Re-Visualization: Interactive Visualization of the Process of Visual Analysis

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Abstract

Despite the analytical power of geographic visualization, it remains difficult for users of these tools to save, re-use, or re-visit what they have discovered. Most current systems are limited to providing screen captures and can only save basic data and layout settings. Since the interactivity of geovisualization is so critical to its utility, there is currently a need for new methods to capture and make use of this rich set of interactions. This paper describes Re-Visualization, a method that can capture and re-use analysis sessions. Low-level state changes are collected during analysis and saved into sessions. These sessions can then be replayed in a way that allows users to review and explore their interactions. During analysis, users can leave breadcrumbs behind that mark portions of the analysis for follow-up. We outline design guidelines for a toolkit called ReVise that implements Re-Visualization. Finally, we describe our substantial progress toward implementing ReVise in the Improvise visualization environment.

Keywords--- **Geovisualization, Interaction Logs, Visual Analytics**

1. Introduction

While the benefits of geographic visualization for exploratory analysis are many, it remains a challenge for users of these tools to save and re-use what they have discovered. Often the only tangibles that can be gleaned from a tool are screen captures and data/layout settings – much is left to the memory of the analyst. Because so much is gained from the highly-interactive nature of geovisualizations, there is a need for methods to save and revisit the rich set of artifacts that is produced during analysis.

This paper describes a method that can be used to capture and re-use analysis sessions done in geovisualization tools. An overview of existing systems and relevant prior work is presented, followed by a description of the Re-Visualization method. Then, we describe our design for a Re-Visualization toolkit (called ReVise). Finally, we show the progress we have made toward implementing ReVise.

2. Background

There are many precedents for the capture of user actions in the realms of human computer interaction (HCI) and usability studies. A wide variety of tools are currently available for supporting the capture and coding of user interactions with software. Many of these methods are included in a recent review by Hilbert and Redmiles (2000). For designers of web pages and other software interfaces, capturing the work of test subjects is often considered an essential component of any evaluation effort. Such observational data can be integrated with the results of eye-tracking studies, verbal reports, and other data sources to reveal the usefulness of a particular piece of software (Shneiderman and Plaisant 2005). This idea has been proposed specifically to support the design and development of geovisualization tools by Haug et al. (2001). Their work suggests that being able to record and replay an analysis session can provide important information for evaluation and design purposes.

Some contemporary visualization tools provide the capability for users to save pieces of what they have accomplished during exploration and analysis. CCMaps (Carr et al. 2005), a conditioned choropleth mapping tool, allows users to snapshot portions of their analysis, label them, and then step through several snapshots in a row for presentation purposes. The Hierarchical Clustering Explorer (Seo and Shneiderman 2002), an interactive environment for exploring multivariate data, provides users with the ability to save static snapshots of its views as well as export options for saving clustering results. One of the most advanced implementations of capture and reuse features in contemporary visualization tools is the DecisionSite Library toolkit included in recent versions of Spotfire DecisionSite. Spotfire DecisionSite is a commercially-available visualization environment that is designed to facilitate decision-making for a wide array of industry and research domains (Ahlberg 2006). The DecisionSite Library lets users save their analysis settings and publish results into web-viewable posters.

There are also examples of geovisualization tools that have incorporated features designed to capture and re-use interactions. MacEachren et al. (2001) developed interaction logging methods designed to support same-time, different-place geocollaboration. They engineered a so-called "watcher window" to show which views were visible in which ways to each user. A more recent effort has focused on extending the usefulness of multivariate geographic clusters. The Visual Inquiry Toolkit (Chen et al. 2006) allows users to place interesting clusters into a so-called "pattern basket" and return to these later.

3. Re-Visualization

The Re-Visualization method proposes to capture all interactions and state-changes that occur during analysis into sessions that allow users to revisit and interactively visualize these interactions. Rather than attempt to decide in advance what will be important, this method by default relies on the full set of possible interaction input parameters. This is also done to support accountability, an increasingly important issue as many domains adopt visualization tools to influence decision-making activities. Some analysts need to show precisely how they arrived at particular hypotheses and conclusions. For times when the full set of details is not desirable, users will have the option to turn off layers that include detailed interaction data. It will also be possible to allow users to set thresholds in the interface so that only certain types of interactions are recorded (classification changes and variable choices, for example).

