Introduction to Human-Computer Interaction

Information Visualization

Lecture 7

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After today you will…

- have gained an overview of the research area
- learned basic principles of data representation and interaction

Why

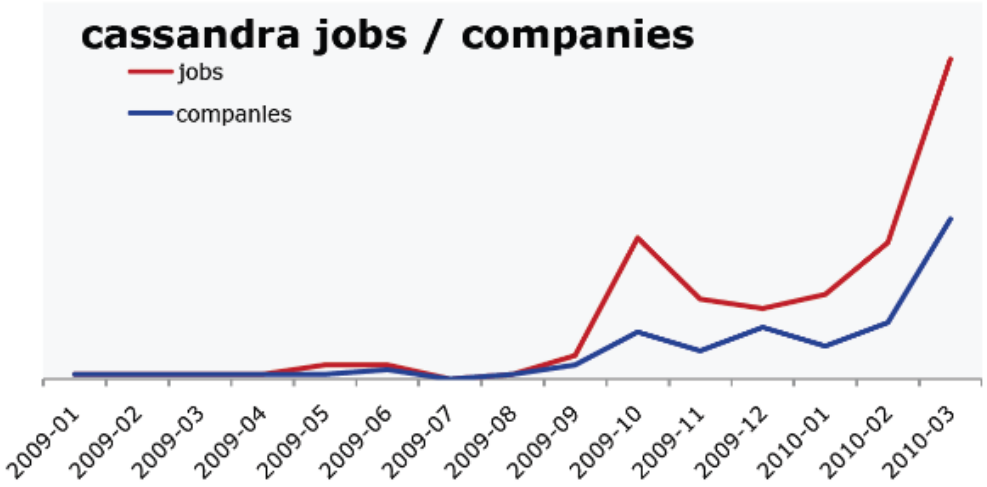
INFORMATION VISUALIZATION

It is estimated that 800 exabyte ($800x\ 10^{19}$) of digital information will be generated this year

[source: The Diverse and Exploding Digital Universe, IDC, 2008]
[credit: Did You Know; Fisch, McLeod, Brenman]


30
sep

Hiring trends for data science



It's not easy to get a handle on jobs in data science. However, data from O'Reilly Research shows a steady year-over-year increase in Hadoop and Cassandra job listings, which are good proxies for the "data science" market as a whole. This graph shows the increase in Cassandra jobs, and the companies listing Cassandra positions, over time.

"The ability to take data -- to be able to understand it, to process it, to extract value from it, to visualize it, to communicate it - that's going to be a hugely important skill in the next decades."

Hal Varian, chief economist at Google

Question

how can we effectively access data?

- understand its structure?
- make comparisons?
- make decisions?
- gain new knowledge?
- convince others?
-...

Many possible ways to address…

Example

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Raw Data from Anscombe’s Quartet

[Source: Anscombe's quartet, Wikipedia]

Statistical Analysis

For all four columns, the statistics are identical

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Mean of x	9.0
Variance of x	11.0
Mean of y	7.5
Variance of y	4.12
Correlation between x and y	0.816
Linear regression line	$y = 3 + 0.5x$

[Source: Anscombe's quartet, Wikipedia]

Visual Representation of the Data

Visual representation reveals a different story

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
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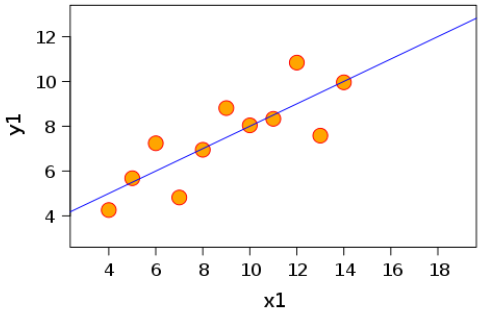
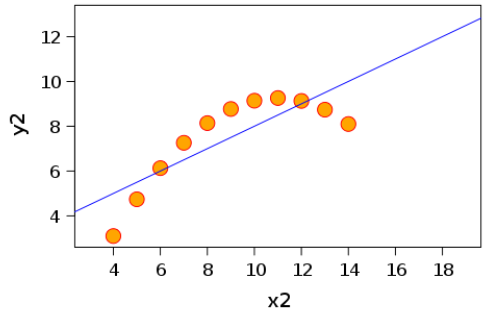
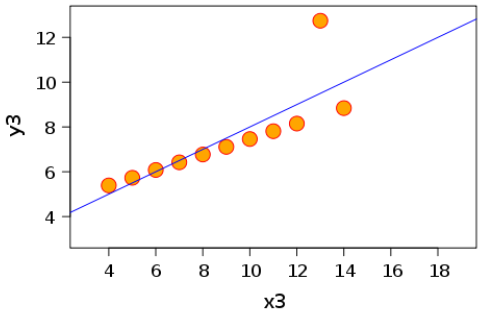
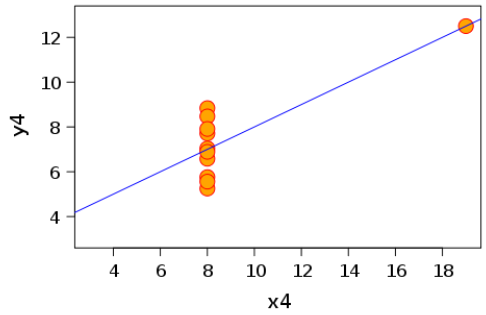






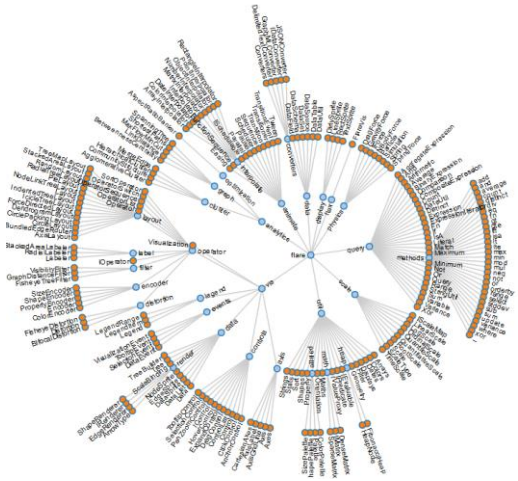


[Source: Anscombe's quartet, Wikipedia]

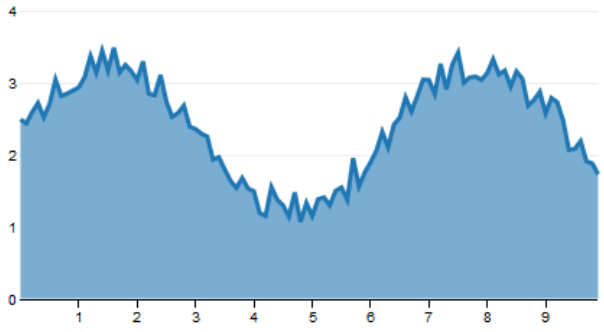
Why visual data representations?

- Vision is our most dominant sense
- We are very good at recognizing visual patterns
- We need to see and understand in order to explain, reason, and make decisions

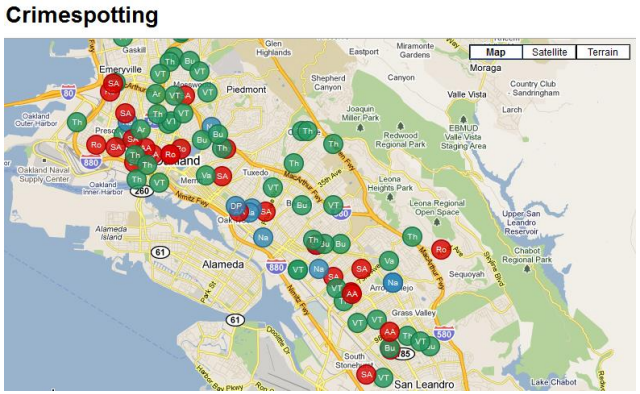
common examples:



graphs / hierarchies



charts

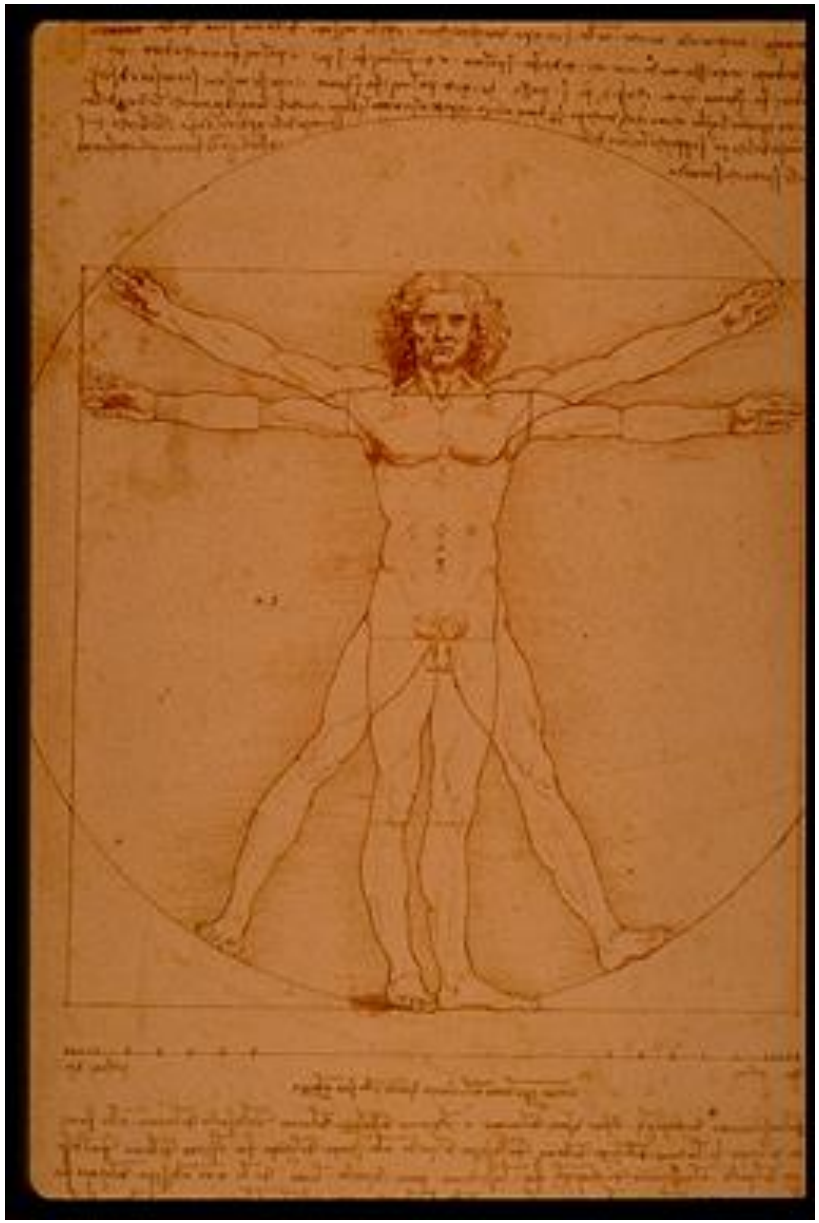


maps

all examples from: http://vis.stanford.edu/protovis/

Other benefits of visualization

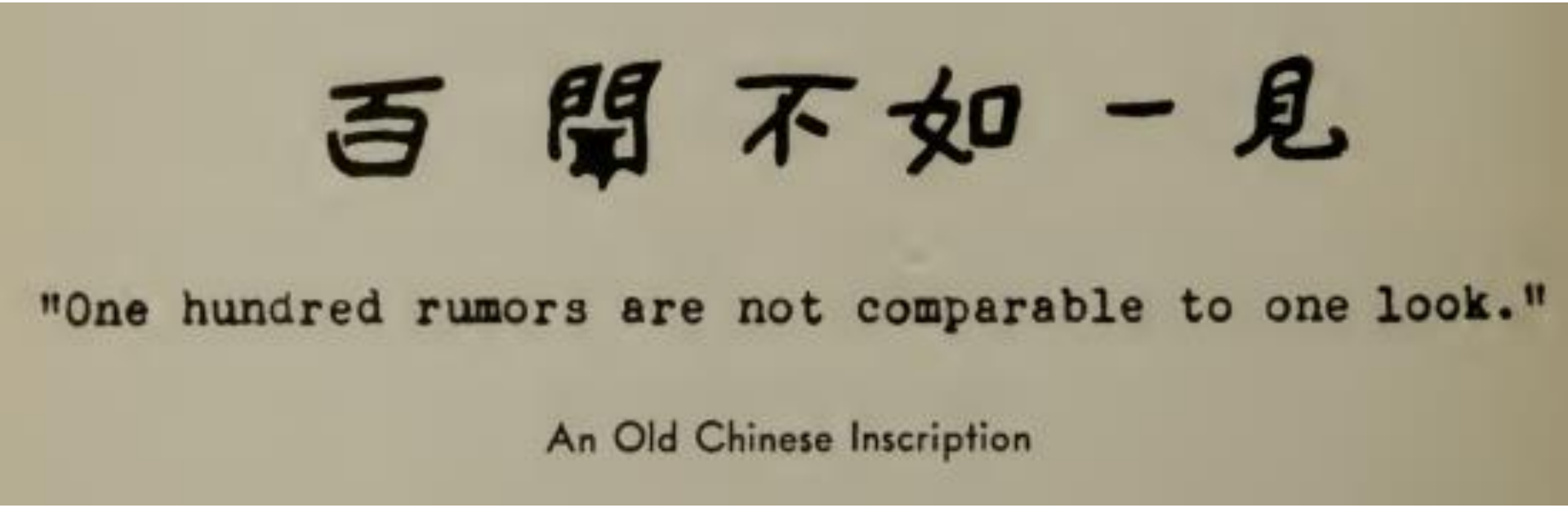
- expand human working memory
  - offload cognitive resources to the visual system,
- reduce search
  - by representing a large amount of data in a small space,
- enhance the recognition of patterns
  - by making them visually explicit
- aid monitoring of a large number of potential events
- provides a manipulable medium & allows exploration of a space of parameter values.



L'occhio,
che si dice finestra dell'anima,
è la principale via donde il comune
senso può piú copiosamente e
magnificamente considerare
le infinite opere di natura.

Leonardo da Vinci
(1452 - 1519)

The eye…
the window of the soul,
is the principal means
by which the central sense
can most completely and
abundantly appreciate
the infinite works of nature.



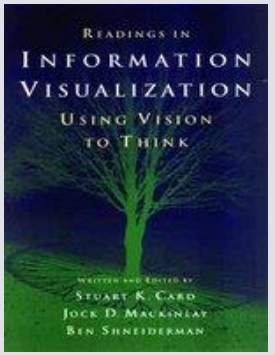
Via Brinton, Graphic Presentation, 1939

Information visualization

- Create visual representation
- Concentrates on abstract data
- Includes interaction

Official Definition:

The use of computer-supported, interactive, visual representations of abstract data to amplify cognition.
[Card et al., 1999]



Functions of Visualizations

- Recording information
  - Tables, blueprints, satellite images
- Processing information
  - needs feedback and interaction
- Presenting information
  - share, collaborate, revise
  - for oneself, for one's peers and to teach
- Seeing the unseen

Visualization of abstract data has been practiced for hundreds of years…

HISTORICAL EXAMPLES

The Broadway Street Pump

- In 1854 cholera broke out in London
  - 127 people near Broad Street died within 3 days
  - 616 people died within 30 days
- "Miasma in the atmosphere"
- Dr. John Snow was the first to link contaminated water to the outbreak of cholera
- How did he do it?
  - he talked to local residents
  - identified a water pump as a likely source
  - used maps to illustrate his theory
  - convinced authorities to disable the pump

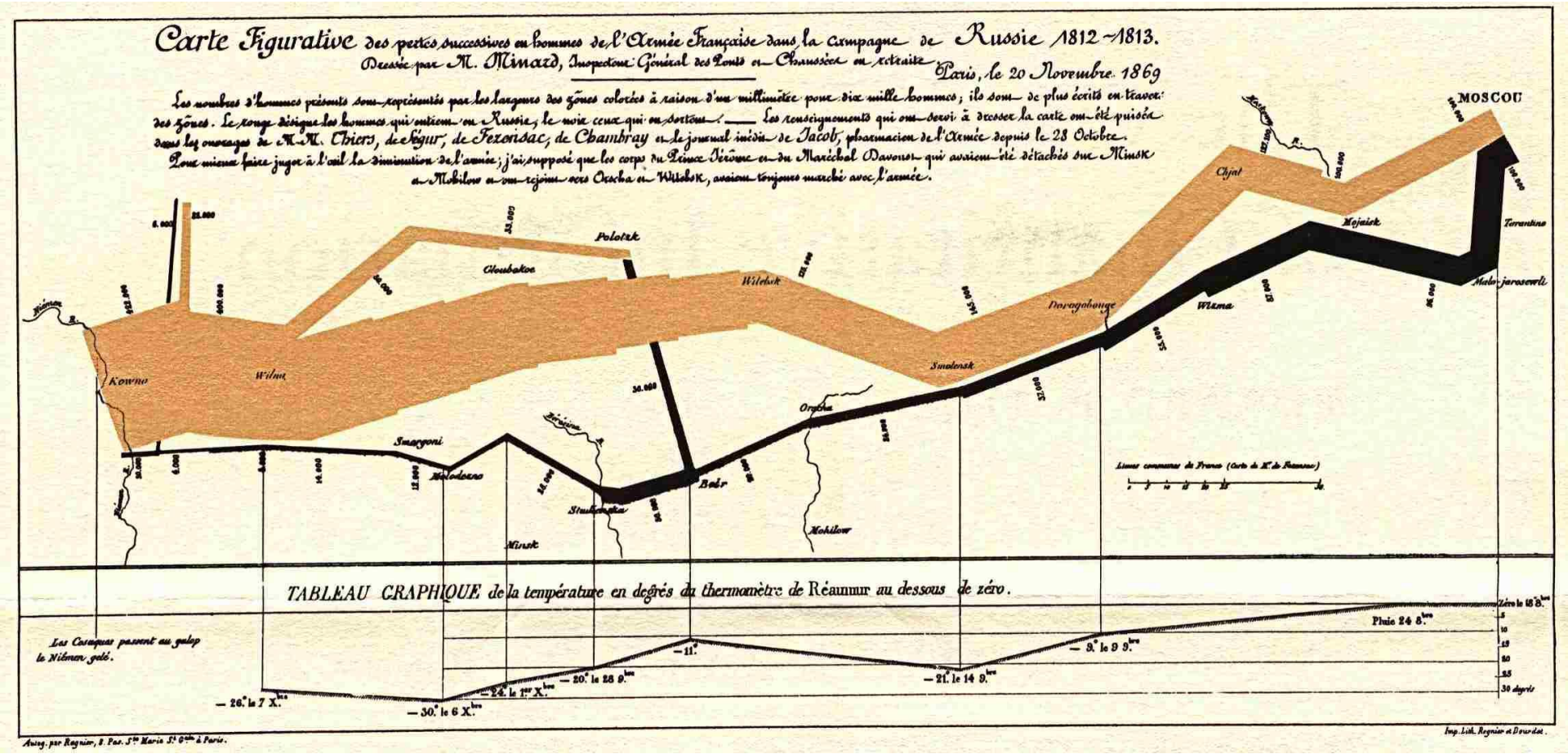
More info here: http://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak

John Snow, 1854

Napoleon's March on Moscow Charles Minard, 1869

Named the best statistical graphic ever drawn (by Edward Tufte)

- Includes: spatial layout linked with stats on: army size, temperature, time
- Tells a story in one overview



More info: The Visual Display of Quantitative Information (Tufte)

CARTE FIGURATIVE des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dressée par **M. Minard**, *Inspecteur Général des Ponts et Chaussées en retraite.*

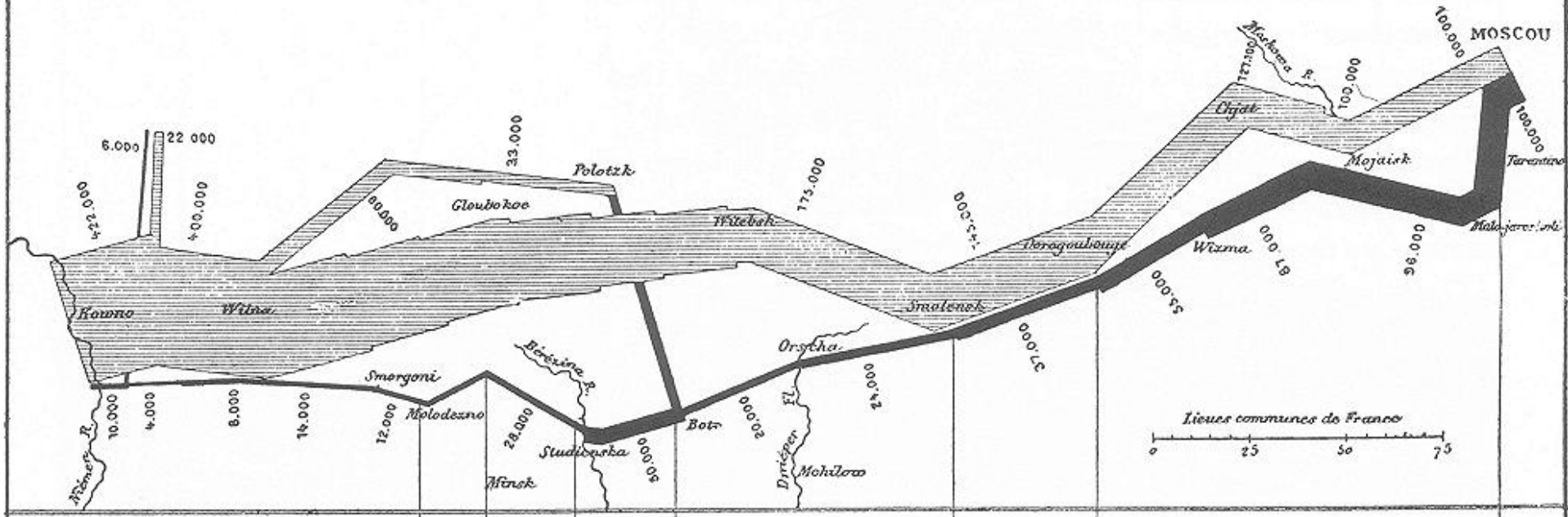
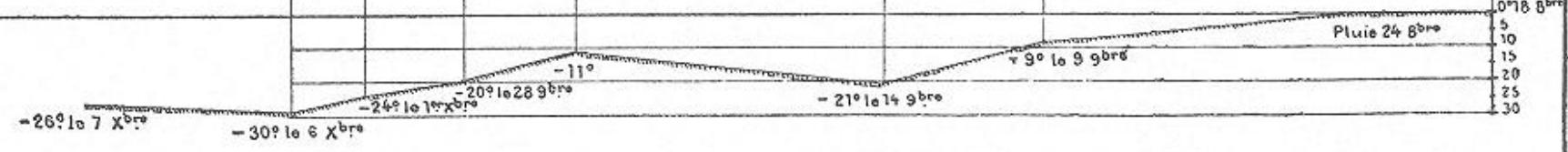


