Synthesis in Geovisualization to Support Epidemiology

Dissertation Proposal by:

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Introduction

Dynamic, multi-representational geovisualization tools are enabling geographers 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 in a non-linear manner. The research I propose focuses on understanding and characterizing the process of result synthesis, developing an approach to apply that understanding to design of synthesis support tools, implementing prototype tools, and testing those prototypes. Geovisualization tools now rely on simple methods to capture maps and graphics to facilitate result synthesis. Users typically synthesize discoveries using other tools, typically with word processing or presentation software, a practice that significantly limits their ability to reach back to previous analyses to continue work, collaborate with others, or compare incoming information to past discoveries.

New geovisualization tools in development at research labs and GIS software companies will feature increasingly diverse sets of visual representations and integrate new data types such as text, pictures, sound, and video. This evolution means that geovisual results will become more powerful as well as more complicated. To address the increasing complexity of analytic results produced by geovisualization tools, I will apply results of field and lab study of the synthesis process to develop and assess a design framework for synthesis-support tools. I will do so with the goal of shaping the development of new synthesis tools that are fully-integrated into the geovisualization itself. Integrated synthesis tools make sense because they can preserve direct links to data and representations used to generate geovisual results, improving users' ability to return to and reuse prior analytical results.

My project focuses on synthesis characterization and design for epidemiologists at the World Health Organization (WHO). Epidemiologists at the WHO Epidemic and Pandemic Alert and Response (EPR) division are one group of experts who are currently supporting the development of geovisualization tools. Users at EPR apply GIS and geovisualization tools to monitor the spread of avian influenza.

The specific research problem can be further understood through the following scenario:

Samantha, a communicable disease epidemiologist at the WHO, uses a geovisualization toolkit to explore the geographic and temporal dimensions of the mortality associated with avian influenza in Southeast Asia. The toolkit she uses offers a choropleth map, a scatter plot, a time-

oriented 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. Every week she receives new datasets and she must make regular reports to her supervisor about what she has found with each new dataset. 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 feeds from PubMed detailing the latest research, and relevant RSS feeds of other news articles that may indicate how the data she is exploring reflects life on the ground in her study area.

Now, imagine if Samantha was asked to recall several of her recent analyses to help create a report to assess a new flu outbreak in Taiwan. Additionally, Samantha is now required to use 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 all the more difficult for Samantha to synthesize information in a separate software environment. What Samantha needs is a set of 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 back 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 task she is trying to accomplish.

Understanding synthesis and designing for 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 interesting ways with diverse data types like notes, photos, and 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.

Synthesis in Geovisualization

Geovisualization tools are designed to support highly-interactive visual exploration and analysis of geospatial data. They enable analysts to look at geospatial data from multiple perspectives and explore complex data relationships that may exist over a wide array of spatial and temporal scales. Geovisualization is differentiated from standard GIS because it is focused on exploratory visual analysis, rather than the pre-defined mapping and analysis processes that GIS systems are designed to facilitate. Geovisualization research focuses particular attention on integrating cartographic approaches with representations and analysis methods from scientific and information visualization, exploratory data analysis, image analysis, and GIScience (Kraak and MacEachren 2005; Dykes et al. 2005).

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 evidence to support the results and presenting those results along with supporting arguments (Figure 1). In this process the scientist switches from an initial focus on visual thinking to a focus on visual communications. 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, the research I propose focuses on design methods to support synthesis – the transitional step from the private realm into the public realm. DiBiase describes this stage as, "…synthesis or generalization of findings."

