CS-184: Computer Graphics

Lecture 24: Visualization

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Announcements

Final Project: multiple due dates

- Project proposal due Wed Nov 17, 11pm
- Progress report 1 due Mon Nov 22, 11pm
- Progress report 2 due Wed Dec 1, 11pm
- Final report due Wed Dec 8, 11pm

Final Exam - Mon Dec 13   8-11am

Topics

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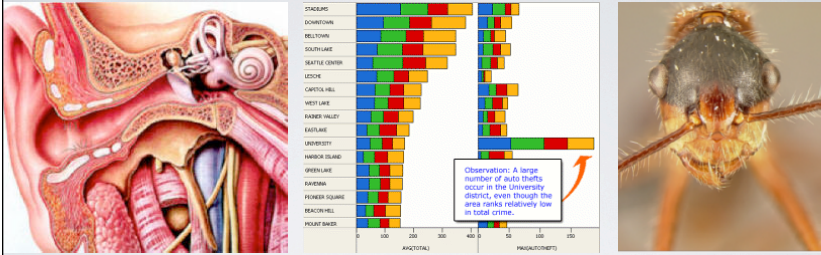Estimating magnitude
Deconstructions

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

Observation: A large number of auto thefts occur in the University district, even though the area ranks relatively low in total crime.

Why Do We Create Visualizations?

Three Primary Functions

Record information
- Photographs, blueprints, …
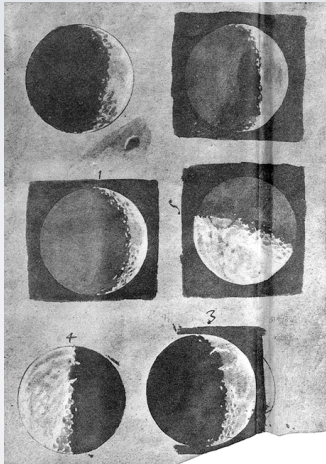
Support reasoning about information (analyze)
- Process and calculate
- Reason about data
- Feedback and interaction

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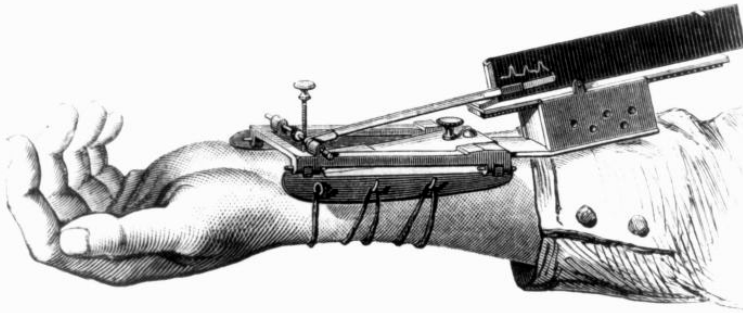
Record Information

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
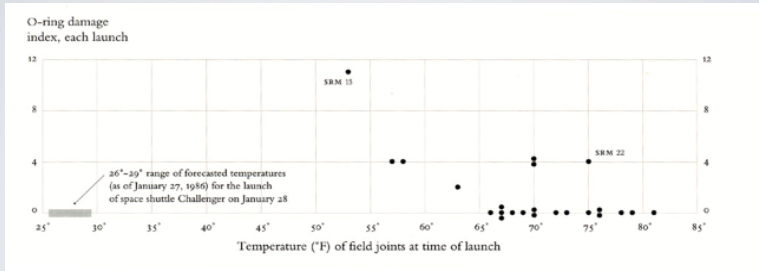médecine.*

Marey's sphygmograph [from Braun 83]

Support Reasoning

Data in Context: Cholera Outbreak

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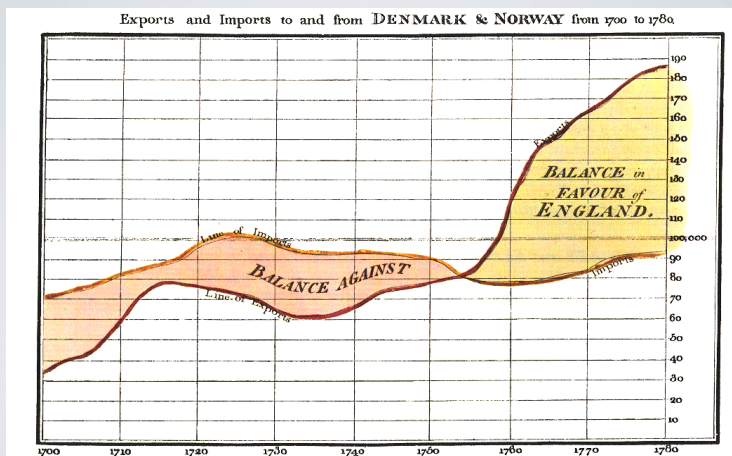on a map. [from Tufte 83]

