

INFORMATION VISUALIZATION

Introduction

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AFTER TODAY YOU WILL...

have gained an overview of Visualization as a research area

learned basic principles of data representation and interaction

Why

VISUALIZE DATA?

DATA EXPLORATION / INSIGHT

confirmatory analysis

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

focus of fully automated analysis methods

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 visualization

DATA EXPLORATION / INSIGHT

Often with expert / complex tools

POLARIS

Database Schema: The user drags fields from the database schema to shelves to define the visual specification.

Layer Tabs: Each layer has its own tab; different transformations and mappings can be specified for each layer.

Axis Shelves: The fields placed here determine the structure of the table and the types of graphs in each table pane.

Context Menu: The context menu provides access to the data transformation and interaction capabilities of Polaris such as sorting, filtering, and aggregation.

Layer Shelf: The fields placed here determine how records are partitioned into layers.

Grouping and Sorting Shelves: The fields placed here determine how records are grouped and sorted within the table panes.

Mark Pulldown: Relations in each pane are mapped to marks of the selected type.

Retinal Property Shelves: The fields placed here determine how data is encoded in the retinal properties of the marks.

Legends: Legends enable the user to see and modify the mappings from data to retinal properties.

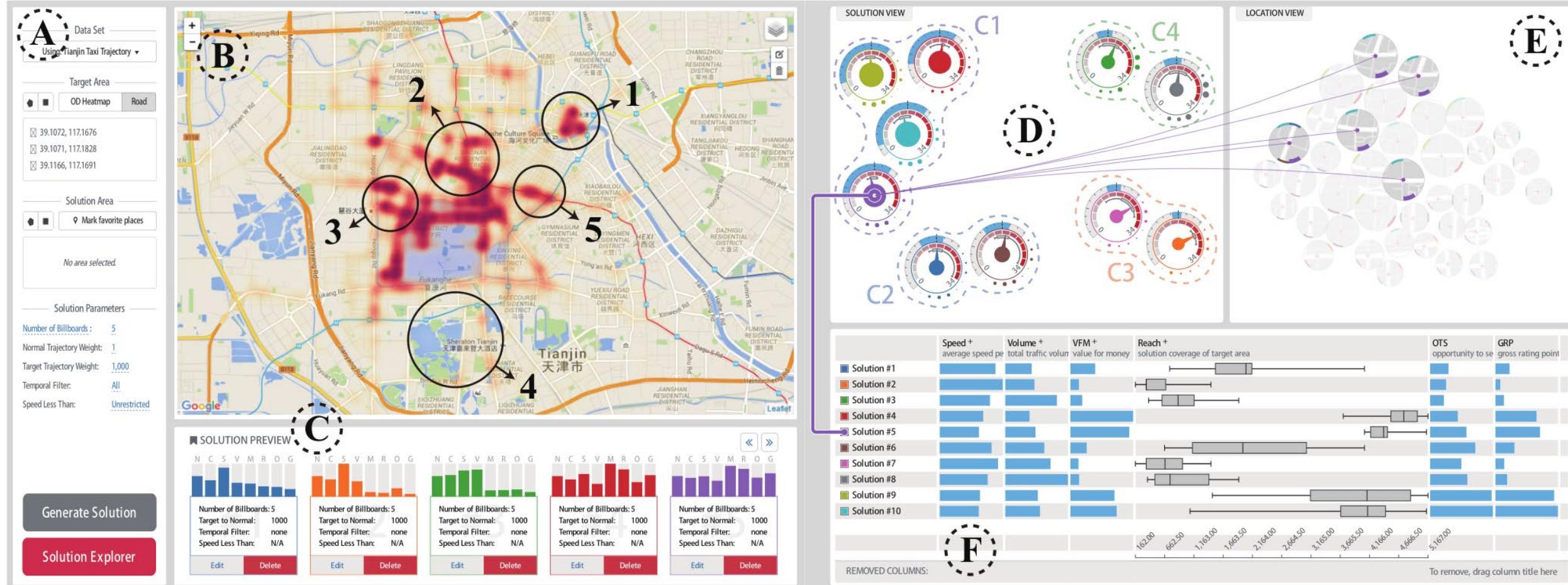
The screenshot shows the Polaris interface with the following components:

