VISUAL HIGHLIGHTING METHODS FOR GEOVISUALIZATION

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ABSTRACT

A key advantage of interactive geovisualization tools is that users are able to quickly view data observations across multiple views. This is usually supported with a transient visual effect applied around the edges of an object during a mouse selection or rollover. This effect, commonly called highlighting, has not received much attention in geovisualization research. Today, most geovisualization tools rely on simple color-based highlighting. This paper proposes additional visual highlighting methods that could be used in geovisualizations. It also presents a typology of interactive highlighting behaviors that specify multiple ways in which highlighting techniques can be blended together or modified based on data values to enhance visual recognition in multiple coordinated view applications.

INTRODUCTION

The key analytical affordances of geovisualization tools include dynamic interactive behaviors and coordinated multiple views of geospatial data. Much attention in geovisualization research is devoted to developing new types of views, integrating new types of data, and designing customized systems for specific analytical tasks and domains (MacEachren and Kraak, 2001). This paper focuses on refining and extending the interactively-driven visual indication, known as highlighting, that allows users to make connections between data objects in multiple views in a geovisualization. As data and the number of views we use to explore those data become increasingly complicated (Andrienko et al., 2007), it is timely to consider new highlighting methods to ensure that visual discovery is efficient and effective.

Settling on a definition for highlighting is challenging because there is little agreement across the literature of geovisualization and information visualization. Becker and Cleveland's (1987) work on brushing scatterplots defines a strategy called transient paint in which data chunks across views are painted with a special color whenever a brush is overhead. In geovisualization literature this technique is sometimes called indication (MacEachren et al., 2003) where it has been described as "…transient picking, as in a mouse-over." Recent information visualization work suggests the term highlighting for the transient visual link across views (Seo and Shneiderman, 2004, Ware and Bobrow, 2005). For the purposes of this research, the term *highlighting* is used to describe the transient visual effect that is applied on data objects across views when they are selected in some fashion (by mouseover, click, click & drag, etcetera).

Recent work by Ware and Bobrow (2004, 2005) focuses on the use of motion as an alternative to static highlighting. Their task-time and accuracy study using both methods with a node-link diagram tool suggests that motion and static highlighting methods are equally effective, and that the two used together are significantly more effective. A key assumption in these studies is that static highlighting is only done using colored outlines.

This paper presents a set of seven visual highlighting methods – substantially extending the current design pattern of highlighting using color alone. Each method is described in detail and graphical examples are provided. This is followed with a typology of interactive behaviors through which highlighting methods can be used in combination to reveal linkages in visually complex displays and to reveal aspects of the underlying data.

VISUAL HIGHLIGHTING METHODS

Multiple potential methods exist for visual highlighting. Few of them have been implemented in visualization environments save for color highlighting, which has achieved wide adoption in visualization tools. The methods described here are not exhaustive, as there are sure to be other ways to indicate linkages across views. The proposed methods focus on visual cues that use preattentive visual variables like color, shape, and depth of field (Ware, 2004) to help ensure maximum visibility. The proposed methods also preserve (in some cases partially) the color, shape, and size of data objects to prevent highlighting from conflicting with accurate data interpretation.

Each style is presented in a figure that simulates coordination between a map, scatterplot, and parallel coordinate plot to show how each method would work with points, lines, and polygons – the basic representations at the core of most geovisualizations.

Color

The most commonly used highlighting style is color highlighting. Color highlighting has data objects in linked views become outlined or filled with a designated bright color.

