Vorlesung
Advanced Topics in HCI
(Mensch-Maschine-Interaktion 2)

Ludwig-Maximilians-Universität München
LFE Medieninformatik
Heinrich Hußmann & Albrecht Schmidt
WS2003/2004
http://www.medien.informatik.uni-muenchen.de/

Chapter 2: Information Visualization

Table of Content

- Information & representation
- What is information visualization
- Perception basics
- Standard techniques
- Principles and Taxonomy
- Options for visualization & Examples

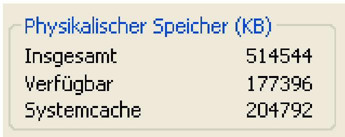
“Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.”

-- Edward R. Tufte

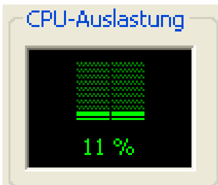
Representation

- What is a good Representation?
  - Capture and present the essential
  - Deliberately hide irrelevant parts
  - Appropriate for the recipient and his/her abilities
  - To understand and interpret by the recipient
  - Appropriate for the task
- “Solving a problem simply means representing it so as to make the solution transparent” (Simon, 1981)
- Allow people to look at the presentation and draw the “right” conclusions!

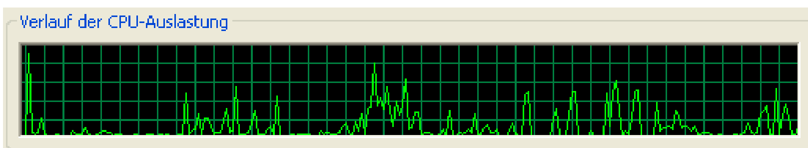
Representations



- Figures / numbers



- Numbers in bar graph
- Plot with history



How to read representations

- Read the plain facts
- Compare representations (visual calculations)
- Identify patterns
- Make interpretations

- Can be enhanced by active diagrams
  - Allow interactive manipulation

External aids for thinking

The power of the unaided mind is highly overrated. Without external aids, memory, thought, and reasoning are all constrained. But human intelligence is highly flexible and adaptive, superb at inventing procedures and objects that overcome its own limits. The real powers come from devising external aids that enhance cognitive abilities. How have we increased memory, thought, and reasoning? By the inventions of external aids: It is things that make us smart. (Norman, 1993)

- External cognition
  - Internal and external representation and processing weave together in thought
- External cognitive aids can enhance cognition
- An important class of external cognitive aids that make us smart are graphical inventions
  - Charts for navigation
  - Diagrams

Use of visual representations

- Pictures and diagrams are used to communicate existing ideas and thoughts
- Graphical representations can help in developing and formulating ideas and thoughts
- Using visual representations "to think"

Information – to visualize

- What is “Information”?
  - Entities, concepts, things, items that may not have a direct physical correspondence
  - Information is often abstract

- Large sets of data and information
  - Great amount of data
  - Information is generates in many processes

- visualize: to form a mental image or vision of …
- visualize: to imagine or remember as if actually seeing.
  (American Heritage dictionary, Concise Oxford dictionary)

What is Information Visualization

- The use of computer-supported, interactive visual representations of data to amplify cognition. (Card, Mackinlay Shneiderman ’98)

- ``Transformation of the symbolic into the geometric''
  (McCormick et al., 1987)

- ``... augmenting … natural intelligence in the best possible way, ... finding the artificial memory that best supports our natural means of perception.'‘ (Bertin, 1983)

- “The depiction of information using spatial or graphical representations, to facilitate comparison, pattern recognition, change detection, and other cognitive skills that make use of the visual system.” (Hearst, 2003, CHI-Tutorial)

Information Visualization

- The basic idea
  - Finding for information items an appropriate and meaningful mapping into a 2-D or 3-D physical space.
  - Creating a visual representation that helps to understand data and is useful for analysis and decision-making
- Visual representation are helpful
  - External cognition
  - frame of reference
  - “temp storage” for thinking
- “The purpose of visualization is insight, not pictures”
  - Insight – understanding, discovery, decision making, explanation

Definition by Shneiderman

Compact graphical presentation and
user interface for
manipulating large numbers of items (10^2 - 10^6),
possibly extracted from far larger datasets.
Enables users to make
discoveries,
decisions, or
explanations
about
patterns (trend, cluster, gap, outlier...),
groups of items, or
individual items.