Re-Visualization is so-called because it allows users to view overlays of their interaction patterns (mouse paths, clicks, scrolls, etc…) in addition to the standard data manipulations they saw when initially working. It follows standard visualization, and provides the opportunity to revisit and revise prior work – hence "Re" visualization. The set of actions that users generate during analysis becomes a new dataset – one which can be visualized and analyzed in its own right. Re-Visualization is a specific use-case of the general method of Metavisualization. Metavisualization is a generic term that refers to a visualization that can be created based on another visualization's structure or operation (Weaver 2005). Improvise currently features a set of views that provide Metavisualization of the coordination between views and their controls. A new set of views will be added to support Re-Visualization and extend Improvise Metavisualization capabilities.

Visualization sessions should be recorded automatically, in a manner transparent to the end-user except for a set of basic recording (start and stop) controls. These sessions can then be made available for playback in a visualization tool called ReVise (described in detail in section three). ReVise provides a set of tools and controls for users to explore their prior work, annotate/narrate over portions of their analysis, and view summaries of their interactions.

2.1. Characterizing what is captured

Much of the power of implementing the Re-Visualization method comes from its ability to allow users and evaluators alike to revisit analysis and explore interactions. Because Re-Visualization functions by capturing low-level interactions, these are easily symbolized and summarized.

Often, what we are attempting to uncover through examination of low-level interactions are in fact high-level interactions. Several individual clicks, scrolls, and key presses may not mean anything by themselves, but taken together could indicate a search for correlation between two variables in a map and scatterplot. For a wide array of visual analytics applications, it would be quite useful to be able to characterize prior work in terms of these higher-level activities. The proposed Re-Visualization method supports this goal by providing users the ability to mark off ranges of time in their analyses to denote "scenes." This function should be available in a basic form in the original visualization, perhaps via a hotkey that analysts can use during their work to leave virtual "breadcrumbs" behind (Instone 2002) that they can revisit later. A theater metaphor allows users to sensibly organize their higher-level actions in multiple scenes that are part of acts, which can be considered parts of a play – a design direction that may help users tell stories based on their analyses.

Re-Visualization is an important step toward the goal of automatically capturing high-level tasks. A group of experts can collect groups of low-level interactions using Re-Visualization and classify these groups into task categories. Then, machine learning techniques may be brought to bear to automatically pick out high-level actions once we have this kind of training set.

2.2. Potential Applications

The Re-Visualization method could be beneficial for a number of applications. For analysts, having immediate, interactive access to prior analysis sessions will provide the opportunity to recall precisely what transpired. It will also be possible for teams of analysts to view and explore each others' work, exactly in the way that it happened, potentially reducing redundant work and errors in interpretation. Team leaders may use Re-Visualization to identify portions of analytical work that are especially good or bad examples, and then use these examples for training purposes. Additionally, the collected views of interactions may reveal how some analysts neglect (or attend to) certain types of representation, data, and analytical approaches.

For geovisualization designers and developers, full-capture of users' work will allow precise evaluations of new tools and methods to take place. In tandem with verbal protocol results (as suggested by Haug et al. 2001; Kort and de Poot 2005), Re-Visualization promises to provide a full accounting for what users have done with prototype toolkits. It will also provide a platform for conducting studies of screen layouts, for quantifying certain types of interactions (like the use of particular menu features, properties, color schemes, etc…), as well as a rich resource for debugging efforts.

3. The ReVise toolkit

This section describes our design of a toolkit that implements the principles of Re-Visualization. Parts of this toolkit are already built, and we are working now on the others. Section four describes our progress on these items. In this section, graphic mockups are provided to help describe our vision for the ReVise toolkit.

