VISUAL ANALYTICS INTRODUCTION

LECTURE 1

Petra Isenberg

informatics mathematics
Inria

INSTRUCTOR

DR. PETRA ISENBERG

petra.isenberg@inria.fr

+

OFFICE — Digiteo Moulon Building

OFFICE HOURS — By appointment

YOU!

QUICK INTROS

Any particular interests?

YOU!

http://bit.ly/vaclass_survey

The Economist

A special report on managing information | February 27th 2010

Special Report | Data, data everywhere

Information has gone from scarce to superabundant. That brings huge new benefits, says Kenneth Cukier (interviewed here)—but also big headaches

Image by Jihyun Ham

JUST A FEW YEARS AGO

- YouTube users upload 300 hours of new video every minute of the day http://expandedramblings.com/index.php/youtube-statistics/
- Facebook has currently on average 1.04 billion active users daily http://newsroom.fb.com/company-info/
- the Library of Congress adds 12,000 items to their collection every day http://www.loc.gov/about/fascinating-facts/

WHAT IS USEFUL?

data != useful information

→ analysis is needed

ANALYSIS IS NOT SIMPLE


Gary King, Harvard

research project: predict U.S. unemployment rate

method: Twitter & social media analysis
→ sentiment analysis by word count

unemployment

jobs

classifieds

Look for counts of those words & correlate to monthly unemployment rate

http://www.infoworld.com/article/2611729/big-data/big-data-without-good-analytics-can-lead-to-bad-decisions.html

ANALYSIS IS NOT SIMPLE

spike in people looking for jobs?

lots of people going to get laid off?

HUMAN-IN-THE LOOP

- it is sometimes dangerous to rely on purely automated analyses
- human judgment and intervention often needed
  - for: background information, flexible analysis (unintended directions), creativity
  - because: data can be incomplete, inconsistent, or deceptive

COURSE OBJECTIVES

learn about data, its properties, and its problems

practical data analysis

LOTS OF ANALYSIS PRACTICE WITH REAL DATA

DATA ANALYSIS HAS BEEN AROUND FOR A WHILE

1935: "The Design of Experiments"

R.A. Fisher

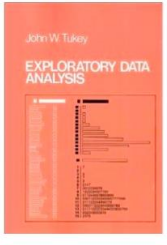
1939: "Quality Control"

W.E. Demming

1958: "A Business Intelligence System"

Peter Luhn

1977: "Exploratory Data Analysis"

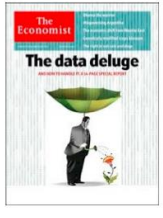


1989: "Business Intelligence"

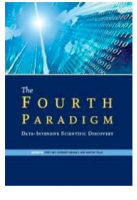
Howard Dresner

1997: "Machine Learning"

2010:"The Data Deluge"



2007:"The Fourth Paradigm"



2009:"The Unreasonable Effectiveness of Data"

1996: Google

Google

Abridged Version of Jeff Hammerbacher's timeline for Berkeley CS 194, 2012

WHAT'S DIFFERENT NOW?

More (accessible) data

Better tools!

More opportunities

“CRITICAL THINKING WITH DATA”

(And building competency actually doing data analysis.)

COURSE INFO

Part 1: Basic VA	Part 2: More advanced VA	Project
September / October	November / December	

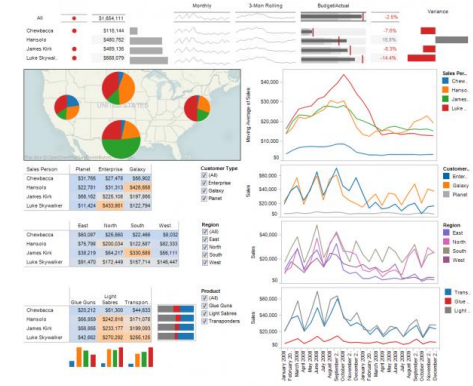
Class website:

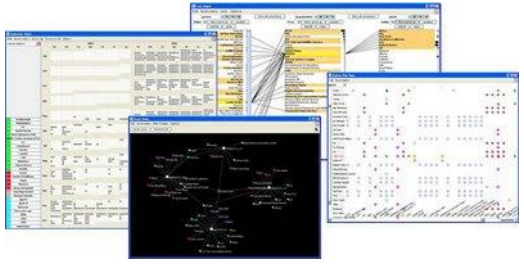
MS Teams – everyone should have gotten an invite

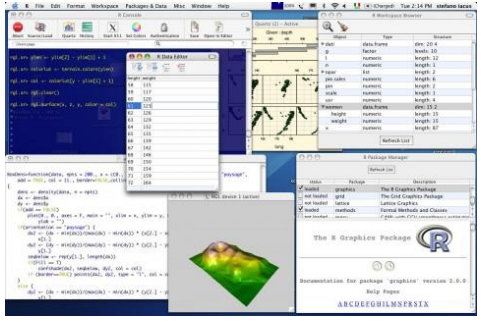
TUTORIALS

You will learn about:

- Data scraping
- Data cleaning
- Simple statistical analysis with R
- Making reports
- how to design visuals to answer questions about data







GRADING SCHEME

- Assignments: 50% (BDMA) or 100% (DS)
  - check the website for due dates of assignments and how to submit them
- Project: 50% (presentation + report) (BDMA)

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

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

QUESTIONS

WHAT IS VISUAL ANALYTICS

And where does it come from?

WHAT IS DATA ANALYSIS?

traditionally: data analysis = statistics

data analysis now covers a range of activities & skills

- defining your problem
- disassembling problems and data into analyzable pieces
- evaluate the data & draw conclusions
- make or recommend a decision

reference [3]

data analysis
=
careful thinking about evidence (data)

VISUAL ANALYTICS

Visual analytics combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex data sets [5].

CONFIRM VS. EXPLORE

confirmatory analysis

- start with a hypothesis about the data
- confirm that it is true

exploratory analysis

- likely no a-priori information about the data
- not sure about patterns and information present
- explore to create hypotheses & confirm later

focus of fully automated analysis methods

focus of visual analytics

SCOPE

visual analytics = an iterative process that involves

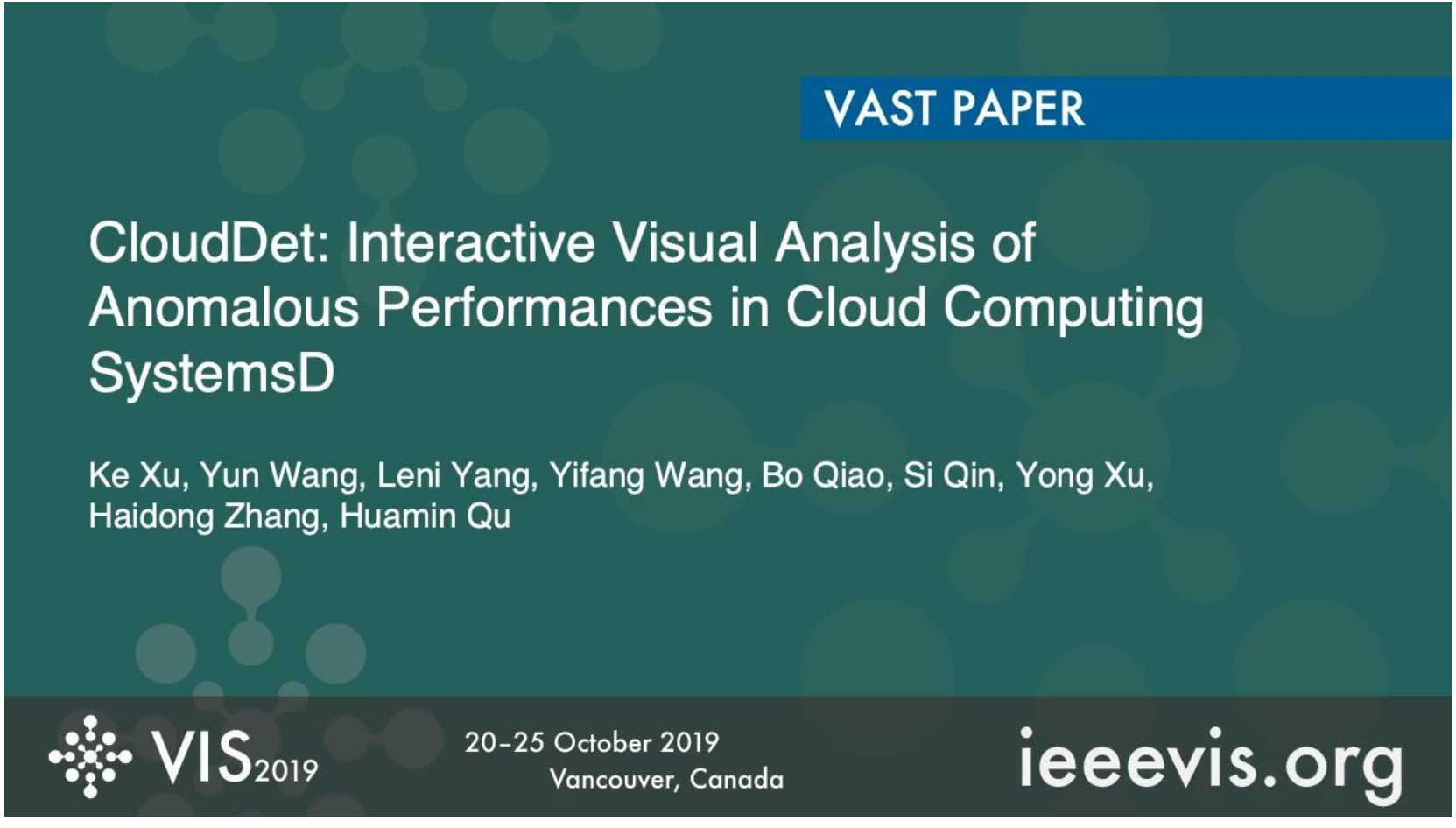
- information gathering
- data preprocessing
- knowledge representation
- interaction
- decision making

Reference [2]