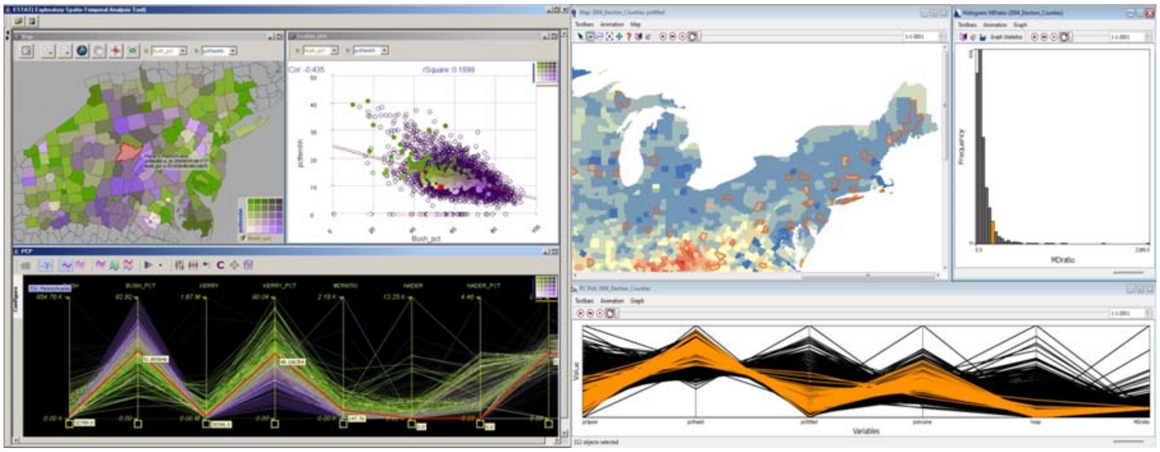

Figure 1. Color highlighting in ESTAT (left) and STIS (right) geovisualization tools.

Figure 1 shows examples of how two geovisualization systems (ESTAT and STIS) apply color-based highlighting (Robinson et al., 2005, Jacquez et al., 2005). Color highlighting (Figure 2-1) can be drawn using various line-widths, colors, and stroke styles. Color highlighting could also be extended to include soft edges and specular effects to simulate realistic backlighting. This may more closely match the real highlighting that one does with a flashlight. Softening the edges also appears to have the effect of 'lifting' the object of interest above its neighbors.

Depth of field

Depth of field highlighting creates areas of contrasting sharpness to visually separate data objects (Figure 2-2). Depth of field is used in photography and cinematography to focus viewer attention in a scene. MacEachren (1992, 1995) suggested the addition of focusing to the Bertin's (1983) set of visual variables. Kosara et al. (2001, 2002) implemented this technique in an information visualization tool. Their Semantic Depth of Field (SDOF) method uses focusing to indicate relevance among a set of observations. User studies of SDOF show that depth of field is processed pre-attentively by humans, making it a promising choice for a highlighting method.

Depth of field can be modified by changing areas in and out of focus. It is possible to incorporate ranking or other measures to control how sharp certain objects appear, but in the case of simply highlighting one data object across linked displays, the problem requires only that we determine how much blur should apply to background information to make the highlighted objects appear linked.

