INFORMATION VISUALIZATION

Introduction

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INSTRUCTOR

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OFFICE HOURS – By appointment

+

YUJIRO OKUYA

YOU!

QUICK INTROS

Any particular interests?

COURSE INFO

Visualization	Visualization	Visualization	Design Critique + Project Presentations
February	March	April	May

Class website:
https://tinyurl.com/psud-gv

+ Slack channel – everyone will get an invite

Slack - infovis-psud-2018-2019

infovis-psud-20...
Petra Isenberg

Jump to...

All Threads

Channels
announcements
assignments
general
interesting
jobs
questions
random
resources
software

+ Add a channel

Direct Messages
Slackbot
Petra Isenberg (you)

#announcements

25 | 3 | Add a topic

Search

SLACK

November 29th, 2018

Yea need to get off one stop later 'moulon'

[redacted] 1:02 PM
Súper, thank you!

Anastasia Bezerianos 2:53 PM
The data provider slides from the datafaire are here: https://drive.google.com/drive/folders/1al-dGhyWqQg56JtoT-FBZNJM2R_YxERa?usp=sharing (edited)

December 5th, 2018

Petra Isenberg 11:06 AM
Tomorrow we will be working with Tableau in class. Please follow the instructions to install Tableau ahead of time - and also bring a laptop with the software installed (if you don't have one, just team up):

Please forward these instructions to your students:

Download Tableau Desktop and Tableau Prep here
Select each product download link to get started. When prompted, enter your school email address for Business E-mail and enter the name of your school for Organization.
Activate with your product key: TCK4-E998-3110-C135-BED8

Are your students new to Tableau? Share our free Data Analytics for University Students guide to help them get started.

Students can continue using Tableau after the class is over by individually requesting their own one-year license through the Tableau for Students program.

Here is the download link that got lost here: https://www.tableau.com/tft/activation

The student guide link: https://www.tableau.com/university-students

and the tableau for students program: http://tableau.com/students

> Tableau Software
> **Tableau for Students**
> Students can download Tableau Desktop and Tableau Prep for free through Academic Programs. Try it now.

TODO

Send me an email now:

Subject: G&V Class

petra.Isenberg@inria.fr

Sign with your full name as I can find it on university info

GRADING SCHEME

- Assignments (40%' of the total grade)
- Final Project (40%)
- Design Critique (15%)
- Participation (5%)

PROJECT

- We will work on a project will scientific value to the domain of visualization
- No good tools and techniques exist to explore the research questions you can choose from

Domains:

Bibliometrics the application of analysis methods to books and other media of communication (Pritchard, 1969)

Scientometrics: the science of measuring and analyzing science

READINGS

No specific readings necessary

Will announce readings on a per-lecture basis for those interested in learning more

ELECTRONICS POLICY

Laptops and devices okay
(in fact you'll need them)
…**but use them for work!**

BEHAVIOR & SOCIETY

Students are Better Off without a Laptop in the Classroom

What do you think they'll actually use it for?

By Cindi May on July 11, 2017

Credit: Getty Images

As recent high school graduates prepare for their migration to college in the fall, one item is sure to top most students' shopping wish lists: a laptop computer. Laptops are ubiquitous on university campuses, and are viewed by most students as absolute must-have items, right alongside laundry detergent, towels, and coffee pots.

Without question, personal laptops can enhance the college experience by facilitating engagement with online course material, providing access to sources for research, maximizing internship searches, and even improving communication with friends and parents. Many students also opt to bring their laptops to class so that they can take notes, view online lecture slides, and search the web for course-related material. This practice, it

LATEST NEWS


Puerto Rico Looks to Alphabet's X Project Loon Balloons to Restore Cell Service


The Ethical Minefields of Technology


Astronomers Are Finally Mapping the "Dark Side" of the Milky Way

AFTER TODAY YOU WILL…

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

Why

INFORMATION VISUALIZATION

“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

“Data visualization is going to change the way our analysts work with data. They’re going to be expected to respond to issues more rapidly. And they’ll need to be able to dig for more insights – look at data differently, more imaginatively. Data visualization will promote that creative data exploration.”

Simon Samuel Head of Customer Value Modeling for a large bank in the UK

Country Profile
France

Factors determining job location decisions

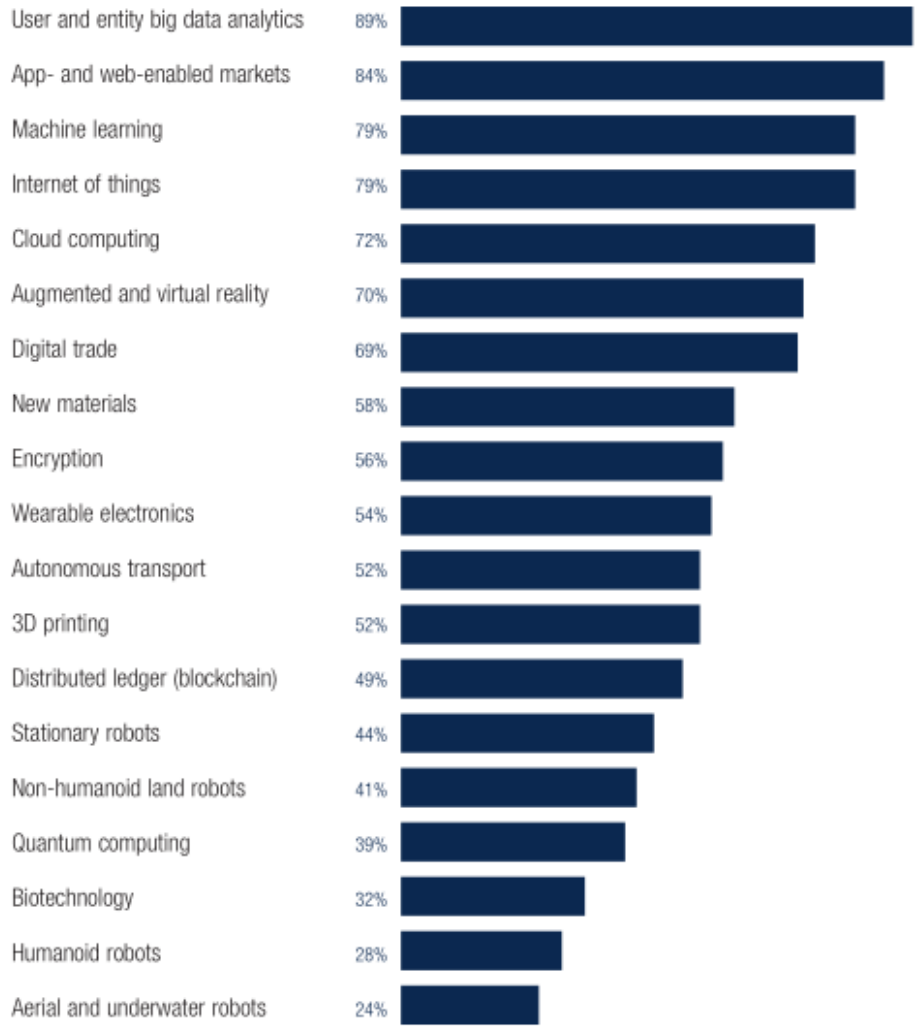
Industry	Primary	Secondary	Tertiary
Automotive, Aerospace, Supply Chain & Transport	Talent availability	Quality of the supply chain	Production cost
Aviation, Travel & Tourism	Talent availability	Organization HQ	Ease of importing talent
Chemistry, Advanced Materials & Biotechnology	Talent availability	Production cost	Labour cost
Consumer	Labour cost	Geographic concentration	Talent availability
Energy Utilities & Technologies	Labour cost	Production cost	Talent availability
Financial Services & Investors	Talent availability	Labour cost	Organization HQ
Global Health & Healthcare	Talent availability	Labour cost	Production cost
Information & Communication Technologies	Talent availability	Labour cost	Organization HQ
Oil & Gas	Geographic concentration	Talent availability	Organization HQ
Professional Services	Talent availability	Strong local ed. provision	Labour cost

Range of options: Flexibility of labour laws, Geographic spread, Quality of the supply chain, Ease of importing talent, Labour cost, Location of raw materials, Organization HQ, Production cost, Strong local education provision, Talent availability.

Emerging job roles

Managing Directors and Chief Executives
Software and Applications Developers and Analysts
Sales and Marketing Professionals
General and Operations Managers
Data Analysts and Scientists
Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products
Assembly and Factory Workers
Human Resources Specialists
Financial and Investment Advisers
Financial Analysts

Technology adoption *(share of companies surveyed)*

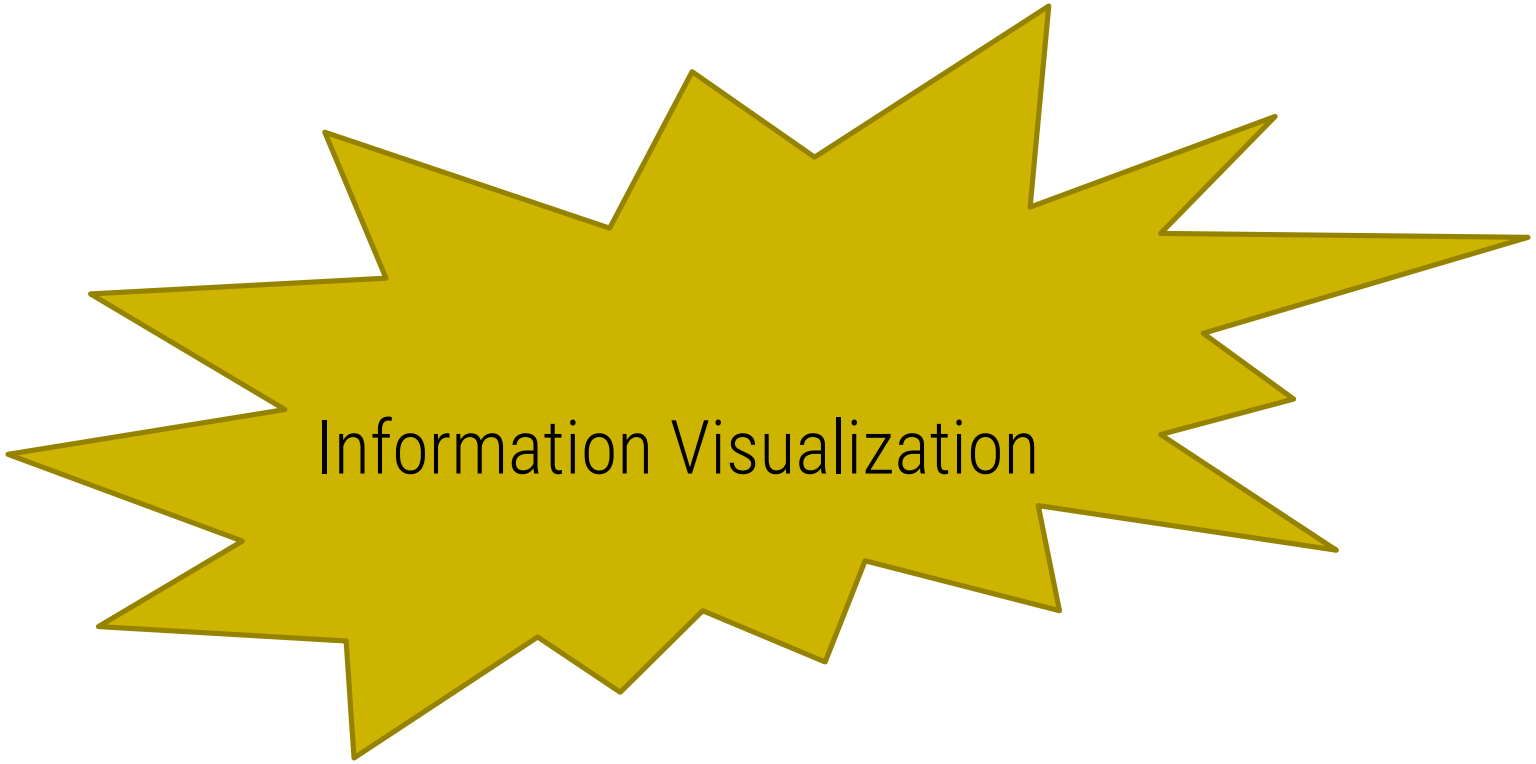


QUESTION

how can humans 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

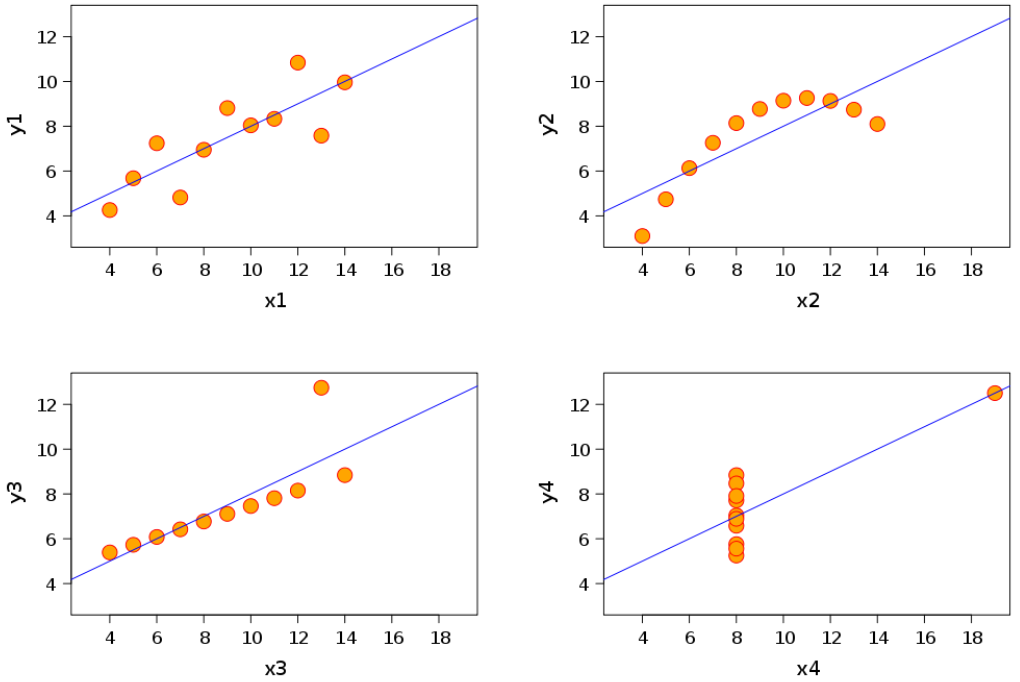
Mean of *x*	9.0
Variance of *x*	11.0
Mean of *y*	7.5
Variance of *y*	4.12
Correlation between *x* and *y*	0.816
Linear regression line	$y = 3 + 0.5x$

[Source: Anscombe's quartet, Wikipedia]