TABLEAU GRAPHIQUE *de la température en degrés du thermomètre de* Réaumur *au dessous de zéro*

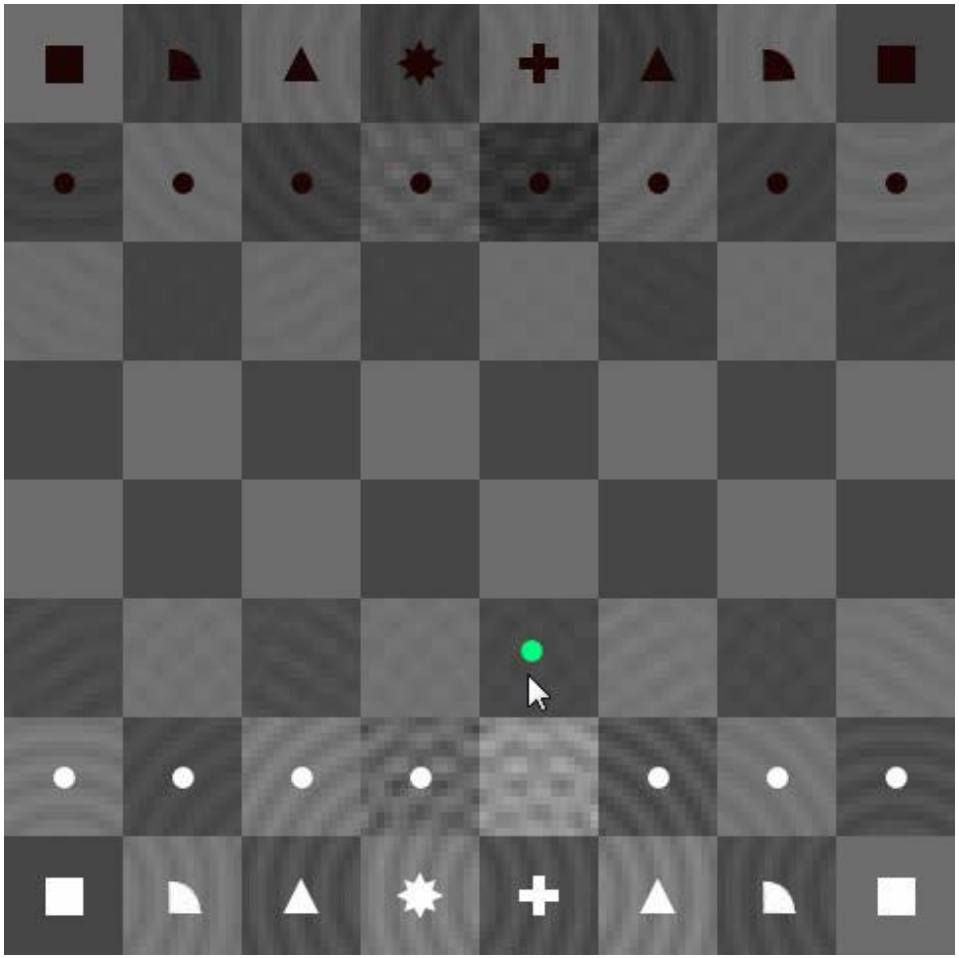


… AND VERY RECENTLY

TrashTrack

Winner of the NSF International Science & Engineering Visualization Challenge!
http://senseable.mit.edu/trashtrack/

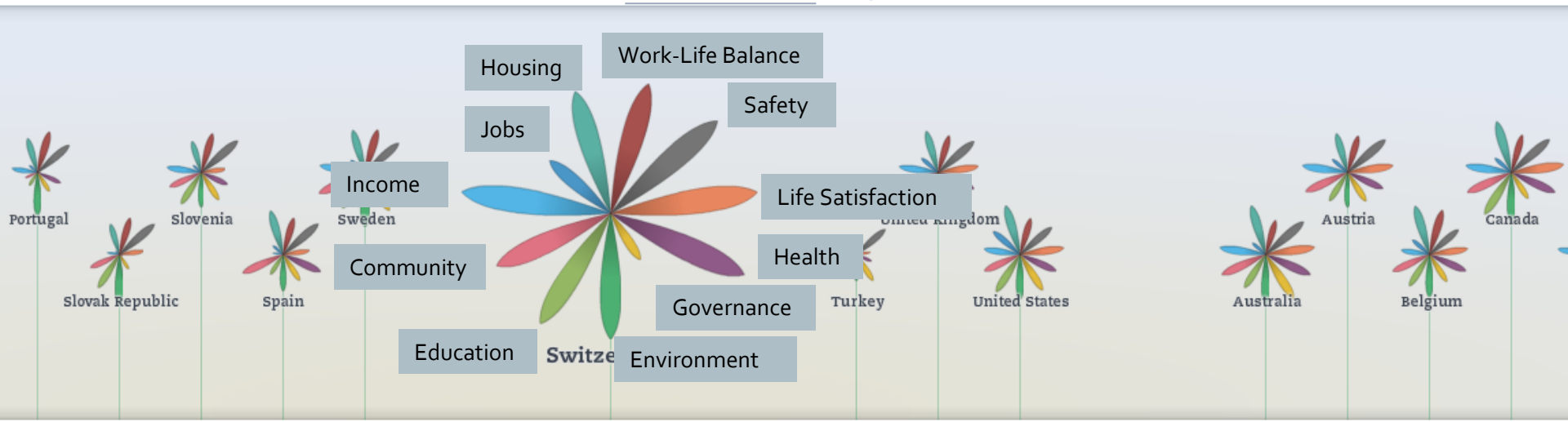
Artificial Intelligence



http://www.turbulence.org/spotlight/thinking/chess.html

Open Data

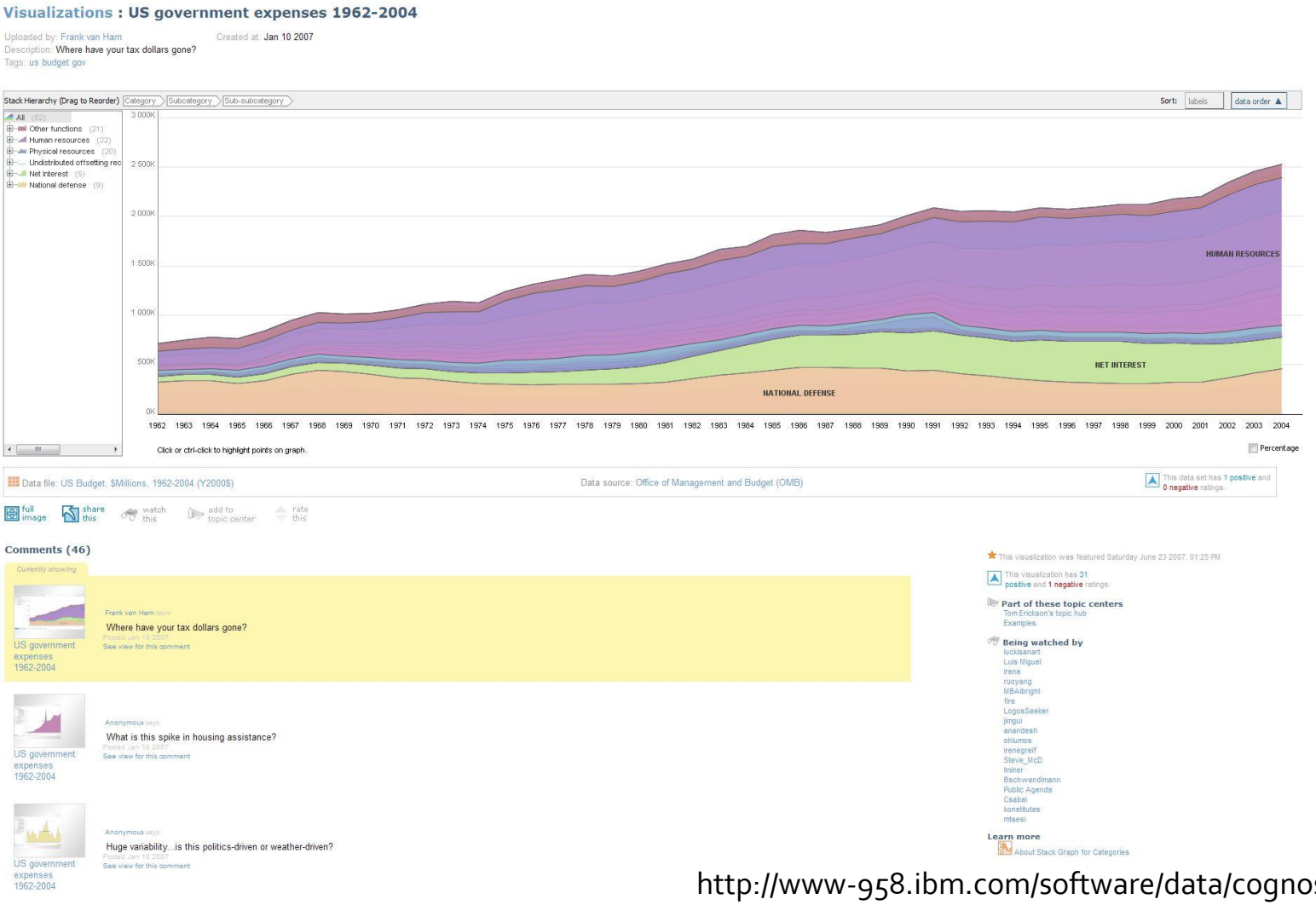
- Movement making government data freely available
- Encourage participation by everyone



OECD Better Life Index: http://www.oecdbetterlifeindex.org/

Many Eyes

- Upload data, create visualizations, discuss
- Distributed asynchronous collaboration



http://www-958.ibm.com/software/data/cognos/manyeyes/

Specific Visualization Environments

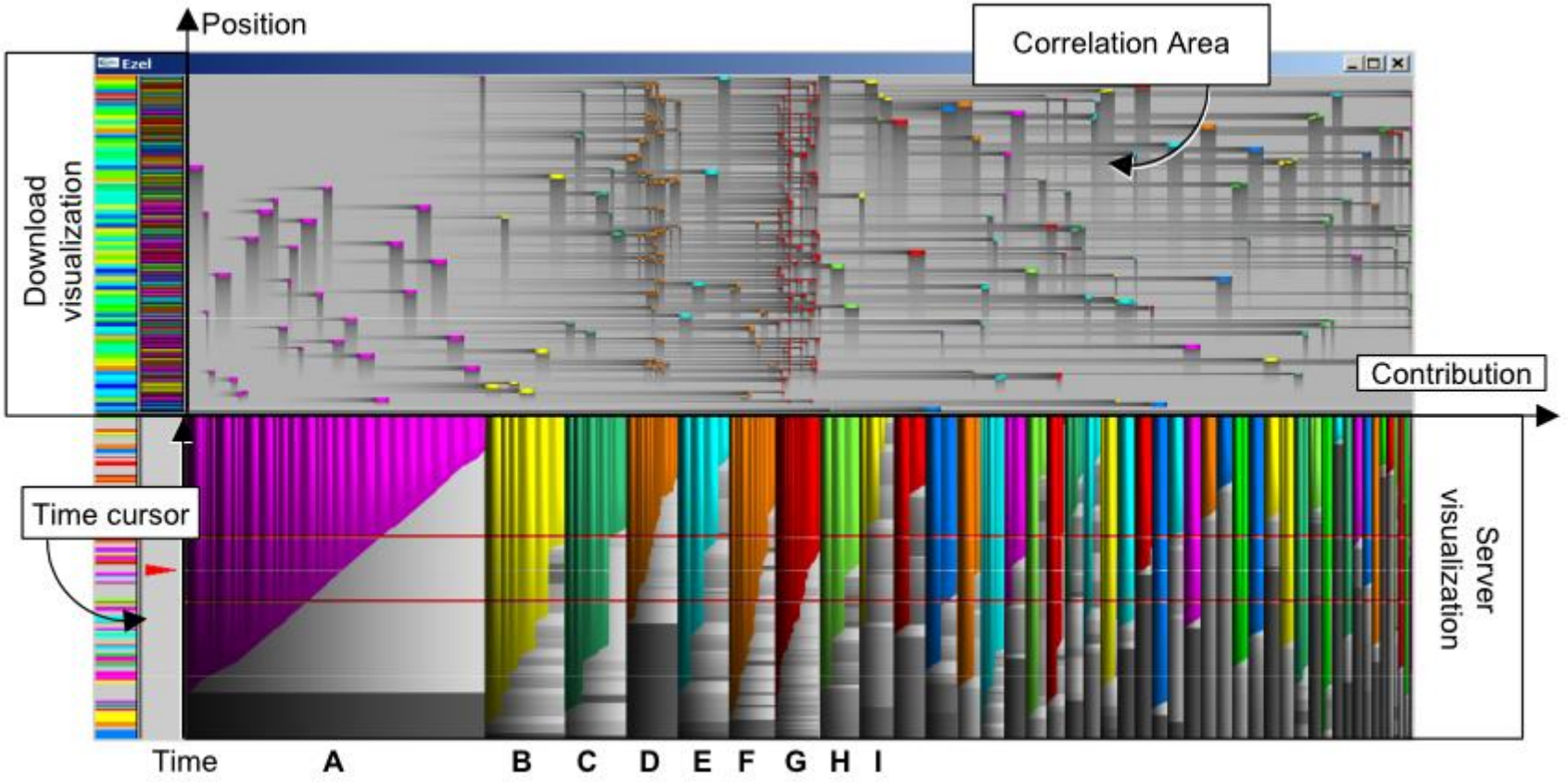
Molecular visualisation in the Reality Cube
University of Groningen, NL

Tabletops for Visualization
University of Calgary

WILD Wall, INRIA

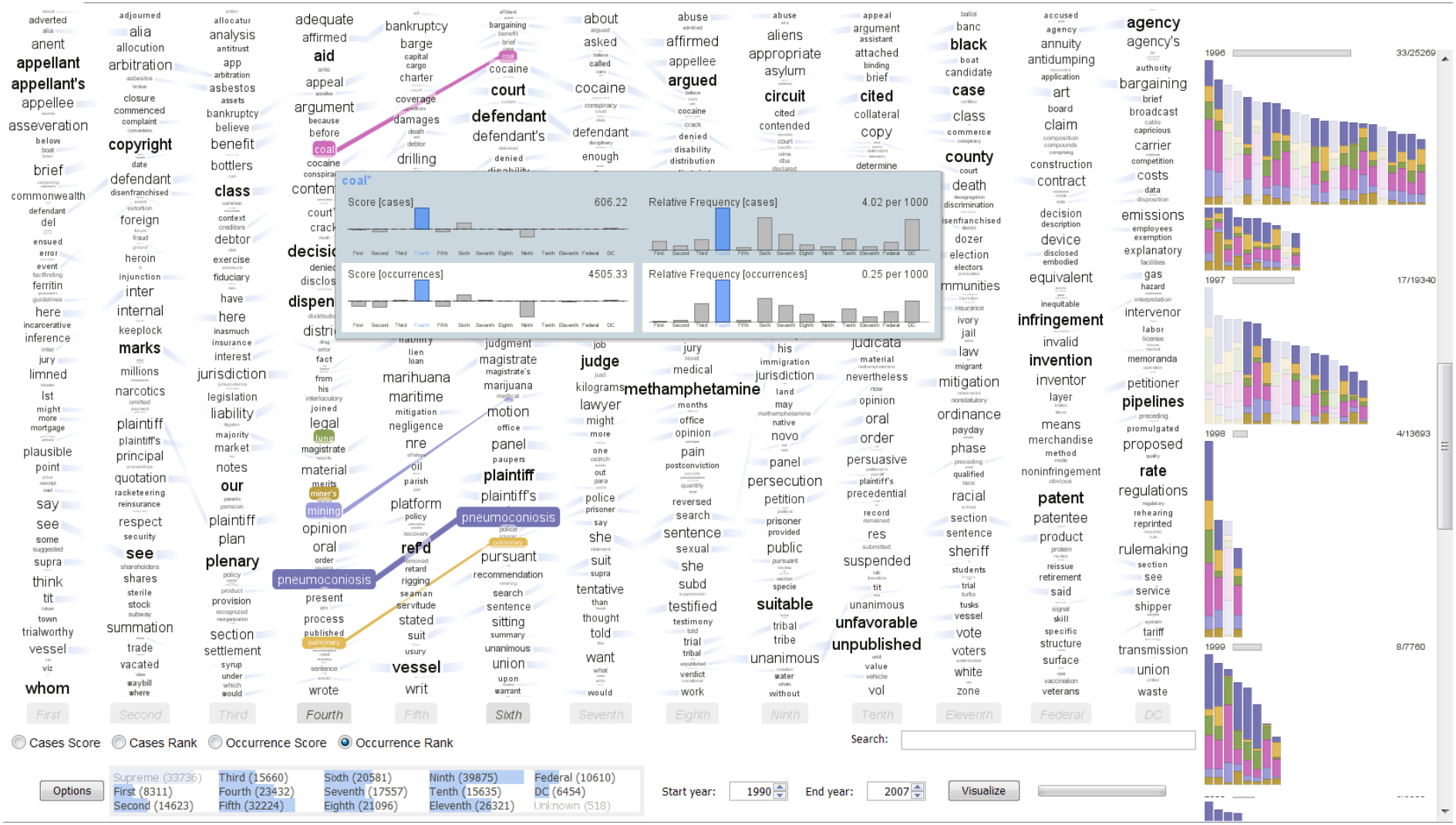
Software Visualization

EZEL: a Visual Tool for Performance Assessment of Peer-to-Peer File-Sharing Networks (Voinea et al., InfoVis, 2004)

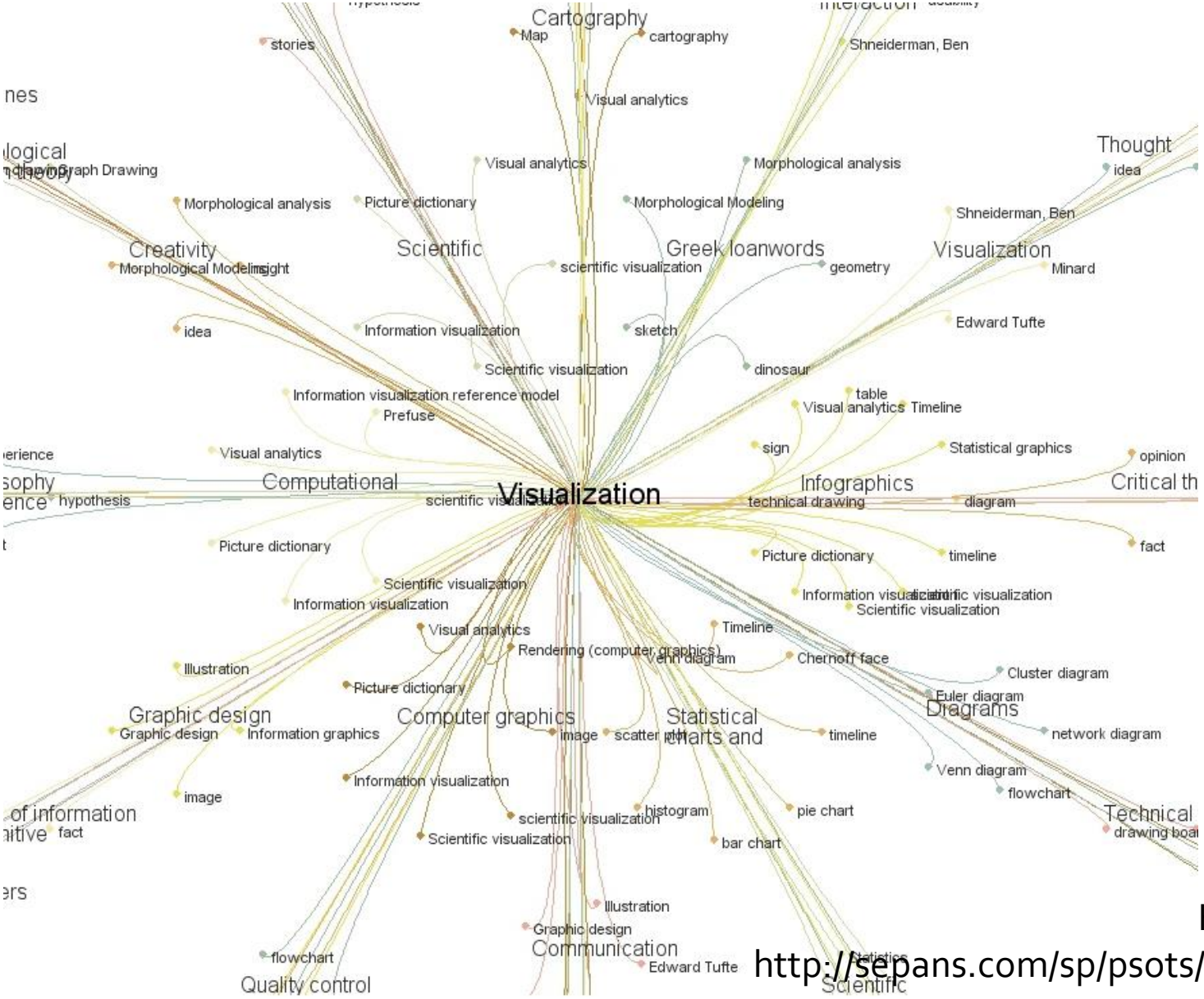


Text Visualization

Parallel Tag Clouds to Explore Faceted Text Corpora (Collins et al., VAST 2009)

