# **INFORMATION VISUALIZATION** Introduction

Petra Isenberg petra.isenberg@inria.fr

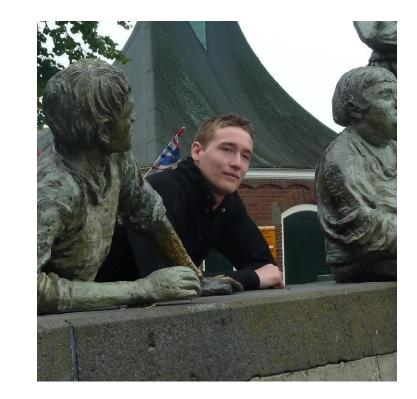




# DR. PETRA ISENBERG petra.lsenberg@inria.fr

**OFFICE** – Digiteo Moulon Building

**OFFICE HOURS** – By appointment





# YOU! QUICK INTROS

Any particular interests?

# **COURSE INFO**



## Class website: See Slack channel – everyone will get an invite

## **GRADING SCHEME**

- Assignments: 66%
  - check the website for due dates of assignments and how to submit them
  - Slack participation
- Exam: 33%

# READINGS

# mostly for additional interest

# will announce readings on a per-lecture basis

# **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

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> 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

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



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







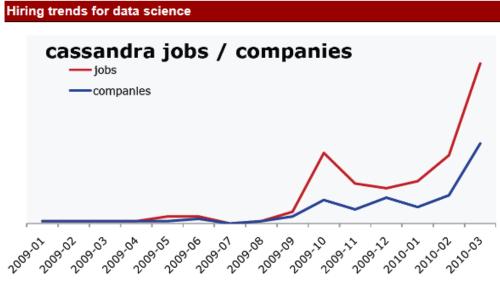


## AFTER TODAY YOU WILL...

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

# **INFORMATION VISUALIZATION**

Why



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

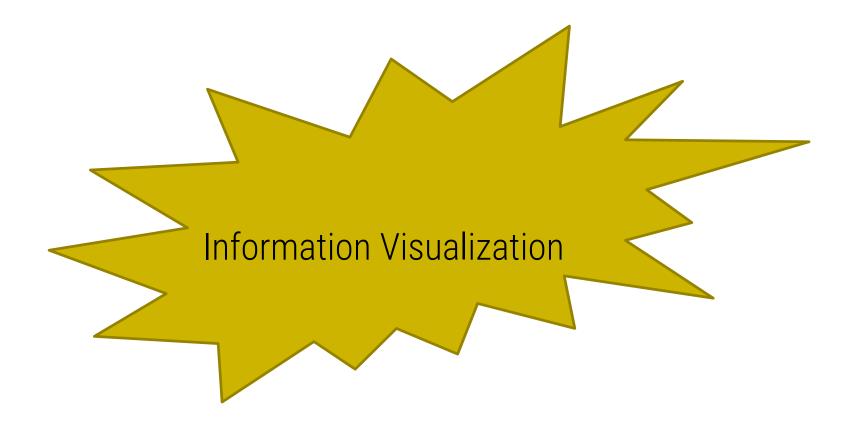
#### QUESTION

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		
х	у	х	у	Х	у	Х	у	
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

#### STATISTICAL ANALYSIS

#### For all four columns, the statistics are identical

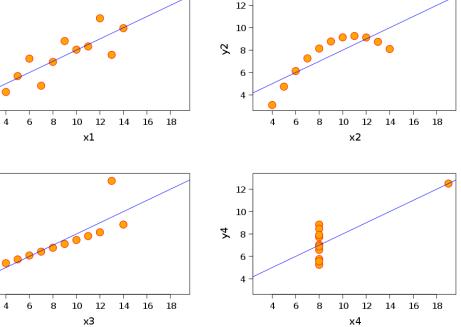
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8.0	6.95	8.0 8.14		8.0 6.77		8.0	5.76	
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71	
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84	
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47	
14.0	9.96	14.0 8.10		14.0 8.84		8.0	7.04	
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25	
4.0	4.26	4.0	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	

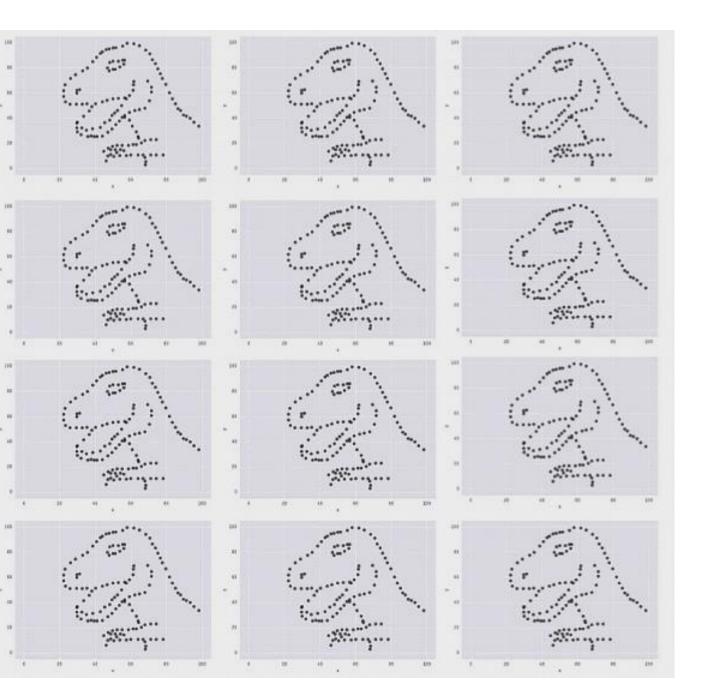
Mean of <i>x</i>	9.0
Variance of <i>x</i>	11.0
Mean of y	7.5
Variance of <i>y</i>	4.12
Correlation between x and y	0.816
Linear regression line	<i>y</i> = 3 + 0.5 <i>x</i>

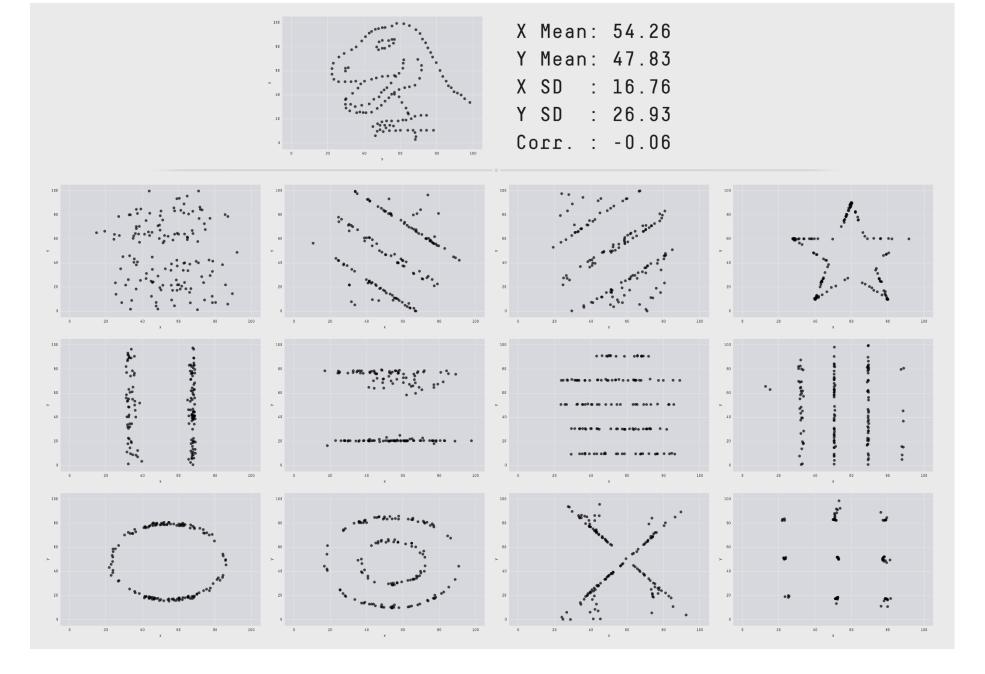
#### **VISUAL REPRESENTATION OF THE DATA**

