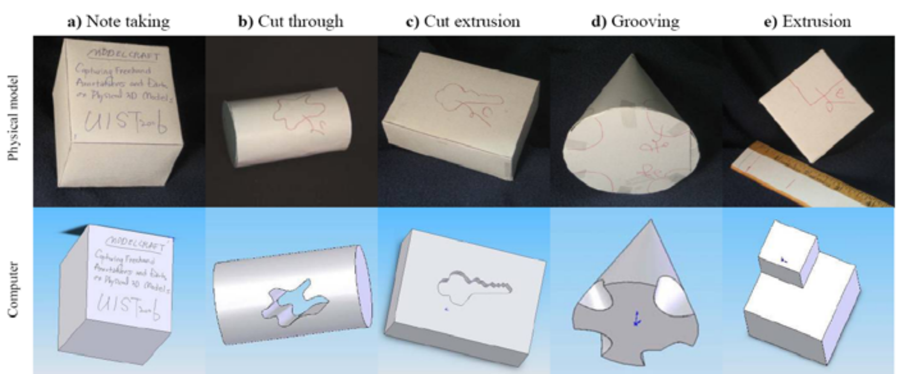
Visual Information Design

CS160: User Interfaces
Maneesh Agrawala



ModelCraft: Capturing Freehand Annotations and Edits on Physical 3D Models [Song 06]

VIDEO

Upcoming Schedule

Pilot User Study (due today before class)

Final Presentation and Report (due Apr 29)

- Revise interface based on pilot study
- Last chance to finish implementation
- Presentations held in my office Apr 29 and May 1
  - Sign up for 15 min slot
- We are planning a project fair for Tue May 6 3:30-5pm

Topics

- Why do we create visualizations?
- Data and image
- Estimating magnitude
- Deconstructions

Why Do We Create Visualizations?

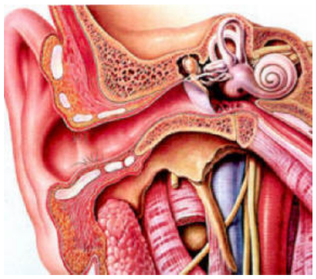
What is Visualization?

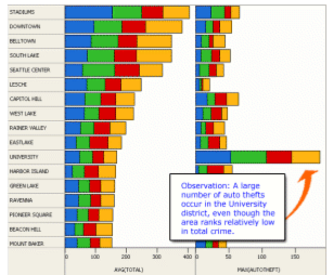
Definition **[www.oed.com]**

1. The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed.

2. The action or process of rendering visible.

Examples





Why Do We Create Visualizations?

Three Primary Functions

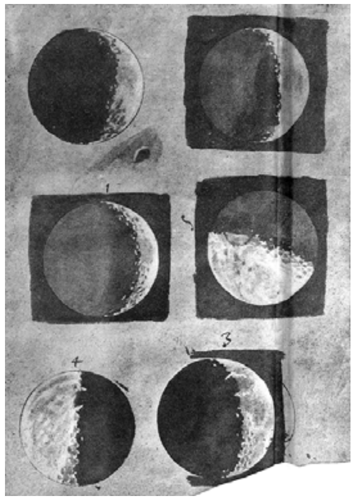
Record information
- Photographs, blueprints, …

Support reasoning about information (analyze)
- Process and calculate
- Reason about data
- Feedback and interaction

Convey information to others (present)
- Share and persuade
- Collaborate and revise
- Emphasize important aspects of data

Record Information

Drawing: Phases of the Moon

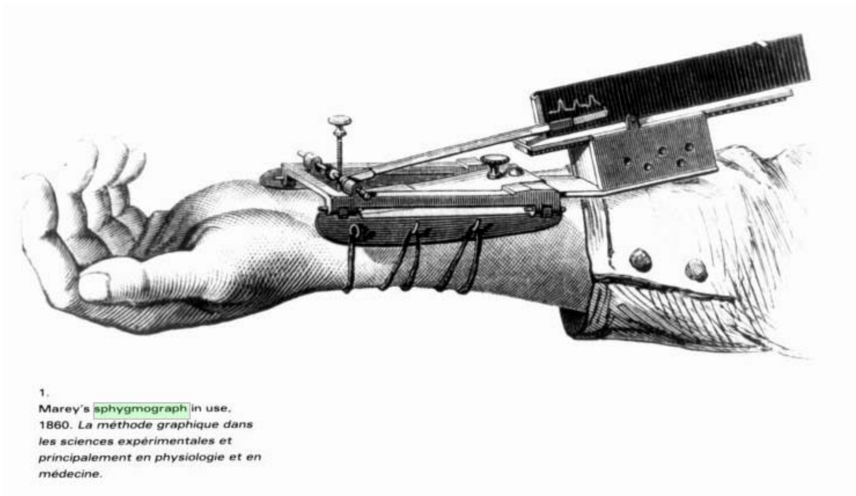


Galileo's drawings of the phases of the moon from 1616
http://galileo.rice.edu/sci/observations/moon.html

