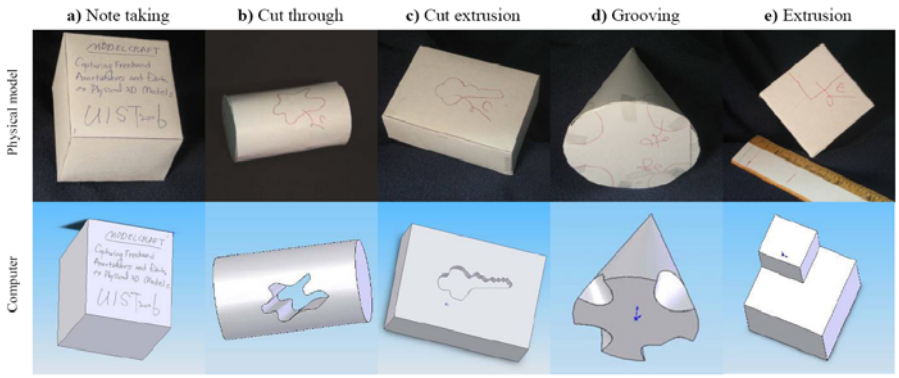
# Visual Information Design

CS160: User Interfaces

Maneesh Agrawala




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

**VIDEO**

# Due Soon

Interactive Prototype (due Apr 6)

- Redesign interface based on lofi feedback
- Create ***first*** working implementation
  - Can include Wizard of Oz parts where **justified**
  - Can include pre-built (canned) functionality **but only if heavily justified**

In class Presentations (Apr 13, 15, 20)

- 10 min slide presentation (be careful about timing)
- Focus on showing prototype
- Feedback from class (you will need to provide feedback on each presentation on the wiki)

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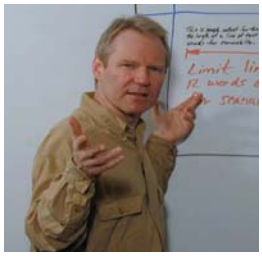
# Upcoming Assignments

Team Assessment (Apr 20)
- Short individual assignment
- Tell us how your team functions

Pilot Usabililty Study (Apr 20)
- Refine your implementation
- Evaluate your implementation

# Upcoming Lectures

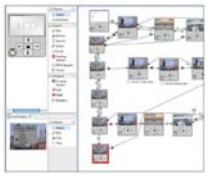
Apr 6: Stephen Few
- Information display



Apr 8: Aaron Marcus
- UI design consultant
- **Elected to CHI Academy this year**

# Talk You Should Attend

Bjoern Hartmann
- HCI faculty candidate
- Works on design, implementation and evaluation of authoring tools for UIs



The *d.tools* visual authoring environment enables rapid construction of UI logic.


This evaluation participant used *Exemplar* to control 2D aiming in a game with an accelerometer, and shooting with a flick of a bend sensor.

**Mon Apr 13: 1-2:30pm Wozniak Lounge**

# Topics

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

# Why Do We Create Visualizations?

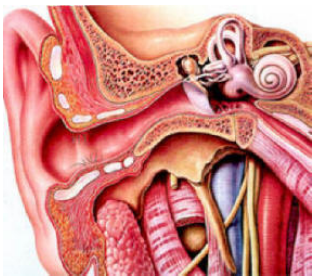
# What is Visualization?

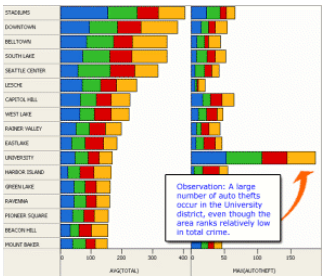
Definition **[www.oed.com]**

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

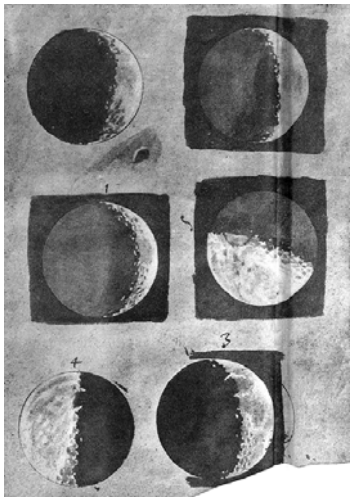
Record information
- Photographs, blueprints, …