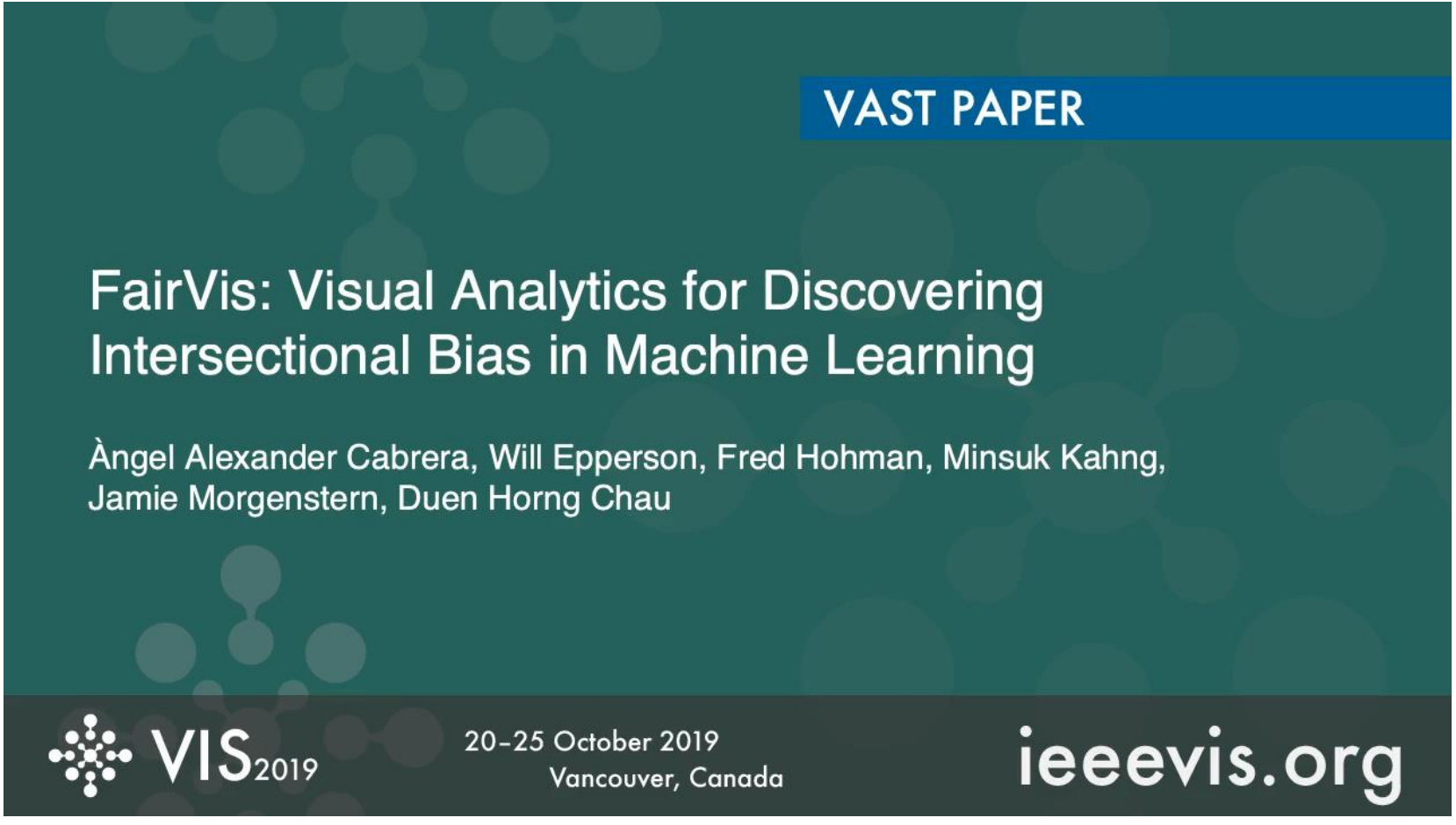
EXAMPLES

https://www.youtube.com/watch?v=K9PvskathGI

EXAMPLES


VAST PAPER
CloudDet: Interactive Visual Analysis of Anomalous Performances in Cloud Computing SystemsD
Ke Xu, Yun Wang, Leni Yang, Yifang Wang, Bo Qiao, Si Qin, Yong Xu, Haidong Zhang, Huamin Qu
VIS 2019
20-25 October 2019
Vancouver, Canada
ieeevis.org

EXAMPLES


VAST PAPER
FairVis: Visual Analytics for Discovering Intersectional Bias in Machine Learning
Àngel Alexander Cabrera, Will Epperson, Fred Hohman, Minsuk Kahng, Jamie Morgenstern, Duen Horng Chau
VIS2019
20–25 October 2019
Vancouver, Canada
ieeevis.org

EXAMPLES


SHORT PAPER
GalStamps: Analyzing Real and Simulated Galaxy Observations
Nina McCurdy, Miriah Meyer
VIS2019
20–25 October 2019
Vancouver, Canada
ieeevis.org

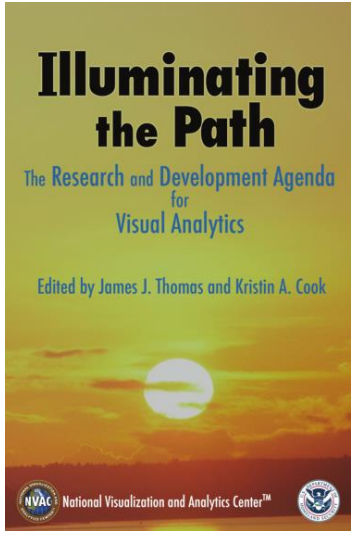
REQUIREMENTS

development & understanding of

- data transformations & analysis algorithms
- analytical reasoning techniques
- visual representations and interactions
- techniques for production, presentation, and dissemination

HISTORY

- outgrowth of the Scientific & Information Visualization community
- started with US National Visualization and Analytics Center (NVAC) at PNNL in 2004
- developed the first research and development agenda “Illuminating the Path”
- sponsored initially by DHS (US Department of Homeland Security)



ORIGINAL GOALS

- analyzing terrorist threats
- safeguarding boarders and ports
- preparing for and responding to emergencies

→ now only part of the larger research goals

HISTORY

- VAST symposium & conference
  - visual analytics, science, and technology
- part of the IEEE Visualization conference
- started Visual Analytics as its own research area in 2006

HISTORY

- 2008 EU funds VisMaster, a Coordination Action to join European academic and industrial R&D
- in Europe initial focus not on “homeland” security, rather broad applicability
  - physics, astronomy, climate monitoring, weather, etc.

FUTURE

The Sexiest Job of the 21st Century: Data Analyst

Chris Morris, Special to CNBC.com
Wednesday, 5 Jun 2013 | 1:00 PM ET

CNBC

Photo: Biddlboo | Getty Images

In tech jobs market, data analysis is tops

Jon Swartz, USA TODAY 10:20 a.m. EDT October 5, 2012

Second of five reports this week on the job outlook in key industries.

(Photo: Elaine Thompson, AP)

256 CONNECT | 215 TWEET | 47 LINKEDIN | 3 COMMENT | EMAIL | MORE

SAN FRANCISCO -- Like a coveted free agent in sports, Kelly Halfin had a multitude of choices when she decided to take a job in tech in the U.S.

The Belgian had five American companies lined up, eager to sign her on to lead their data analysis

http://www.cnbc.com/id/100792215#.

VISUALIZATION

Why focus on visual representation?

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

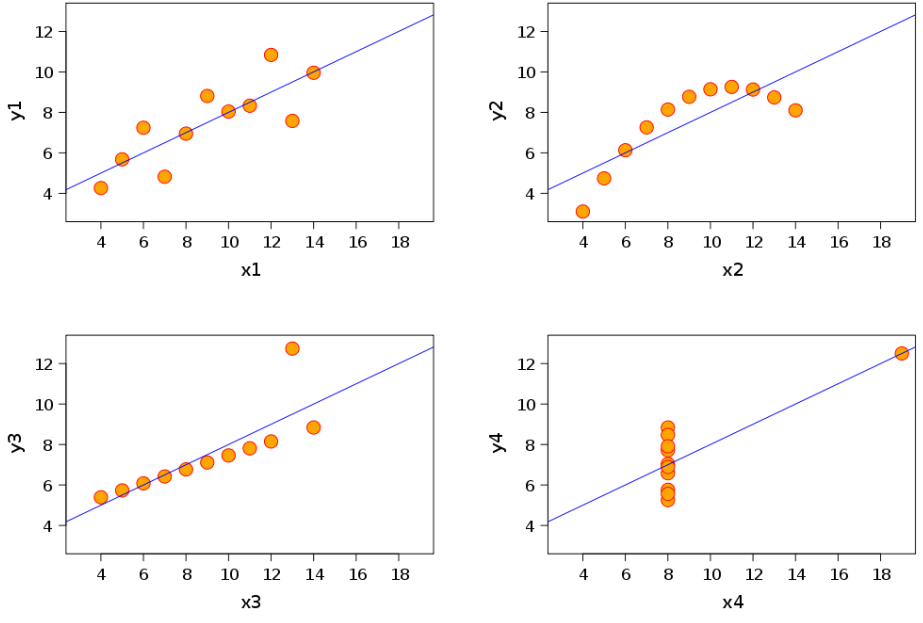
Mean of x	9.0
Variance of x	11.0
Mean of y	7.5
Variance of y	4.12
Correlation between x and y	0.816
Linear regression line	$y = 3 + 0.5x$

[Source: Anscombe's quartet, Wikipedia]

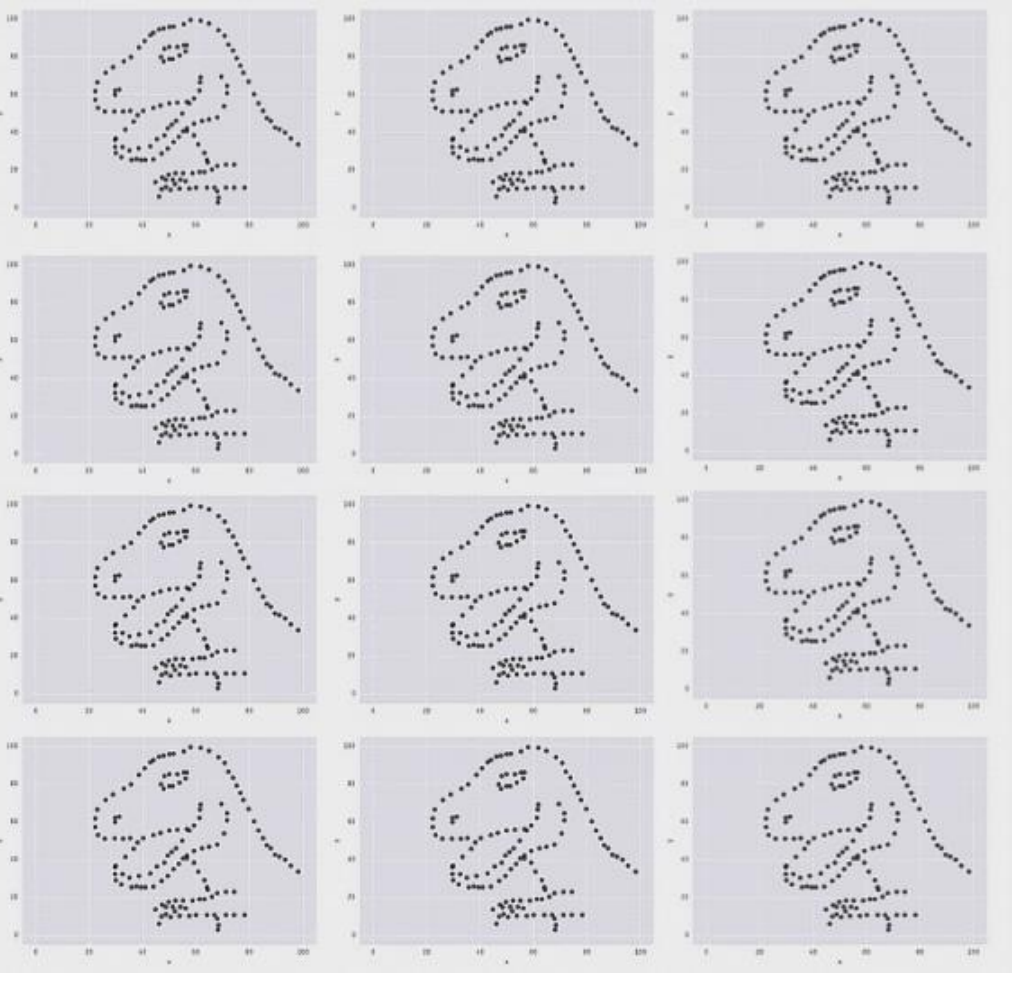
VISUAL REPRESENTATION

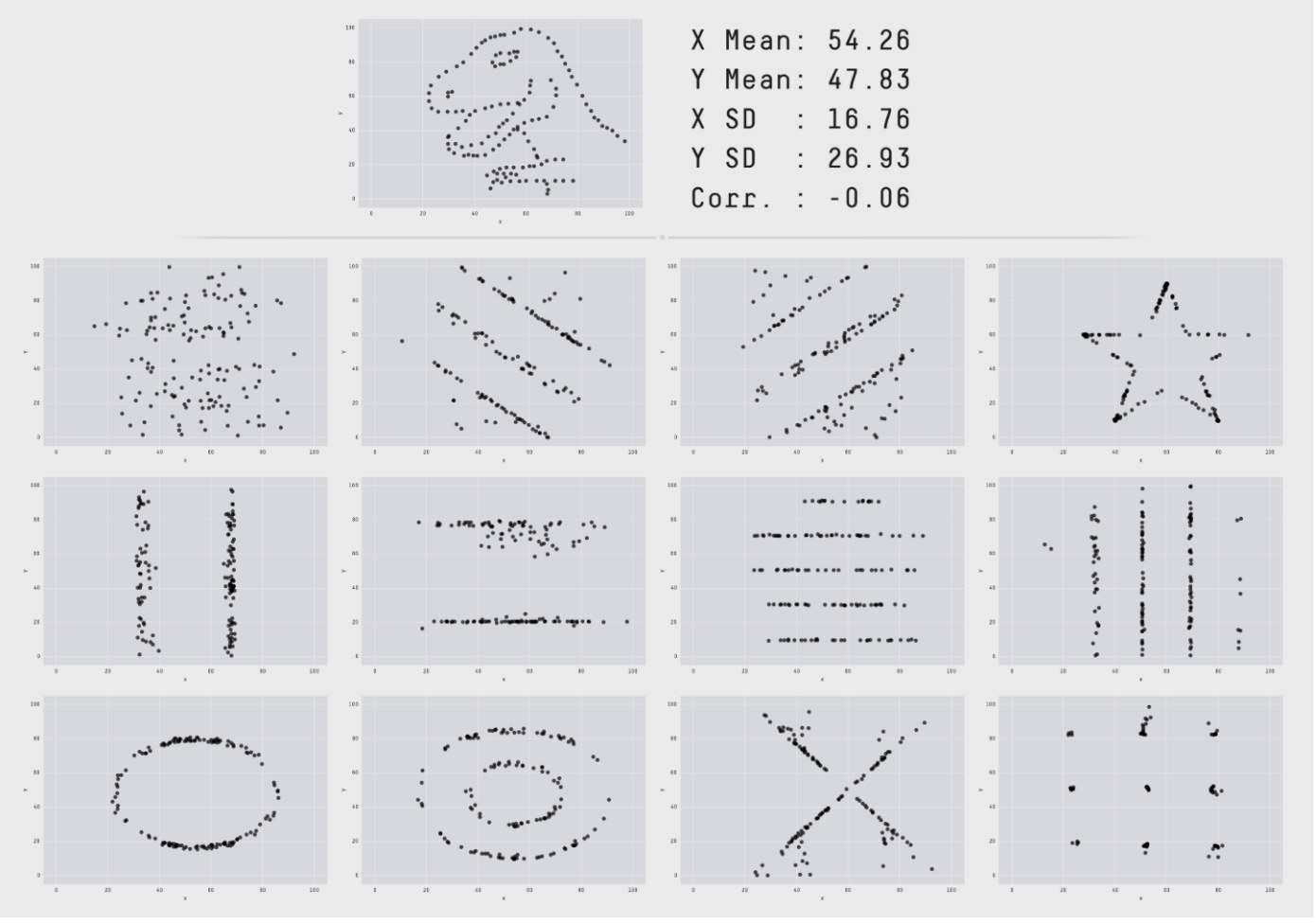
reveals a different story

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]



