Feature-Enhanced Map for 2D Multivariate Data with Uncertainty

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ABSTRACT

We present our method to solve the challenge of visualizing multivariate data with uncertainty in a single image. First, layers of spots enhanced with contour patterns are designed to encode multivariate information. Second, star glyphs are adapted to encode uncertainty information with each branch representing the uncertainty of an individual variable. Layers of sparse and similar glyphs allow for an easy and accurate interpretation of uncertainty. Distinct shapes and colors of spots and stars reduce the interference between the individual variables and their uncertainties. This feature enhancement allows the major features of individual variables to stand out in a sea of information.

Keywords: Multivariate maps, uncertainty, glyph-based technique

Index Terms: I.3.3 [COMPUTER GRAPHICS]: Picture/Image Generation—Display Algorithms; I.3.8 [COMPUTER GRAPHICS]: Applications

1 INTRODUCTION

Scientific data are often of multivariate and uncertain nature. While uncertainty attracts increasing interest in the visualization community, representing multivariate scalar maps with uncertainty remains an elusive goal.

Visualizing n-variate data with uncertainty is, in many cases, a 2n-variate visualization. A good multivariate or multilayer visualization [1-3] has most, if not all, of the following properties: accurate reading of quantities at discrete points, easy interpretation by a general audience, minimal interference between individual variables and their uncertainties, and feature preservation. Our goal is to design a multivariate display with these properties.

2 METHOD

The feature-enhanced multivariate map with uncertainty glyphs is designed for an uncertain 2D multivariate scalar field. It is composed of layers of spots representing individual variables and a layer of star-shaped uncertainty glyphs with each star branch indicating the uncertainty of each variable. Our task (Fig. 1) includes representing individual variables with layers of spots, designing multivariate uncertainty glyphs, and, in the near future, a user study to validate our design.

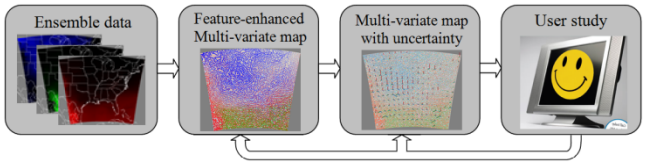

Figure 1: The pipeline for multivariate uncertainty visualization.

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2.1 Feature-Enhanced Multivariate Map

Our method is partly inspired by Van Gogh's oil painting, Starry Night (Fig. 2), in which the halo of the moon and the light of star are rendered by constant strokes surrounding them, making the light swirling as flows. In a visualization sense, Van Gogh emphasized scalar features — the peak of luminance — by using flow features — vortices. We therefore introduce a new type of multivariate map, feature-enhanced multilayer spots where spots are placed and distorted to give a sense of flow around extrema.

Figure 2: "Starry Night" by Van Gogh, 1889.

We derive a flow field to arrange spots to mimic contour patterns. Given a 2D scalar field S, the orthogonal flow field $V_\perp = (-\partial S/\partial y, \partial S/\partial x)$ of its gradient field V is obtained by rotating all the vectors of V 90 degree clockwise. The streamlines of $V_\perp$ are coherent with the contours of S. This allows us to place glyphs to depict contour patterns by following the vector directions in $V_\perp$.

Guided by the vector directions of V, we develop a greedy seeding scheme which repeatedly propagates new seeds from the existing ones until the whole map is filled with spots (Fig. 3). To exaggerate the swirling effect, a spot is distorted slightly into a winding ellipse aligned to $V_\perp$. The ellipse is defined as:

$$\frac{((y-y')\cos(\alpha)+(x-x')\sin(\alpha))^2}{|A|}+\frac{((x-x')\cos(\alpha)-(y-y')\sin(\alpha))^2}{|B|}<=1$$

where its center is point $p(x', y')$ and its axes are A and B. A is decided by the magnitude of S at p. $B = aA$, $0.5 < a < 1$. α is the angle between x-axis and the vector of $V_\perp$ at a location $p(x, y)$ within the ellipse.

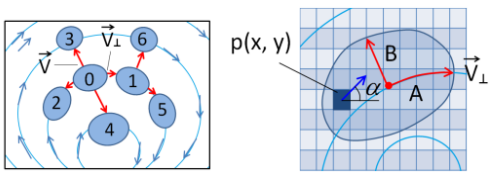

Figure 3: Feature enhancements. Left: a sequence of spots placed along streamlines. Spots are numbered according to the order of their placements. Right: construction of a slightly winding ellipse.

Fig. 4 shows a comparison between multiple single-variate images, a multilayer spot map, and a feature-enhanced multilayer spot map. The feature-enhanced map dramatically improves the perception of underlining patterns of the data, especially those around extrema, over the usual multilayer spots.

