CHI 2002 Tutorial Proposal

Title

Information Visualization and Visual Perception

Instructors

Ed H. Chi
Xerox PARC

Stuart K. Card
Xerox PARC

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.

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:

1. Introduction

Part 1, the introduction, will describe what is information visualization (info vis), 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. 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.

2. 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.

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.

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.

3. 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.

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.

4. Case Studies and Practical Principles

The fourth part 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). 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.

5. Conclusions and Discussion

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

Justification for a CHI Audience

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.

The tutorial will be taught by both instructors jointly, in roughly 50% each.

Schedule

Discussion of the human visual system and what it means to base visualization on science, rather than on design.

9:00 – 9:10: Introduction, Tutorial objectives: get to know the audience.

9:10 – 9:35: Course Introduction:

- Overview
- What is (scientific and information) visualization
- Goals of information visualization
- Why visualization is important (now)
- Some choices (color, representational dimensionality and space type, style, interactivity)
- Visualization in the age of the WWW & the Internet
- Different user tasks

9:35 – 10:35: Visualization and Interaction Techniques, Part 1

- Display Techniques
  - Node and link diagrams
  - Hierarchical data
  - Data landscapes
  - Representations for text
  - Other techniques
- Introduction to color and properties of color opponent channels. Coding data using color.

10:35 – 10:50: Break

10:50 – 11:10: Groups of 3 or 4, designing distinct icons on overhead transparencies.

11:10 – 11.30: Presentation and (positive) critique of some of the design solutions. Group test using rapid presentation.

11.30 – 12.15: Visualization and Interaction Techniques, Part 2

- Pattern perception: Gestalt Laws.
- Object perception.
- Lessons relate to the effective design of systems that incorporate interactive visualization.
- Focusing
- Filtering
- Linking

LUNCH (12:15 to 1:30)

1:30 – 2:15: Perceptual Basis of Information Visualization

- Semiology of Information Visualization
- Early visual processing: Attention, simple coding: shape, motion, stereo depth, etc.
- Information Processing Principles
- The Dual Perceptual System
- Focus + Periphery Dynamic Displays
- 3D space perception and the organization of information in space.

2:15 – 2:40: Work in groups of two to design object displays on overheads.
2:40 – 3:00: Presentation and positive critique of design solutions.

3:00 – 3:20: Break.

3.20 – 4:00: Case Studies and Practical Principles

- The WWW (browsing, organizing info)
- Querying & searching in the WWW & data bases
- Text & document visualization
- – Pictures & text (text & images are not equivalent)
- – Visualization of lists
- – Correlations within documents
- – Organizing information from selected documents
- – Higher levels of information organization
- Time dependence (e.g., time lines, flip book, animation, side by side)
- Zooming techniques
- Icons
- Different display devices
- Visualization of an imperfect world

- Guidelines for developing visualization to given information
- Challenges
- Available visualization tools

4:00 – 4:10: Short break

4:10 – 5:00: More Case Studies, Conclusion and Discussion.

- Thinking with Visualization: Perceptual Externalizations.
- Perception for cognition: Solving problem with visual externalization.

Materials

We will use 35mm slides, Powerpoint slides, and short sections of videotape to enhance the lectures. To involve the audience, we will show a number of live demos. We will need laptop projection.

The tutorial notes will include copies of all of the overhead slides used by the lecturers with spaces for the attendees to take notes. Tutorial notes will also include an abstract, an agenda, instructor biographies and an extensive bibliography.

Transparencies and markers will be provided for the hands-on exercises.

History

Parts of this tutorial were successfully given at ACM CHI97, CHI98, CHI99, CHI2000 and at ACM SIGGRAPH 96. The proposed tutorial will be similar except that it will be longer and will stress aspects of interest to the CHI community, such as what areas of information visualization could benefit from effective usability studies. It will capture relevant advances done in the past year (e.g., the use of the Web as visualization delivery medium and visualization of imperfect information and data). Parts of this tutorial draw on the three years of SIGGRAPH color tutorials that Colin Ware gave with William Cowan in the mid eighties. These tutorials were always highly rated. Ed H. Chi add some of experience from their experiences as visualization researchers and application designers.

The feedback from previous years' audiences will be implemented. Presentations will be improved by providing more interaction with the audience, more hands-on demonstrations, and more animation.

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 CHI Achievement Award and is a co-author of a Visualization book, an instructor for numerous tutorials at the CHI Conferences.