- Schema Tab:** Displays a list of database fields: Quarter, Month, Market, State, MrktSize, ProductType, Product, Decaf, Profit, Margin, Sales, COGS, TotalExpenses, Marketing, Payroll, Misc, Inventory, Opening, Additions, Ending, MarginRate, ProfitRatio, BudgetProfit, BudgetMargin, BudgetSales, BudgetCOGS, BudgetPayroll, BudgetAdditions.
- Import Tab:** Contains buttons for Back, Forward, and Clear.
- CoffeeChain Layer Tab:** Shows settings for grouping by State, sorting, and marking (Glyph).
- Data Tables:** Four tables showing sales and profit data for Coffee, Espresso, Herbal Tea, and Tea across four quarters (Qtr1, Qtr2, Qtr3, Qtr4). Each table includes a context menu for data transformation.
- Brushing and Filtering:** A context menu is open over the Espresso table, showing options like Filter..., Partition..., Bin By..., Use for Brushing/Toolips, SUM, MIN, MAX, AVG.

Either for any data (here data tables)

Taxi Trajectories for Selecting Billboard Locations

Dongyu Liu, Di Weng, Yuhong Li, Jie Bao, Yu Zheng, Huamin Qu, and Yingcai Wu



Or for dedicated data / tasks

PERSUASION, EDUCATION, MOTIVATION



U.S. VIRUS DEATHS NEARING 500,000 IN JUST ONE YEAR

MORE THAN IN 3 WARS

Empty Spaces in Cities,
Towns, Restaurants,
Homes and Hearts

By JULIE BOESMAN

CHICAGO — A nation numbed by misery and loss is confronting a number that still has the power to shock: 500,000.

Roughly one year since the first known death by the coronavirus in the United States, an unfathomable toll is nearing — the loss of half a million people.

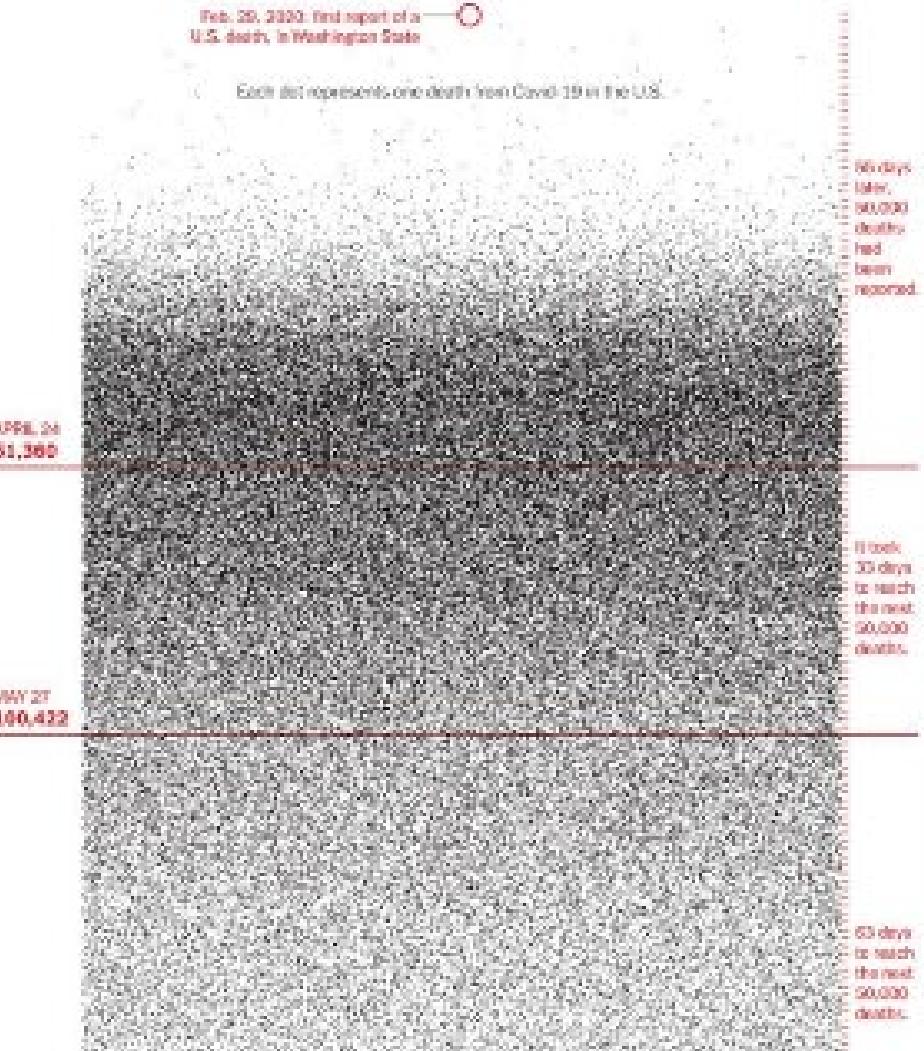
No other country has counted so many deaths in the pandemic. More Americans have perished from Covid-19 than on the battle-scarred World War I, World War II and the Vietnam War combined.

