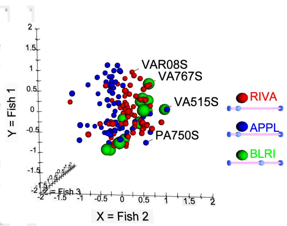
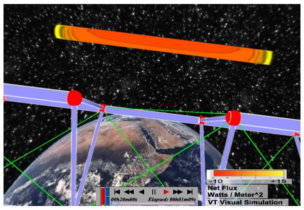
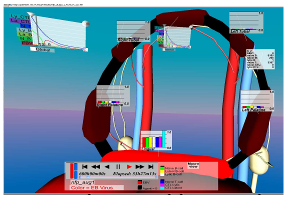






Visualization (part 1)

Nicholas F. Polys, Ph.D.
VT Research Computing

Overview

- Designing Graphics for Communication
  - Visualization Principles
- Publishing Graphics
  - Data formats & Tools
- Resources for Visualization
  - Research Computing
  - Center for HCI
  - Proposal Boilerplates

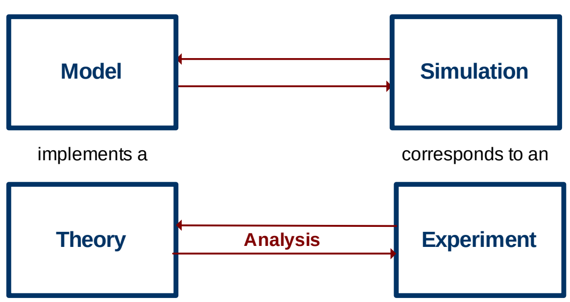
theory = conceptual description of reality

experiment = test theory in physical world

Scientific method, 15th-20th centuries

model = formal representation of reality

simulation = behavior of model over time

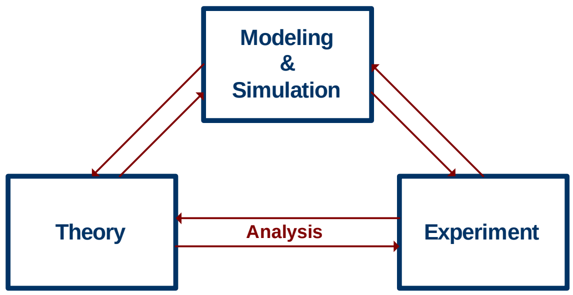


Scientific method, 1950-present

running together

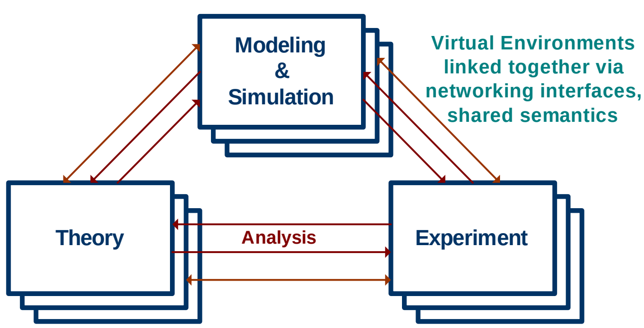
model = formal representation of reality

simulation = behavior of model over time



Scientific method, 1950-present

Virtual environments can connect
all models and simulations together



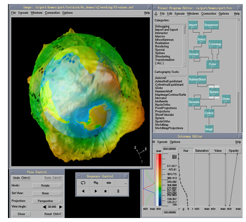
Scientific method, emerging 21 st century

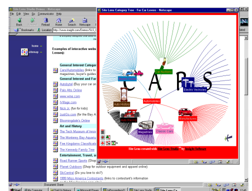
Visualization: definition

- Generally:
  - The use of computer-supported, interactive, visual representations of data to amplify cognition

    Card, McKinlay and Schneiderman

  - Scientific Visualization
  - Information Visualization
  - Virtual Environments





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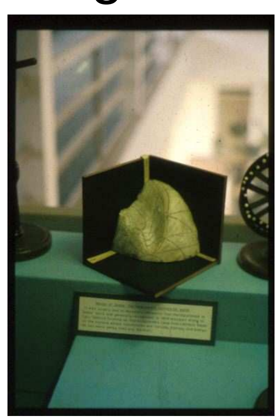
Visual Thinking

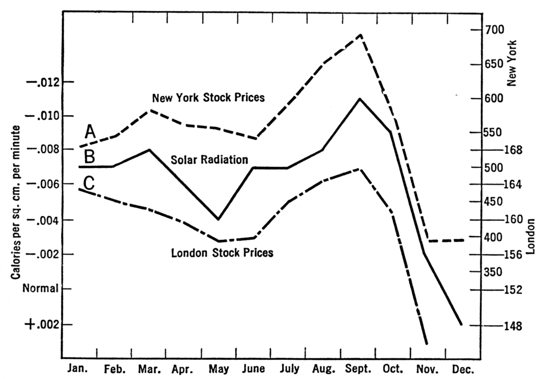
- Many of the great scientists were good at visual thinking:
  - Leonardo da Vinci
  - James Clerk Maxwell
  - Michael Faraday
  - Albert Einstein
- This was often at the expense of verbal skills
- Tom West : “In the Mind’s Eye”
  - See also http://www.krasnow.gmu.edu/twest/maxwell_visual.html



Maxwell’s clay model now in
New Cavendish Laboratory, Cambridge
(picture by Tom West)