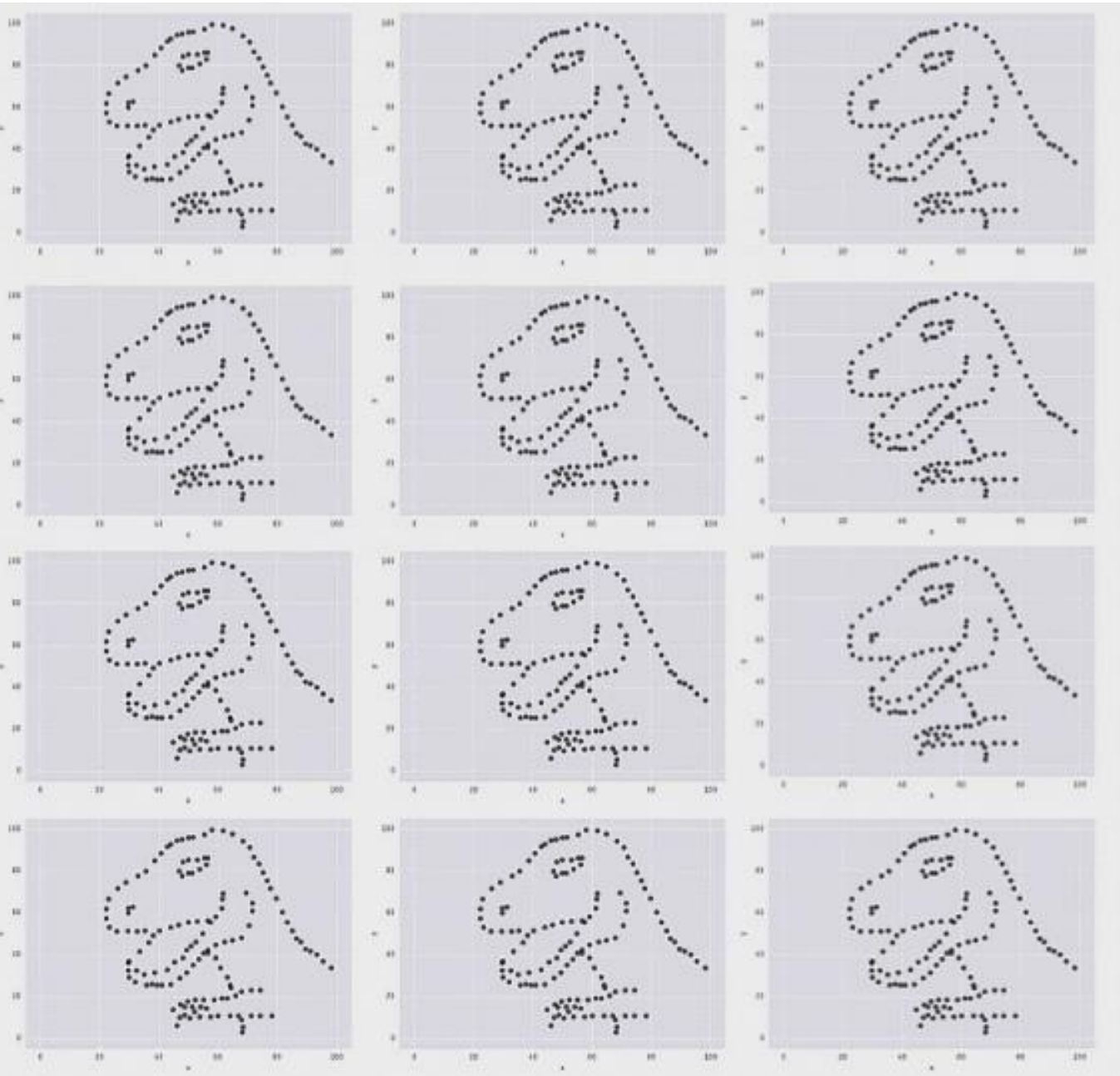
VISUAL REPRESENTATION OF THE DATA

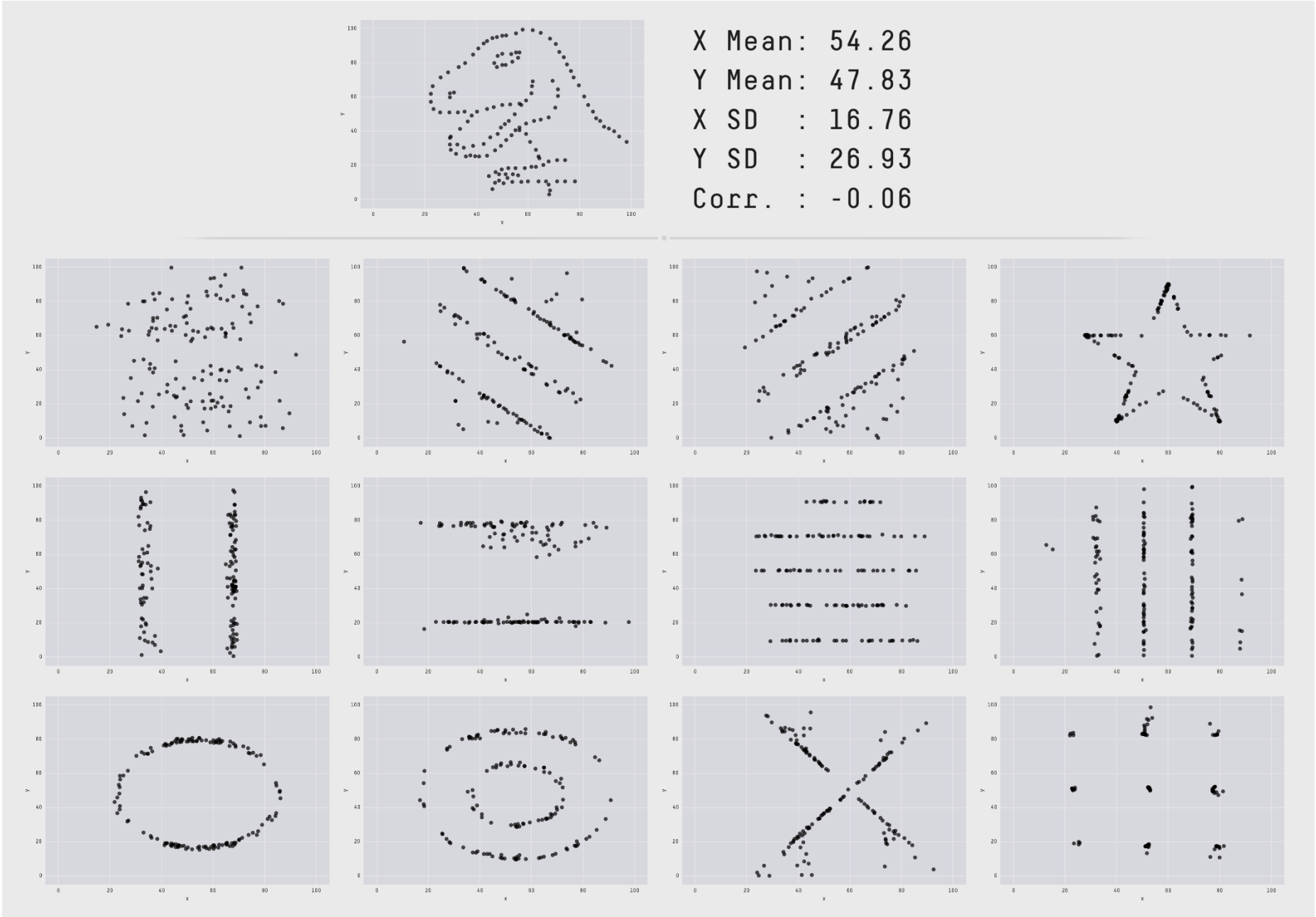
Visual representation reveals a different story

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
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



[Source: Anscombe's quartet, Wikipedia]



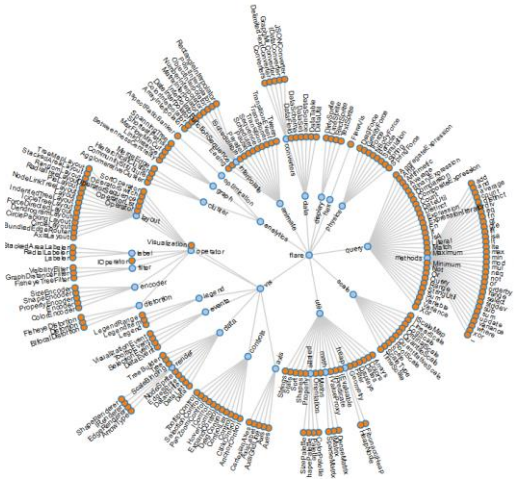


https://www.autodeskresearch.com/publications/samestats

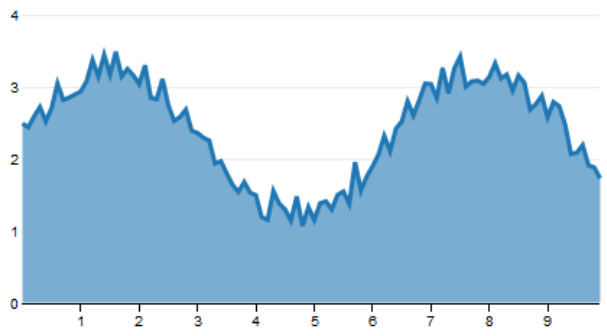
Why visual data representations?

- 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

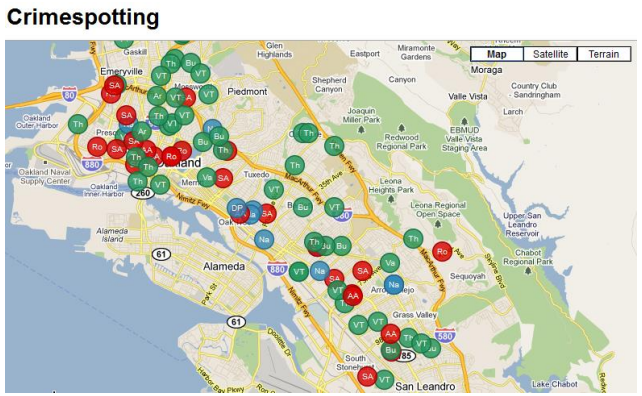
common examples:



graphs / hierarchies



charts

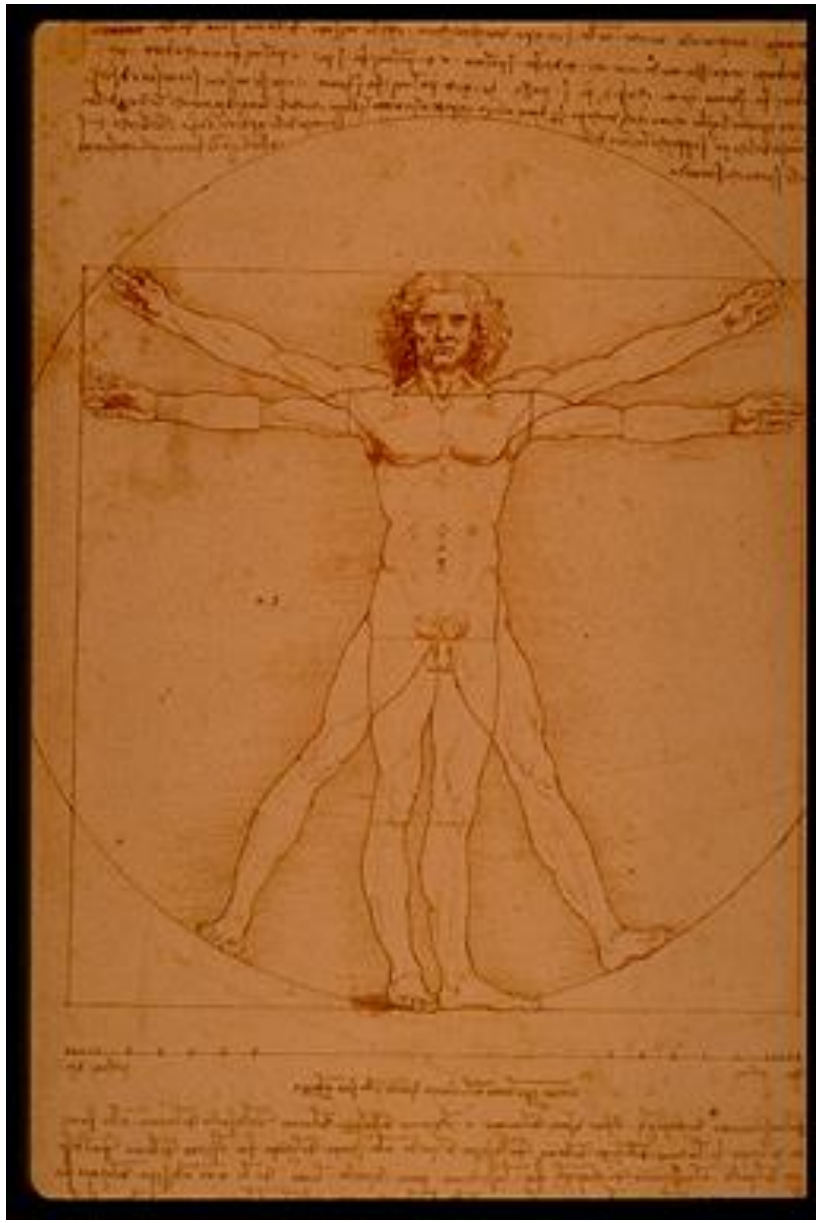


maps

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)

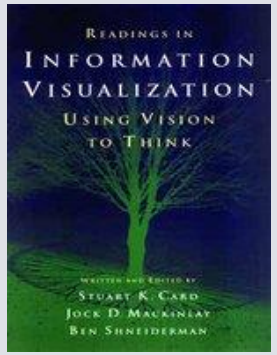
The eye…
the window of the soul,
is the principal means
by which the central sense
can most completely and
abundantly appreciate
the infinite works of nature.