The milestone comes at a hopeful moment: New virus cases are down sharply, deaths are slowing and vaccines are steadily being administered.

But there is concern about emerging variants of the virus, and it may be months before the pandemic is contained.

Each death has left behind numbered markers, a sprawling toll that has swept over towns and cities. Each death has left an empty space in communities

The Toll: America Approaches Half a Million Covid Deaths



Garland Faces Resurgent Peril Of Extremism

Oklahoma City Attack Shaped His Views

By MARK LEIBOVICH

WASHINGTON — Judge Merrick B. Garland always made a point of wearing a cap and tie when he surveyed the wreckage at the site of the 1995 Oklahoma City bombing, the worst domestic terrorist attack in American history.

He had been dispatched from Washington to oversee the case for the Justice Department, and he told colleagues that he viewed his daily uniform as a gesture of respect for a community left devastated after Timothy J. McVeigh placed a 7,000-pound bomb in a Ryder truck and blew up the Alfred P. Murrah Federal Building, killing 168 people, including 19 children.

"It really looked like a war zone," Judge Garland said in recalling the destroyed and still-smoldering building, part of an oral history he participated in for the Oklahoma City National Memorial and Museum. "The site was lit up like a sun, like the middle of the day." The worst part, he said, was seeing the demolished day care center. "There was nothing there," he said. "It was just a big, empty concrete." His own daughters were 4 and 3 at the time.

The Oklahoma City case, he later

STORMS EXPOSING A NATION PRIMED FOR CATASTROPHE

CLIMATE CHANGE WRATH

Unprepared for Threats Facing Power Grids, Water and Roads

This article is by Christopher Flavelle, Rand Foster and Hiroko Tabuchi.

Even as Texas struggled to restore electricity and water over the past week, signs of the risks posed by increasingly extreme weather to America's aging infrastructure were cropping up across the country.

The continent-spanning winter storms triggered blackouts in Texas, Oklahoma, Mississippi and several other states. One-third of oil production in the nation was halted. Drinking-water systems in Ohio were knocked offline. Road networks nationwide were paralyzed and vaccination efforts in 20 states were disrupted.

The crisis carries a profound warning. As climate change brings more frequent and intense storms, floods, heat waves, wildfires and other extreme events, it is placing growing stress on the foundations of the country's economy: its network of roads and railways, drinking-water systems, power plants, electrical

Late Edition

Today: plenty of sunshine, chilly, high 33. Tonight, increasing clouds, low 21. Tomorrow, intervals of snow and rain, little to no accumulation, high 41. Weather map, Page 33



BIG RESEARCH QUESTION IN VISUALIZATION

how can humans effectively access data?

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

THE MANY FLAVORS OF VISUALIZATION

VISimageNavigator

Getting started Explore About Updates

Visitors: 1994

Query by Terms in paper authors' keywords e.g. biomedical Submit

Authors: All Vis SciVis InfoVis VAST

Image type(s): Figure(s) Table(s) Algorithms(s) Equations(s)

Visualization Types: TEXT VIS

Coders' perceived difficulty level(s): Nothing selected

Dimensionality of the rendering: 2D 3D

Functional Types: GUI

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images per page 200 First Page < 1 2 3 4 5 6 7 8 9 10 > Last page go to page 158 page(s) 31493 images in total fixed this pane random order