Data in Context: Cholera Outbreak

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

Make a Decision: Challenger

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]

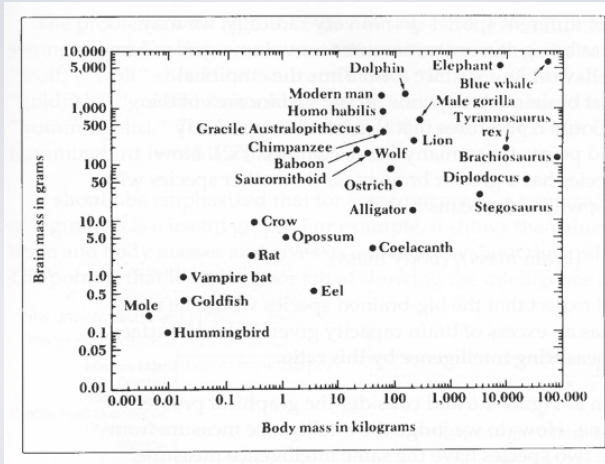## Convey Information to Others

Present Argument: Exports & Imports

[Playfair 1786]
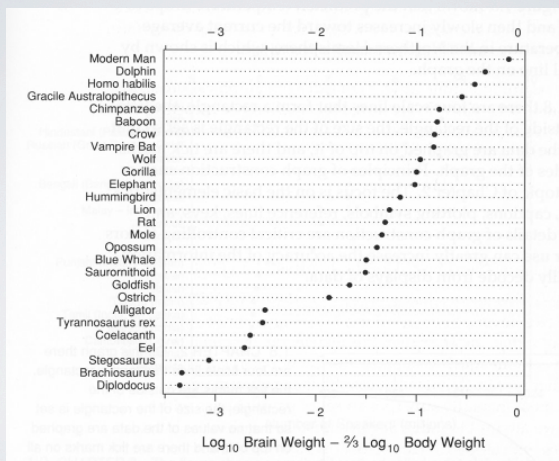
Tell Story: Most Powerful Brain?

Tell Story: Most Powerful Brain?

The Dragons of Eden [Carl Sagan]

Tell Story: Most Powerful Brain?

The Elements of Graphing 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)

Image

Jacques Bertin

Visual Variables

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

LES VARIABLES DE L'IMAGE

POINTS · LIGNES · ZONES

- XY 2 DIMENSIONS DU PLAN
- Z TAILLE
- VALEUR

LES VARIABLES DE SÉPARATION DES IMAGES

- GRAIN
- COULEUR
- ORIENTATION
- FORME

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)

C
B
A

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"

	N	O	Q
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
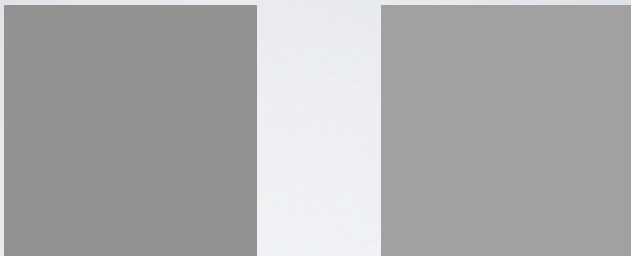
Which is brighter?

Detecting Brightness

(128, 128, 128)   (144, 144, 144)

Which is brighter?

Just Noticeable Differences

JND (Weber's Law)

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

Ratios more important than magnitude

Most continuous variations perceived in discrete steps

Steven's Power Law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate
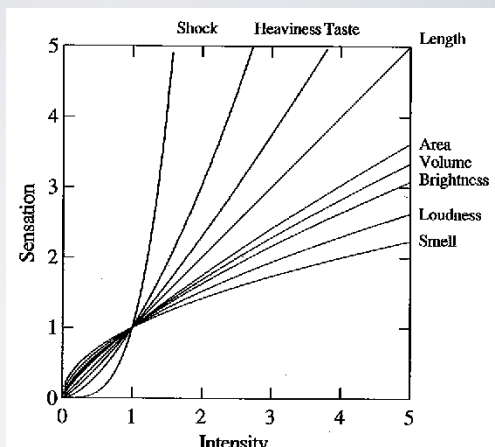
[graph from Wilkinson 99, based on Stevens 61]