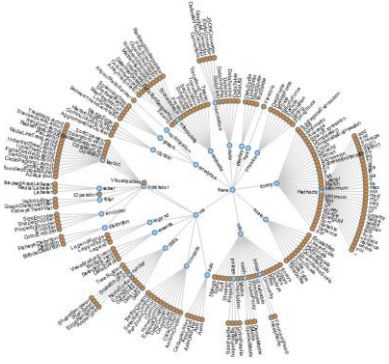


https://www.autodeskresearch.com/publications/samestats CHI-2017

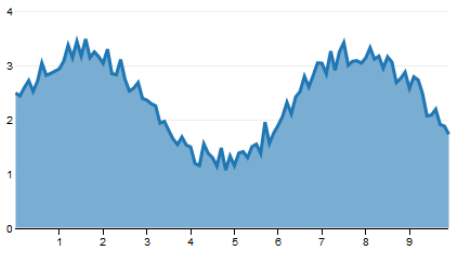
VISUALS ARE POWERFUL

- 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

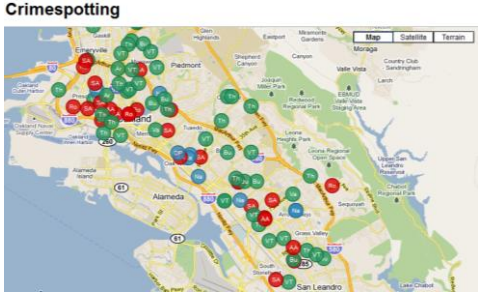
common examples:



graphs / hierarchies



charts



maps

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

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

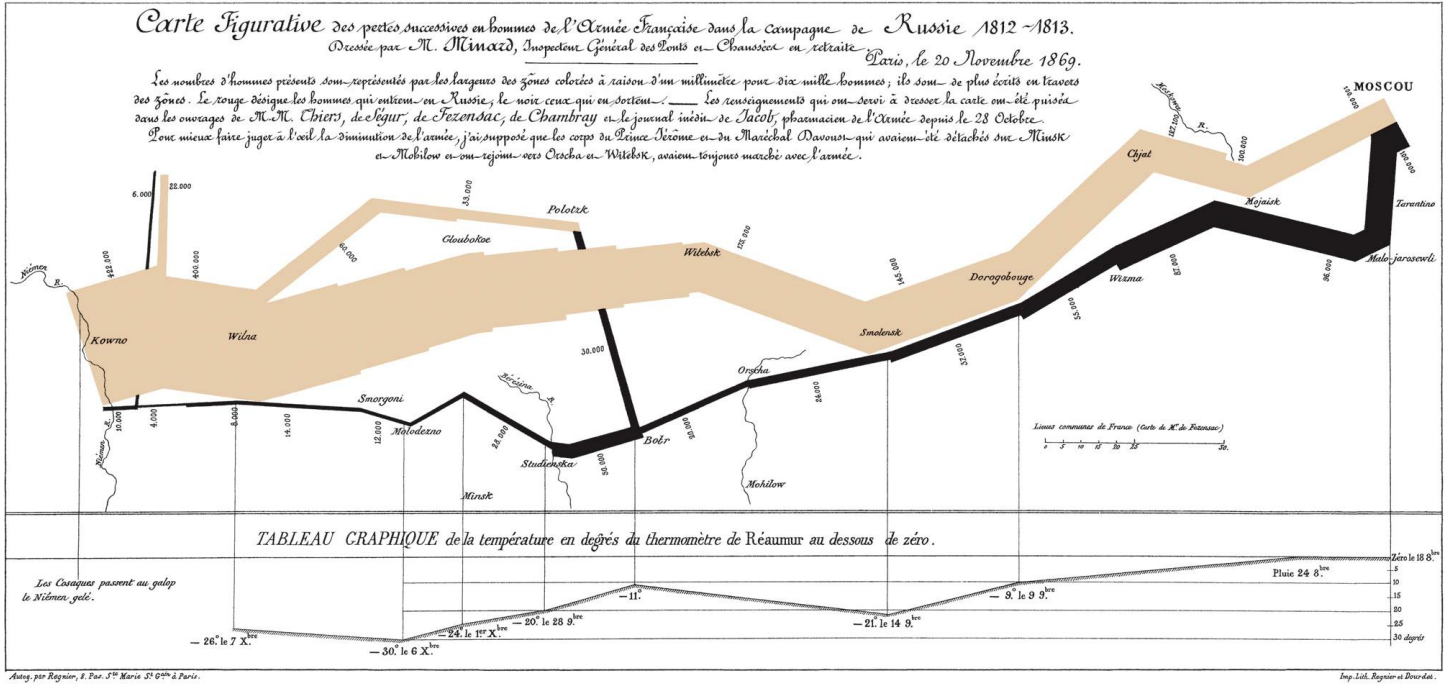
HISTORICAL EXAMPLES

Visualization of data has been practiced for hundreds of years...

NAPOLEON'S MARCH ON MOSCOW

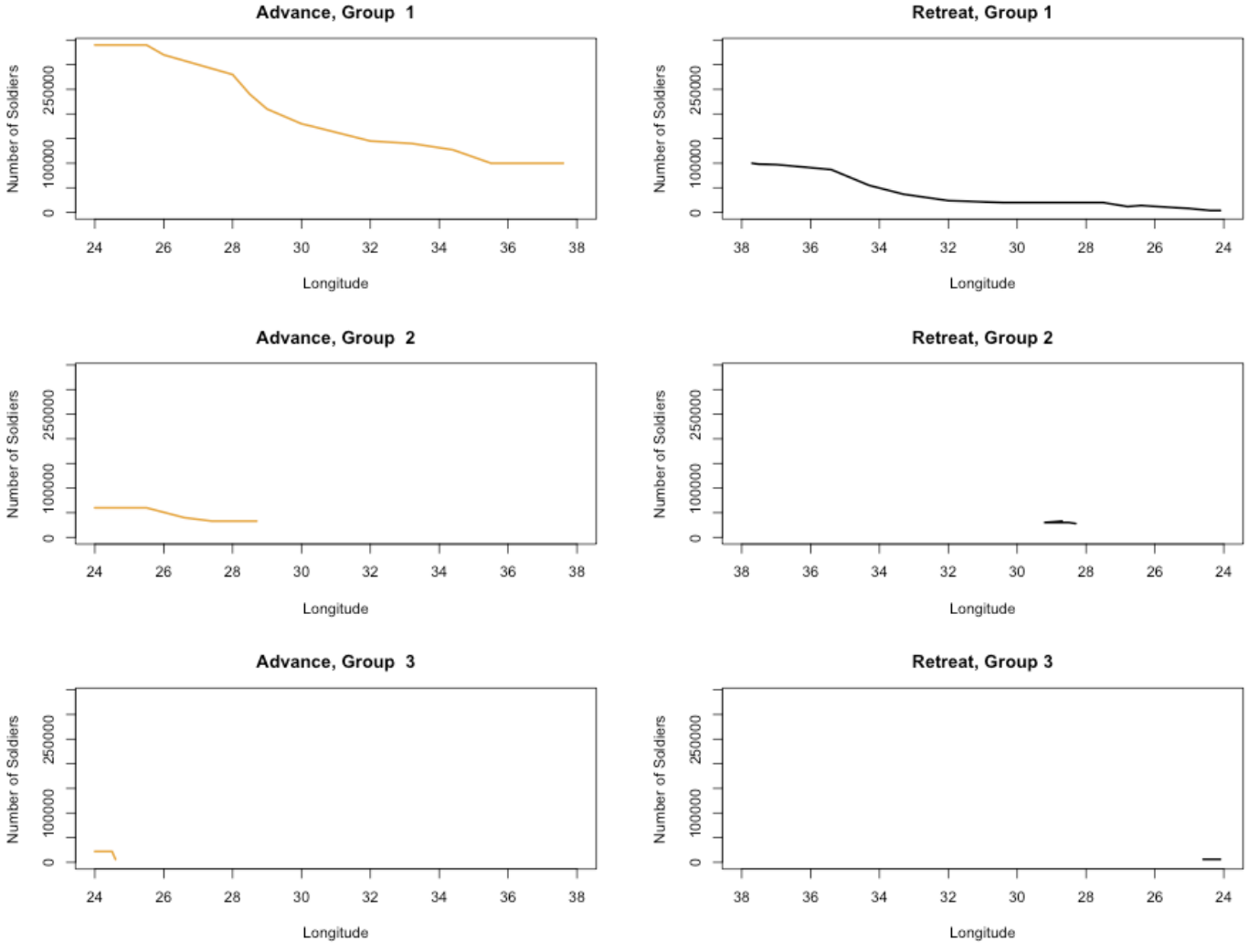
Named the best statistical graphic ever drawn (by Edward Tufte)

