CHI 2002 Tutorial

Information Visualization and Visual Perception

Instructors

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Schedule

9:00 – 9:05:
Introduction, Tutorial objectives: get to know the audience.

9:05 – 9:25:
Course Introduction:
- · Overview
- · What is (scientific and information) visualization
- · Goals of information visualization
- · Why visualization is important (now)

9:25 – 10:30:
Visualization and Interaction Techniques, Part 1
- Structures of Visualization
- Data State Reference Model
- · Some choices (color, representational dimensionality and space type, style, interactivity)
-
· Display Techniques
  1 variable
  2 variable
  3 variable

10:30 – 11:00: Break

11.00 – 12.00:
Perceptual Basis of Information Visualization
Early visual processing
- · Visual Attention
- Popout effects, conjunction
- · Introduction to color
- properties of color opponent channels.
- Coding data using color.

12:00 – 12:15: Groups of 3 or 4, designing distinct icons on overhead transparencies.
12:15 – 12.30: Presentation and (positive) critique of some of the design solutions.
Group test using rapid presentation.

LUNCH (12:30 to 2:00)

2:00 – 3:00:
Visualization and Interaction Techniques, Part 2
– Hierarchical data
– Node and link diagrams

- Interaction
· Lessons relate to the effective design that incorporate interactive visualization.
. Zooming techniques
· Focusing
· Filtering
· Linking
· Focus + Periphery Dynamic Displays
– Data landscapes
– Representations for text

3:00 – 3:15: Work in groups of two to design object displays on overheads.
3:15 – 3:30: Presentation and positive critique of design solutions.

3:30 – 4:00: Break

4:00 – 5:00:
Visual Perception Part 2: Gestalt Laws, 3D Depth, Motion, and Diagrams.
simple coding: shape, motion, stereo depth, etc.
. Pattern perception: Gestalt Laws.
· Object perception.
· Semiology of Information Visualization
· 3D space perception and the organization of information in space.

5:00 – 5:30: Conclusion and Discussion.
– Higher levels of information organization
· Thinking with Visualization: Perceptual Externalizations.
· Perception for cognition: Solving problem with visual externalization.
· Different user tasks
- Conclusion & discussion

CONTENT

Throughout the tutorial, examples will be taken from well-known visualization techniques. This will both to present the techniques and to enable a critical analysis from a perceptual perspective. The tutorial will consist of the following parts:

Introduction

Part 1, the introduction, will describe what is information visualization (InfoVis), and how it is similar and different from scientific data visualization. The introduction will state the goals of information visualization as well as why is information visualization is important for information technology. Choices available for information visualization will be described including color, representational dimensionality (e.g., 3D vs. 2D) and space type, style, and interactivity.

Visualization and Interaction Techniques

The second part, Visualization and Interaction Techniques, will describe display techniques such as node and link diagrams, hierarchical data, data landscapes, representations for text, and other techniques as well as interaction techniques (focusing, filtering, and linking).

Object perception: Theories about visual object perception are introduced and applied to the interesting issue of displaying data. An object display is a display that uses visual objects as a way of displaying complex data. The different attributes of the data object can be mapped to an object's overall structure, shape, surface texture, and surface color. Applications are given in the design of object displays.

Color vision and color opponent channels are covered with particular attention paid to the different properties of the achromatic and chromatic channels. Design lessons are given in two application areas: i) color coding maps ii) color coding discrete data.

Perceptual Basis of Information Visualization

Part 3, Perceptual Basis of Information Visualization, will describe the semiology of information visualization, information processing principles, the dual perceptual system, and focus + periphery dynamic displays. The visual system as a whole is introduced together with some general background to introduce such concepts as J.J. Gibson's ecological approach to perception. The subject of what captures visual attention is introduced beginning with the searchlight metaphor.

This lecture also introduces the key concept of pre-attentive processing and applies it to designing displays so that critical information is immediately perceived. Design lessons relate to i) glyph design, and ii) multivariate "hyper" scatter plots (useful for data mining).

Pattern and object perception and displaying data patterns. In exploratory data analysis, the goal of the analyst or researcher is to discover unknown patterns in the data. This lecture will focus on what it takes to make a pattern easily recognized. Design lessons relate to organizing information and visualizing vector fields.