Virginia Tech

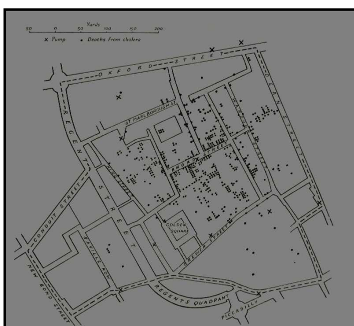
Of course, statistical graphics, just like statistical calculations, are only as good as what goes into them. An ill-specified or preposterous model or a puny data set cannot be rescued by a graphic (or by calculation), no matter how clever or fancy. A silly theory means a silly graphic:

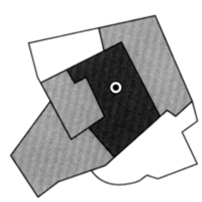


Solar Radiation and Stock Prices

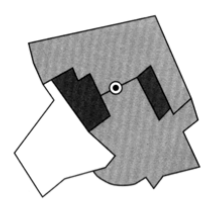
A. New York stock prices (Barron's average). B. Solar Radiation, inverted, and C. London stock prices, all by months, 1929 (after Garcia-Mata and Shaffner).

Tufte



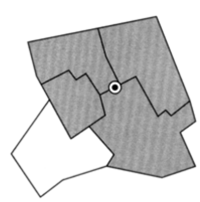


In this aggregation of individual deaths into six areas, the greatest number is concentrated at the Broad Street pump.



In this aggregation of the deaths, the two areas with the most deaths do not even include the infected pump!

[18] Mark Monmonier, *How to Lie with Maps* (Chicago, 1991), pp. 142–143.



Using different geographic subdivisions, the cholera numbers are nearly the same in four of the five areas.

Visual Analysis Overview

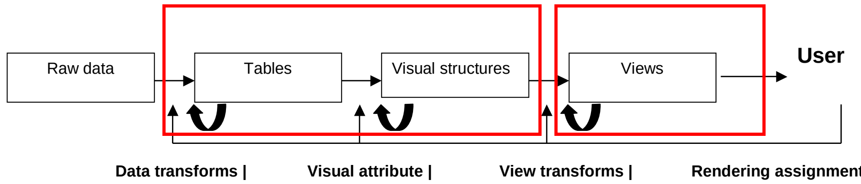


Figure 2.1: Processing in a typical visualization pipeline (from Card et al, 1999)

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First Steps

Extract data and Map

- **Data transformation**
  - Raw data -> attributes of interest
  - File formats or scripts are usually employed
- **Visual attributes**
  - Assign attributes -> visual representation
  - Typically use some tool (e.g. Paraview, Excel, Gnuplot)

Virginia Tech

Second Steps

Publish and Deliver

- **View transformation**
  - ‘Camera’ location and properties
- **Rendering assignment**
  - Print vs. interactive
  - Resolution, size
  - Stereo, immersion

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Visual Analysis Overview

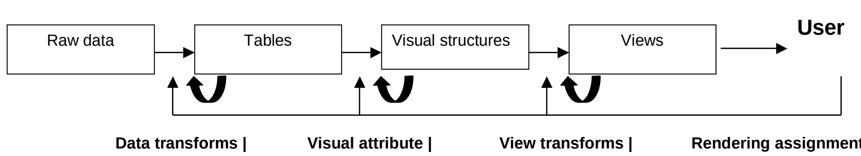

Figure 2.1: Processing in a typical visualization pipeline (from Card et al, 1999)

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Rewind- to first principles

- The human mind is still the best analyst; how do we:
  - discover trends and relationships
  - communicate concept and results graphically
- How can perception inform design?

Virginia Tech

What is HCI?

- A multidisciplinary science of the interface: *psychology, design & media, human factors, sociology, computer science*

- Experimental methods to rationalize UI features, design, and software architecture

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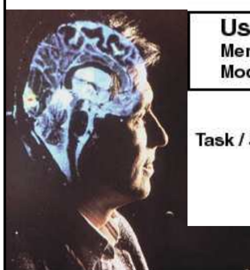
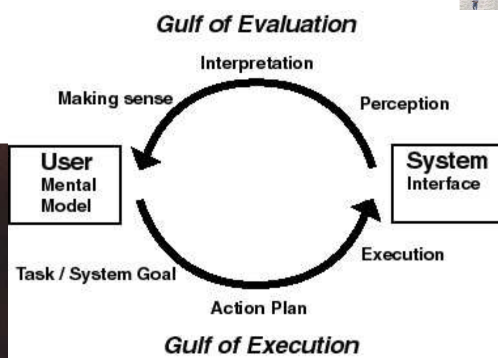
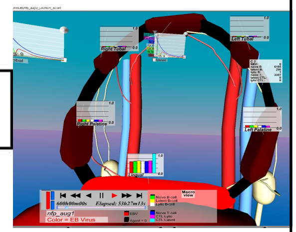
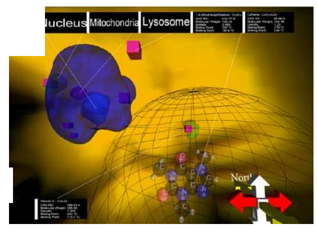
Norman's Gulfs









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Don Norman, 1986

Communication Across the Gulfs

User-centered design:

- ***Evaluation*** : Information Design
  - What do I see?
  - What does it mean?