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]



Hint: but there is more to it

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…

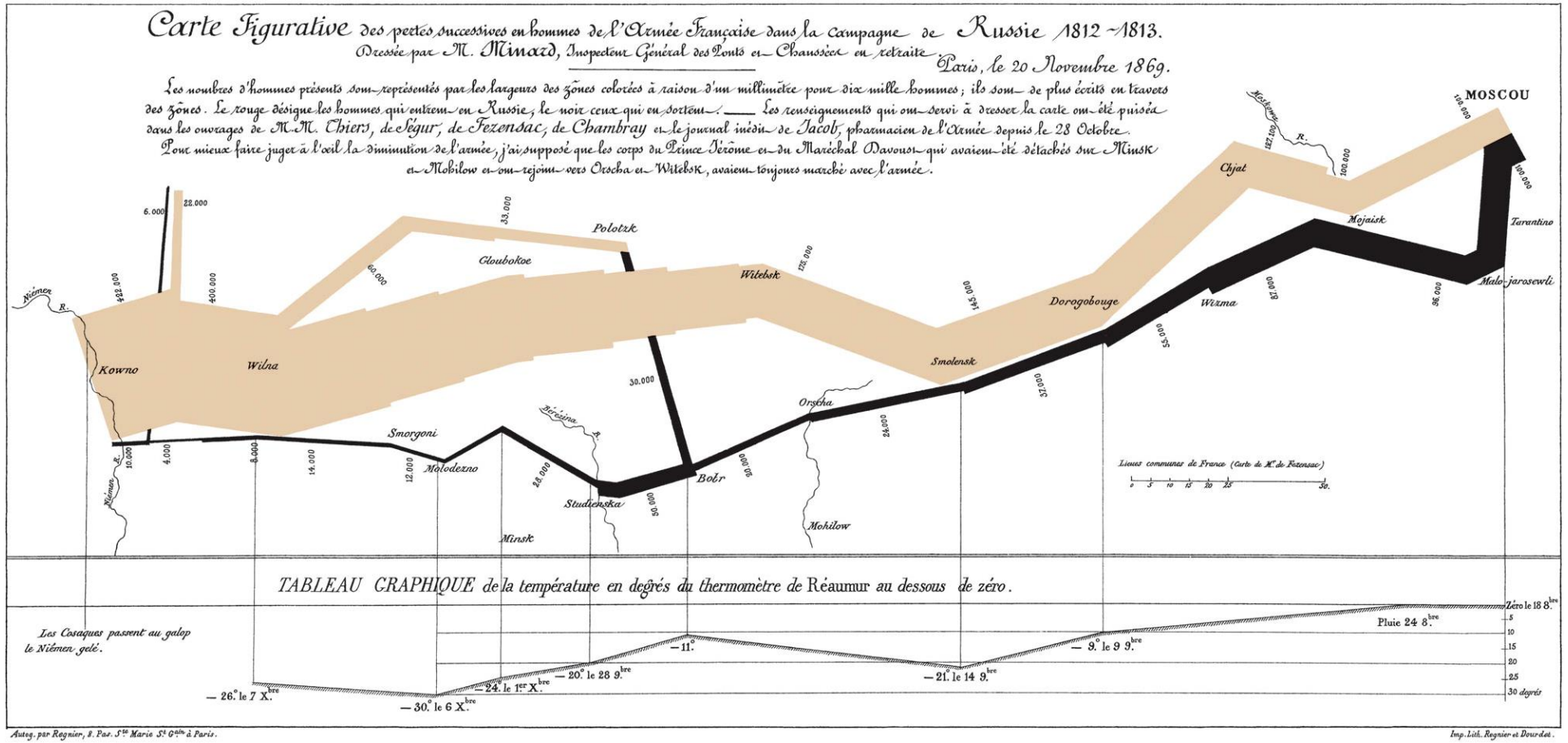
HISTORICAL EXAMPLES

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

Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes ; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. ___ Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'oeil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mohilow en ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.

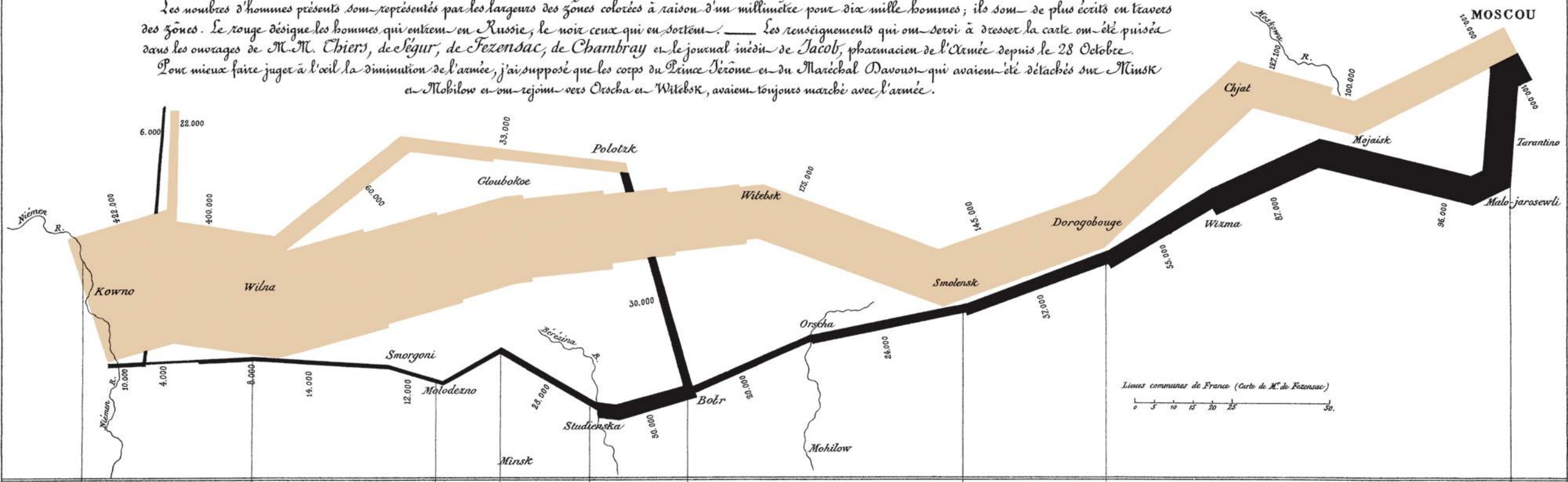
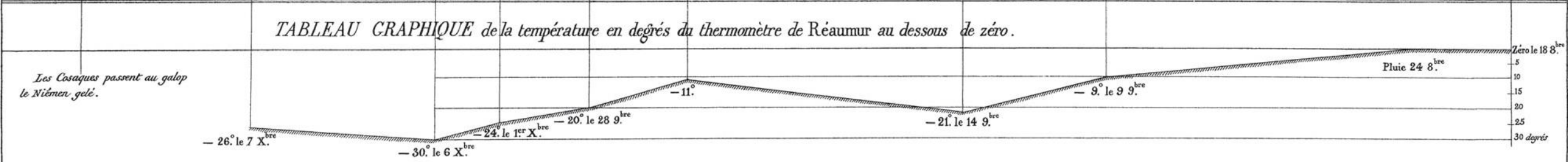


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.



Autog. par Regnier, 8. Pas. Ste Marie St Gain à Paris.

Imp. Lith. Regnier et Dourdet.

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

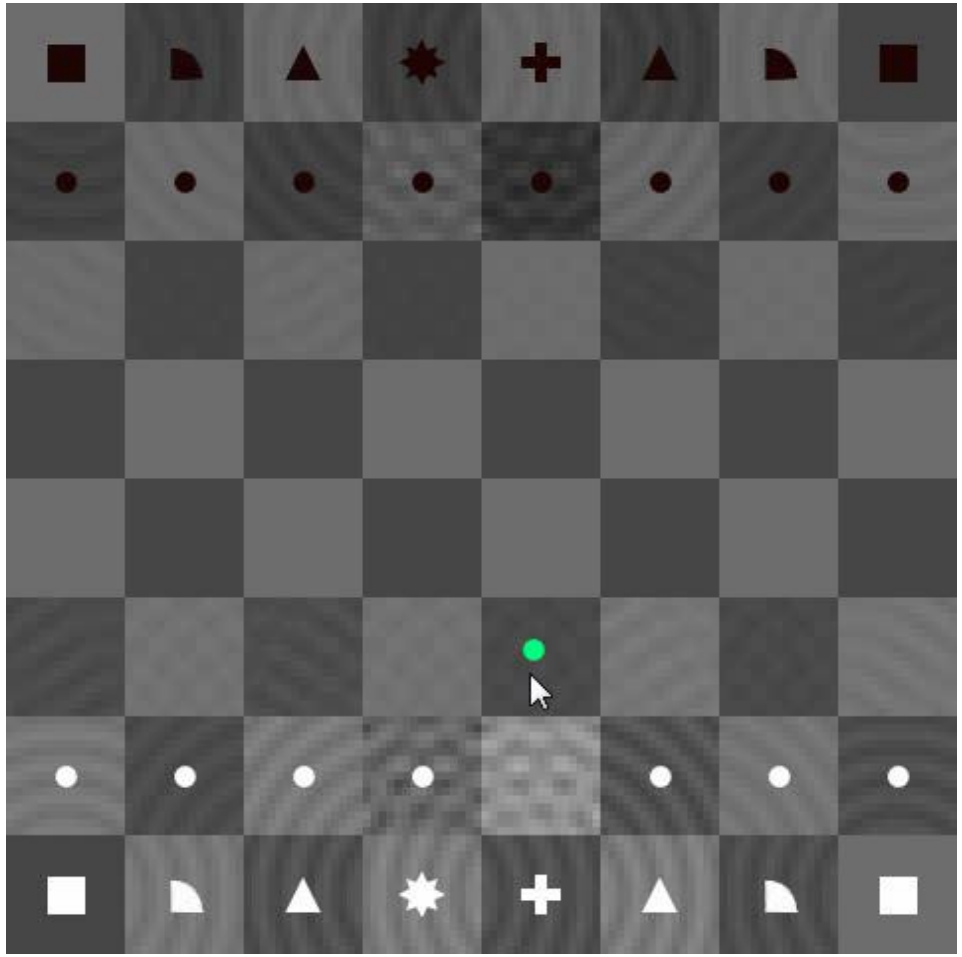
John Snow, 1854

… AND MORE RECENTLY

TrashTrack

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

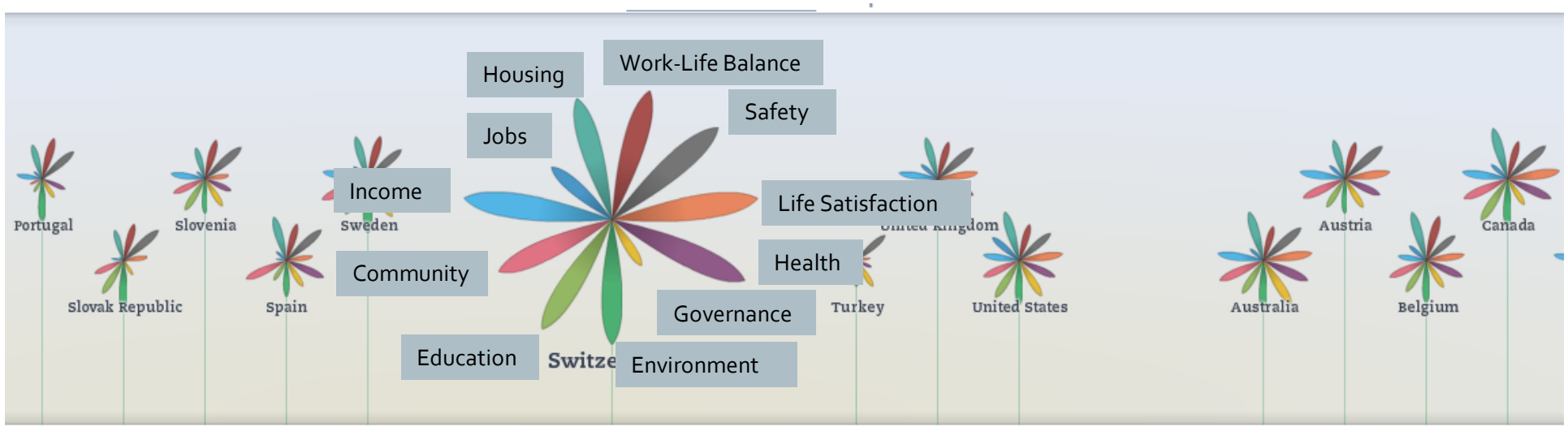
Artificial Intelligence



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/

Specific Visualization Environments

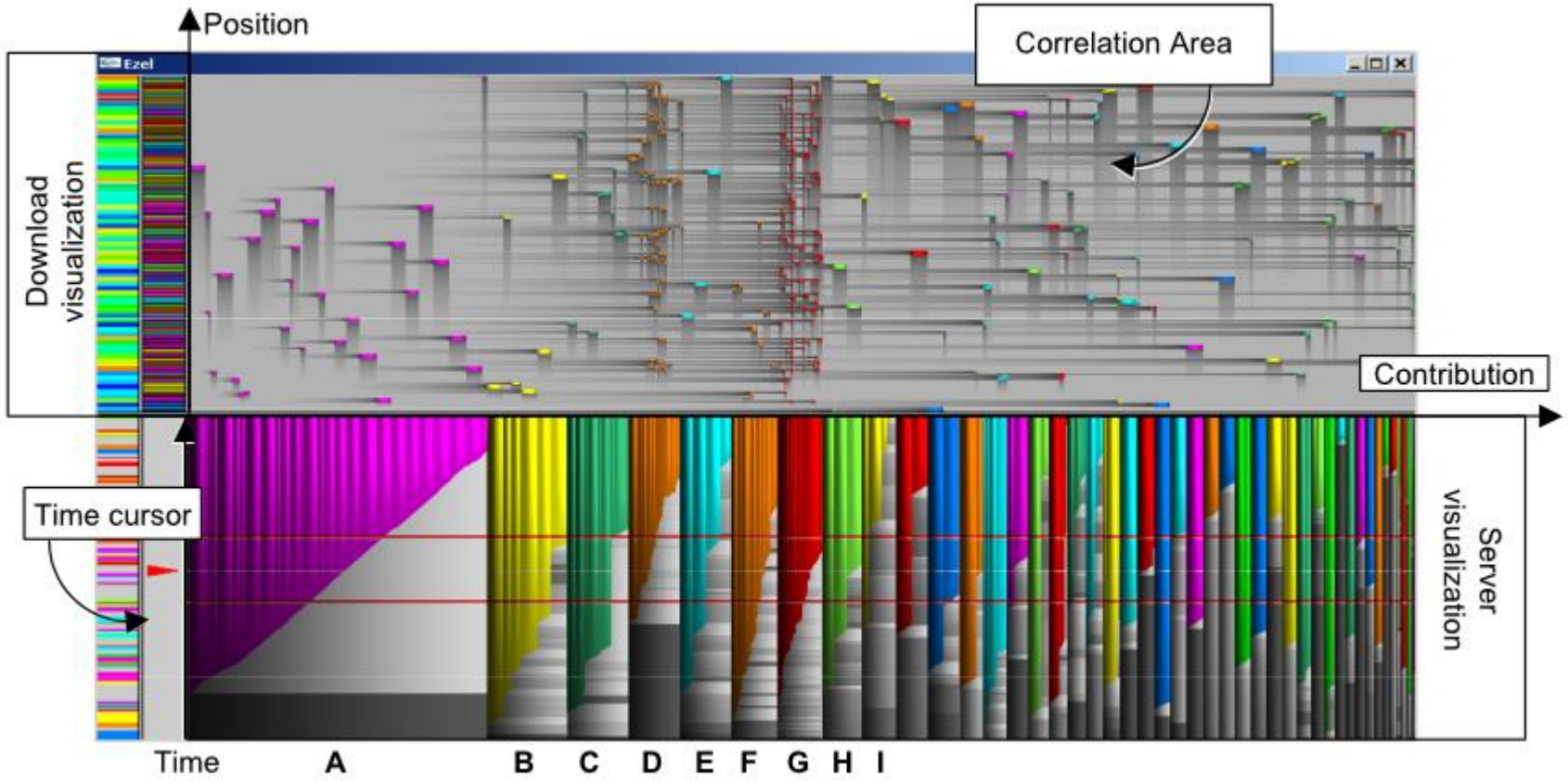
Molecular visualisation in the Reality Cube
University of Groningen, NL