3D space perception: The factors involved in the perception of 3D spatial information are reviewed and the various tradeoffs involved in designing 3D vs. 2D displays is discussed. Lessons relate to organizing information and rapid navigation.

Case Studies and Practical Principles

Part 4 will describe selected case studies illustrating the principles discussed in the previous parts and how they are applied in real-world applications. Emphasis will be given to how to construct appropriate visualizations for particular information and tasks. Examples will include the WWW (browsing, organizing information), query & search in data bases & the WWW, and visualizing text (e.g., the difference between pictorial and textual representations). The introduction will also describe the impact of the WWW on visualization and vice versa as well as different user's tasks where information visualization could help and functional levels of visualization of retrieved information. This part will also deal with time dependence (e.g., time lines, flip book, animation, side by side), zooming techniques, icons, and different display devices. Guidelines for developing effective visualizations to given information will be presented as well as challenges facing the field and available visualization tools.

Conclusions and Discussion

Part 5 will include conclusions about future trends, key issues, and final discussion.

ABOUT THE INSTRUCTORS

Ed H. Chi is a Research Scientist at the Xerox Palo Alto Research Center (PARC) in the User Interface Research Group. He has been working in Information Visualization since 1993. His area of research and expertise is software systems for 3D and 2D user interfaces and computer-human interaction. Ed H. Chi received his Ph.D. 1996-1999, M.S. 1994-1996, and B. Comp Sci. 1992-1994 in Computer Science from University of Minnesota. He has won awards for both teaching and research (1997 Computer Science Department Best Teaching Award).

Stuart Card, a Xerox Research Fellow, manages the User Interface Research group at the Xerox Palo Alto Research Center performing research on theory and design of interactive computing systems. A recognized figure in our field, Card is winner of 1999 CHI Achievement Award and is a co-author of a Visualization book, an instructor for numerous tutorials at the CHI Conferences.

ABSTRACT

Information Visualization is an area that is rapidly expanding as the need for people to interact with very large amounts of data becomes ever more critical.

This one-day tutorial introduces the general field of information visualization including cognition and visual perception. Rules for visualization design are derived from visual perceptual literature. It covers the background, and the benefit of knowing visual perception in interface design, and the process of applying the knowledge in data displays. The tutorial will also feature two hands-on exercises that directly apply the learned knowledge.

Keywords
Information Visualization, Data Visualization, Visual Perception, Data Display, Display Design, User Interface Design.

INTRODUCTION

Visual representation of information requires merging of data visualization methods, computer graphics, design, and imagination. This course describes the emerging field of information visualization including visualizing retrieved information from large document collections (e.g., digital libraries), the World Wide Web, and databases. The course highlights the process of producing effective visualizations, making sense of information, taking users' needs into account, and illustrating good practical visualization procedures in specific case studies.

Visualization is *more* than a method of computing. It is a process of transforming information into a visual form enabling the user to *observe* the information. On the computer science side, it uses techniques of computer graphics and imaging. Besides relying on visual computing and display it involves human beings. Thus, we need to take

into account human perceptual and cognitive capabilities, human variations, and task characteristics. The human visual system is a pattern seeker of enormous power and subtlety. The eye and the visual cortex of the brain form a massively parallel processor that provided the highest bandwidth channel into human cognitive centers. At these higher levels of processing, perception and cognition are interrelated. This is the reason why the words "understanding" and "seeing" are often synonymous. We'll focus on those areas of perception research that have the most direct applications in information visualization. Rules for visualization design can be derived from what we know about human visual perception.

Visualization is *more* than pretty pictures. Successful visualizations can reduce the time it takes to get the information, make sense out of it, and enhance creative thinking. In contrast with most data used in scientific visualization, information is usually non-spatial or abstract. To create visualization, one needs to map the information into a physical space that will represent relationships contained in the information faithfully and efficiently. This could enable the observer to use his/her innate abilities to understand spatial relationships. Finding a good spatial representation of the information at hand is one of the most difficult tasks in visualization of abstract information.

OBJECTIVES

This tutorial is intended to provide attendees with:

- An understanding of fundamental visualization techniques
- An understanding of interaction techniques with visualizations.
- A hands-on analysis of some practical principles of visualization design.
- Perceptual and cognitive processing using visualization.
- Information on the physiological basis of vision, such as early visual processing, including pre-attentive processing of motion, shape, etc.
- An understanding of color theory and how to code data using color.
- An understanding of the Gestalt Laws of pattern perception and how to apply them.
- An understanding of object perception and designing glyphs for data display.
- An understanding of 3D spatial perception, and issues relating to its use in visualization displays.
- Hands-on experiences in visualization display design.