#### Visual representation reveals a different story

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	4 -	5.76	8.0	6.77	8.0	8.14	8.0	6.95	8.0
	4	7.71	8.0	12.74	13.0	8.74	13.0	7.58	13.0
4 6 8 10		8.84	8.0	7.11	9.0	8.77	9.0	8.81	9.0
		8.47	8.0	7.81	11.0	9.26	11.0	8.33	11.0
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-	12 -	5.25	8.0	6.08	6.0	6.13	6.0	7.24	6.0
	10 -	12.50	19.0	5.39	4.0	3.10	4.0	4.26	4.0
	-8 X	5.56	8.0	8.15	12.0	9.13	12.0	10.84	12.0
	6 -	7.91	8.0	6.42	7.0	7.26	7.0	4.82	7.0
	4 -	6.89	8.0	5.73	5.0	4.74	5.0	5.68	5.0



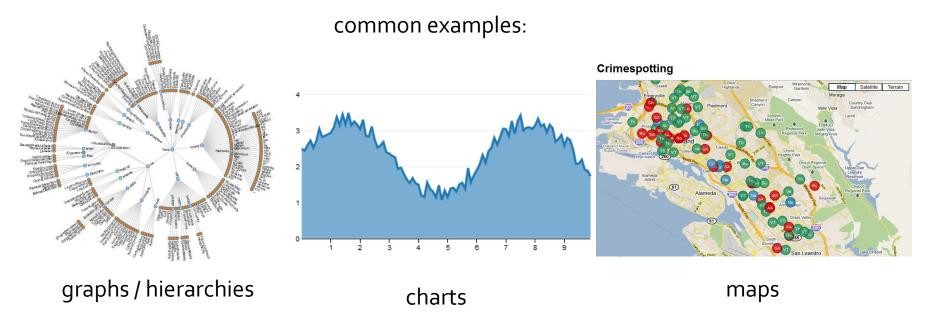




https://www.autodeskresearch.com/publications/samestats

### Why visual data representations?

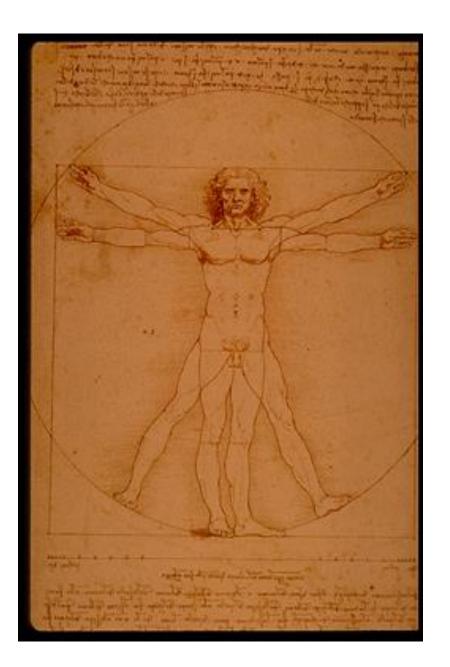
- Vision is our most dominant sense
- We are very good at recognizing visual patterns
- We need to see and understand in order to explain, reason, and make decisions



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.