- ***Execution*** : Interaction Design
  - What is my next goal?
  - How do I achieve it?
  - Make it happen!

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Information Design

Goal: identify methods for representing and arranging the objects and actions possible in a system in a way that facilitates perception and understanding

Virginia Tech

Information Design

- Define and arrange the visual (and other modality) elements of a user interface
  - Screen layout, icon design, vocabulary selection
  - But also the “big picture” or overall info model
  - Models of perception, psychology guide this
- Engineering an information design
  - Make sure what people see (hear, etc.) makes sense, and helps them to pursue meaningful goals
  - Depends on *what they are doing*, hence the important role of user interaction scenarios

Virginia Tech

Good Graphics

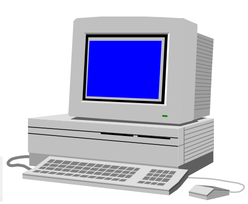
- Precision
- Clarity
- Maximize Data-to-ink ratio
  - Data Ink Ratio = (data ink) / (total ink in the plot)
- Minimize Lie factor
  - Lie factor = (size of graphic) / (size of data)

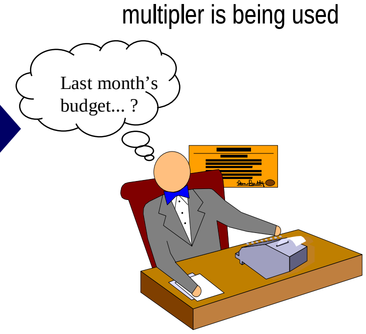
Making Sense of an Information Display

Interpretation
Excel worksheet, a cell is selected, formula is displayed at top

Perception
color, shading, lines characters, squares, spatial organization

Making Sense
Income worksheet, Total tax income is being calculated, the wrong multipler is being used





Perception for Design

- Using our understanding of the human perceptual systems to guide design
  – Visual system
  – Auditory system
  – Vestibular system
- Leverage pre-attentive facilities
- Reduce cognitive overhead

Virginia Tech

Perception

- Organize and encode sensory data in the mind
  – Lines, shapes, colors are "extracted"
  – Very fast, generally with no conscious thought
  – May be influenced by expectations, "top-down"
- Low-level units then grouped and organized
  – Perceived as rows, columns, grids, figures
  – Seeing the relationships among different elements
- Design goal: make this perceptual process rapid and accurate

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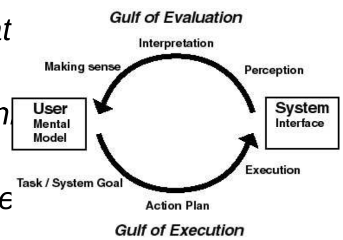
Background: Information Psychophysics

- Edward Tufte, *Envisioning Informat*
  (1983, 1990)
- Jaques Bertin, *Semiology of Graph*
  (1983)
- Donald Norman, *Cognitive Enginee*
  (1986)
- Joseph Goguen, *Semiotic Morphisms*
  (2000)
- Colin Ware, *Perception for Design*
  (2003)



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Pre-attentive Processing

- Involuntary, do not require conscious attention
- Parallel
- Efficient
- Resistant to instruction

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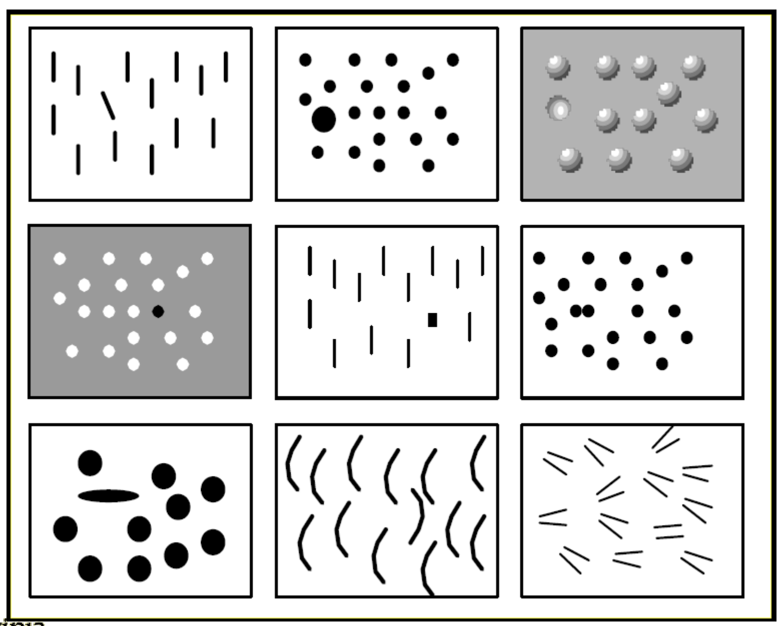
Attention

- Pop out effects ‘stand out’ in some simple dimension (conjunctions don’t):
  – Rapid visual search
  – Form, color, simple motion/blinking, spatial stereo depth, shading, position

12987621909023748
59432908706548394
05602485954372890
09890509874632234



Ware

Frame Rate

- Threshold for perceiving continuity:
  - flicker < 50 Hz
  - > 24 fps looks smooth & plenty interactive
- Flicker & Attention can lead to change blindness (Simmons, 2000)

- Browser.getCurrentFrameRate()
- Implementing X3DPerFrameObserverScript
  - public void prepareEvents (){}

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Attention and blindness

- http://viscog.beckman.uiuc.edu/djs_lab/demos.html
- http://www.psych.ubc.ca/~rensink/flicker/
  - http://www.psych.ubc.ca/~rensink/flicker/download/index.html

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Animation Guidelines

- The higher the frame-rate the better
- Beware data assumptions:

  Interpolation versus Sequencing
- Provide user control over time ?