Samples of materials that will be included in the tutorial notes
See attached.

Bibliography

Bruce, V., Green, P.R. and Georgeson, M.A. (1996) "Visual Perception: Physiology, Psychology, Ecology" 3rd Edition. , Hove, UK: Laurence Erlbaum Associates.

Card, S.K., Mackinlay, J., and Schneiderman, B. (1999). *Readings in Information Visualization.* Los Altos, CA: Morgan Kaufman.

Card, S., Visualizing retrieved information. IEEE Computer Graphics & Applications, March 1996, pp. 63-67.

Card, S., Eick, S.G., and Gershon, N., (editors). Proceedings of Information Visualization Symposium '96, Computer Society Press, Los Alamitos, CA, 1996

Cutting, James E., Vishton, Peter M. Handbook of Perception and Cognition: Perception of Space and Motion, Volume 5, Academic Press, 1996.

Edwards, Betty. Drawing on the Right Side of the Brain. JP Tarcher, 1989.

Eick S.G., Aspects of network visualization. IEEE Computer Graphics & Applications, March 1996, pp. 69-72.

Gershon, N. and Eick S.G. (editors). Proceedings of Information Visualization Symposium '95, Computer Society Press, Los Alamitos, CA, 1995

Gershon N., Moving happily through the World Wide Web. IEEE Computer Graphics & Applications, March 1996, pp. 72-75.

Gershon, N. and Eick, S.G. Visualization's new tack: Making sense of information. IEEE Spectrum, November 1995, pp. 38-56.

Gershon N., Visualization of an Imperfect World. IEEE Computer Graphics & Applications, July-August 1998, pp. 43-45.

Gershon N. and Eick, S.G., Scaling to New Heights. IEEE Computer Graphics & Applications, July-August 1998, pp. 16-17.

Gibson, James J. The Ecological Approach to Visual Perception. Lawrence Erlbaum Assoc., 1987.

IEEE Computer Graphics & Applications, Special Issue on Information Visualization, Eick, S.G., and Gershon, N., (editors), July-August 1997

Robertson, G.G., Card S. K., and Mackinlay J. D. Information visualization using 3D interactive animation., Commun ACM, 36, pp. 57–71, 1993

Tufte, Edward. Visual Explanations. Graphics Press, 1997.

Tufte, Edward. The Visual Display of Quantitative Information. Graphics Press, 1992.

Tufte, Edward. Envisioning Information. Graphics Press, 1990.

Wandell, Brian A. Foundations of Vision. Sinauer Associates: Sunderland, Massachusetts, 1995.

Ware, Colin. Visual Perception and Data Visualization. Morgan Kaufman, 2000.

Wilding, J. M. Perception: From sense to object. Hutchinson and Company, Ltd., 1982.

Representing Data using Static and Moving Patterns

Ed H. Chi

Xerox PARC

•1

Introduction

- Finding patterns is key to information visualization.
- Example Questions:
  - Patterns showing group?
  - Patterns denote distinct regions?
  - When are patterns similar?

•2

Stages of Object recognition

- 1. Parallel processing of
  - orientation, texture, color, motion
- 2. Detection of 2D patterns, contours, regions
- 3. Object Identification
  - Working memory
- Feedback loop

•3

Two parts

- Part I: Static Patterns
- Part II: Patterns in Motion

•4

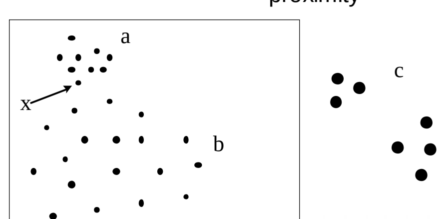
Part I: Static Patterns

- Gestalt Laws
  - [Max Westheimer, Kurt Koffka, and Wolfgang Kohler (1912)]
- Proximity
- Similarity
- Continuity
- Symmetry
- Closure
- Relative Size
- Figure and Ground

•5

1. Proximity

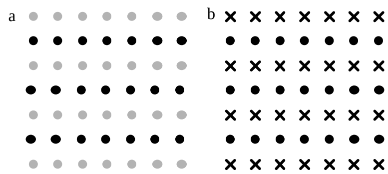
- Spatial Concentration
- Emphasize relationship by proximity