The ReVise interface (Figure 1) is designed around a central primary display of the visualization session. This main display is augmented with a timeline control at the bottom center of the user interface. Additional icon-driven tools are located at the left of the timeline control. This layout is designed to provide as much space as possible to the primary visualization.
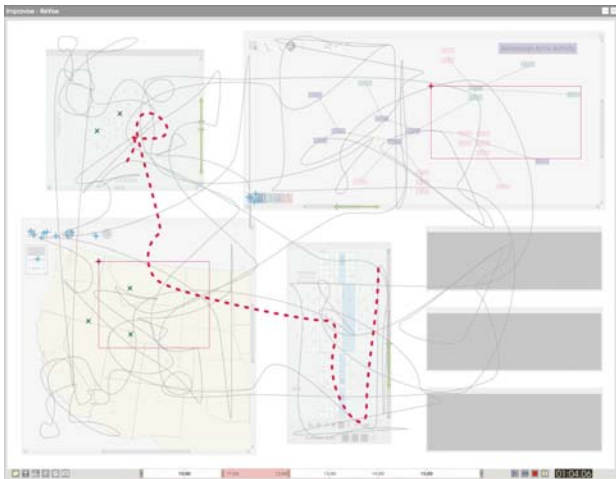

Figure 1: The ReVise toolkit

3.2 Primary controls

The ReVise interface is controlled primarily through a nested scrollbar timeline (Figure 2). This timeline shows time elapsed during the original analysis and indicates progress with regularly placed tick marks. Inside the timeline is a nested control that allows users to select a slice of time out of an analysis session. The length of this slice can be modified by dragging the handles on either side. Standard playback controls are also provided to play, step forward, stop, and pause. A clock displays the precise time of the current frame (or two times indicating the endpoints of the nested slice).

Figure 2: Nested scrollbar timeline control

3.3. Analytical tools

A set of tools (Figure 3) are provided to load/save sessions, jump in to the analysis, modify visible layers, create annotation and narration, generate screen captures, and to explore summaries of interactions.
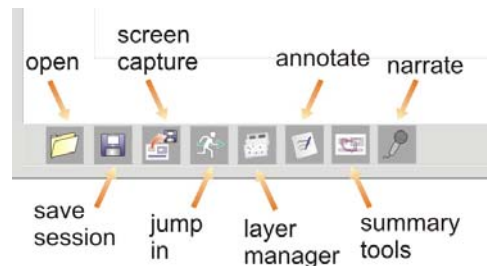

Figure 3: Analytical tools in ReVise

"Jump In" Capability

There are times when a user to would like to return directly to the original visualization and continue or extend analysis. This is a particularly relevant feature for analysts in collaboration when one user needs to understand (or attempt to extend) another's' work. ReVise provides the ability to "jump in" to the visualization at any point by using the "jump in" tool which lets users select a point along the timeline where they would like to enter.

Layer Management

A key component of the ReVise interface is its layer manager (Figure 4). It is an interactive legend that allows users to control symbology and the visibility of the different types of interactions that are being displayed. This interface is inspired by layer managers found common GIS software like ArcGIS and MapInfo. Layers can be swapped in any order, their visibility can be quickly changed, and a set of pre-defined symbols for each interaction type is available for changes to the visual appearance.
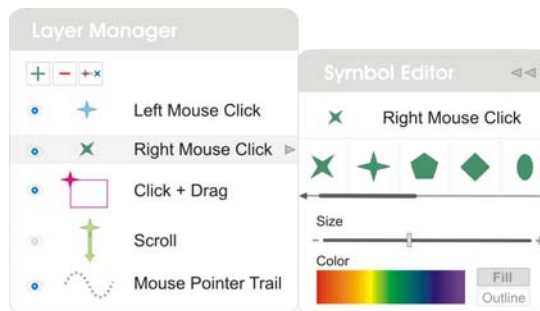

Figure 4: The ReVise layer manager

Window Visibility

ReVise functions by allowing users to explore their prior work with overlays of their interactive behavior. There are times in which it may make sense to change how much the original visualization is emphasized. For example, in a tool evaluation context, it may be interesting to see only the interactions over the bare frames of the original windows to get a general sense of how much each view was interacted with during

analysis. A similar technique has been used in the past to support different-place, same-time collaborative work with geographic data (MacEachren et al. 2001). On the other hand, there are times when analysts may wish to focus primarily on what they (or a colleague) saw as it happened originally. To support these different goals, ReVise allows the original visualization to be displayed at varying levels of opacity. Clicking on a window frame during playback will cycle that frame through 3 default levels; frame only, 50% opaque, and 100% opaque (Figure 5).

