Synthesizing Results in Geovisualization

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Abstract

The transition from geovisual analysis to presentation involves an intermediate stage called synthesis. In this stage of analysis, analysts collect and combine results to generalize their discoveries. Despite its presence in most theories of geovisualization design, synthesis is a topic that has remained largely unexplored in geovisualization research. This paper examines the use of synthesis in geovisualization theory and the definitions that have been used to describe it as a stage of analytical work. Several potential interface metaphors are proposed for supporting synthesis. These designs are inspired by tools and techniques that are commonly used by analysts outside of current geovisualization environments. Finally, a set of key research questions are suggested for future work to understand and characterize geovisual synthesis.

Introduction

Dynamic, multi-representational geovisualization tools are enabling geographers and others to explore and analyze multivariate spatial data to answer complicated geographic questions. The theoretical approach that has spurred geovisualization development describes geovisual analysis as a process that begins with data exploration, continues to analysis, transitions into synthesis of results, and finishes with presentation of findings. This approach calls for specialized tools to support each stage that allow users to work across stages as desired.

This paper focuses on research challenges related to understanding and characterizing the process of geographical results synthesis, with the aim of applying that understanding to the design of synthesis support tools. Geovisualization tools currently rely on simple methods to capture maps and graphics to facilitate synthesis – defined broadly as organization and generalization of findings. Users typically synthesize discoveries using external tools like word processing or presentation software, a practice that significantly limits their ability to reach back to previous analyses to continue work, to collaborate with others, or to compare incoming information with past discoveries.

The real-world problem that synthesis research responds to is illustrated through the following prototypical scenario in which geovisual synthesis methods are needed:

Samantha, an infectious disease epidemiologist at the World Health Organization, uses a geovisualization toolkit to explore the geographic and temporal dimensions of mortality associated with avian influenza in Southeast Asia. The toolkit she uses offers a choropleth map, a scatter plot, a temporal graph, and a parallel coordinate plot all showing a common set of disease outcomes (mortality and incidence rates) and indicators (socioeconomic measures, access to screening, etc…) that are regularly updated and linked to statistical models of avian influenza. Every week she receives new datasets and she must make regular reports to her supervisor about what she has found with each update. The current state of the art in geovisualization tools allows her to save screen captures during data exploration, and to save data loading configurations as projects for later use. To build her report, Samantha must rely on generic office productivity software to organize the screen captures together with her notes, relevant email messages from other expert colleagues, relevant RSS newsfeeds from PubMed detailing the latest research, and other relevant RSS feeds that may indicate how the data she is exploring relates to life on the ground in her study area.

Now, Samantha has been asked to recall several of her recent analyses to help create a report on a new flu outbreak in Taiwan. Additionally, Samantha has been given a new version of the geovisualization toolkit that has been extended to support additional data resources – notes, news articles, photographs, and audio/video clips.

This additional complexity makes it more difficult for Samantha to synthesize information in a separate software environment. Samantha will need new tools to help her marshal the information at hand within the geovisualization toolkit itself. Allowing synthesis to take place inside the analytical software provides the opportunity to preserve interactive connections to real data and particular states of the geovisualization. This would make the task Samantha is facing (to recall prior work and develop a summary) far more efficient – an important goal considering the time-critical task she is trying to accomplish.

Background

The theory driving geovisualization development connects geovisualization tools to a research process proposed by DiBiase (1990), and elaborated upon later by MacEachren (1994; 1995). DiBiase describes a research process that begins in the private realm of the individual analyst exploring data, developing hypotheses, and iteratively carrying out analysis tasks to assess and refine the hypotheses, to the public realm of synthesizing results and supporting evidence, and presenting those results along with supporting arguments (Figure 1). In this process the analyst switches from an initial focus on visual thinking to a focus on visual communication. Contemporary geovisualization tools provide strong support for analytical tasks that occupy the private realm – the result of much emphasis in early geovisualization research on supporting that realm. Based on the theoretical emphasis on synthesis as a separable stage of work with geovisualization tools, and the lack of attention to this stage so far, there is a need to develop new tools to support synthesis – the transitional step from the private realm into the public realm. DiBiase describes this stage as, "…synthesis or generalization of findings."