•6

2. Similarity

- Visual Grouping by similarity

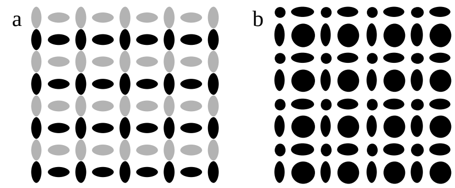


•7

2. Similarity (Continued)

•Separable dimensions

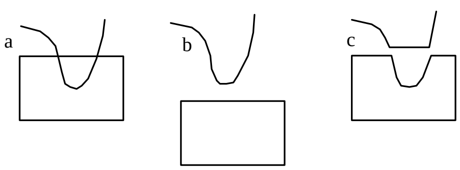
•Integral dimensions



•8

3. Continuity

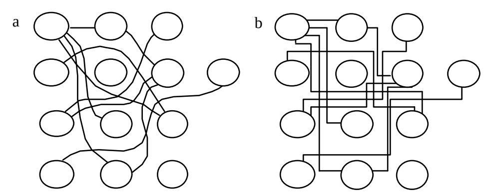
- Visual entities tend to be smooth and continuous



•9

3. Continuity in Diagrams

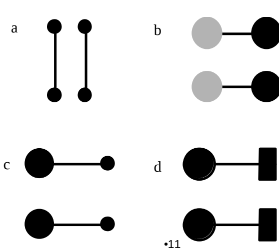
- Connections using smooth lines



•10

3. Connectedness

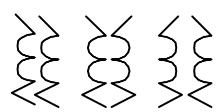
- Connectedness assumed in Continuity



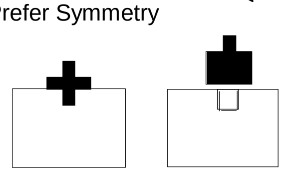
•11

4. Symmetry

- Symmetry create visual whole

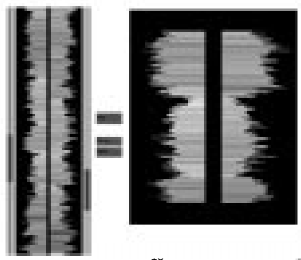


- Prefer Symmetry



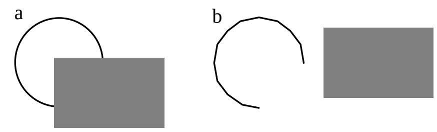
4. Symmetry (cont.)

- Using symmetry to show Similarities between time series data



5. Closure

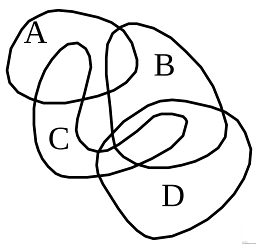
- Prefer closed contours



•14

5. Closure (cont.)

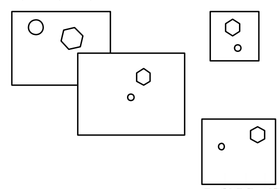
- Closed contours to show set relationship



•15

5. Closure (cont.)

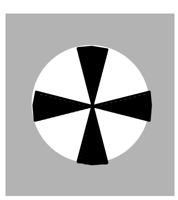
- Segmenting screen
  - Creating frame of reference
  - Position of object judged based on enclosing frame.



•16

6. Relative Size

- Smaller components tend to be perceived as objects

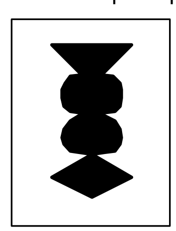


  - prefer horizontal and vertical orientations

•17

7. Figure and Ground

- Symmetry, white space, and closed contour contribute to perception of figure.



•18

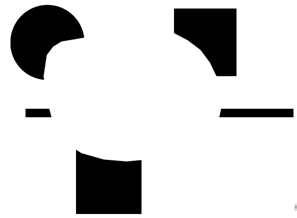
7. Figures and Grounds (cont.)