Answer Question

Gallop, Bay Horse "Daisy" [Muybridge 1884-86]

Other Recording Instruments



Marey's sphygmograph [from Braun 83]

Support Reasoning

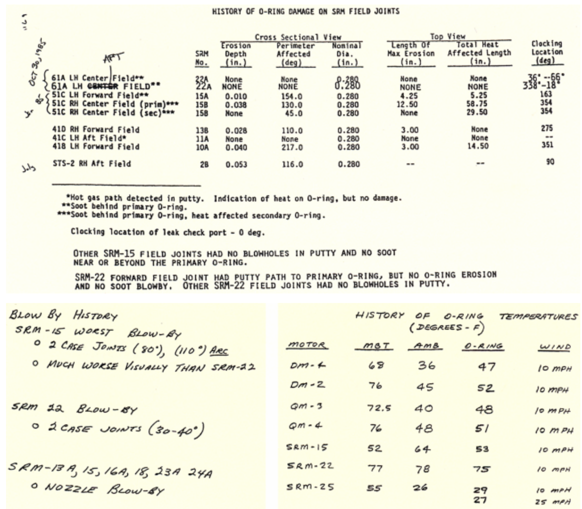
Data in Context: Cholera Outbreak

In 1864 John Snow plotted the position of each cholera case on a map. [from Tufte 83]

Data in Context: Cholera Outbreak

Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]

Make a Decision: Challenger



HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

	SRM No.	Cross Sectional View: Erosion Depth (in.)	Cross Sectional View: Perimeter Affected (deg)	Cross Sectional View: Nominal Dia. (in.)	Top View: Length Of Max Erosion (in.)	Top View: Total Heat Affected Length (in.)	Clocking Location (deg)
61A LH Center Field**	22A	None	None	0.280	None	None	36°-66°
61A LH ~~CENTER~~ FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338°-18°
51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	--	90

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

BLOW BY HISTORY
SRM-15 WORST BLOW-BY
- 2 CASE JOINTS (80°), (110°) ARC
- MUCH WORSE VISUALLY THAN SRM-22

SRM 22 BLOW-BY
- 2 CASE JOINTS (30-40°)

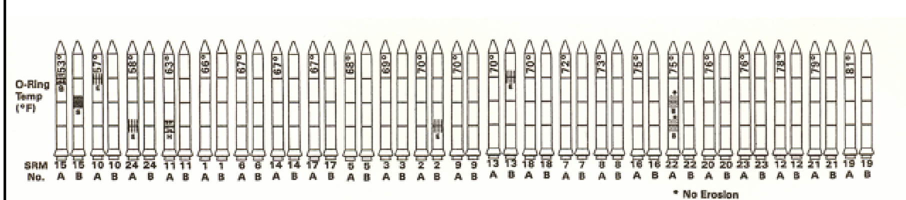
SRM-13A, 15, 16A, 18, 23A 24A
- NOZZLE BLOW-BY

HISTORY OF O-RING TEMPERATURES (DEGREES - F)

MOTOR	MBT	AMB	O-RING	WIND
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29 27	10 MPH 25 MPH

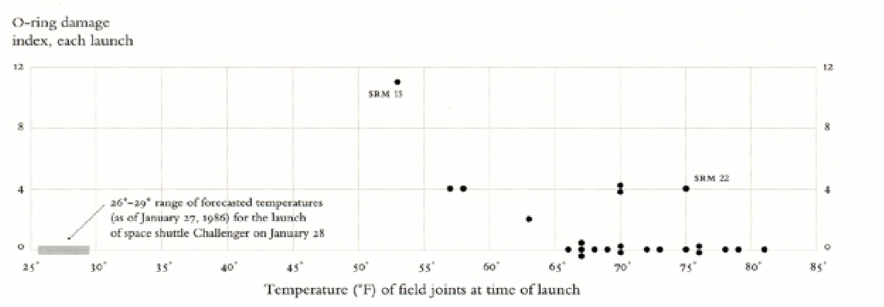
2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]