Tabletops for Visualization
University of Calgary

WILD Wall, INRIA

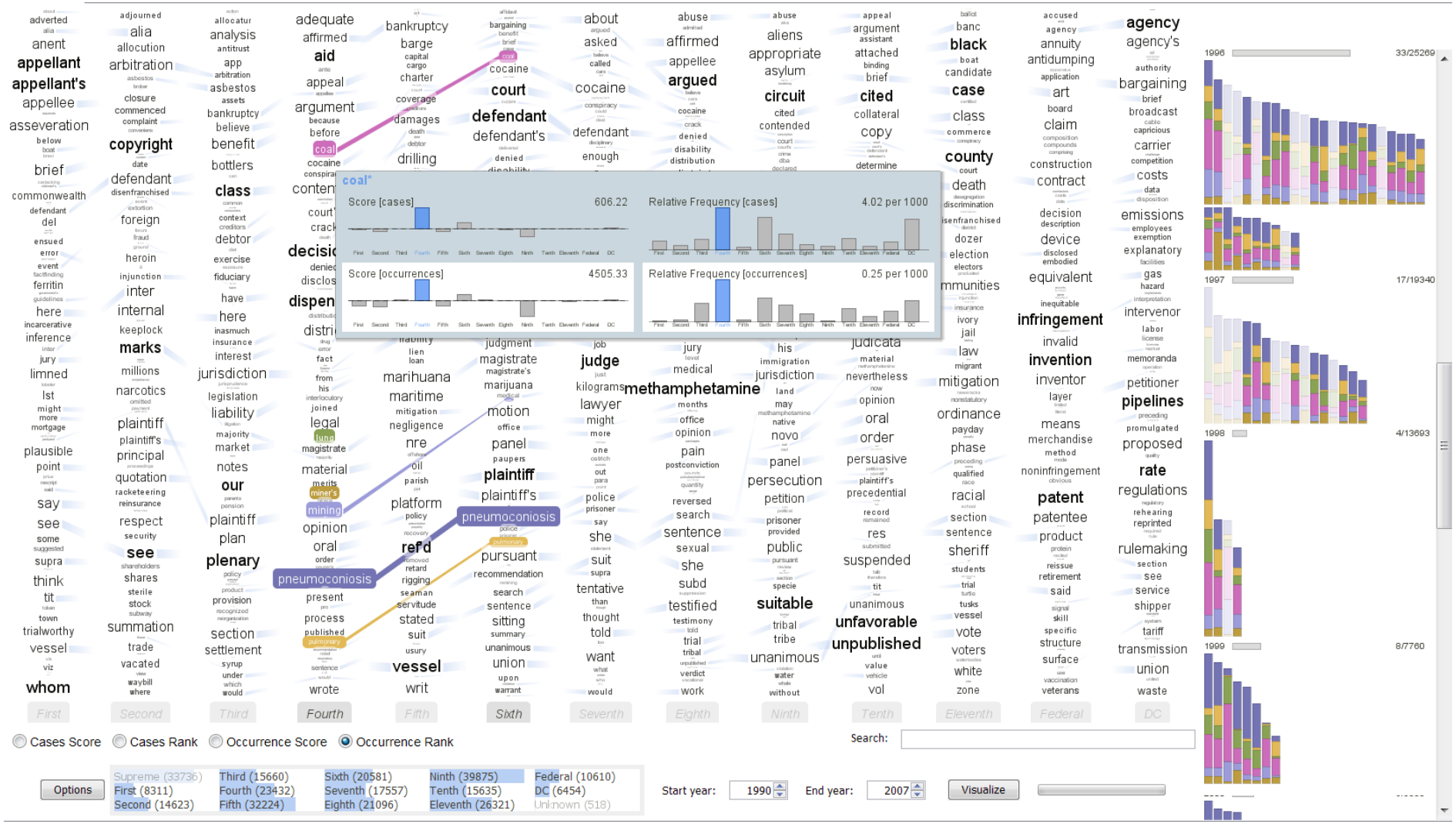
Software Visualization

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



Text Visualization

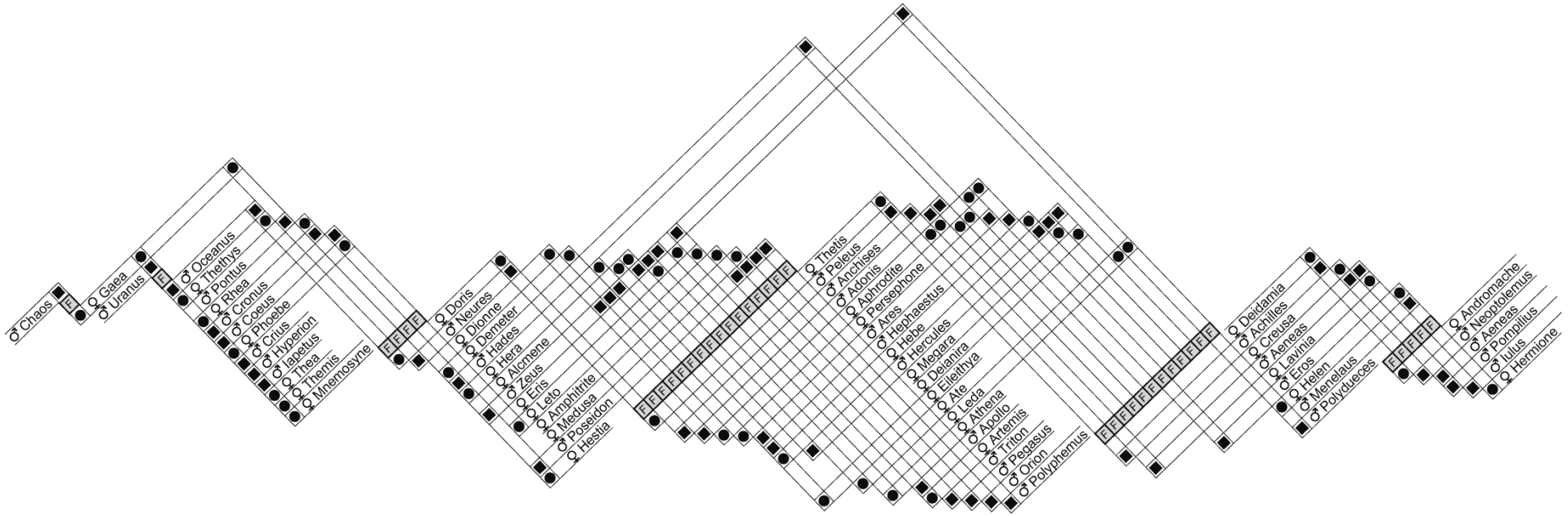
Parallel Tag Clouds to Explore Faceted Text Corpora (Collins et al., VAST 2009)



Graphs

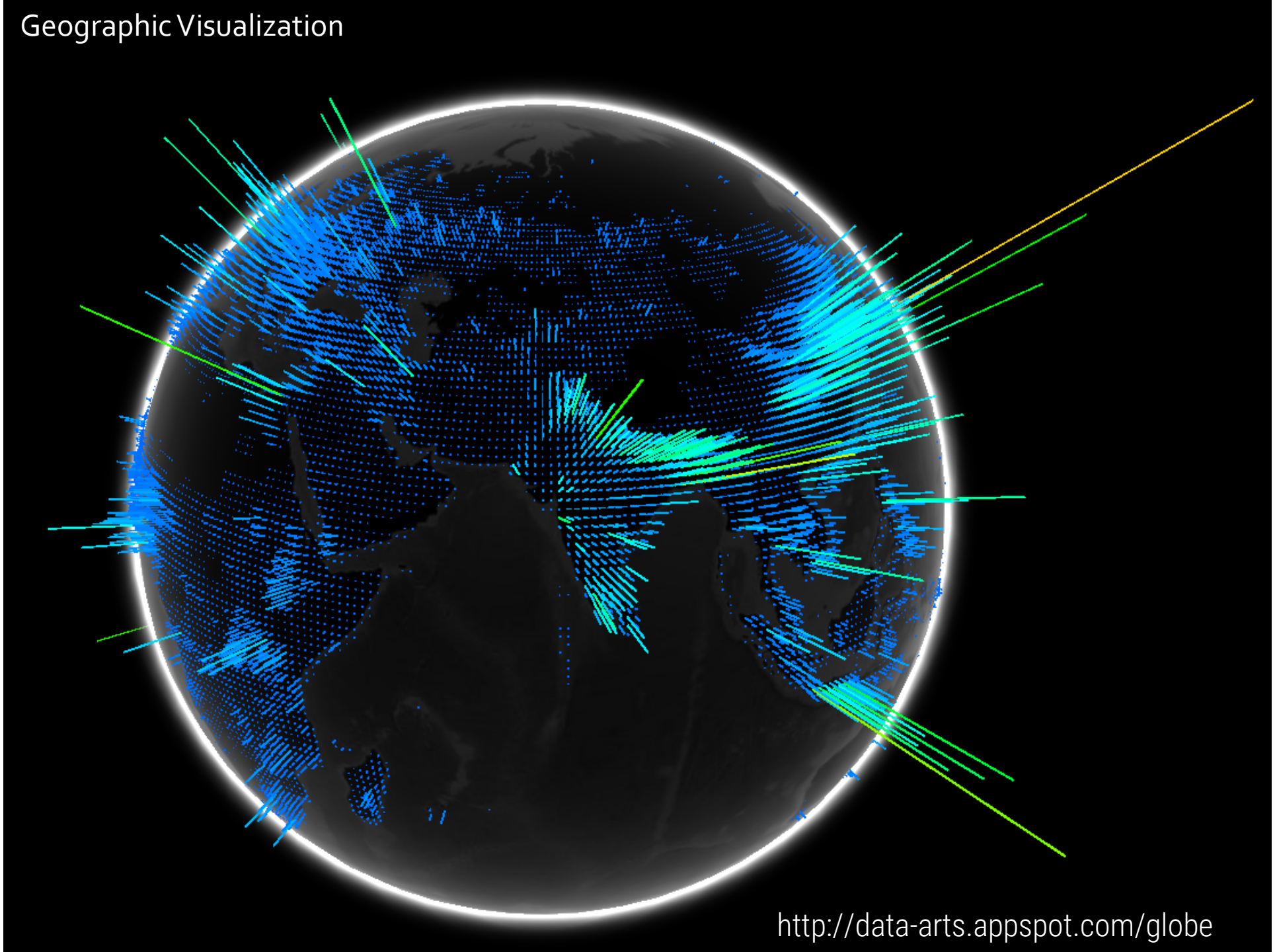
http://www.facebook.com/note.php?note_id=469716398919
Visualizing Friendships by Paul Butler on Tuesday, December 14, 2010