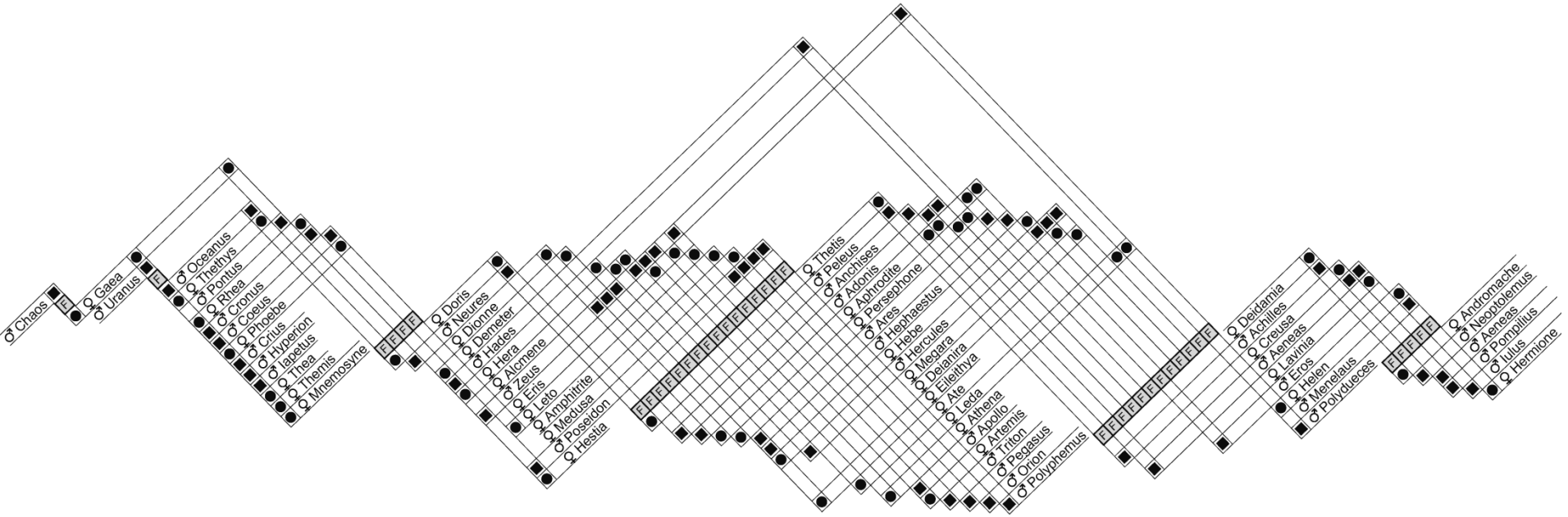


Graphs



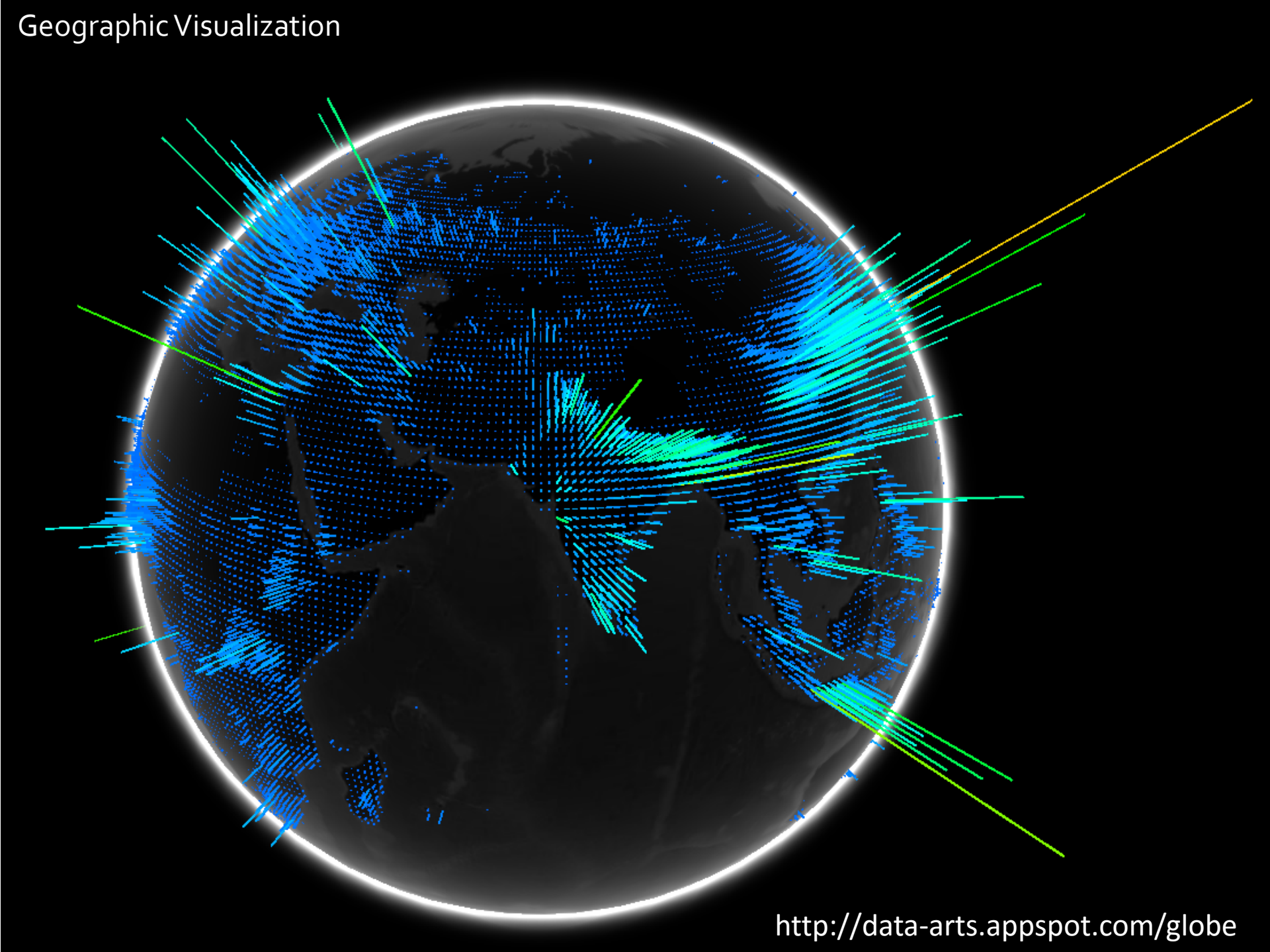
Here Wikipedia
http://sepans.com/sp/psots/wiki_category/

Family Trees



http://www.aviz.fr/geneaquilts/

Geographic Visualization

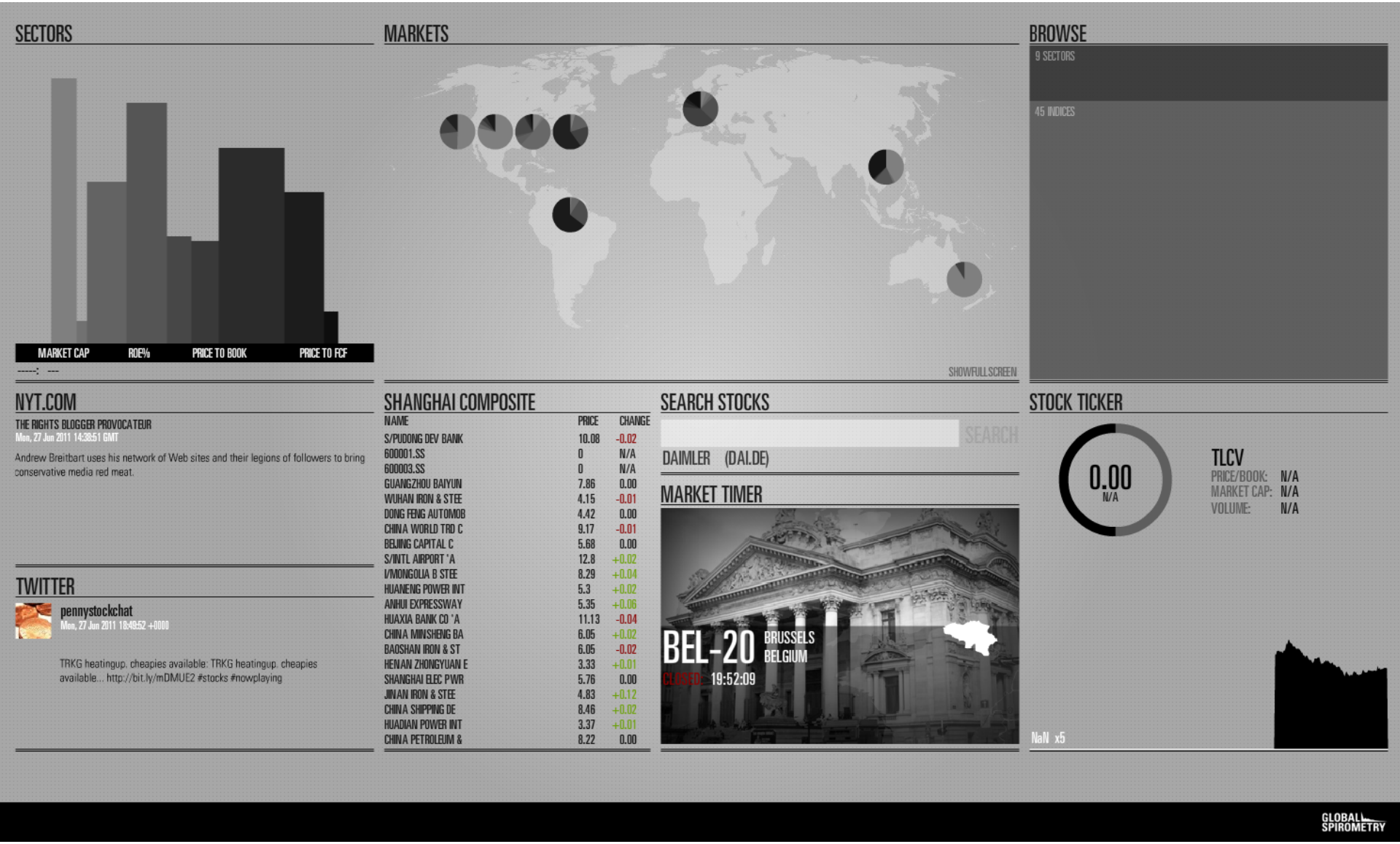


http://data-arts.appspot.com/globe

Weather

http://weatherspark.com/

Data Dashboards



http://globalspirometry.com

Resources for more examples

- Visualization conferences
- Blogs
  - http://infosthetics.com/
  - http://fellinlovewithdata.com/
  - http://eagereyes.org/
  - http://flowingdata.com/
  - http://www.informationisbeautiful.net/
- Books
  - Textbooks
    - Readings in Information Visualization: Using Vision to Think (a bit old now but good intro)
    - Information Visualization (Robert Spence – a light intro, I recommend as a start)
    - Information Visualization Perception for Design (Colin Ware, focused on perception and cognition)
    - Interactive Data Visualization: Foundations, Techniques, and Applications (Ward et al. – most recent)
  - Examples
    - Beautiful Data (McCandless)
    - Now You See it (Few)
    - Tufte Books: Visual Display of Quantitative Information (and others)
    - … (many more, ask me for details)

It is difficult to create

CREATE VISUALIZATIONS


Cem

What is a representation?

- A representation is
  - a formal system or mapping by which the information can be specified (D. Marr)
  - a sign system in that it stands for something other than its self.
- for example: the number thirty-four

34 decimal

100010 binary

XXXIV roman

Presentation

- different representations reveal different aspects of the information

  decimal: counting & information about powers of 10,

  binary: counting & information about powers of 2,

  roman: impress your friends (outperformed by positional system)

- presentation

  how the representation is placed or organized on the screen

34, **34**, <u>34</u>

Principles of Graphical Excellence

- Well-designed presentation of interesting data – a matter of *substance*, *statistics*, *design*
- Complex ideas communicated with clarity, precision, efficiency
- Gives the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space
- Involves almost always multiple variables
- Tell the truth about the data

Or a bit more simply…

- Solving a problem simply means representing it so as to make the solution transparent … (Simon, 1981)
- Good representations:
  - allow people to find relevant information
    - information may be present but hard to find
  - allow people to compute desired conclusions
    - computations may be difficult or "for free" depending on representations

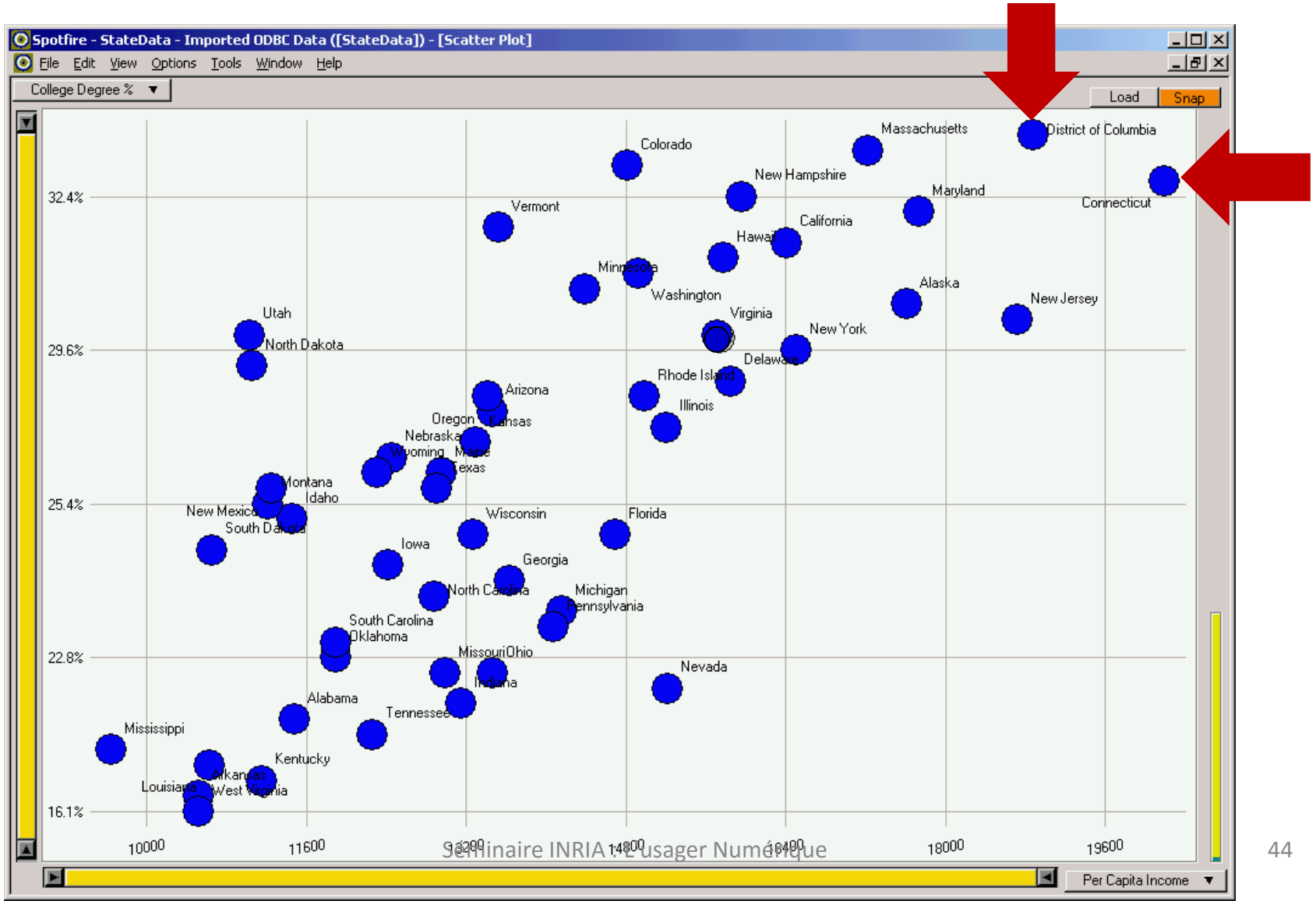
Good representation?

Table - StateData ()

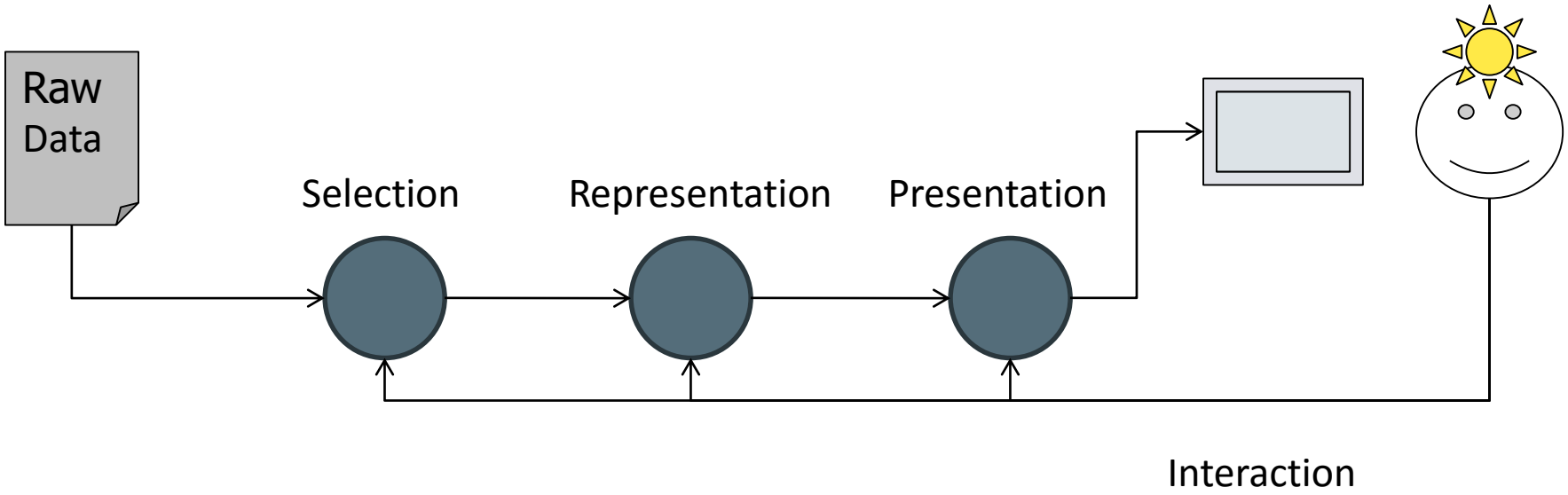
Load | Snap

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

Good representation!



How do we arrive at a visualization?