Leader lines

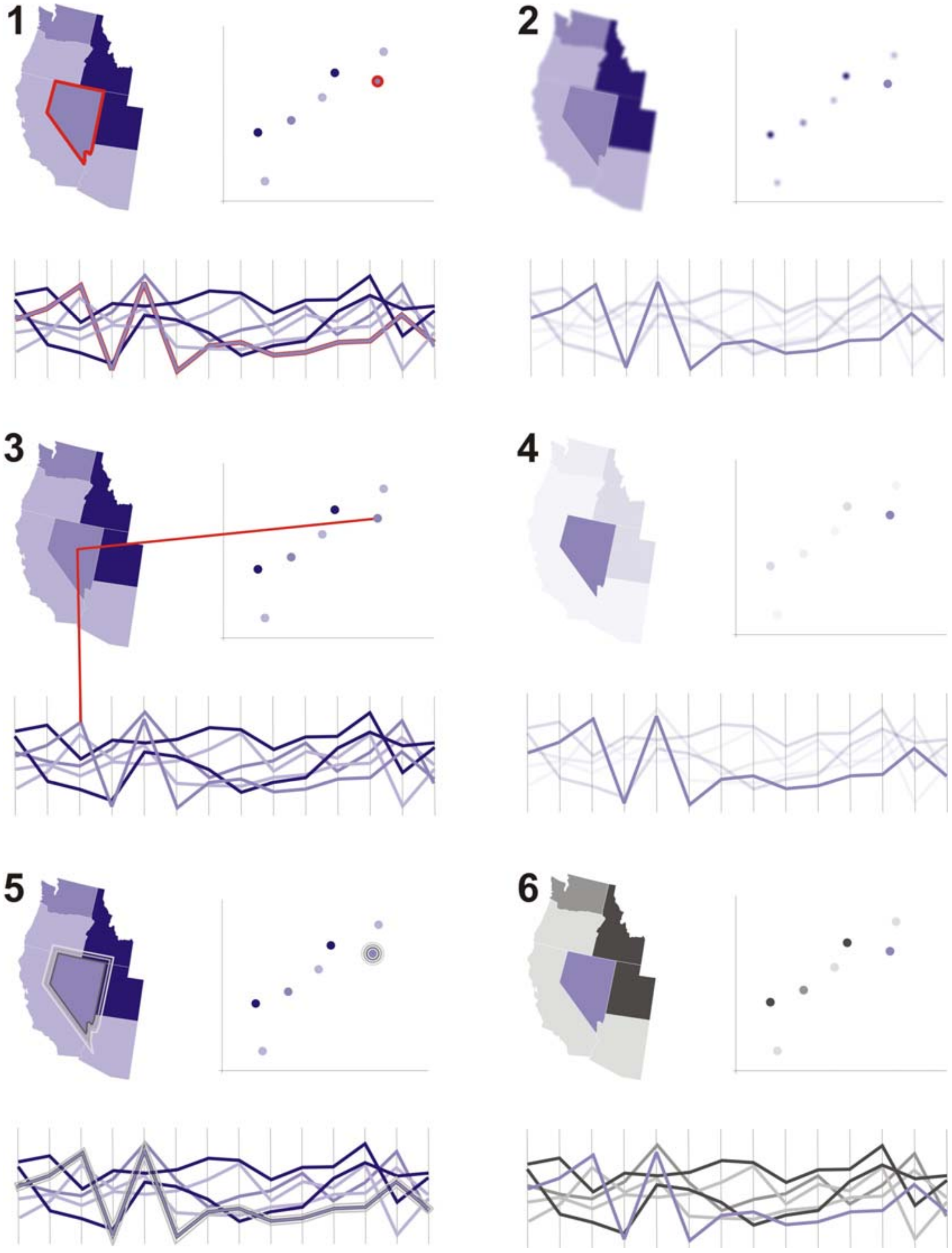

Figure 2. Six proposed highlighting methods for geovisualization.

Cartographers have commonly used leader lines to connect labels to geography when the map format prevents close placement . Leader lines can be used to connect data objects in linked visualization environments in much the same way (Figure 2-3).

As a highlighting method, leader lines could be drawn dynamically based on mouse cursor position. These lines can radiate from the cursor out to the data objects in question. This is a sensible strategy if we assume that users are starting exploration at the data object underneath their cursor location. Leader lines can be drawn in variations of color, width, and stroke style. One challenge associated with leader lines involves connecting them to linear representations as shown in the parallel coordinate plot. A decision must be made regarding where the line connects - this problem requires careful evaluation.

Transparency

Transparency can be used to dissolve the context around the object of interest. This proposed highlighting method focuses attention on linked objects by increasing the transparency of unselected observations (Figure 2-4). Transparency applied in this way reduces visual complexity, but preserves to some extent the integrity of color and symbol information outside of the highlighted points in each view. Like depth of field, transparency was added to the list of common cartographic visual variables by MacEachren (1995).

Transparency can be controlled by setting the alpha level of objects as they are rendered in the display. One challenge that transparency highlighting presents is to determine the appropriate level of transparency for displays that have been colored with light-to-dark color schemes - light colors disappear faster than dark ones.

Contouring

A technique inspired by map design is the use of contour outlines (Figure 2-5). This method uses multiple outlines around data objects to create an effect that objects are “higher” than non-contoured neighbors.

Contour lines can be expressed visually by changing the number of contours, their width/color/stroke style, and the distance between contours. The example in Figure 2-5 shows three steps of contouring using a dark-to-light color gradient from inside to outside.

Color Desaturation

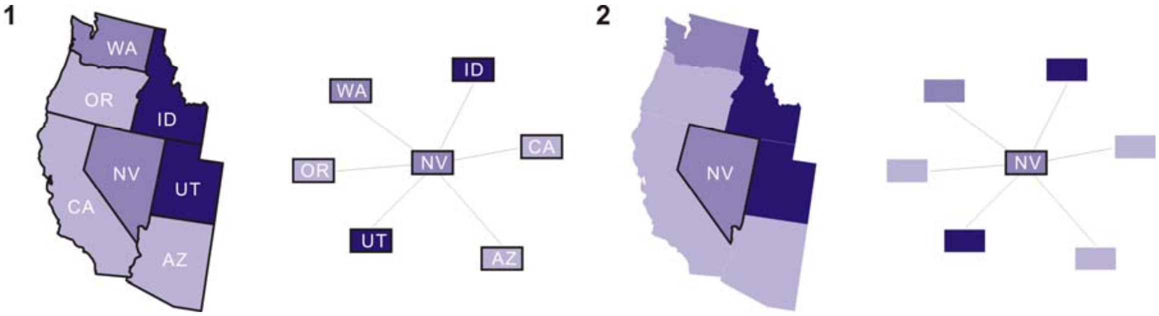

Figure 3. Style reduction highlighting (1 – prior to selection, 2 –after selection)

Color desaturation can be used to visually separate highlighted objects from their context. This highlighting method would essentially make objects of interest retain normal color intensity, while others would appear more gray and faded as a result of desaturation (Figure 2-6).