  (e.g. DVDTimeController)

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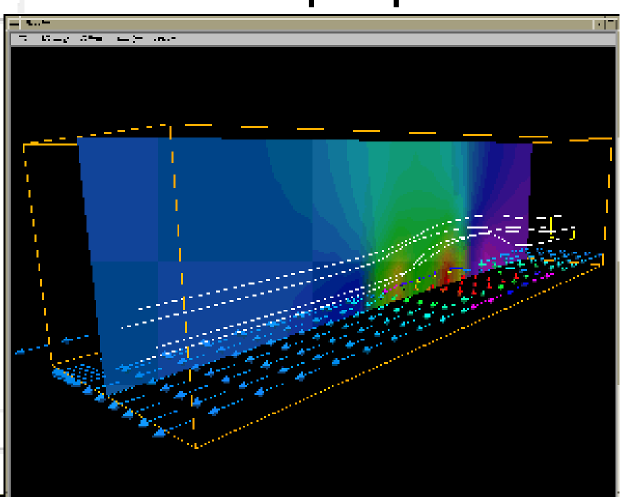
Representing multiple properties



- Flow of air around a car
  - Vectors and particle paths illustrate flow
  - Coloured slice indicates pressure

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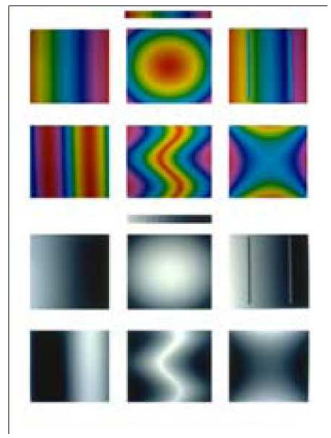
Features: Color

- Luminance channel (3x spatial accuity)
- Red / Green channel
- Yellow / Blue channel

The spectrum is not a perceptually linear sequence (not pre-attentive)!
(Keller 1993; Ware, 2000)



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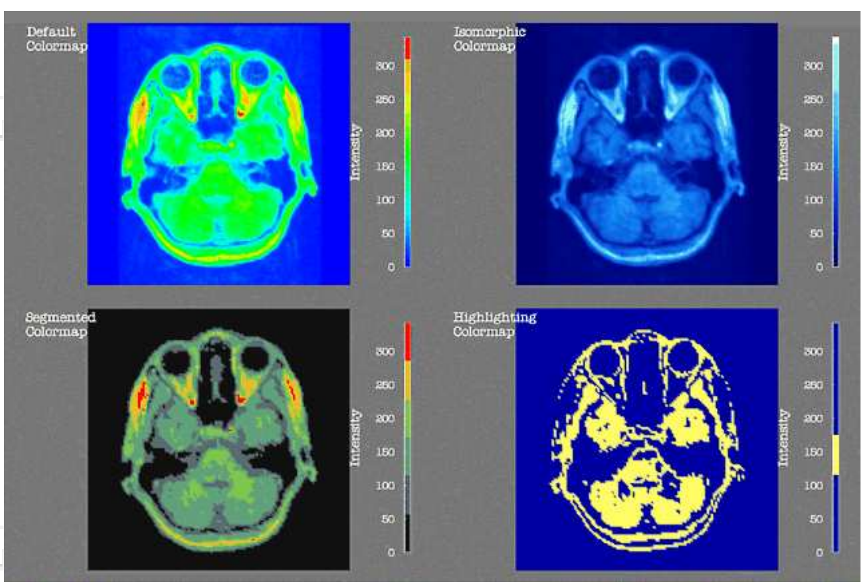
Ware



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IBM

Color (again)

- **IBM Research and color maps:**
  http://www.research.ibm.com/dx/proceedings/pravda/truevis.htm

- **Human factors in visualization research**
  Tory, M.; Moller, T.;
  Visualization and Computer Graphics, IEEE Transactions on
  Volume 10, Issue 1, Jan-Feb 2004 Page(s):72 - 84
  http://doi.ieeecomputersociety.org/10.1109/TVCG.2004.1260759

- **Color Spectra and Scales**
  http://geography.uoregon.edu/datagraphics/EOS/Light&Bartlein_EOS2004.pdf

- **Some guidelines for Sci Vis:**
  http://www-ugrad.cs.colorado.edu/~csci4576/SciVis/SciVisColor.html#ColorGuidelines

- **More detail about CG color models**
  http://www.ncsu.edu/scivis/lessons/colormodels/color_models2.html