- Rubin's Vase
  - Competing recognition processes

•19

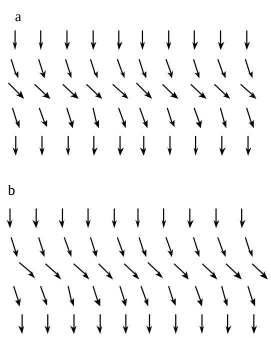
More Contours

- Illusionary contours
  - neural basis: feedback system



•20

More Contours

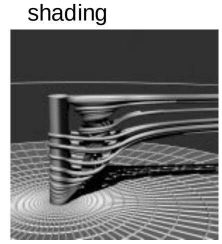


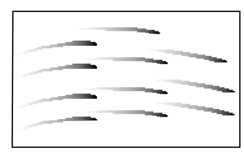
- Direct application to vector field display

•21

More Contours

- Contours and pen strokes, 3D, shading

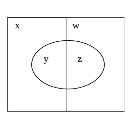




•22

Transparency

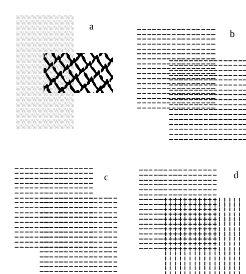
- Continuity is important in transparency
- x < y < z or x > y > z
- y < z < w or y > z > w



•23

More Transparency

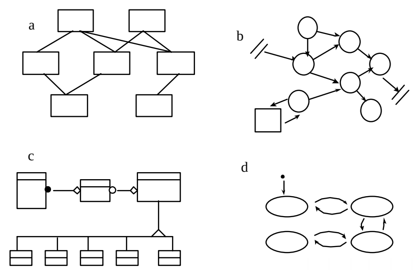
- Layered data: be careful with composites of textures



•24

Patterns in Diagrams

- Patterns applied



•25

Visual Grammar of diagram elements

Graphical code	Visual instantiation	Semantics
1. Closed contour		Entity, object, node
2. Shape of closed region		Entity type
3. Color of enclosed region		Entity type
4. Size of enclosed region		Entity value Larger = more
5. Partitioning lines within enclosed region		Entitity partitions are created e.g. treemaps.
6. Attached shapes		Attached entities Part_of relations
7. Shapes enclosed by contour		Contained entities

Visual Grammar of diagram elements

Graphical code	Visual instantiation	Semantics
8. Spatially ordered shapes		A sequence
9. Linking line		Relationship between entities
10. Linking line quality		Type of relationship between entity
11. Linking line thickness		Strength of relationship between entities
12. Tab connector		A fit between components
13. Proximity		Groups of components

•27

Visual Grammar of Map Elements

Graphical code	Visual Instantiation	Semantics
1. Closed contour		Geographic region
2. Colored region		Geographic region
3. Textured region		Geographic region
4. Line		Linear map features such as rivers, roads, etc. Depends on scale.
5. Dot		Point features such as town, building. Depends on scale
6. Dot on line		Point feature such as town on linear feature such as road.

•28

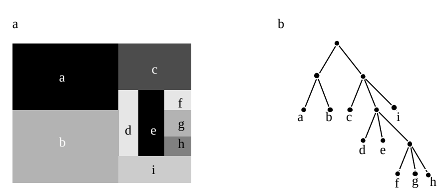
Visual Grammar of Map Elements

Graphical code	Visual Instantiation	Semantics
7. Dot in closed contour		Point feature such as town located within a geographic region.
8. Line crosses closed contour region		Linear feature such as river, crossing geographic region.
9. Line exits closed contour region		A linear feature such as a river terminates in a geographic region.
10. Overlapping contour, colored regions, textured regions.		Overlapping geographically Defined areas.

•29

Treemaps and hierarchies

- Treemap is an example of using these grammar to create new information visualizaitons.



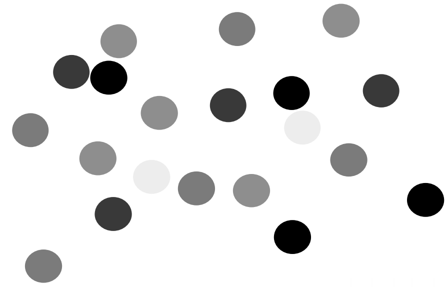
•30

Part II: Patterns in Motion

- How can we use motion as a display technique?

•31

Patterns in change blindness

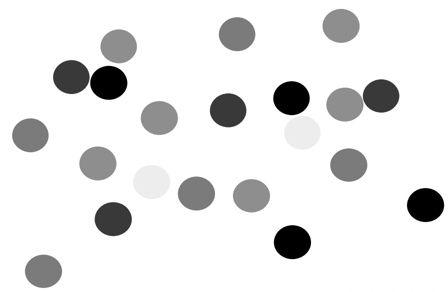


•32

Patterns in change blindness

•33

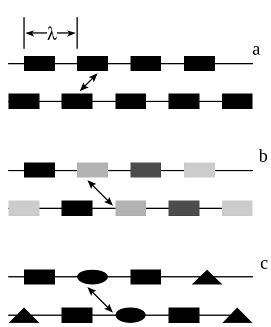
Patterns in change blindness



•34

Limitation due to Frame Rate

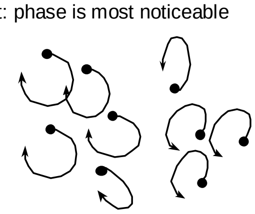
- Can only show motions that are limited by the Frame Rate.
- We can increase by using additional symbols.