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

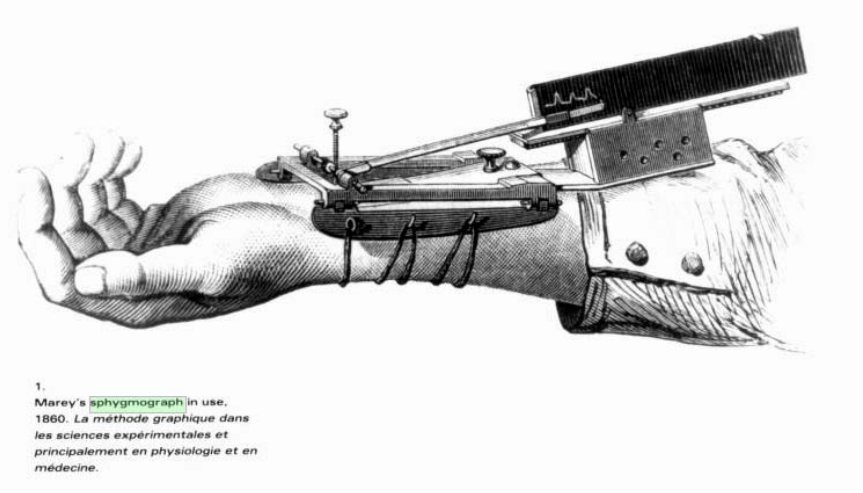


Galileo's drawings of the phases of the moon from 1616
http://galileo.rice.edu/sci/observations/moon.html

# Answer Question

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

# Other Recording Instruments



1.
Marey's sphygmograph in use, 1860. *La méthode graphique dans les sciences expérimentales et principalement en physiologie et en médecine.*

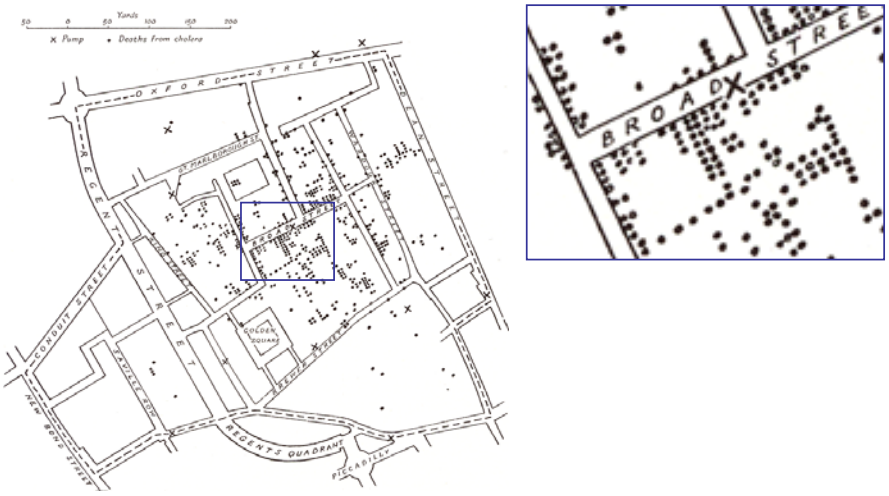
Marey's sphygmograph [from Braun 83]

# Support Reasoning

# Data in Context: Cholera Outbreak

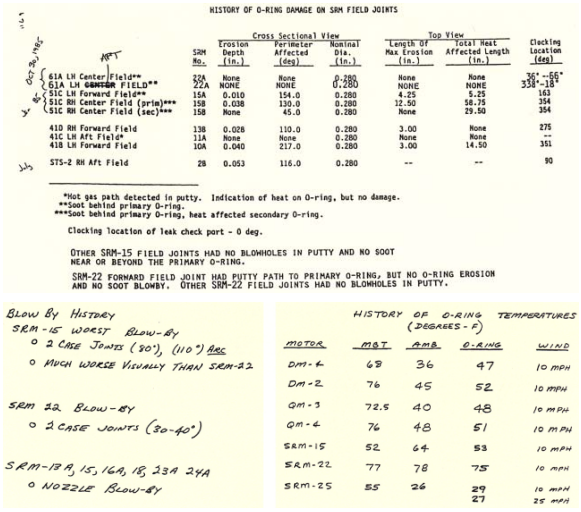

In 1864 John Snow plotted the position of each cholera case on a map. [from Tufte 83]

# 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 (30°), (110°) ARC
- MUCH WORSE VISUALLY THAN SRM-22

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

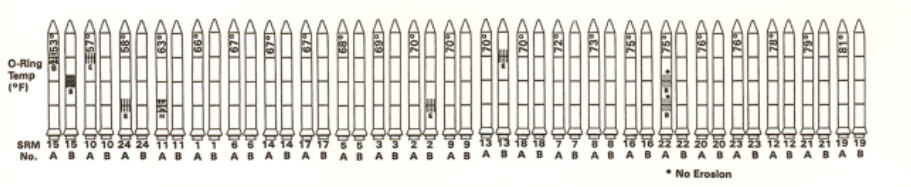
SRM-13A, 15, 16A, 18, 23A 24A
- NOZZLE BLOW-BY

HISTORY OF O-RING TEMPERATURES (DEGREES-F)

| MOTOR | MST | AMB. | O-RING | WIND |
|---|---|---|---|---|
| DM-1 | 68 | 36 | 47 | 10 MPH |
| DM-2 | 76 | 45 | 52 | 10 MPH |
| QM-1 | 72.5 | 40 | 48 | 10 MPH |
| QM-2 | 76 | 48 | 51 | 10 MPH |
| SRM-15 | 52 | 64 | 53 | 10 MPH |
| SRM-22 | 77 | 78 | 75 | 10 MPH |
| SRM-25 | 55 | 26 | 29<br>27 | 10 MPH<br>25 MPH |