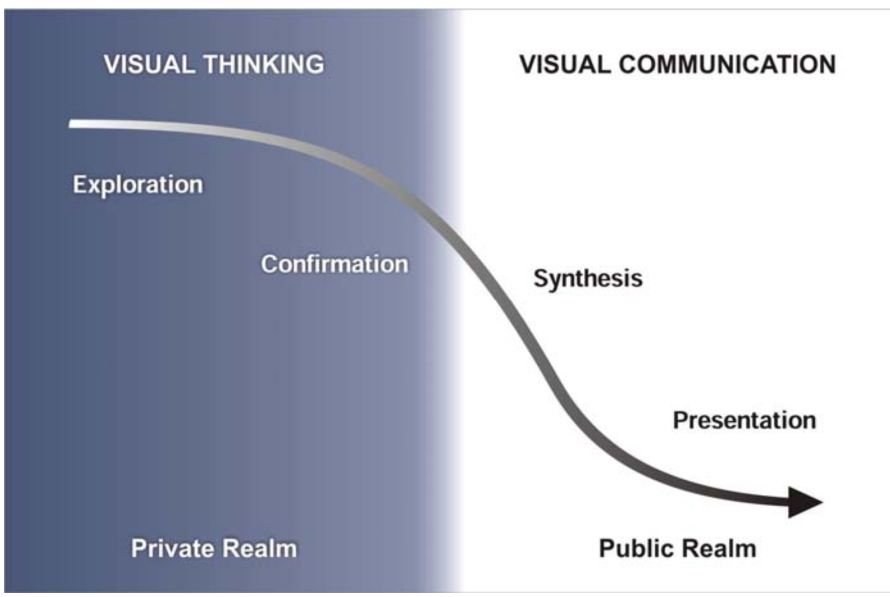

Figure 1: The geovisualization research process (often called the "swoopy" diagram) as conceived by DiBiase (1990).

When viewed from the (**cartography)**[3] framework of cartographic visualization (Figure 2), (MacEachren 1995) this research is positioned to design strategies for composing and generalizing exploratory and analytical results, as the task shifts from knowledge construction over 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).

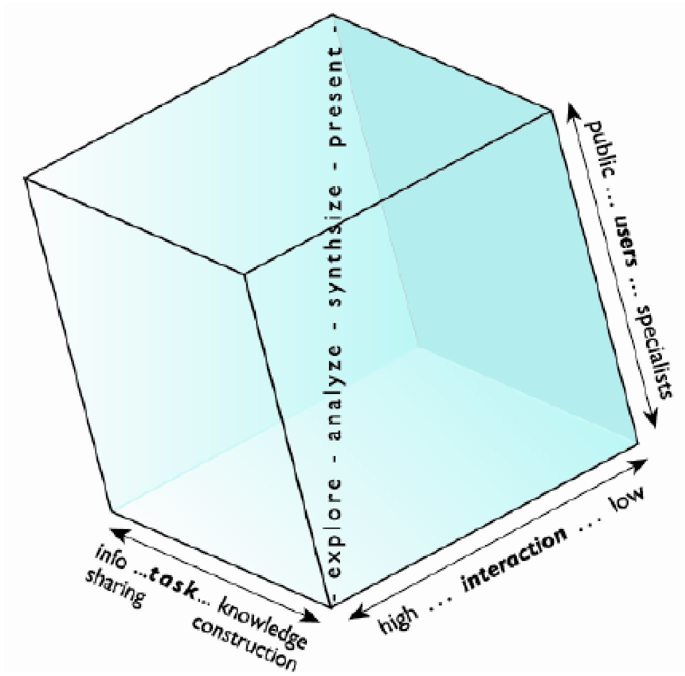

Figure 2: The (cartography)[3] diagram depicting the basic functions of geovisualization proposed by MacEachren (1995, 2004).

A commonly referenced theoretical framework in GIScience by Gahegan and Brodaric (2002) describes synthesis in somewhat different manner than my proposed focus. 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.

Because the definition for synthesis varies in the literature, it is important that I define it clearly for my proposed research. My focus is on the result generalization and organization stage of the scientific process – a (thus far) largely unexplored topic in geovisualization research. Therefore, I use the term "synthesis" in the sense initially articulated by DiBiase (1990) and MacEachren (1995; 2004), not in the sense it has been used by Gahegan and Brodaric (2002). The proposed research treats synthesis as *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*.

Design and Evaluation of Geovisualization Tools

There are many recent examples of design and evaluation efforts to create and refine geovisualization tools. These efforts span a wide array of application domains, including epidemiology (Edsall 2003; Robinson et al. 2005; Koua et al. 2006), decision support (Aggett and McColl 2006; Andrienko et al. 2002; Haklay and Tobon 2003), and crisis management (Schafer et al. 2005; MacEachren et al. 2005). In terms of methodology, these studies typically make use of iterative design techniques that incorporate multiple methods. They share a sharp focus on incorporating the evaluated needs of end-users as primary inputs to design.