Name Parameters
*CreateImage char *image_data pixel_t *image_dim image_convert_t *functs

index	R	G	B
i=0-255	i	255-i	0
i=256-511	255	256-i	0
i=512-767	255	255	i-512

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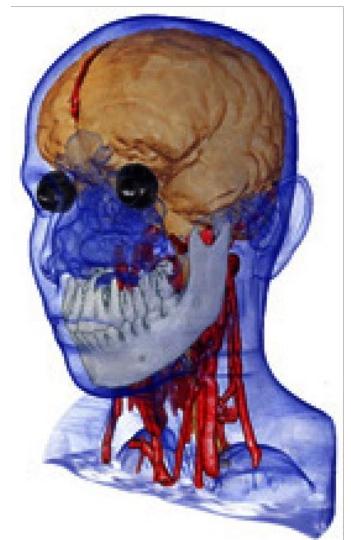
Figure 1059

Figure 1060

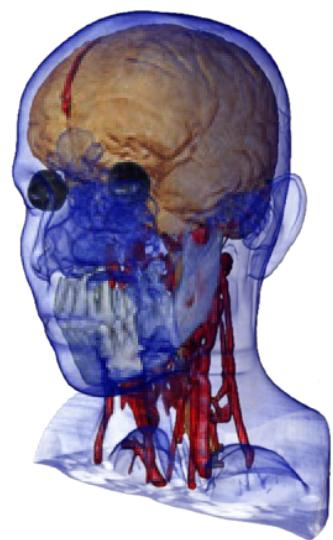
Figure 1061

Figure 1

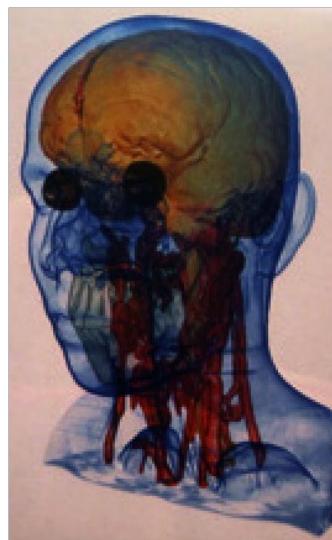
“Scientific Visualization”