Family Trees

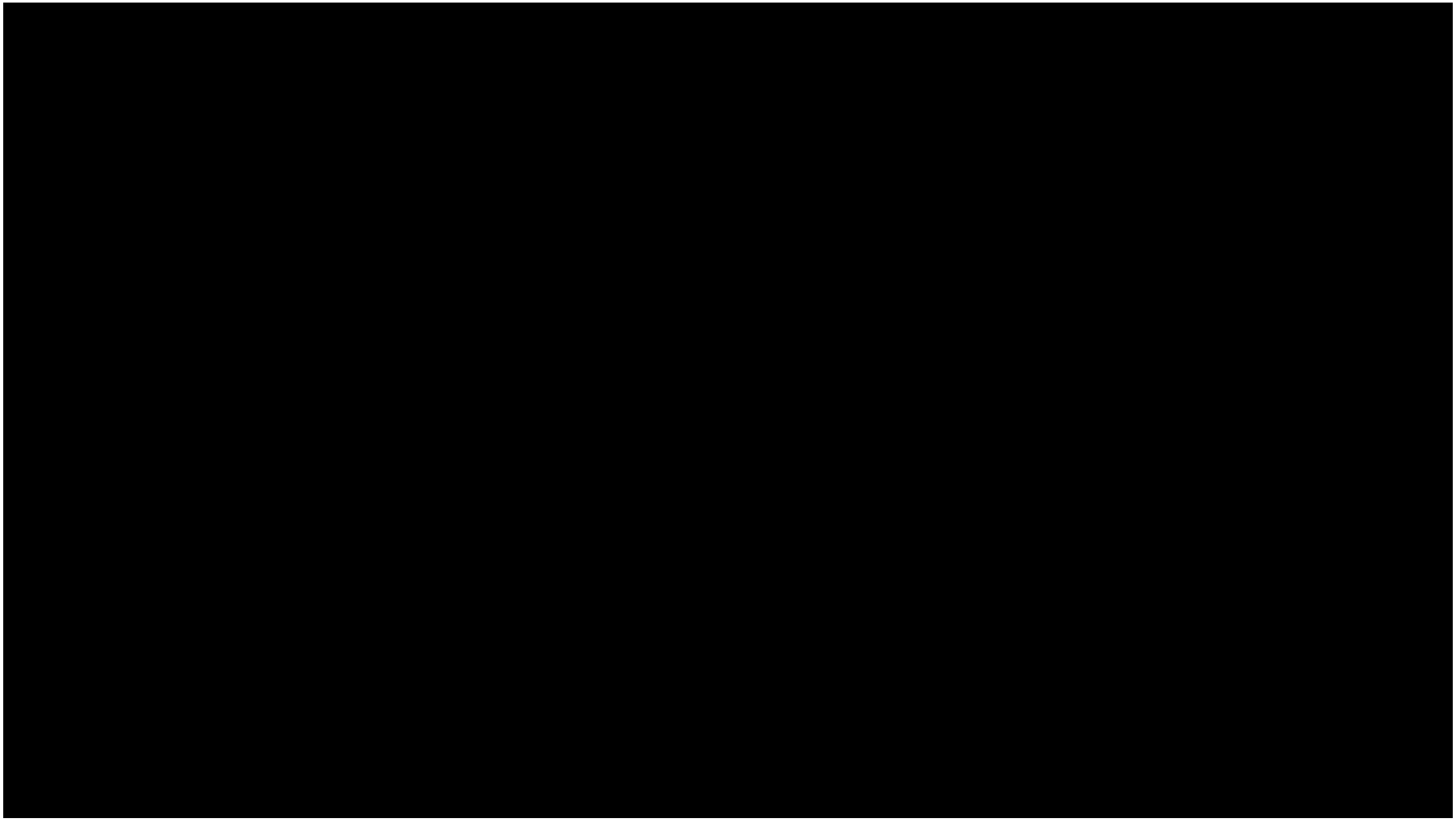


http://www.aviz.fr/geneaquilts/

Geographic Visualization



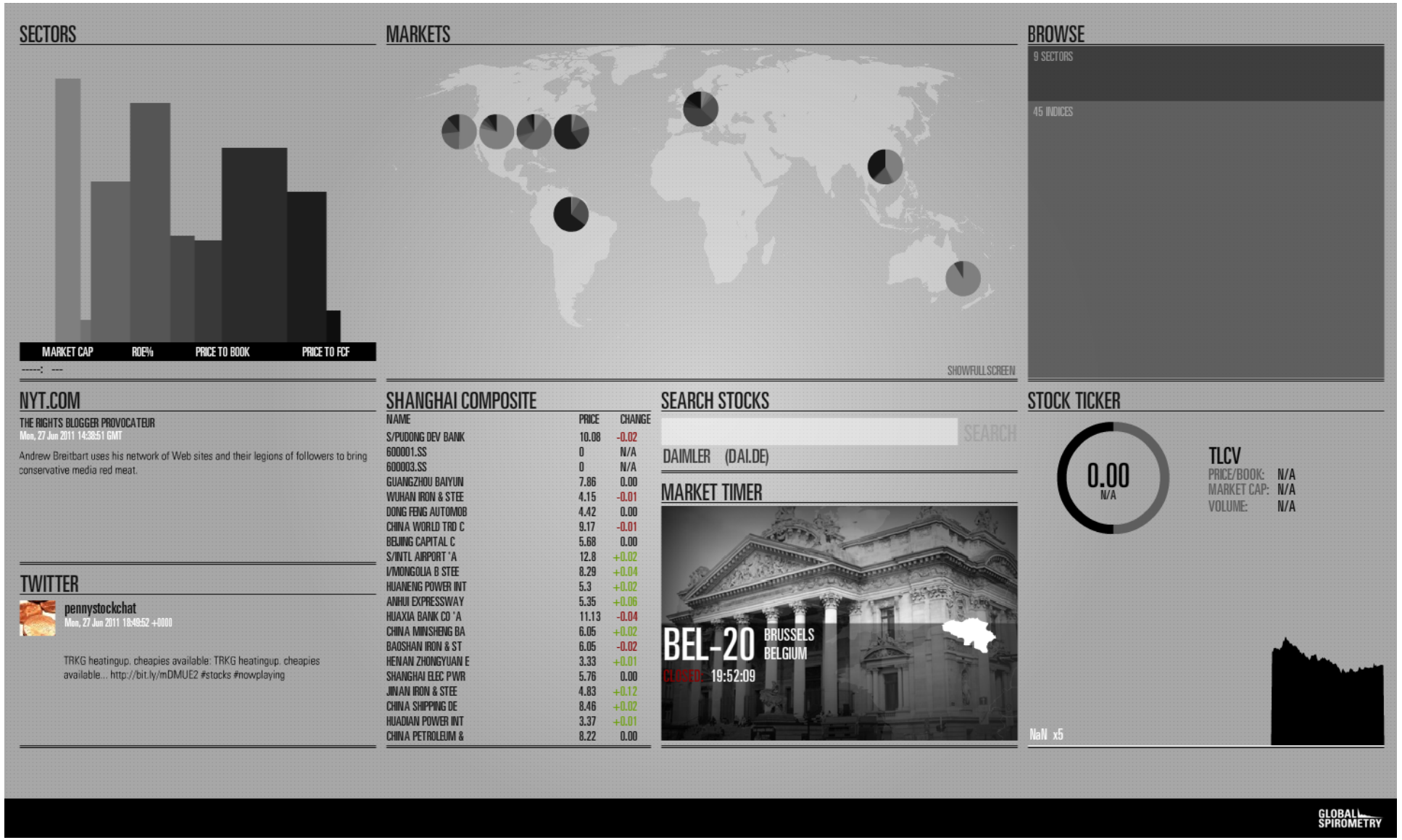
http://data-arts.appspot.com/globe



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.)
    - Visualization Analysis and Design (Tamara Munzner, most recent book)
  - 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	100010	XXXIV
decimal	binary	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

The Visual Display of Quantitative Information, Tufte

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

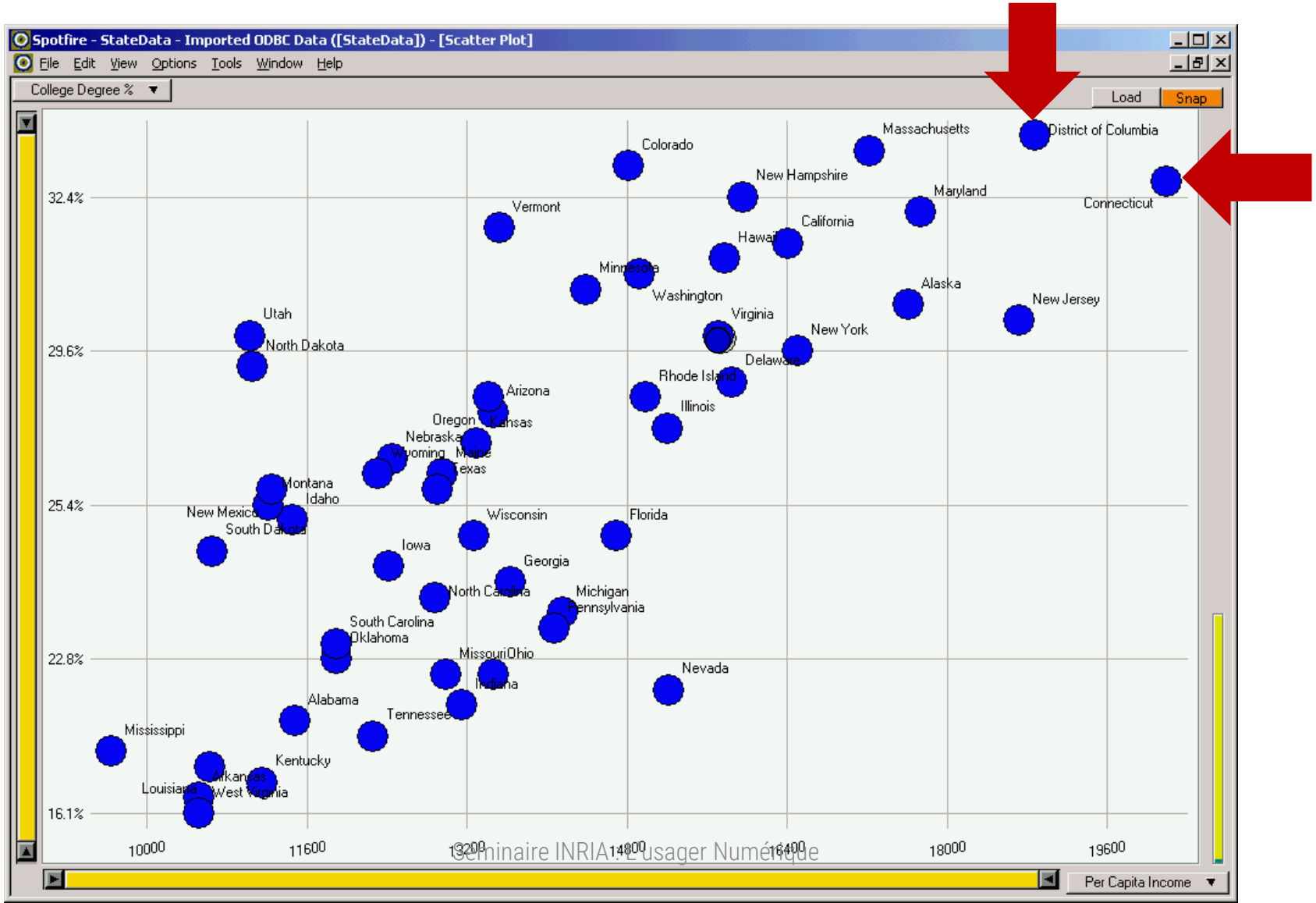
Good representation?

Table - StateData ()

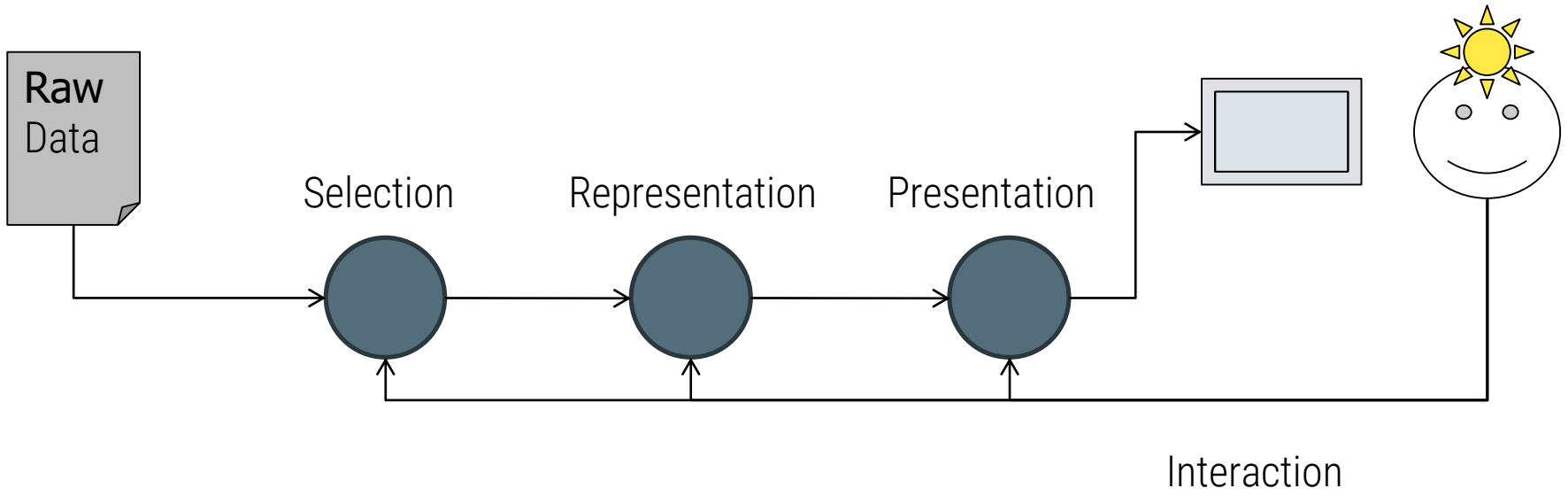
Load | Snap

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

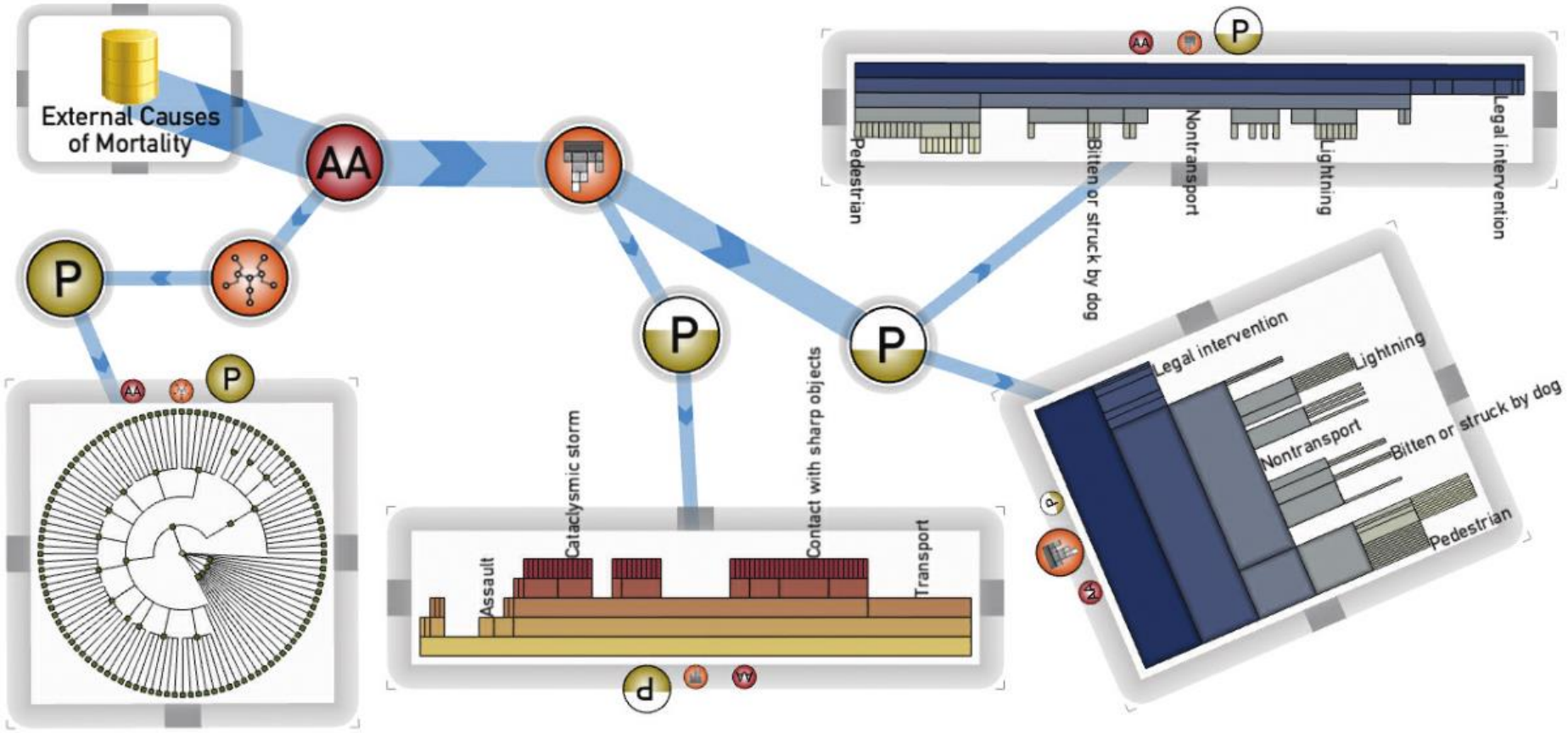
Spatial Mapping Transformation

Presentation Transformation

View Transformation

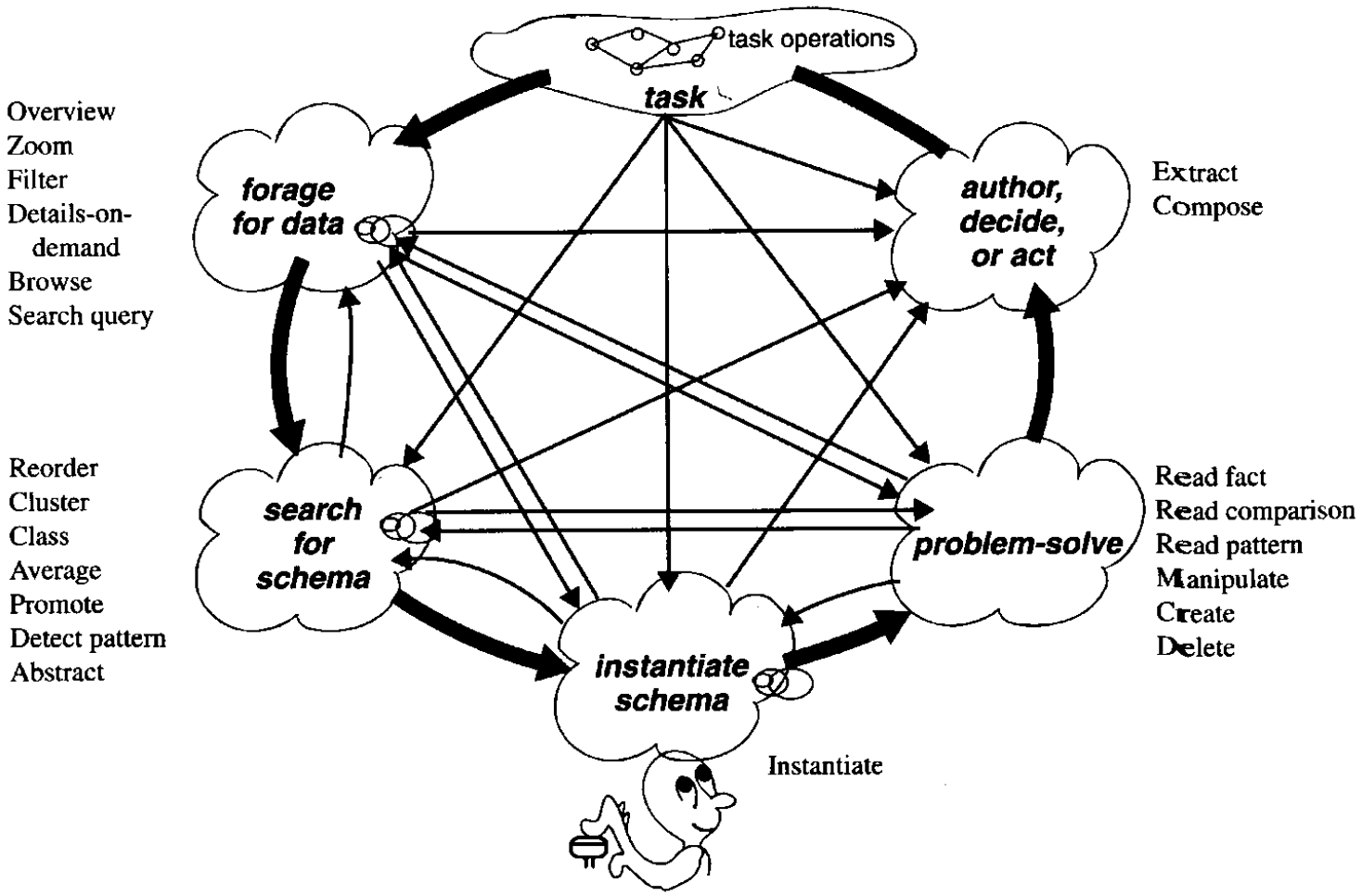
From [Card et al., Readings in Information Visualization]