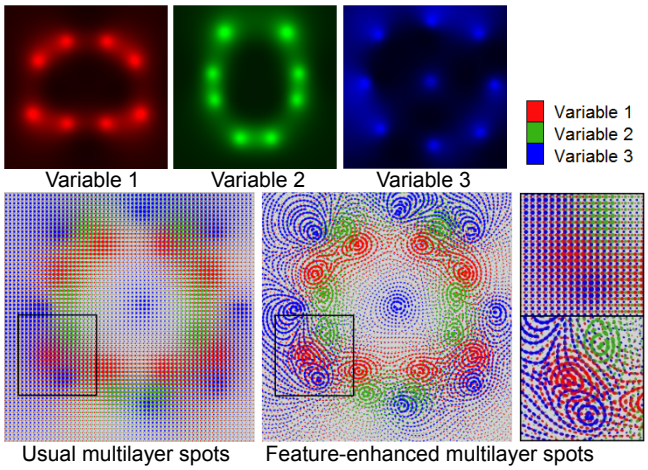

Figure 4: Multilayer spots for 3-variate maps and two close-ups bottom right) showing regions around some maxima.

2.2 Integrate Multivariate Map and Uncertainty Glyphs

The star glyph is adopted to express uncertainty due to its simplicity. Its star-like shape allows it to "pop out" of a multilayer spot background and its branch lengths allow for magnitude estimation.

The value of uncertainty is measured by standard deviation, inter-quartile range, or the width of the 95% confidence interval. A star glyph creates branches emanating at equal angles from a point on the display, where each branch indicates the uncertainty of a single variable. Glyphs are placed uniformly. With simple star glyphs, one can easily locate the place where the uncertainty is generally high among variables and estimate the specific uncertainty value for a single variable at certain location.

Eventually, star glyphs are laid over the new multivariate map to create an integrated visualization. Given the rich information, n variables, features, and uncertainties of the n variables, the color scheme is critical. It is our intuition that assigning similar but differentiable hues to a variable and its uncertainty helps separate between variables and their uncertainties. Fig. 5 illustrates our color schemes. Each variable is assigned a distinct hue. Light red for variable 1, light green for variable 2, and light blue for variable 3. The branch of each star glyph is assigned a similar hue with its corresponding variable.

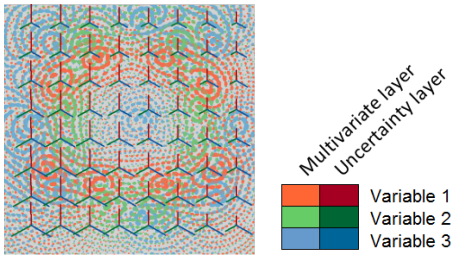

Figure 5: Feature-based multivariate uncertainty visualization with light multivariate map and dark uncertainty glyph.

3 Results

Fig. 6 demonstrates our current results in visualizing Weather Research and Forecasting (WRF) model data of 1993 supper storm. The results show that the feature-enhanced multilayer spots provide information about underlying data patterns with limited interference with the uncertainty glyphs. Overlaying simple star glyphs on top of the spots conveys quantitative and easy-to-interpret information of the data and uncertainty. The exaggerated features facilitate a fast recognition of similarity and discrepancy among multiple variables and increase the visibility of features in the data.

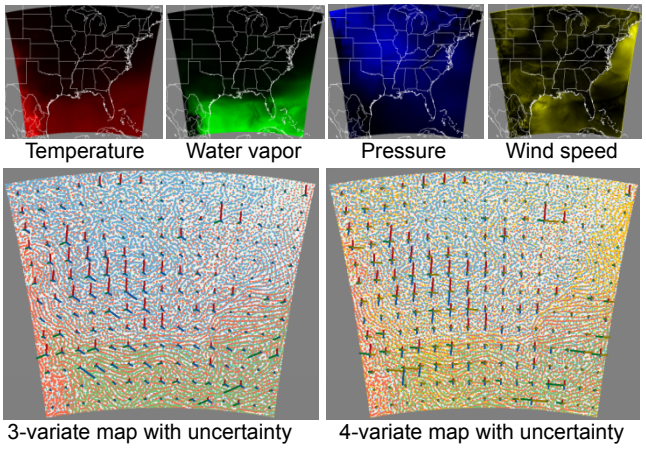

Figure 6: Multivariate maps for a slice of WRF simulation of 1993 supper storm.

4 Conclusion and Future Work

This poster describes a novel method to solve the challenge of visualizing multivariate data with uncertainty in a single image. A sparse placement of the glyphs allows visualization of large and high-dimensional data. The distinct shape and color of spots and stars and the new feature enhancement scheme allow the major features of individual variables to stand out amidst crowded information while the interference between the individual variables and their uncertainties is suppressed.

Eventually, a user study will be conducted to explore user performance in viewing our maps with different data complexity and number of variables. Further, the combination of different multivariate maps and uncertainty representations will be tested to gain valuable insights into future multivariate uncertainty visualization designs.

Acknowledgment

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