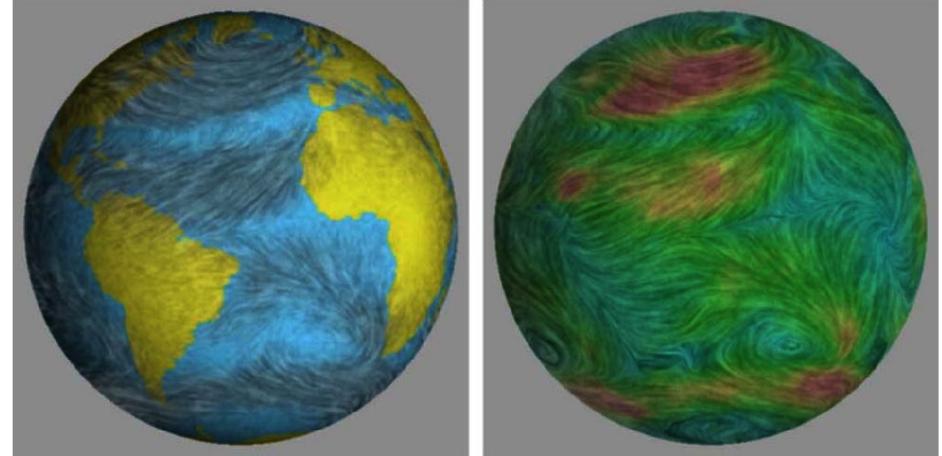
a



b

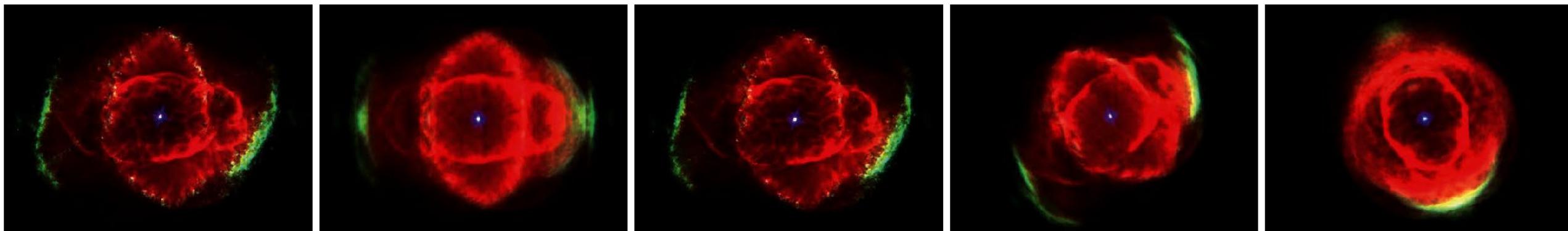


c



<http://dx.doi.org/10.1109/VISUAL.2003.1250363>

<http://dx.doi.org/10.1109/TVCG.2016.2599211>



(a)

(b)

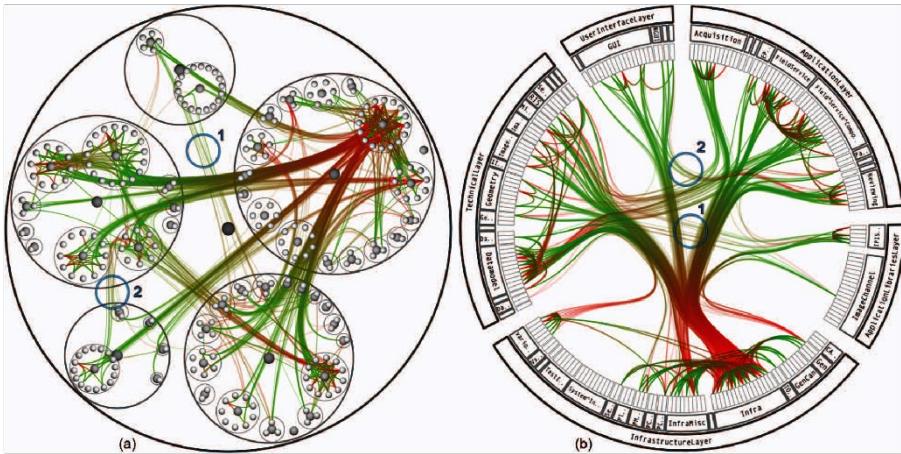
(c)

(d)

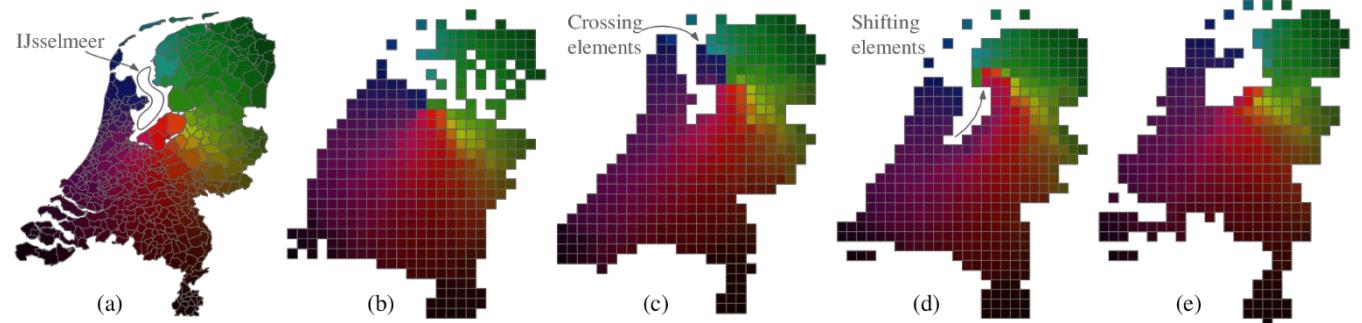
(e)