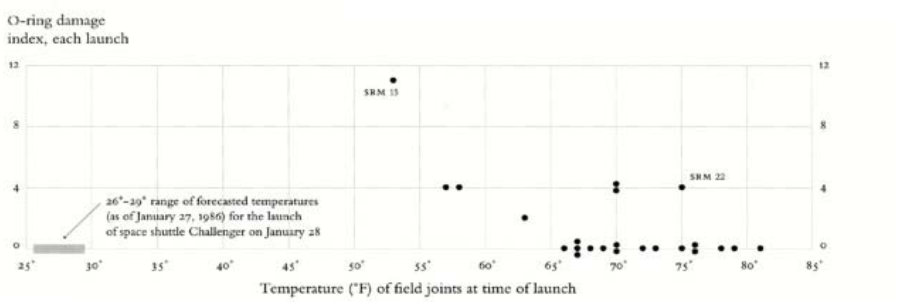
2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]

# Make a Decision: Challenger




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

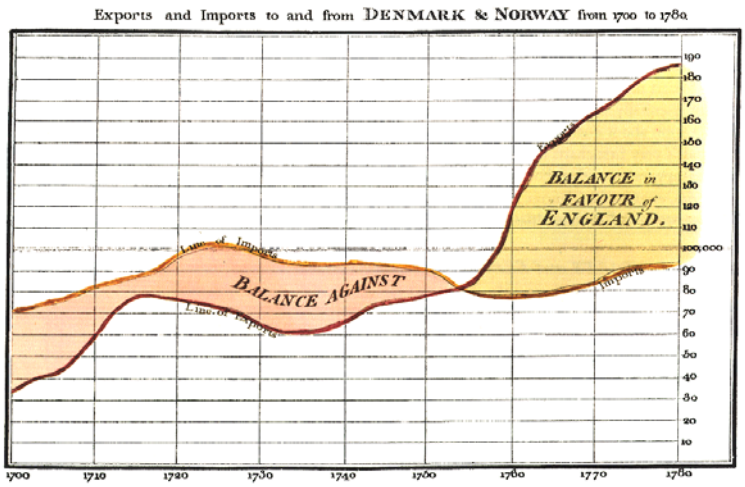
# Make a Decision: Challenger




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

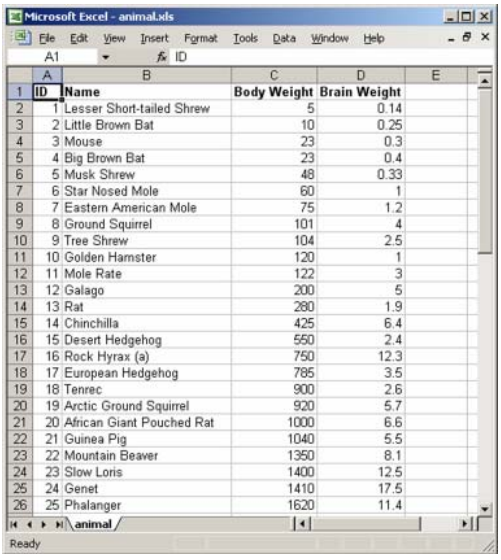
# Convey Information to Others

# Present Argument: Exports & Imports




[Playfair 1786]