The Visualization Pipeline

From [Spence, 2000]

Visualization Reference Model

Also a visualization pipeline a bit expanded

Data Transformation

Spatial Mapping Transformation

Presentation Transformation

View Transformation

From [Card et al., Readings in Information Visualization]

Pitfalls

- Selecting the wrong data
- Selecting the wrong data structure
- Filtering out important data
- Failed understanding of the types of things that need to be shown
- Choosing the wrong representation
- Choosing the wrong presentation format
- Inappropriate interactions provided to explore the data

Recap

- So far you
  - learned what information visualization is
  - learned about the advantages of visualization
  - saw a number of examples (historical and new)
  - tried to create your own first visualization from a dataset

- Next
  - you will get to know your data
  - you will learn about the basic components of visualization
  - try another example

Data

- Data is the foundation of any visualization
- The visualization designer needs to understand
  - the data properties
  - know what meta-data is available
  - know what people want from the data

Nominal, Ordinal and Quantitative

- Nominal (labels)
  - Fruits: apples, oranges
- Ordered
  - Quality of meat: grade A, AA, AAA
  - Can be counted and ordered, but not measured
- Quantitative: Interval
  - no clear zero (or arbitrary)
  - e.g. dates, longitude, latitude
  - usually compare differences (intervals)
- Quantitative: Ratio
  - meaningful origin (zero)
  - physical measurements (temperature, mass, length)
  - counts and amounts

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

Nominal, Ordinal and Quantitative

- Nominal (labels)
  - Operations: =, ≠
- Ordered
  - Operations: =, ≠, <, >
- Quantitative: Interval
  - Operations: =, ≠, <, >, -, +
  - Can measure distances or spans
- Quantitative: Ratio
  - Operationrs: =, ≠, <, >, - , +, ×, ÷
  - Can measure ratios or proportions

[1989 – 1999] + [2002 – 2012]

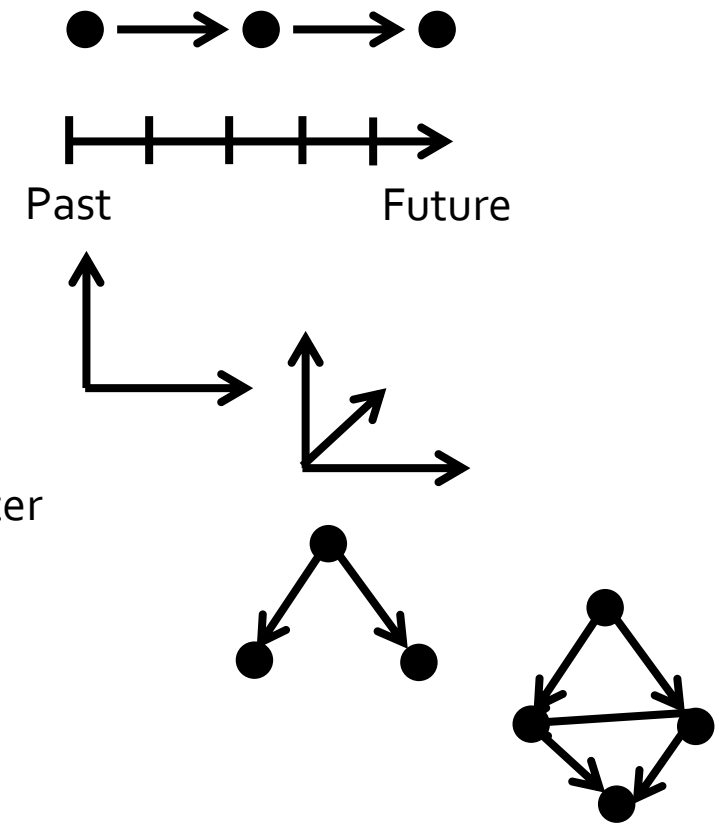
10kg / 5kg

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

Data-Type Taxonomy

- 1D (linear)
- Temporal
- 2D (maps)
- 3D
- nD (relational)
- Trees (hierarchies)
- Networks (graphs)

vis examples later



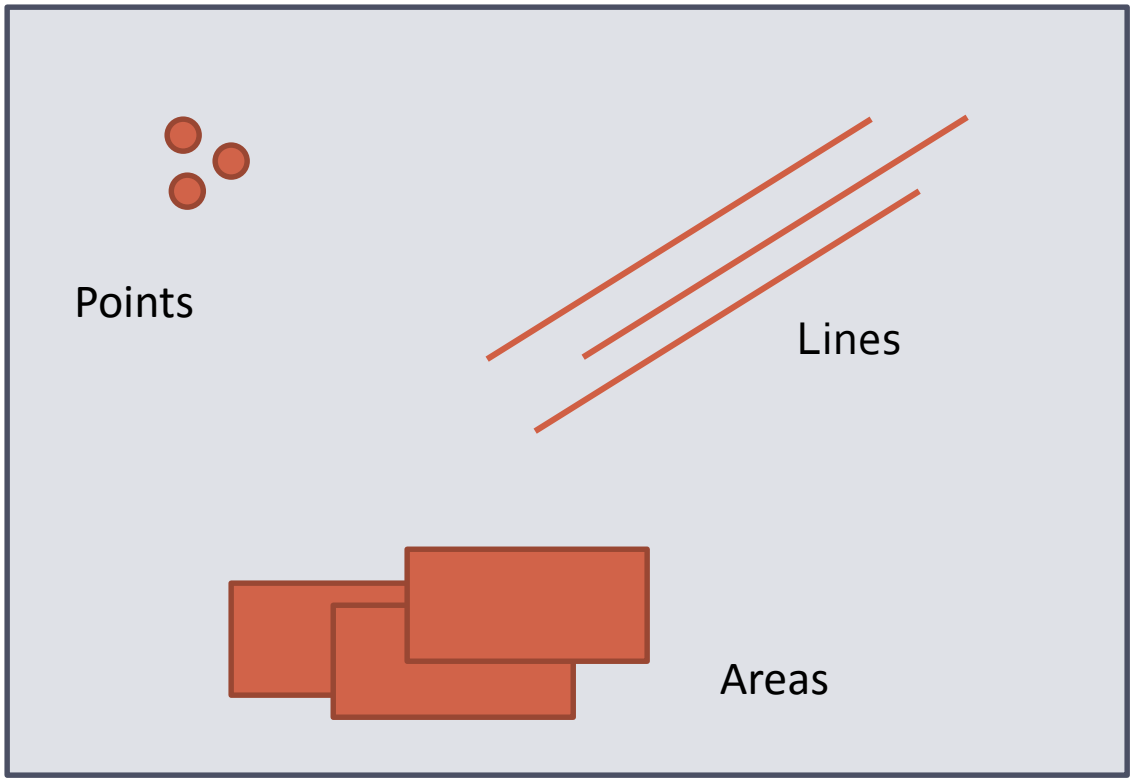
Shneiderman: The Eyes Have It

Why is this important?

- Nominal, ordinal, and quantitative data are best expressed in different ways visually
- Data types often have inherent tasks
  - temporal data (comparison of events)
  - trees (understand parent-child relationships)
  - …
- But:
  - any data type (1D, 2D,…) can be expressed in a multitude of ways!

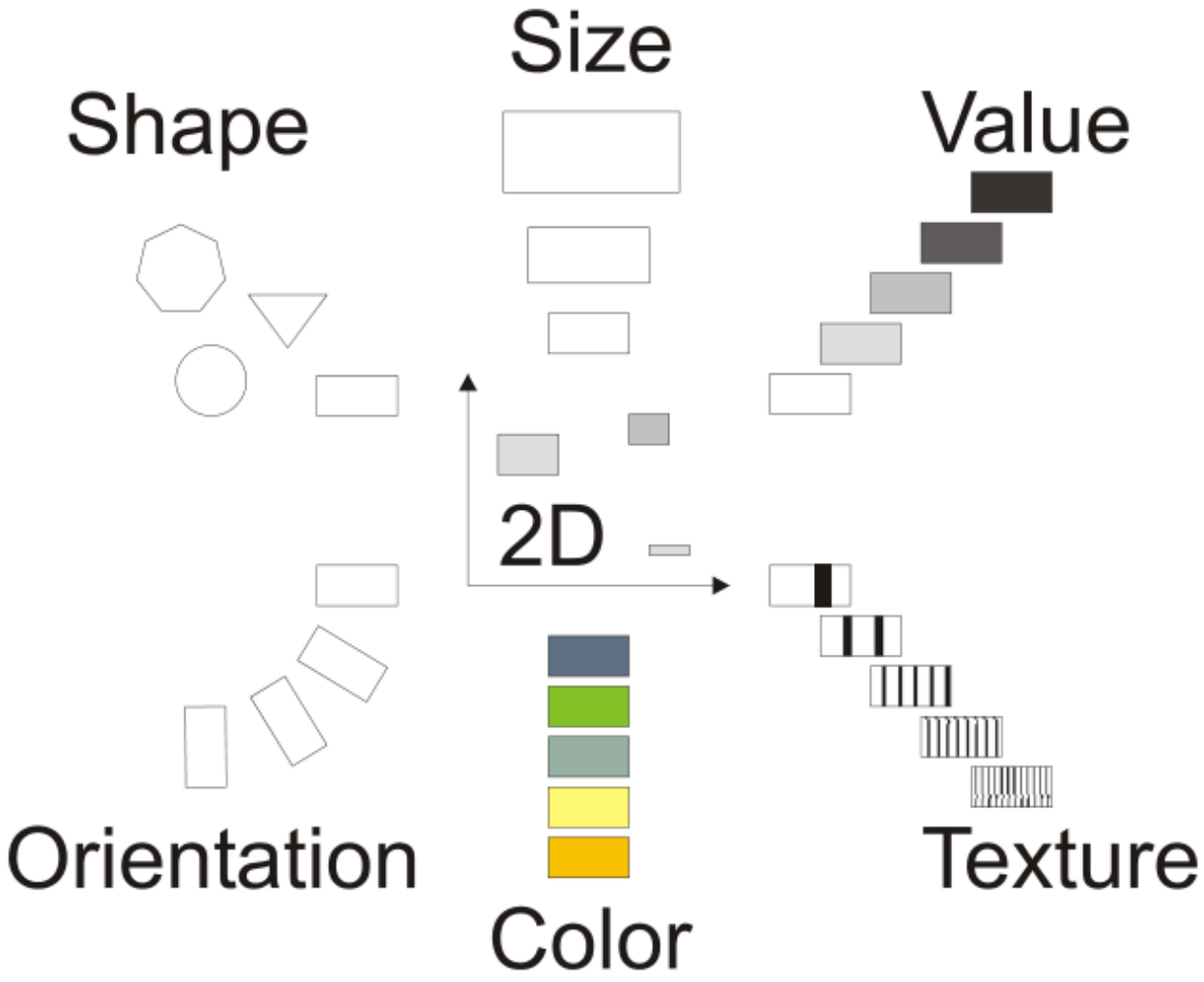
Visualization's Main Building Blocks

Marks which represent:



From Semiology of Graphics (Bertin)

Visual Variables Applicable to Marks

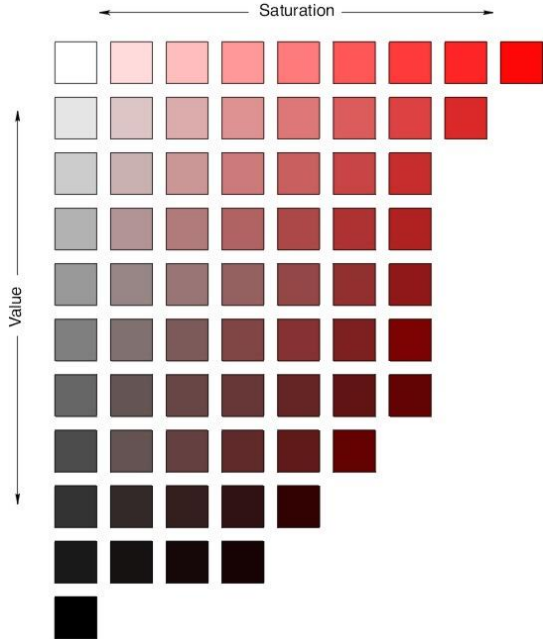


From Semiology of Graphics (Bertin)

Additional Variables for Computers

- **motion**
  - direction, acceleration, speed, frequency, onset, 'personality'

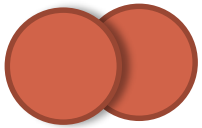
- **saturation**
  - colour as Bertin uses largely refers to hue, saturation != value

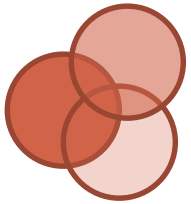


Extending those from Semiology of Graphics (Bertin)

Additional Variables for Computers

- **flicker**
  - frequency, rhythm, appearance
- **depth?** 'quasi' 3D
  - depth, occlusion, aerial perspective, binocular disparity
- **Illumination**
- **transparency**





From Semiology of Graphics (Bertin)

Characteristics of Visual Variables

- Selective:
  Is a change in this variable enough to allow us to select it from a group?
- Associative:
  Is a change in this variable enough to allow us to perceive them as a group?
- Quantitative:
  Is there a numerical reading obtainable from changes in this variable?
- Order:
  Are changes in this variable perceived as ordered?
- Length (resolution):
  Across how many changes in this variable are distinctions possible?

From Semiology of Graphics (Bertin)

Visual Variables

Visual Variable	Selective	Associative	Quantitative	Order	Length
Position	Yes	Yes	Yes	Yes	Dependant on resolution
Size	Yes	Yes	Approximate	Yes	Association: 5; Distinction: 20
Shape	With Effort	With Effort	No	No	Infinite
Value	Yes	Yes	No	Yes	Association: 7; Distinction: 10
Hue	Yes	Yes	No	No	Association: 7; Distinction: 10
Orientation	Yes	Yes	No	No	4
Grain	Yes	Yes	No	No	5
Texture	Yes	Yes	No	No	Infinite
Motion	Yes	Yes	No	Yes	Unknown

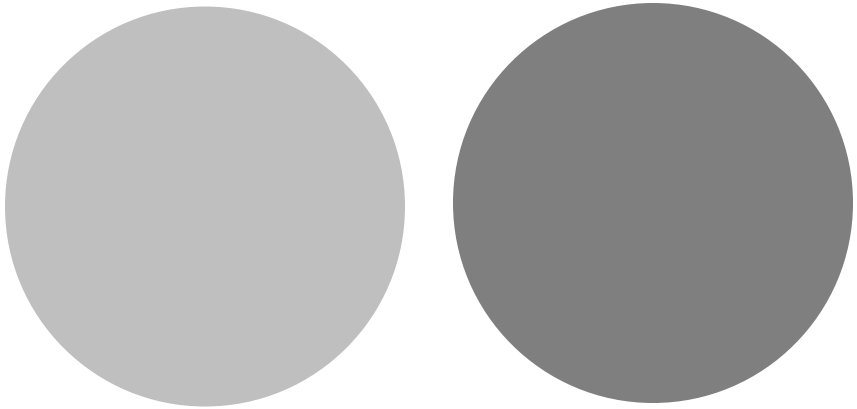
Elementary Graphical Perception Tasks

William S. Cleveland 1980s

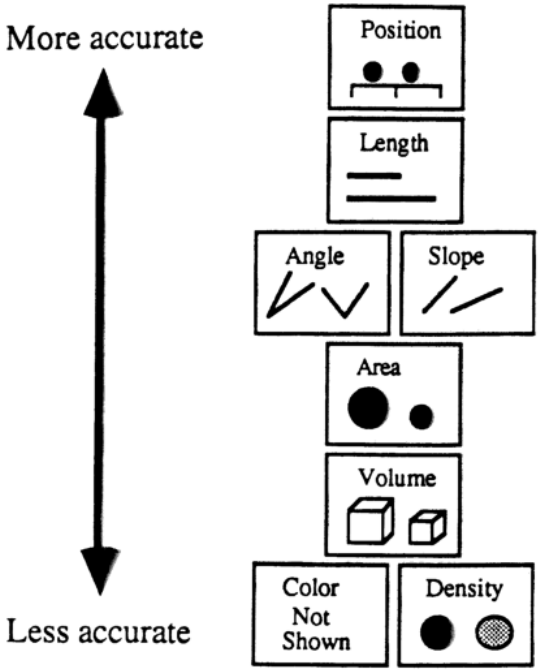
- Performed controlled experiments to find out how effectively people could judge changes in visual features
- Focus on quantitative information
- Variables used: angle, area (size), color hue, color saturation, density (value), length, position, slope, volume

Value

- What percentage in value is the right from the left (=100%) ?

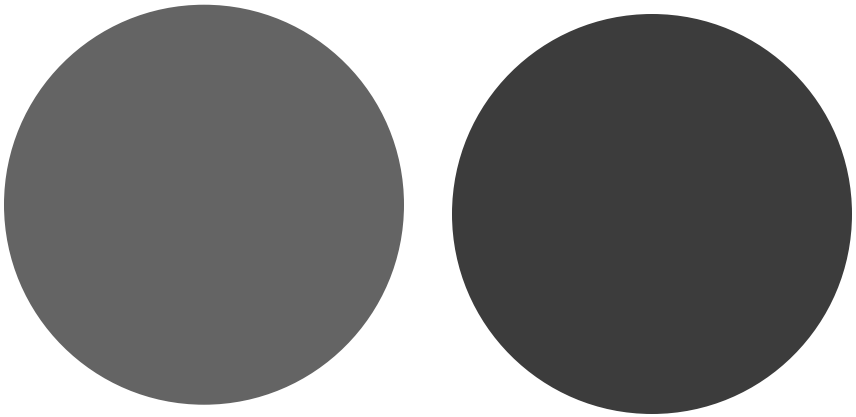


66%

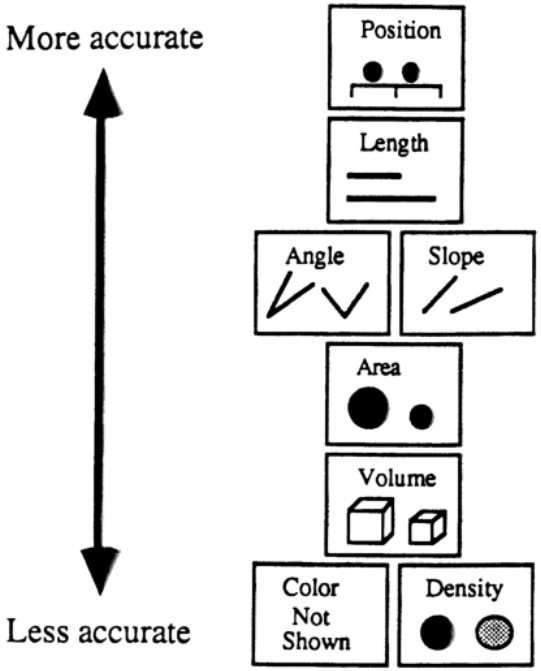


Value

- What percentage in value is the right from the left (=100%)?

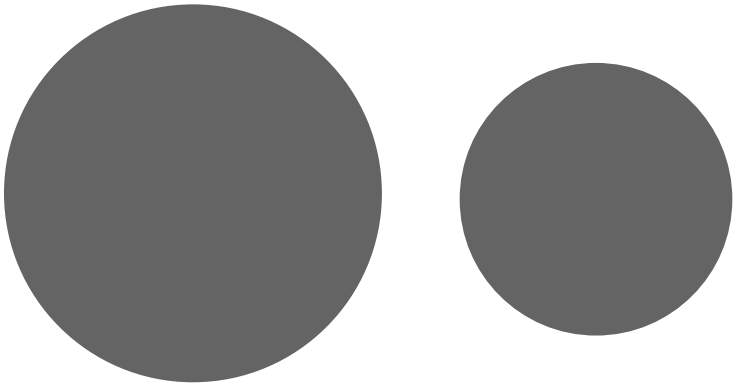


60%

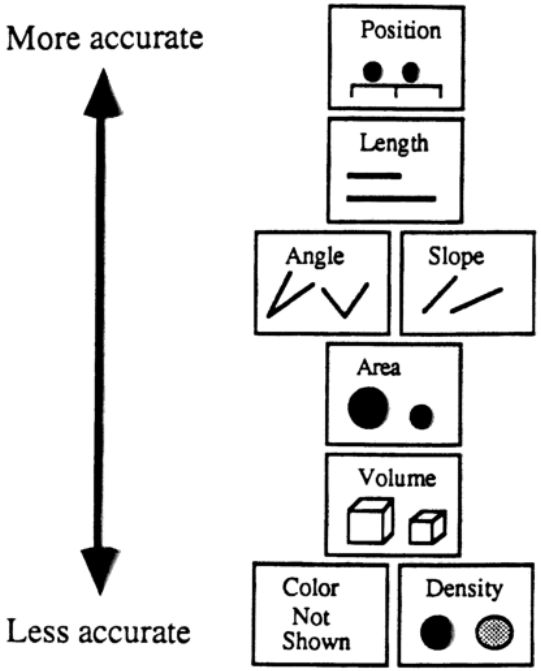


Area

- What percentage in size is the right from the left (=100%)?

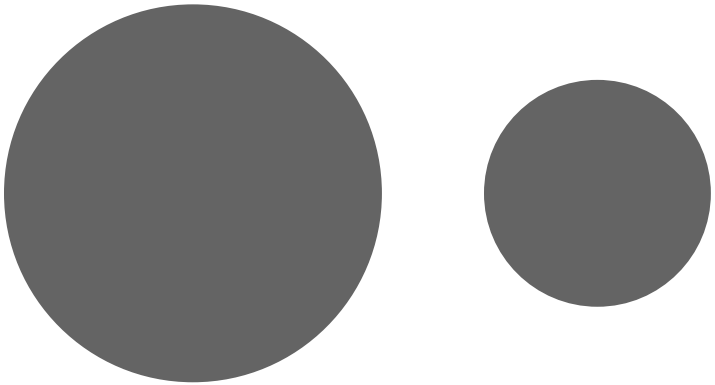


52%

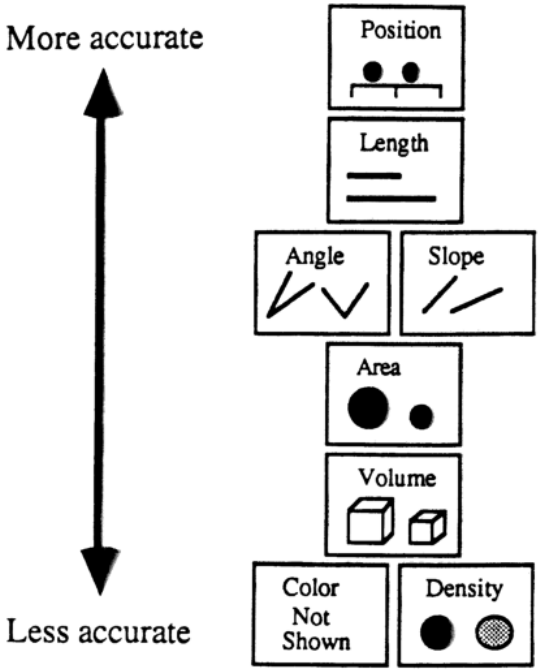


Area

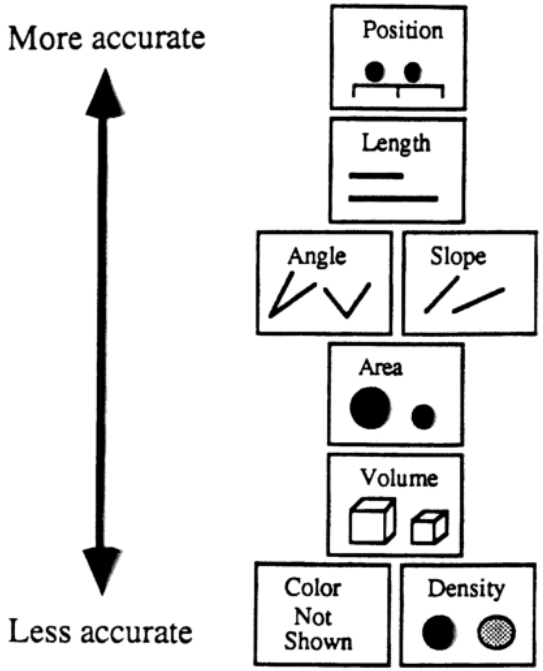
- What percentage in size is the right from the left (=100%)?