<http://dx.doi.org/10.1109/TVCG.2012.281>

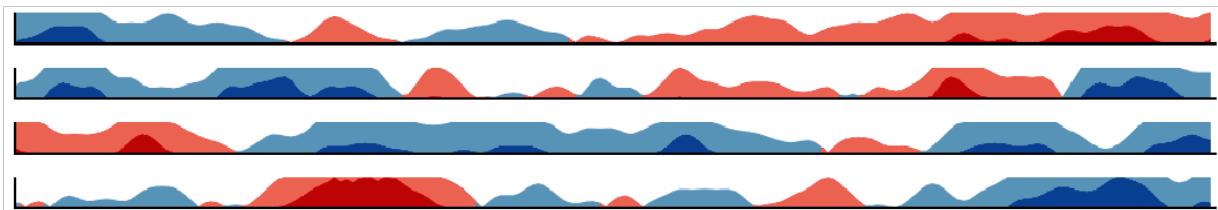
“Information Visualization”



<http://dx.doi.org/10.1109/TVCG.2006.147>

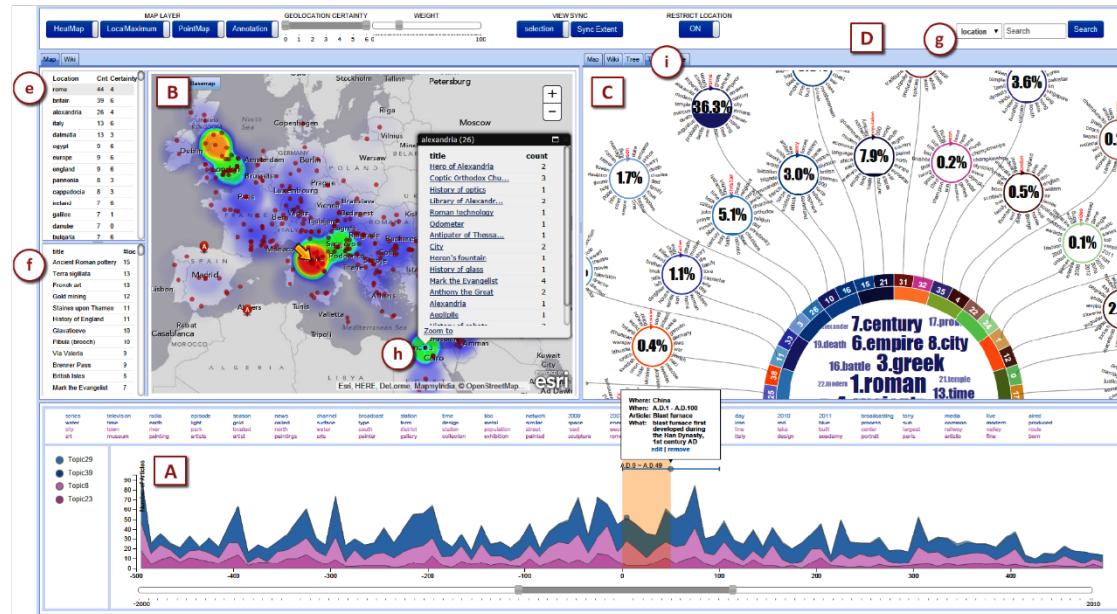


<http://dx.doi.org/10.1109/TVCG.2020.3028953>

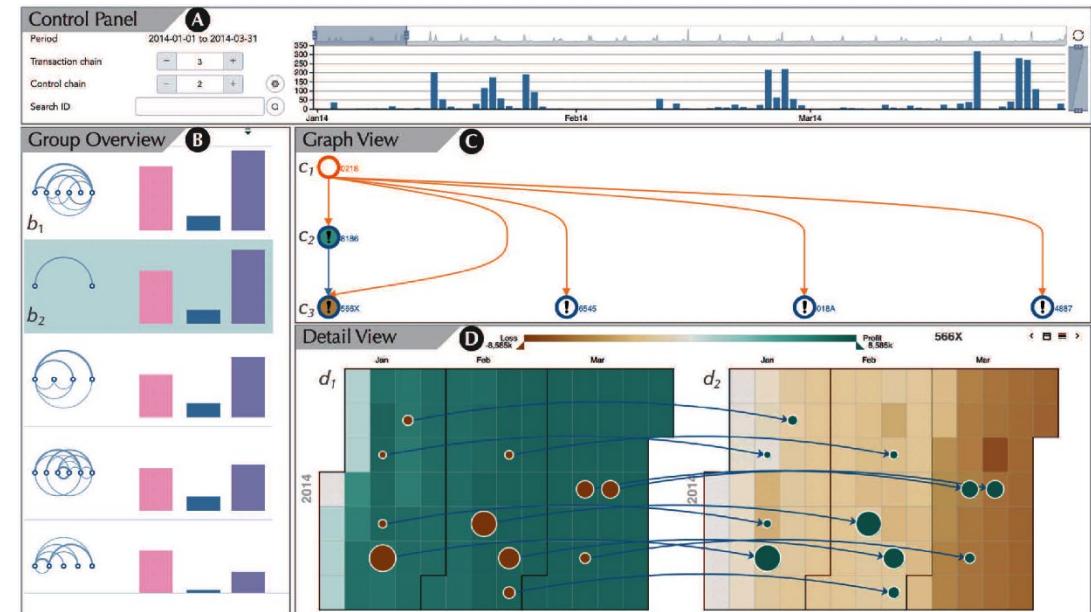


<http://dx.doi.org/10.1109/TVCG.2010.162>

“Visual Analytics”