# 写開不如一見 "One hundred rumors are not comparable to one look." An Old Chinese Inscription

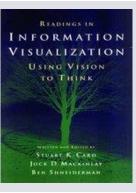
Via Brinton, Graphic Presentation, 1939

### 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...

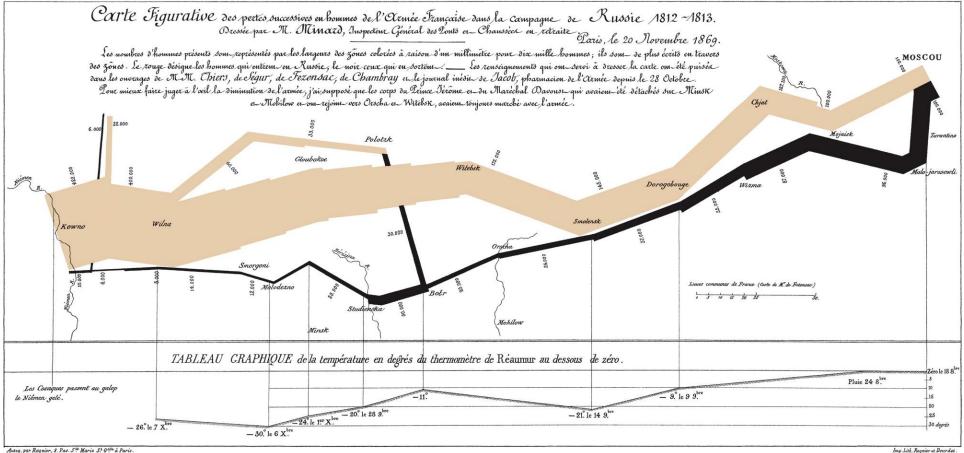
#### **HISTORICAL EXAMPLES**

## 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 \_

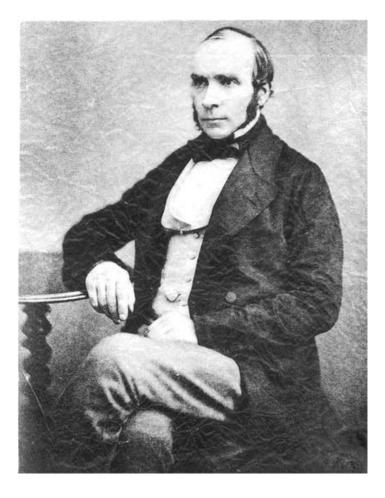


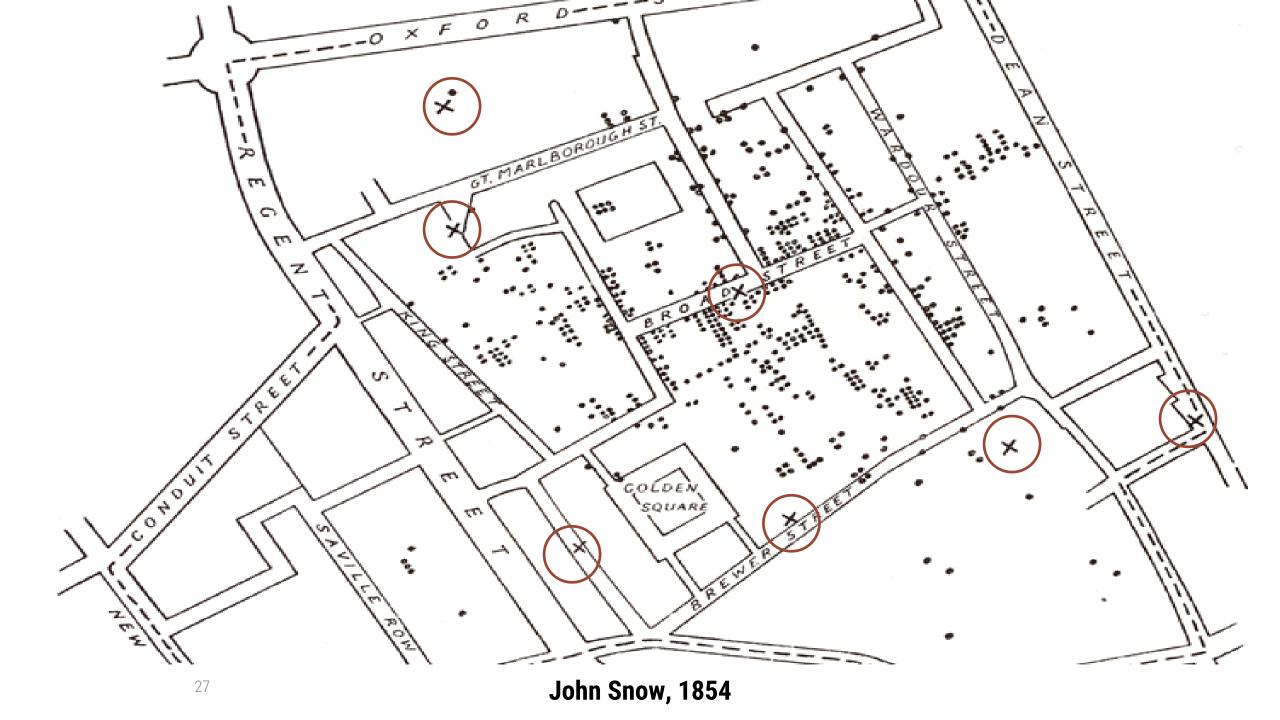
Autog. par Regnier, 8. Pas. Ste Marie St Gain à Paris.

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

### **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





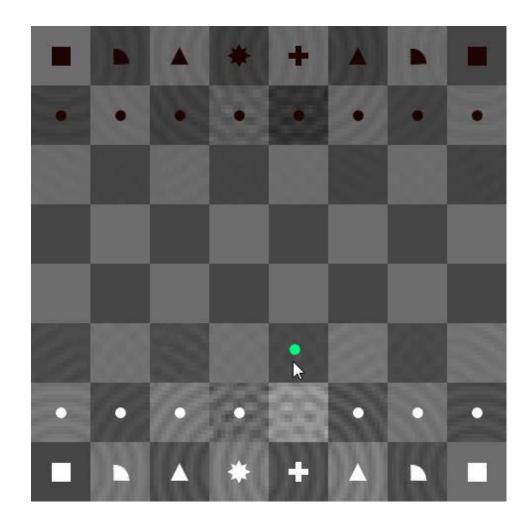
#### **... AND MORE RECENTLY**

#### TrashTrack



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

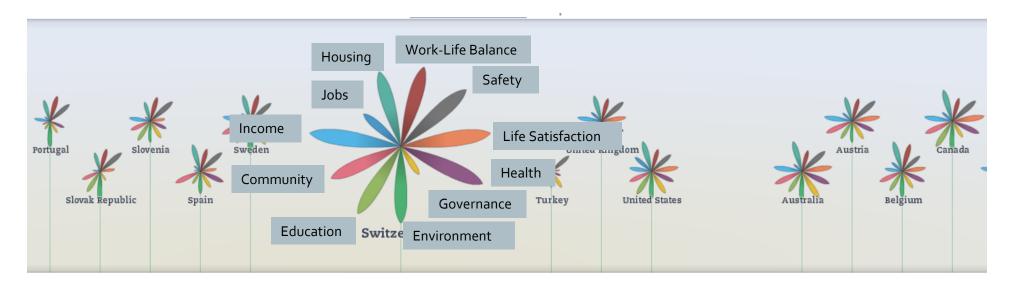
### **Artificial Intelligence**



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



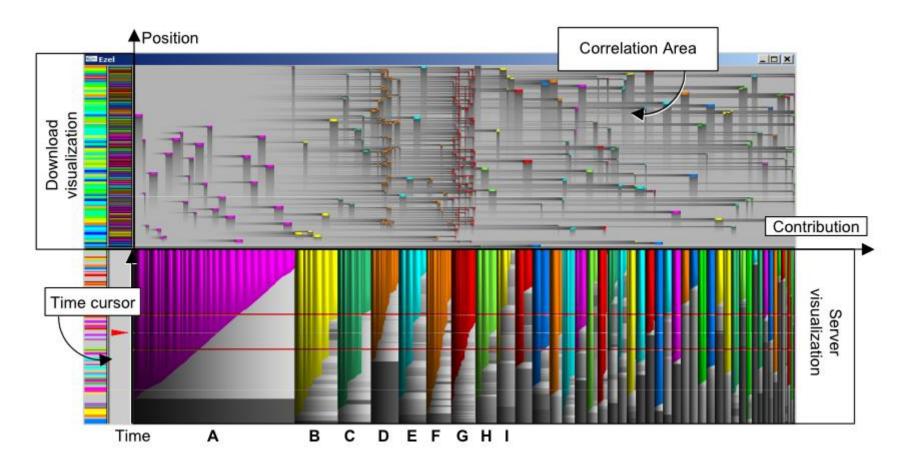
Tabletops for Visualization University of Calgary



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)

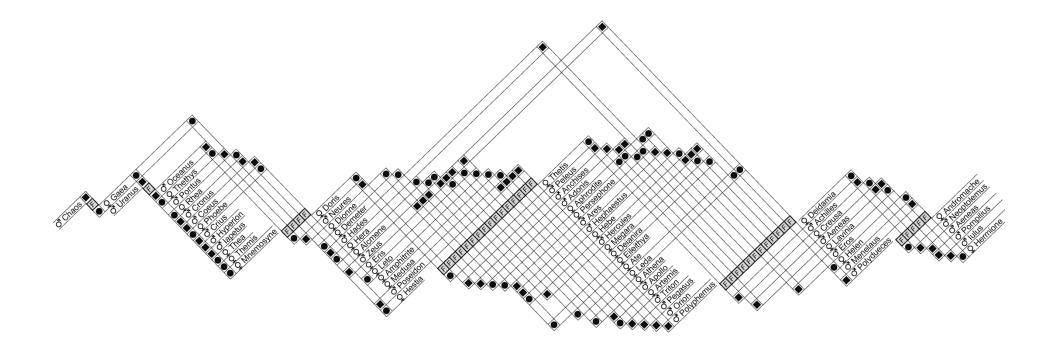
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### Graphs