Visualization pipeline in an image



[Tobiasz et al., 2009]

Knowledge Crystallization Cycle



Working with visualizations in NOT a linear process

[Card et al., 1999]

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)

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

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

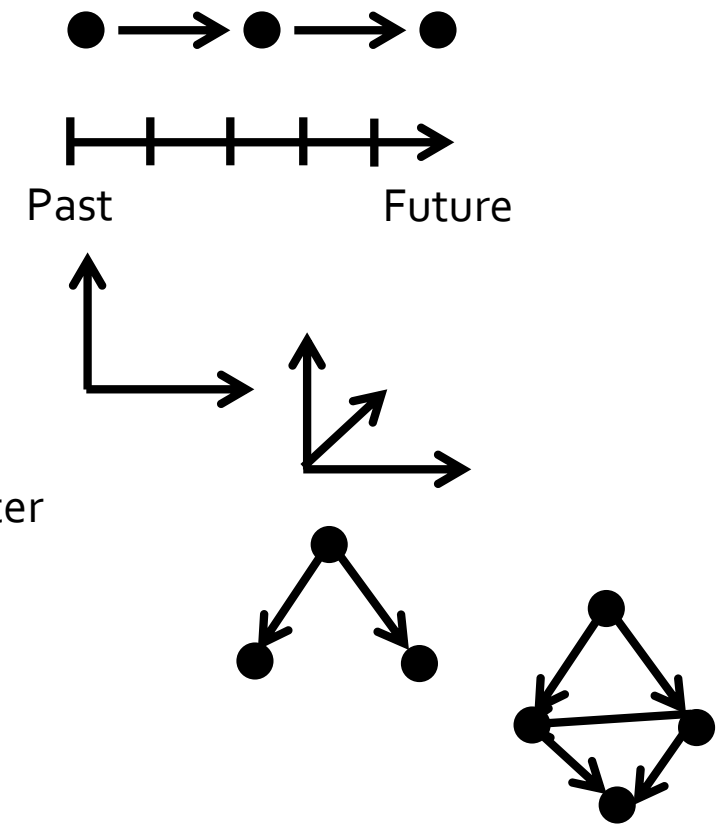
Nominal, Ordinal and Quantitative

- Nominal / Categorical (labels)
  - Fruits: apples, oranges
- Ordered
  - Quality of meat: grade A, AA, AAA
  - Can be counted and ordered, but not measured
- Quantitative
  - Intervals or Ratios
  - Can do arithmetic on it

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

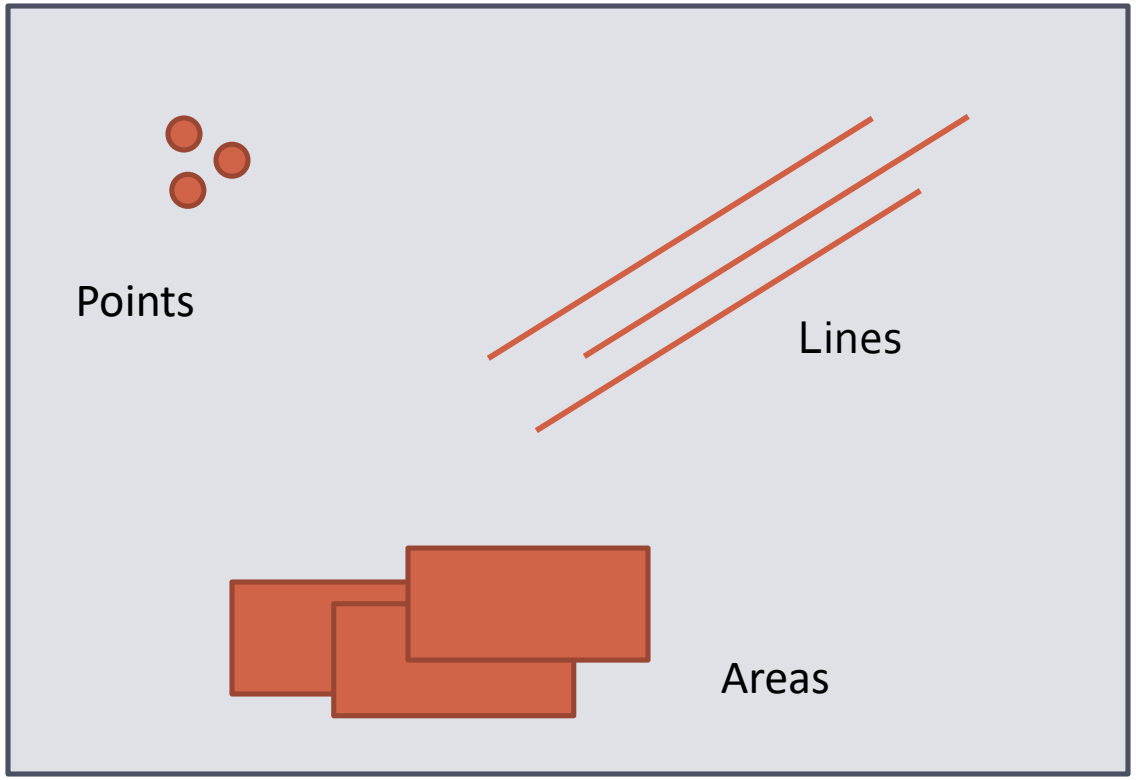
Shneiderman: The Eyes Have It

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

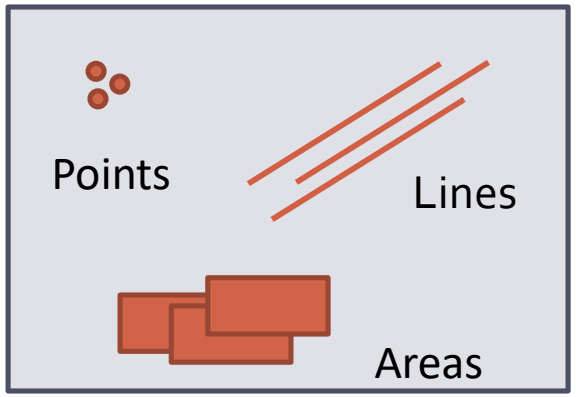
Marks which represent:



From Semiology of Graphics (Bertin)

Points

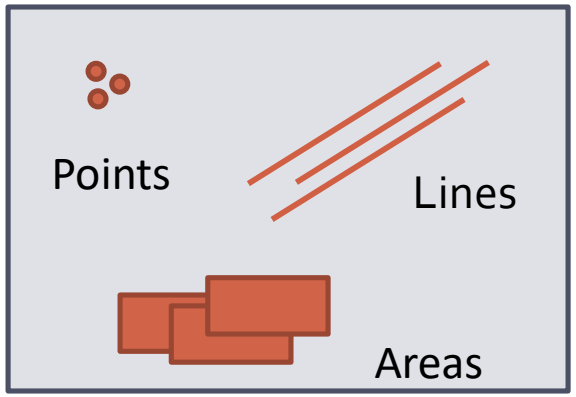
- “A point represents a location on the plane that has **no theoretical length or area**. This signification is independent of the size and character of the mark which renders it visible.”
- a location
- marks that indicate points can vary in all visual variables



From Semiology of Graphics (Bertin)

Lines

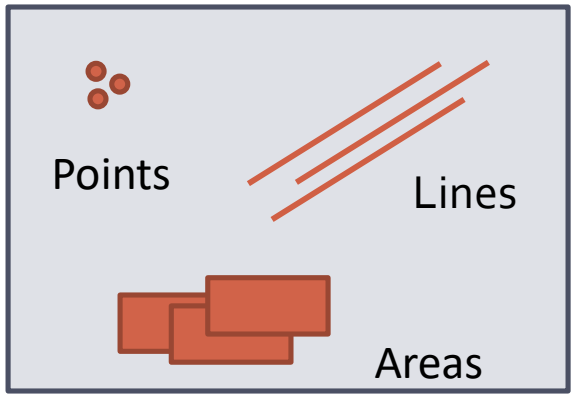
- “A line signifies a phenomenon on the plane which has **measurable length but no area**. This signification is independent of the width and characteristics of the mark which renders it visible.”
- a boundary, a route, a connection



From Semiology of Graphics (Bertin)

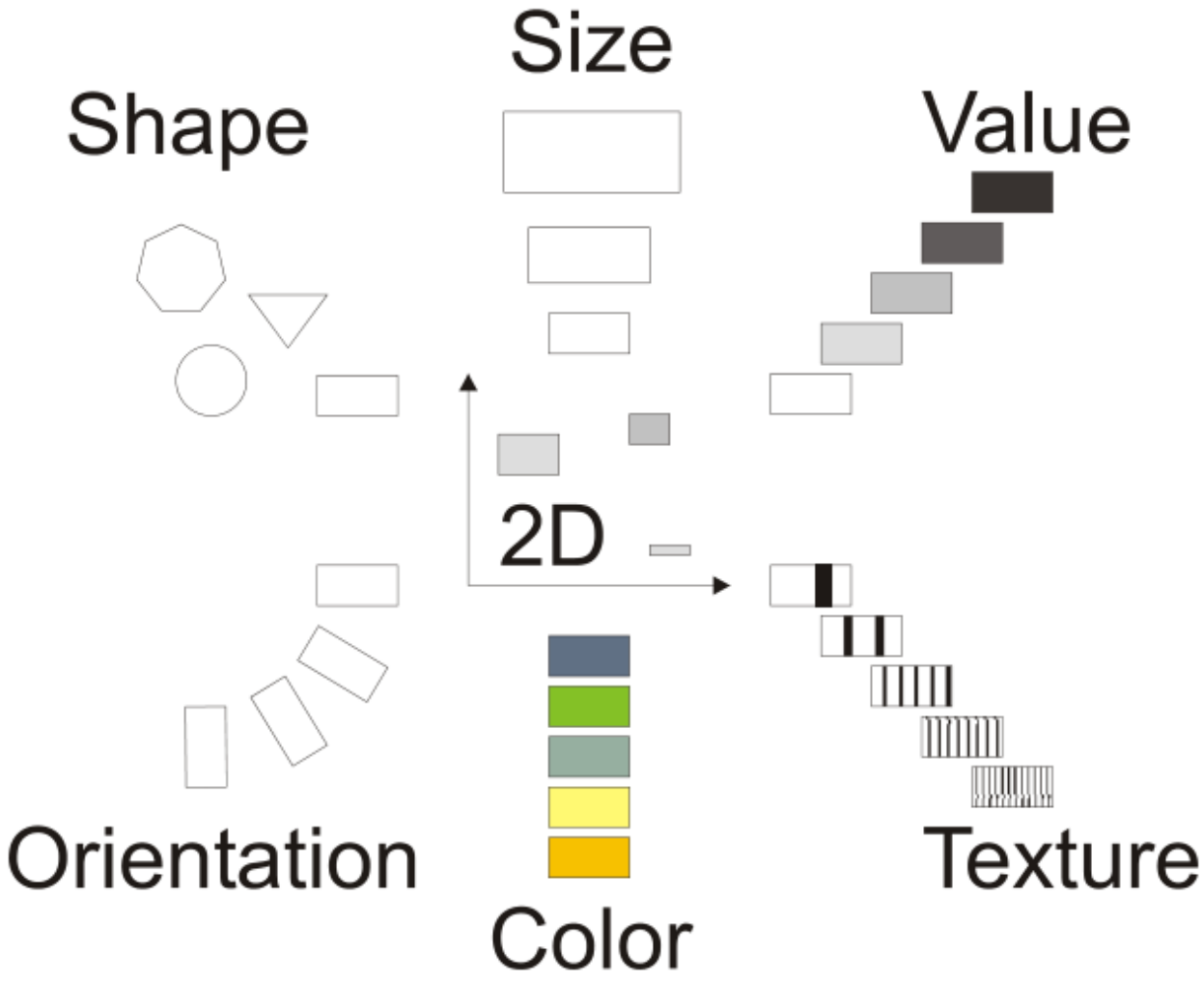
Areas

- “An area signifies something on the plane that **has measurable size**.
  This signification applies to the entire area covered by the visible mark.”
- an area can change in position but not in size, shape or orientation without making the area itself have a different meaning



From Semiology of Graphics (Bertin)

Visual Variables Applicable to Marks

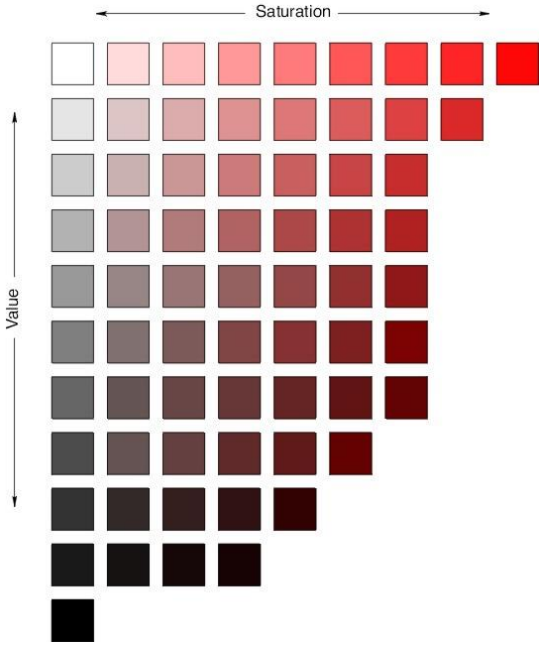


From Semiology of Graphics (Bertin)