# Tell Story: Most Powerful Brain?



Microsoft Excel - animal.xls

File Edit View Insert Format Tools Data Window Help

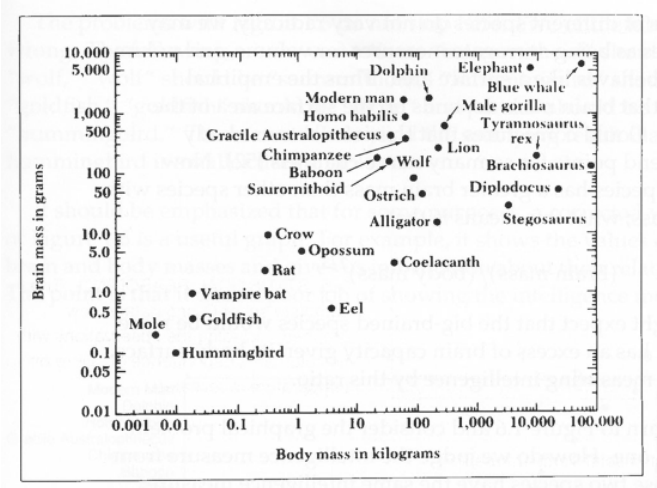
A1 ID

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | ID | Name | Body Weight | Brain Weight | |
| 2 | 1 | Lesser Short-tailed Shrew | 5 | 0.14 | |
| 3 | 2 | Little Brown Bat | 10 | 0.25 | |
| 4 | 3 | Mouse | 23 | 0.3 | |
| 5 | 4 | Big Brown Bat | 23 | 0.4 | |
| 6 | 5 | Musk Shrew | 48 | 0.33 | |
| 7 | 6 | Star Nosed Mole | 60 | 1 | |
| 8 | 7 | Eastern American Mole | 75 | 1.2 | |
| 9 | 8 | Ground Squirrel | 101 | 4 | |
| 10 | 9 | Tree Shrew | 104 | 2.5 | |
| 11 | 10 | Golden Hamster | 120 | 1 | |
| 12 | 11 | Mole Rate | 122 | 3 | |
| 13 | 12 | Galago | 200 | 5 | |
| 14 | 13 | Rat | 280 | 1.9 | |
| 15 | 14 | Chinchilla | 425 | 6.4 | |
| 16 | 15 | Desert Hedgehog | 550 | 2.4 | |
| 17 | 16 | Rock Hyrax (a) | 750 | 12.3 | |
| 18 | 17 | European Hedgehog | 785 | 3.5 | |
| 19 | 18 | Tenrec | 900 | 2.6 | |
| 20 | 19 | Arctic Ground Squirrel | 920 | 5.7 | |
| 21 | 20 | African Giant Pouched Rat | 1000 | 6.6 | |
| 22 | 21 | Guinea Pig | 1040 | 5.5 | |
| 23 | 22 | Mountain Beaver | 1350 | 8.1 | |
| 24 | 23 | Slow Loris | 1400 | 12.5 | |
| 25 | 24 | Genet | 1410 | 17.5 | |
| 26 | 25 | Phalanger | 1620 | 11.4 | |

animal

Ready

# Tell Story: Most Powerful Brain?




The Dragons of Eden [Carl Sagan]

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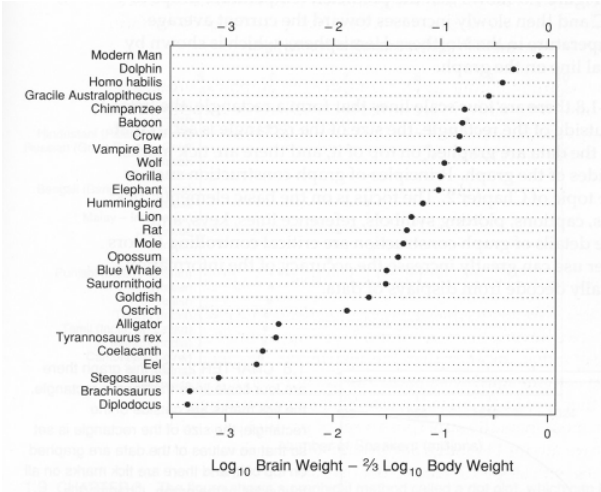
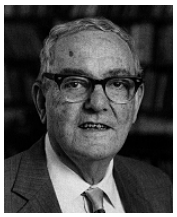



The Elements of Graping Data [Cleveland]

# 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)

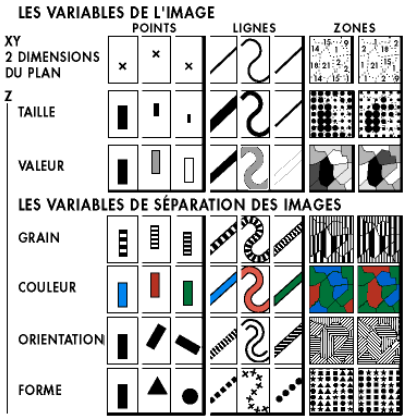
[based on slide from Munzner]

# Image

Jacques Bertin

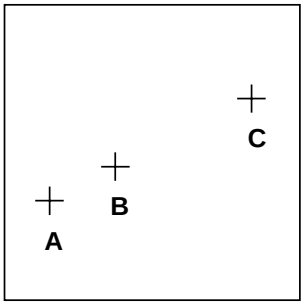
# Visual Variables

- 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**

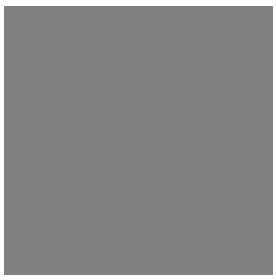
# Estimating Magnitude

# Detecting Brightness

**Which is brighter?**

# Detecting Brightness

(128, 128, 128)



(144, 144, 144)

**Which is brighter?**

# Just Noticeable Difference

- JND (Weber's Law)