•35

Motion as a visual attribute

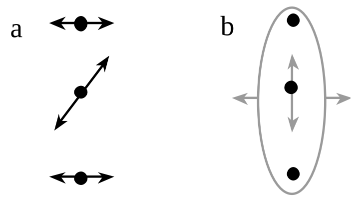
- correlation between points:
  - frequency, phase or amplitude
  - Result: phase is most noticeable



•36

Motion is Highly Contextual

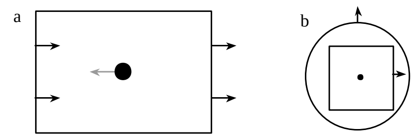
- Group moving objects in hierarchical fashion.



•37

Frame as motion context

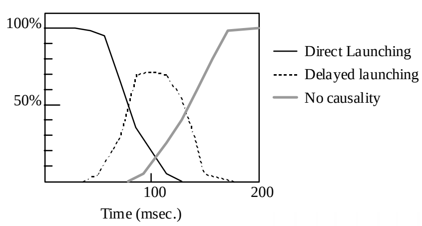
- **The stationary Dot is perceived as moving in (a).**
- **The circle has no effect on this process in (b).**



•38

Motion to express causality

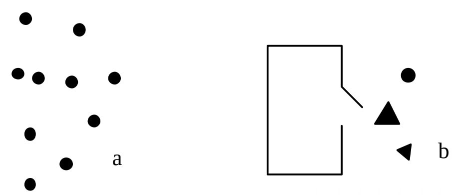
- Objects coming into contact



•39

Anthropomorphic Form from motion

- Pattern of moving dots (captured from actor body)
- Attach meaning to movements



•40

Can see Picture Objects in Rapid Sequences

- Up to 16 images for second in object identification
- Applications in image searching interfaces

•41

Summary

- Discovery of spurious patterns is a concern.
  - Understanding of pattern perception, therefore, is key.
- Gestalt Laws are useful as design guidelines.
- We have a rich set of visual grammar.
- Motion is under-researched, but evidence suggest its power.

•42

Tutorial Description for the Advance Program

Information Visualization and Visual Perception

Ed Chi– *Xerox PARC*
Stuart K. Card – *Xerox PARC*

BENEFITS

This 1-day tutorial will communicate a working knowledge of the field of information visualization including retrieved information from large document collections, the Web, and data bases. It will highlight the process of producing effective visualizations, making sense of information, and taking users' needs into account. Through an understanding of human perception learn to make data visualizations more effective. Appreciate what makes icons or data glyphs more visible, and how information should be organized for patterns to be perceived.

ORIGINS

The instructors presented tutorials on Information Visualization at CHI97, CHI98, CHI99, CHI 2000, and at SIGGRAPH 96 and co-organized the Information Visualization Symposia.

FEATURES

- Learning objectives are gaining a working knowledge of how to effectively visualize abstract information and how to apply this knowledge to specific areas.
- Effective use of color in classifying data , Making patterns in data easier to perceive, Pre-attentive processing theory and how it can be applied to grab attention, Object perception and the object display, Use and misuse of 3D viewing
- Visualization for problem solving

AUDIENCE

It should be of special interest to people designing data visualization applications, or engaged in visualization research. Anyone who is interested in understanding human perception and applications in data visualization. The participants should have some basic knowledge in graphics and visualization and interest to understand this emerging and significant area.

PRESENTATION

Lectures, demonstrations, and hands-on exercises

INSTRUCTORS

Ed H. Chi is currently doing visualization research at Xerox PARC where he is a Research Scientist. He has a PhD. in Information Visualization, and has won awards for both teaching and research. **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. Card is winner of 1999 CHI Achievement Award

CHI2002
Information Visualization and Visual Perception
Requirements List

Transparencies for students
Transparency pens for students
Overhead projector

We will need LCD Projectors to hook up our laptops.