CHI and Information Visualization

The subject of information visualization is important for the CHI community for a number of reasons. With the availability of information resulting from advances and implementations of information technology and the Internet, users are becoming at times overwhelmed by massive amounts and by complexity of information. Thus, there is a need for finding ways to represent the information visually to enable users to get the information effectively and to make sense of the information. Introducing some science into data visualization is important because many of the techniques that are developed are ineffective for reasons that are plain, given our knowledge of human perception.

The CHI community can:

- Make the field of information visualization more usable by finding ways to conduct effective usability studies
- Bridge the gap between the related fields of information visualization and user interface.
- Provide a large number of practical guidelines that can be used in creating visualizations.

The tutorial will provide the CHI community with an outlook on this field, preparing the participants to apply their expertise to improve information visualization. The tutorial will be pitched at an intermediate level. However, it should be easily understood by anyone who has some background in graphics, psychology, or some prior interest in human perception.

Finally it will be a reference source for visualization researchers using perceptually based techniques. This tutorial will help to build the bridges between science and applications that are central to the success of CHI.

The vision research literature contains much practical and useful information that relates to data visualization. Unfortunately most of this material is couched in jargon and inaccessible. The proposed tutorial will make this literature accessible, as it will explain the key concepts and their relevance to visualization using non-technical language, as far as possible.

How the Tutorial will be Conducted

The format of this tutorial is approximately four hours of lectures, interspersed with two hands-on exercises. The instruction process will be interactive, i.e., participants will be encouraged to interact with the instruction process at any time during the course. Interactive demonstrations are scattered through the lectures. Design lessons are frequently summarized and illustrated.

The exercises will involve groups of 3 or 4 attendees designing visualization solutions to common but challenging problems. These will be drawn by hand on overhead transparencies and then presented to the group as a whole and discussed. The first exercise will involve participants developing methods for displaying layered data. In the second exercise, participants will be asked to design an object-based display.

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CHI 2002 Tutorial

Information Visualization and Visual Perception: Lecture 6 Conclusions

Mpls, MN
April 2002

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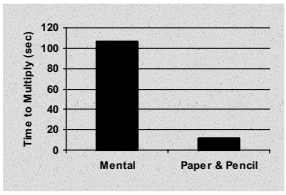
Thinking is Aided by External Representations

$$\begin{array}{r} 34 \\ \underline{\times\ 72} \\ 68 \\ \underline{23^{2}8\ .} \\ 24^{1}48 \end{array}$$

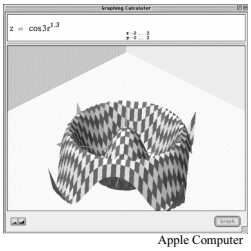


Why it works: Don't have to remember intermediate results

2

Visual interpretation of computation

Hewlett-Packard

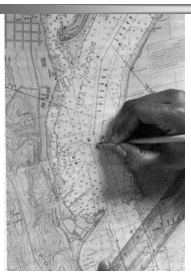


Apple Computer

Why it works: Can see larger patterns

3

Data-intensive computation



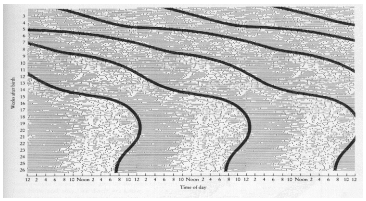
Why it works:

- **Map holds massive detail**
- **Physical analogues computation**

Hutchins (1996)

Diagrams

3 million observations of sleeping and feeding for newborn



Winfree (1987)

Why it works: Macro/micro reading

Two concepts

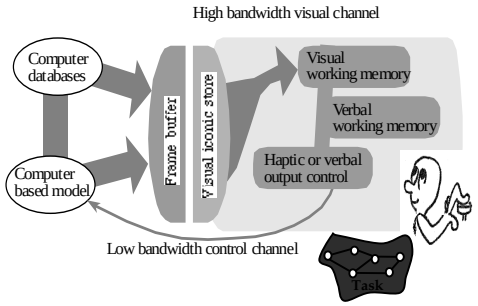
Visual Externalization

- **Active attention is filled with external visual information**
- **Visual memory extension**
- **Seeing solutions (by pattern finding)**