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

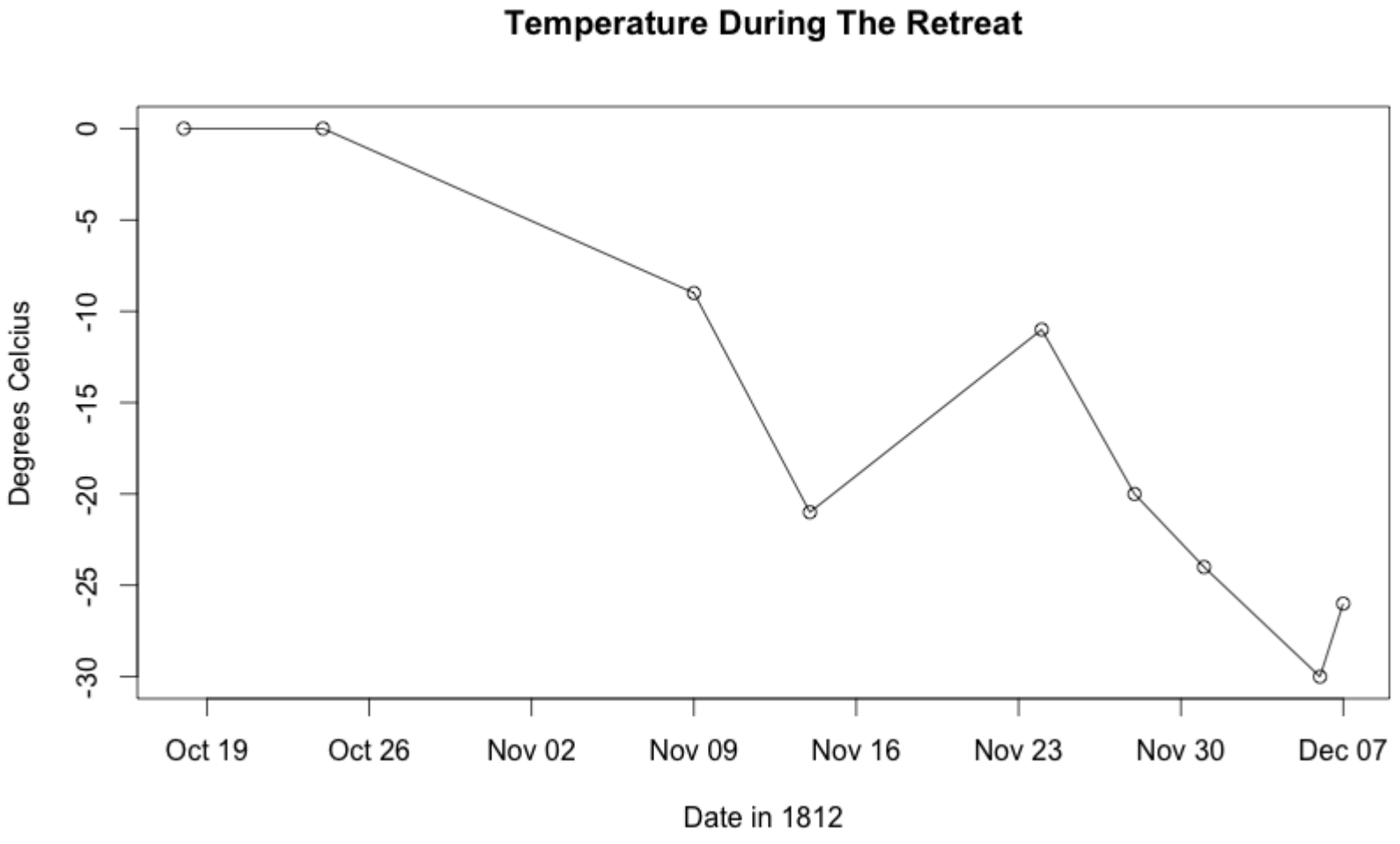


Charles Minard, 1869

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



https://thoughtbot.com/blog/analyzing-minards-visualization-of-napoleons-1812-march



https://thoughtbot.com/blog/analyzing-minards-visualization-of-napoleons-1812-march


Advance
Retreat

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'œil 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 Mobilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.

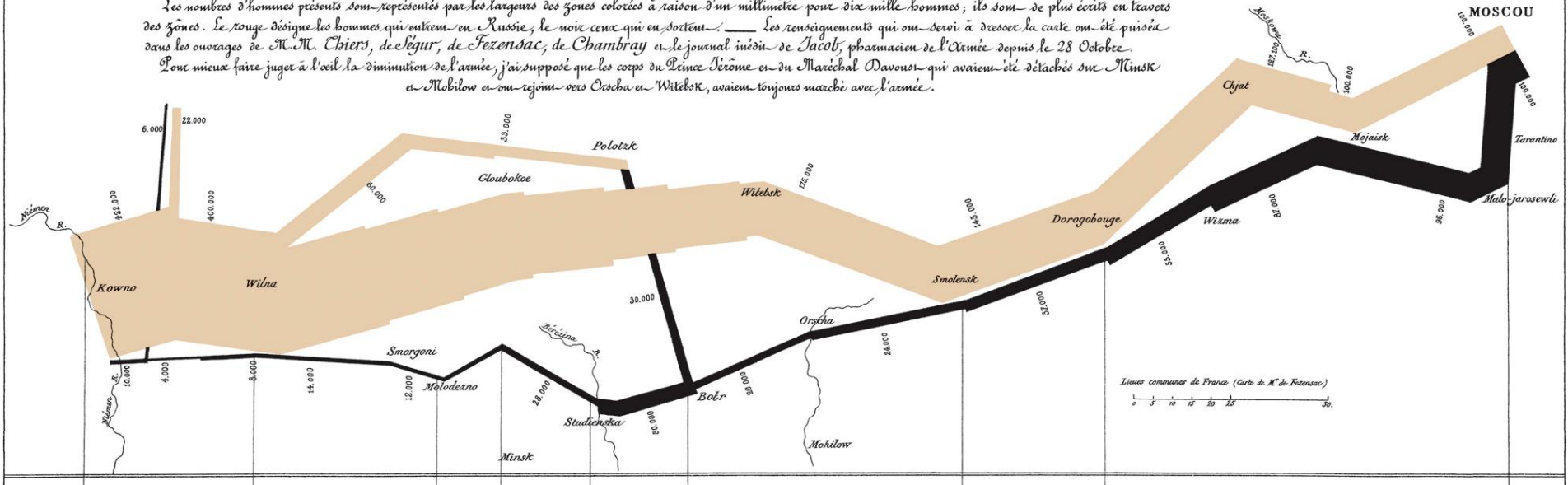
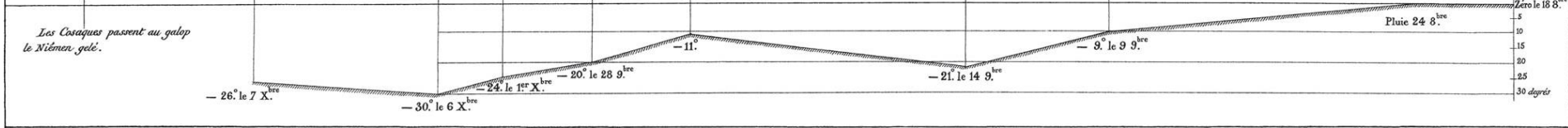


TABLEAU CRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.



Autog. par Regnier, 8. Pas. Ste Marie St Gdin 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

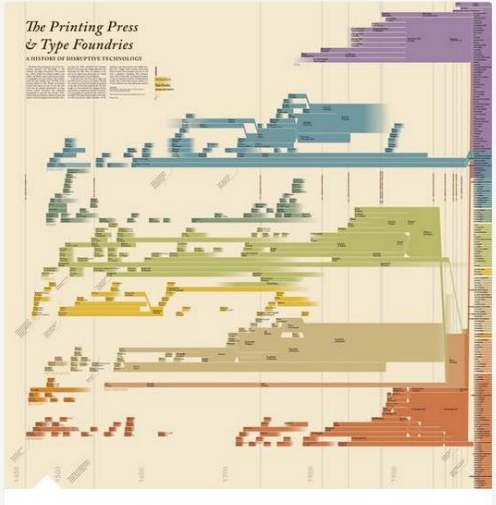
JOHN SNOW, 1854

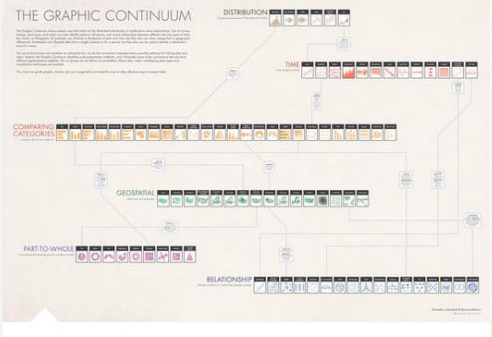
Awards Challenges

All 2019 2018 2017 2016 2015 2014 2013 2012

All Shortlist ★ Winners Gold Silver Bronze Rising Star Outstanding Individual Best-Non-English-Language Outstanding Outfit Student Community Most Beautiful

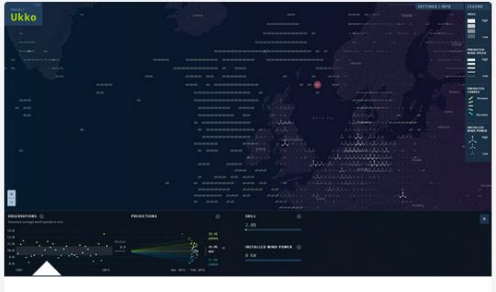
All Arts, Entertainment & Culture Breaking News Humanitarian Leisure, Games & Sport Maps, Places & Spaces News & Current Affairs People, Language & Identity Politics & Global Visualization & Information Design Science & Technology Unusual





The Graphic Continuum

The Graphic Continuum is our view of the many different types of visualizations available to us when we encode and present data. We've plotted nearly 90 different graphics across five main...

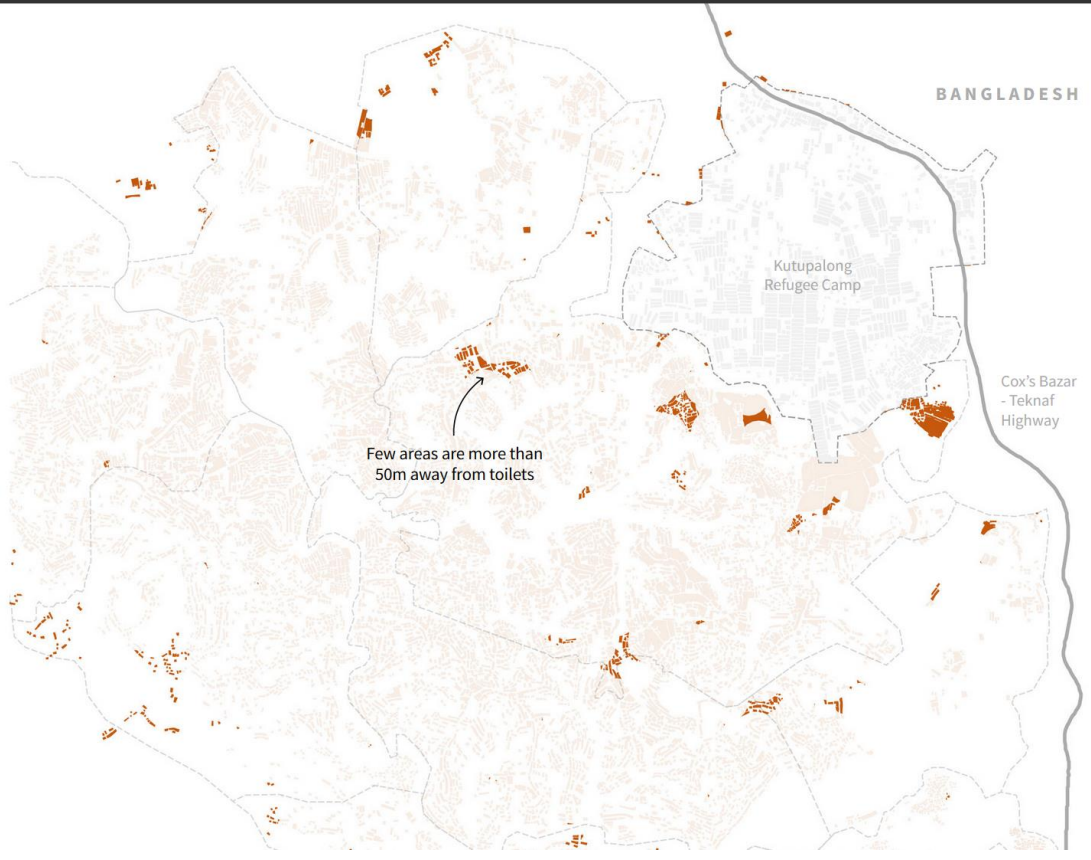


Project Ukko - Seasonal Wind Predictions for the Energy Sector

Weather forecasts predict future wind conditions only in the range of weeks. Climate predictions look at big changes over years and decades. However, for energy traders, wind farm managers and...

HTTP://FINGFX.THOMSONREUTERS.COM/GFX/RNGS/MYANMAR-ROHINGYA/010051VB46G/INDEX.HTML

REUTERS GRAPHICS



Too far from a latrine

Refugee households should be within 50 metres of a latrine. "Close enough to encourage their use but far enough to prevent problems with smells and pests," the UNHCR guideline says. This map shows refugee shelters that are too far from a latrine.

Award 2018

The Winners of the World Data Visualization Prize

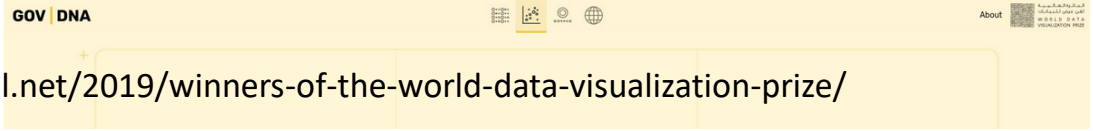
The results are in. After combing through hundreds of impressive, insightful and creative entries, we've decided on the winners of the World Data Visualization Prize 2019.