Making Sense of an Information Display

Perception
color, shading, lines
characters, squares,
spatial organization

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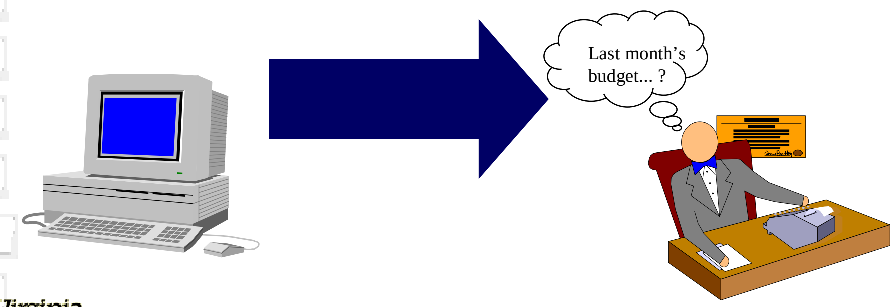

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Interpretation

- Perceiving enables interpretation
  - Perceptual processing identifies major display structures (rectangles, text strings, etc)
  - Users must interpret what these display structures mean in the system
- Designers must anticipate and support user reactions to interface elements
  - Choosing familiar images, symbols, words
  - Refining elements through abstraction
  - Promoting affordances that users can recognize

Virginia Tech

Depth Cues

Structure the world- locating objects and relationships in space

- Stereoscopy
- Motion parallax
- Relative size / scale
- Fog / atmosphere…

Virginia Tech

Patterns & Grouping

- Gestalt principles

- Also: continuation, closure, common fate
- Guiding Law of Pragnanz (simplest, most stable configuration)

Gestalt principles

- Palmer & Rock, 1990– review & update principles; grouping based on perceived proximity in 3D space (not 2D proximity on retina)
- Quinlan & Wilton, 1998 – study involving Gestalt conflict; proposed resolution mechanisms
- Polys 2006 – users rely on different cues depending on the task and display venue

Objects

- Feature Binding – putting the streams together for internal represenation
  - color, form, motion
  - Just in time?
- 2.5 D sketch (Marr, 1982)
- Geons (Biederman, 1993)

Virginia Tech

Fundamental Data Types

- Spatial / perceptual data:

  geometry, colors, textures, lighting
- Abstract data / world & object attributes:

  nominal, ordinal, quantitative
- Temporal data / behaviors:

  states, dynamics

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InfoVis: Visual Markers

Data Type	Quantitative	Ordinal	Nominal
Graphical Representation	position length angle / slope area volume color / density (Cleveland and McGill, 1980)	position density color texture connection containment length angle slope area volume (Mackinlay, 1986)	position color texture connection containment density shape length angle slope area volume (Mackinlay, 1986)

MOST (PRE-ATTENTIVE) LEAST

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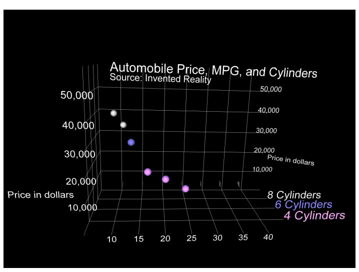

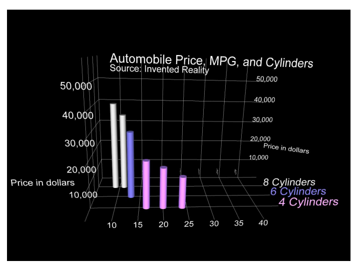

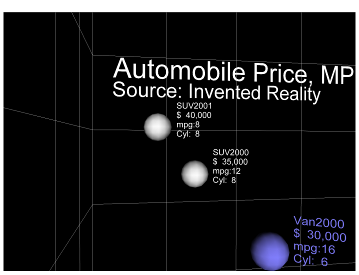

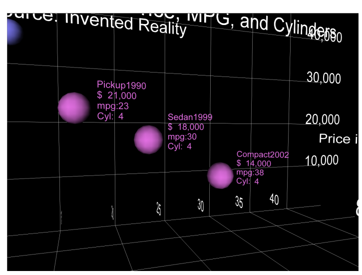

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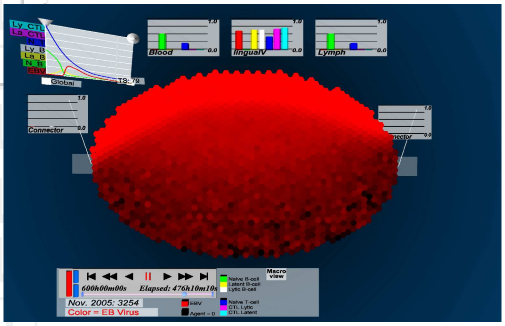
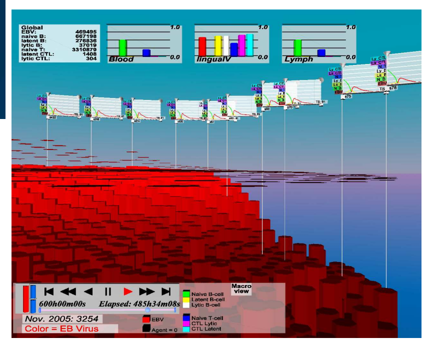
PathSim example