Additional Variables for Computers

- motion
  - direction, acceleration, speed, frequency, onset, ‘personality’

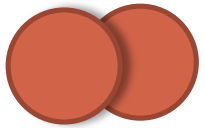
- saturation
  - colour as Bertin uses largely refers to hue, saturation != value



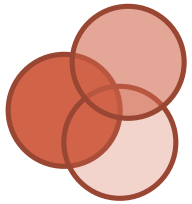
Extending those from Semiology of Graphics (Bertin)

Additional Variables for Computers

- flicker
  - frequency, rhythm, appearance
- depth? ‘quasi’ 3D
  - depth, occlusion, aerial perspective, binocular disparity
- Illumination



- transparency



From Semiology of Graphics (Bertin)

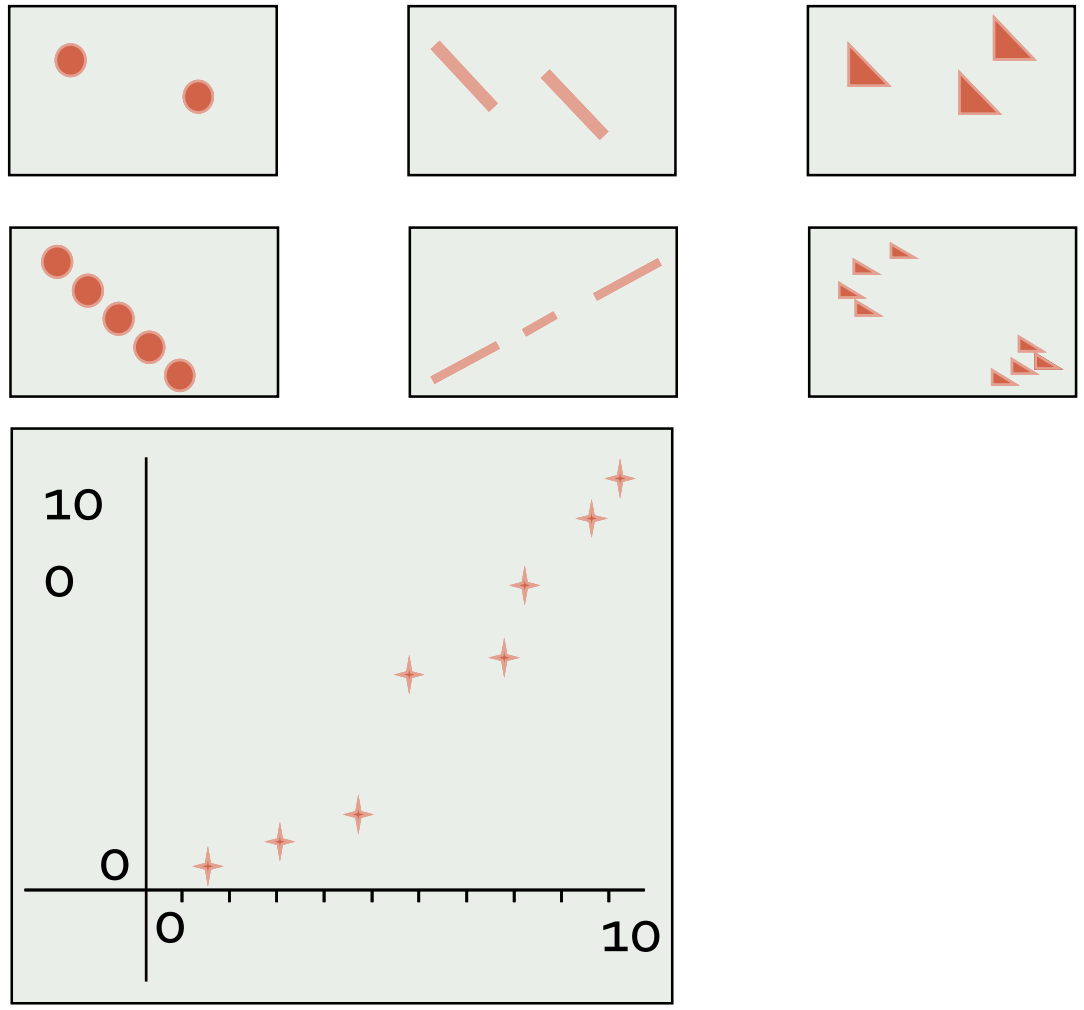
Characteristics of Visual Variables

- Selective:
  Can this variable allow us to spontaneously differentiate/isolate items from groups?
- Associative:
  Can this variable allow us to spontaneously group items in a group?
- Ordered:
  Can this variable allow us to spontaneously perceive an order?
- Quantitative:
  Can the difference between two marks in this variable be interpreted numerically ?
- Length (resolution):
  Across how many changes in this variable are distinctions possible?

From Semiology of Graphics (Bertin)

Visual Variable: Position

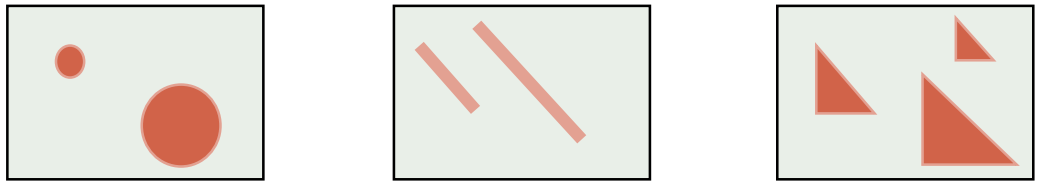
- ✓ selective
- ✓ associative
- ✓ quantitative
- ✓ order
- ✓ length (resolution)

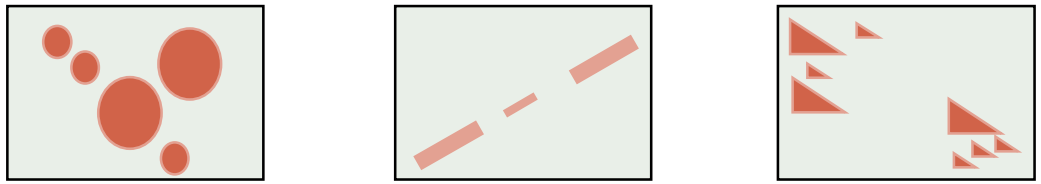


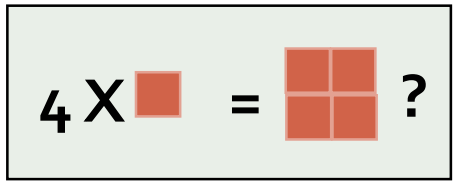
From Semiology of Graphics (Bertin)

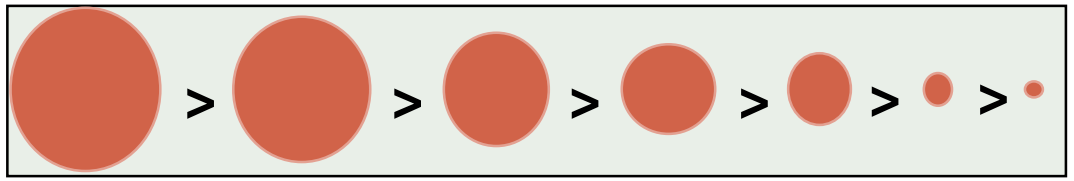
Visual Variable: Size

- ✓ selective
- ✓ associative
- ≈ quantitative
- ✓ order
- ✓ length (resolution)









Size

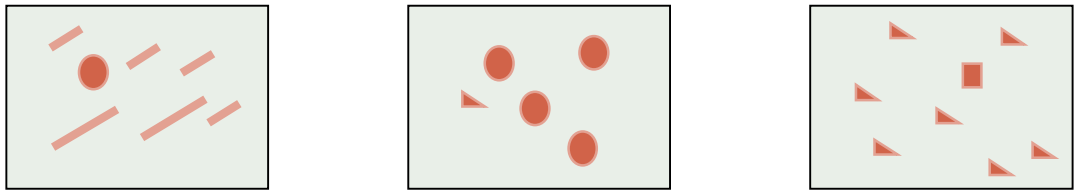
points

lines

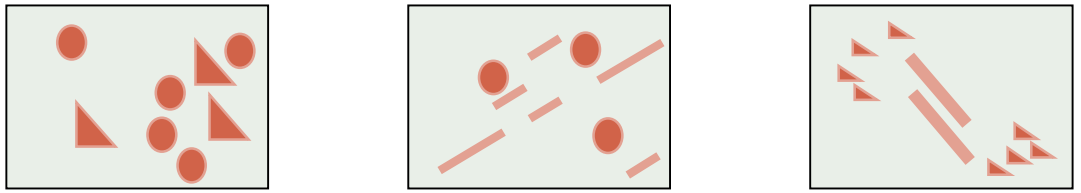
areas

Visual Variable: Shape

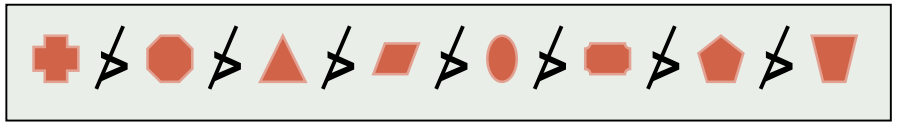
≤ • selective



≤ • associative

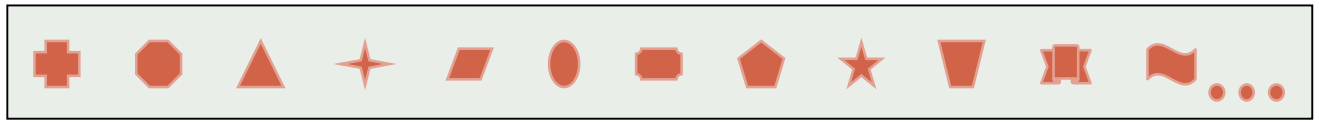


≠ • ordered



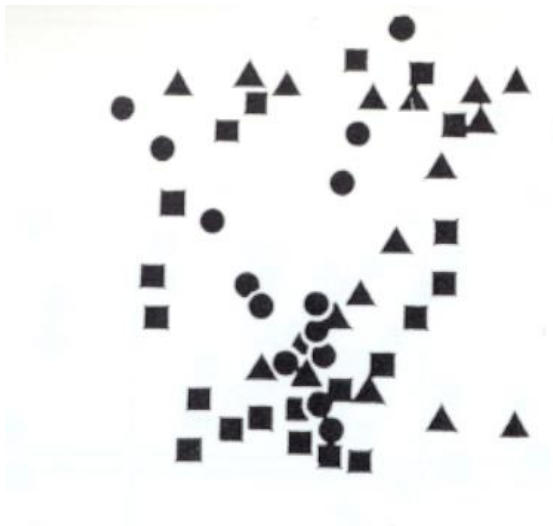
≠ • quantitative

✓ • length (resolution)



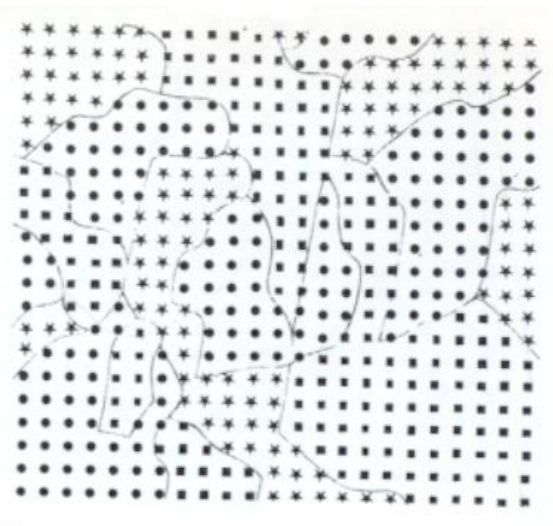
  – infinite

Shape



points

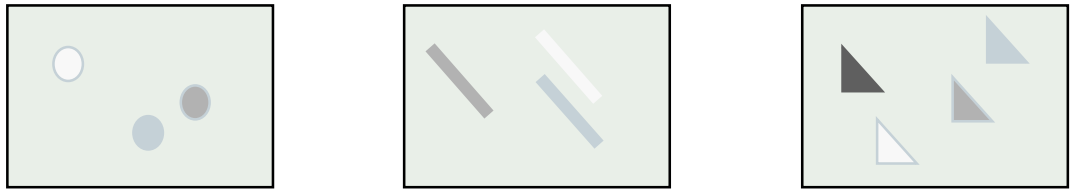
lines



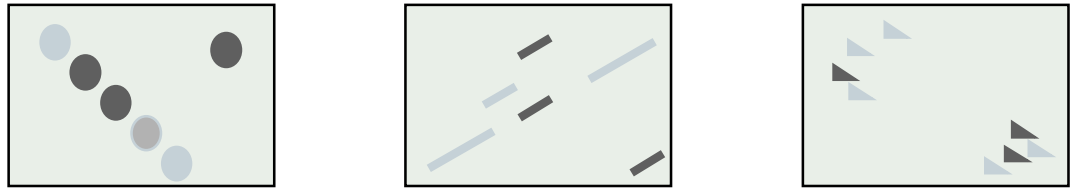
areas

Visual Variable: Value

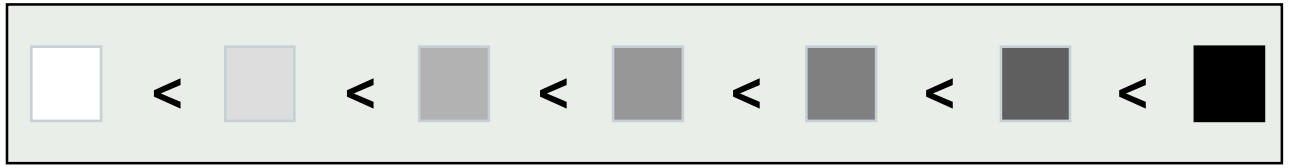
- ✓ selective



- ✓ associative



- ≠ quantitative
- ✓ order



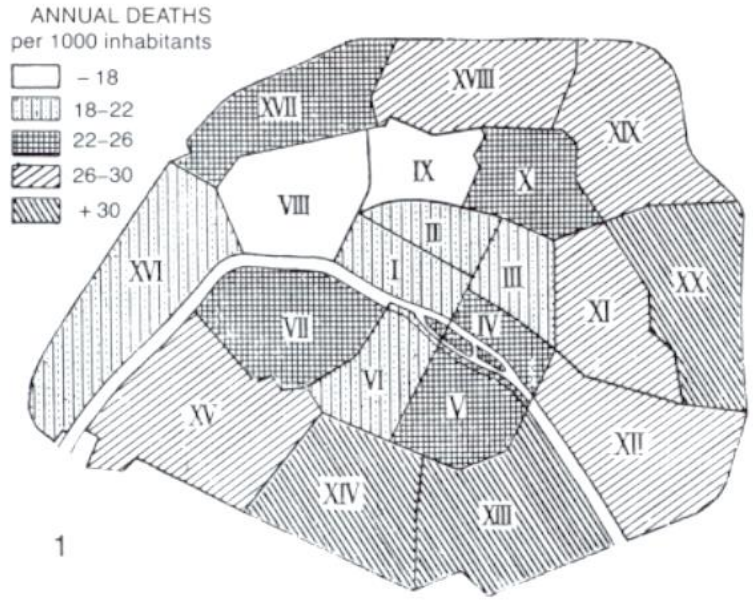
- ✓ length (resolution)
  - theoretically infinite but practically limited
  - association and selection ~ < 7 and distinction ~ 10

