Comparing Color and Leader Line Approaches for Highlighting in Geovisualization

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1. Introduction

In most coordinated multiple view geovisualization systems a visual effect is used to mark observations across views when a user brushes with a mouse or other input device. This transient visual effect is called highlighting and is the focus of our recent research efforts. Current geovisualization systems make use of colored outlines or fills to mark highlighted observations, but there remain a wide range of alternatives to color that have yet to be implemented or compared in terms of user performance.

This paper describes the results of an experiment we developed to compare the performance of two highlighting methods (color and leader lines). Our approach makes use of an eye-tracking system to capture users' gaze patterns while they answer questions that require attention to highlighted observations. The overall goal of our research is to explore whether or not there are good alternatives to color-based methods for highlighting in multiple views. In the following sections we briefly describe the motivation behind our work, the methodology we developed to compare highlighting methods, and preliminary results from our first experiments.

2. Background

Coordinated, multiple view geovisualization systems support brushing, which is the mechanism by which observations are dynamically filtered, queried, and selected (Roberts and Wright 2006). We define *highlighting* as the transient visual effect applied to observations in multiple views as a result of brushing. Earlier work called this effect *transient paint* (Becker and Cleveland 1987) and *indication* (MacEachren et al. 2003). The information visualization literature primarily refers to these techniques as *highlighting* (Ware and Bobrow 2005).

In most current systems, highlighting is implemented through the use of static color outlines or fills on observations in multiple views. Colors used for highlighting tend to be bright and highly saturated to draw user attention. Geovisualization systems that use color highlighting include the GeoViz Toolkit (Hardisty and Robinson In Press) and GAV Toolkit (Jern et al. 2007).

Some prior work in information visualization has focused specifically on highlighting. Ware and Bobrow (2005) compared the use of motion as an alternative or complement to static highlighting. This research compared motion and static color highlighting methods in terms of user performance with node-link graphs. Motion and static highlighting methods were found to be equally effective, and used in combination they can also be effective. These results inspired us to explore whether alternative static highlighting methods would perform similarly.

Our broader focus is to identify and evaluate approaches for capturing visual attention in geovisualization systems. While color is a good method for attracting visual attention, it is not the only possible technique. In the following section we focus on potential highlighting methods that extend beyond the use of color.

3. Highlighting Methods

In earlier work we proposed seven possible candidates for highlighting in geovisualization to include color, depth of field, leader lines, transparency, contouring, color desaturation, and style reduction (Robinson 2009). A natural starting point for describing the wider range of possibilities for highlighting methods is the twelve visual variables compiled by MacEachren (1995). Some of these visual variables (orientation and location, for example) are difficult to envision as useful highlighting methods, but remain possible to apply.

In this research we focus specifically on comparing two approaches; color and leader lines. Color highlighting uses a dedicated color to outline or fill observations in multiple views. In contrast, the leader line approach draws lines out from the selected observation to its counterparts in other views (Figure 1).

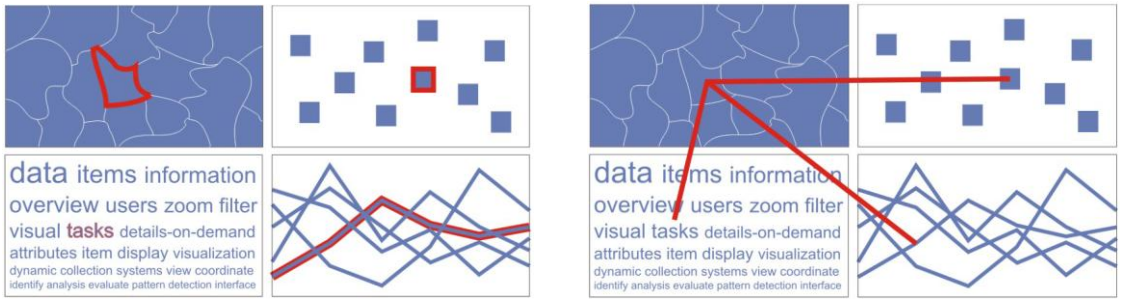

Figure 1. Color (left) and leader line (right) highlighting examples.

4. Evaluation Methodology

To explore the ability of the two methods of highlighting to support the visual search for information in linked representations, we designed an experiment to test two hypotheses:

- Null Hypothesis #1: There is no significant difference in the ability of color or leader lines to support the *effective* search for linked values in a coordinated display.
- Null Hypothesis #2: There is no significant difference in the ability of color or leader lines to support the *efficient* search for linked values in a coordinated display.

Our experiment had two independent variables: highlighting method (color, leader line) and representation type (scatterplot (SP), parallel coordinate plot (PCP)); and three dependent variables: task accuracy (unit difference from correct value); task efficiency (seconds) and speed of finding highlighted object (seconds). We used a balanced Latin Squares rotation of stimuli to avoid order effects among our subjects. Thirty-two participants recruited from staff and students at the University of New South Wales viewed both highlighting methods within each representation type (within subjects design).