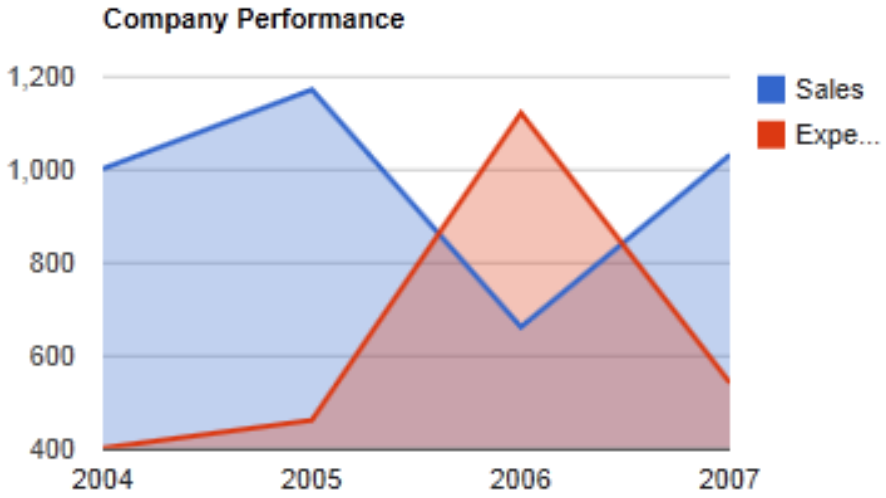
36%



Area



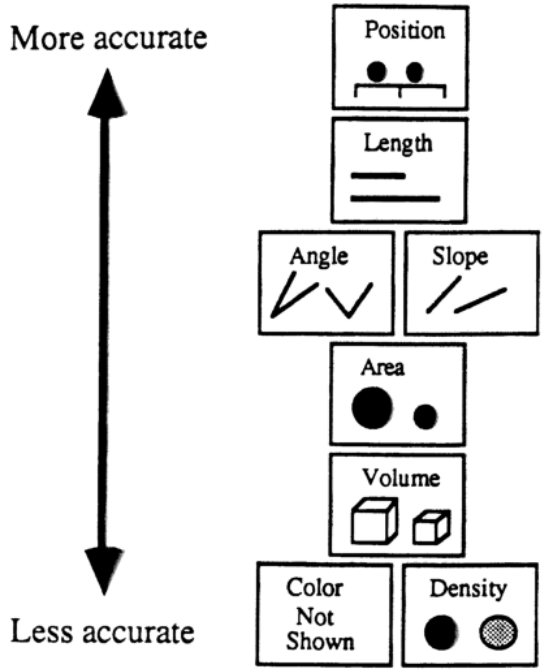
- What percentage in size is the red from the blue (=100%)?



no idea – this is very difficult

Length

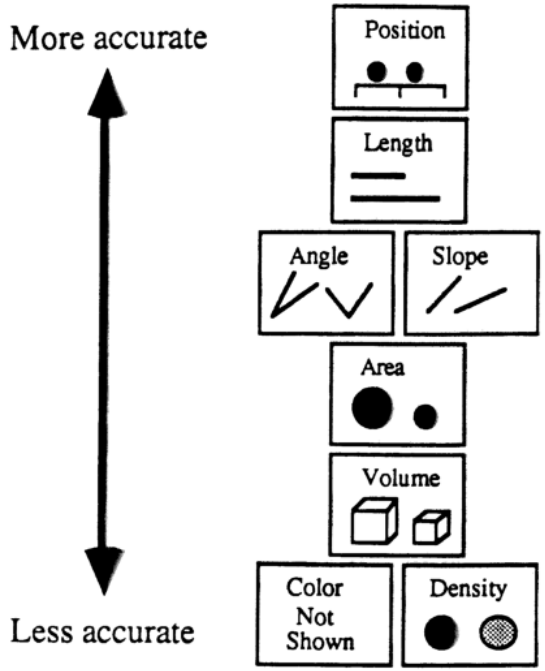
- What percentage in length is the right from the left (=100%)?



75%

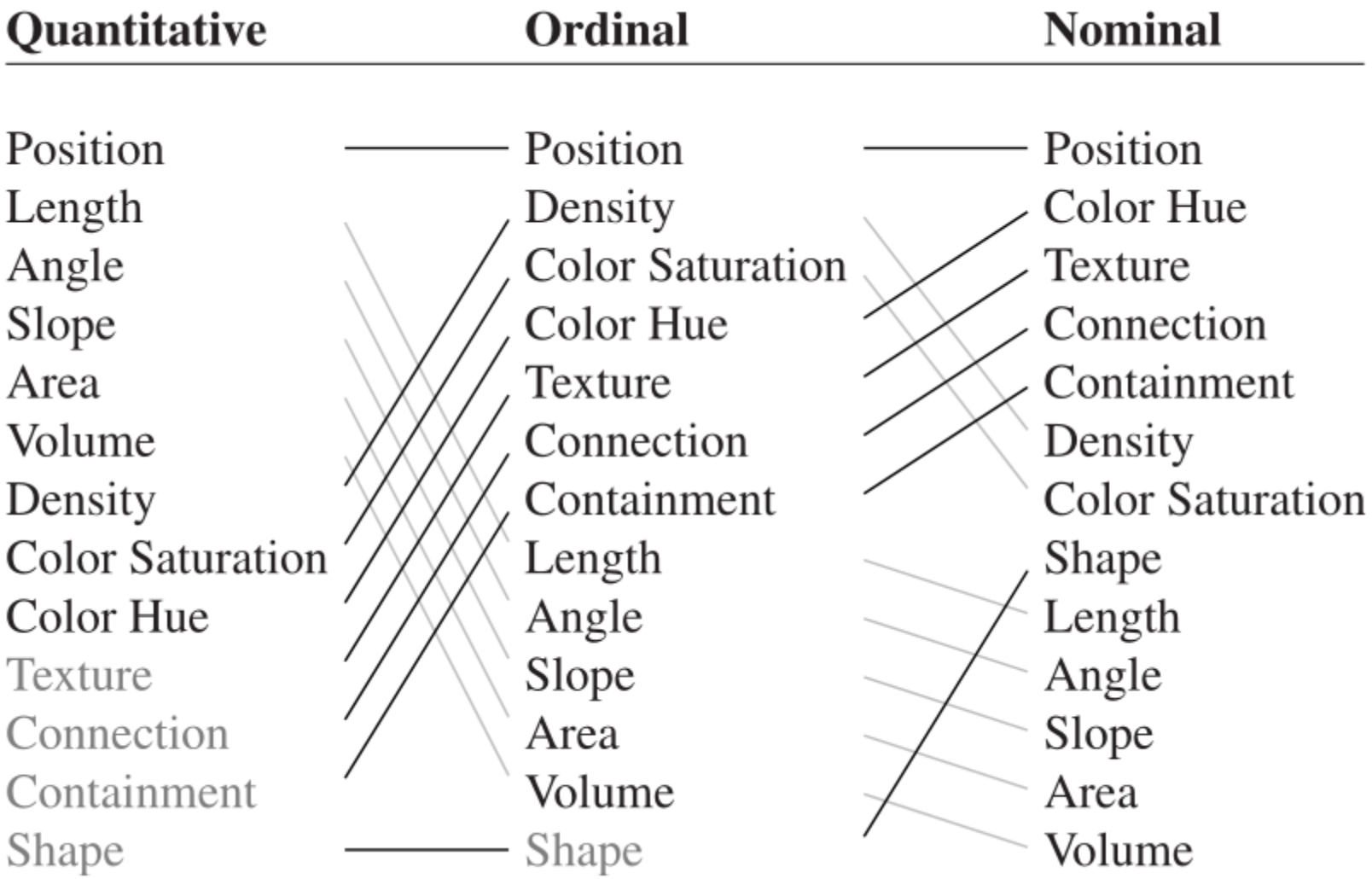
Length / Position

- What percentage in length is the right from the left (=100%)?



25%

Effectiveness of Data Encodings (Conjecture)



Mackinlay 1986

Applying what we know to

ASSESS VISUAL REPRESENTATIONS

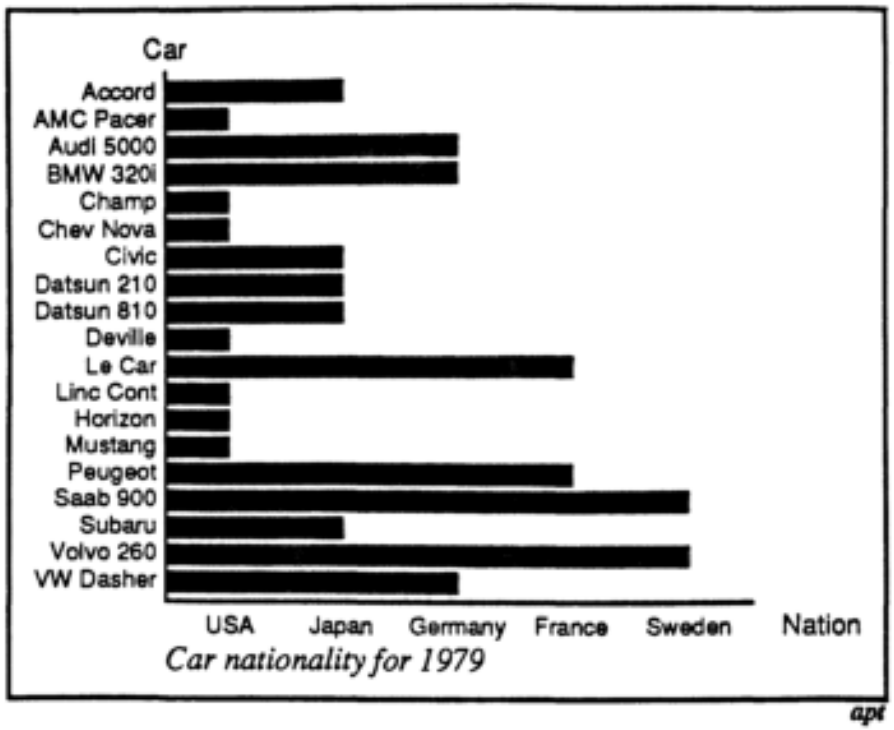
Let's evaluate…

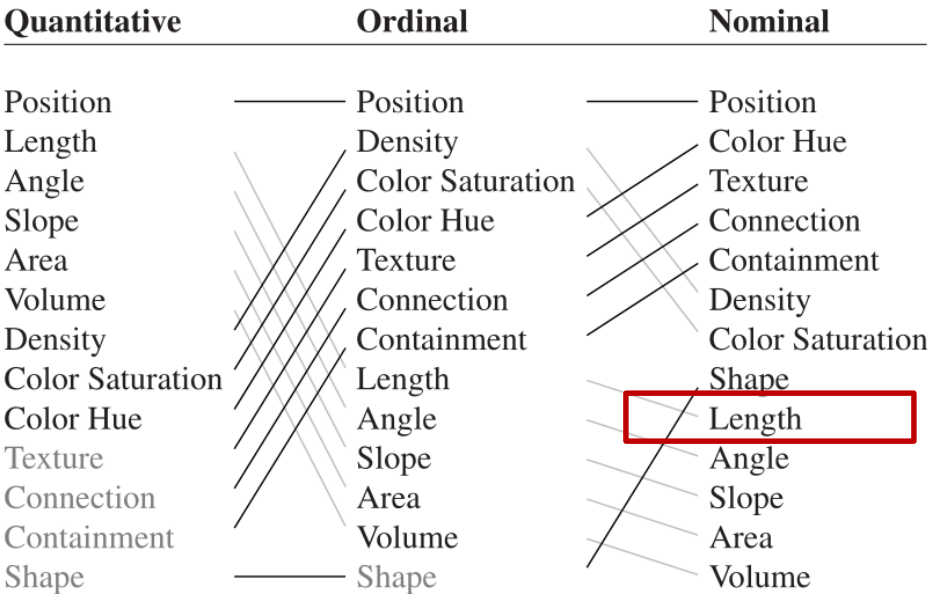
Car / Nation	USA	Japan	Germany	France	Sweden
Accord		x			
AMC Pacer	x				
Audi 5000			x		
BMW 320i			x		
Champ	x				
Chev Nova	x				
Saab 9000				x	

What kind of data are we looking at?

Nations: Nominal
Cars: Nominal
(Nation,Car): Nominal

Let's evaluate…

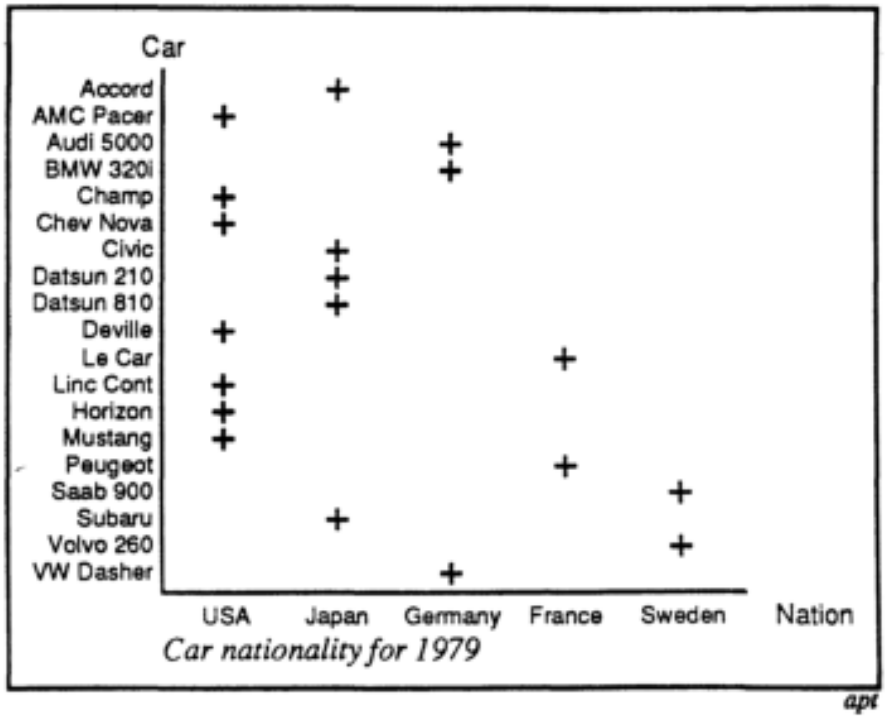


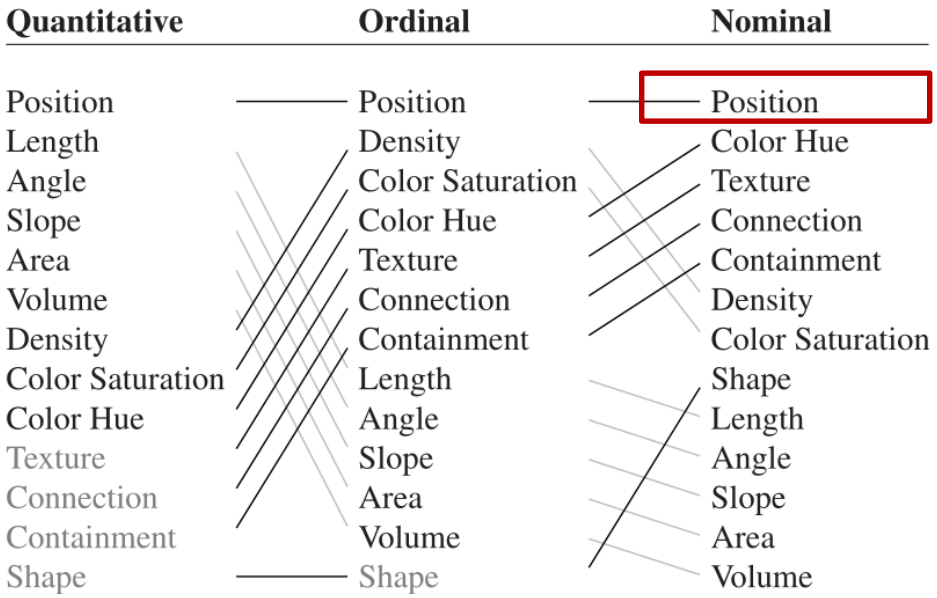


Problem:

Length of bar suggests an order or quantity (e.g. Swedish cars are better)

Let's evaluate…





Better!

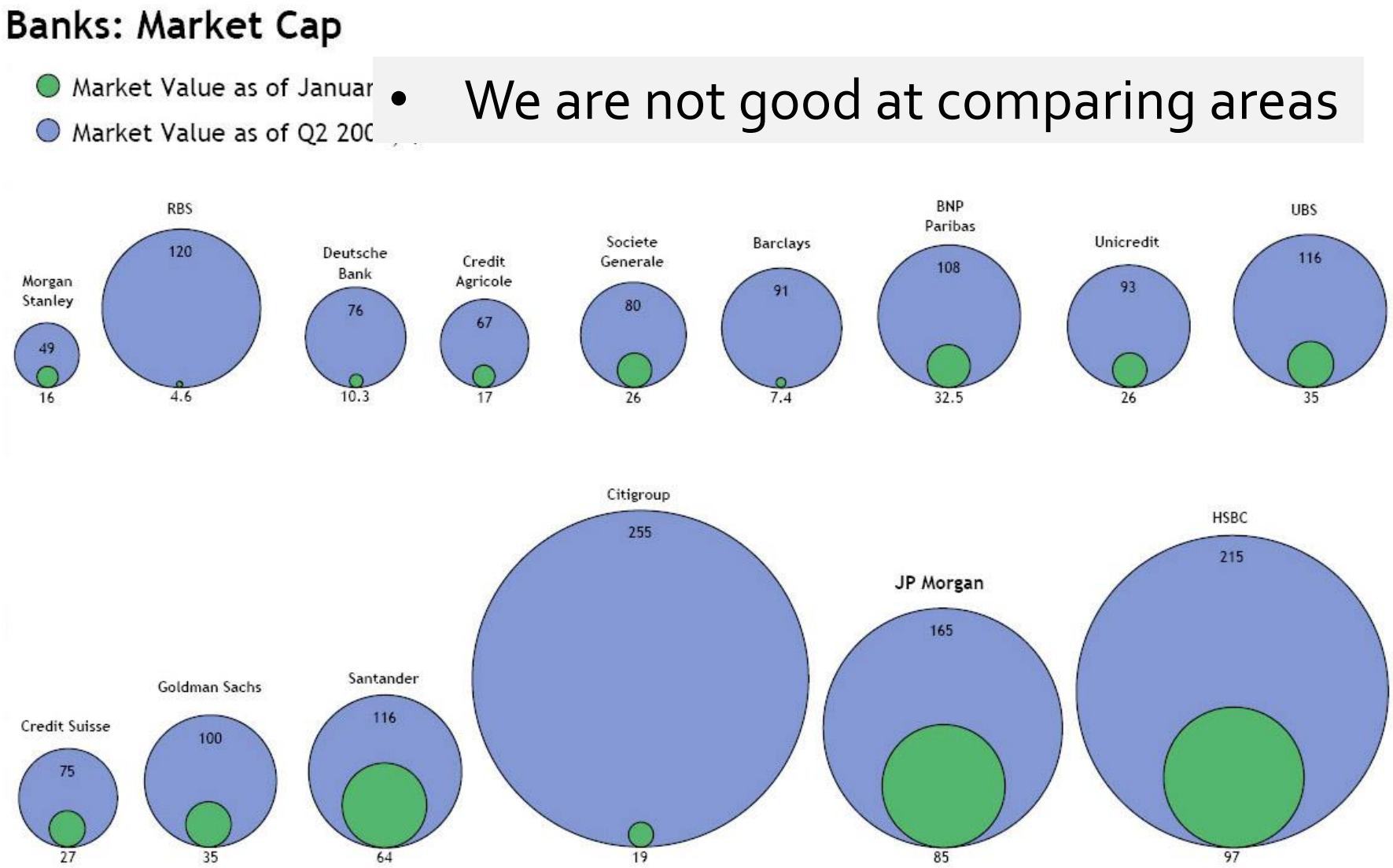
Let's evaluate…

Market Capitalization
= What would it cost to buy all of a company's stock at the current price

Compares 15 major banks on two dates:
- January 20th, 2009
- Q2 2007 before banking crisis hit

Source: Bloomberg, Jan 20th 2009

Problems here?

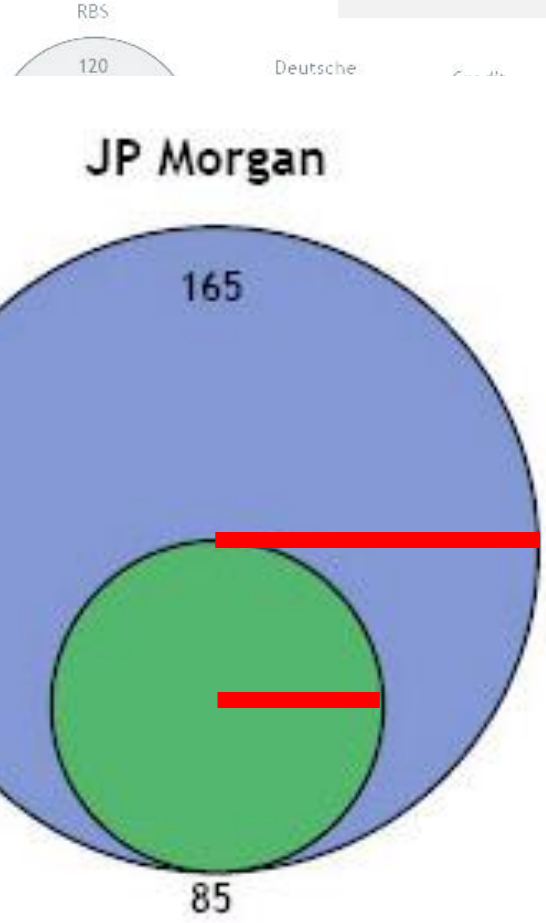


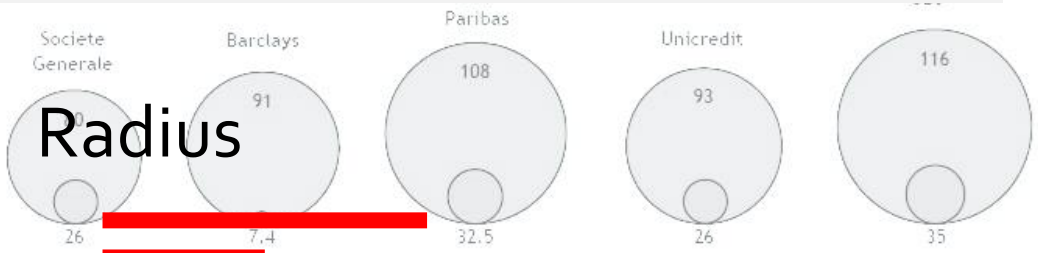
- We are not good at comparing areas

Source: Bloomberg, Jan 20th 2009

Problems here?