Value

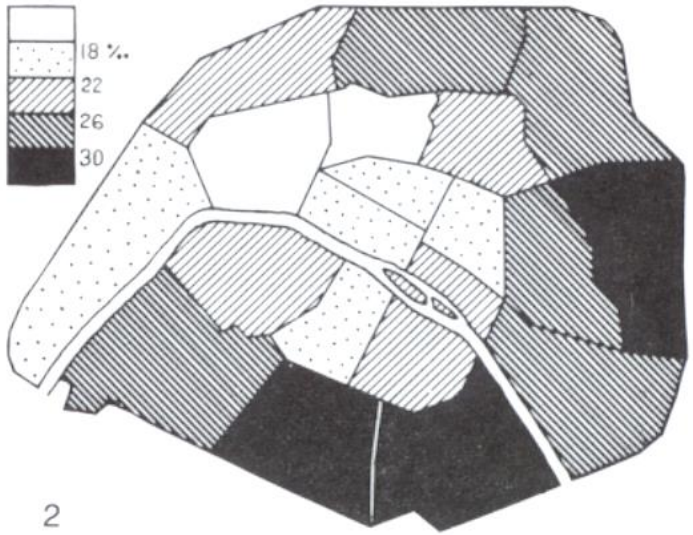
points lines areas

Value

ordered, cannot be reordered



Values not ordered correctly according to scale
Information has to be read point by point

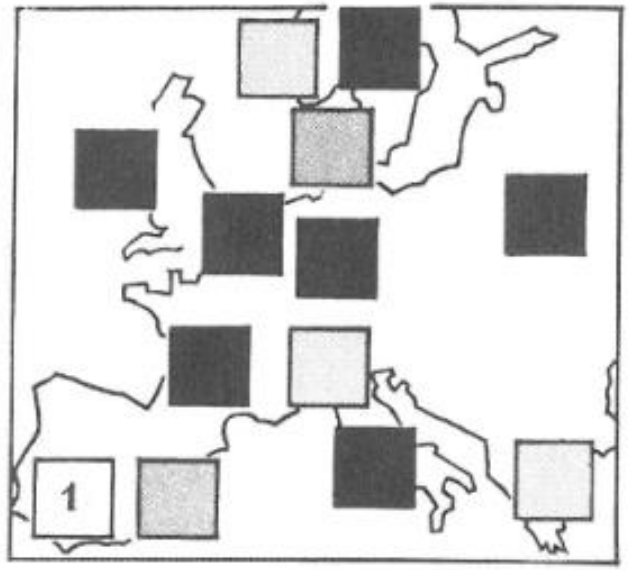


Values ordered correctly
Image much more useful

annual deaths per 1000 inhabitants, Paris

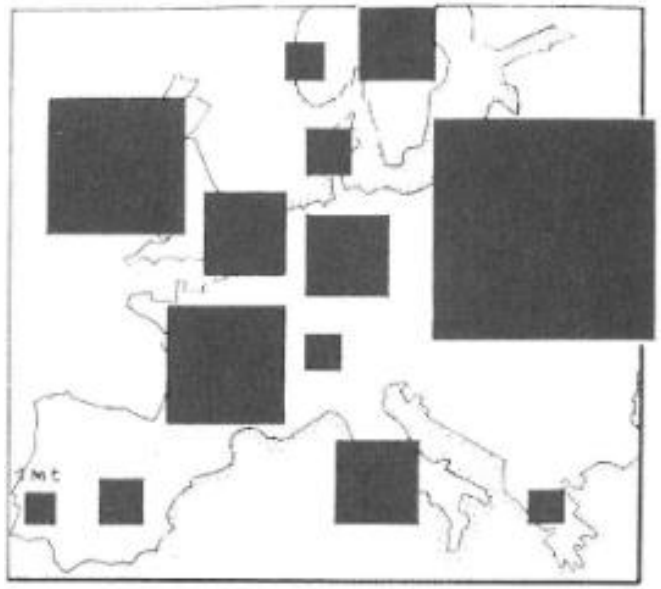
Value

is not quantitative



if Portugal is 1, what is France?

you need a legend!

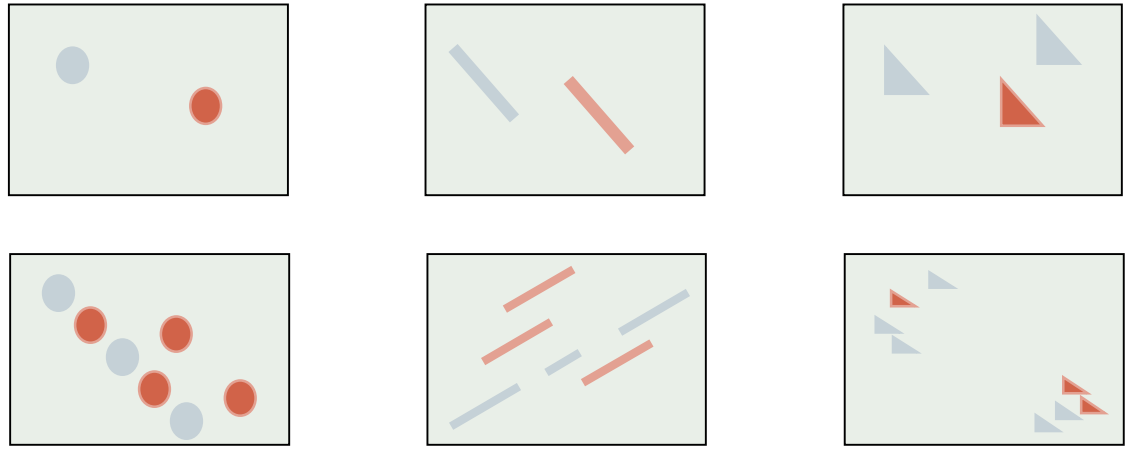


if Portugal is 1, what is France?

still hard, but doable

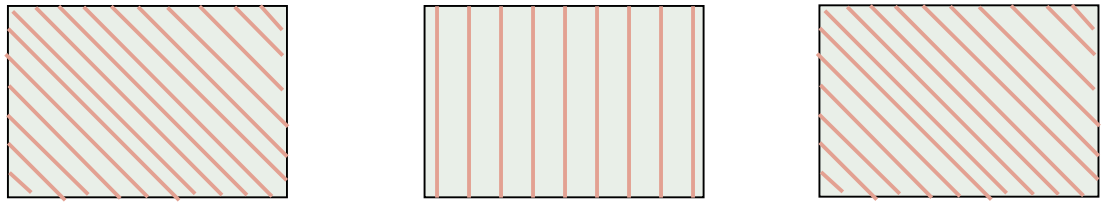
Visual Variable: Colour

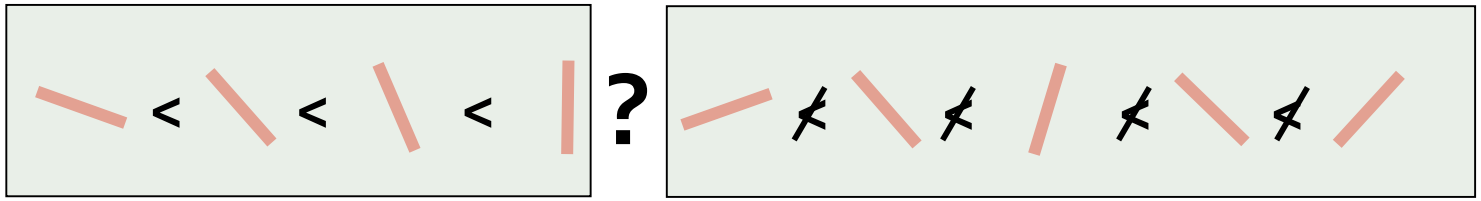
- ✓ selective
- ✓ associative
- ≠ quantitative
- ≠ order
- ✓ length (resolution)
  - theoretically infinite but practically limited
  - association and selection ~ < 7 and distinction ~ 10



Visual Variable: Orientation

- ✓ selective
- ✓ associative
- ≠ quantitative
- ≠ order
- ✓ length (resolution)
  - ~5 in 2D; ? in 3D

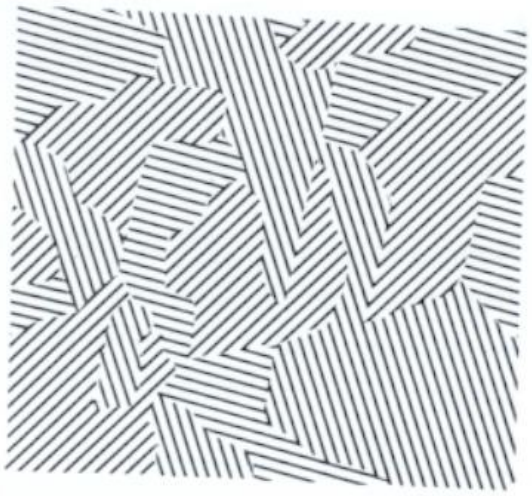




Orientation

points

lines



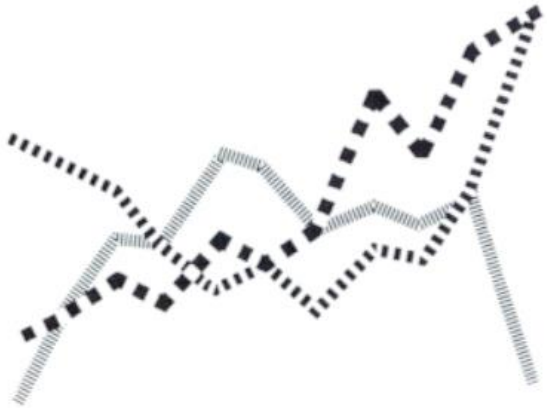
areas

Visual Variable: Texture

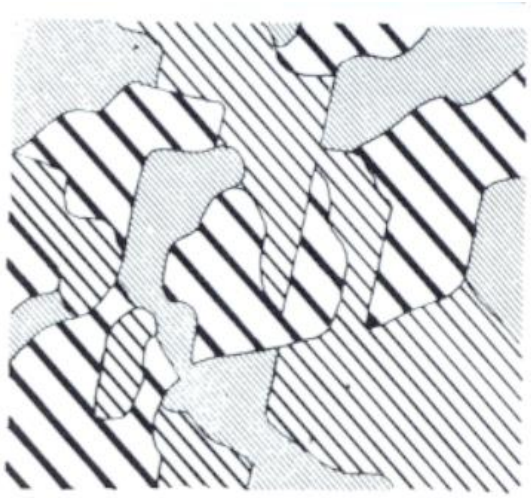
- ✓ selective
- ✓ associative
- ≠ quantitative
- ≠ order
- ✓ length (resolution)
  - theoretically infinite

Texture

points



lines



areas

Visual Variable: Motion

- ✓ selective
  - motion is one of our most powerful attention grabbers
- ✓ associative
  - moving in unison groups objects effectively
- ≠ quantitative
  - subjective perception
- ≠ order
- ? length (resolution)
  - distinguishable types of motion?

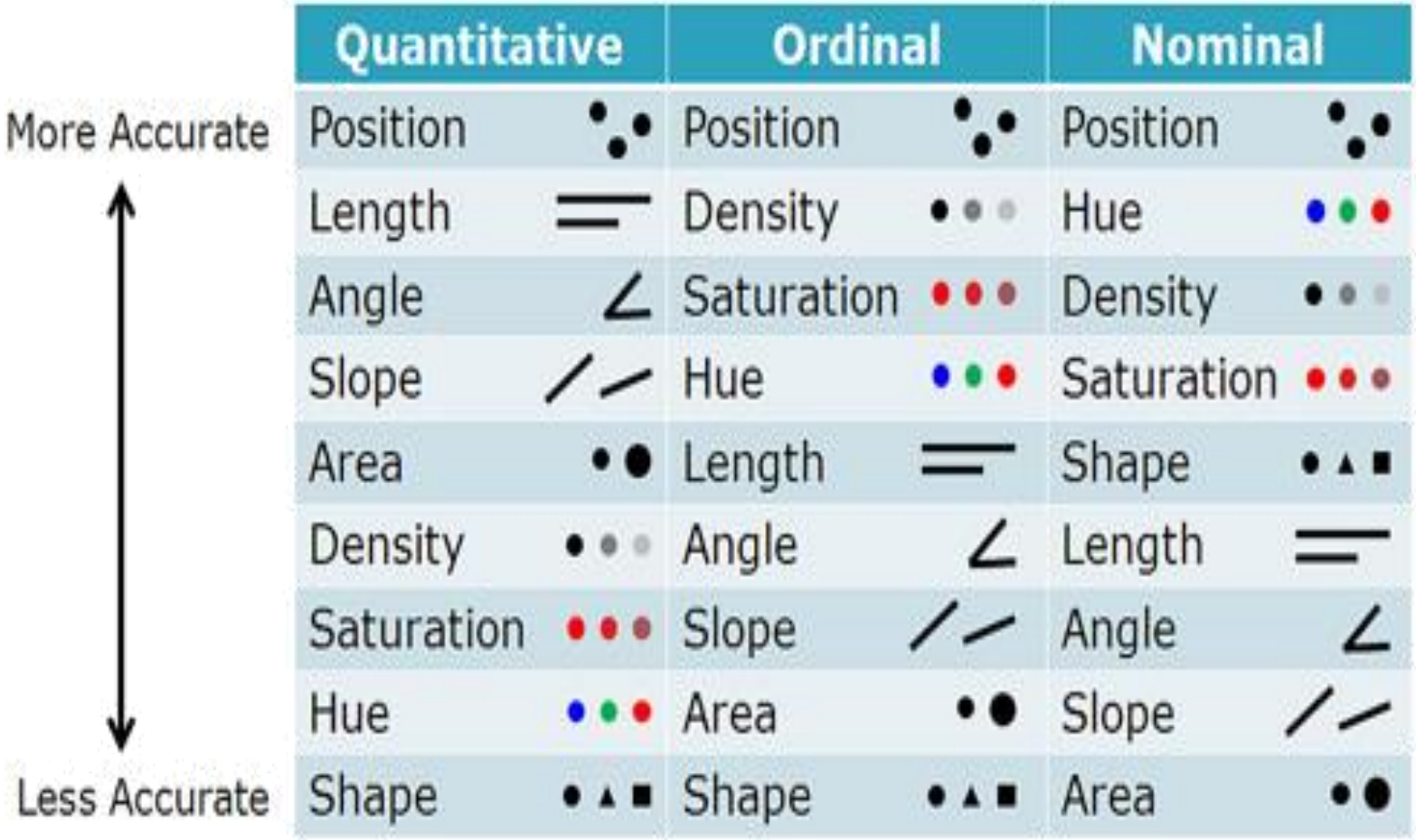
Motion

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

Carpendale, 2003

Summary



Jacques Bertin refined by Cleveland&McGill then by Card&Mackinlay

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