Make a Decision: Challenger



Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

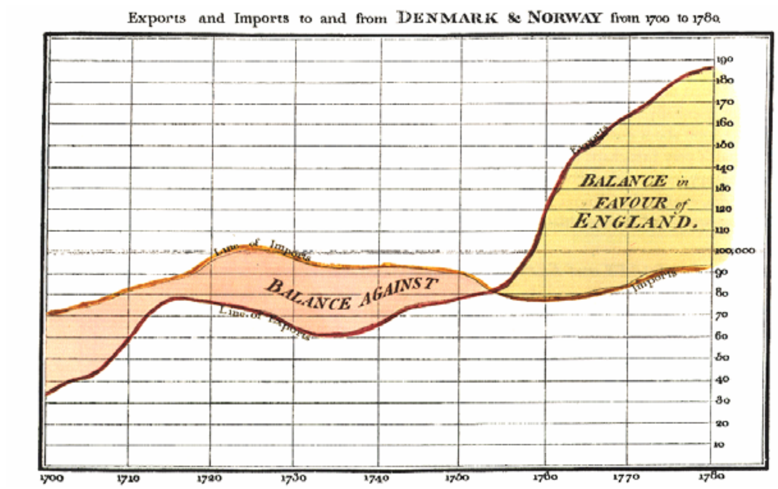
Make a Decision: Challenger



Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

Convey Information to Others

Present Argument: Exports & Imports



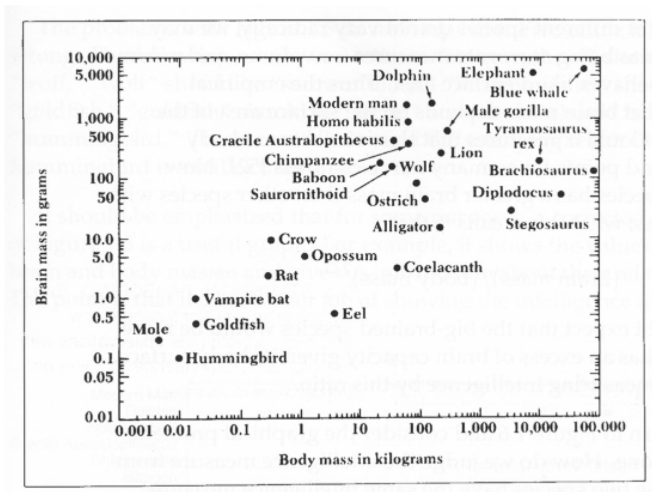
[Playfair 1786]

Tell Story: Most Powerful Brain?

Microsoft Excel - animal.xls

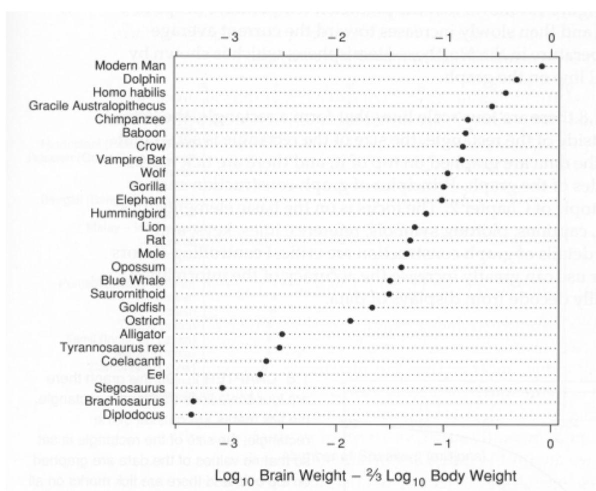
ID	Name	Body Weight	Brain Weight
1	Lesser Short-tailed Shrew	5	0.14
2	Little Brown Bat	10	0.25
3	Mouse	23	0.3
4	Big Brown Bat	23	0.4
5	Musk Shrew	48	0.33
6	Star Nosed Mole	60	1
7	Eastern American Mole	75	1.2
8	Ground Squirrel	101	4
9	Tree Shrew	104	2.5
10	Golden Hamster	120	1
11	Mole Rate	122	3
12	Galago	200	5
13	Rat	280	1.9
14	Chinchilla	425	6.4
15	Desert Hedgehog	550	2.4
16	Rock Hyrax (a)	750	12.3
17	European Hedgehog	785	3.5
18	Tenrec	900	2.6
19	Arctic Ground Squirrel	920	5.7
20	African Giant Pouched Rat	1000	6.6
21	Guinea Pig	1040	5.5
22	Mountain Beaver	1350	8.1
23	Slow Loris	1400	12.5
24	Genet	1410	17.5
25	Phalanger	1620	11.4

Tell Story: Most Powerful Brain?