Our stimuli (Figure 2) included maps based on fifty US counties from Georgia, which we chose because Georgia's counties are fairly regular in shape. We did not expect our Australian participants to be familiar with the region, but we rotated the counties at 45 degree angles to avoid learning effects. To create the PCPs, we randomly generated data points in Excel (0-100) for each of the five variables. The highlighted observation was randomly chosen for each of the 16 trial pairs. The map colors were randomly assigned to each polygon in the map and its corresponding line in the PCP or point in the scatterplot using five quantile classes. The images were created at a resolution of 1680x1050 (displayed on a 21" monitor).

Our experimental task asked participants to name the highlighted region and estimate its value for a specified variable in the coordinated statistical graph. Participants verbalized their answers to the task question. Their answers were recorded via a videocam integrated with our eye-tracker. Their eye-movements were recorded using a Tobii X120 eye-tracker operating at 60Hz.

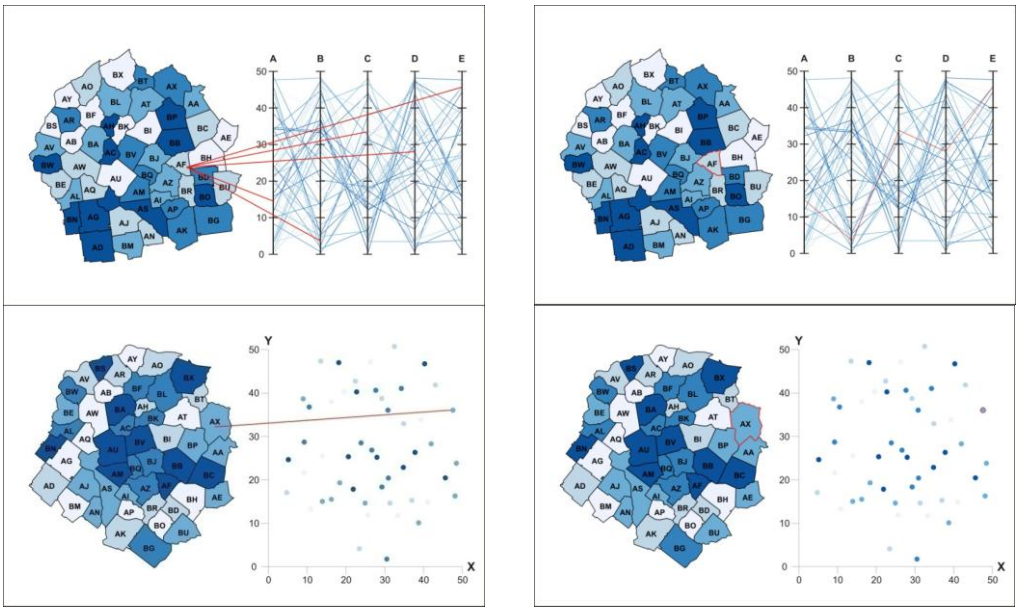

Figure 2. Example stimuli pairs for the PCP (top) and SP (bottom) conditions.

5. Results

Our preliminary results (n = 8 participants) suggest that we will be unlikely to find a significant difference in either the efficiency or effectiveness of the two highlighting methods in supporting the visual search for information in linked displays (Figures 3-4). Participants had slightly (but not significantly) lower mean absolute value estimation errors in the leader line condition (0.79 versus 0.91 units) for both the scatterplots and the parallel coordinate plots (1.06 versus 1.14 units) Our results also suggest that differences in efficiency are unlikely to be significantly different. Mean response times were slightly (but not significantly) faster using the leader lines for the scatterplot condition (4.57s versus 4.91s) and slightly (but not significantly) slower for the leader lines than color for the parallel coordinate plot (4.89s versus 4.73s).

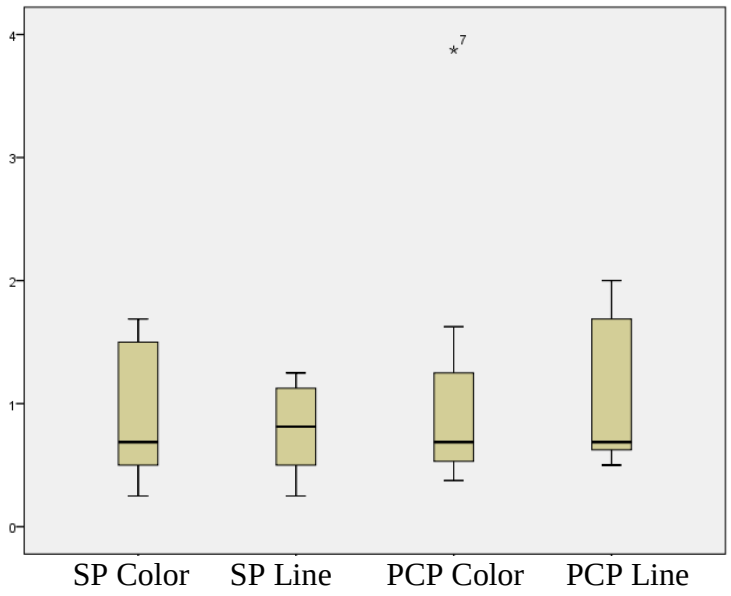

Figure 3. Effectiveness (Accuracy) of Highlighting Methods in Supporting Visual Search.