Conducted in partnership with the World Government Summit, the prize focuses on how governments are improving citizens' lives. We asked entrants to use the power of data-visualization to illuminate data on the innovations and decisions – seen and unseen – that drive progress.

Scroll through the interactive, static and hand-drawn "napkin" category winners to see who took the grand prize of $25,000.

Interactive

Winner – $6,000



https://informationisbeautiful.net/2019/winners-of-the-world-data-visualization-prize/

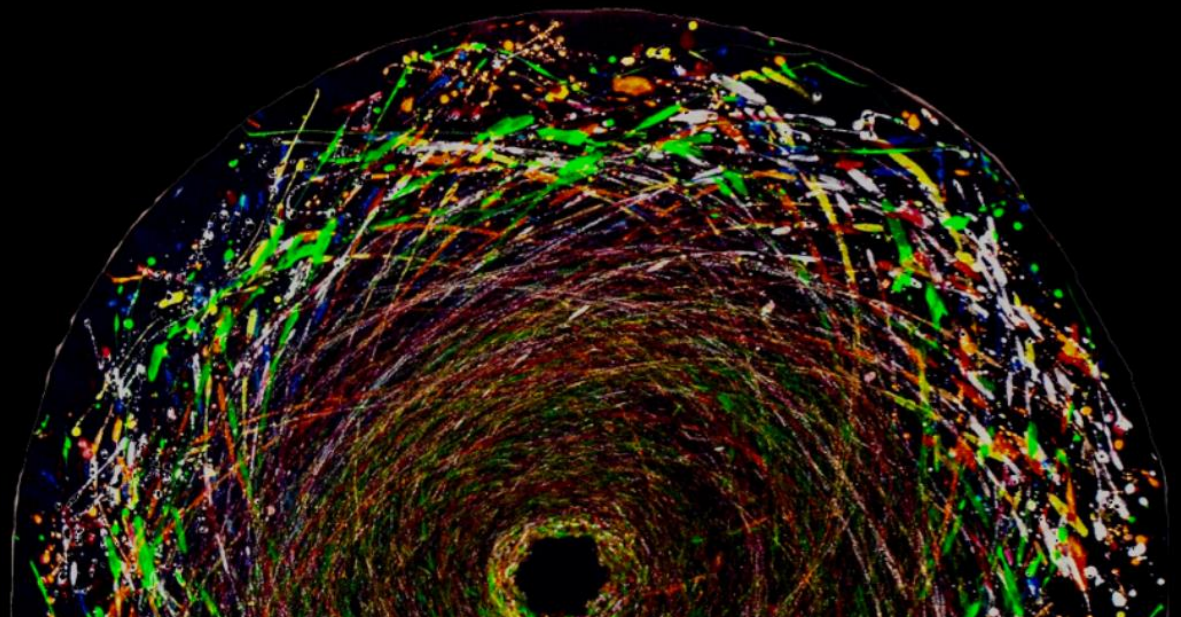
https://govdna.sudox.nl/#layout/dna/country/0/x/32/y/5/z/8/a/0

THE Vizzies

VISUALIZATION CHALLENGE

The most beautiful visualizations from the worlds of science and engineering

2018 Winners Announced!



RESOURCES

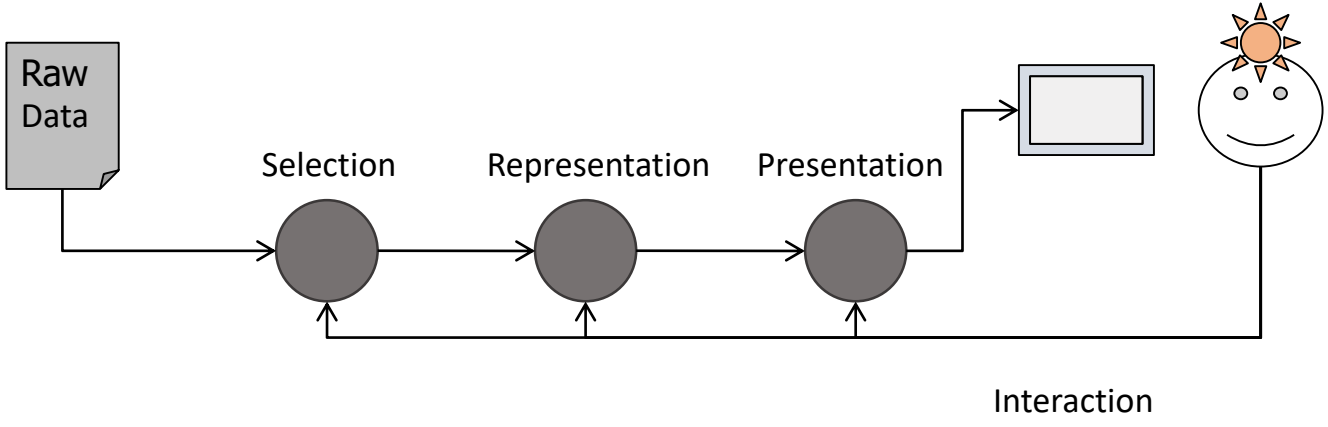
- Visualization conferences
  - ieeevis.org -- attend for free this year !
- Blogs
  - http://eagereyes.org/
  - http://flowingdata.com/
  - http://www.informationisbeautiful.net/
  - https://www.visualisingdata.com/blog/
  - https://pudding.cool/
  - https://junkcharts.typepad.com/
- Books
  - Textbooks
    - 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

VISUALIZATIONS


Cem

HOW DO WE ARRIVE AT A VISUALIZATION?



The Visualization Pipeline

From [Spence, 2000]

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 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

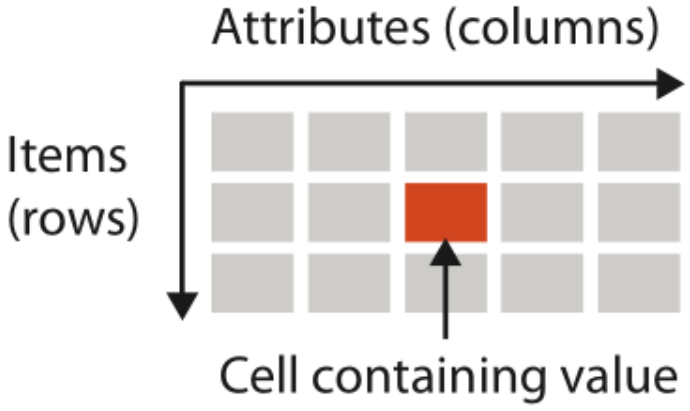
DATA

- 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

DATA SET TYPES

(some of them, more later & even more in the cited literature)

TABLES

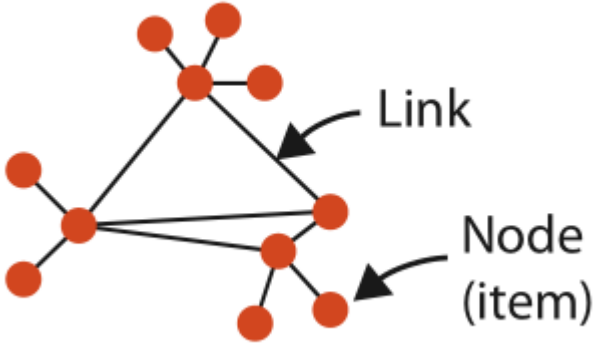


Example:

Items: drinks
Attributes: color, calories, name, …

[Munzner, Visualization Analysis and Design]

NETWORKS



Example:

Item = nodes: people
Item = links: co-authorship

Node attributes: name, experience, …
Link attributes: #of papers

[Munzner, Visualization Analysis and Design]

GEOMETRY (SPATIAL)

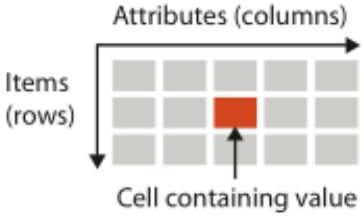
Specifies information about the shape of items with explicit spatial position

Item = countries
Positions = location on the planet

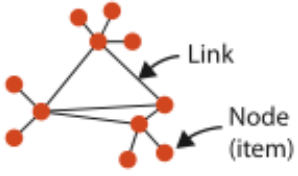
[Munzner, Visualization Analysis and Design]

Dataset Types

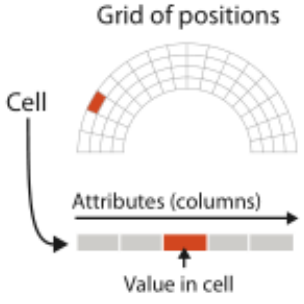
Tables



Networks

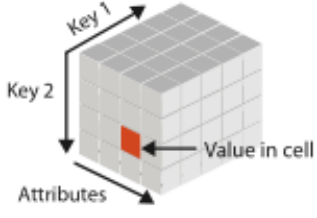


Fields (Continuous)



Geometry (Spatial)

Multidimensional Table



Trees

Figure 2.4. The detailed structure of the four basic dataset types.

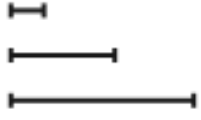
[Munzner, Visualization Analysis and Design]

ATTRIBUTE TYPES

- Nominal (sometimes called categorical)
  - Fruits: apples, oranges
  - Can be compared =, ≠

- Ordered
  - Ordinal
    - T-shirt sizes: S, M, L, XL
    - Can be compared & ordered, but not measured: =, ≠, <, >

  - Quantitative
    - Counts and amounts, 5kg / 10kg
    - you can do =, ≠, <, >, - , +, x, ÷



WHY IS THIS IMPORTANT?

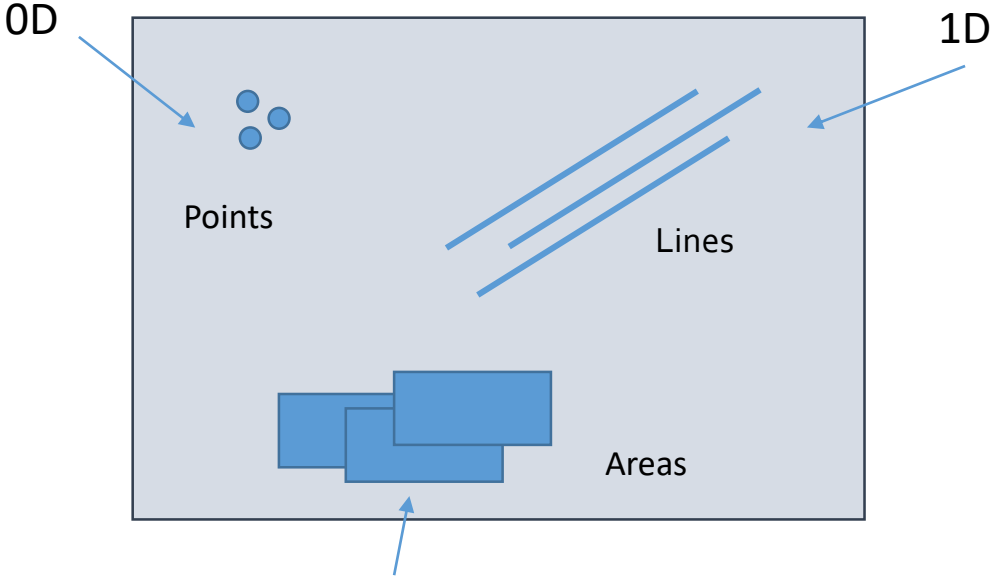
- Nominal, ordinal, and quantitative data are best expressed in different ways visually
- Data types often have inherent tasks
  - geometry (understand spatial relationships)
  - trees (understand parent-child relationships)
  - …

- But:
  - any data type (1D, 2D,…) can be expressed in a multitude of ways!