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]
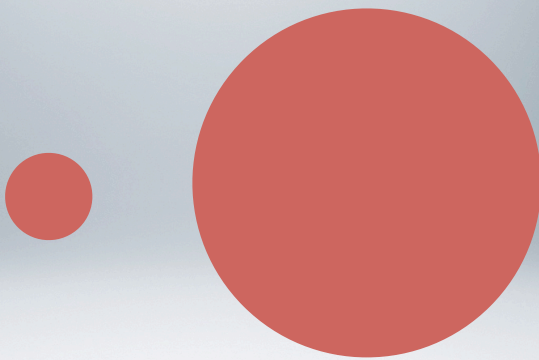
Compare area of circles

Proportional Symbol Map

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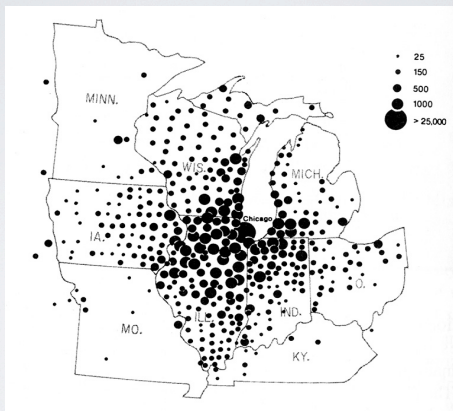
[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]

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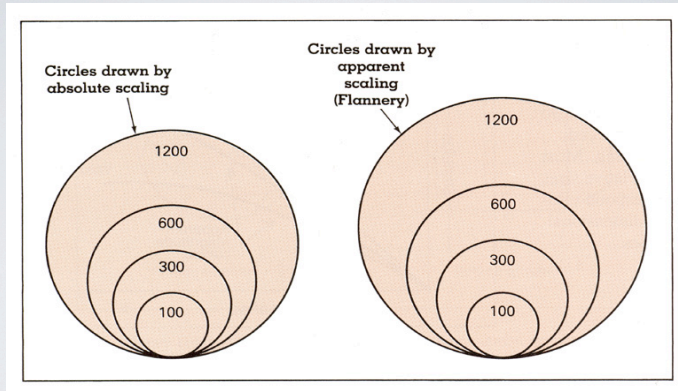
[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

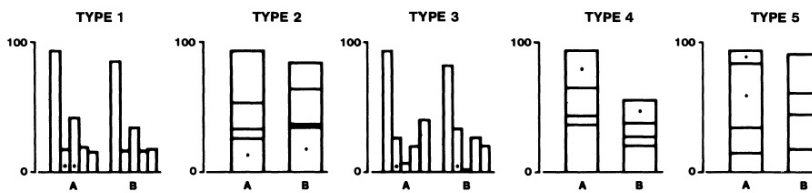$S = 0.98A^{0.87}$ [from Flannery 71]

Figure 4. Graphs from position–length experiment.
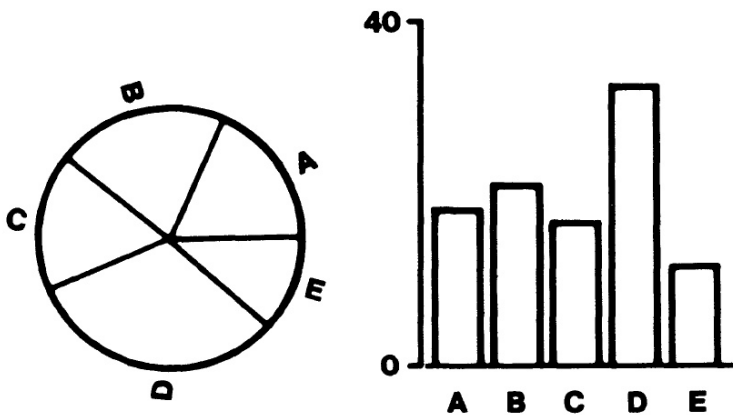
[Cleveland and McGill 84]