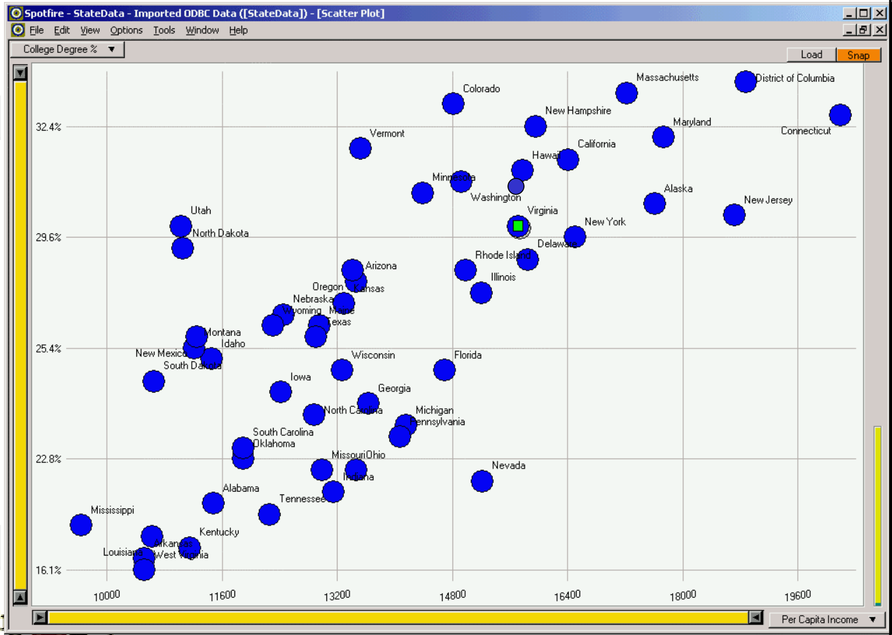


Virginia Tech

- Which state has highest income?
- Relationship between income and education?
- Outliers?

Table - StateData ()

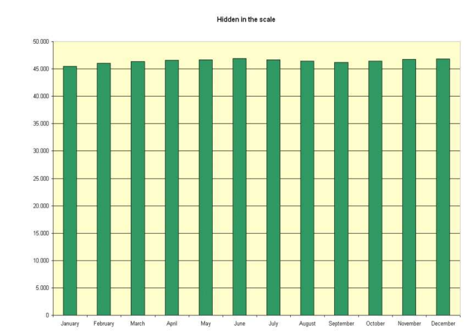
State	College Degree %	Per Capita Income
Alabama	20.6%	11486
Alaska	30.3%	17610
Arizona	27.1%	13461
Arkansas	17.0%	10520
California	31.3%	16409
Colorado	33.9%	14821
Connecticut	33.8%	20189
Delaware	27.9%	15854
District of Columbia	36.4%	18881
Florida	24.9%	14698
Georgia	24.3%	13631
Hawaii	31.2%	15770
Idaho	25.2%	11457
Illinois	26.8%	15201
Indiana	20.9%	13149
Iowa	24.5%	12422
Kansas	26.5%	13300
Kentucky	17.7%	11153
Louisiana	19.4%	10635
Maine	25.7%	12957
Maryland	31.7%	17730
Massachusetts	34.5%	17224
Michigan	24.1%	14154
Minnesota	30.4%	14389
Mississippi	19.9%	9648
Missouri	22.3%	12989
Montana	25.4%	11213
Nebraska	26.0%	12452
Nevada	21.5%	15214
New Hampshire	32.4%	15959
New Jersey	30.1%	18714
New Mexico	25.5%	11246
New York	29.6%	16501
North Carolina	24.2%	12885
North Dakota	28.1%	11051
Ohio	22.3%	13461
Oklahoma	22.8%	11893
Oregon	27.5%	13418
Pennsylvania	23.2%	14068
Rhode Island	27.5%	14981
South Carolina	23.0%	11897
South Dakota	24.6%	10661
Tennessee	20.1%	12255
Texas	25.5%	12904
Utah	30.0%	11029
Vermont	31.5%	13527
Virginia	30.0%	15713
Washington	30.9%	14923
West Virginia	16.1%	10520
Wisconsin	24.9%	13276
Wyoming	25.7%	12311