Information Visualization is applicable to:

- Text, documents, text archives
- Databases
- Statistics
- Financial data, business data
- Geographic data
- Network information, internet information
- Software
- ...

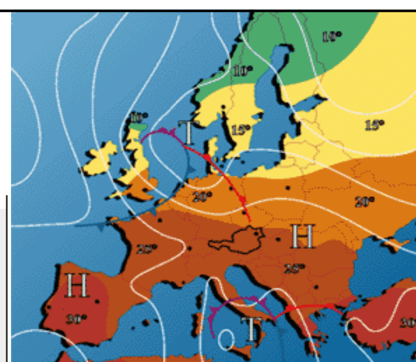
What tasks are supported by Information Visualization?

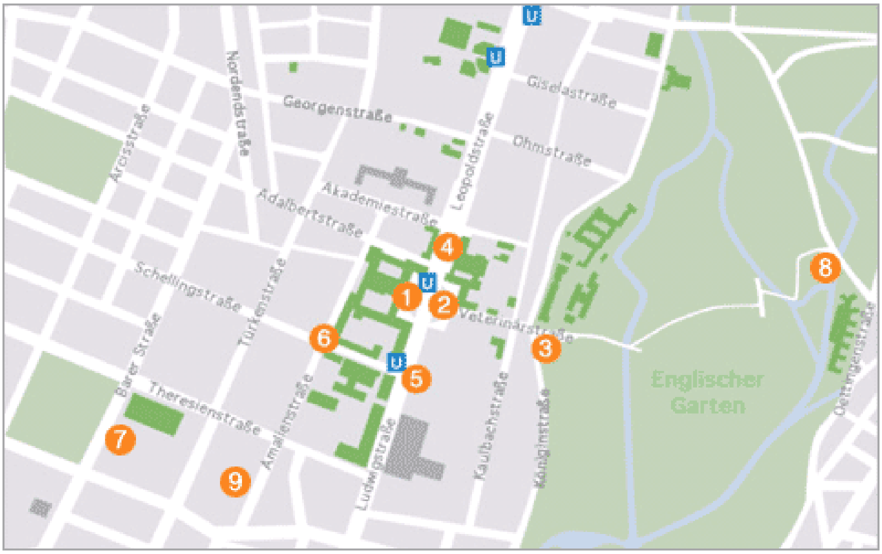
- Search
  - Finding a specific information in a data set
- Browse
  - survey, inspect, look for interesting information
- Analysis
  - Comparison-Difference, find outliers and extremes, spot patterns

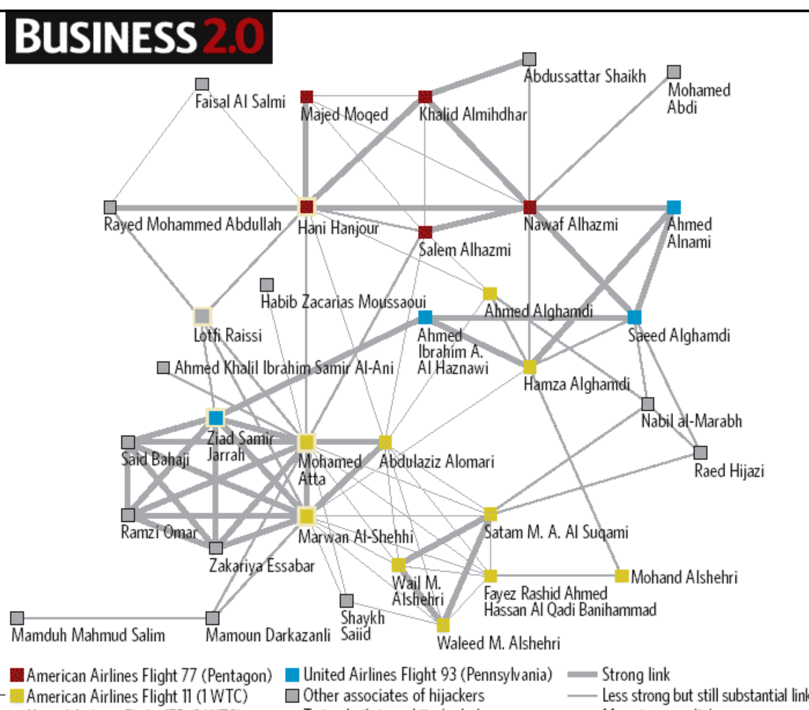
- Many more…
  - Categorize, Associate
  - Locate, Rank
  - Identify, Reveal
  - Monitor, Maintain awareness