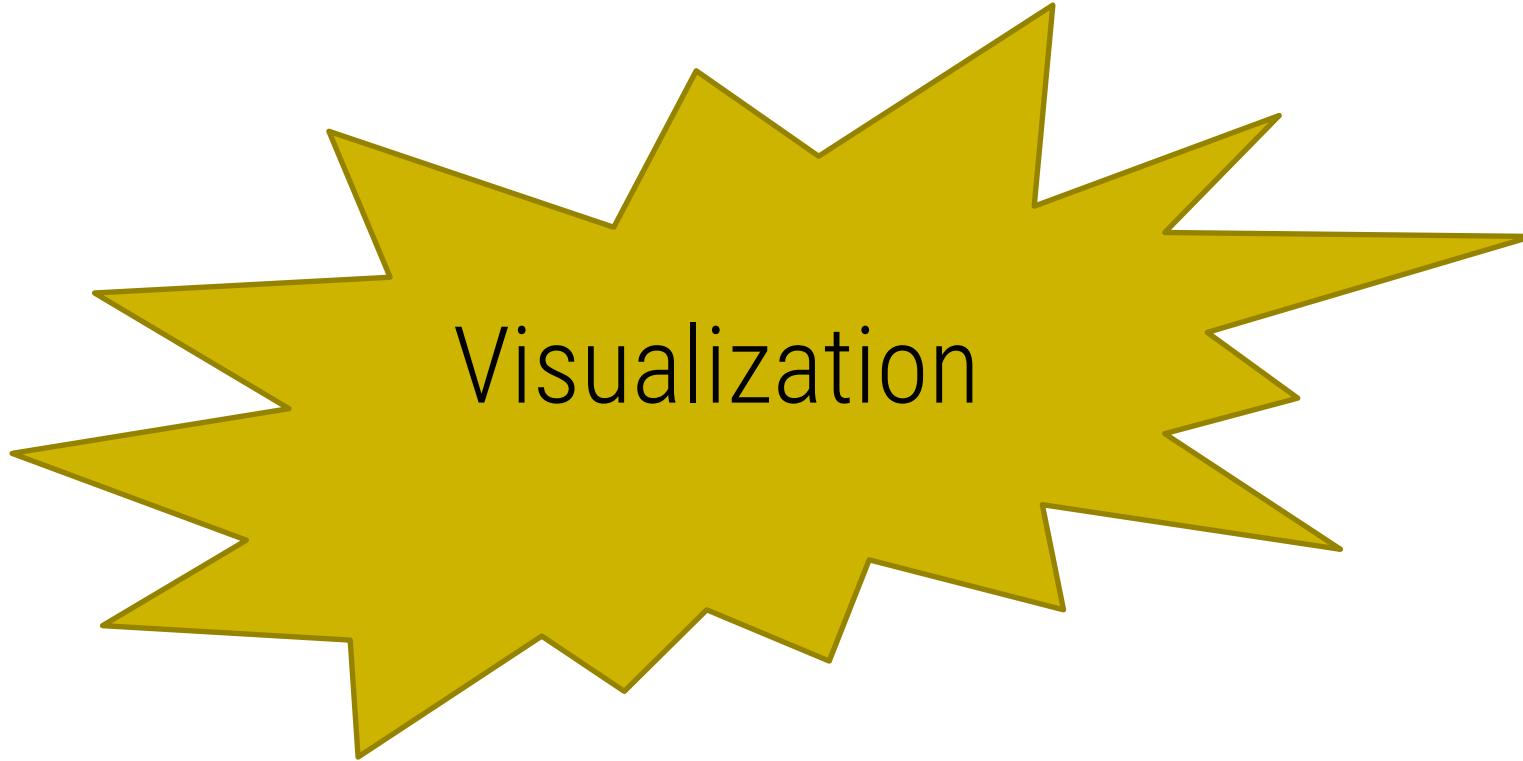


<http://dx.doi.org/10.1109/TVCG.2015.2467971>



<http://dx.doi.org/10.1109/TVCG.2020.3030370>

OK, BUT WHY...



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