Figure 5: Window transparency options
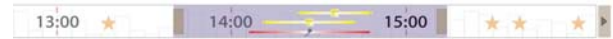
Annotation and Narration

Analysts need tools to help encode their mindset in the form of annotation. ReVise will support this through the use of virtual sticky-notes. These can be added as another layer into the main ReVise interface (Figure 6). After a note has been added, a glyph appears in the timeline to indicate that a note has been added (Figure 7). The duration for which the note appears can be set by dragging the edges of the glyph outward. Narration is supported in ReVise in a similar manner. Users can record brief audio clips and move them around the timeline interactively.
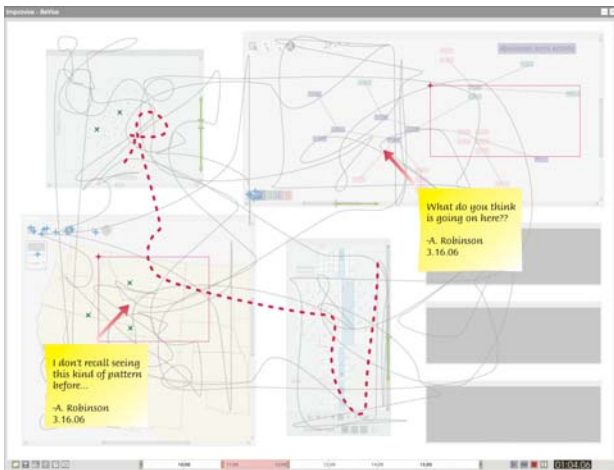
Figure 6: Annotation features in ReVise

ReVise also allows analysts to return to "breadcrumbs" (Instone 2002) left behind during the initial work that indicate key points during the analysis. These appear on the timeline in ReVise automatically (Figure 7) and users have the option of leaving these as track markers, and/or extending them by adding narration or written annotation.

In the future, we envision extending the annotation capabilities of ReVise to support drawing gestures to identify interesting analytical artifacts as described by Denisovich (2005). Denisovich identifies computational operations that can be based on drawn objects overlaid on a geographic visualization to reveal summaries of relevant data and as a method of windowing views of alternative sets of variables.


Figure 7: Annotation, narration, and breadcrumbs in the timeline

Snapshots

The Snapshot tool allows screen captures to be made and saved of the ReVise visualization. ReVise will support standard bitmap captures as well as Scalable Vector Graphic (SVG) standard captures. The latter are useful for instances in which users would like to create publication-quality graphics in graphic design software like Adobe Illustrator or CorelDRAW.