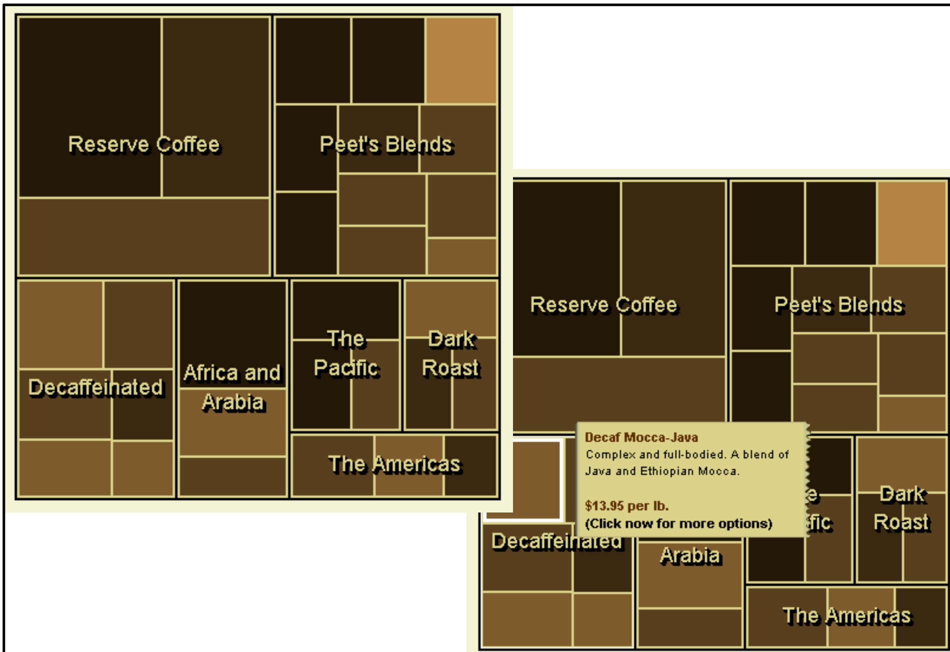
Examples


1997
1998
1999
2000
2001
2002
381,75
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
53,60
VOD.ISE
612 %HIGH-LOW
Splits
BPC
Volumen(rot-grün)
Steigende Kurse
Fallende Kurse
875M
555M
235M
(c) 2002 Innovative Software
Intervall: 1 Tag
24.05.02 14:43

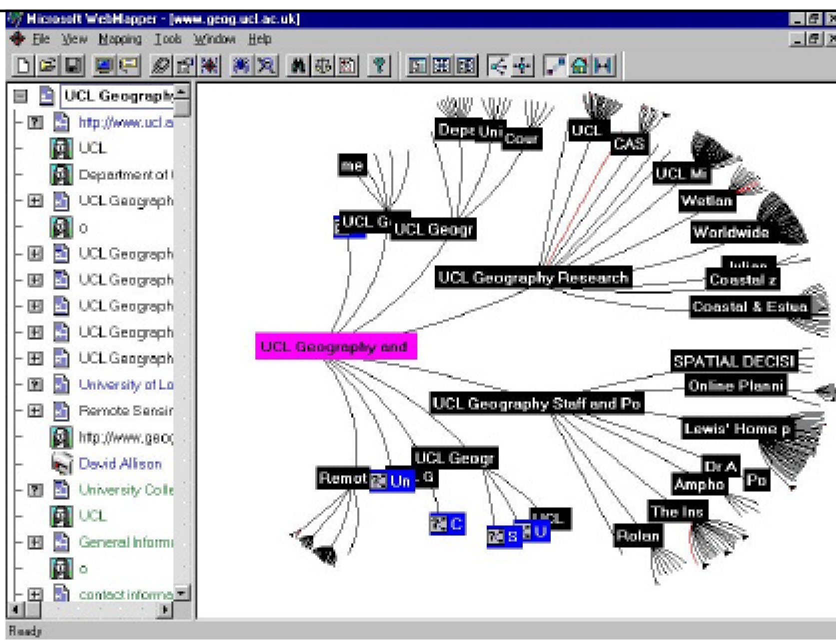

T
H
H
T


Nordendstraße
Georgenstraße
Giselastraße
Ohmstraße
Arcisstraße
Leopoldstraße
Akademiestraße
Adalbertstraße
Schellingstraße
Türkenstraße
Veterinärstraße
Barer Straße
Theresienstraße
Amalienstraße
Ludwigstraße
Kaulbachstraße
Königinstraße
Englischer Garten
Oettingenstraße
1
2
3
4
5
6
7
8
9