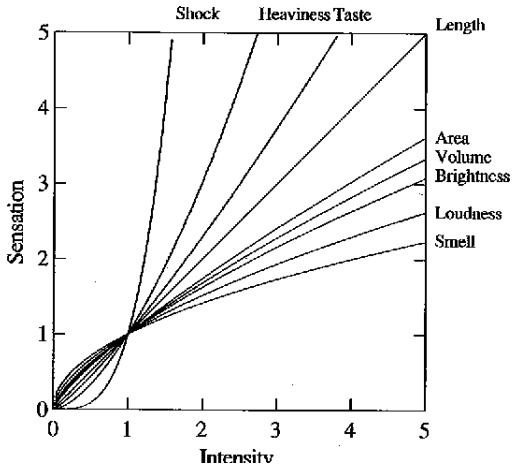
$$\Delta S = k\frac{\Delta I}{I}$$

- 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**



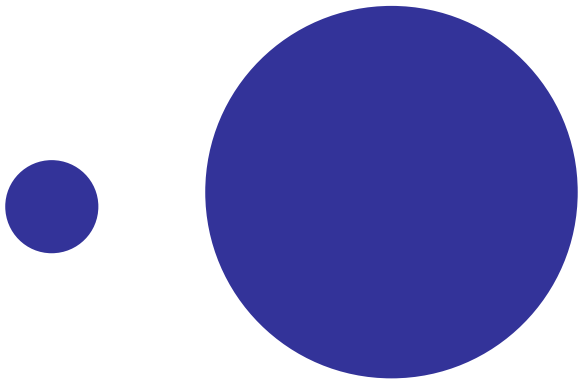

[graph from Wilkinson 99, based on Stevens 61]

[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 |

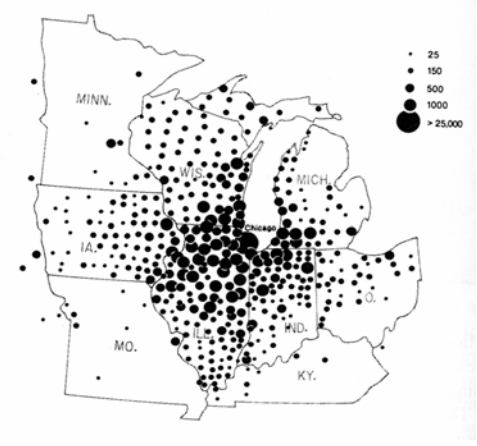
[Psychophysics of Sensory Function, Stevens 61]



**Compare area of circles**

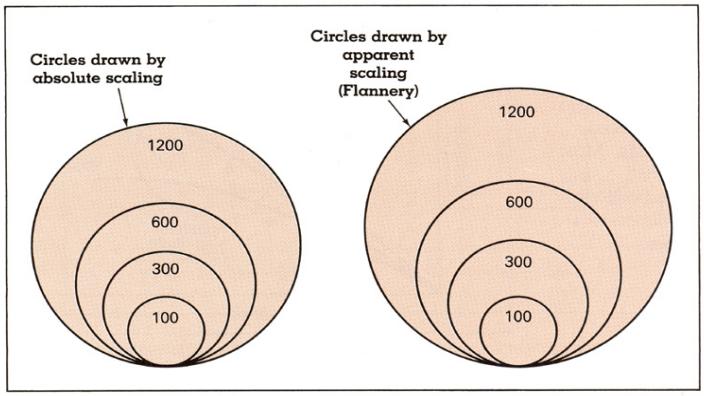
# Proportional Symbol Map

**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]

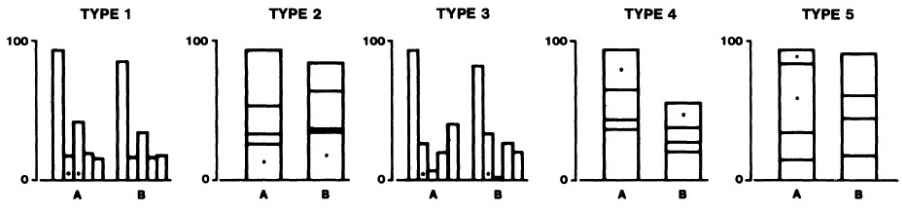



*Figure 4. Graphs from position–length experiment.*

[Cleveland and McGill 84]

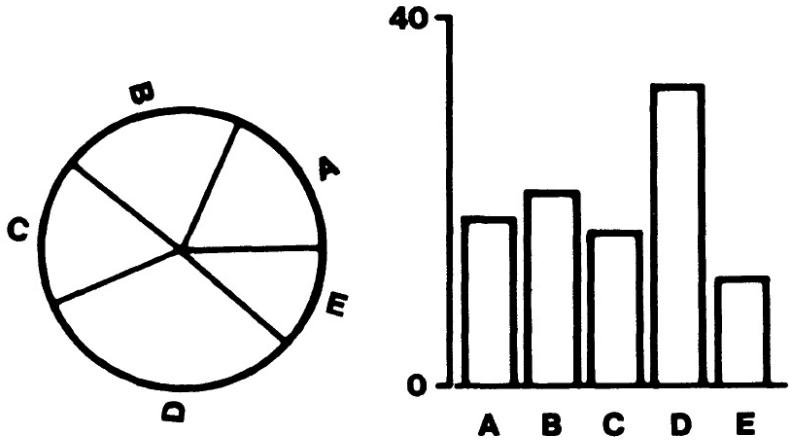



*Figure 3. Graphs from position–angle experiment.*

[Cleveland and McGill 84]