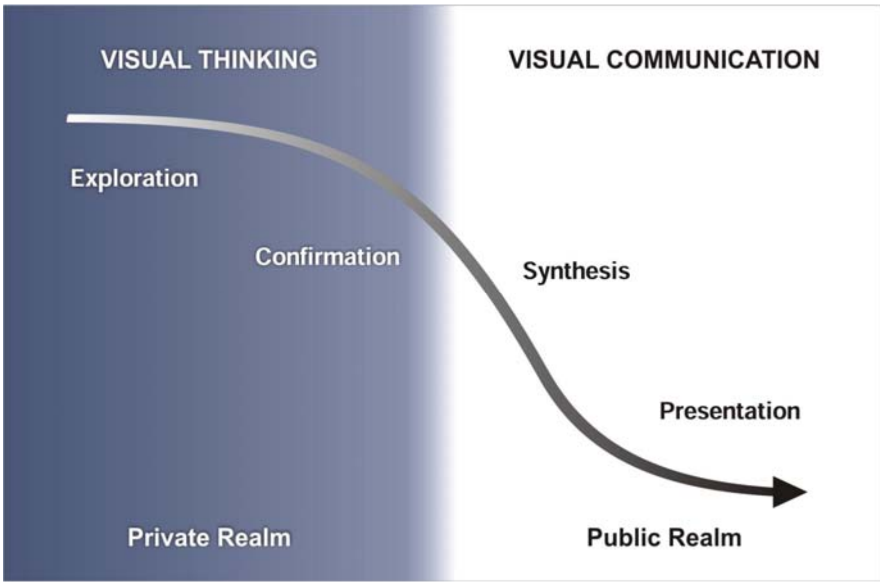

Figure 1: The geovisualization research process as conceived by DiBiase (1990).

When viewed from the (**cartography)**[3] framework of cartographic visualization (Figure 2), (MacEachren 1995) synthesis research should aim to design strategies for composing and generalizing exploratory and analytical results, as analytical tasks shift from knowledge construction to information sharing. These strategies will support the formative stages of condensing what has been discovered using geographic visualization, as analysts change goals from revealing unknowns to presenting knowns (e.g., from uncovering unexpected patterns to interpreting and explaining those patterns).

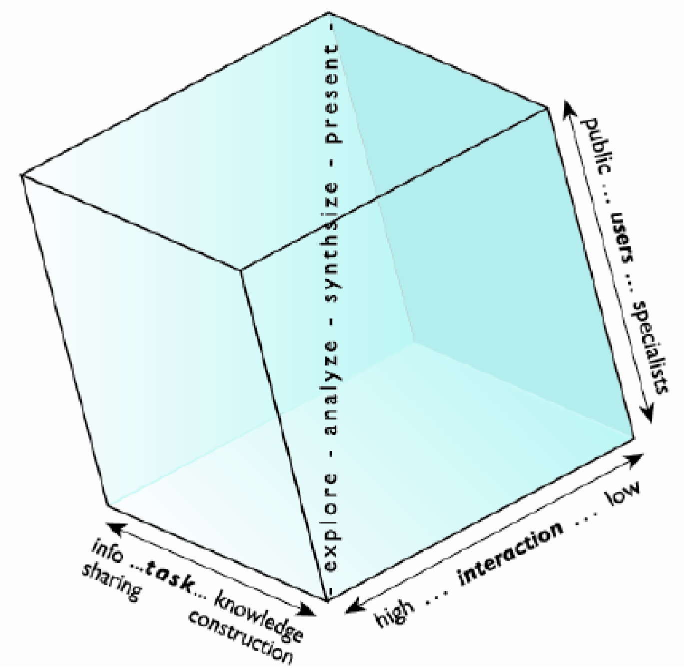

Figure 2: The (cartography)[3] diagram depicting the basic functions of geovisualization proposed by MacEachren (1995, 2004).

A commonly referenced theoretical framework in GIScience by Gahegan and Brodaric (2002) describes synthesis in somewhat different manner. In their framework of geoscientific discovery, synthesis involves creating taxonomies from data – often in the form of classification schemes. As an example of synthesis, Gahegan and Brodaric describe how analysts could visually explore and identify suitable classification schemes with landcover data – making synthesis an activity that occurs quite early in the scientific process.