BUSINESS 2.0
Faisal Al Salmi
Majed Moqed
Khalid Almihdhar
Abdussattar Shaikh
Mohamed Abdi
Rayed Mohammed Abdullah
Hani Hanjour
Salem Alhazmi
Nawaf Alhazmi
Ahmed Alnami
Habib Zacarias Moussaoui
Ahmed Alghamdi
Lotfi Raissi
Ahmed Ibrahim A. Al Haznawi
Saeed Alghamdi
Ahmed Khalil Ibrahim Samir Al-Ani
Hamza Alghamdi
Nabil al-Marabh
Ziad Samir Jarrah
Said Bahaji
Mohamed Atta
Abdulaziz Alomari
Raed Hijazi
Ramzi Omar
Marwan Al-Shehhi
Satam M. A. Al Suqami
Zakariya Essabar
Wail M. Alshehri
Fayez Rashid Ahmed Hassan Al Qadi Banihammad
Mohand Alshehri
Mamduh Mahmud Salim
Mamoun Darkazanli
Shaykh Saiid
Waleed M. Alshehri
American Airlines Flight 77 (Pentagon)
American Airlines Flight 11 (1 WTC)
United Airlines Flight 175 (2 WTC)
United Airlines Flight 93 (Pennsylvania)
Other associates of hijackers
Trained pilots on hijacked planes
Strong link
Less strong but still substantial link
More tenuous link



http://www.peets.com/selector_coffee/coffee_selector.asp



http://www.cybergeography.org/atlas/siteanalyst.jpg

Goal of Information Visualization

- Use human perceptual capabilities to gain insights into large data sets that are difficult to extract using standard query languages
- Exploratory Visualization, look for
  - Structure
  - Patterns
  - Trends
  - Anomalies
  - relationships
- Provide a qualitative overview of large, complex data sets
- Help to find regions of interest and appropriate parameters for more focused quantitative analysis

Knowledge crystallization

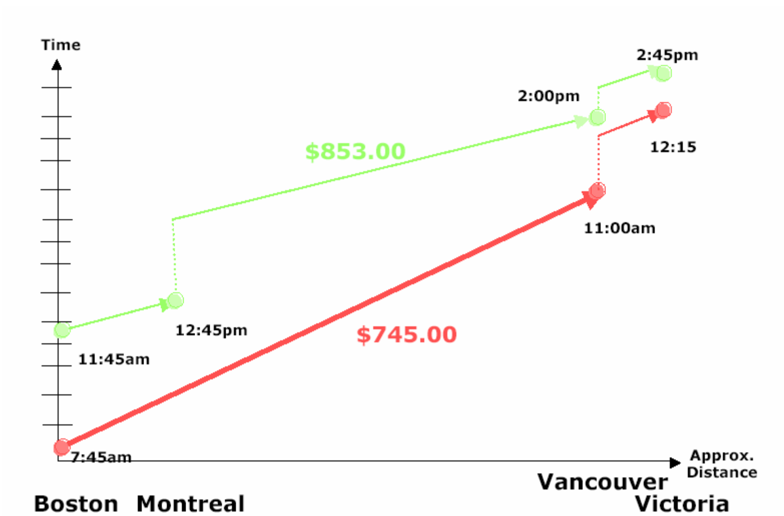
- Knowledge crystallization involves getting insight about data relative to some task
- Steps required in a Knowledge Crystallization task:
  - Information foraging/browsing (from repositories, people…)
  - Search for/build a schema (representation) –need to know what to include/omit
  - Instantiate schema with data
  - Problem solve to trade-off features
  - May have to search for a new schema..
  - Package the patterns found in some output product (i.e. a concise briefing of results)
- A visualization tool has to support or automate some of these steps, it is a cognitive aid during our process of schematization
- So we need data, a task and a schema

(Storey, 2004)

Example – Air fare (1)