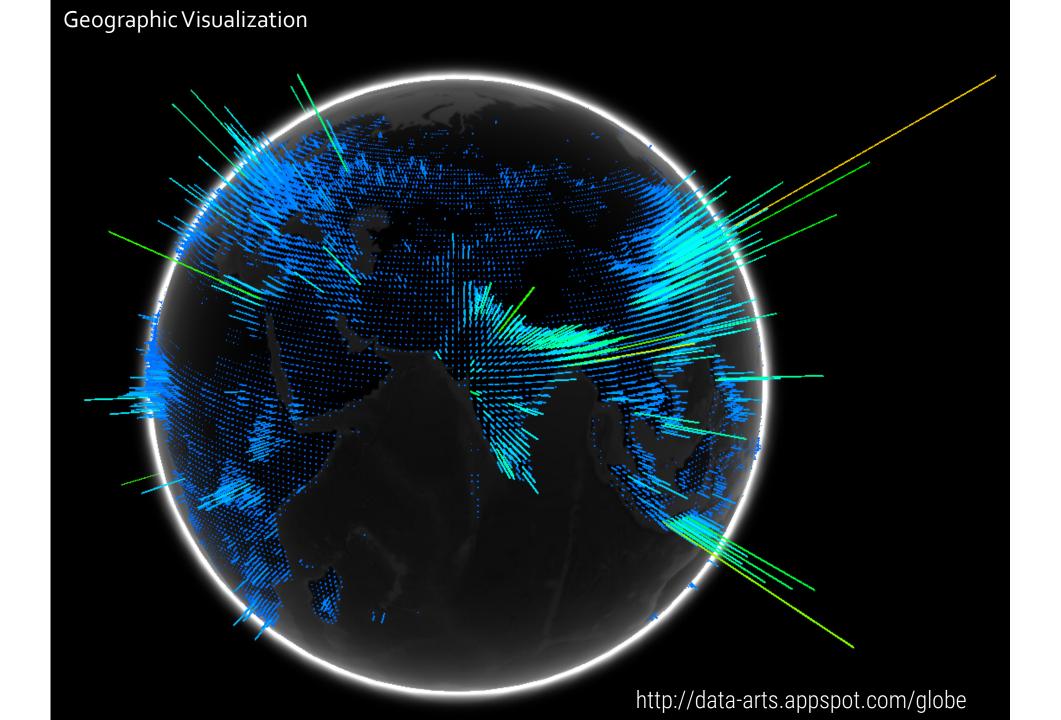


<u>http://www.facebook.com/note.php?note\_id=469716398919</u> Visualizing Friendships by <u>Paul Butler</u> on Tuesday, December 14, 2010

### Family Trees



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

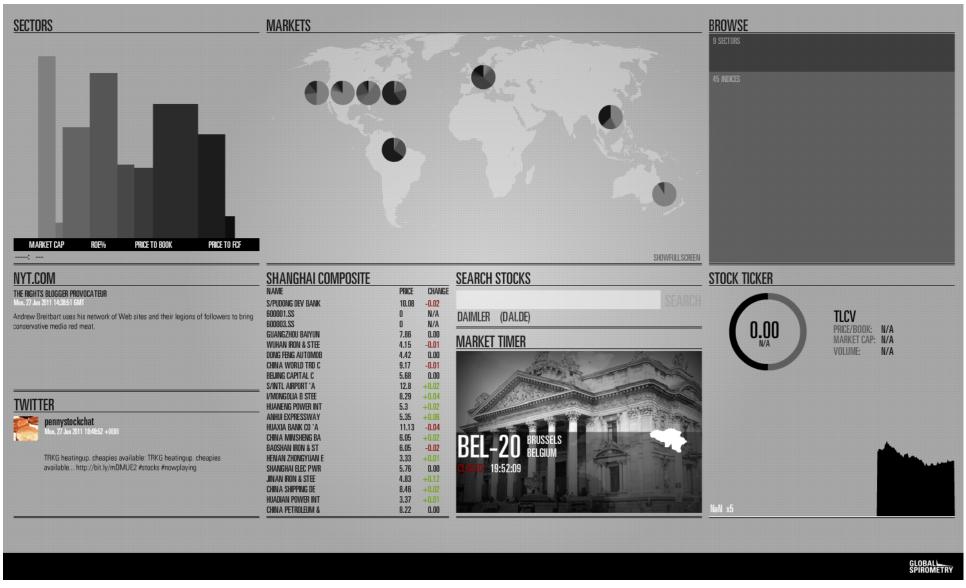


#### Weather



http://weatherspark.com/

#### Data Dashboards



http://globalspirometry.com

## **Resources for more examples**

- Visualization conferences
- Blogs
  - <u>http://infosthetics.com/</u>
  - <u>http://fellinlovewithdata.com/</u>
  - <u>http://eagereyes.org/</u>
  - <u>http://flowingdata.com/</u>
  - <u>http://www.informationisbeautiful.net/</u>
- 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





#### 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



#### 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

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

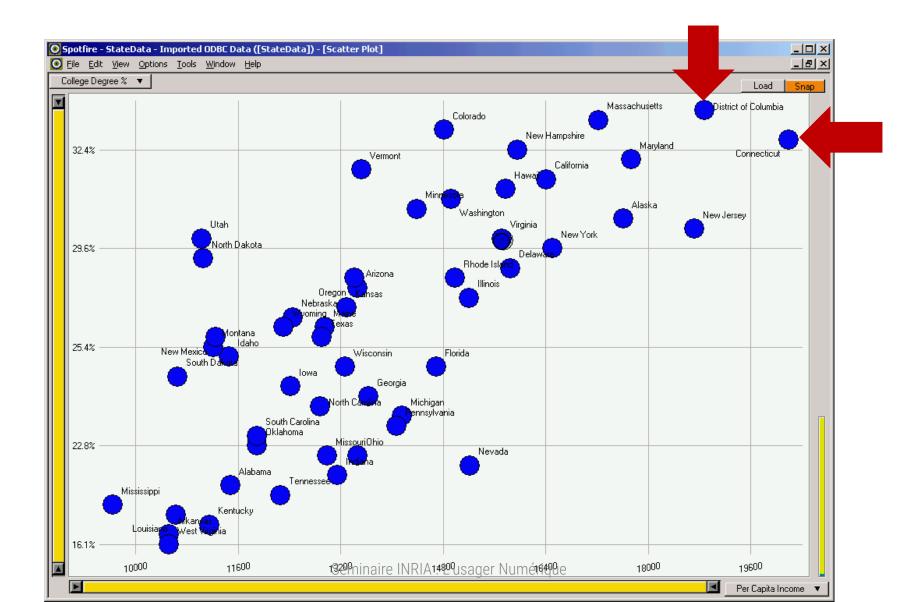
## Or a bit more simply...