Many design methodologies employed in contemporary geovisualization research are rooted in traditions from human-computer interaction (HCI) studies, an offshoot of computer science. Jakob Nielsen's *Usability Engineering* (Nielsen 1993) outlines the "standard" set of HCI methods for refining and evaluating software interfaces. Nielsen's work, which is focused on producing quantifiable improvements in utility and efficiency has provided the foundation for a vast number of contemporary software evaluation efforts. Shneiderman and Plaisant (2005) offer a thorough review of knowledge elicitation and usability techniques which are described in terms of visualization design efforts they have undertaken.

HCI is not the only domain that has provided design and evaluation methodologies to geovisualization development efforts. Cognitive science approaches are also frequently used to evaluate how people work with tools. Ware (2004) outlines a comprehensive approach to visualization design that focuses on basic visual design principles founded upon evidence from cognitive (largely perceptual) studies. McNeese (2004) describes a tool design method built around cognitive systems engineering called the living laboratory framework. The living lab approach contrasts with Ware's by focusing instead on studying the situated actions of users as they attempt to solve realistic problems.

The cartographic literature provides a broad set of methodologies for studying how people use maps. These studies can be broken down into three major categories: map-design research, map-psychology research, and map-education research (Montello 2002). Map-design research is the most relevant to the research I propose, as it examines use and usability. Studies of map-design have often focused on individual visual elements and how they quantitatively influence map use. In recent years, qualitative map-design studies have become common for projects focused on how maps are used in real world situations (Suchan and Brewer 2000). Qualitative methods are often used in combination to triangulate results – a practice described by Buttenfield (1999).

Evaluation efforts for geovisualization design have often followed the quantifiable utility and efficiency goals outlined by Nielsen (1993). As the tasks envisioned for visualization tools have increased in complexity, so have evaluation efforts. Recently, there has been a detectable shift away from one-off evaluations of task time and performance to larger efforts that are iterative and longitudinal in nature (Shneiderman and Plaisant 2006). Shneiderman and Plaisant propose a set of twelve guidelines for conducting multi-dimensional, in-depth, long-term case studies (MILC) of information visualizations. These guidelines connect principles from ethnography to the context of design and evaluation for visualization software. In geovisualization research, there are recent design efforts that could be considered MILCs (Slocum et al. 2003; Griffin 2003; Robinson Submitted). The research I propose builds upon prior work to design and evaluate information visualizations and geographic visualizations. My research plan comprises a MILC designed to study synthesis in epidemiology.

Research Questions

To characterize and design for synthesis of geovisual results, I propose a research project to answer the following questions based on a longitudinal mixed-method study of analysts from the domain of disease epidemiology.

1. What do analysts currently do to synthesize the results of geovisual exploration?

2. What do analysts wish they could do to better synthesize the results of geovisual exploration?

3. How do analysts synthesize results in a simulated real-world situation, and what does this tell us about how synthesis is conceptualized?

4. What interface metaphors emerge from analysts' current, projected, and demonstrated synthesizing behavior?

The general goal here is to use evidence from knowledge elicitation activities to define general synthesis strategies and specific tool design guidelines that can be used to integrate synthesis tools with future geovisualizations.

Examples of Possible Synthesis Methods

While the proposed research will characterize analysts current and projected needs to design synthesis tools, I have developed an initial conceptualization about the forms that synthesis support might take. These conceptualizations are derived from previous formal and information work with a number of information analysts in several domains ranging from epidemiology, through intelligence analysis, to crisis response. The mock-up in Figure 3 shows several of these ideas, each based on the notion that users will need to combine results together into coherent groups that are assigned meaning. I present these ideas as examples to show how synthesis methods might *generally* work with geovisual results. My work will focus on how synthesis methods like these (but not necessarily identical in terms of interface metaphor or functionality) could work for WHO epidemiologists.