(Storey, 2004)

Example – Air fare (2)



(Storey, 2004)

Knowledge crystallization (2)

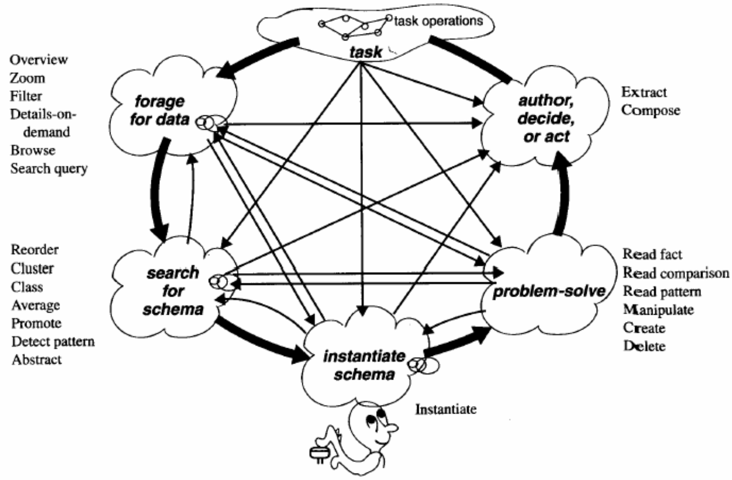


FIGURE **1.15**

Knowledge crystallization.

(Storey, 2004)

Mapping Problem

- A lot of information does not imply any obvious spatial mapping!
- Basic Question:
  How to map non-spatial abstractions into effective visual representation?
- Approach:
  Use interactive techniques and visual representations to augment or amplify the users cognition

How Information Visualization can Amplifies Cognition

Different ways that visualizations *could* help amplify cognition:

1. By increasing memory and processing resources available
   - Parallel perceptual processing
   - Offload work from cognitive to perceptual system
2. By reducing the amount of time to search
   - High data density
   - Greater access speed
3. Enhancing the detections of patterns and enabling perceptual inference operations
   - Abstraction and Aggregation
4. Aid perceptual monitoring
   - Color or motion coding to create pop out effect
5. By encoding information in an Interactive Medium

Information Visualization Basic Key Principles

- Abstraction
- Overview ➔ Zoom+Filter ➔ Details-on-demand
- Direct Manipulation
- Dynamic Queries
- Immediate Feedback
- Linked Displays
- Linking + Brushing
- Provide Focus + Context
- Animate Transitions and Change of Focus
- Output is Input
- Increase Information Density

Human Perception & Visual Properties

Human Perception & Visual Properties

- Preattentive Processing
- Accuracy of Interpretation of Visual Properties
- Illusions and the Relation to Graphical Integrity

All Preattentive Processing figures from Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

Users Expectations from the physical world

- Well-Defined Surfaces

  Objects have mostly smooth surfaces
- Temporal Persistence

  Objects don't randomly appear/vanish
- Light travels in Straight Lines

  reflects off surfaces in certain ways
- Law of Gravity

Hearst, 2003

Perception & Representation

- Sensory Representations

  Tap into Perceptual Power of Brain Without Learning
- Sensory Representations Effective

  because well matched to early stages of neural processing

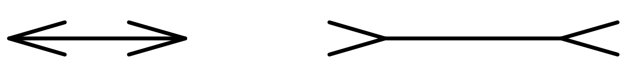
Visual Illusions

- People don’t perceive length, area, angle, brightness they way they “should”.
- Some illusions have been reclassified as systematic perceptual errors
  - e.g., brightness contrasts (grey square on white background vs. on black background)
  - partly due to increase in our understanding of the relevant parts of the visual system
- Nevertheless, the visual system does some really unexpected things.

