Considering Connectivity for Visualization Design

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A connected life is changing the way people deal with data. Information can be collected, received, and analyzed almost anywhere. As a result, people can use decision-making in a broader variety of situations. For example, dietary trackers inform what people order for lunch; mobile devices allow environmental researchers to collect large amounts of complex data in the field; businessmen can analyze multivariate sales data on their phones to respond to major economic events.

In the face of increased mobility and use of data analytics, these analytic interfaces must adapt to better support such *in situ* analytics. While visualization researchers have explored the engineering challenges associated with mobile analytics [1, 2], I argue that a connected life means visualization researchers need to fully reconsider what it means to **design** effective visualization systems. A connected world is changing how users attend to, perceive, and interpret information. This changes the rules of how designers think about visualizations.

Existing guidelines are heavily rooted in perceptual psychology and laboratory studies with traditional desktop interfaces. As data becomes mobile, factors such as changes in devices, usage scenarios, and environments impinge on the validity of these guidelines for *in situ* analysis. Specifically, we must understand how to make visualizations intuitive and accessible for at-a-glance exploration by everyday users, how to create design guidelines robust across different devices and environments, and how to fluidly integrate analytics and context to support decision making.

Attending to Visualized Information: Methods for evaluating visualizations typically fall into two categories. First, insight-based studies evaluate how well visualization systems support users in conducting in-depth or longitudinal analyses. People (often the expert users systems were designed for) interact with systems over the course of days or weeks to report new or reconfirmed discoveries found using the system. Second, graphical perception studies measure the effectiveness of visualization techniques by asking people targeted statistical questions about canned datasets to compare performance across several techniques.

However, a connected life means that people of varying levels of expertise are engaging with data in everyday scenarios to make more informed decisions. Rather than complex insights developed by experts overtime or targeted statistical questions, people increasingly want to explore potentially new and unfamiliar data to make effective decisions without extensive analysis. Their attention may be divided between multiple tasks or they may need to make judgements quickly. For example, someone without formal nutritional training may need to compare nutritional attributes across a menu during working lunch to decide the best dietary choice relative to recent choices and goals.

This kind of "at a glance" analysis requires new ways of thinking about what makes a "good" visualization. What kinds of information or structures within data pop-out? What kinds of information might these structures obscure? Understanding trade-offs in salient patterns across different designs can lead to design decisions that make important patterns intuitively emerge.

Perceiving Visualized Information: Design guidelines for effective visualization generally come from perceptual science or controlled laboratory studies. However, situational factors such as lighting, device, and distance to the screen all influence how visual input is perceived. For example, high levels of ambient or direct lighting reduce perceived color contrasts [3].

In a connected world, these situational factors dramatically affect how accurately viewers perceive visualized information. For example, traditional colorimetry models used in visualization design underpredict perceptions for web users by a factor of five [5]. Smaller displays exponentially degrade color comparisons [4]. How can we help designers create or adapt visualizations to support shifting perceptions caused by situational factors?

A connected life means we must reconsider established perceptual guidelines for effective design. Specifically, we need to create new approaches that can capture and adapt visualization designs for situational viewing or sample from target scenarios to inform design guidelines that are robust to situational factors. These protocols prioritize quick and simple questions and models to minimize impact on users, to work using commodity hardware and to simplify use by system designers. These protocols provide designers with probabilistic control over how well visualizations communicate data across a breadth of use scenarios.

Interpreting Visualized Information: Data can now be analyzed in the same environment it's collected in or the same environment where decisions are enacted. This breaks the traditional paradigm of divided data collection and analysis as people no longer need to sit down at a machine in a controlled location to engage with data. This provides an opportunity for visualization systems to take advantage of environmental contexts to support people in better understanding their data. How might blending collection and analysis change the way people use data to make informed decisions? How might visualization systems more seamlessly integrate real-time context into analytics technologies?

Visualization platforms traditionally prioritize information as data: contextual information is provided on demand and traditionally relegated to "detail" windows divorced from the primary display. However, context situates data with respect to details that are lost when abstracting data into a visualization. By integrating context more visibly into visualization interfaces, people may choose to collect additional data from the environment or make decisions informed by additional information not readily captured through qualitiative or quantitative methods.

For example, we are currently exploring how augmented reality can provide contextual information for field researchers and remote collaborators. Recent technological advances allow for data collection and analysis using a mobile phone. Using pass-through AR on mobile devices, we can superimpose data visualizations over images of the environment in which data is being collected. This allow field researchers to actively engage in data analysis and also stream these contexts to remote analysts. Through these technologies, we can start to explore how contextual information might supplement data analysis to improve decision making or steer data collection and exploration.

A connected life means visualization designers must consider how context might influence people's interpretations of data. How might shifting visual priority from data to context change the insights and decisions arising from a visualization? How might systems effectively collect and synthesize new information about recently collected data? How might context be shared in collaborative work? Answering these questions leads to new designs that holistically frame the data landscape to support cognitive challenges in interpreting and situating analyses for data-driven decision making.

A connected life means new uses (and users) for visualization systems. These changes are removing us from traditional environments modeled by laboratory studies and pushing us to reconsider what it means to design "effective" analytics interfaces. In a connected world, the rules of visualization must adapt to accomodate challenges in how people attend to, perceive, and interpret visualized information in a variety of environments and scenarios. This empowers people to optimize how they interpret and interact with the world around them through data-driven decision making.

References

[1] N. Elmqvist and P. Irani. Ubiquitous analytics: Interacting with big data anywhere, anytime. *Computer*, (4):86–89, 2013.

[2] J. C. Roberts, P. D. Ritsos, S. K. Badam, D. Brodbeck, J. Kennedy, and N. Elmqvist. Visualization beyond the desktop–the next big thing. *Computer Graphics and Applications, IEEE*, 34(6):26–34, 2014.

[3] A. Sarkar, L. Blondé, P. L. Callet, F. Autrusseau, P. Morvan, and J. Stauder. A color matching experiment using two displays: design considerations and pilot test results. In *Conference on Colour in Graphics, Imaging, and Vision*, volume 2010, pages 414–422. Society for Imaging Science and Technology, 2010.

[4] M. Stone, D. A. Szafir, and V. Setlur. An engineering model for color difference as a function of size. In *Color and Imaging Conference*, volume 2014, pages 253–258. Society for Imaging Science and Technology, 2014.

[5] D. A. Szafir, M. Stone, and M. Gleicher. Adapting color difference for design. In *Color and Imaging Conference*, volume 2014, pages 228–233. Society for Imaging Science and Technology, 2014.