- 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?**

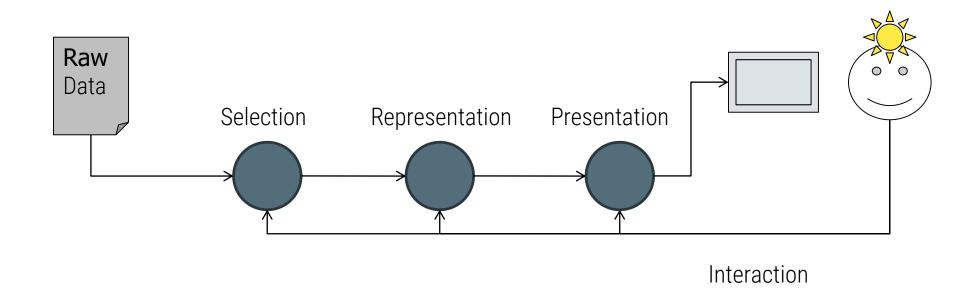
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		Load Snap		Minnesota	30.4%	14389
State	College Degree %	Per Capita Income		Mississippi	19.9%	9648
Alabama	20.6%	11486		Missouri	22.3%	12989
Alaska	30.3%	17610		Montana	25.4%	11213
	27.1%	13461		Nebraska	26.0%	12452
Arizona				Nevada	21.5%	15214
Arkansas	17.0%	10520		New Hampshire	32.4%	15959
California	31.3%	16409		New Jersey	30.1%	18714
Colorado	33.9%	14821		New Mexico	25.5%	11246
Connecticut	33.8%	20189		New York	29.6%	16501
Delaware	27.9%	15854		North Carolina	24.2%	12885
District of Columbia 🤇	36.4%	18881		North Dakota	28.1%	11051
Florida	24.9%	14698		Ohio	22.3%	13461
Georgia	24.3%	13631		Oklahoma	22.8%	11893
Hawaii	31.2%	15770		Oregon	27.5%	13418
				Pennsylvania Dhada laland	23.2%	14068
Idaho	25.2%	11457	-	Rhode Island	27.5%	14981
Illinois	26.8%	15201	$\vdash$	South Carolina South Dakota	23.0%	<u>11897</u> 10661
Indiana	20.9%	13149	-		20.1%	12255
lowa	24.5%	12422		Tennessee Texas	25.5%	12255
Kansas	26.5%	13300		Utah	30.0%	11029
Kentucky	17.7%	11153		Vermont	31.5%	13527
Louisiana	19.4%	10635		Virginia	30.0%	15713
Maine	25.7%	12957	F	Washington	30.9%	14923
Maryland	31.7%	17730		West Virginia	16.1%	10520
Massachusetts	34.5%	17224		Wisconsin	24.9%	13276
Michigan	24.1%	14154		Wyoming	25.7%	12311
Minnesota	30.4%	14389	•			

#### **Good representation!**



49

#### How do we arrive at a visualization?

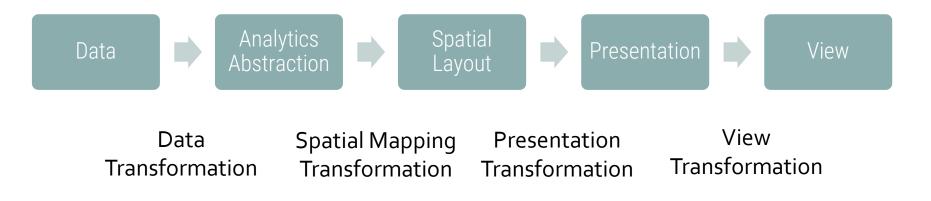


#### The Visualization Pipeline

From [Spence, 2000]

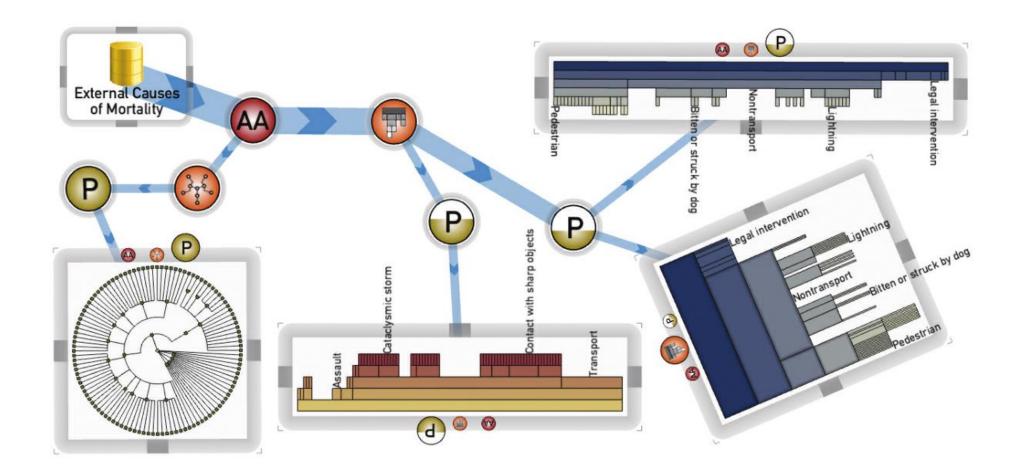
#### **Visualization Reference Model**

Also a visualization pipeline a bit expanded



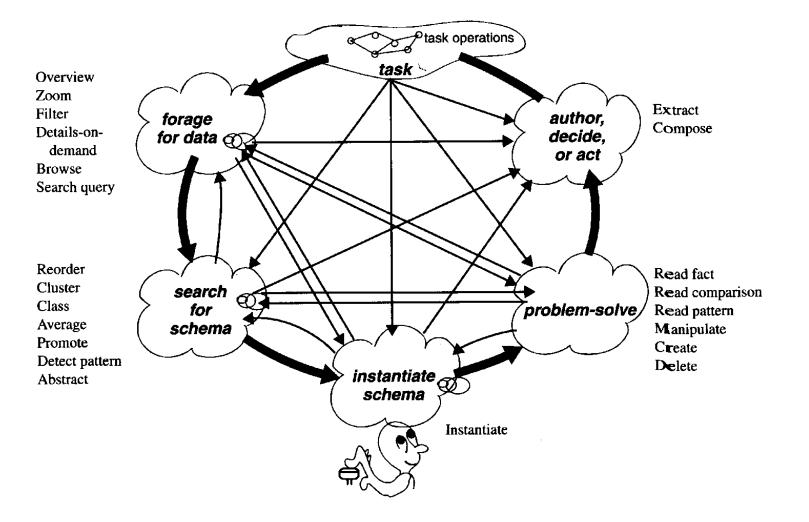
From [Card et al., Readings in Information Visualization]

#### 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

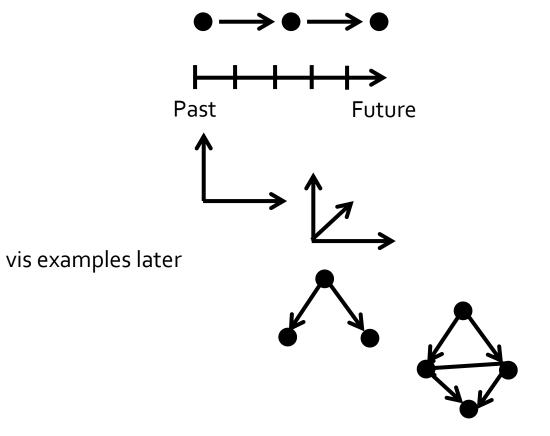
- Data is the foundation of any visualization
- The visualization designer needs to understand
  - the data properties
  - know what meta-data is available
  - know what people want from the data

## 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

# Data-Type Taxonomy

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



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)

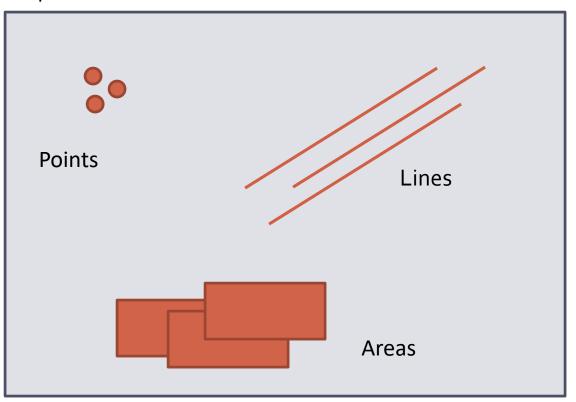
• But:

...