In more generic terms, the Oxford English Dictionary assigns multiple meanings to the word (Simpson and Weiner 1989). As related to its use in logic, synthesis refers to the transition from causes to effects. In its use in chemistry and physics, synthesis is the process of creating a compound from individual constituents. The philosopher Immanuel Kant described synthesis as the cognitive understanding one achieves from combining perceptual inputs and prior experiences. Finally, the popular definition for synthesis considers it the, "…putting together of parts or elements so as to make up a complex whole."

Because the definition for synthesis varies in the literature, it is important that we define it clearly for research. The current relevant focus is on the result generalization and organization stage of the scientific process – a (thus far) largely unexplored topic in geovisualization research. Therefore, the term “synthesis” in the sense initially articulated by DiBiase (1990) and MacEachren (1995; 2004) seems appropriate, in contrast to the way synthesis has been described by Gahegan and Brodaric (2002). The proposed definition considers synthesis *the stage of an analytic process in which analysts organize and combine individual analytical results into coherent groups that are used to assign meaning and/or encapsulate complex ideas*.

Interfaces for Synthesis Tools

Supporting synthesis in geovisualization will require specialized tools for collecting and annotating results. Interfaces to synthesis support tools could take advantage of a wide array of interface metaphors. This section proposes a number of potential synthesis support interface designs (Figure 3). These designs are inspired by common analog and digital methods of organizing information. Substantial user-centered design and evaluation is necessary in order to determine which methods will best support analytical work.

The designs presented here make the assumption that analytical results arrive into the synthesis environment in the form of individual “chunks.” In the interface mockups shown here, these chunks are represented by screenshots. Original research is needed to identify effective visual representations for analytical results for use in synthesis.

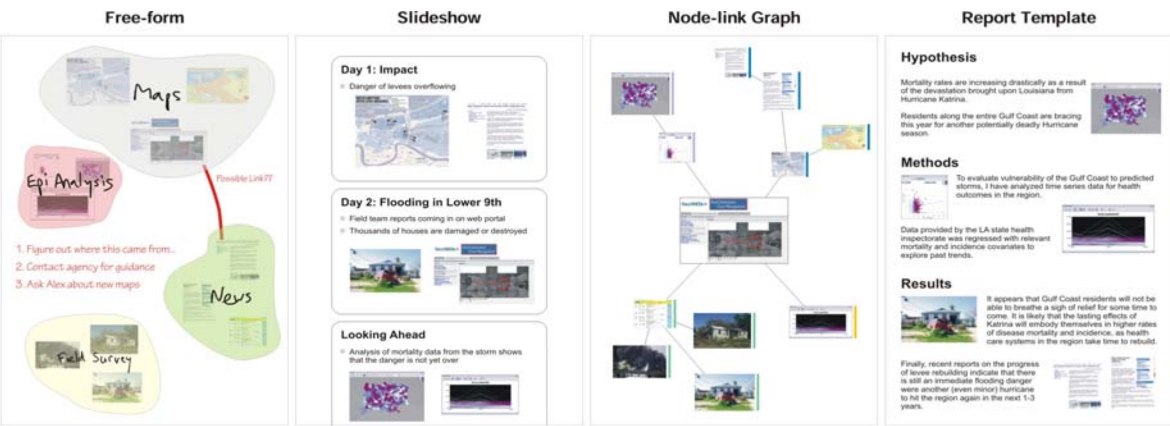

Figure 3: Potential interface metaphors for geovisual synthesis support tools.

Free-form

The free-form interface metaphor is inspired by analog and digital whiteboards that are commonly used in office and educational settings. This synthesis interface would allow users to assign arbitrary written annotations to chunks, as well as ad hoc grouping and linkages. The free-form interface may encourage users to be creative when synthesizing their results, as it imposes few constraints on how information is grouped or annotated.

Slideshow

Analysts currently use PowerPoint and other slideshow tools to present results at meetings and conferences. For this reason, many users are comfortable with this mechanism for gathering multimedia, and therefore this interface metaphor is proposed as a possible method for geovisual synthesis. As a synthesis tool, the slideshow metaphor would potentially influence users to organize results chronologically, and showing linkages across items that fall into multiple groupings would be difficult. However, the slideshow interface would have the advantage of easing the transition from synthesis to presentation.