The Dragons of Eden [Carl Sagan]

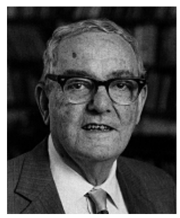
Tell Story: Most Powerful Brain?



The Elements of Graping Data [Cleveland]

Attention

"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."



~Herb Simon
as quoted by Hal Varian
Scientific American
September 1995

[slide from PARC UIR group]

Data

Data Types

Physical type (model)
- Characterized by storage format
- Characterized by machine operations

Example:
bool, short, int32, float, double, string, …

Abstract type
- Provide (conceptual) descriptions of the data
- May be characterized by methods/attributes
- May be organized into a hierarchy

Example:
nominal, ordinal, quantitative, …,
plants, animals, metazoans, …

Nominal, Ordinal & Quantitative

N - Nominal (labels)
- Fruits: Apples, oranges, …

O - Ordered
- Quality of meat: Grade A, AA, AAA

Q - Quantitative
- Real numbers
- Ordered, with measurable distances, or amounts
- Dates: Jan, 19, 2006; Location: (LAT 33.98, LONG -118.45)
- Physical measurement: Length, Mass, Temp, …

S. S. Stevens, On the theory of scales of measurements, 1946

From Data Model to Data Type

Data model
- 32.5, 54.0, -17.3, …
- floats

Conceptual model
- Temperature

Data type
- Burned vs. Not burned (N)
- Hot, warm, cold (O)
- Continuous range of values (Q)

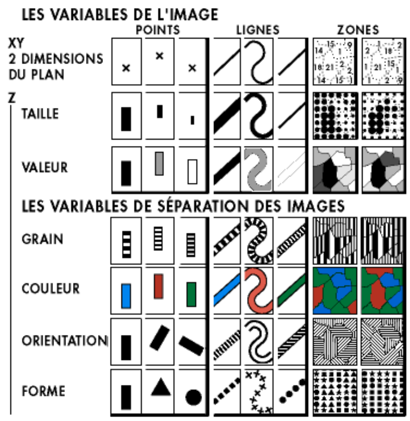
[based on slide from Munzner]

Image

Jacques Bertin

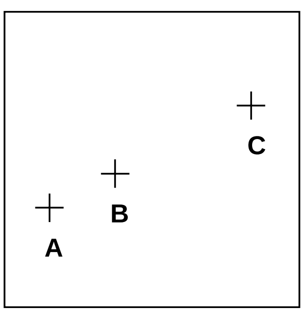
Visual Variables

- – Position
- – Size
- – Value
- – Texture
- – Color
- – Orientation
- – Shape



- Note: Bertin does not consider 3D or time
- Note: Card and Mackinlay extend the number of vars.

Information in Position



1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.

4. ∴ Encode quantitative variables (Q)

Information in Color and Value

- Value is perceived as ordered
  - ∴ Encode ordinal variables (O)

  - ∴ Encode continuous variables (Q) [not as well]

- Hue is normally perceived as unordered
  - ∴ Encode nominal variables (N) using color

Bertins' "Levels of Organization"

Position	N	O	Q
Size	N	O	Q
Value	N	O	Q
Texture	N	O	
Color	N		
Orientation	N		
Shape	N		

N Nominal
O Ordinal
Q Quantitative

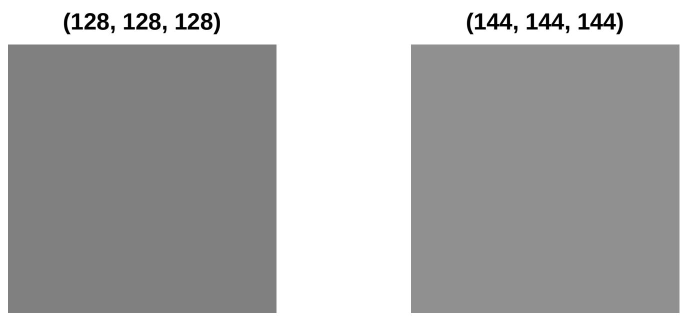
Note: Q < O < N

Estimating Magnitude

Detecting Brightness

Which is brighter?