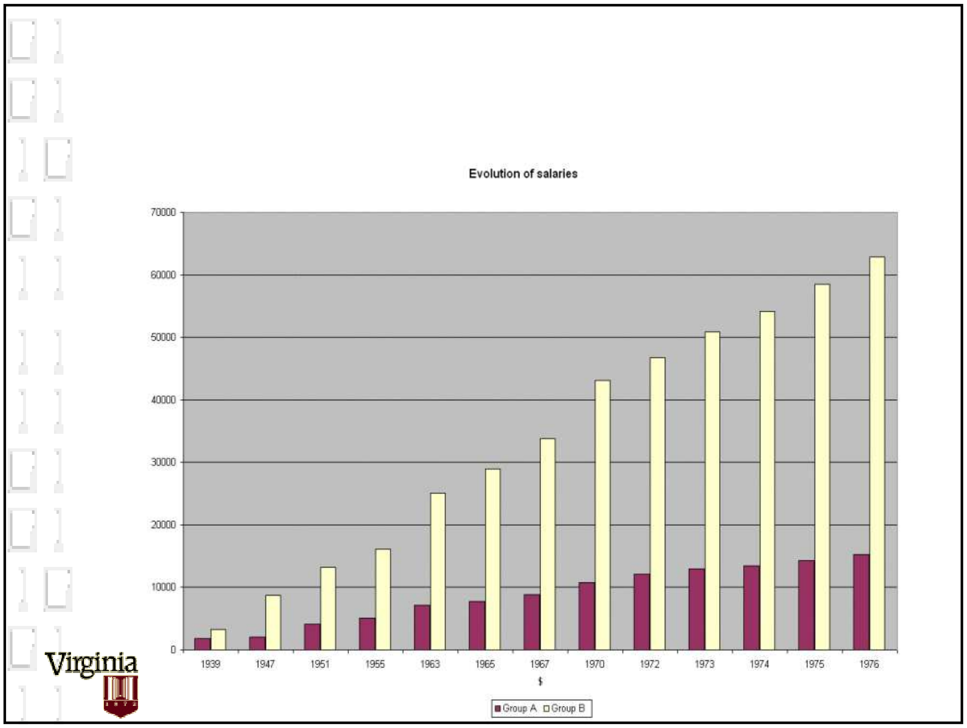


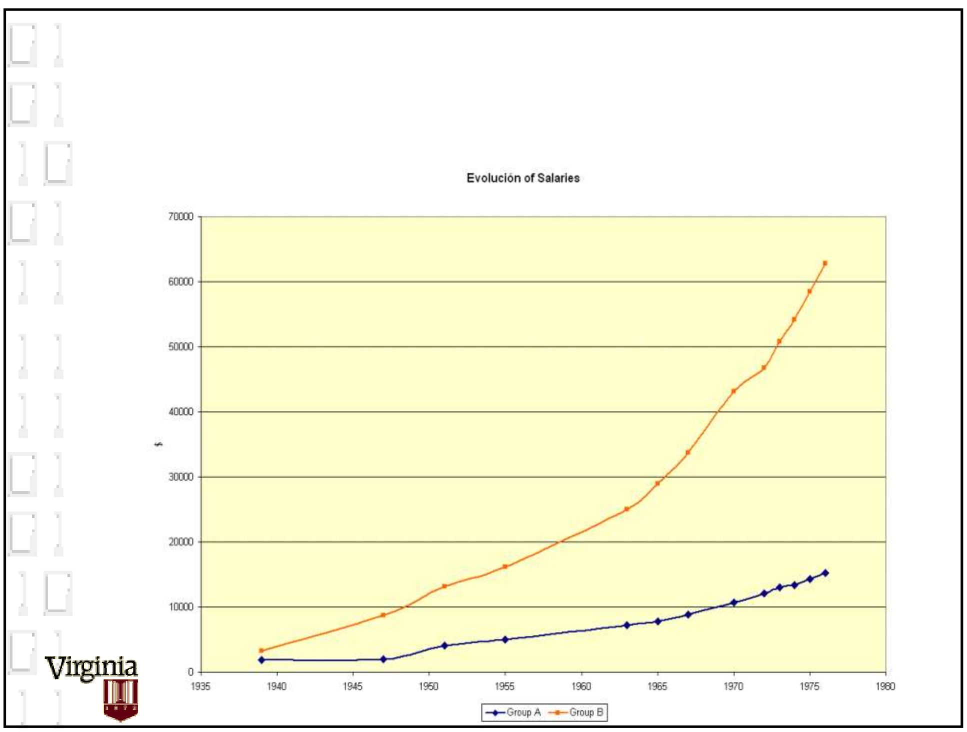
College Degree %

Per Capita Income

Scale

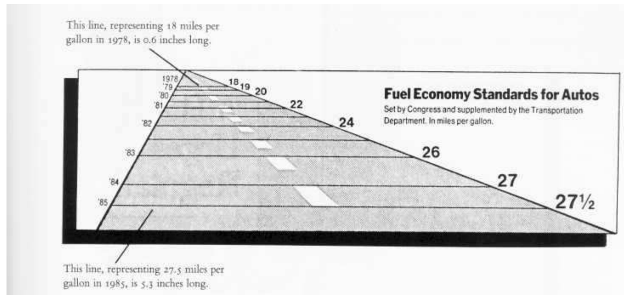



Evolution of salaries
70000
60000
50000
40000
30000
20000
10000
0
1939
1947
1951
1955
1963
1965
1967
1970
1972
1973
1974
1975
1976
$
Group A
Group B
Virginia

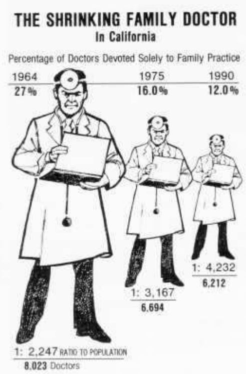

Evolución of Salaries
70000
60000
50000
40000
30000
20000
10000
0
$
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
Group A
Group B
Virginia

Lying

From Tufte
1983

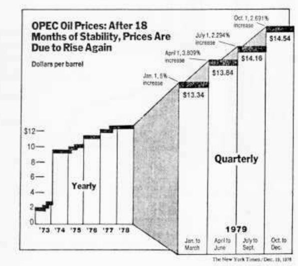


New York Times, August 9, 1978, p. D-2.



Los Angeles Times, August 5, 1979, p. 3.

Design variation corrupts this display:



New York Times, December 19, 1978, p. D-7.