VISUALIZATION BUILDING BLOCKS

MARKS

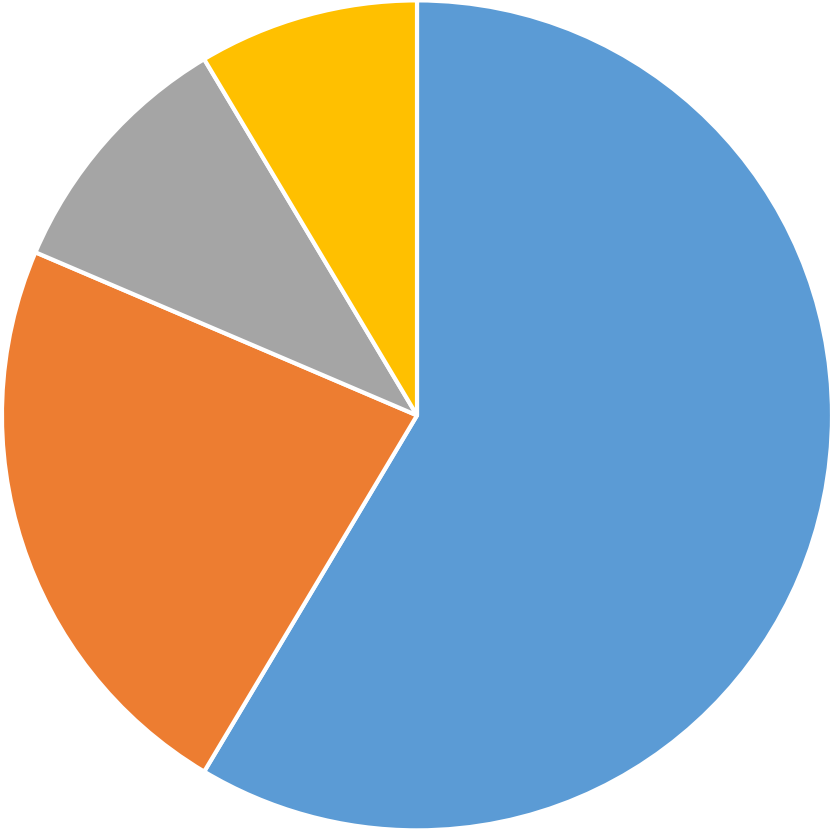
Basic geometric element data depict items or links



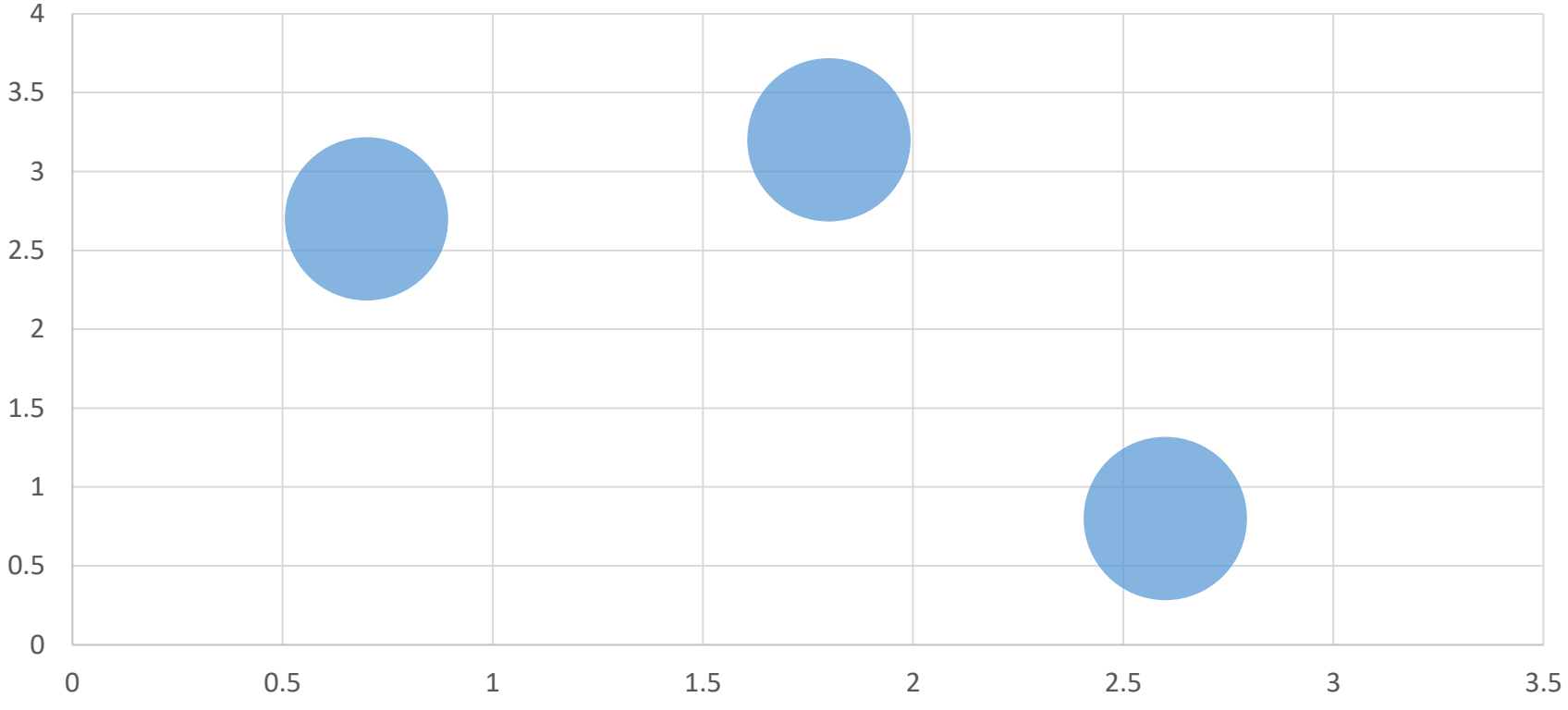
From Semiology of Graphics (Bertin)

which marks do you see?

which marks do you see?



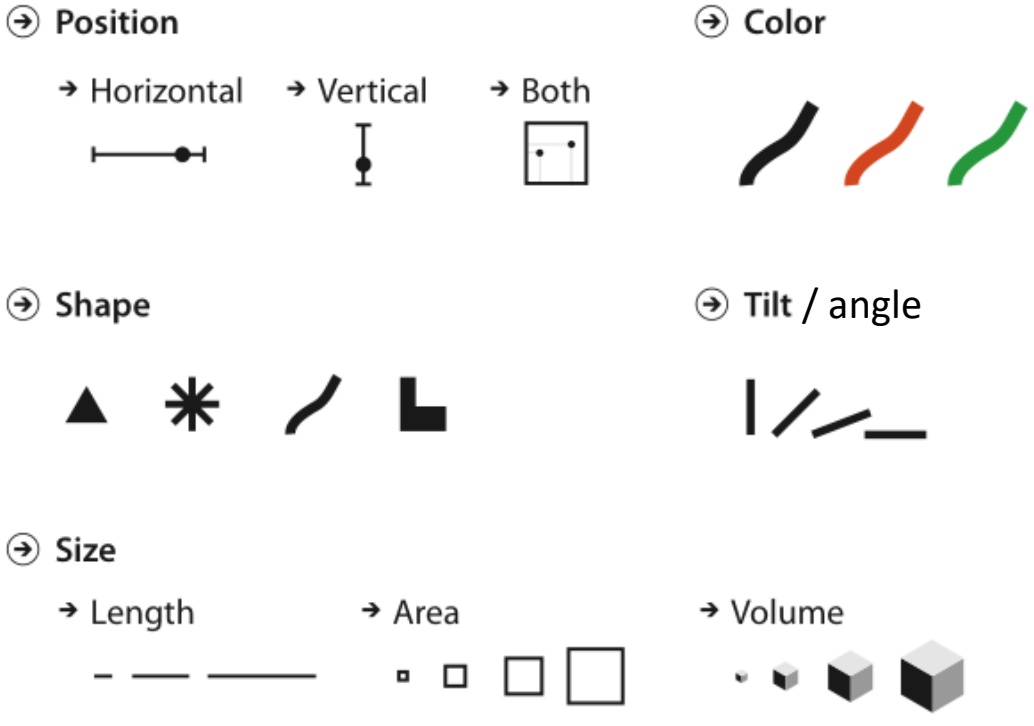
which marks do you see?



VISUAL CHANNELS

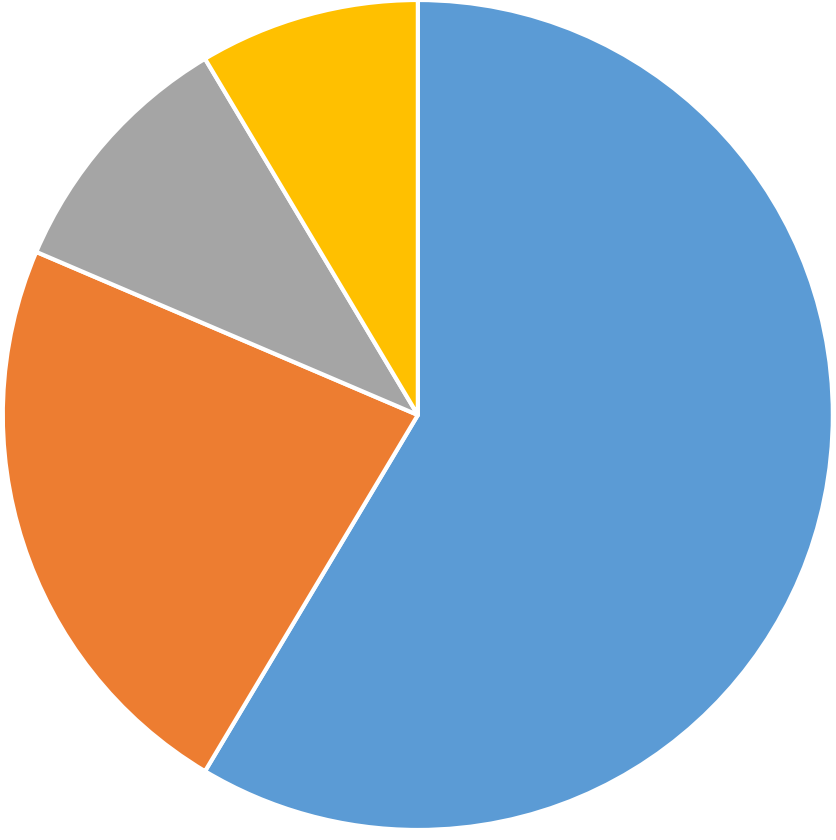
Also often called visual variables

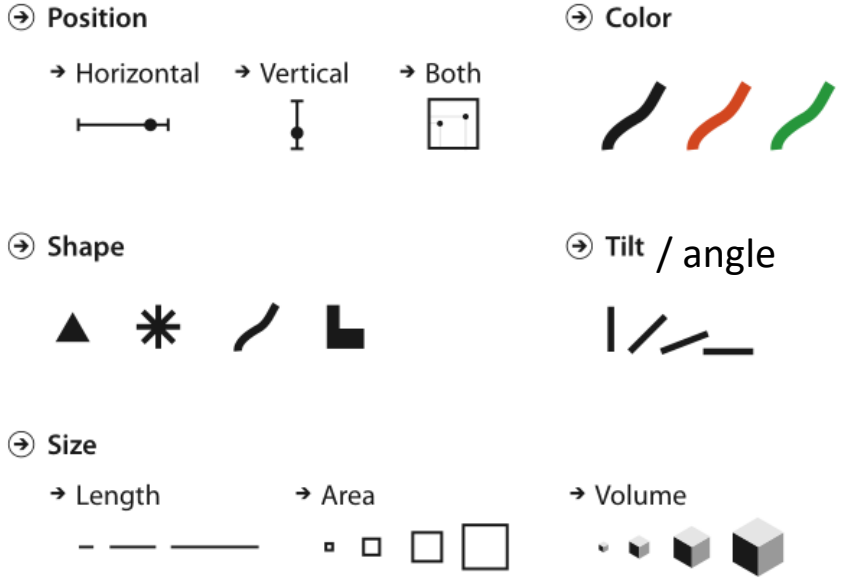
Modify marks
independent of the
dimensionality of the
mark