Figure 3. Graphs from position–angle experiment.
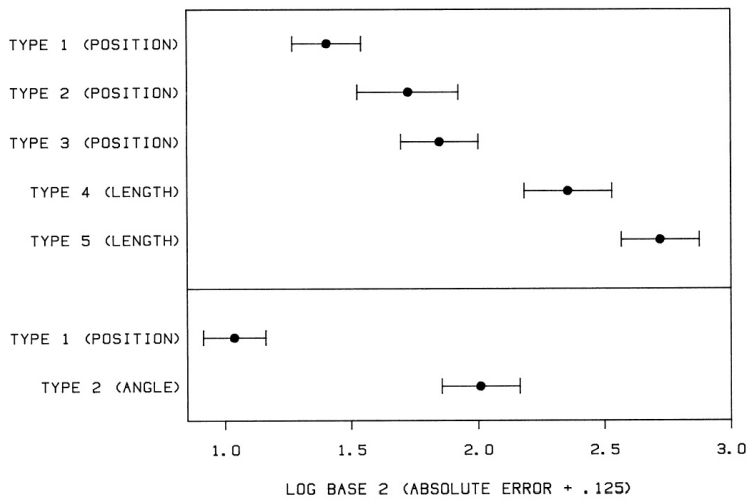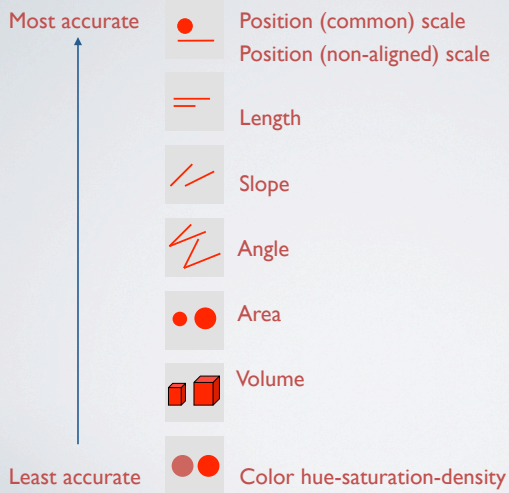
[Cleveland and McGill 84]

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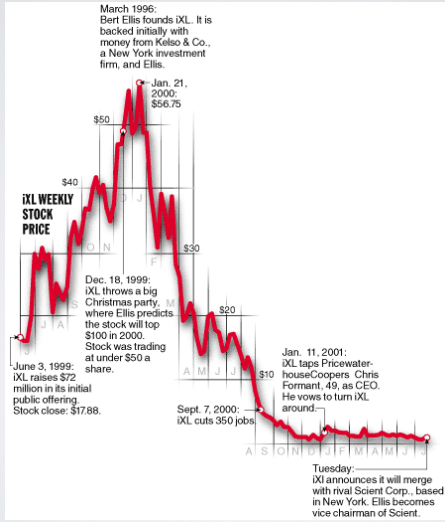

Relative Magnitude Estimation

Most accurate

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

Length

Slope

Angle

Area

Volume

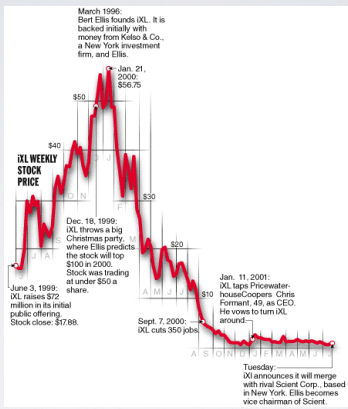Least accurate   Color hue-saturation-density

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Deconstructions

Stock Chart

Stock Chart

x-axis: time (Q)

y-axis: price (Q)

Exports and Imports [Playfair 1786]

Exports and Imports [Playfair 1786]

Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780

BALANCE in FAVOUR of ENGLAND.

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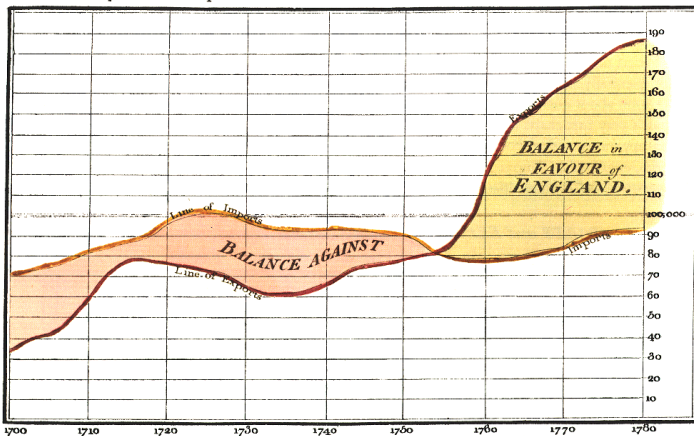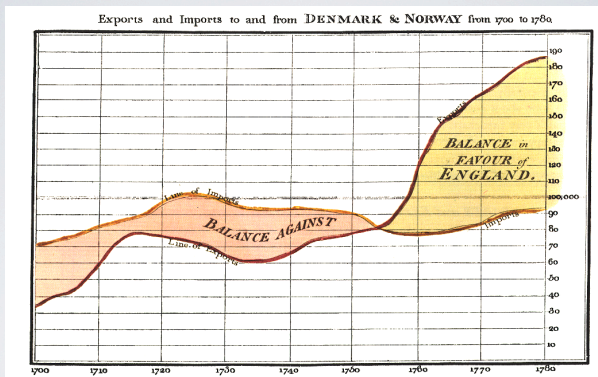
x-axis: year (Q)
y-axis: currency (Q)
color: imports/exports (N)
color: positive/negative (O)

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