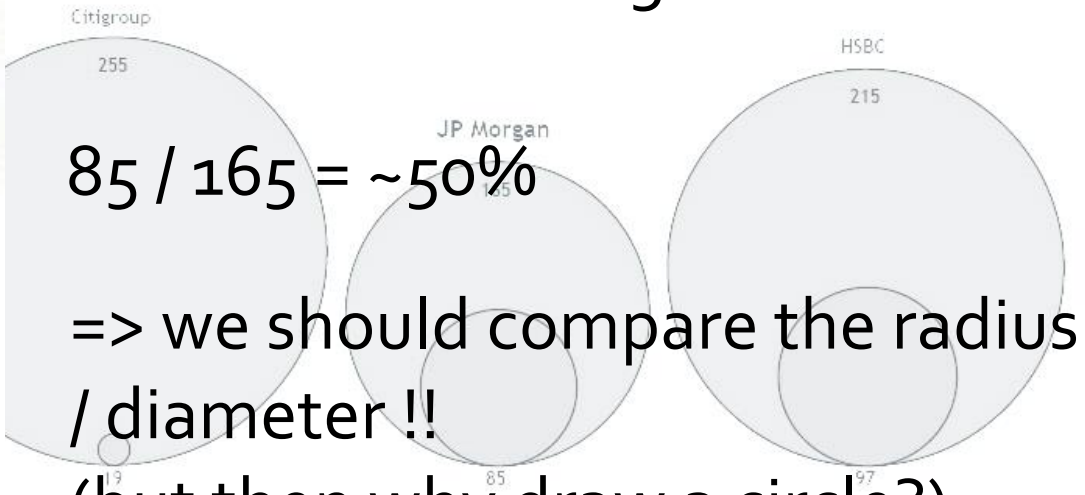
- We are not good at comparing areas
- What should we read here?





Radius

Area difference ~25%

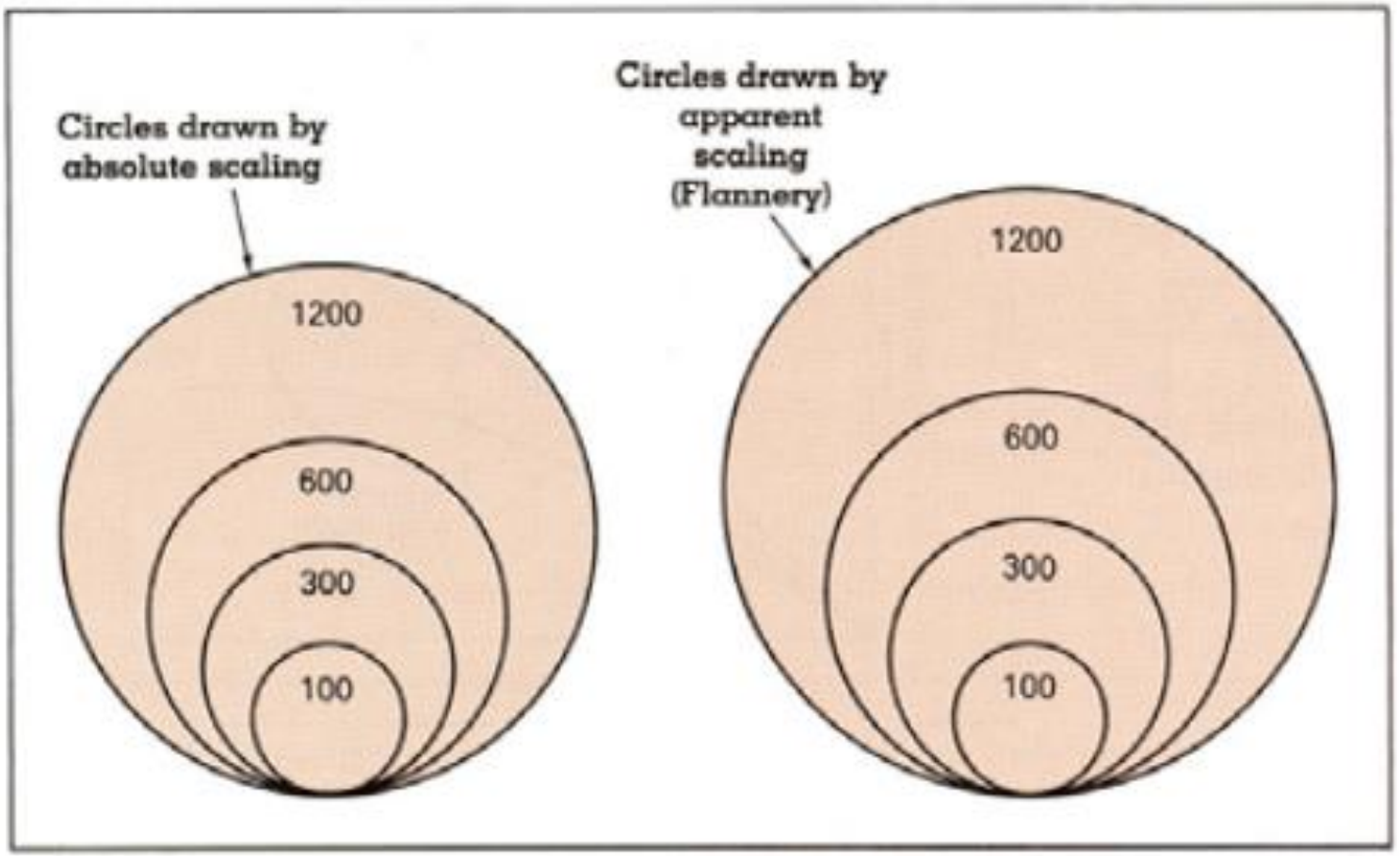


85 / 165 = ~50%

=> we should compare the radius / diameter !!

(but then why draw a circle?)

Source: Bloomberg, Jan 20th 2009

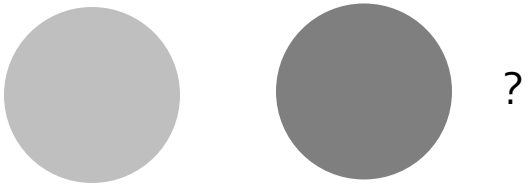


[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

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

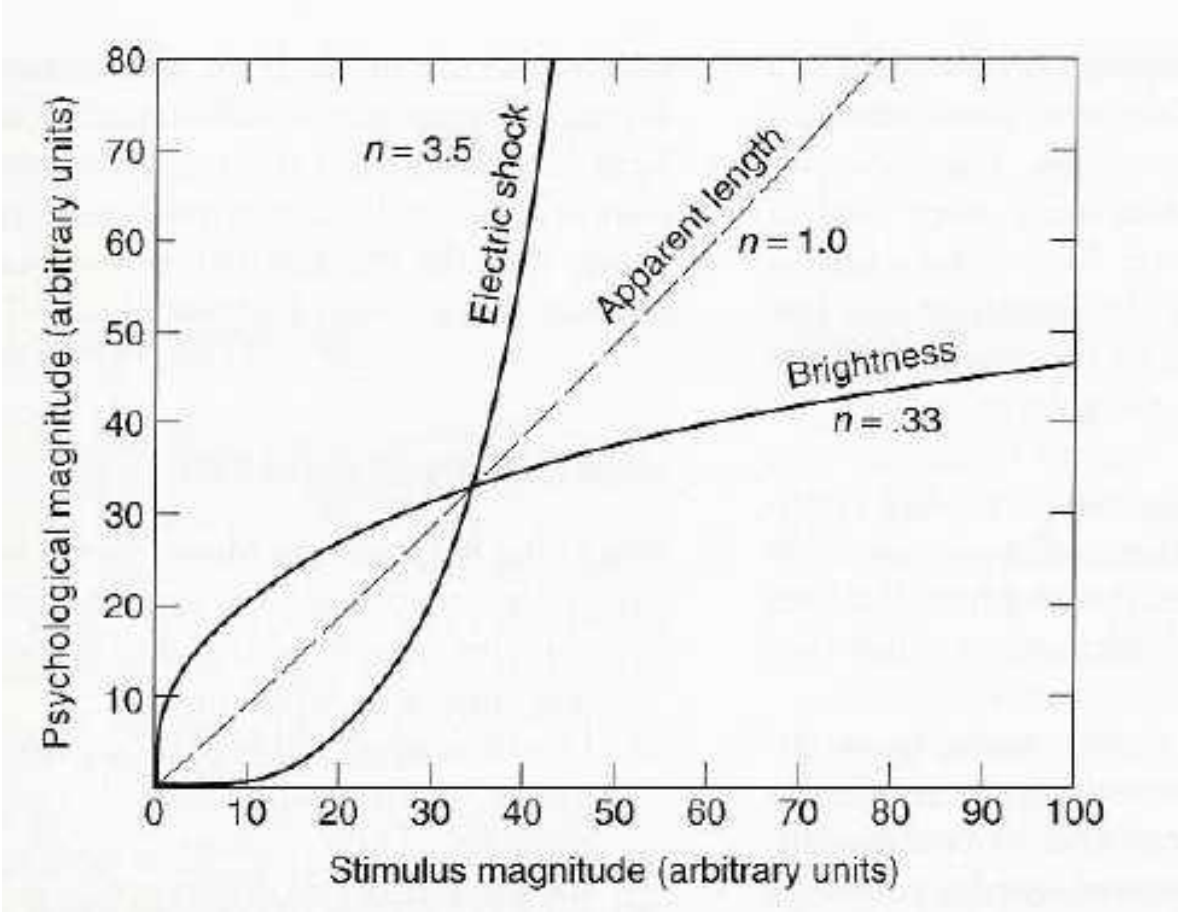
Magnitude estimation experiments

- We did a very(!) simplified magnitude estimation experiment earlier (comparing stimulus/modulus)

100%  ?

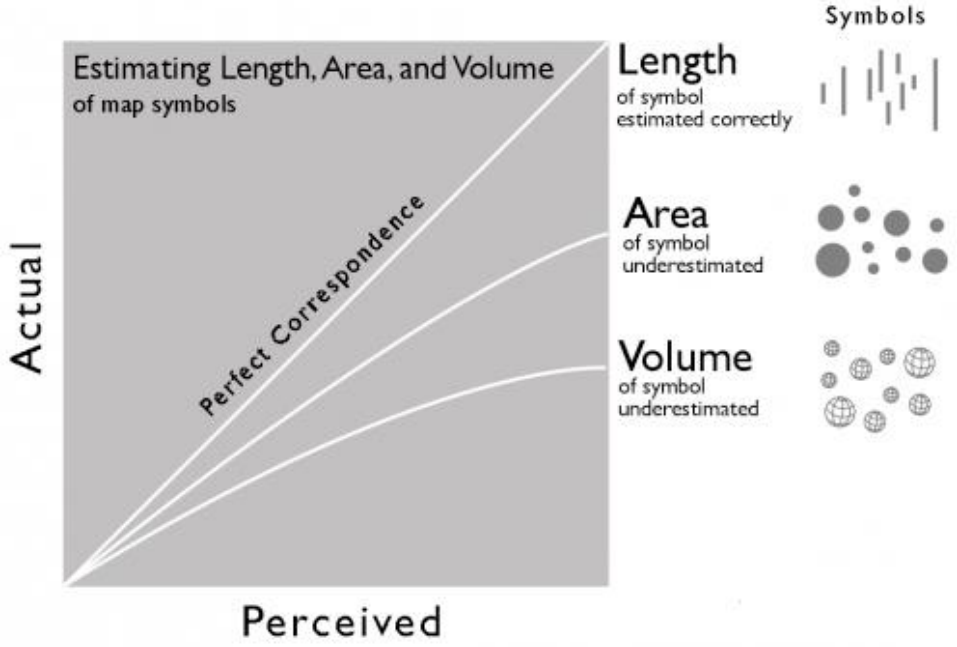
- **Stevens' power law** describes a relationship between a physical stimulus (S) and its **perceived** intensity or strength (P)

$$P = kS^n$$

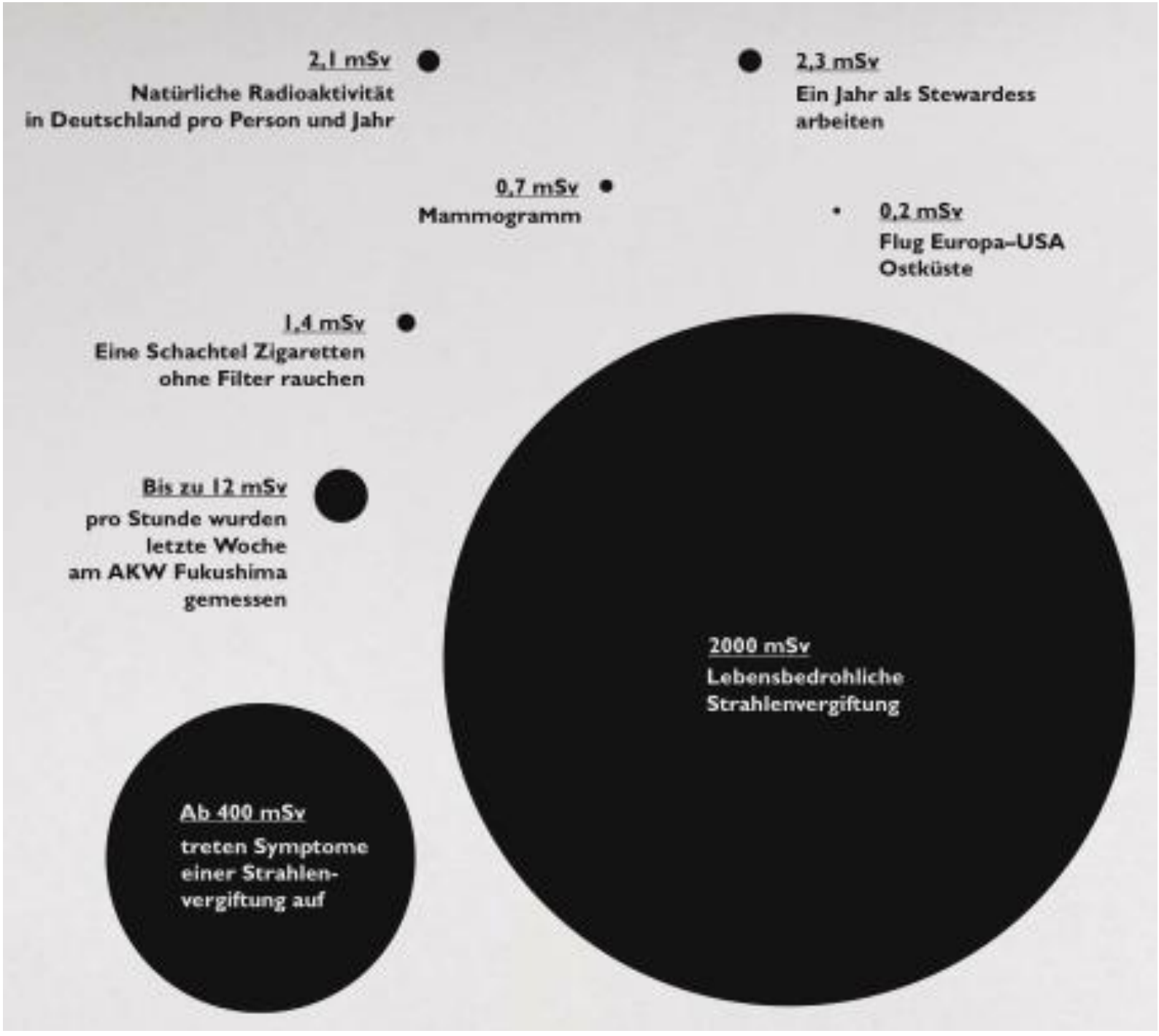

Psychological magnitude (arbitrary units)
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
Stimulus magnitude (arbitrary units)
n = 3.5
Electric shock
Apparent length
n = 1.0
Brightness
n = .33

Perception

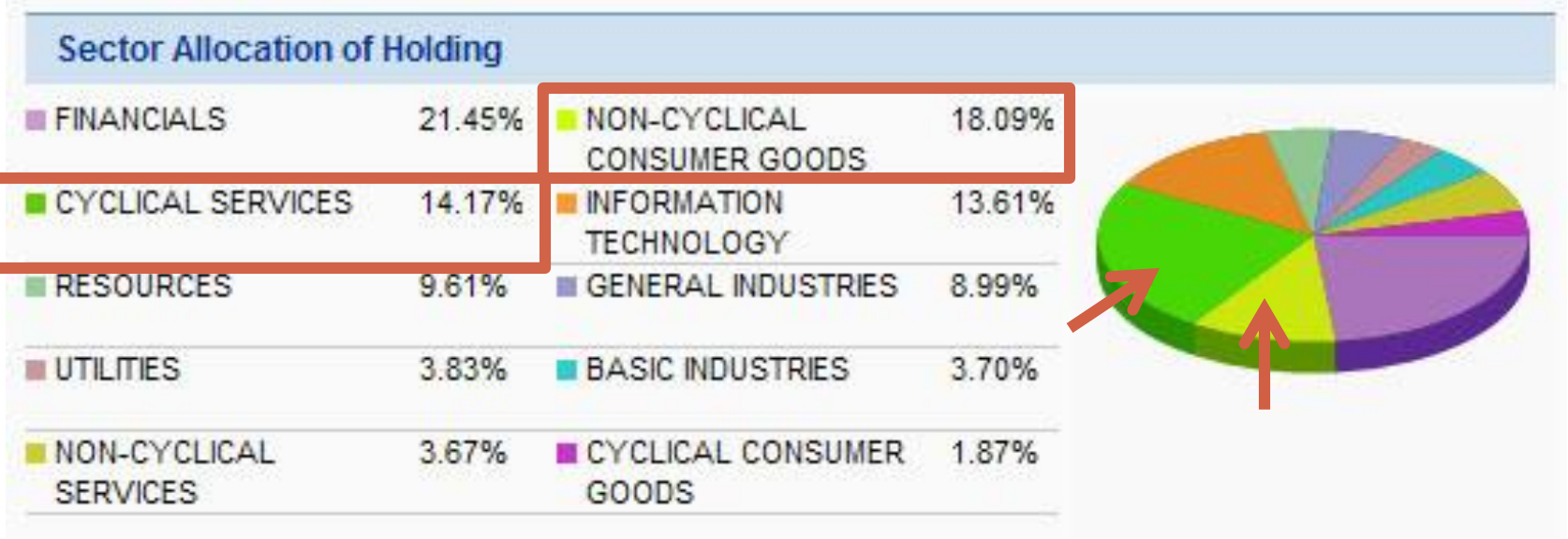
- People tend to **correctly estimate lengths**
- They tend to **underestimate areas and volumes.**
  - When asked to pick a circle that is two times the size of another most people would pick a circle ~1.8 times the size. This tendency gets worse with larger areas, and is worse in general for estimations of volumes.



http://makingmaps.net/2007/08/28/perceptual-scaling-of-map-symbols/

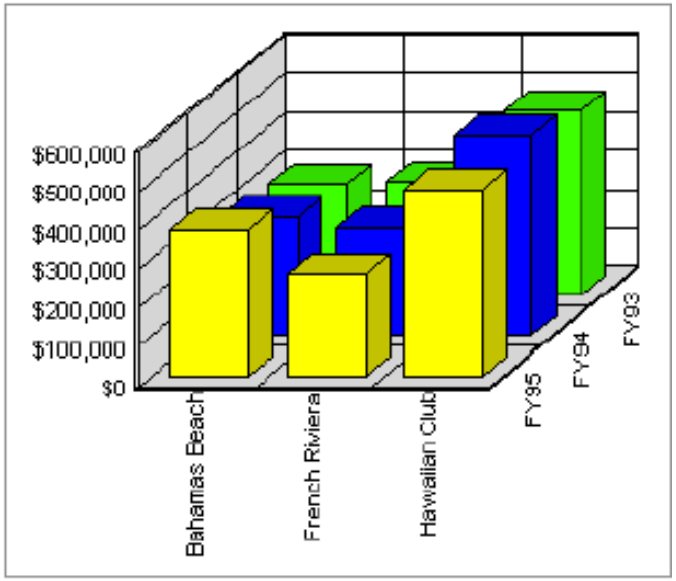

2,1 mSv
Natürliche Radioaktivität in Deutschland pro Person und Jahr
2,3 mSv
Ein Jahr als Stewardess arbeiten
0,7 mSv
Mammogramm
0,2 mSv
Flug Europa–USA Ostküste
1,4 mSv
Eine Schachtel Zigaretten ohne Filter rauchen
Bis zu 12 mSv
pro Stunde wurden letzte Woche am AKW Fukushima gemessen
2000 mSv
Lebensbedrohliche Strahlenvergiftung
Ab 400 mSv
treten Symptome einer Strahlen-vergiftung auf

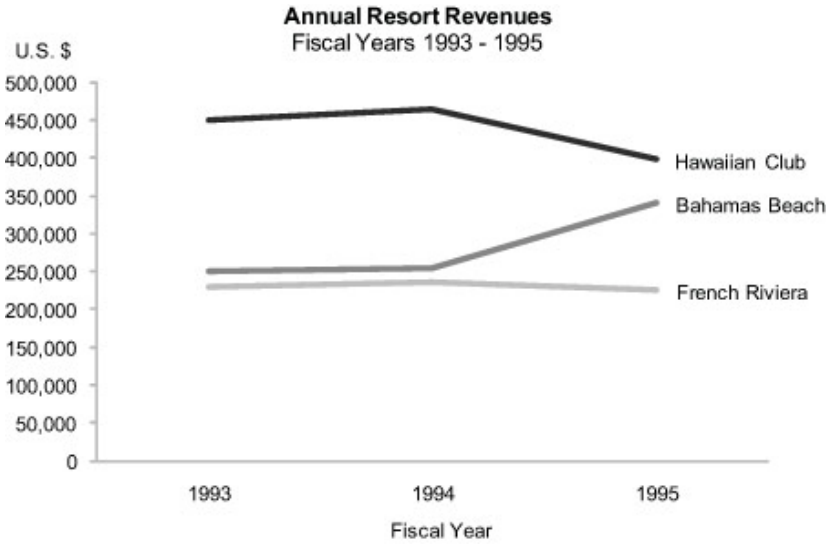
Problem here?