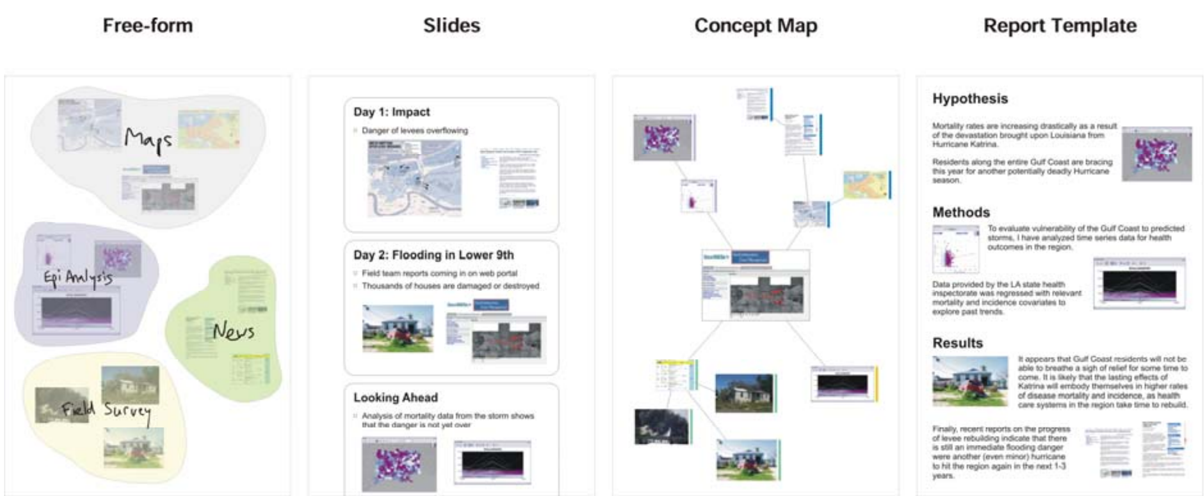

Figure 3: Possible general designs for geovisual synthesis tools. From left, the free form metaphor would function like an interactive whiteboard, the slide metaphor would mirror basic functions from common presentation software, the concept map would allow results to be organized in temporal or conceptual orderings, and the report template may work for analysts who commonly need to provide results in a standard structure.

Methodology

This project uses a mixed-method qualitative methodology for characterizing synthesis activities and designing synthesis tools to support geovisual analysis. Mixed-method qualitative investigations have been used in the past to evaluate geovisualization tools (Robinson et al. 2005; Slocum et al. 2003; Andrienko et al. 2002) as well as information visualization tools (Seo and Shneiderman 2006; Saraiya et al. 2004). They are especially useful for formative design efforts. In general, design efforts can be classified into two large groups – those that are formative in nature and those that are summative. Buttenfield (1999) describes these two types of evaluation in terms of an effort to design a geospatial digital library. An early discussion about these types of evaluation efforts comes from the HCI community (Hix and Harston 1993). Formative design involves the development of new design ideas through knowledge elicitation activities, usually with a small group of end-users. Summative evaluations are designed to compare tools against each other to assess how well they work, often with the goal of obtaining generalizable results. The research I propose here is a formative design effort, as I seek to understand synthesis and develop our understanding of it into design guidelines for new synthesis tools.

Scenario-based design appears as part of the methodology outlined in the following sections. Scenarios as used in the design and evaluation of software tools are envisioned depictions of user needs and activities, usually embedded in a narrative (Carroll 1994). They are useful for design and evaluation to explore current and/or envisioned situations – and they are usually implicit in design efforts that rely on other design/usability methods. Scenarios can be based on observing analysts at work and/or on critical incidents identified in debriefing sessions. The particular edge that scenario-based design lends to my work is that it enables a holistic evaluation of tools as they are situated in realistic work, with realistic constraints, and in a way that encourages users to draw upon their previous experience.

This study focuses on avian influenza epidemiology as the target domain. Epidemiologists at the WHO EPR are already making use of geovisualization tools, and there are active research efforts dedicated toward expanding/enhancing these tools to support time-critical avian flu surveillance efforts. I am currently in the process of securing formal cooperation with WHO leadership to conduct research with epidemiologists there.

I plan to conceptualize, design, and evaluate synthesis strategies through a multi-phased research program. In the first phase, I will focus on studying systematically how analysts currently synthesize, how they envision doing so in the future, and how they conceptualize the problem of organizing and generalizing geovisual results. In the second phase I will develop working prototype tools based on analysts' reported behavior as well as what I have observed of them in the structured synthesis exercise from phase one. Following this, the third phase will involve having analysts evaluate the synthesis tool prototypes. As a final step, I will distill the results from the initial and secondary evaluation studies in order to refine the synthesis tool designs, to identify common synthesis strategies, and to develop a set of design guidelines for future tool development.

