Cognitive Science in the Design of Graphical Images and Interfaces

Brian Fisher (bfisher@sfu.ca)
Interactive Arts & Technology, Simon Fraser University
250-13450 102 Ave., Surrey BC V3T 0A3

W. Bradford Paley (brad@didi.com)
Computer Science, Columbia University and Information Esthetics
170 Claremont Avenue, Suite 6, New York, NY 10027

Zenon Pylyshyn (zenon@ruccs.rutgers.edu)
Centre for Cognitive Science, Rutgers University
152 Frelinghuysen Road Piscataway, NJ 08854-8020

Ronald A. Rensink (rensink@cs.ubc.ca)
Psychology & Computer Science, University of British Columbia
2136 West Mall, Vancouver, B.C. Canada, V6T 1Z4

Barbara Tversky (bt@psych.stanford.edu)
Psychology, Stanford University
Jordan Hall, Bldg. 420, 450 Serra Mall, Stanford, CA 94305

Keywords: visual analytics; graphical communication; spatial structure; spatial cognition; psycholinguistics

Introduction

Innovations in information and communication technology enable us to collect, process, and graphically portray novel conceptual diagrams or immense quantities of data. These data can potentially inform learning and decision-making in areas as diverse as science and medicine, design and manufacturing, and law enforcement and disaster relief. To do so will require us to learn how to make information easily accessible and understandable.

The *information visualization* approach to this problem relies on graphical representations of information that are generated by computers on request. Currently, these representations compare unfavorably to those produced by skilled graphical designers who undergo extensive training to master the ability to generate effective visual representations.

Visual analytics takes a cognitive approach to the design of the interactive visual interface. It is informed by graphical design and the perceptual and cognitive sciences. Its goal is to produce computer-generated graphical representations of complex datasets that support users' innate "visual intelligence" to help them to understand the situations those data represent.

This symposium will explore the interaction between cognitive science and the design of graphics and interactive visualization systems. This interaction can take multiple forms:

- Applying research in human perception, spatial cognition, and communication to the design of visualization environments.

- Working with skilled designers to elicit design knowledge that may be applied in the design of visualization environments.

- Analyzing the perceptual and cognitive processes that occur in human interaction with graphical information.

The talks will examine the application of perceptual and cognitive science to the design of graphical representations and interactive visual interfaces. They will also explore ways in which new research questions and methods emerge from visualization tasks and problems, as well as the potential for emergence of a cognitive science of visual analytics. The speakers include familiar cognitive science researchers and their collaborators in graphical and interaction design. Discussion will focus on research problems and approaches that combine cognitive science and visual representation.

Format will include 15-20 minute talks from three participants followed by a panel discussion with substantial input from workshop attendees.

Topics

Computer graphics and perception: Parsing complex graphical scenes, role of attention and spatial indexing, change blindness in dynamic display environments. Psychophysical and cognitive testing. Links to traditional human-computer interaction approaches. Perception and action in large screen and stereo (3D) displays.

Spatial cognition: How does the spatial structure of visualizations affect reasoning? Representing space, time, & agents. Cognitive design principles. Human spatial orientation.

Graphical design and information esthetics: Spatial structures for abstract ideas. Descriptive, depictive, and gestural explanations.

Pragmatics of collaboration: Application areas, research groups, and funding programs. Collaboration models. Venues for publication and presentation of results.

Presentations

Brian Fisher
Visual Analytics as a Cognitive Science

The 2006 IEEE International Symposium on Visual Analytics Science and Technology defined visual analytics as "the science of analytical reasoning supported by the highly interactive visual interface." The goal of visual analytics is to "stimulate analytical insight from massive, dynamic, ambiguous, and often conflicting information" (Thomas and Cook, 2005). I will discuss the origin and development of this new approach to understanding human-computer cognitive systems. The science of visual analytics was developed in part to support the design of innovative interactive techniques and visual representations for use in real-world applications. I will argue that this requires us to develop new design and testing methodologies that examine perceptual, distributed, and embodied cognition in human-information discourse.

W. Bradford Paley
Externalizing Implicit Spatializations of Abstract Data: Cognitive Science & Psycholinguistics Applied at the New York Stock Exchange

One segment of a new interaction design methodology is presented and demonstrated in the context of three designs for actual trading systems used on the floor of the New York Stock Exchange. The new methodology is tailored to take advantage of the shared reference frame that binds individuals who have practiced together in the same knowledge-work domain: it does not work for all applications, but can greatly ease abstract concept recognition and manipulation in designs for narrowly-scoped, domain-specific applications that support knowledge work.

A segment of that methodology supported a 15-fold speedup of NYSE floor brokers in their most time-critical task (placing an order from a handheld computer) from 7 or more seconds down to less than a second. This was accomplished by determining the implicit spatial representations the brokers shared, a la Lakoff's *Metaphors we Live By*, then explicitly representing them on the handheld display in terms of data

field layout, draggable objects, and stylus gestures. The concept of a "Performative Space," an interface analog to the "Performative Sentence" of linguistics is introduced.

Zenon W. Pylyshyn
Sense Of Space: From Poincaré's Problem to Harnessing Spatial Skills in Collaborative Problem Solving

At the turn of the last century Poincaré worried about how we come to our amazing sense of unitary 3D space when all our sensory inputs are multidimensional and multimodal. This fundamental problem has motivated our recent basic research, which we hope will shed light on how we think spatially and how we use space to organize memory and gestural communication, as well as on the question of how we might capitalize on our particular spatial skills in a mind-machine partnership to aid visualization and collaborative work.

Ronald A. Rensink
A New Look at Seeing: Implications for Visual Interaction

As technology advances, the limiting factor in the creation of highly effective and interactive visual displays is no longer the production of graphical representations, but rather, our ability to couple them effectively to the human visual system. Doing so requires sound knowledge of how human vision works. Recent work has argued against the idea that our brains contain a complete, detailed, representation of the scene. Instead, it appears that a more dynamic, "just-in-time" representation is involved, one with deep similarities to the way that users interact with external displays. It is argued here that these similarities can provide a basis for the design of intelligent display systems that can interact with humans in highly effective and novel ways.

Barbara Tversky
How Spatial Structures Convey Meaning

One reason visualizations can be difficult is that too much is packed into them. Yet another reason is that they don't correspond to the ways people think about the phenomena. Spatial structures, such as lines, bars, blobs, arrows, and circles, carry implicit meaning. Insights into how people translate abstract ideas into spatial structures can be gained from their descriptive, depictive, and gestural explanations of them, as well as from their interpretations of descriptions, depictions, and gestures. People's descriptions, depictions, and gestures can reveal their mental models of phenomena as well as providing design principles for communicating them.

References

Thomas, J. & Cook, K. A. (Eds.), (2005) Illuminating the Path-- Research and Development Agenda for Visual Analytics: IEEE Press.