Detecting Brightness



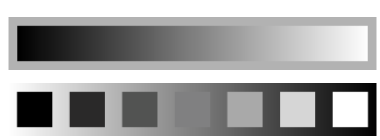
Which is brighter?

Just Noticeable Difference

- JND (Weber's Law)

$$\Delta S = k \frac{\Delta I}{I}$$

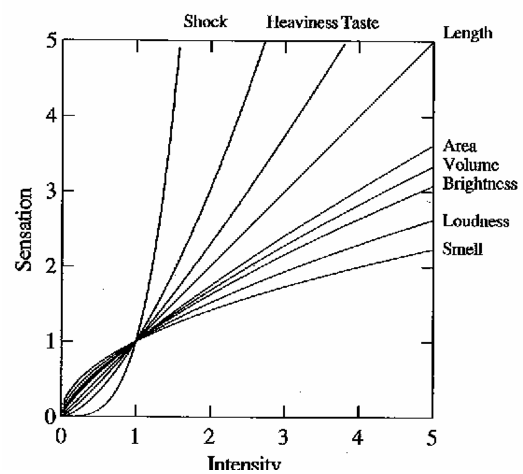
- Ratios more important than magnitude
- Most continuous variations in stimuli are perceived in discrete steps



Steven's Power law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



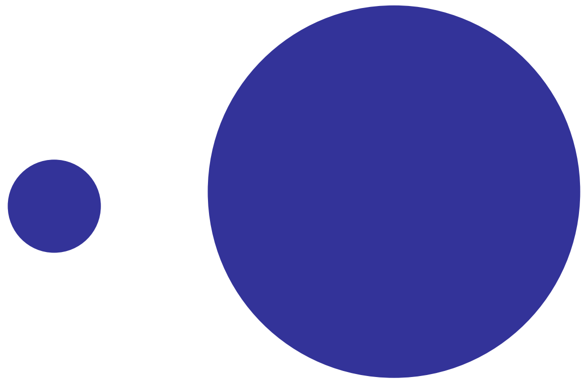
[graph from Wilkinson 99, based on Stevens 61]

[alternate graph : http://www.undergrad.ahs.uwaterloo.ca/~wchedder/stevenspowerlaw.htm]

Exponents of Power Law

Sensation	Exponent
Loudness	0.6
Brightness	0.33
Smell	0.55 (Coffee) - 0.6 (Heptane)
Taste	0.6 (Saccharine) -1.3 (Salt)
Temperature	1.0 (Cold) – 1.6 (Warm)
Vibration	0.6 (250 Hz) – 0.95 (60 Hz)
Duration	1.1
Pressure	1.1
Heaviness	1.45
Electic Shock	3.5

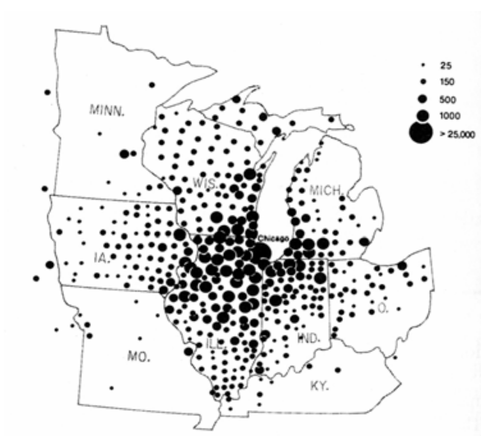
[Psychophysics of Sensory Function, Stevens 61]



Compare area of circles

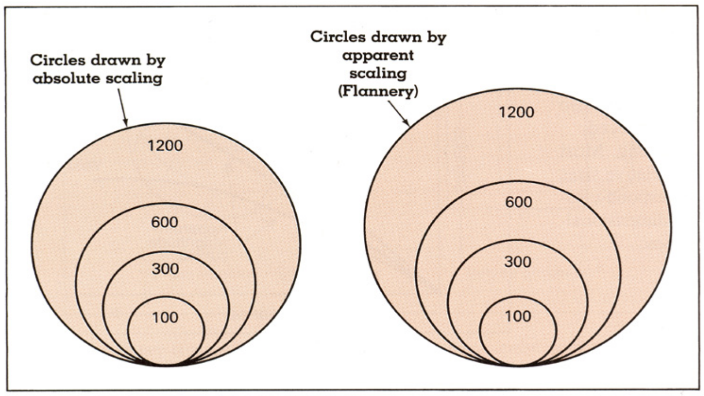
Proportional Symbol Map

Newspaper Circulation



[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]

Apparent Magnitude Scaling



[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

$S = 0.98A^{0.87}$ [from Flannery 71]