Summary Tools

ReVise will provide a set of summary tools designed to provide quantitative summaries of the interactions recorded in each session. The total time spent in each analysis session is displayed, along with the number of "breadcrumbs" left behind, the number of annotations, number/duration of narrations, and number of instances for each separable interaction type. These values can be further explored by selecting individual windows in various combinations to see how many of these occurred in each window (Figure 8).
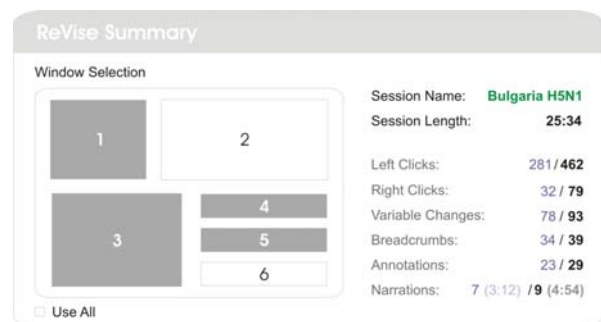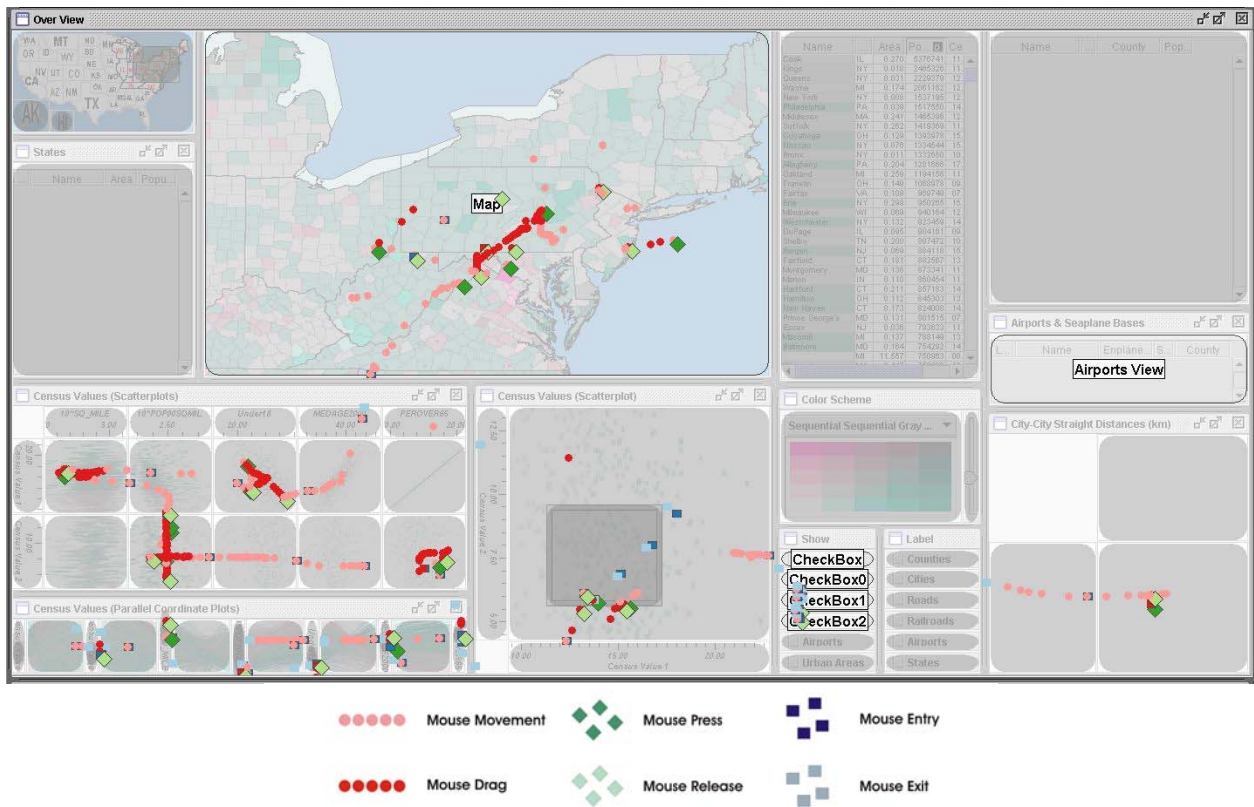

Figure 8: Quantitative summary tools

4. Initial Implementation of ReVise

Full implementation of the tools and methods described here will take a substantial development effort. This is only warranted if initial experiments with recording and Re-visualizing interactions appear to be as useful as this paper assumes. Toward that end, a

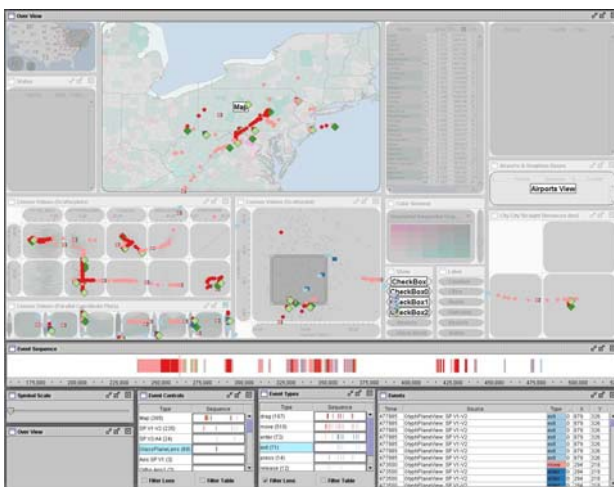**Figure 9: Visualization of interactions from a test analysis using the development version of ReVise**

prototype of ReVise is currently in development. This prototype features a basic implementation of Re-Visualization that supports the capture and replay of sessions of low-level interaction events.