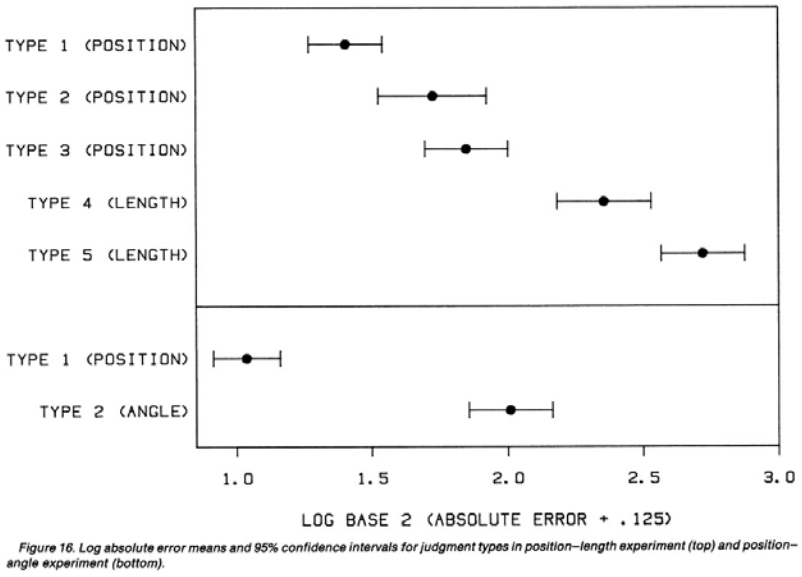



*Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).*

[Cleveland and McGill 84]