The level of desaturation used to distinguish highlighted objects could be variable depending on the data and views associated with a specific geovisualization. Particularly complicated views may require more dramatic desaturation to achieve effective visual separation.

Style Reduction

Style reduction can also be used to highlight data objects in geovisualizations. This method selectively reduces the outlines, labels, and other graphical elements to visually separate highlighted objects from others (Figure 3). Style reduction for highlighting can only work with visual representations that are designed with multiple graphical elements. For example, style reduction highlighting will work in mapping applications where regions have a label, outlines, and other graphical elements that can be removed without erasing the data object entirely.

To effectively apply style reduction, decisions must be made regarding which graphical elements should be taken away during highlighting. Such decisions will depend on the specific graphical representations used in geovisualization views.

TYPOLOGY OF INTERACTIVE HIGHLIGHTING BEHAVIORS

Here, interactive highlighting behaviors are defined as the mechanisms through which highlighting methods are applied to views in a geovisualization. This section describes three basic interactive highlighting behaviors that include single, compound, and categorical methods.

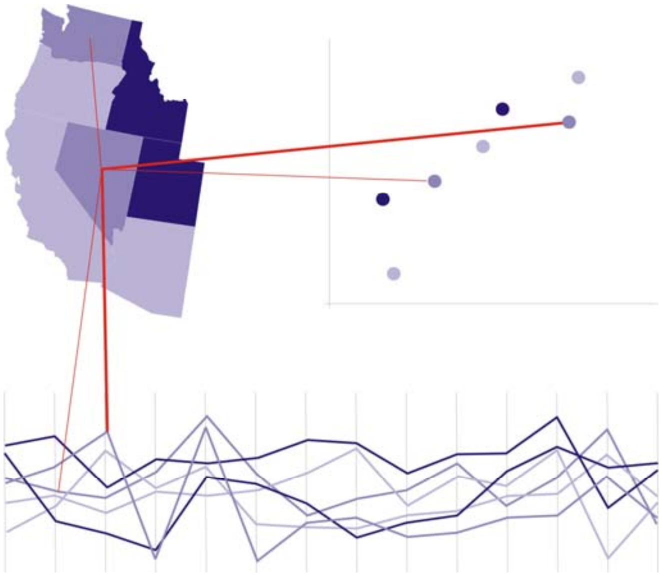

Figure 4. Categorical highlighting using leader lines.

Single

Single method highlighting is the simple application of one highlighting style upon rollover of a data object. This is the interactive highlighting behavior implemented in the vast majority of contemporary geovisualization tools. In each view of a coordinated multiple-view geovisualization, a single highlighting method is used for data objects that have been selected in some way.

Compound

Compound highlighting applies multiple highlighting methods together for the data objects of interest that have been selected. Compound highlighting may facilitate quick interpretation when a single method fails to adequately reduce visual complexity. Compound highlighting may be either conjunctive (same combination of highlighting methods in each view) or disjunctive (different combinations of highlighting methods in each view).

Categorical

Highlighting methods can be categorically applied, rather than using a simple binary “on or off” method common in most visualization software. Many of the visual highlighting methods presented earlier in this paper could be applied in a way that helps reveal the data objects of interest as well as their nearby context. Categorical highlighting could follow a classification that has been applied to a dataset to modify the highlighting method's visual intensity accordingly.

An example of this using the leader line highlighting method is shown in Figure 4 where the directly linked object in each view has the strongest line width associated with it, while other members of the same category of classification use lighter widths. This is designed to convey the direct connection first and allow the context to appear as a secondary effect.

In similar fashion, contour highlighting could be applied categorically by modifying line widths or the number of contour steps. Transparency, color desaturation, style reduction, and depth-of-field present a greater challenge because their effects may not match well to multiple perceptual steps if they are intended to show multiple categories.

DESIGN AND IMPLEMENTATION CHALLENGES

The design and implementation of the highlighting methods and interactive highlighting behaviors proposed here will require attention to issues of usability, performance, and limitations imposed by common programming paradigms.

In terms of usability, well-designed interface controls are essential to the effective implementation of new highlighting strategies. It is possible to parameterize many aspects of the visual highlighting methods proposed in this paper. This could potentially allow users the flexibility to tailor visual highlighting effects to their own preferences or for particular analysis scenarios. Deciding which parameters should be exposed and how those parameters should be best controlled are open questions for further user-centered design research.

The types and overall number of views as well as the display resolution will have an impact on which highlighting methods best accomplish the tasks of transient picking and selection. For example, methods such as depth of field, transparency, and desaturation will likely have a specific useful range in which they support visual separation. Additional research is required to characterize the suitability of highlighting methods for varying data types and to identify how strong different visual highlighting methods must be to ensure visual separation between data objects.

