Challenges in Visualization Research

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One goal of visualization research is to develop automated tools and techniques for synthesizing informative visual displays – displays that help viewers understand and explore the underlying data. But today, even the most advanced algorithms for transforming numerical data sets into visualizations rarely produce displays that are as useful as hand-crafted visualizations. To automatically generate effective visualizations we must first determine what makes the best hand-designed visualizations so effective.

The fundamental challenge for visualization research is to **understand how visualizations work**. How do good visualizations communicate information to viewers? In general, the best visualizations are carefully designed to make optimal use of the human perceptual system and cognitive capabilities. Therefore, theories that explain how visualizations work must be based on models of human perception and cognition. Such models can tell us how viewers connect external visual representations of the data with their internal mental representations of it. Good models of human perception and cognition can also help us identify design principles for creating effective visualizations. For example, vision scientists have used models of the human visual system to identify many useful principles on the effective use of color, texture, and shading in visualizations. I believe that we have only begun to identify such visualization design principles and much more work remains to be done, particularly in identifying design principles based on higher-level models of cognition.

Often there are many different ways to visualize the same information. How can we pick the best visual representation amongst all the possibilities? The visualization research challenge is to **develop techniques for evaluating the effectiveness of visualizations.** Ideally such techniques should allow us to compare different visualizations and identify advantages and drawbacks of each of them. One approach is to experimentally evaluate the effectiveness of different visual representations via human subject experiments. Human-subject experiments assess how well a given visualization conveys information to the viewer by directly measuring factors such as comprehension, memory, and information access speed. Such experiments are essential for validating visualization designs. Another approach to evaluating different visualization techniques is to algorithmically predict their effectiveness based on models of human perception and cognition. Fully automated visualization design systems commonly used such predictive evaluations to choose between different design alternative. Predictive algorithms could also be built into human-in-the-loop visualization design system and like spelling or grammar checkers, they could be used to help human designers avoid common mistakes..

Ubiquitous network connectivity has created a dynamic environment in which input devices, data sources, the needs of the user and display devices are constantly changing. The visualization research challenge is to **develop visualization techniques that can adapt to best match the needs of users within dynamic environments**. For example, visualizations should automatically update as the underlying data or the goals of the user change. Similarly as users move between cell phones, PDAs, laptops, desktops and wall sized displays, the visualizations should adapt to the unique input and out characteristics of the devices.