Multivariate Visualization of Continuous Datasets, a User Study

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ABSTRACT

Effectively displaying large continuous multivariate datasets remains a challenging problem. Quantifying the capabilities of different visualization techniques based on analytics tasks will provide valuable insights that help researchers choose appropriate visual representations. In this work, we present the design of a study to investigate the effectiveness of three multivariate visualization methods. The study compares and contrasts the strengths and weaknesses of using natural textures [10], perceptually-based brush strokes [3] and weaving side by side colors [2] through map reading tasks.

KEYWORDS: Multivariate Visualization, Color, Texture, Perception

INDEX TERMS: I.2.10 [Vision and Scene Understanding]: Perceptual Reasoning; Texture]; H.5.2 [Information Interfaces and representation]: User Interfaces— Evaluation/methodology

1 INTRODUCTION

Field experts in domains such as turbulent flow, meteorology, geology, and astronomy routinely make important decisions based on the relationships among multiple data variables. Effectively displaying multivariate data such that it neither leads to perceiving nonexistent patterns nor clutters the display remains a challenge. In short, the presentation of information must coherently and precisely visualize relationships among different variables, allowing different pieces of information to be accurately compared [11], [12].

Various strategies have been proposed for representing multivariate datasets [1]. We focus on comparing the three methods presented in [2], [3], and [10].

In [2], Hagh-Shenas et al. provide observers with an estimate of the error they may expect when using color blending vs. viewing the colors side by side. The colors are chosen to be "perceptually equal" to each other to ensure there is no advantage to the representation of one variable over another. Four variables are mapped to four separate colours, then distributed over the map using a noise texture. A similar method of visualization was proposed by Miller [7], [8].

In [3], Healey et al. argue that aesthetic appeal affects viewer engagement and so aesthetics may be able to improve the effectiveness of visualizations. The authors combine techniques from nonphotorealistic rendering, Impressionistic painting, and human perception to build brush stroke glyphs that vary their visual properties to represent the underlying data. Three data attributes are mapped to the color, size, and orientation of individual strokes. One attribute is mapped to the local percent of canvas coverage with brush strokes.

In [10], Tang et al. present a method to visualize weather data through multi-layer controllable texture synthesis. In controllable texture synthesis, easily distinguishable foreground and background textures are synthesized separately. Three attributes are mapped to changes in scale, orientation, and brightness of the background texture and the forth is mapped to the density of the foreground texture.

This poster presents a user study designed to evaluate the information carrying capabilities of each of these method.

2 EXPERIMENTAL METHOD

2.1 Apparatus

The displays in our study visualize a meteorological dataset provided by the Intergovernmental Panel on Climate Change (IPCC) that contains 30-year monthly average temperature, precipitation, pressure, and wind speed conditions for the years 1961 to 1990, recorded at 1/2º latitude and longitude steps for positive elevations world-wide. The data belonging to each weather condition was cropped to regular grids that contain 122 by 90 data points. These smaller datasets are then visualized using each of the three methods.

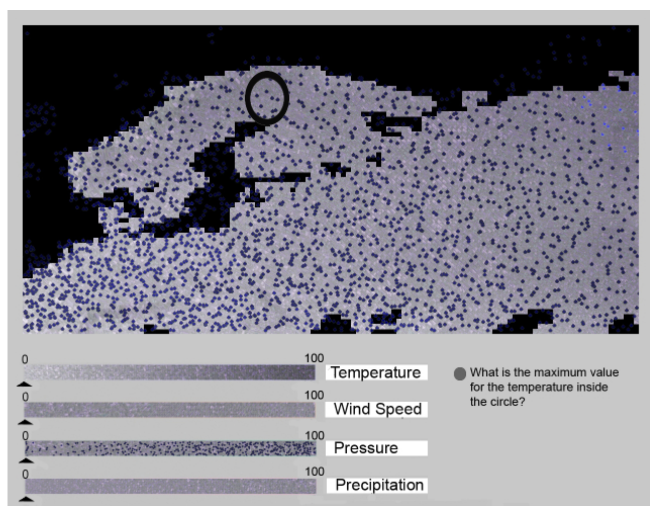

Figure 1. Display using the natural texture method [10].