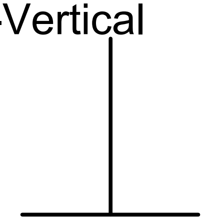
Hearst, 2003

Illusions of Linear Extent

- Mueller-Lyon (off by 25-30%)



- Horizontal-Vertical



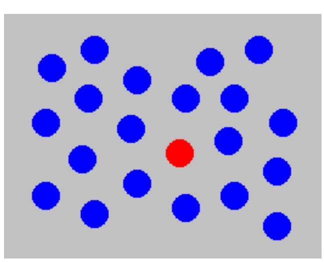
Hearst, 2003

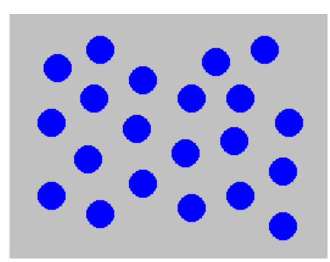
Preattentive Processing

- A limited set of visual properties are processed preattentively
  - (without need for focusing attention).
- This is important for design of visualizations
  - what can be perceived immediately
  - what properties are good discriminators
  - what can mislead viewers

Hearst, 2003

Example: Color Selection

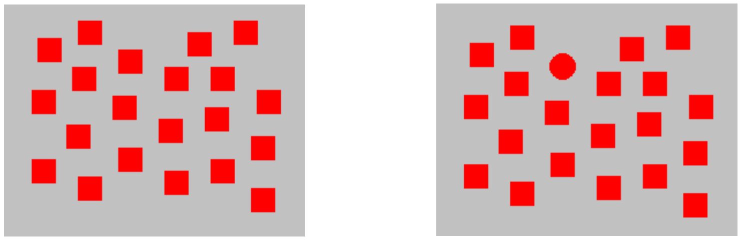




Viewer can rapidly and accurately determine whether the target (red circle) is present or absent. Difference detected in color.

Hearst, 2003

Example: Shape Selection



Viewer can rapidly and accurately determine whether the target (red circle) is present or absent. Difference detected in form (curvature)

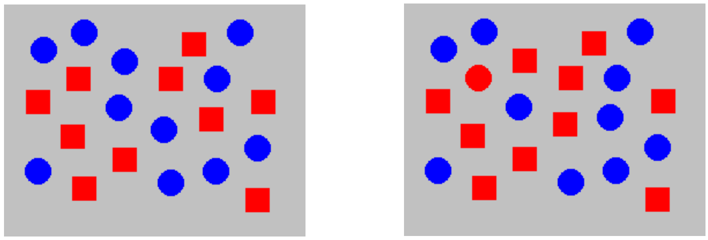
Hearst, 2003

Pre-attentive Processing

- < 200 - 250ms qualifies as pre-attentive
  - eye movements take at least 200ms
  - yet certain processing can be done very quickly, implying low-level processing in parallel
- If a decision takes a fixed amount of time regardless of the number of distractors, it is considered to be preattentive.

Hearst, 2003

Example: Conjunction of Features



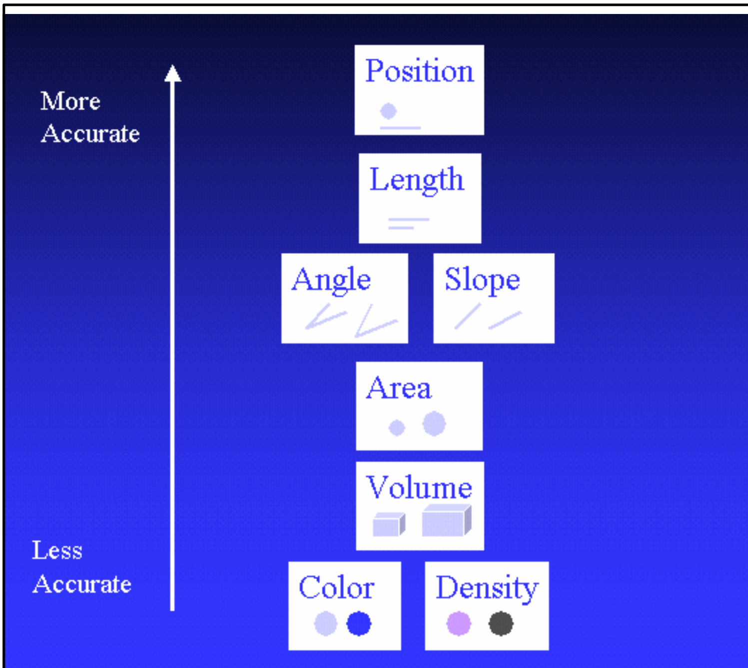
Viewer *cannot* rapidly and accurately determine whether the target (red circle) is present or absent when target has two or more features, each of which are present in the distractors. Viewer must search sequentially.