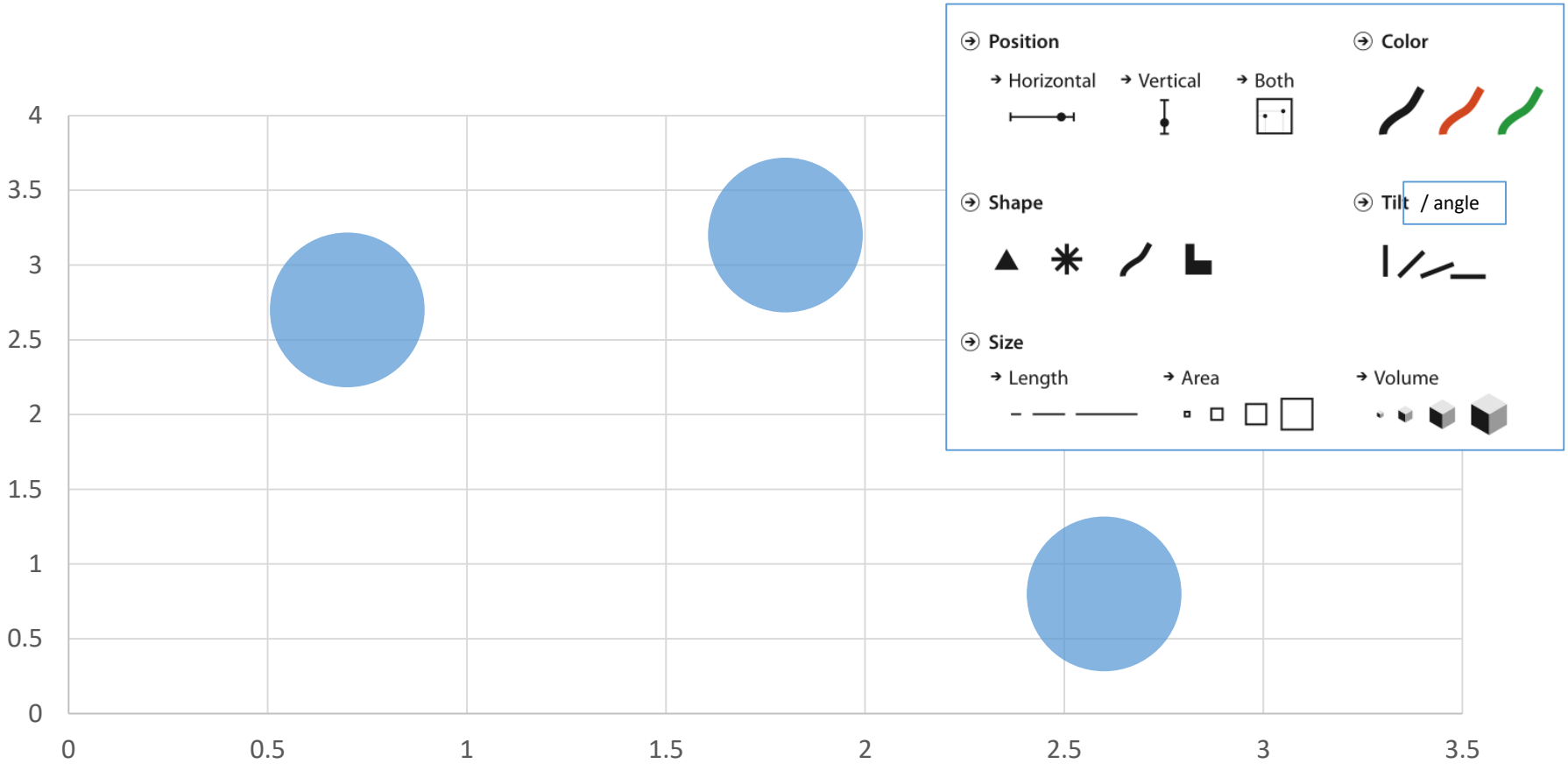
These are just some of them

which visual channels encode data?





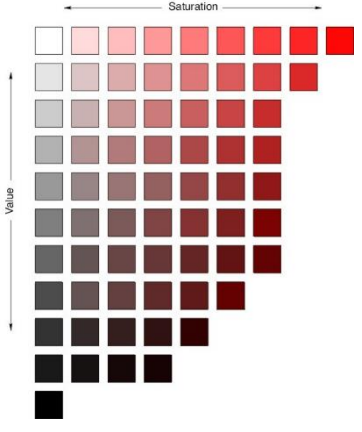
which visual channels encode data?



ADDITIONAL CHANNELS

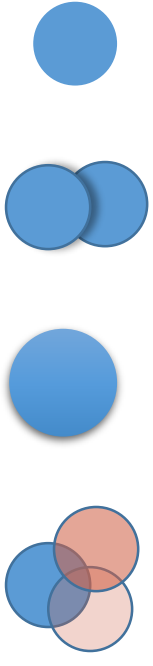
- motion
  - direction, acceleration, speed, frequency, onset, ‘personality’

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



ADDITIONAL CHANNELS

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



HOW TO CHOOSE CHANNELS?

EXPRESSIVENESS

show **all but only** the attribute information
(nothing more, nothing less)

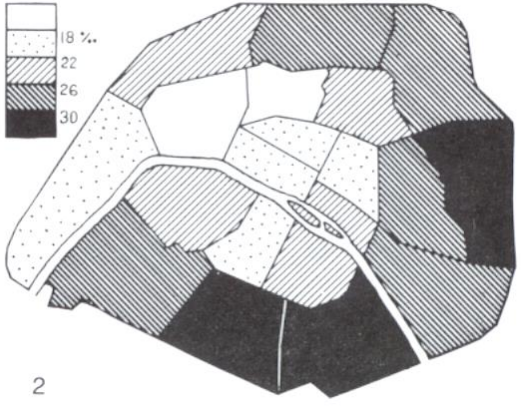
Example:
an ordered attribute needs to look ordered,
an unordered attribute should not

This mismatch is a common beginner's mistake

EXPRESSIVENESS

luminance is ordered, cannot be reordered

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

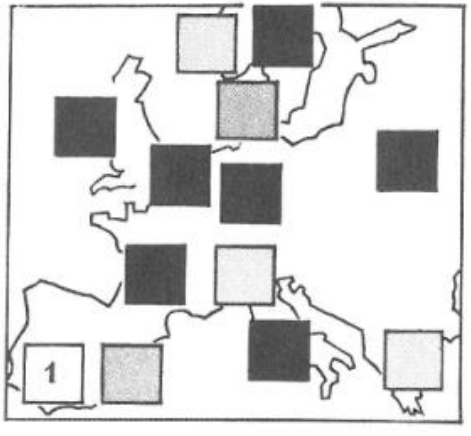


Values ordered correctly
Image much more useful

annual deaths per 1000 inhabitants, Paris

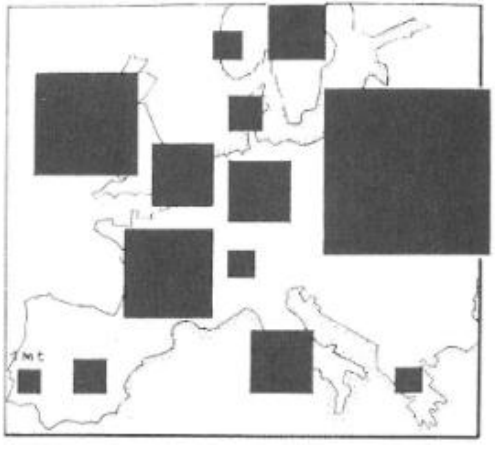
EXPRESSIVENESS

luminance 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

HOW TO CHOOSE CHANNELS?

EFFECTIVENESS

the importance of the attribute matches the salience of the channel

(the most important attributes should be encoded with the most effective channels)

EFFECTIVENESS

Accuracy: How accurately values can be estimated.

Discriminability: How many different values can be perceived.

Separability: How much interaction there is with multiple encodings.

Popout: How easy it is to spot some values from the rest.

Grouping: How good a channel is in conveying groups.

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

Same

Same

Most

Effectiveness

Least

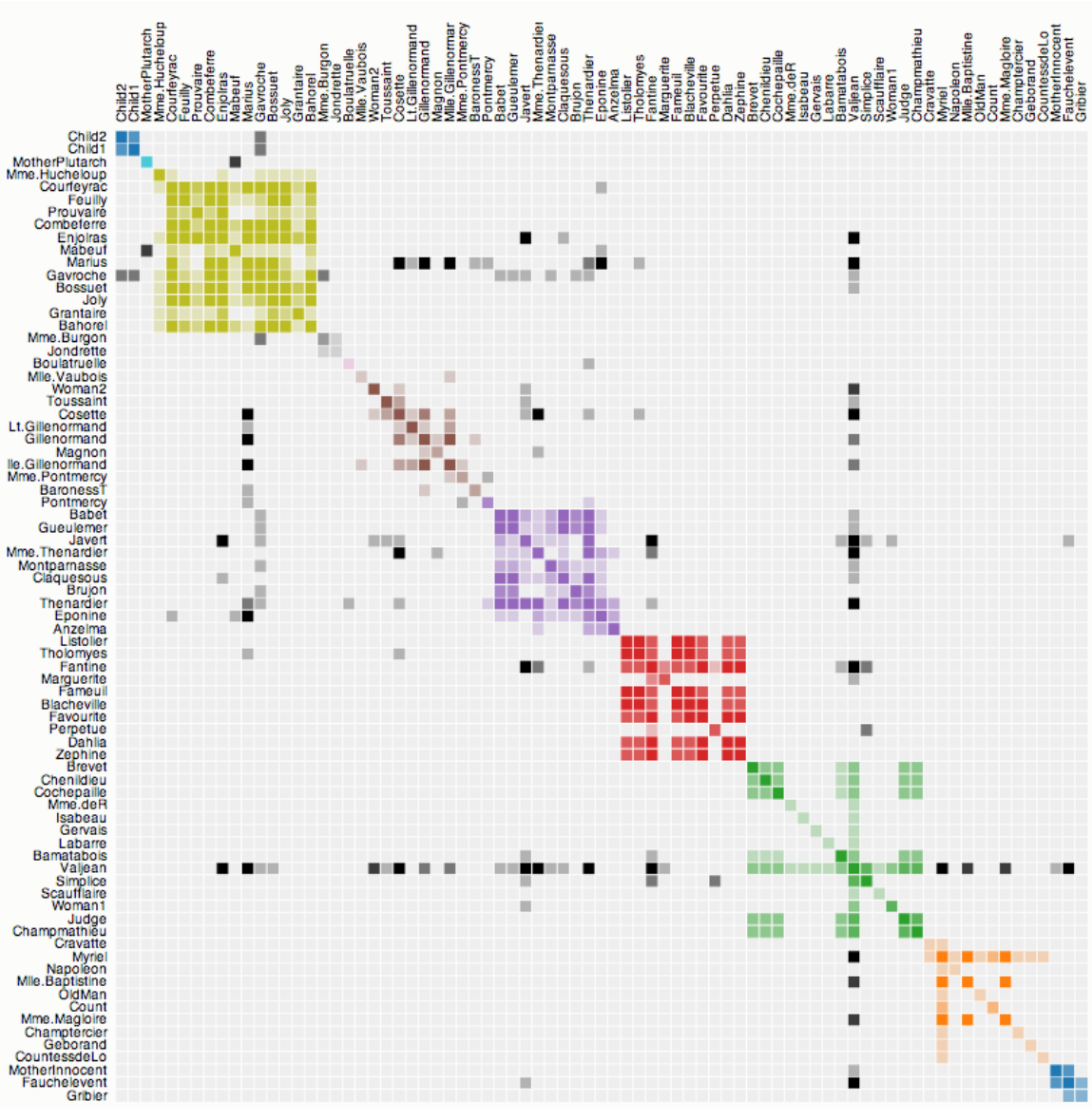
Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

