12 Visualizing Uncertainty in Natural Hazards

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12.1 Introduction

"Presenting data without error rate is misleading". This is a quote from the O.J. Simpson defense team regarding the presentation of DNA evidence without valid error rate statistics. Taken more generally, this practice is a prevalent shortcoming in the scientific and information visualization communities where data are visualized without any indication of their associated uncertainties. While it is widely acknowledged that incorporating auxiliary information about data, i.e. data quality or uncertainty, is important, the relative amount of work in this area is small. On the other hand, developments by the geographic, cartographic, and GIS communities in this regard is much more concerted. Some of the early efforts were spearheaded by the participating members of the National Center for Geographic Information and Analysis (NCGIA) initiatives (Beard et al. 1991; Goodchild et al. 1994), where different methods of displaying and animating data with uncertainty were proposed. An excellent summary of this body of work can be found in (MacEachren et al. 2005). Combining these works with those from the information and scientific visualization communities, a typology for uncertainty visualization was presented which tries to map data, uncertainty, and tasks with the appropriate visual presentation (Thomson et al. 2005). Specifically, the typology for uncertainty visualization would give the user some guidance about the visual representations for the different types of uncertainty.

There are some key differences in the approaches between the first (geographers, cartographers) and the second (information and scientific visualization researchers). On one hand, the first group focuses on the identifying and characterizing the type, nature, source, and characteristics of uncertainty; as well as map-based uncertainty visualizations. On the other hand, the second group focuses on the task of visually mapping the different facets of uncertainty, and extending the techniques to higher dimensional data sets as well. Clearly, we need to bridge this gap in order to provide an end-to-end solution to the users.

Good visualizations need to target the results to the needs of the users. This means that not only do we need to identify who the users are, we also need to identify the particular task they're trying to do with the given data at that particular moment. Thus, the same data set can be presented in a number of ways – perhaps at various levels of detail, emphasizing or de-emphasizing different regions and features, and employing different visualization techniques to best present the message. However, there are also occasions were the users' goals are not known. In such situations, it is not uncommon to see visualization systems that try to provide interactive exploration of the data sets, or a flexible framework for specifying and emphasizing different aspects of the data set. Frequently, the tradeoff for having a flexible system is that the users need to specify more parameters before they can get their visualizations. Likewise, interactivity usually comes at a cost, both in terms of increased computational resources, but also in the quality of the renderings (e.g. tradeoff in quality versus speed (Ma et al. 2003)). Hence, the exploratory process needs to be followed by a refinement stage where feature extraction may be encoded as the users get a better grasp and can better define what the important features are, and the visualizations and user interfaces are streamlined so that the desired visualizations can be obtained with minimal effort. The description above is also reflective of the multidisciplinary nature of the visualization researcher in combining engineering, science, and art. Engineering in that the visualizations are problem driven with users trying to understand or look for features in their data sets and the visualization researchers specifying the best practice approach. Science in that the visualization researcher also needs to draw upon various established fields such as perceptual and cognitive psychology, mathematical and physical analyses, etc. Visualization is also an art in that the results need to be tailored to the particular task, needs, and occasion.

What was just described is true whether uncertainty is taken into account or not. Uncertainty surely does not simplify matters. It adds to the computational task of handling and presenting them, but also to the cognitive task of the users to understand them. This paper focuses on visualizing uncertainty in data sets, particularly those found in geospatial applications.