# Relative Magnitude Estimation

Most accurate

Least accurate

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

Length

Slope

Angle

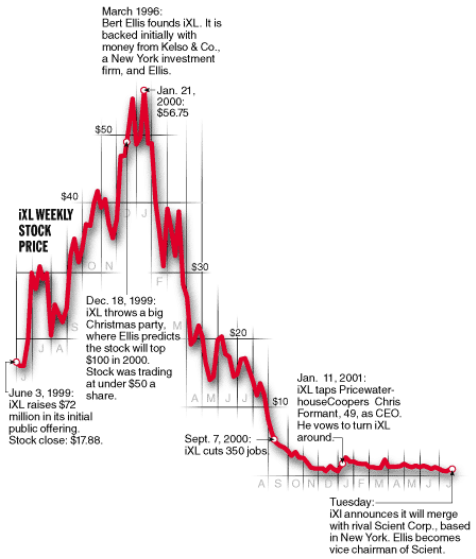
Area

Volume

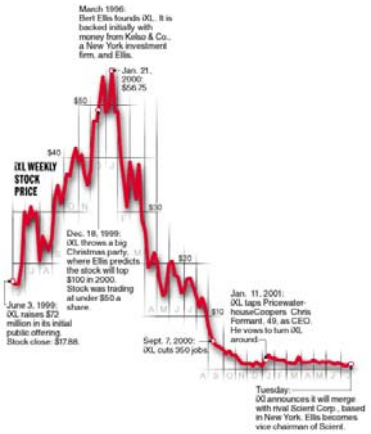
Color hue-saturation-density

# Deconstructions

# Stock Chart

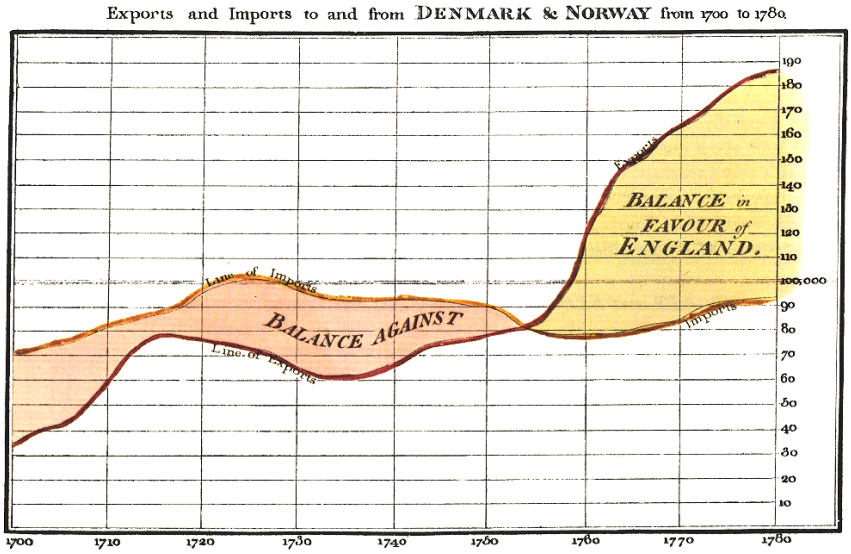



# Stock Chart



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

# Exports and Imports [Playfair 1786]

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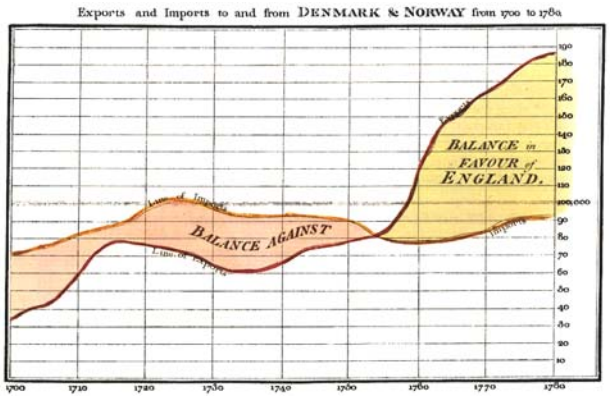
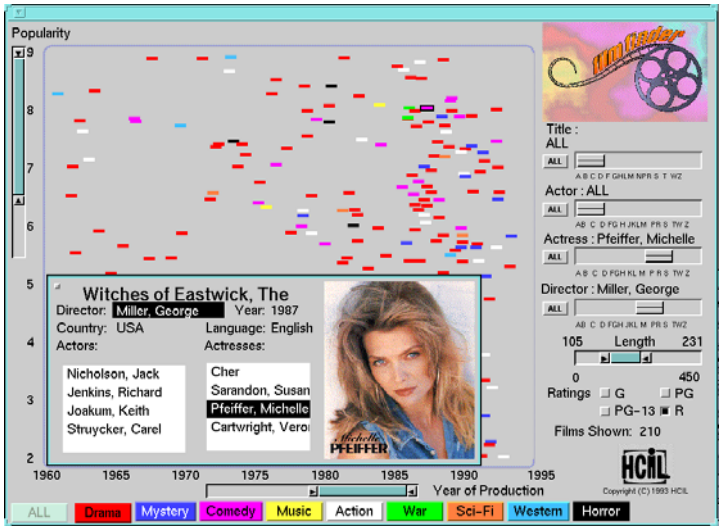


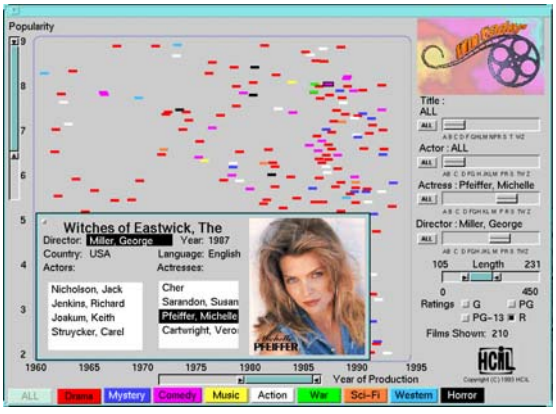

- x-axis: year (Q)
- y-axis: currency (Q)
- color: imports/exports (N)
- color: positive/negative (O)

# FilmFinder [Ahlberg 1994]



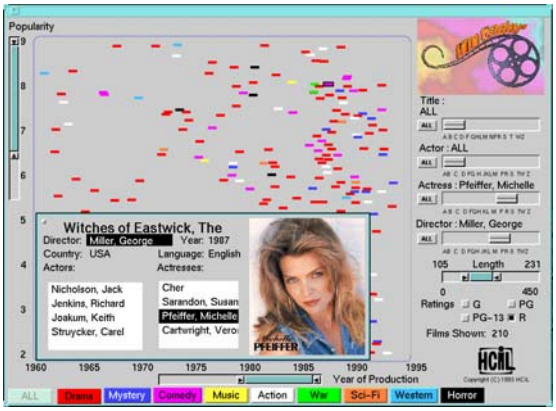

# FilmFinder [Ahlberg 1994]

- 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

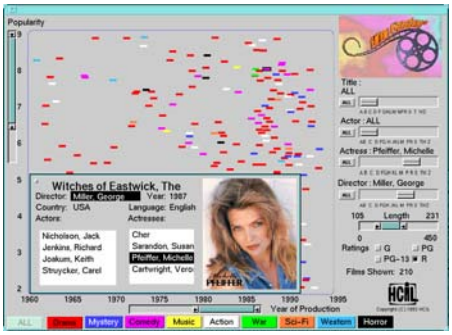



# Multi-Dimensional Data

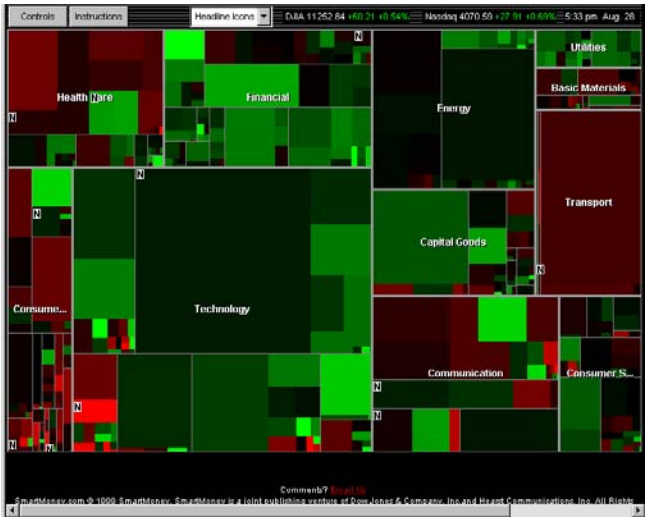
FilmFinder visualizes 3 dimensions

- 2 spatial dimensions
- 1 color dimension

Can we see more dimensions simultaneously?