- Pie slices are difficult to compare in area
- There is likely a bug or error in the data
- Perspective distortion adds to the problem
- Colors are difficult to distinguish

Similarly…3D bar charts are not recommended



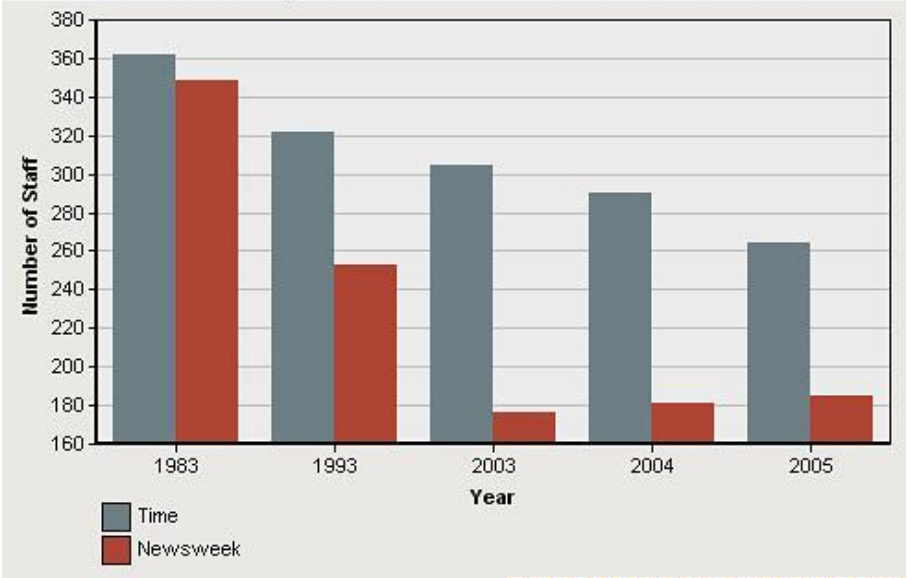


This is much easier to see and compare!

Problem here?

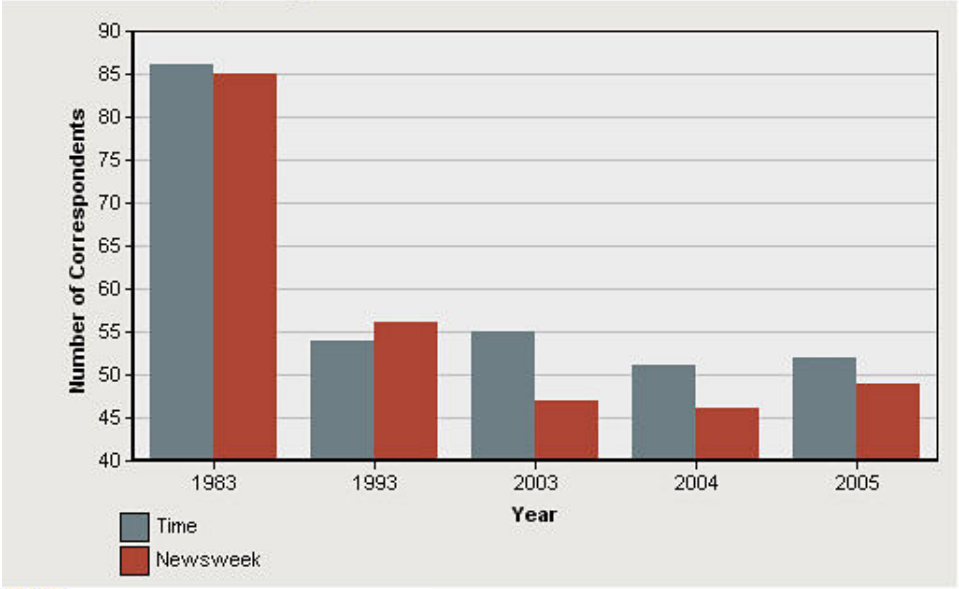
NEWS MAGAZINE STAFF SIZE OVER TIME

Time and Newsweek select years 1983 - 2005



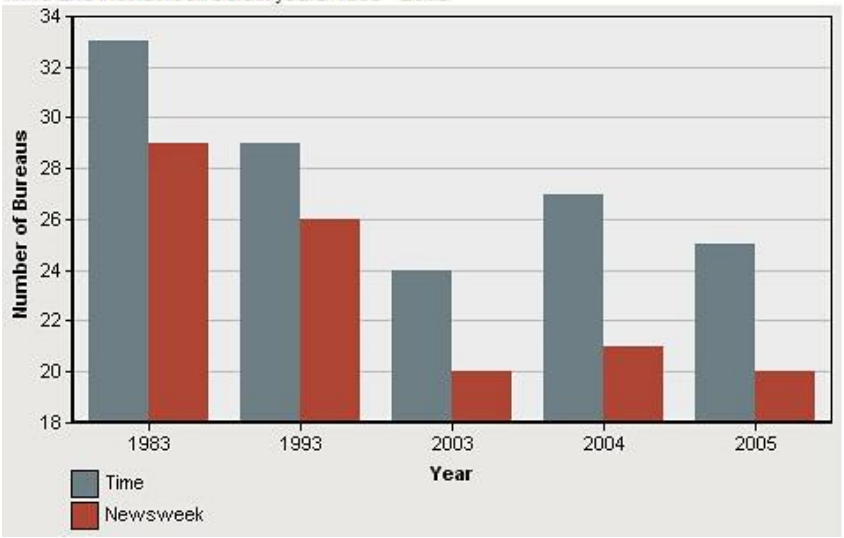
NUMBER OF CORRESPONDENTS IN BUREAUS OVER TIME

Time and Newsweek, select years 1983 - 2005

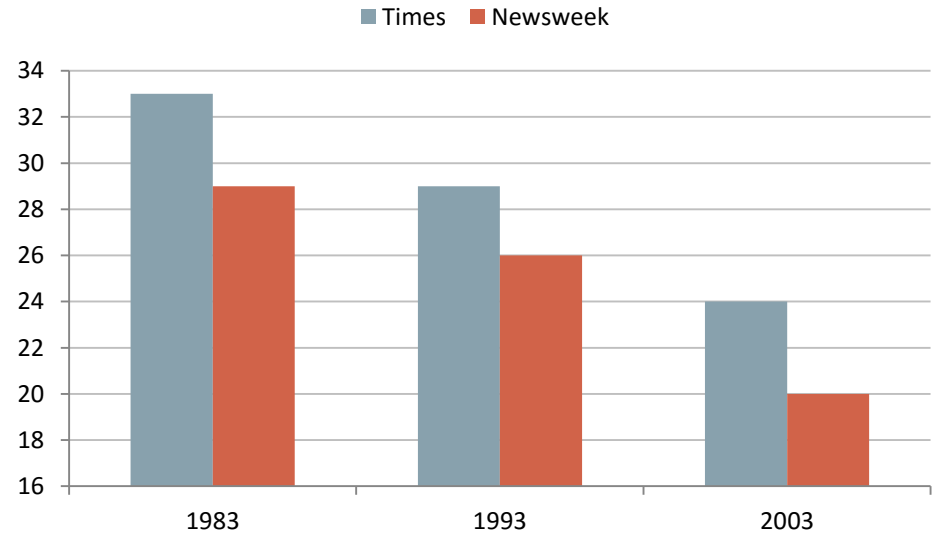


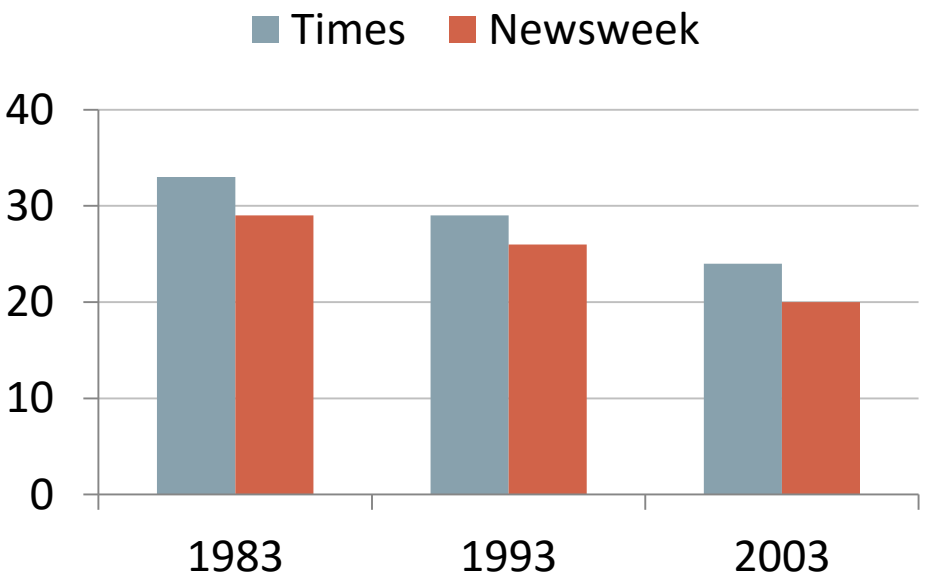
NEWS MAGAZINE BUREAUS OVER TIME

Time and Newsweek select years 1983 - 2005



Length Comparison

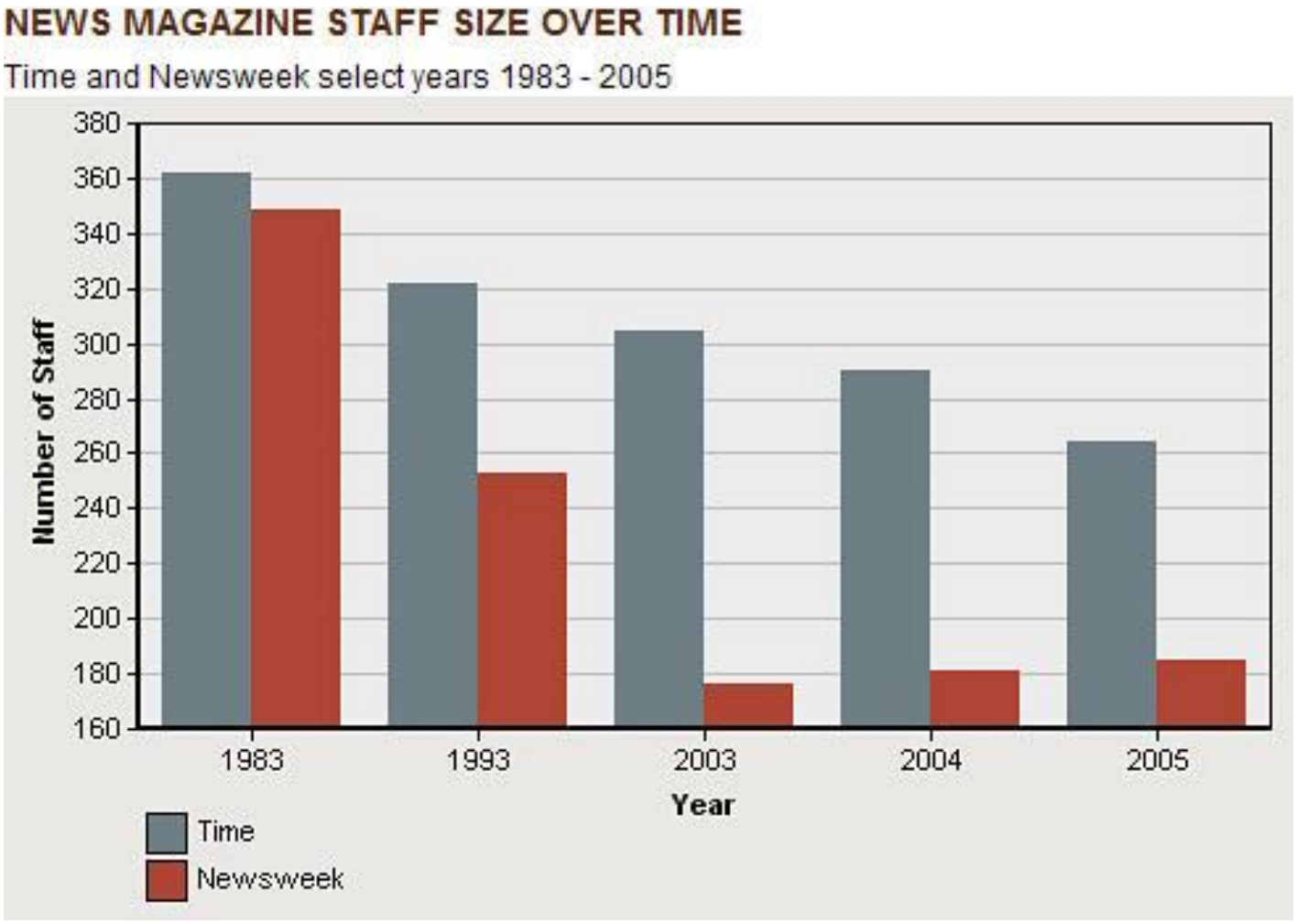




At first glance:
2003: Newsweek is 50% of Times

If we add a proper 0:
2003: Newsweek is ~80% of Times

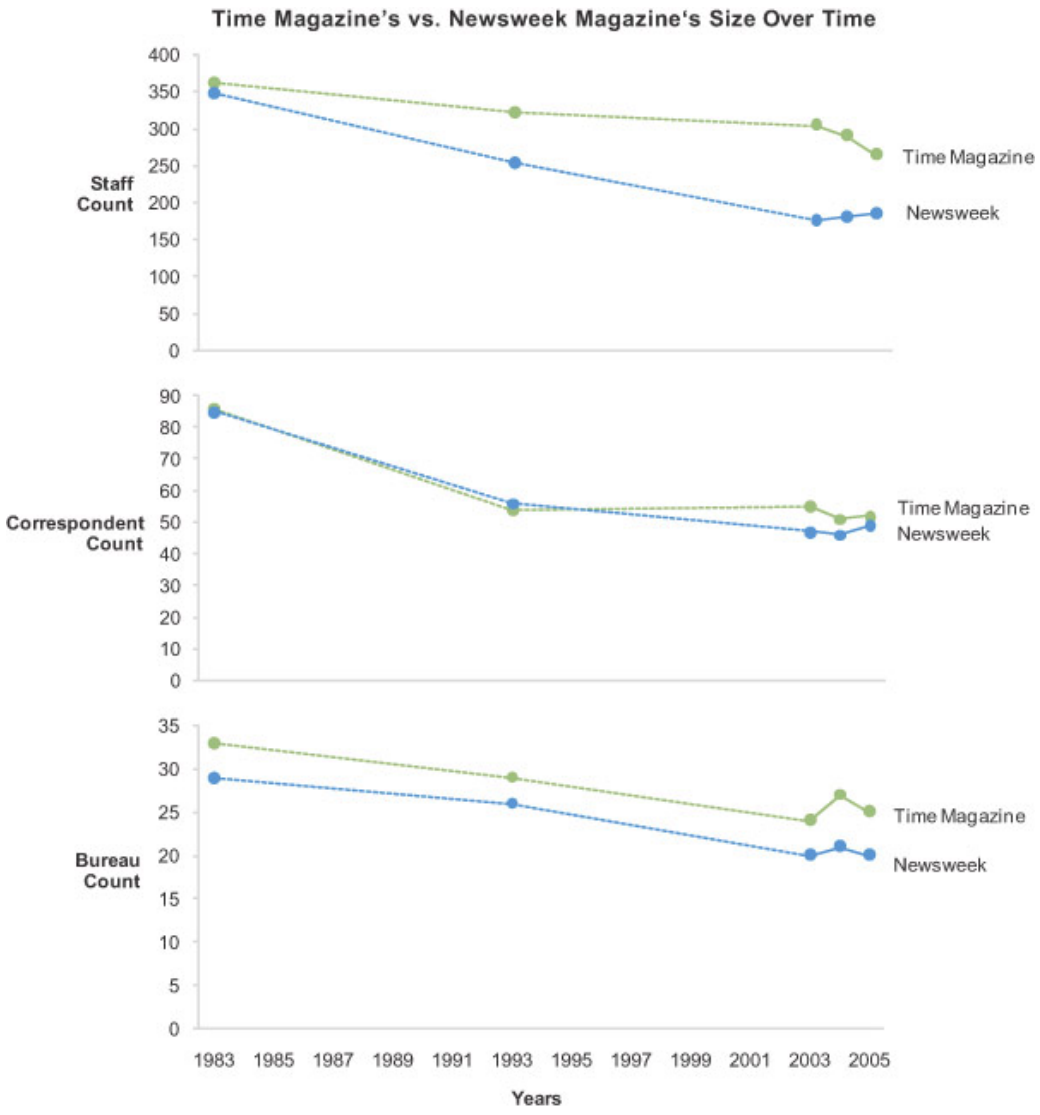
Moreover…



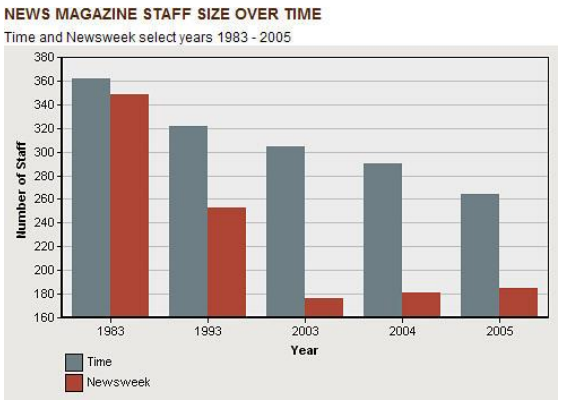
10 years

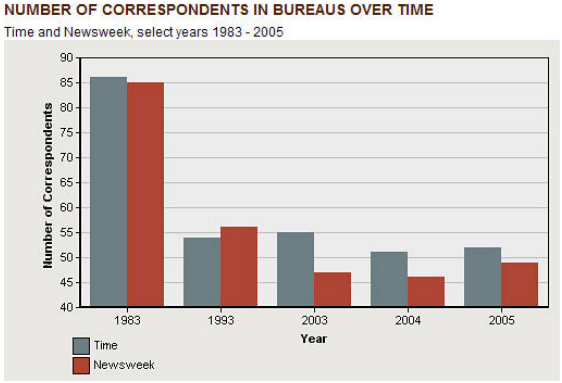
1 year

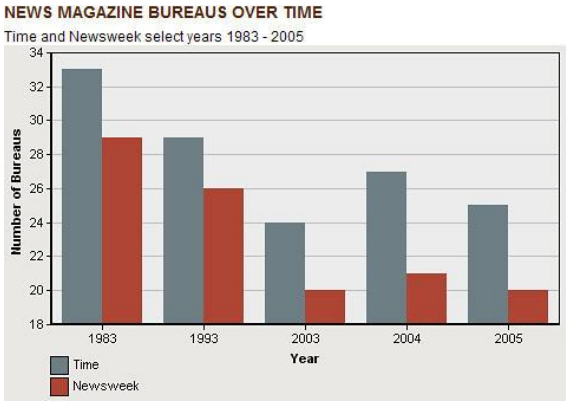
Redesign (by Stephen Few)



Note: A dashed line connecting two points indicates that there are years between the points for which values were not available. If the values were available, the shape of the lines might vary significantly.