A basic map reading question will be asked for each of the four variables and for each of the three methods. Each display will be repeated twice to increase the accuracy of the readings. Eleven additional questions will be asked regarding possible correlation between the variables. Thus, the study will include 90 trials.

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2.2 Procedure

Four general conceptual goals for geographic visualization have been presented by MacEachran and Kraak in [4] and [5]: exploration, analysis, synthesis, and presentation. Our emphasis in this research is on information exploration. The context specific goal is to facilitate exploration of spatially varying factors in climate change datasets. Specifically, in the three methods, [2], [3], and [10], we first would like to identify the base level error by quantifying:

1) How well can naive observers read and understand the basic information that the map presents?
2) How well can naive observers recognize possible patterns in each variable as well as relationships between the variables, and how well can they draw conclusions from such relationships.

These goals translate to identifying and verifying the hotspots of one variable (e.g., maximum temperature), finding clusters in the maps, and searching for relationship between two or more variables [6].

Tasks to study these questions include:

1) Highlighting high/low/medium values, then asking for estimates of the actual values.
2) Searching for visible regions/clusters in a specific region of the display.
3) Exploring association by asking, for example, "Do variable *x* and *y* have a positive, negative, or no relationship?"

Similar to [9], after answering a question that appears on each display, observers will be asked to rate their level of confidence from 1 (low) to 10 (high). The time observers take to make their decisions will also be recorded.

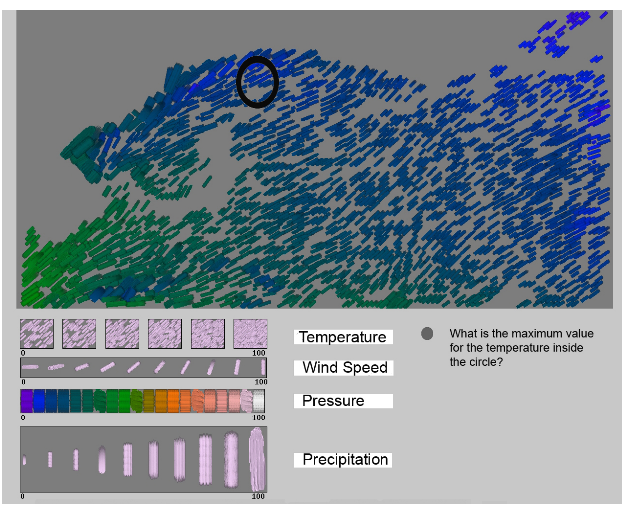

Figure 2. Display using the perceptually-based brush stroke [3].

3 Conclusion

We have proposed a study to evaluate three multivariate visualization techniques with task-based questions. We believe this will provide insights into the effectiveness of the chosen methods for each task. Additionally, we aim to identify a set of tasks that facilitate a thorough evaluation of a multivariate visualization method for representing continuous datasets. Preliminary study results study will be presented in the accompanying poster.

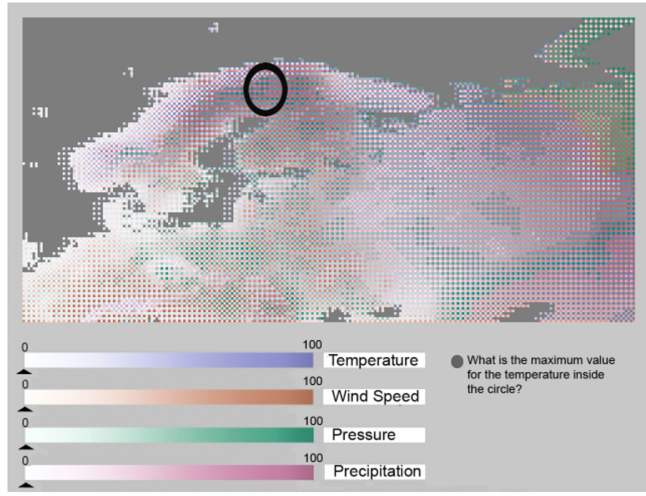

Figure 3. Display using the color weave process [2] (attribute blocks: [7][8]).

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