We will look at effectiveness a lot more throughout the lectures

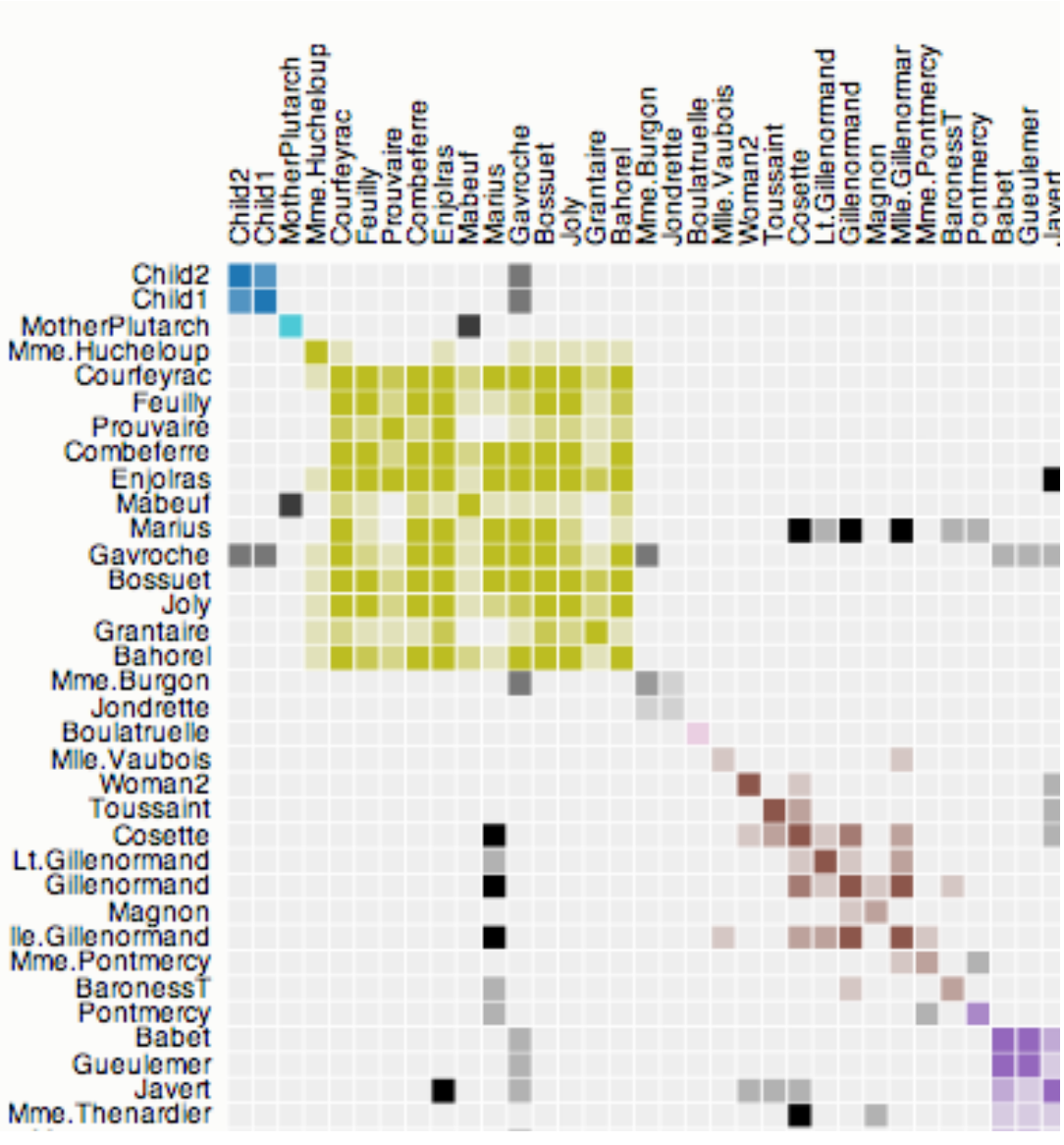
ASSIGNMENT 1

Training



Characters Co-occurrence in Les Misérables

source: http://bost.ocks.org/mike/miserables/

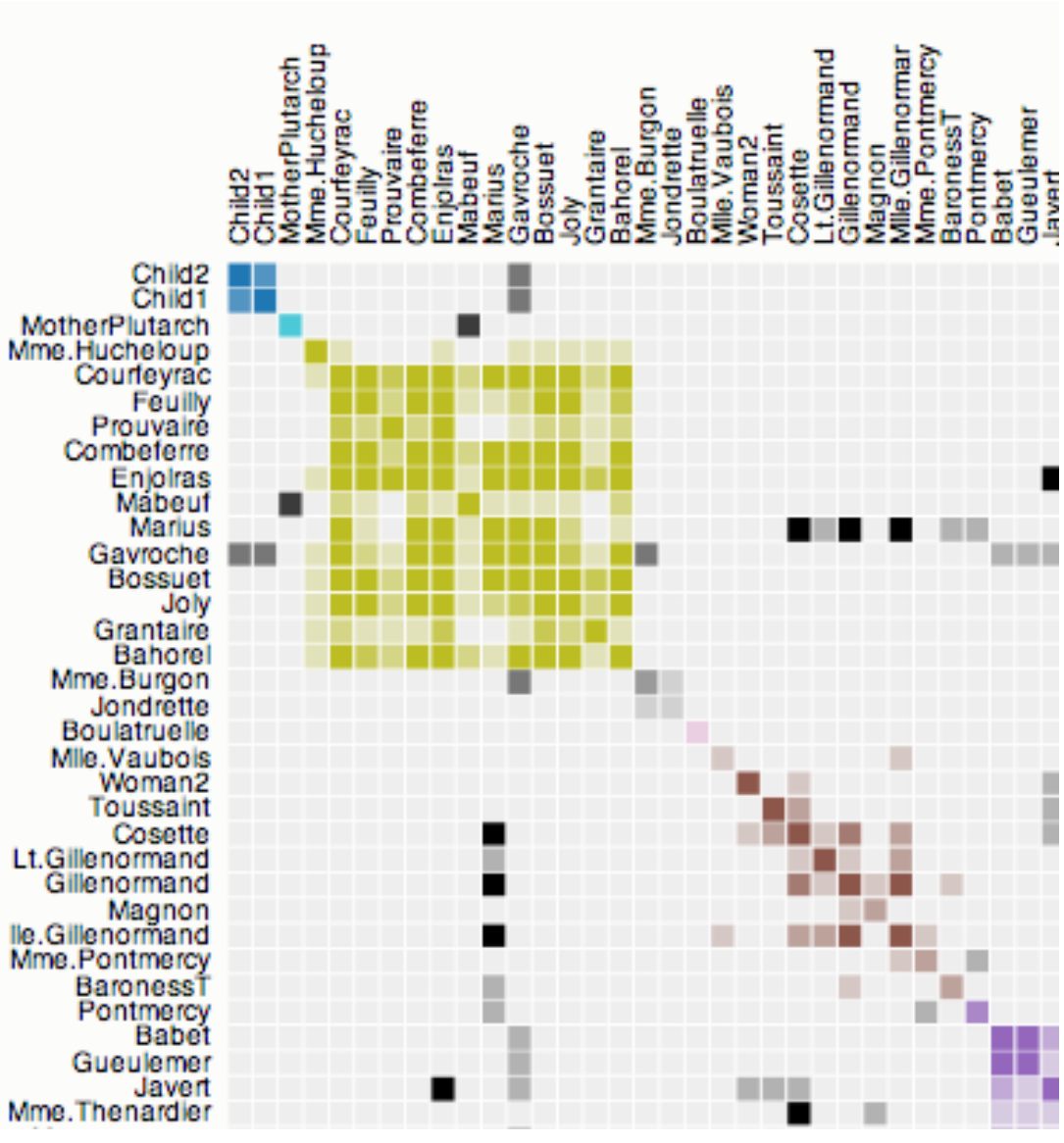


Data Items

Visual Marks

Attributes

Channels



Data Items: Co-occurrences

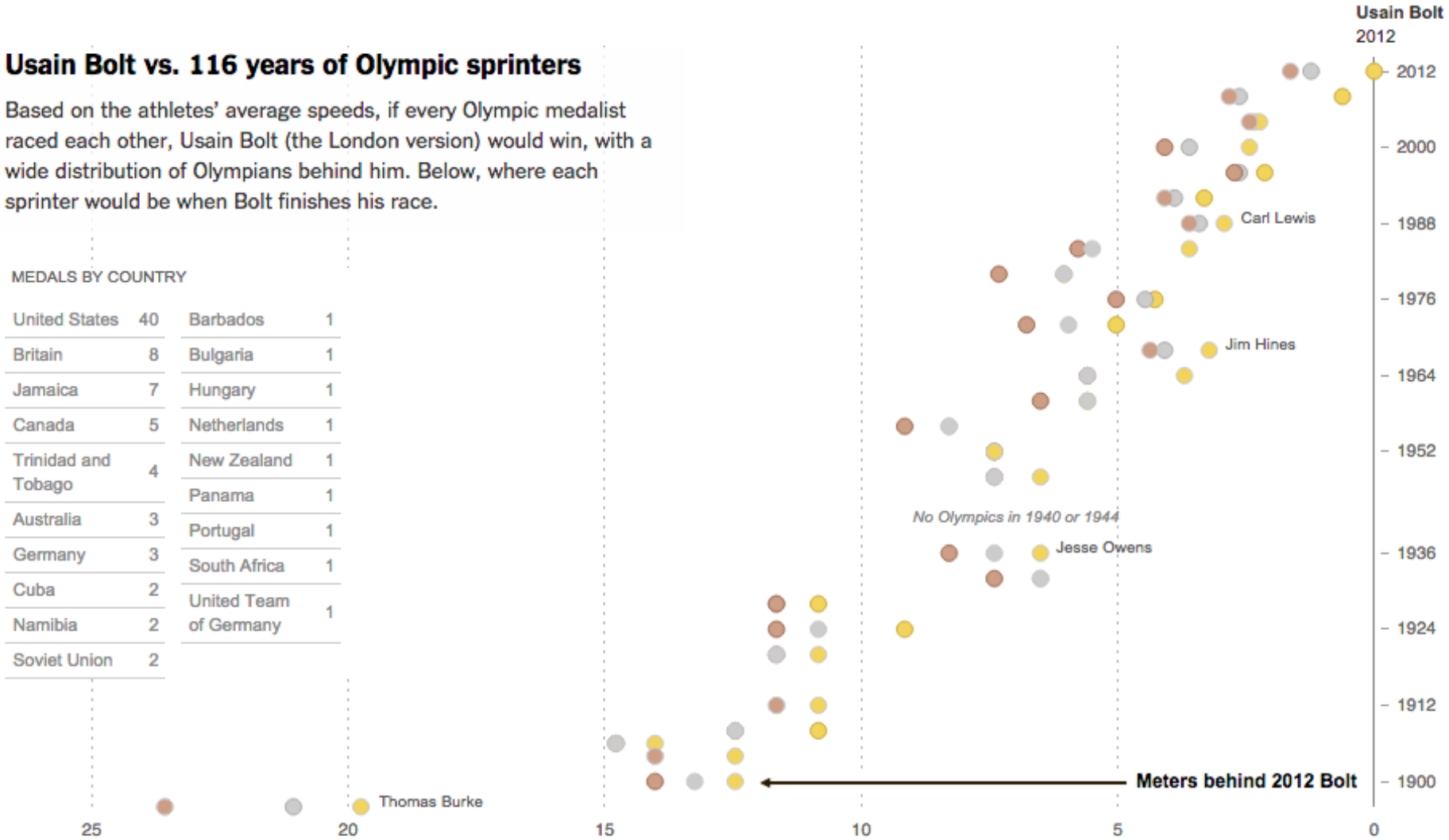
Visual Marks: Point

Attributes: Name 1, Name 2, Cluster, Frequency

Channels:
Position x, Position y: Names
Color hue: cluster
Color saturation: frequency

Usain Bolt vs. 116 years of Olympic sprinters

Based on the athletes' average speeds, if every Olympic medalist raced each other, Usain Bolt (the London version) would win, with a wide distribution of Olympians behind him. Below, where each sprinter would be when Bolt finishes his race.



MEDALS BY COUNTRY

United States	40	Barbados	1
Britain	8	Bulgaria	1
Jamaica	7	Hungary	1
Canada	5	Netherlands	1
Trinidad and Tobago	4	New Zealand	1
Australia	3	Panama	1
Germany	3	Portugal	1
Cuba	2	South Africa	1
Namibia	2	United Team of Germany	1
Soviet Union	2		

This chart includes medals for the United States and Australia in the "Intermediary" Games of 1906, which the I.O.C. does not formally recognize.

http://www.nytimes.com/interactive/2012/08/05/sports/olympics/the-100-meter-dash-one-race-every-medalist-ever.html?_r=0

SUMMARY

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

READINGS

1. Illuminating the Path: The Research and Development Agenda for Visual Analytics Paperback – January 1, 2005 by James J. Thomas (Editor), Kristin A. Cook (Editor)
2. Daniel A. Keim and Florian Mansmann and Jörn Schneidewind and Hartmut Ziegler and Jim Thomas, *Visual Analytics: Scope and Challenges*, 2008, Visual Data Mining: Theory, Techniques and Tools for Visual Analytics, Springer, Lecture Notes In Computer Science (lncs)
3. Michael Milton. Head First Data Analysis: A learner's guide to big numbers, statistics, and good decisions.
4. Keim, D., Andrienko, G., Fekete, J. D., Görg, C., Kohlhammer, J., & Melançon, G. (2008). Visual analytics: Definition, process, and challenges (pp. 154-175). Springer Berlin Heidelberg.