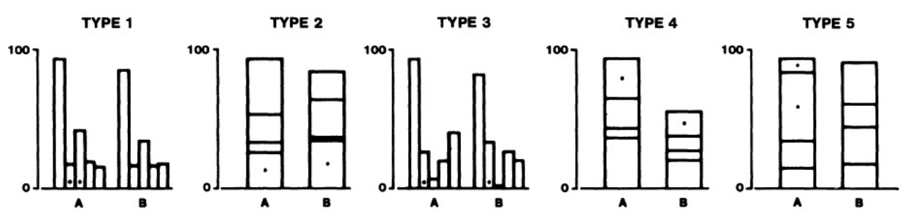


Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

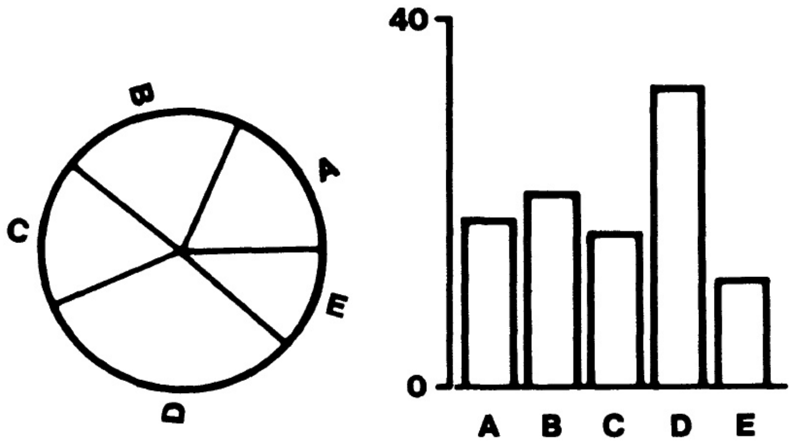


Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

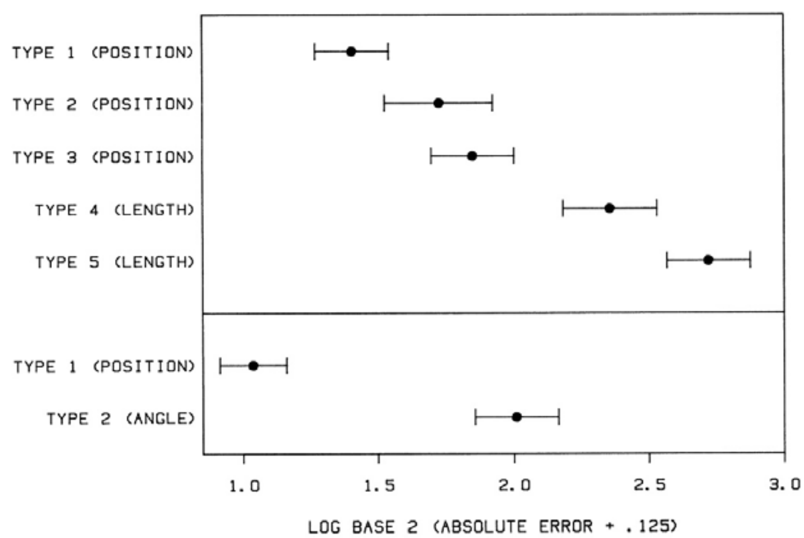
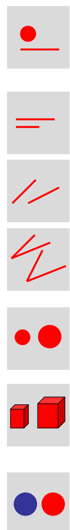


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[Cleveland and McGill 84]