- 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)

The following slides on the topic adapted from Sheelagh Carpendale

#### **Points**

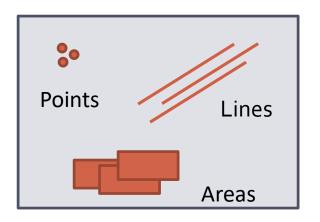
- "A point represents a location on the plane that has no theoretical length or area. This signification is independent of the size and character of the mark which renders it visible."
- Points Lines Areas

- a location
- marks that indicate points can vary in all visual variables

#### Lines

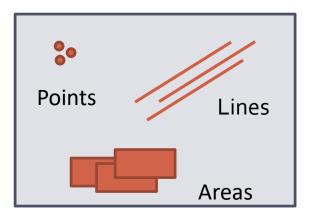
 "A line signifies a phenomenon on the plane which has measurable length but no area. This signification is independent of the width and characteristics of the mark which renders it visible."



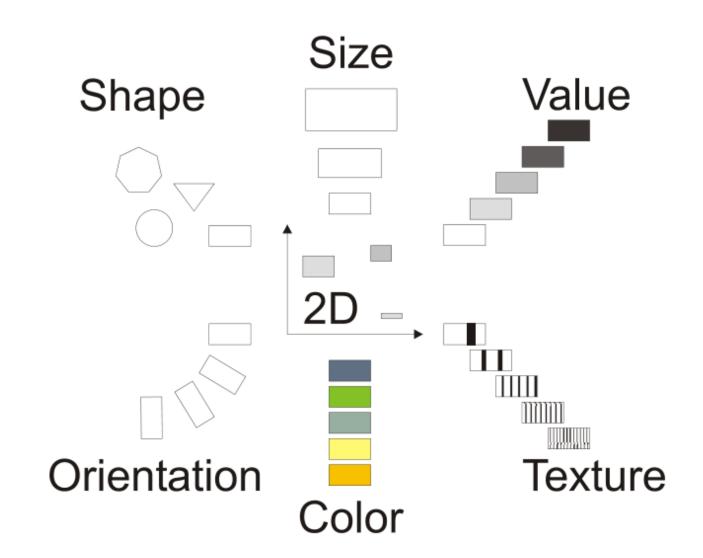


#### Areas

- "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



#### **Visual Variables Applicable to Marks**



From Semiology of Graphics (Bertin)

#### saturation

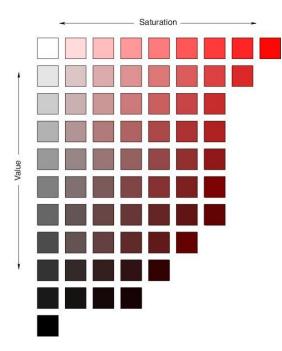
 colour as Bertin uses largely refers to hue, saturation != value

#### Extending those from Semiology of Graphics (Bertin)

#### **Additional Variables for Computers**

## motion

 direction, acceleration, speed, frequency, onset, 'personality'





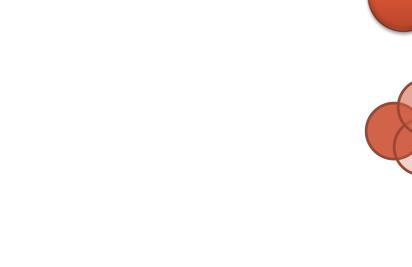
## **Additional Variables for Computers**

- flicker
  - frequency, rhythm, appearance

From Semiology of Graphics (Bertin)

- depth? 'quasi' 3D
  - depth, occlusion, aerial perspective, binocular disparity
- Illumination

• transparency



#### **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?

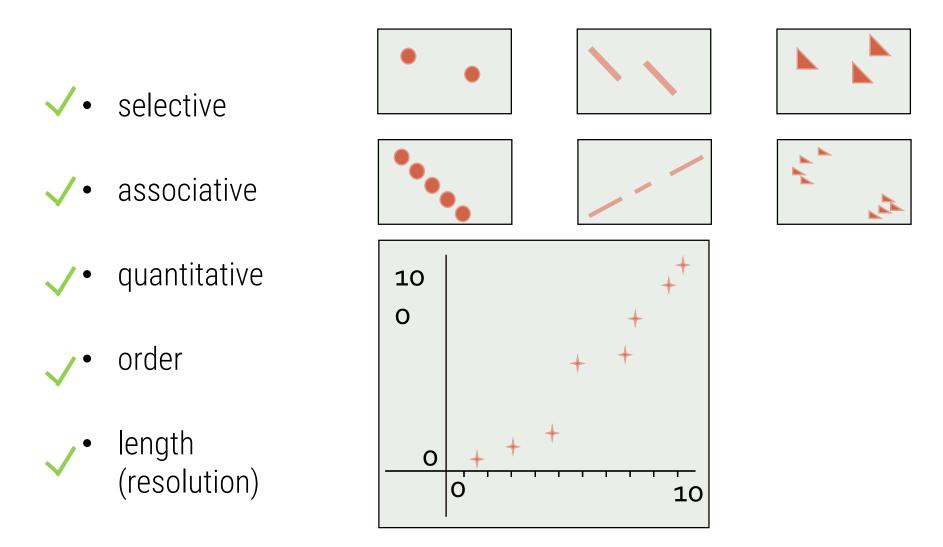
• Quantitative:

Can the difference between two marks in this variable be interpreted numerically ?

• Length (resolution):

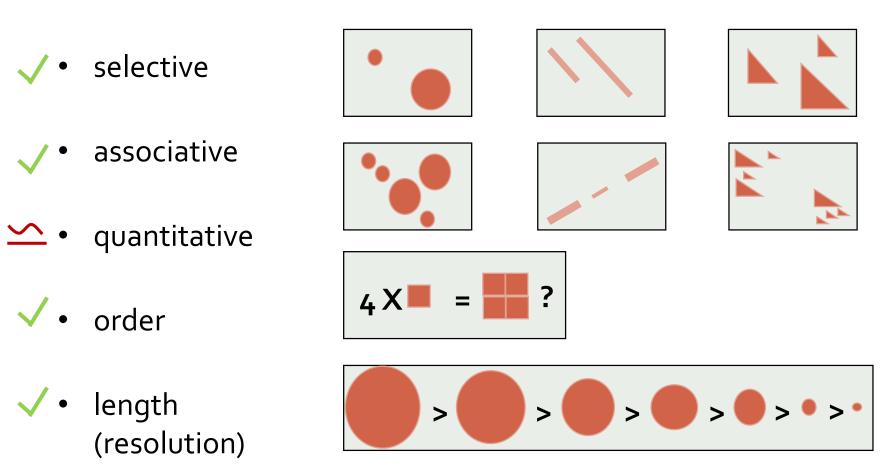
Across how many changes in this variable are distinctions possible?