Phase One

Purpose of this Phase: To characterize how analysts conduct geovisual synthesis

In this Phase I will conduct multiple knowledge elicitation activities for analysts at WHO EPR who are likely to use geovisualization tools. The number of analysts I recruit for in-depth knowledge elicitation activities will be no more than ten. Because I will rely on a longitudinal study with multiple iterations with each user, I must limit the problem to a reasonable sample size that is manageable for my iterative study. Prior formative evaluation work with information visualization tools has suggested that efforts like the one I propose are often accomplished with a small number of participants over a long-term case study (Shneiderman and Plaisant 2006). To support the design and evaluation of a geovisualization tool for visualizing uncertainty in the future global water balance, Slocum et al. had six representative experts use and evaluate their software (Slocum et al. 2003). I will follow these examples and focus my attention on acquiring in-depth knowledge from a small and carefully chosen user base.

Throughout the activities of this phase, I will shadow the day-to-day work by the epidemiologists to observe how they synthesize analytical results for use in meetings, presentations, and publications. Observation is a structured and systematic technique that focuses on evaluating people in terms of the processes in which they participate and the context that surrounds them (Silverman 2001). This methodology typically involves collecting fieldnotes as a primary source of data. Over a period of nine weeks, I will have the opportunity to observe analysts as they work with and synthesize their data, paying particular attention to especially successful or unsuccessful synthesis efforts. Fieldnotes will be augmented with photos, audio, and copies of relevant graphics (for example, a set of maps that were used as examples during a meeting) when appropriate. These will be immediately useful with scenario development for follow-up activities as well as inputs to the design of prototype tools that will occur in Phase Two.

The first portion of this Phase focuses on understanding and characterizing how analysts currently synthesize their analytical results. To achieve this goal I will conduct one hour long interviews with each epidemiologist, asking them to identify the kinds of synthesis strategies they use when they are putting together analytical results. These questions will include software or tool specific questions as well as prompts to discuss how these tools succeed and/or fail under certain circumstances (i.e. critical incidents). Critical incidents are steps during work that run into serious problems and threaten the ability of users to accomplish their work successfully. These incidents were originally described by Flanagan (1954) and subsequently they have been used in design and evaluation efforts by HCI practitioners (Nemeth 2004). While the traditional definition of a critical incident is a negative event – one that impairs a user's ability to accomplish a task, it is also possible to look for critical incidents in terms of moments when tools were particularly helpful toward achieving a complex goal. Shneiderman (2000) describes this kind of event as a moment of evolutionary creativity, examples of which include a doctor diagnosing a disease, an editor assembling an article, or a lawyer finishing a brief.

In the second portion of Phase One I will ask epidemiologists to participate in an exercise in which they will synthesize physical artifacts that have been created to simulate real results. These artifacts will include maps, news clippings, notes, and graphs. I will present analysts with a scenario in which the artifacts have been generated, and ask them to synthesize these artifacts on a large, blank sheet of paper with the goal of creating coherent groups of artifacts that reflect meaning and encapsulate ideas. During the exercise, analysts will be asked to verbally describe what they are doing. This is a common HCI knowledge elicitation technique called verbal protocol analysis (Ericsson and Simon 1993). I will categorize the synthesis results based on strategies described by Straker (1997) for using post-it notes to conduct problem-solving exercises. Straker describes a wide array of strategies for organizing "chunks" using post-it notes. I expect that some of Straker's strategies may be useful interface metaphors for organizing geovisual results; hence my interest in exploring how the structures of analysts' results from the physical artifact synthesis activity match with Straker's categories.

The third portion of Phase One will focus on the goal of eliciting ideas for new software tools. I will administer a survey in which epidemiologists can rank order and comment on a number of potential features of a new synthesis tool. Then I will ask them to sketch (if possible) their ideas for synthesis tools while they discuss how these tools might work.

Phase Two

Purpose of this Phase: To develop prototype designs based on Phase One results.

Phase Two of the proposed research will focus on creating working prototypes that demonstrate several different geovisual synthesis methods. Each of the activities from Phase One will offer results to suggest interface metaphors and essential functions for new software tools. Observations and transcripts will be coded and searched to identify possible interface metaphors (e.g. a whiteboard) and necessary functionality (e.g. "I need to be able to group items together in loose categories."). The suggested interface metaphors will guide the creation of several basic design options (e.g. whiteboard, concept map, slide organizer, etc…) to which a common set of the most mentioned essential functionality will be attached.