Relative Magnitude Estimation

Most accurate



Position (common) scale
Position (non-aligned) scale

Length

Slope

Angle

Area

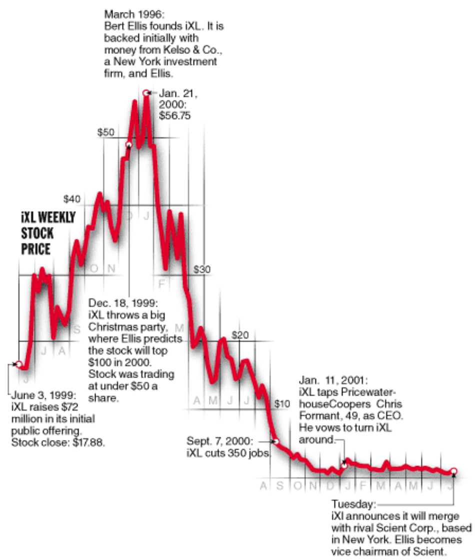
Volume

Color hue-saturation-density

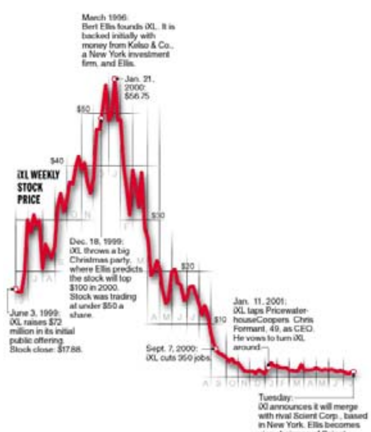
Least accurate

Deconstructions

Stock Chart

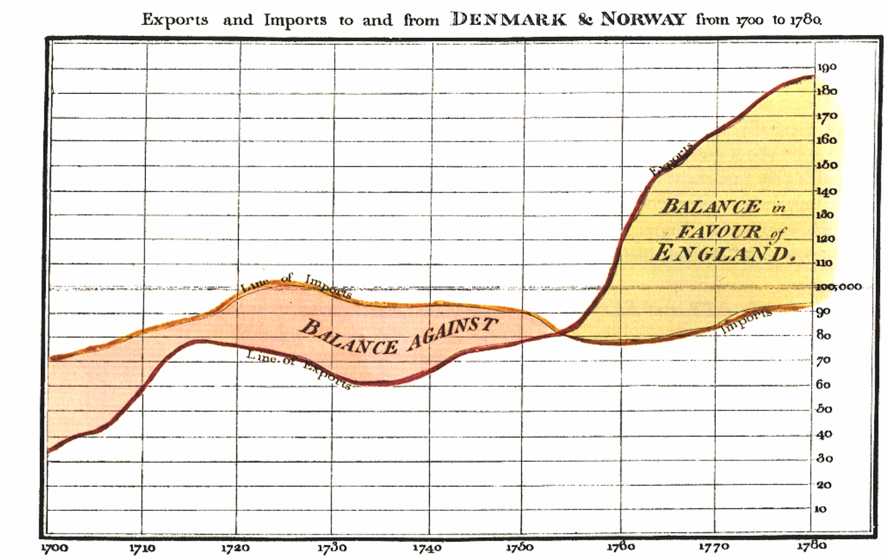


Stock Chart

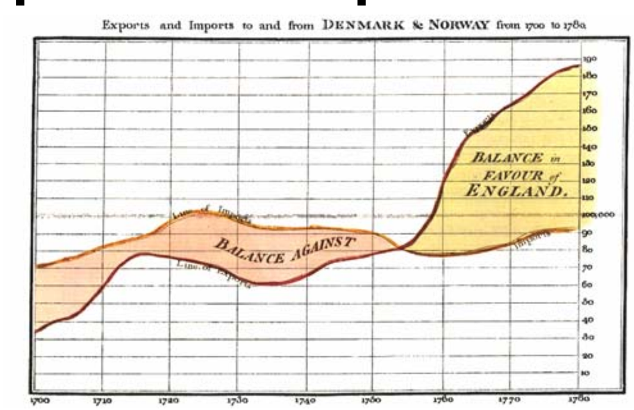


x-axis: time (Q)
y-axis: price (Q)

Exports and Imports [Playfair 1786]

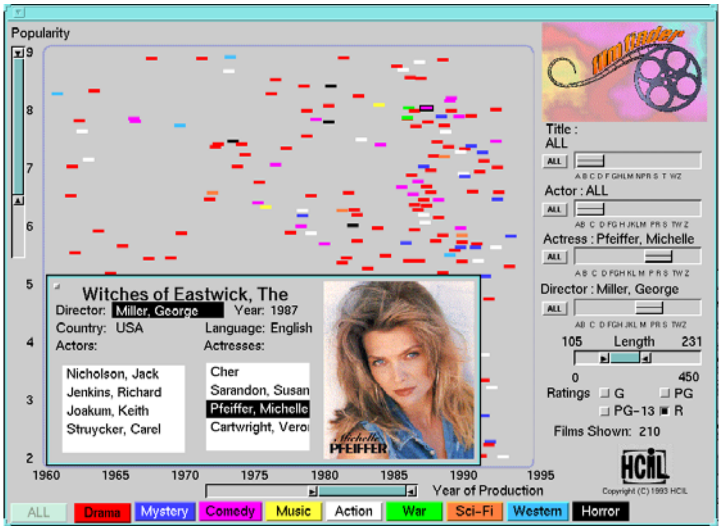


Exports and Imports [Playfair 1786]