Node-link Graph

The node-link graph interface is commonly used now for knowledge representation in the form of concept maps and hierarchies. Tools like ConceptVISTA (MacEachren et al. 2004) and MindMapper (SimTech 2007) enable users to couple ideas (nodes) with relationships (links). Adapting this for geovisual synthesis would allow users to link results together in a similar manner. While this method may benefit from being relatively familiar to many users, it may be detrimental to require users to link objects that may not necessarily be related (or relationships may be unknown).

Report Template

Analysts often report results in standard or semi-standardized formats. Those who work at government agencies do so more commonly than those who work in the academic realm, though academics usually present results using a structure inspired in some way by the scientific method. The report template interface metaphor for synthesis would allow users to group and annotate analytical results under previously specified headings to match a standard reporting format. While this structure would ease the transition into presentation, it may hinder users who have tasks whose structures are not already well-understood or predictable.

Other Metaphors

Beyond these basic interface metaphors, we may wish to turn to the more idiosyncratic habits of users, exploring how their hobbies or interests outside of work reveal strategies for how they organize and synthesize information. A musician may be comfortable organizing analytical chunks in virtual “tracks” in the way audio-editing software functions. A photographer might compose chunks in a collage, modifying color and depth-of-field accordingly.

Research Challenges

To characterize, understand, and design for synthesis support in geovisualization, the following initial research challenges are proposed for future research:

To characterize synthesis as a stage of geovisual analysis

While current geovisualization theory recognizes synthesis as a critical stage of geovisual analysis, research has not yet been completed to describe what analysts do during synthesis. The basic tasks that encompass synthesis are not adequately described. Particular attention should be paid to the role visual representations take in synthesis as it is currently done. This will ensure that we may choose wisely when creating visualization methods to support synthesis.

To develop visual representations and interfaces that support synthesis

To support synthesis in geovisualization we must design and evaluate visual representations and interfaces that will best match the needs of synthesis. Decisions must be made regarding the ways that analytical results are represented. This is a substantial challenge because many results will be the product of prolonged interactive work with dynamic tools. The interfaces in which analysts collect and organize these results must also be carefully designed to ensure their suitability to the tasks of geovisual synthesis – applying appropriate organizational metaphors and providing the tools necessary to enhance and enable analytical work.

To explore the transitions between synthesis and other analytical process stages

The theory that currently describes synthesis places it as a transitional stage between analysis and presentation. Following this lead, we should explore the transitions at both sides, to characterize how users take results out from analysis into synthesis, and then after synthesis, how they move synthesized results forward into presentation. This knowledge will help us design analytical outputs that are appropriate for synthesis. It will also aid the creation of synthesis export tools to package results into useful visual products for dissemination.

To identify how geovisual synthesis feeds into group work and collaboration

A key advantage of supporting synthesis with dedicated, integrated tools is that it will enhance analysts' ability to reach-back to prior work when necessary. It is also important to consider how results that have been synthesized can be taken advantage of in collaborative situations. Because it is likely that users will have creative and individualized habits for annotating and organizing their results, it will be necessary to develop strategies for comparing differently-structured synthesis collections. Additionally, we must consider that analytical results themselves may be the product of collaborative work, and therefore methods are needed for ensuring that data provenance is integrated and visually represented in the synthesis environment.

Conclusion

Understanding synthesis and designing tools to support it is a near-term priority because there are geovisualization tool development efforts underway (Thomas and Cook 2005) that are focused on incorporating/enabling exploration and analysis through space and time using traditional table-based digital databases that can coordinate in novel ways with diverse data types like notes, photos, videos, and news articles. The problem-solving goals of these projects are ambitious, and the problem domains they support are of high-importance (disease epidemiology, vulnerability to natural disasters, threat assessment, etc.). Analysts will need to rapidly explore and analyze massive databases, all the while capturing and synthesizing their results in ways that will be easy to return to at a later time, in a format that is amenable to collaboration with others. It will be essential for analysts to be able to explain precisely how they arrived at a conclusion, and to re-use portions of prior work when similar situations arise and they need to conduct comparative analyses.

A research project is currently underway to characterize and design for geovisual synthesis with infectious disease analysts at Pacific Northwest National Laboratory (PNL) and the Center for Infectious Disease Dynamics (CIDD) at Penn State. The goals of this project are to develop an understanding of how analysts currently synthesize geovisual results and to apply that knowledge toward the development of multiple synthesis support interface designs. These designs will be implemented as interactive prototypes and subjected to evaluation to determine which methods show the most promise for full implementation into geovisualization environments.

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