Human Limitations for Short-Term Memory

- Miller's 7 +/- 2 magic number
  - People can recognize 7 +/- 2 chunks of information at a time and hold these chunks in memory for 15-30 seconds
- Chunking
  - Ability to cluster information together
  - Size of chunk depends on knowledge, experience, and familiarity

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Chunking Example 1

HEC ATR ANU PTH ETR EET

Chunking Example 2

THE CAT RAN UP THE TREE

Other Chunking Examples

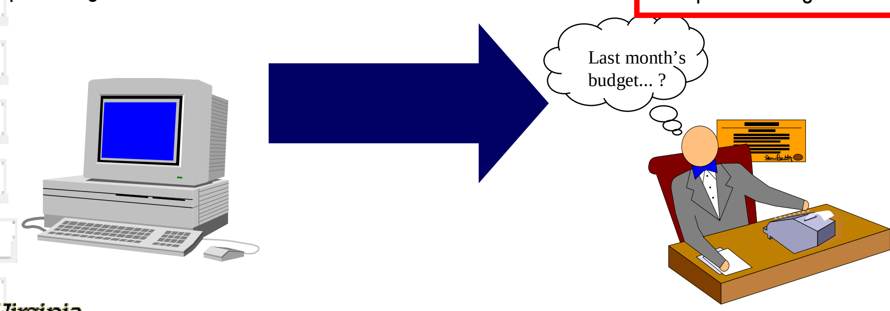
- Image sequences
- Facial recognition
- Word/letter familiarity
- Hierarchies of information
- Others?

Making Sense of an Information Display

Interpretation
Excel worksheet, a cell is selected, formula is displayed at top

Perception
color, shading, lines characters, squares, spatial organization

Making Sense
Income worksheet, Total tax income is being calculated, the wrong multipler is being used

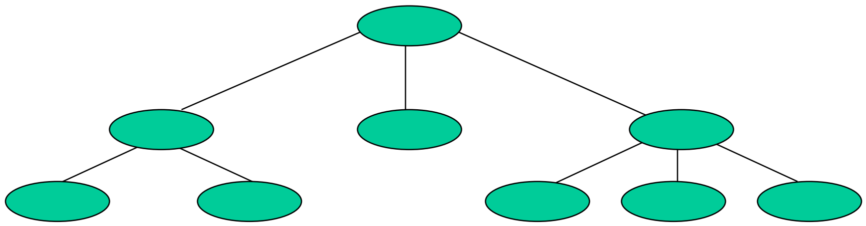


Making Sense

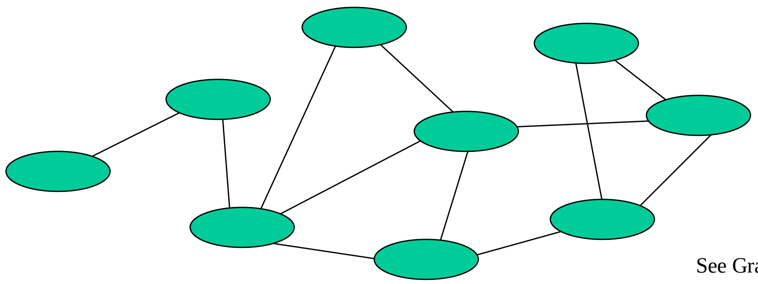
- Last step in crossing the Gulf of Evaluation
  - Information has been perceived and interpreted
  - Users must "make sense" of information by relating it to their tasks, goals, and interests
- Designers must support people's abilities to detect patterns and relationships
  - Consistent use of shape, size, color, position
  - Information models (e.g., hierarchies) organize data
  - Dynamic displays cue users to structure

Important Considerations

- Understanding the domain
- Understanding the Research Question
- Understanding the purpose of the Vis
  - User and reader tasks

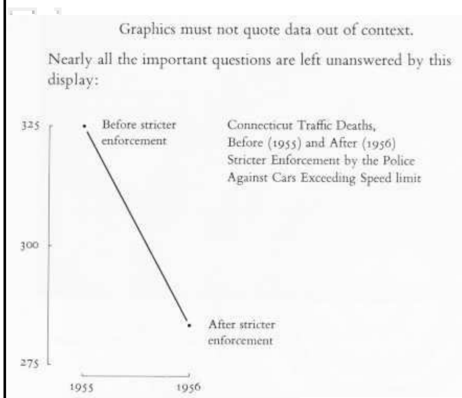


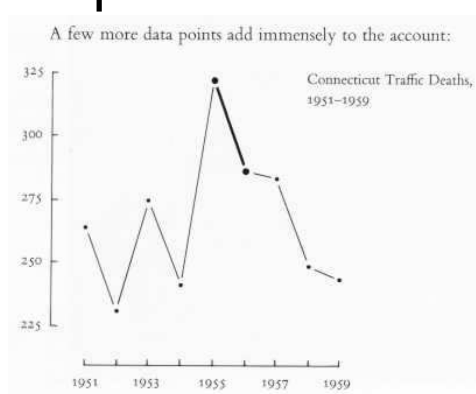
Which network is easier to understand?

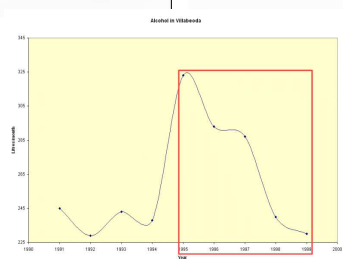


See Graph Vis !

Context Required







Virtual Environments

- Leveraging Spatial perception and knowledge
- Examples
- More next time!

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ParaView

- Use your knowledge to present the important aspects of the simulation data as:
- An image
- A movie

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