- x-axis: year (Q)
- y-axis: currency (Q)
- color: imports/exports (N)
- color: positive/negative (O)

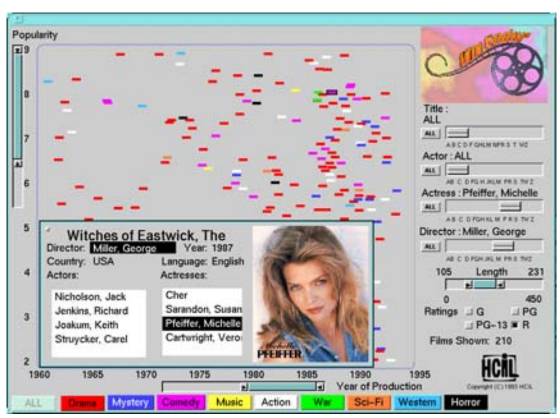
FilmFinder [Ahlberg 1994]



FilmFinder [Ahlberg 1994]

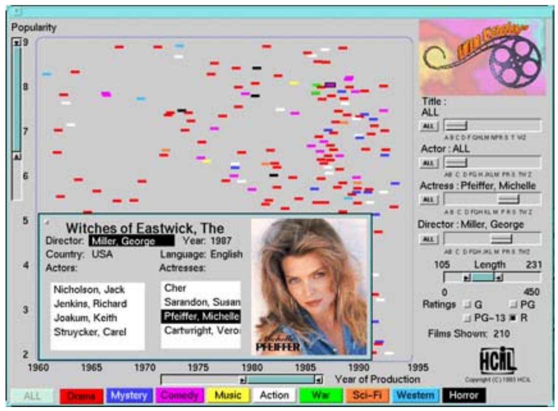
- x-axis: year of release (quantitative)
- y-axis: popularity (quantitative)
- color: genre (nominal)
- dynamic query filters

  title (nominal)
  actor (nominal)
  actress (nominal)
  director (nominal)
  length (quantitative)
  rating (ordinal)



Interactivity

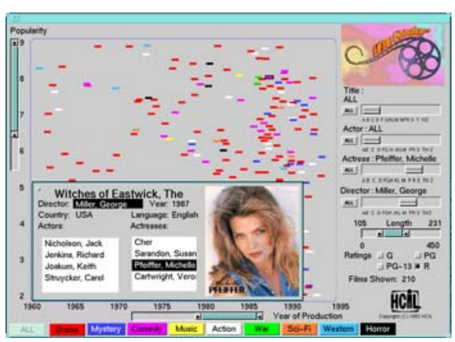
- Turn visual analysis into a real-time iterative process
- Explore various hypotheses or interests
- Filter to hone in on data of interest
- Get details on demand



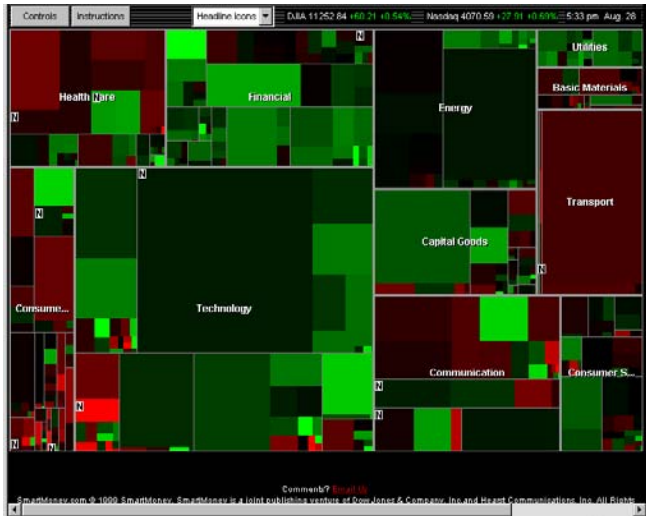
Multi-Dimensional Data

FilmFinder visualizes 3 dimensions
- 2 spatial dimensions
- 1 color dimension

Can we see more dimensions simultaneously?



Map of the Market [Wattenberg 1998]



http://www.smartmoney.com/marketmap/

Map of the Market [Wattenberg 1998]

- rectangle size: market cap (Q)
- rectangle position: market sector (N), market cap (Q)
- color hue: loss vs. gain (N, O)
- color value: magnitude of loss or gain (Q)