaction* is described as the dialogue between a human and a map made through a computing device [1], emphasizing interactions that are inherently digital (Figure 1). Secondary sources from the related fields of Human-Computer Interaction, Information Visualization, and Visual Analytics were reviewed to understand the current state of science regarding cartographic interaction. This review revealed a framework comprising six mostly unanswered questions that a science of cartographic interaction must address (Table 1).

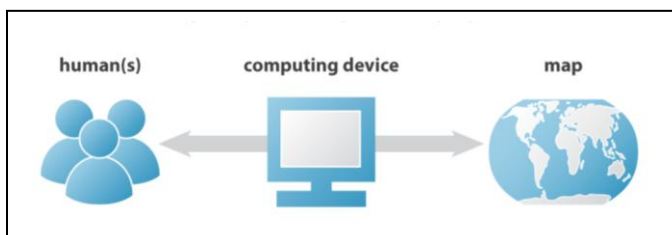


Figure 1: Cartographic Interaction

Question	Description
What?	the definition of cartographic interaction in the context of cartographic research
Why?	the purpose of cartographic interaction and the value it provides
When?	the times that cartographic interaction positively supports work or play, and should therefore be provided
Who?	the types of users provided cartographic interaction and the way in which differences across users impacts interactions
Where?	the computing device through which cartographic interaction is provided and the limitations/constraints imposed by the device
How?	the fundamental cartographic interaction primitives and the design of cartographic interfaces that implement them

Table 1: Six Fundamental Questions for a Science of Cartographic Interaction

Method: A set of semi-structured interviews were administered to generate initial insight into the six fundamental questions of a science of cartographic interaction [2]. Twenty-one participants were sampled across government, industry, and university sectors from one of seven application domains: emergency response/crisis management, environmental science/human-environment geography, epidemiology/public health, history/historical geography, intelligence analysis, news/new media, and resource management. All participants were characterized as power users of interactive maps and map-based systems, allowing for comparison between the current states of science and practice regarding cartographic interaction.

The interview protocol included *key* and *prompt* questions regarding each of the six fundamental questions in Table 1 [3]; a portion of the interview session was reserved for participant demonstration of the interactive maps and map-based systems used in support of their work. Following recommendations on *qualitative data analysis* (QDA) [4], interview recordings were transcribed and codified by two independent coders using a fourteen-part coding scheme based on the six fundamental questions in Table 1, resulting in reliability scores of 90.7% and 90.2% respectively. A comprehensive discussion of results following a synoptic style of reporting are provided in [1].

Result and Discussion: The interview study revealed numerous insights into the six fundamental questions of a science of cartographic interaction. Several of the generated insights showed congruency between science and practice,

including the general definition of cartographic interaction, the appropriateness of focusing solely on digital interactions, the conceptualization of cartographic interaction as a continuum from high to low rather than a binary of interactive versus non-interactive, the broad-based need for additional interactive links between visual and computation methods (i.e., visual analytics [5]), a notion that higher levels of cartographic interaction should be provided as user expertise increases, and the perception that the speed of the interaction is the most important system constraint (although no immediacy threshold must be met for the map to be 'interactive').

However, many of the insights revealed a direct disconnect between science and practice, such as the application of cartographic interaction primarily in support of analysis and presentation rather than exploration, an overall desire for a larger number of interactions with increased freedom, an emphasis on user expertise over user ability or user motivation, the relatively uncommon application of a user-centered approach to design and development of a cartographic interface, and an overall technological concern regarding bandwidth connectivity and security rather than processing power.

The cartographic interaction interviews also identified several topics not frequently considered in contemporary scientific work, such as the importance of live information to the quality of interaction, a request for developers to experiment with their cartographic interface designs instead of relying on convention, and the impact of institutional- and individual-level barriers to acquiring and using cartographic interaction. Finally, the cartographic interaction interview study also demonstrated several variations across practice, such as the overall disagreement among participants on what constitutes an 'interactive map' and the disagreement over the relative importance of expertise acquired through education versus experience.

Conclusion and Future Work: The combined reviews of science and practice provide a contemporary snapshot of what we know, and what we need to know, about cartographic interaction. Insights generated by the research are useful for identifying key gaps in our existing knowledge on interactive mapping and for structuring future research on cartographic interaction. Feedback acquired through the interview study currently is being used to answer the important *how?* question of cartographic interaction, which ultimately may lead to development of a taxonomy of cartographic interaction primitives—or the basic building blocks of a user's interaction strategy—a framework that would be tantamount to the role of the visual variables for cartographic representation.

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