# Map of the Market [Wattenberg 1998]

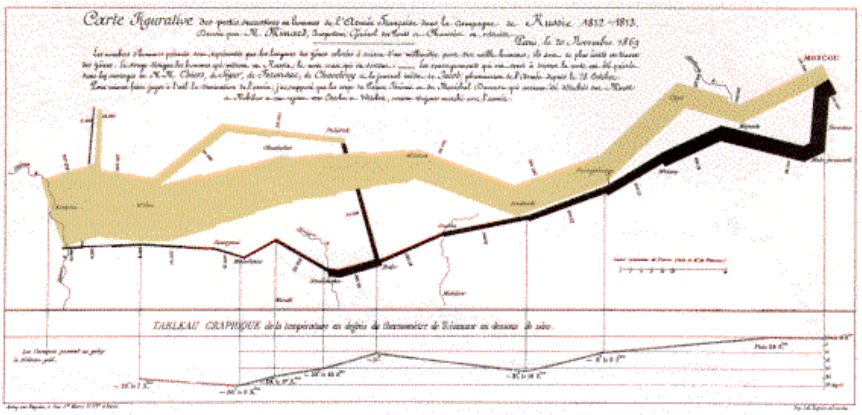



http://www.smartmoney.com/marketmap/

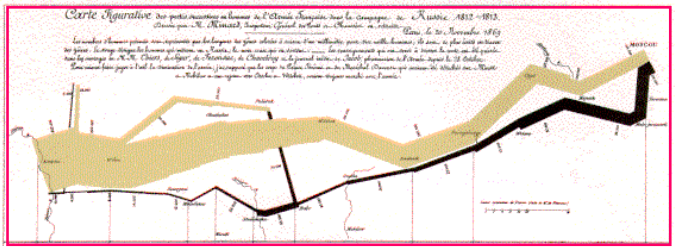
# Map of the Market [Wattenberg 1998]

- 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)

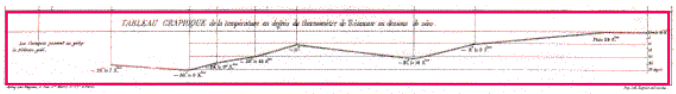
# Napoleon's March [Minard 1869]




# Single Axis Composition



+



=

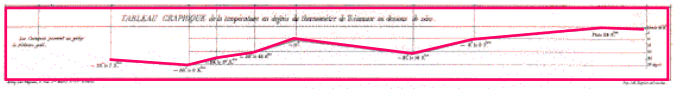
[based on slide from Mackinlay]

# Mark Composition

y-axis: temperature (Q)

\+ x-axis: time (Q)

=



temp over time (Q x Q)

[based on slide from Mackinlay]

# Mark composition

y-axis: longitude (Q)

\+ x-axis: latitude (Q)

\+ width: army size (Q)

=

army position (Q x Q) and army size (Q)

[based on slide from Mackinlay]

longitude (Q)

latitude (Q)

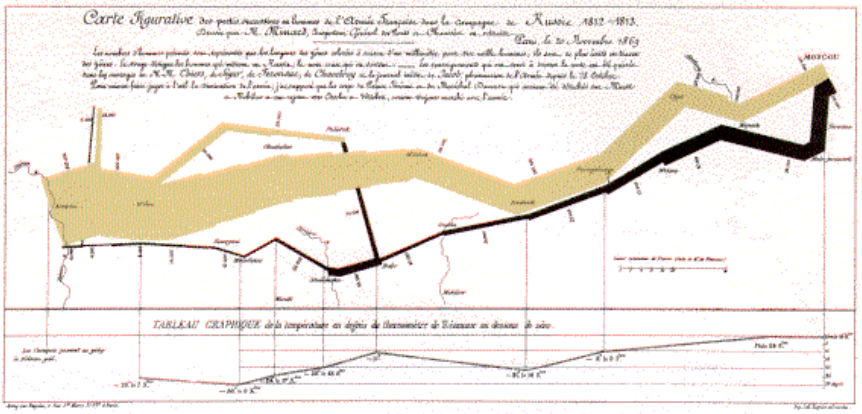
army size (Q)

temperature (Q)

time (Q)

[based on slide from Mackinlay]

# Napoleon's March [Minard 1869]




- Depicts at least 5 quantitative variables
- Any others?

# Summary

We create visualizations to
- Record information
- Support reasoning about the information
- Convey information to others

Choose the right mark for your data
- Position good for N, O, Q, but Hue best only for N

With careful design it is possible to display many dimensions at once