#### **Visual Variable: Position**



From Semiology of Graphics (Bertin)

#### Visual Variable: Size



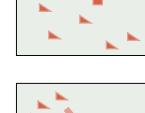
Size



points lines areas

#### Visual Variable: Shape

- $\sim$  selective
- ∽ associative



≠• ordered



- ✓ quantitative
- length (resolution)

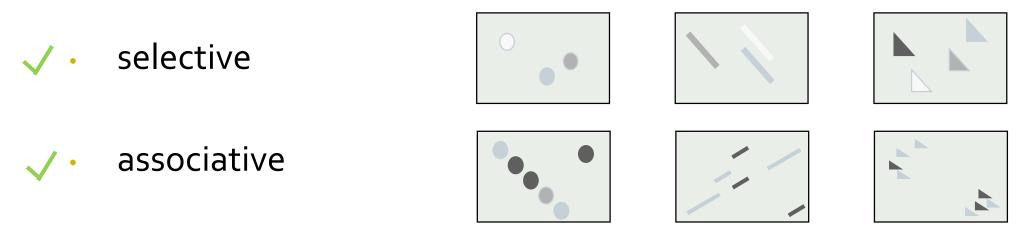


## Shape



points lines areas

# Visual Variable: Value



 $\neq$  · quantitative



#### length (resolution)

- theoretically infinite but practically limited
- association and selection ~ < 7 and distinction ~ 10</li>

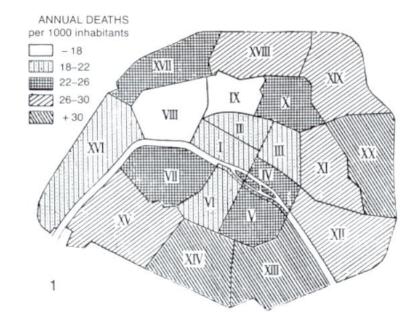
# Value



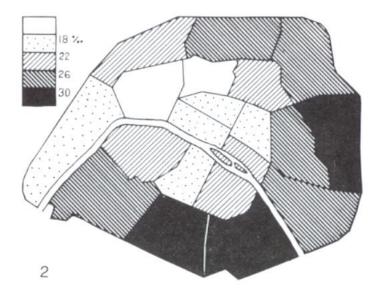
points lines areas

### Value

## ordered, cannot be reordered



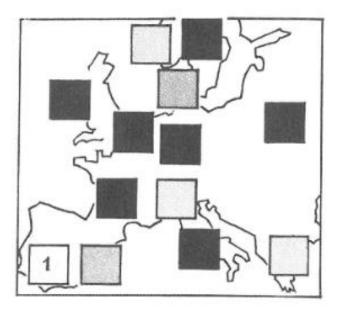
Values not ordered correctly according to scale Information has to be read point by point



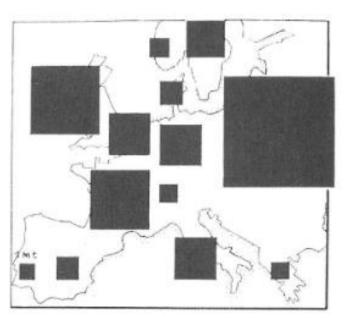
Values ordered correctly Image much more useful



### is not quantitative

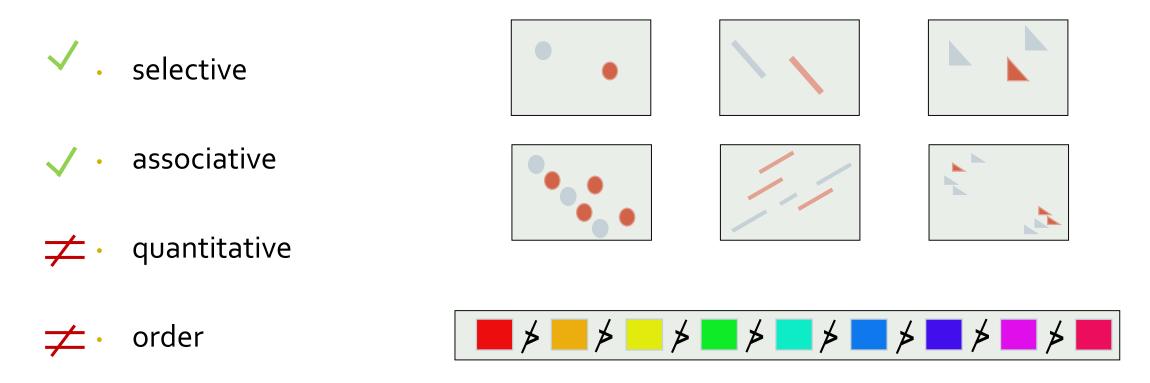


if Portugal is 1, what is France? you need a legend!



if Portugal is 1, what is France? still hard, but doable

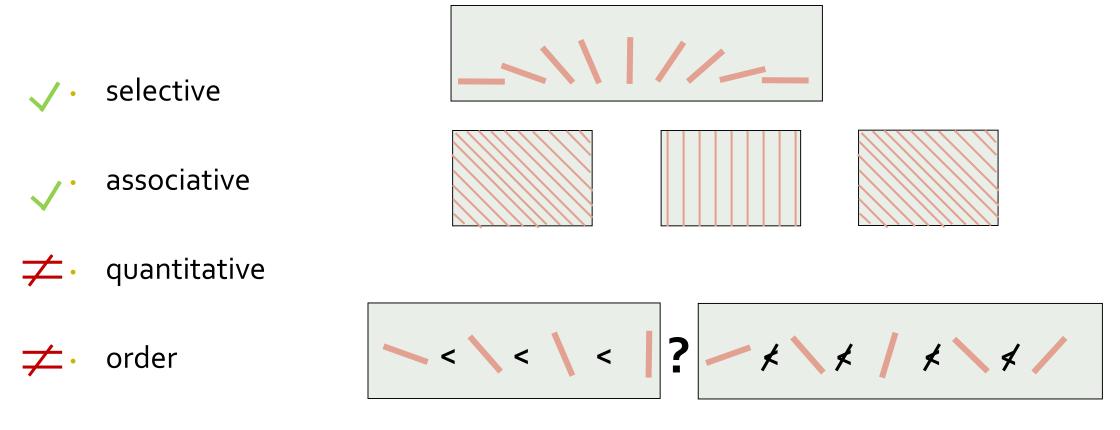
# **Visual Variable: Colour**





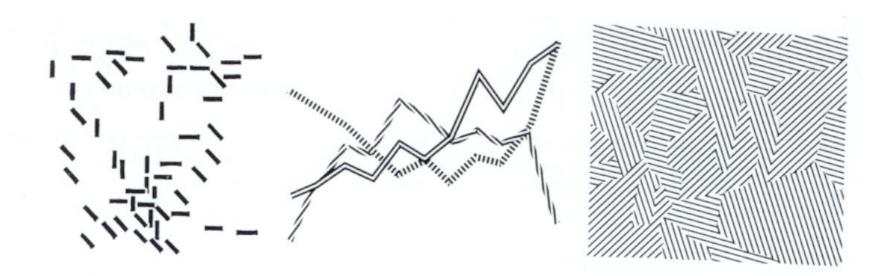
- length (resolution)
  - theoretically infinite but practically limited
  - association and selection ~ < 7 and distinction ~ 10</li>