Distributed Cognition

- **Procedural information and processes are externalized**
- **By writing and running programs**

A problem solving system



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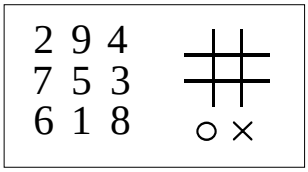
Tic Tac Toe



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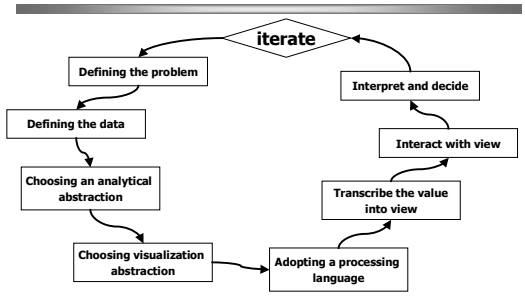
Visual Sensemaking Cycle



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Information Level

- **Goal of sensemaking is to discover new higher-level knowledge in the information**
  - Elementary or Local Level: Uncovering local info in raw data, i.e. detail-on-demand.
  - Intermediate or Comparison Level: Relationships between subsets of info.
  - Overall or Global Level: Condensed knowledge from the correlation between one aspect of the data with another aspect.

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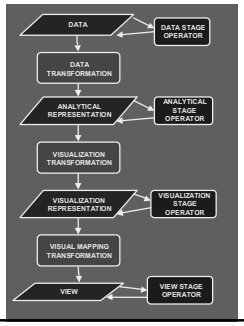
Data State Reference Model



- **Uses four data representation stages**
- **Operators between and within stages**
- **State Model**

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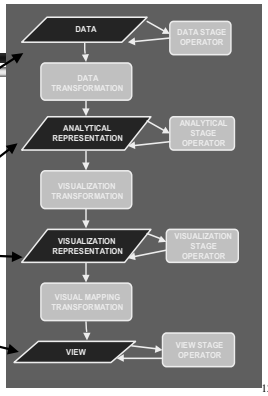
State Stages

- Value (Data)
  - unprocessed abstract data not ready for direct viewing.
- Analytical Abstraction
  - partially processed data not ready for mapping.
- Visualization Abstraction
  - processed data ready for mapping.
- View
  - data mapped into graphical representation for display.



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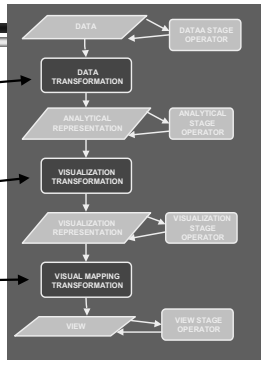
Transformation Operators (between stage)

- Data Transformation
  - i.e. extract web page linkage to create graph
- Visualization Transformation
  - i.e. breadth first traversal to create tree
- Visual Mapping Transformation
  - i.e. Disk Tree



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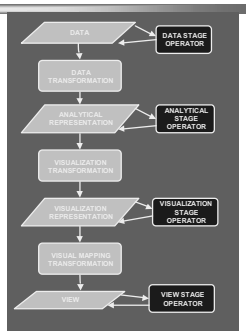
Within Stage Operators

- Data Stage Operator
  - i.e. filtering based on keyword
- Analytical Abstraction Stage Operator
  - i.e. filter, normalize vector
- Visualization Abstraction Stage Operator
  - i.e. filter, variable-to-axis mapping
- View Stage Operator
  - i.e. filter, rotate, scale, translate



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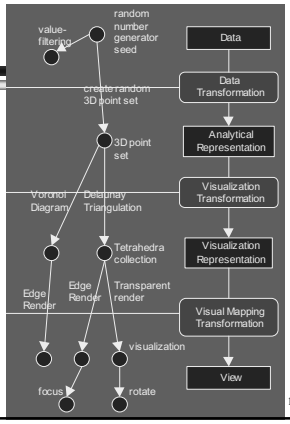
State Model

- **Many views and values**
  - node = data state
  - edge = transform data from one state to another state



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