The prototypes I create will make use of a pre-determined set of geovisual results much like the one used during the second portion of Phase One when analysts work with real objects and a blank sheet of paper. Data chunks will be created to simulate previously-discovered results, including captures from maps, graphs, notes, and articles. These chunks will be manipulable in different ways depending on the interface metaphor that is used, and which essential functionality is appropriate within that metaphor.

To build design prototypes I will use Adobe Flex, an integrated development environment that allows users to build highly-interactive web-delivered applications that look and feel like Adobe Flash – a popular computer animation platform known for its ability to support the creation of usable and aesthetically pleasing interactive interfaces.

To ensure that technical errors do not corrupt the follow-on evaluations of the prototypes I will conduct a brief, semi-formal usability assessment with GIScience graduate students. This usability assessment will focus on weeding out bugs and other interface problems that might hinder the capture of useful data from the WHO epidemiologists. Ten graduate students will be recruited to perform a small set of example tasks with the prototype tools. They will then be asked to discuss problems they encountered and will fill out a brief survey to evaluate basic usability and user satisfaction.

Phase Three
Purpose of this Phase: To evaluate prototype designs with epidemiologists.

In Phase Three I will return to the epidemiologists I worked with during Phase One. This portion of the research methodology focuses on evaluating the prototypes created in Phase Two in terms of their basic design and usability.

Prototype evaluation will take a form similar to the paper-based synthesis activity described in Phase One. Users will work with the prototypes simulating a realistic scenario to synthesize results. For this stage I will recruit additional epidemiologists, so that there are at least fifteen in the test group. Guidance from the HCI literature suggests anywhere from five to twenty users are "enough" for usability testing (Virzi 1992; Landauer and Nielsen 1993; Faulkner 2003). A recent comparative study of different group sizes by Faulkner (2003) shows that very reliable results (at least 90% of usability problems are found) are obtainable with fifteen subjects.

As mentioned in the Phase Two description, the prototype designs will provide users the ability to manipulate and organize a preset variety of analysis results. I will develop different preset data scenarios to match the number of prototypes I build. Two randomized sequences will be assigned to each analyst, one for the data scenarios and one for the prototypes. By conducting the evaluation this way I will reduce order effects which could bias my results. While users work through each scenario/prototype combination, they will be asked to provide a verbal protocol to be recorded along with a video capture of their computer screen.

Following prototype evaluation, I will ask users to complete a brief usability survey. The survey will be based on the SUS metric (Brooke 1996) for evaluating software tools. The verbal protocols I gather will be coded generally according to each interface metaphor, their essential functionality, and basic usability. The precise scheme will draw upon examples from other geovisualization evaluation activities, including those that I have conducted or participated in (Bhomick et al. In Progress; Robinson Submitted). Bhomick et al. code results according to application design, tool design, data issues, and analytical support issues. Robinson coded results according to tool design, application design, analytical support, and external factors. Another coding scheme was suggested in early geovisualization design work by Howard and MacEachren (1996) who proposed designing geovisualization interfaces for three analytical levels; the conceptual level, operational level, and implementation level. Recently, Marsh et al. (Marsh et al. 2006) used a coding scheme focused on usability, ideation/learning, interaction/exploration, and other issues. I will select (and potentially modify) a specific coding scheme following analysis of results from Phase One.

This phase will conclude with a distributed focus group (Weaver et al. 2006) with analysts to discuss possible additions to the prototypes. Focus group questions will be designed to prompt analysts elaborate their ideas and envision relevant scenarios.

Phase Four
Purpose of this Phase: From evaluation results, construct set of design guidelines for incorporating synthesis tools into geovisualization tools.

The results from Phase Three will provide feedback from users that can be structured into a set of evidence-based guidelines for the design of new synthesis tools. Analyst verbal protocols and video captures will be used along with post-test usability survey results to formulate these guidelines. At the highest level I will describe the set of general strategies analysts have taken to synthesize results. Then I will structure tool-specific results according to interface metaphor (e.g. concept map), and within each metaphor I will describe guidelines based on the coding scheme described in Phase Three.