All Preattentive Processing figures from Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

Preattentive Visual Properties
(Healey 97)

length	Triesman & Gormican [1988]
width	Julesz [1985]
size	Triesman & Gelade [1980]
curvature	Triesman & Gormican [1988]
number	Julesz [1985]; Trick & Pylyshyn [1994]
terminators	Julesz & Bergen [1983]
intersection	Julesz & Bergen [1983]
closure	Enns [1986]; Triesman & Souther [1985]
colour (hue)	Nagy & Sanchez [1990, 1992]; D'Zmura [1991] Kawai et al. [1995]; Bauer et al. [1996]
intensity	Beck et al. [1983]; Triesman & Gormican [1988]
flicker	Julesz [1971]
direction of motion	Nakayama & Silverman [1986]; Driver & McLeod [1992]
binocular lustre	Wolfe & Franzel [1988]
stereoscopic depth	Nakayama & Silverman [1986]
3-D depth cues	Enns [1990]
lighting direction	Enns [1990]

Hearst, 2003



Accuracy Ranking of Quantitative Perceptual Tasks Estimated; only pairwise comparisons have been validated (Mackinlay 88 from Cleveland & McGill)

Hearst, 2003

Interpretations of Visual Properties

Some properties can be discriminated more accurately but don’t have intrinsic meaning

(Senay & Ingatious 97, Kosslyn, others)

- Density (Greyscale)
  Darker -> More
- Size / Length / Area
  Larger -> More
- Position
  Leftmost -> first, Topmost -> first
- Hue
  ??? no intrinsic meaning
- Slope
  ??? no intrinsic meaning

Hearst, 2003

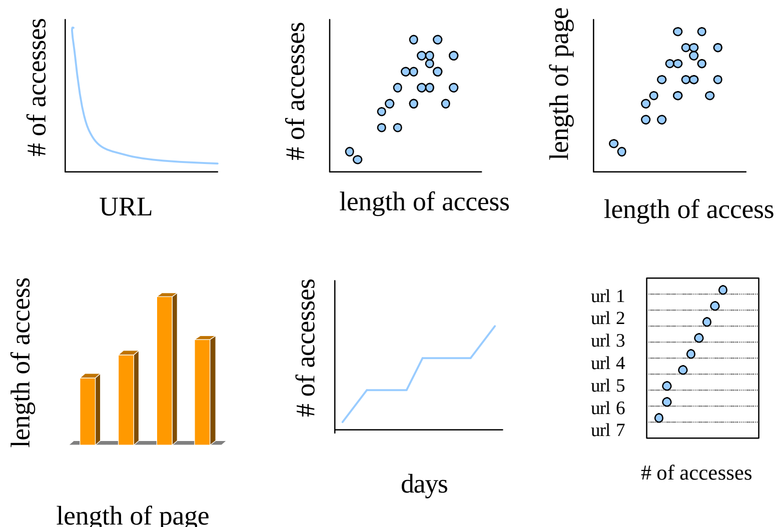
Ranking of Applicability of Properties for Different Data Types
(Mackinlay 88, Not Empirically Verified)

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density	Color Hue
Angle	Color Saturation	Texture
Slope	Color Hue	Connection
Area	Texture	Containment
Volume	Connection	Density
Density	Containment	Color Saturation
Color Saturation	Length	Shape
Color Hue	Angle	Length

Hearst, 2003

Standard Visualization

Common Graph Types



Hearst, 2003

When to use which type?

- Line graph
  - x-axis requires quantitative variable
  - Variables have contiguous values
  - familiar/conventional ordering among ordinals
- Bar graph
  - comparison of relative point values
- Scatter plot
  - convey overall impression of relationship between two variables
- Pie Chart?
  - Emphasizing differences in proportion among a few numbers

Experimentally Motivated Classification (Lohse et al. 94)

- Graphs
- Tables (numerical)
- Tables (graphical)
- Charts (time)
- Charts (network)
- Diagrams (structure)
- Diagrams (network)
- Maps
- Cartograms
- Icons
- Pictures

References

- Marti Hearst
  - http://bailando.sims.berkeley.edu/infovis.html
  - http://bailando.sims.berkeley.edu/talks/chi03-tutorial.ppt
- Margret-Anne Storey
  - http://www.csr.uvic.ca/~mstorey/
  - http://www.cs.uvic.ca/~mstorey/teaching/infovis/course_notes/introduction.pdf
- Ben Shneiderman
  - http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/readings/shneiderman96eyes.pdf