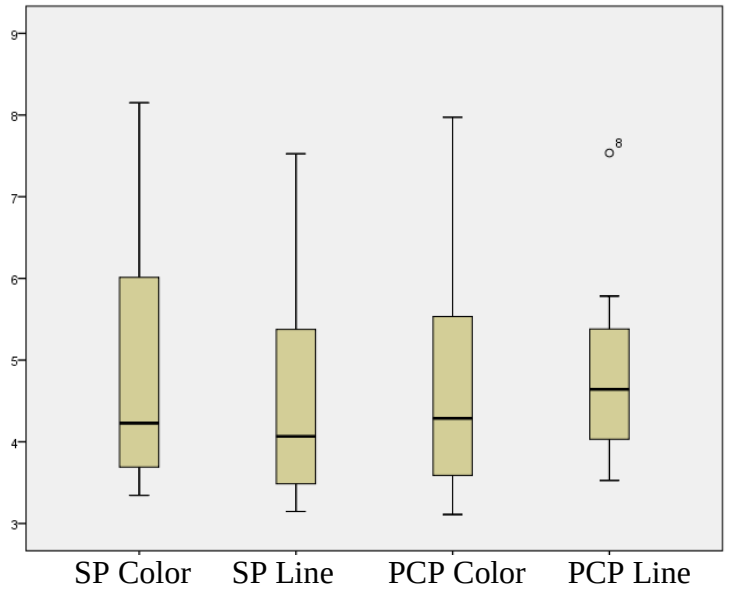

Figure 4. Efficiency of Highlighting Methods in Supporting Visual Search.

Inspection of the eye-tracking data suggests that the more efficient performance seen for the scatterplot condition may be related to more focused patterns of visual search that the leader line highlighting method appears to afford. Notice the higher levels of spatial clustering of fixation counts for the leader line condition, shown by the more compact radii of fixation clusters around task-relevant locations (Figure 5).

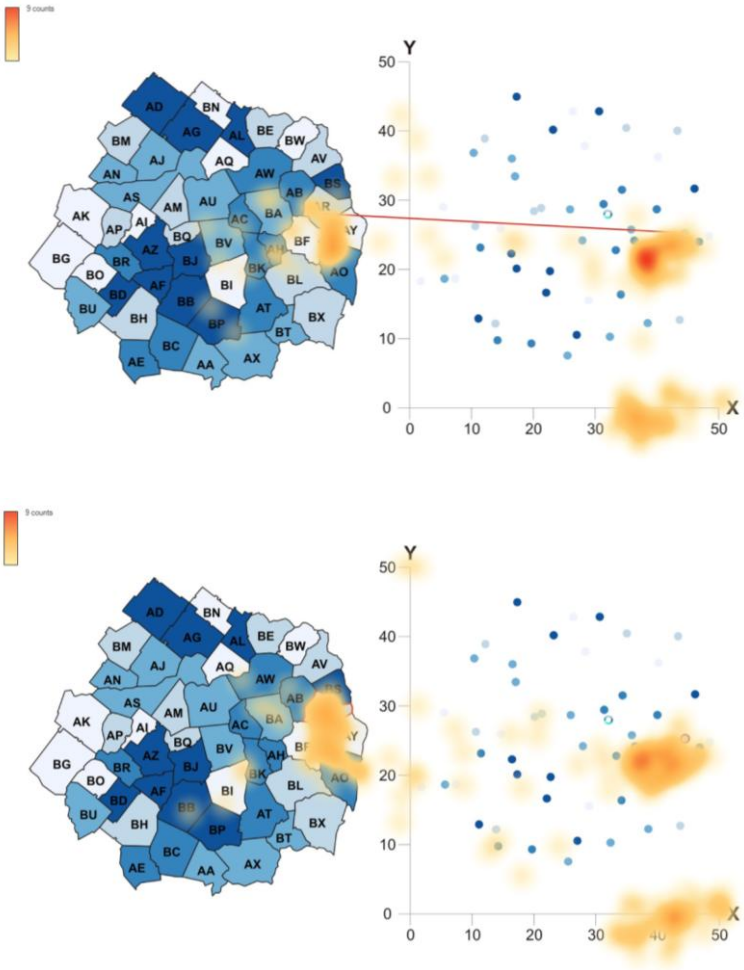

Figure 5. Fixation counts for the leader line (top) and color (bottom) highlighting conditions.

Our preliminary results suggest that leader lines are just as effective and efficient at linking information for single entities in coordinated displays. This implies that visualization designers can reserve the visual variable of color (both hue and value) for communicating information embedded in the data. We suspect that further investigation will identify other effective and efficient alternatives (other than leader lines) to color for supporting highlighting in coordinated displays.

References

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