The interactive application of some types of highlighting methods (depth-of-field and transparency, most notably) could pose rendering performance issues for geovisualization software systems that already make use of substantial computational resources to draw objects in multiple views.

Finally, a challenge associated with the use of leader lines as a highlighting method is that it requires rendering to occur across window frames that hold views. The view-in-a-window design is a very common programming paradigm in geovisualization and information visualization, and supporting highlighting methods that reach across those frames will require creative solutions.

CONCLUSION

A prototype tool (accessible at http://www.personal.psu.edu/acr181/hlight.swf) featuring five of the proposed highlighting methods (desaturation and style reduction are not included) has been developed using Adobe Flash. This prototype includes a simulated map, scatterplot, and parallel coordinate plot. Highlighting methods can be switched on and off using mode buttons and specific parameters for each method can be adjusted by making changes to the ActionScript code. The purpose of this prototype is to support basic formative evaluation of the proposed highlighting methods to identify and iteratively refine their parameters.

The highlighting methods and interactive behaviors described here refer to to static visual techniques. But it is also important to explore the potential that motion, sonic, and haptic methods may hold for future systems. Our hope is that by starting with the ideas proposed in this paper, we can begin learning best practices for highlighting in geovisualization and then move on to exploring dynamic methods.

New highlighting methods and interactive behaviors like those described here could help facilitate effective data exploration and analysis using geovisualization tools. It is particularly important to develop creative visual methods for interacting with and understanding data object linkages across views as geovisualization systems begin to tackle difficult problem domains that involve the use of a large number of views (and a correspondingly diverse set of data representations) simultaneously. Current systems rely almost exclusively on one of many potential highlighting methods, and the additional methods and interactive behaviors presented here have yet to be evaluated to see if they might offer advantages.

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REFERENCES

ANDRIENKO, G., ANDRIENKO, N., JANKOWSKI, P., KEIM, D., KRAAK, M. J., MACEACHREN, A. M. & WROBEL, S. (2007) Geovisual analytics for spatial decision support: setting the research agenda. *International Journal of Geographical Information Science,* 21**,** 839-857.

BECKER, R. A. & CLEVELAND, W. S. (1987) Brushing scatterplots. *Technometrics,* 29**,** 127-42.

BERTIN, J. (1983) *Semiology of Graphics: Diagrams, Networks, Maps,* Madison, WI, University of Wisconsin Press.

JACQUEZ, G. M., GREILING, D. A. & KAUFMANN, A. M. (2005) Design and implementation of a space-time intelligence system for disease surveillance. *Journal of Geographical Systems,* 7**,** 7-23.

KOSARA, R., MIKSCH, S. & HAUSER, H. (2001) Semantic depth of field. *IEEE Symposium on Information Visualization 2001.* San Diego, CA.

KOSARA, R., MIKSCH, S. & HAUSER, H. (2002) Focus+context taken literally. *IEEE Computer Graphics and Applications (CG&A), Special Issue on Information VIsualization,* 22**,** 22-29.

MACEACHREN, A. M. (1992) Visualizing uncertain information. *Cartographic Perspectives***,** 10-19.

MACEACHREN, A. M. (1995) *How Maps Work: Representation, Visualization and Design,* New York, Guilford Press.

MACEACHREN, A. M., HARDISTY, F., DAI, X. & PICKLE, L. (2003) Supporting visual analysis of federal geospatial statistics. *Communications of the ACM,* 46**,** 59-60.

MACEACHREN, A. M. & KRAAK, M.-J. (2001) Research challenges in geovisualization. *Cartography and Geographic Information Science,* 28**,** 3-12.

ROBINSON, A. C., CHEN, J., LENGERICH, G., MEYER, H. & MACEACHREN, A. M. (2005) Combining usability techniques to design geovisualization tools for epidemiology. *Cartography and Geographic Information Science,* 32.

SEO, J. & SHNEIDERMAN, B. (2004) A rank-by-feature framework for unsupervised multidimensional data exploration using low dimensional projections. *IEEE Symposium on Information Visualization.* Austin, Texas.

WARE, C. (2004) *Information Visualization: Perception for Design,* San Francisco, Morgan Kaufman.

WARE, C. & BOBROW, R. (2004) Motion to support rapid interactive queries on node-link diagrams. *ACM Transactions on Applied Perception,* 1**,** 1-15.

WARE, C. & BOBROW, R. (2005) Supporting visual queries on medium sized node-link diagrams. *Information Visualization,* 4**,** 49-58.