### **Visual Variable: Orientation**



- length (resolution)
  - ~5 in 2D; ? in 3D

#### Orientation



points

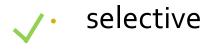
lines

areas

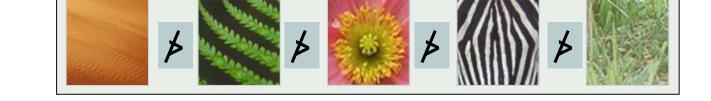
### **Visual Variable: Texture**





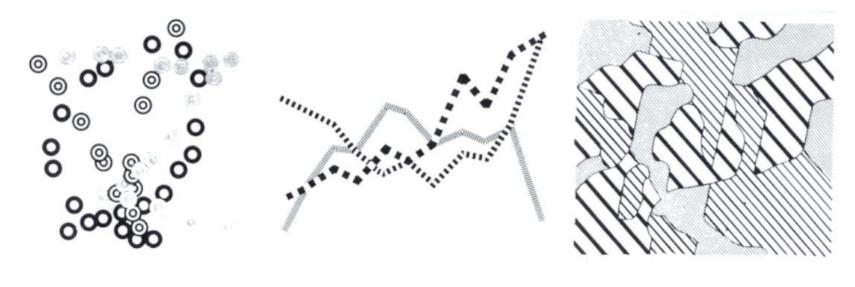


- associative
- ✓ quantitative
- **≠** order



- length(resolution)
  - theoretically infinite

#### Texture

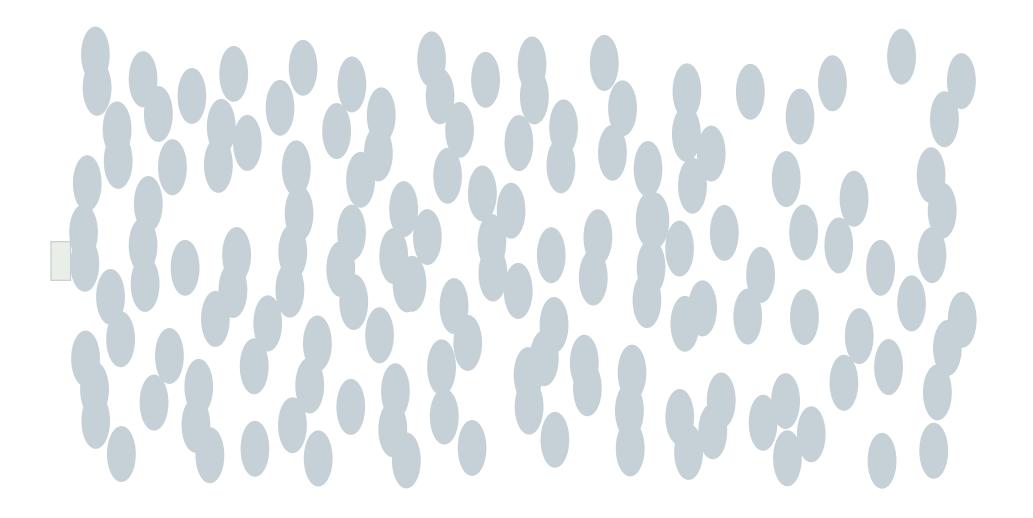


points lines areas

# **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?





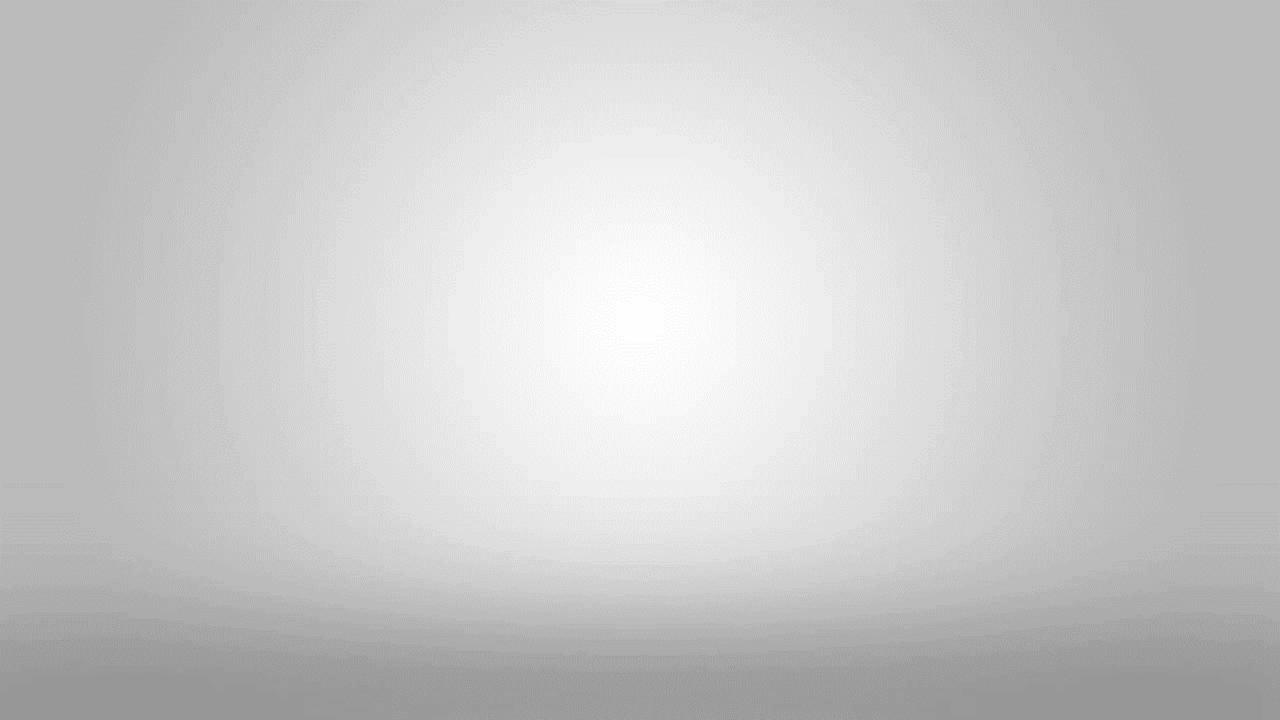
# **Visual Variables**

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	

# Summary

	Quantita		Ordinal		Nominal	
More Accurate	Position	•.•	Position	•.•	Position	•.•
1	Length	=	Density		Hue	•••
	Angle	4	Saturation		Density	
	Slope	1-	Hue		Saturation	
	Area	••	Length	=	Shape	
	Density		Angle	2	Length	=
	Saturation		Slope	11	Angle	4
↓ ↓	Hue	•••	Area	••	Slope	1-
Less Accurate	Shape		Shape		Area	
	10 S.C.					

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