The ReVise toolkit is being built with the Improvise visualization environment. Improvise provides a flexible architecture for users to create dynamic, coordinated visualizations (Weaver 2004). It is also capable of capturing a detailed real-time record of the interactions that occur during a visualization session – thereby fundamentally enabling the implementation of ReVise.

Figure 10: Census Geovisualization integrated with ReVise

Our initial implementation of ReVise allows users to view the overlay of their interactions in real time. A special view has been designed to overlay the interface and allow control over which portions of the display one may view interactions (Figure 10). A nested scrollbar has been linked to the interaction dataset to allow for selection and scrubbing over time. Several summary views have been created that allow users to explore and filter interactions by type or the view in which they occurred. Timelines for each interaction type are provided so that users can explore patterns of specific interaction types over time. ReVise currently captures and displays six interaction types; mouse movement, mouse drag, press, release, enter, and exit. We are working on support for additional interaction types.

The example in Figure 9 shows the logged interactions following a simple simulated user task with an Improvise toolkit designed to explore Census data. The task here was to explore several of the views in order to examine the high and low values among variables from the 2000 U.S. Census. The total time of this task was approximately 5 minutes. With a limited task and a small amount of analysis time, the interaction overlays are not too overwhelming. Many real world tasks take longer and are expected to result in much more complicated collections.

Selected interactions appear with glyphs that provide information regarding the event type, its position, and the time at which it occurred (Figure 11). We intend for these glyphs to eventually show higher-level information

encoded by analysts – for example, that a series of clicks was part of a search through outliers.
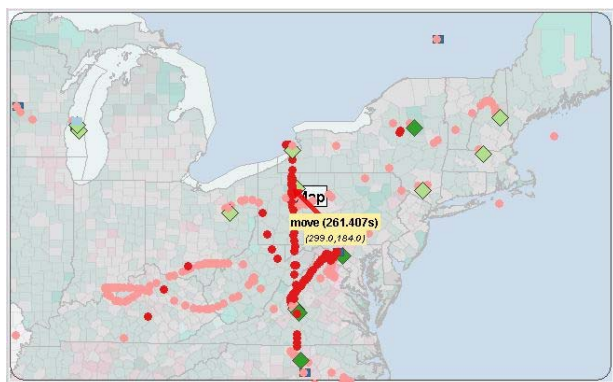
Figure 11: Selected interactions are indicated with a brief description and an arrow

Our next steps will involve the addition of annotation tools to ReVise per the design outlined in section four, and to enable playback controls to facilitate Re-Visualization of recorded sessions.

5. Challenges

There are many salient challenges that need to be addressed in order for Re-Visualization to be maximally effective. Beyond simple quantitative measurements to summarize what occurred during analysis, there are ways in which we can provide a visual summary. An interpolated surface, much like a digital elevation model – but based on the "depth" of interactions at a particular location, is one strategy that we will try. A grid can be imposed over the visualization layout, and interactions can be counted for each grid cell to create a surface. Fabrikant (2000) described a framework which we may use to effectively spatialize our interaction logs.

Another particularly difficult issue is how to deal with moving windows (and moving within windows, like zooming on a map) during an analysis session. In terms of summarizing the session, how can we ensure that it's evident that windows changed position or size? One method may be to "burn in" windows into the overlay according to how long they remained in a particular position or size.