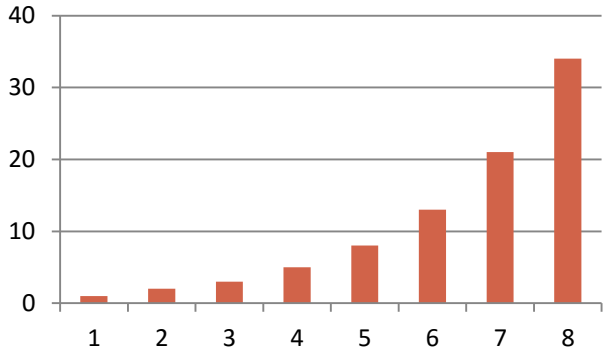


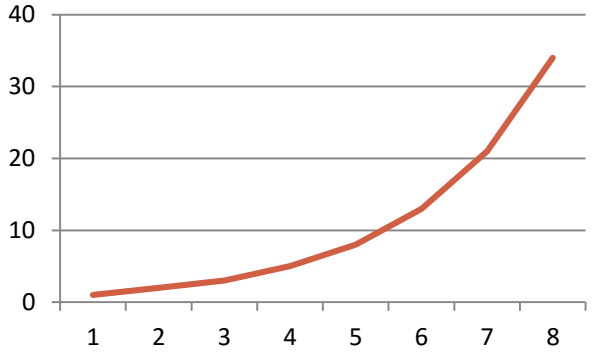


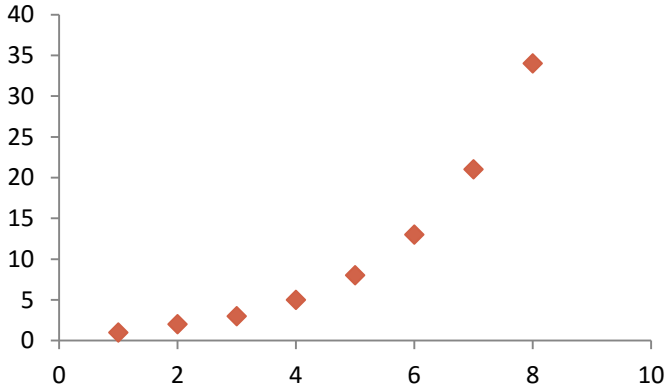


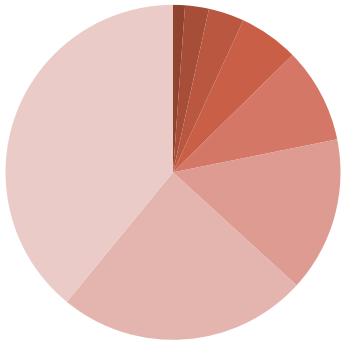
Perception and Charts

- Bar Charts
- Line Charts
- Pie Charts
- Dot Charts
- …







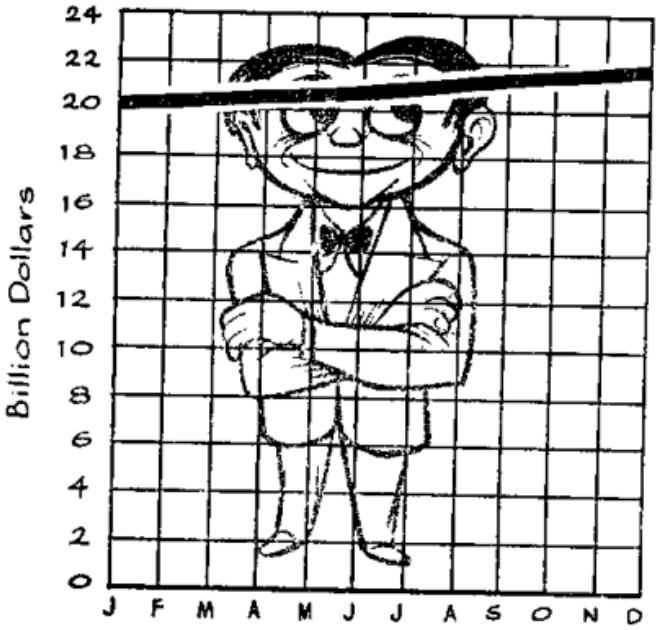


A few more words on charts

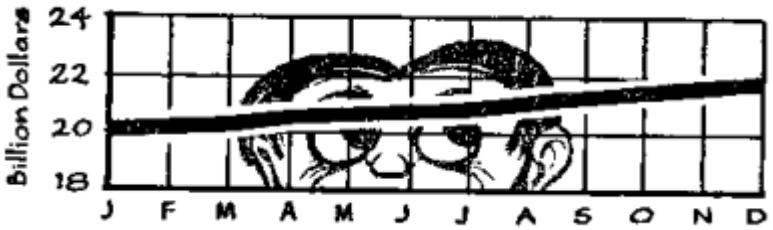
Good reference: How to Lie with Statistics, by Darrell Huff

Chart Rules

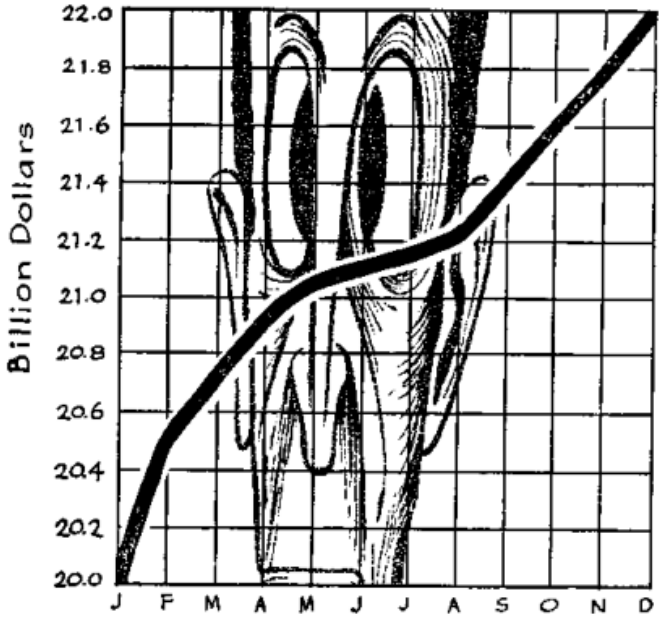
- Provide a proper baseline



A 10% increase. Good!



Already looks more impressive



Wow!

Chart Rules

- Provide a proper baseline & label your axes

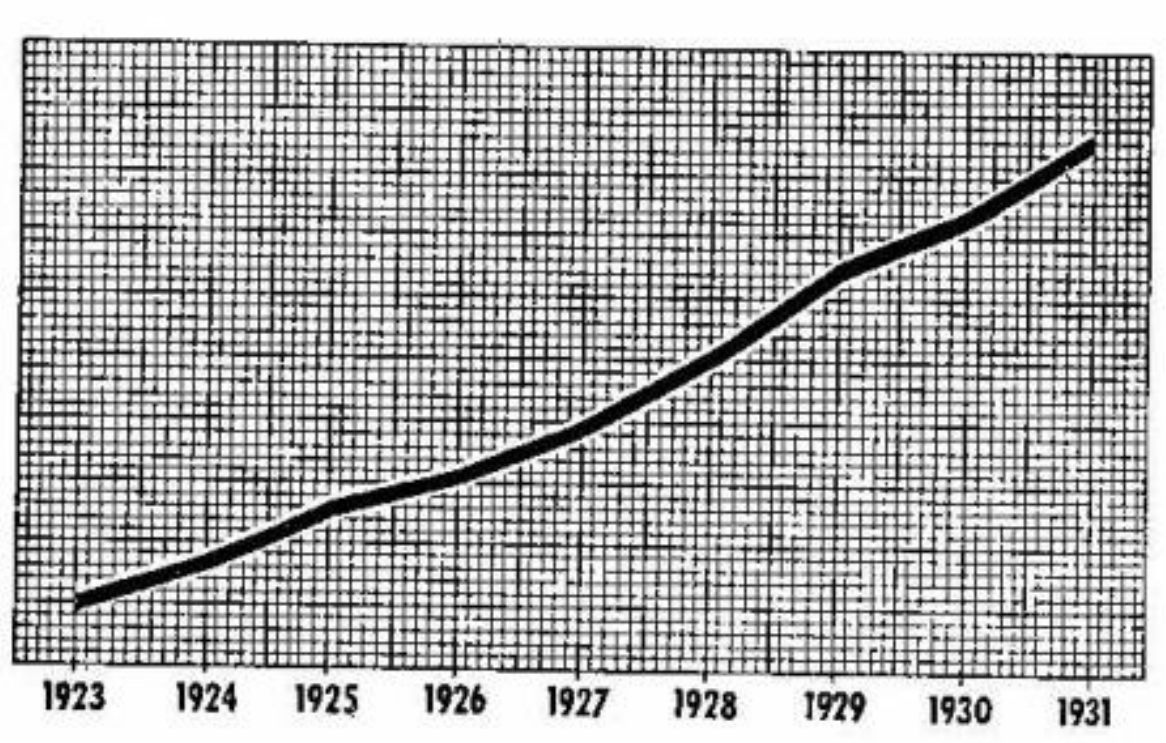
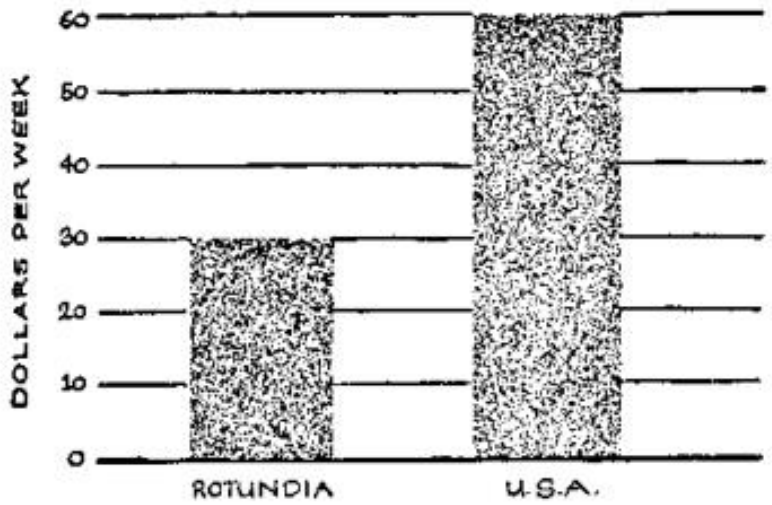


Chart Rules

- Provide a proper baseline & label your axes
- Avoid eye-candy



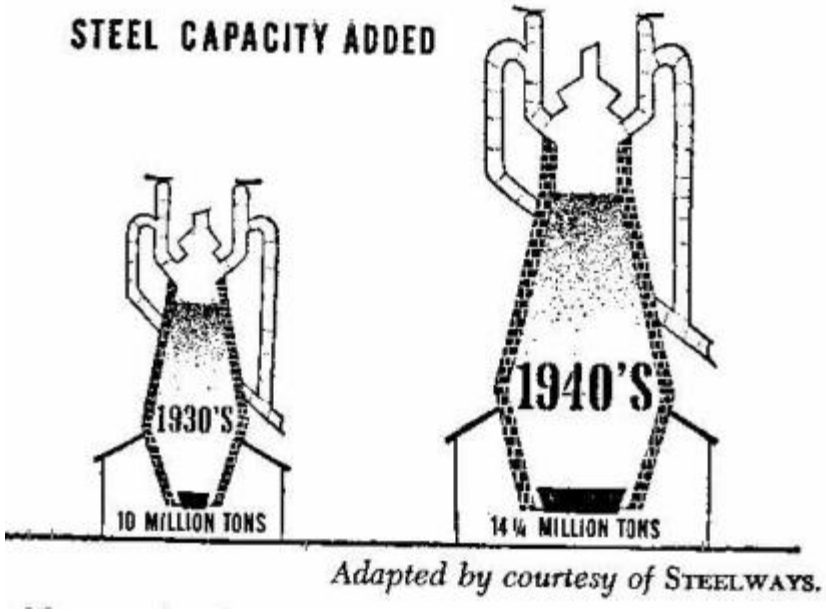
True data

same data with eye-candy & no numbers but tells the same general story

impressive but a lie!

Chart Rules

- Provide a proper baseline & label your axes
- Avoid eye-candy
- Don't make people compare areas when not necessary



Schwimmende Schlote

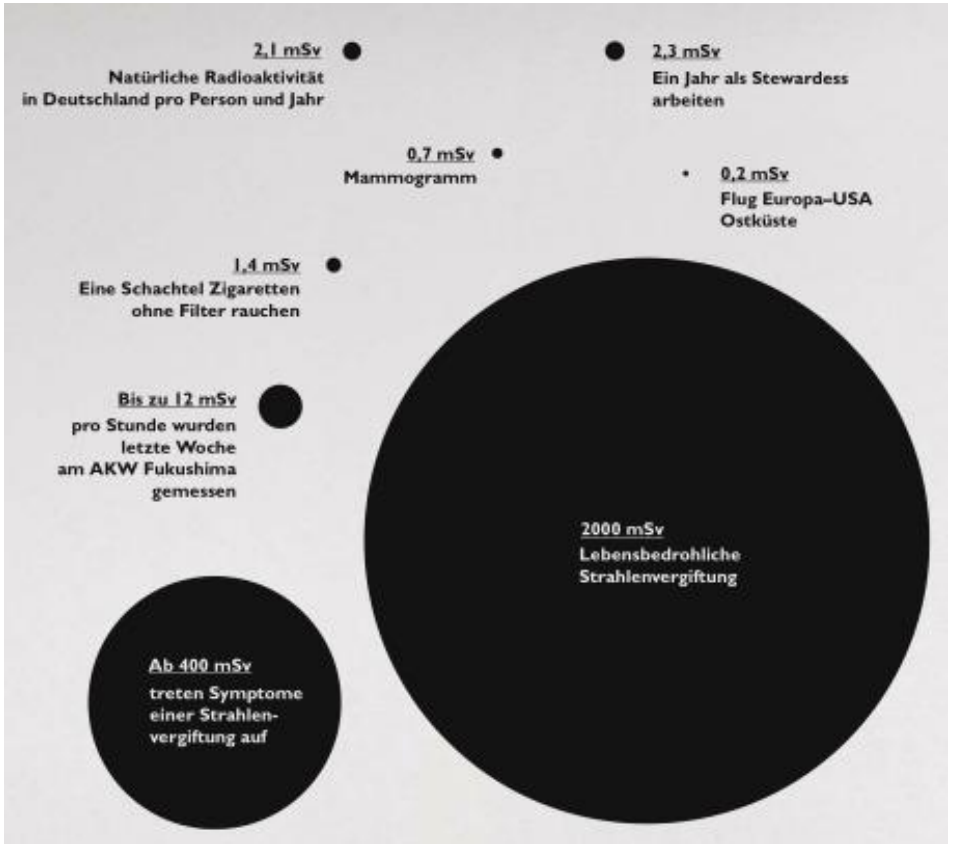
Der internationale Schiffsverkehr boomt. Seit 1990 hat sich der Treibstoffverbrauch auf dem Meer verdoppelt. Die dreckigen Abgase der Schiffe gelangen weitgehend ungefiltert in die Atmosphäre

http://images.zeit.de/wissen/2011-04/s41-infografik-schiffsverkehr.pdf

Do the boxes represent the little white numbers??

A few more recent chart sins

All from www.zeit.de/grafik



The numbers are the only useful part here.
The areas are not comparable

Radiation Dose Chart

This is a chart of the ionizing radiation dose a person can absorb from various sources. The unit for absorbed dose is "sievert" (Sv), and measures the effect a dose of radiation will have on the cells of the body. One sievert (all at once) will make you sick, and too many more will kill you, but we safely absorb small amounts of natural radiation daily.
Note: The same number of sieverts absorbed in a shorter time will generally cause more damage, but your cumulative long-term dose plays a big role in things like cancer risk.

- Sleeping next to someone (0.05 µSv)
- Living within 50 miles of a nuclear power plant for a year (0.09 µSv)
- Eating one banana (0.1 µSv)
- Living within 50 miles of a coal power plant for a year (0.3 µSv)
- Arm x-ray (1 µSv)
- Using a CRT monitor for a year (1 µSv)
- Extra dose from spending one day in an area with higher-than-average natural background radiation, such as the Colorado plateau (1.2 µSv)
- Dental x-ray (5 µSv)
- Background dose received by an average person over one normal day (10 µSv)
- Airplane flight from New York to LA (40 µSv)
- Using a cell phone (0 µSv)—a cell phone's transmitter does not produce ionizing radiation* and does not cause cancer.

* Unless it's a bananaphone.

- Chest x-ray (20 µSv)
- All the doses in the blue chart combined (~60 µSv)
- Extra dose to Tokyo in weeks following Fukushima accident (40 mSv)
- Living in a stone, brick, or concrete building for a year (70 µSv)
- Average total dose from the Three Mile Island accident to someone living within 10 miles (80 µSv)
- Approximate total dose received at Fukushima Town Hall over two weeks following accident (100 µSv)
- EPA yearly release limit for a nuclear power plant (250 µSv)
- Yearly dose from natural potassium in the body (390 µSv)
- Mammogram (400 µSv)
- EPA yearly limit on radiation exposure to a single member of the public (1 mSv=1,000 µSv)
- Maximum external dose from Three Mile Island accident (1 mSv)
- Typical dose over two weeks in Fukushima Exclusion Zone (1 mSv, but areas northwest saw far higher doses)
- Head CT Scan (2 mSv)
- Normal yearly background dose. About 85% is from natural sources. Nearly all of the rest is from medical scans (~4 mSv)

- EPA yearly release target for a nuclear power plant (30 µSv)
- Dose from spending an hour on the grounds at the Chernobyl plant in 2010 (6 mSv in one spot, but varies wildly)
- Chest CT scan (7 mSv)
- Maximum yearly dose permitted for US radiation workers (50 mSv)

■ = (0.05 µSv)

■ = (20 µSv)

- Approximate total dose at one station at the north-
- All doses in
- Radiation worker one-year dose limit (50 mSv)
- Lowest one-year dose

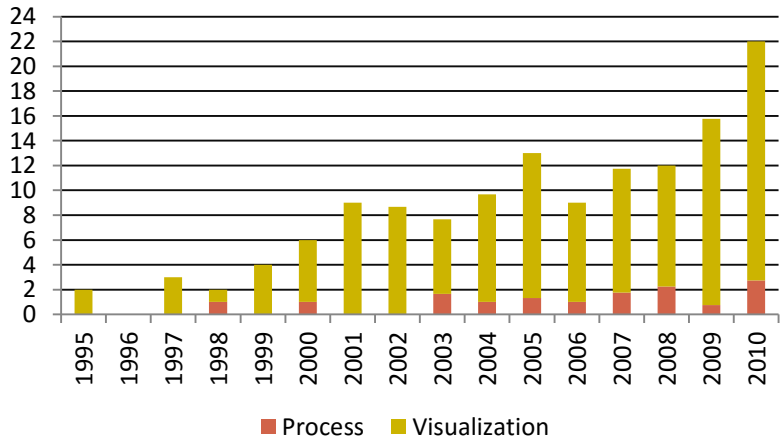
via xkcd

Chart Rules

- Provide a proper baseline & label your axes
- Avoid eye-candy
- Don’t make people compare areas when not necessary
- Provide legends

Chart Rules

- Provide a proper baseline & label your axes
- Avoid eye-candy
- Don't make people compare areas when not necessary
- Provide legends
- Grids help but make them subtle (no black lines!)



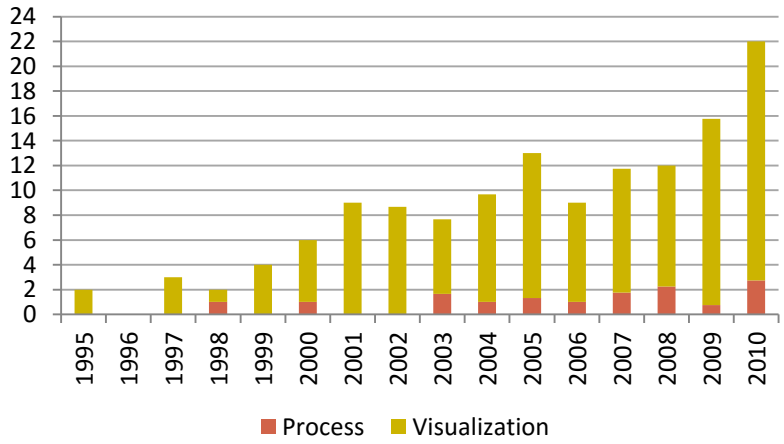
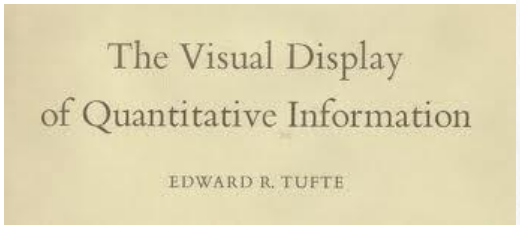
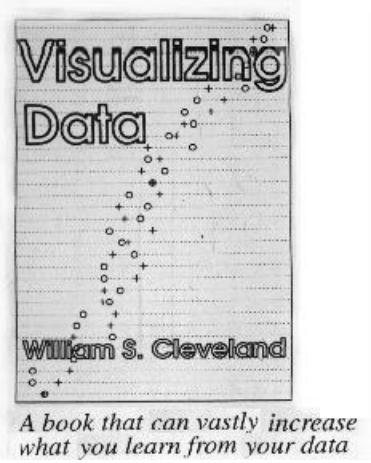
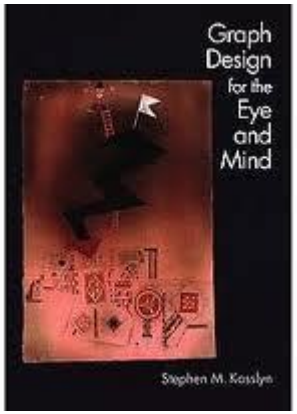


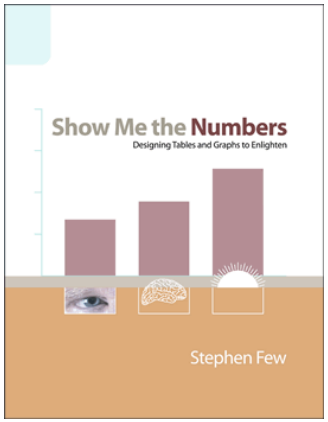
Chart Rules

- Provide a proper baseline & label your axes
- Avoid eye-candy
- Don't make people compare areas when not necessary
- Provide legends
- Grids help but make them subtle (no black lines!)
- Many more…









Summary

- Now you know the main building blocks are **marks**
- Marks are modified by **visual variables**
- Visual variables have **specific characteristics**
- These characteristics influence how the data will be perceived

15 minute break then

LAB

What will the exam be about?

- lectures
- normally 3 parts
  - course questions (MC + open answer)
  - UI critique (probably)
  - creative task (maybe)
- memorization alone will not help you. You need to be able to apply your knowledge

Bring a pencil + eraser