Research Schedule

I will complete each of the research phases proposed in the previous sections according to the timeframe outlined in Figure 4. Phase One will require the most time because it involves recruiting epidemiologists and a substantial period of observation on-site. While the stages in Figure 4 are presented without overlap, it is likely that I will begin working on prototype development in small pieces during Phase One in order to build libraries of basic functionality in Adobe Flex (for example, drag & drop of text and graphics) for use with specific interface metaphors later.

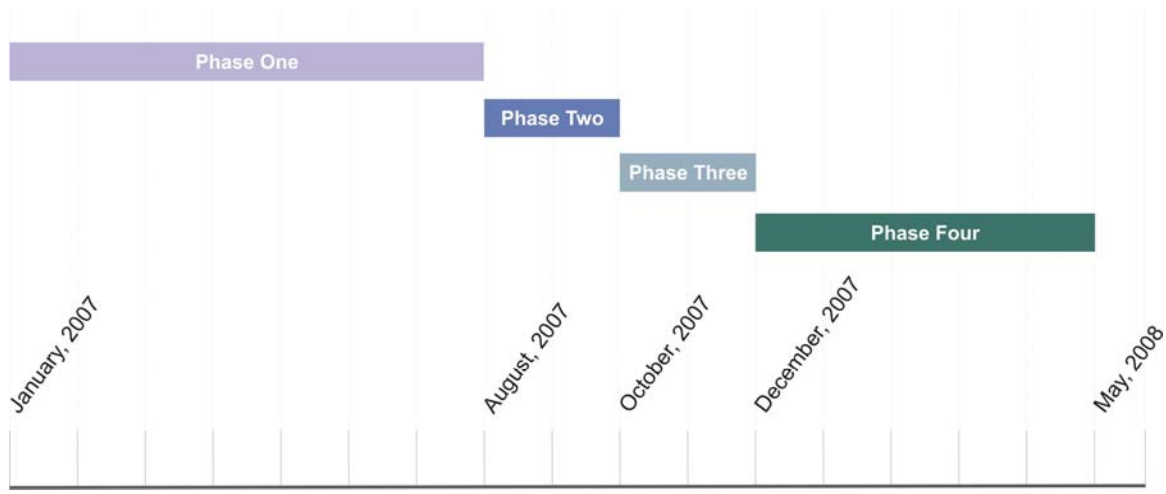

Figure 4: Proposed research schedule based on the methodology phases described in previous sections.

Significance and Limitations

The proposed research advances the discipline of Geography because it explores a crucial portion of the geovisual analysis process that has to date been left untouched in other research. New tools to support synthesis of geovisual results will enable users to construct meaningful representations and summaries of their discoveries. To date there are few (if any) examples of similar work on the role of synthesis in GIScience. It was described by DiBiase (1990), accepted as a critical stage of geovisualization in work endorsed by the International Cartographic Association (MacEachren and Taylor 1994) and has been left largely unexplored ever since. Following the completion of my research, I will have deep insight into how epidemiologists at WHO approach the problem of synthesizing the results they discover with geovisualization tools.

The designs and design guidelines that result from the proposed research may be fed directly into geovisualization software development efforts currently underway.

My project will directly impact epidemiologists at WHO, who are poised to take advantage of new tools for synthesizing their results. What I determine from this study will guide the creation of tools that preserve direct connections to data and enable long-term analytical recall and/or collaboration. Providing useful and usable tools for synthesizing results will increase analysts' task efficiency as well as reducing the amount of repeated work that occurs when epidemiologists are asked to evaluate a particular problem. Facilitating epidemiological work benefits us *all* through more effective public health programs and policies. Disease screening, surveillance and treatment efforts are most often started by research projects that are successful at communicating analytical results – a task that will be made easier as a product of the proposed research.

The proposed research will identify general synthesis strategies and provide design guidelines for new tools to help users synthesize the results of their geovisual exploration and analysis. Because these designs are based on a longitudinal, mixed-methods study of epidemiologists using geovisualization tools, they will be most pertinent to that audience. However, because these users conduct and present analyses in ways quite similar to analysts in other domains, I expect significant portions of my findings will be applicable to applications in other domains like historical geography or crisis management. In future work I will follow-up on my findings in other problem domains to further understand and characterize synthesis of geovisual results.

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