Selecting a subspace in the timeline can reveal a slice of interactions, but the visualization shown underneath can not be easily interpolated to summarize what happened over that time period. One sensible near-term solution is to display the end-state for that scene by default and to allow users to mouse over the timeline to reveal other frames that were captured on-the-fly. One way to indicate the start/end points of a slice of overlaid interactions is to use color or transparency (with an accompanying legend to indicate how they are interpreted) to indicate age. Another method would be to brush each discrete interaction with a colored highlight depending on the frame that the user has hovered over on the timeline. Users could then quickly "scrub" each scene to browse how analysis occurred.

6. Evaluation and Future Directions

An iterative evaluation will take place with prototypes of the ReVise toolkit. Following our initial implementation, graduate students with GIScience and Information Visualization backgrounds will participate in formative evaluations to suggest extensions and modifications to the interface. Our focus will be on questions that reveal how we should provide well-matched tools and symbology to enhance usefulness. Additionally, we will ask users about coding techniques/tools we can support to help users group sets of interactive steps into higher-level tasks (multiple clicks and scrolls turned into an entity called a "search," for example).

Following initial formative evaluations, we will focus attention on assessing whether or not ReVise helps analytical work. We will solicit user feedback based on visual analysis sessions that occur with and without the ability to use ReVise. These sessions will be conducted with analysts in public health and intelligence analysis domains. Qualitative comparisons can then be made between the stories generated using traditional means as well as with the aid of ReVise.

Re-Visualization is one way in which we can begin to tackle the difficult problem of saving and reusing geovisual analysis. The ReVise toolkit will provide the ability for us to evaluate the Re-Visualization concept and it promises to expand upon our abilities to support and enhance geovisual analytics.

References

[1]   Ahlberg, C.Spotfire decisionsite 8.2.1, Somerville, MA http://www.spotfire.com/.

[2]   Carr, D., D. White, A. M. MacEachren, and D. MacPherson. 2005. Conditioned choropleth maps and hypothesis generation. *Annals of the Association of American Geographers* 95(1):32-53.

[3]   Chen, J., A. M. MacEachren, and D. Guo. 2006. Visual inquiry toolkit - an integrated approach for exploring and interpreting space-time, multivariate patterns. Proceedings of the Auto-Carto 2006, Portland, OR, June 25-28.

[4]   Denisovich, I. 2005. Software support for annotation of visualized data using hand-drawn marks. Proceedings of the 9th International Conference on Information Visualization (IV '05), London, July 6-8.

[5]   Fabrikant, S. I. 2000. Spatialized browsing in large data archives. *Transactions in GIS* 4(1):65-78.

[6]   Haug, D. B., A. M. MacEachren, and F. Hardisty. 2001. The challenge of analyzing geovisualization tool use: Taking a visual approach. Proceedings of the 20th International Cartographic Conference, Beijing, China, August 6-10.

[7]   Hilbert, D. M., and D. F. Redmiles. 2000. Extracting usability information from user interface events. *ACM Computing Surveys* 32(4):384-421.

[8]   Instone, K. 2002. Location, path, and attribute breadcrumbs. Proceedings of the 3rd Annual

Information Architecture Summit, Baltimore, MD, March 15-17.

[9]   Kort, J., and H. de Poot. 2005. Usage analysis: Combining logging and qualitative methods. Proceedings of the CHI 2005, Portland, OR, April 2-7.

[10]   MacEachren, A. M., I. Brewer, and E. Steiner. 2001. Geovisualization to mediate collaborative work: Tools to support different-place knowledge construction and decision-making. Proceedings of the 20th International cartographic conference, Beijing, China, August 6-10.

[11]   Seo, J., and B. Shneiderman. 2002. Interactively exploring hierarchical clustering results. *Computer* 35(7):80-86.

[12]   Shneiderman, B., and C. Plaisant. 2005. *Designing the user interface: Strategies for effective human-computer interaction.* Boston, MA: Addison-Wesley.

[13]   Weaver, C. 2004. Building highly-coordinated visualizations in improvise. Proceedings of the IEEE Symposium on Information Visualization 2004, Austin, TX.

[14]   Weaver, C. 2005. Visualizing coordination in situ. Proceedings of the IEEE Symposium on Information Visualization, Minneapolis, MN, October 23-25.