Cartographic Challenges for Representing and Interacting with Big Data

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ABSTRACT
Emergent forms of spatial data provide massive, streaming sources that challenge existing paradigms for the design of maps and their corresponding interfaces. In this position paper we propose key research problems and problem contexts for effective cartographic representation and interaction with big data.

Author Keywords
Cartography; Research Challenges; Visual Analytics, Sensemaking, Big Data.

INTRODUCTION

Here we propose four key areas of inquiry in order to advance the state of the art in cartographic design to support visual analytics of big data. Building on previous research agendas in cartography [1-4], we focus on challenges that remain unmet, or are emerging as the result of new technologies, data sources, and modes of interaction. We begin by proposing key questions for the design of map interfaces to provide overviews of multimedia content. Next, we focus on the challenges associated with pattern recognition. This is followed by proposed aims for new map interfaces that help reveal and predict change. Finally, we highlight research opportunities for improving map-centric support for result synthesis and dissemination. For each section we offer example research questions, recognizing that there are many others that relate to each broad area of inquiry.

SENSEMAKING STARTS WITH AN OVERVIEW

The rapid proliferation of multimedia with spatial references, including text from social media sources and geotagged photos and videos makes it essential now to develop new map-oriented overviews that support the aggregation and simplification of these diverse original sources. Where in the past we have had the challenge of showing hundreds of socio-economic variables at once, we now also have millions of sources like microblog entries or snapshots to represent and explore using maps. These new forms of spatial media are particularly challenging because each observation (tweet, photo, or video, for example) may encapsulate a unique story that includes multiple relevant locations, times, and subjects.

- How can maps be used to provide an effective overview representation of media that reference multiple locations and times?

Previous efforts have attempted to show multimedia via overlay, aggregation, and using coordinated views. While we know each approach has limitations in terms of how many observations can be shown and understood, we do not have evidence to draw upon to clarify these limits so that we can begin to systematically work beyond or around them.

- What are the cognitive and usability limitations associated with analyzing spatial information using coordinated views and interactive maps?

REVEALING PATTERNS AND SEEKING EXAMPLES

Exploratory spatial data analysis typically seeks to reveal new patterns in complex datasets to prompt engagement and (hopefully) new discoveries. Pattern detection methods are abundant today, employing a wide range of quantitative techniques for uncovering clusters and outliers.

- How can we represent patterns on maps as distinct elements that are easily seen and interacted with across temporal and spatial scales?

The next generation of techniques and tools must also support users who wish to seek examples for what they already have in mind. This should build on work initiated as early as 1990 by cartographers who proposed a cognitive framework for how humans explore data on maps which relies on the recognition of patterns [5]. Pattern matching techniques are in development today for a wide range of domains and data types. We need to provide users with effective visualizations that show interesting spatiotemporal patterns, and we also must give them the ability to provide their own concept of a relevant pattern and have the system find examples of similar patterns in their data. To support the latter we must design and evaluate approaches that support the flexible expression of a user-desired multivariate spatio-temporal pattern. An expressed pattern

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could come in the form of a verbal or written description, or via a graphical depiction.

- How can users express and match a spatiotemporal pattern they have in mind using the map as an interface?

RECOGNIZING AND ANTICIPATING CHANGE

The dynamic behavior of people and their environments is now captured and streamed in real-time [6]. Although there are a range of representation techniques for showing change, maps suffer well-known issues associated with change blindness [7]. Yet it is more important than ever for users to recognize change when it is occurring in their datasets, and to be able to anticipate future changes through the use of predictive techniques.

- How can map-oriented interfaces be designed to prompt attention to important changes in dynamic data sources?

Solving problems associated with recognizing change on maps is an essential step toward tackling the larger issue of prompting change prediction using maps. Effective situational awareness requires knowledge of the key spatio-temporal elements, understanding their meaning, and making predictions about their status into the future [8]. Most dynamic mapping and visualization systems are only designed to support the first two priorities.

- What can maps do to help people predict changes in dynamic phenomena?

SYNTHESIZING RESULTS TO MAKE DECISIONS

Progress made toward the development of better map overview methods, pattern analysis techniques, and dynamic spatial visualizations will set the stage for research to improve methods and interfaces for synthesizing results [9]. Map users need the ability to add meaning to individual findings in mapping interfaces, to ensure that provenance is maintained, and to develop sharable stories to support decisions.

- How can maps serve as interfaces to support long-term analytical engagement with complex spatio-temporal problems?

Decision making is almost always a collaborative task, and yet we currently have few guidelines to follow for designing effective maps and map-based interfaces to support collaborative decision making. Much of the research on this area was completed in the early age of web-mapping, and does not account for mobile devices, cloud computing, augmented reality, and other significant technological and methodological transformations.

- How can we support collaborative decision making using the map as a mutual interface?

THE ULTIMATE GOAL: MAKING MAPS THAT MATTER

We believe that answering the key research aims we have presented here will help advance the state of the art of mapmaking to support visual analytics of big data. However, these general aims must also be grounded in problem contexts that are relevant and have the strong potential to make a sizable impact on humanity. For this reason, we suggest that the next research agenda for cartography should propose grand challenges for investigation that are explicitly linked to major global issues such as food/water security, disease dynamics, renewable energy systems, and disaster response. Framing these challenges within scenarios, as done in the recent past by cartographers to explain key challenges in spatio-temporal analytics [6], is one way in which research and societal goals can be integrated and expressed in an actionable form.

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