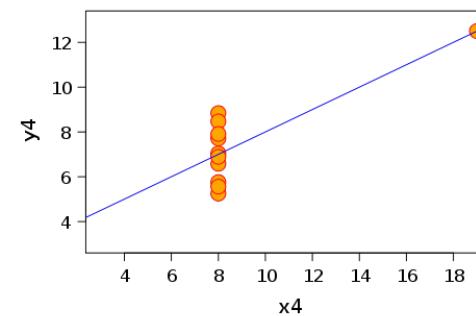
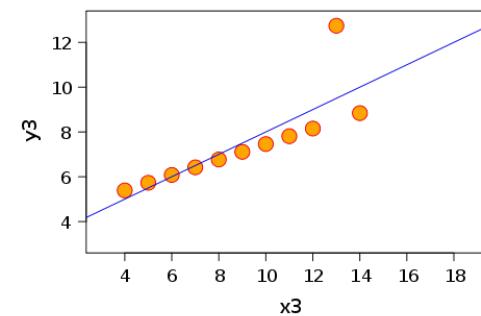
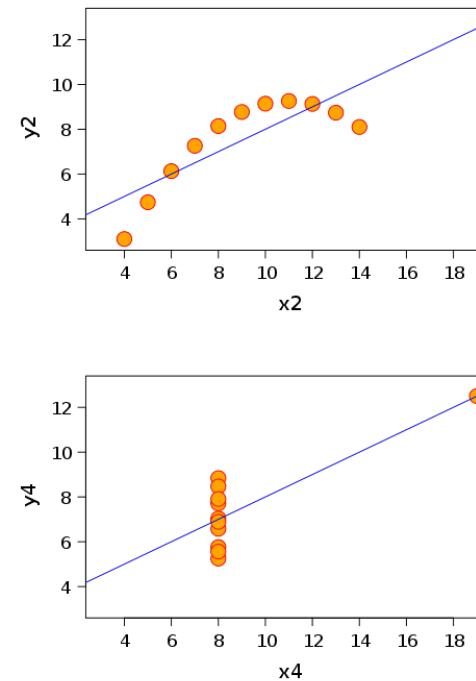
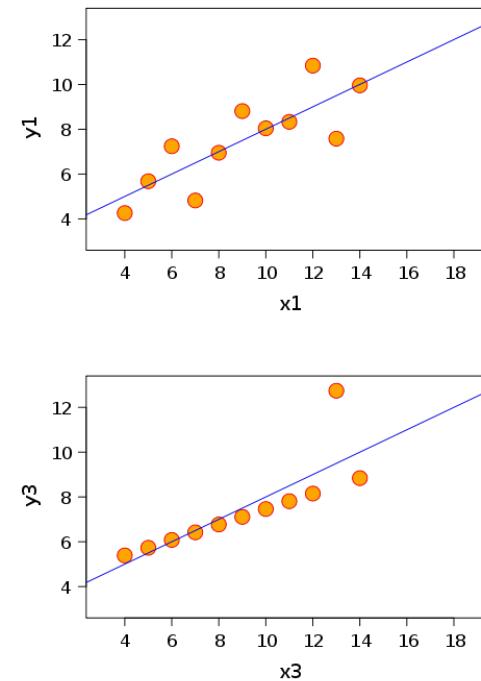
I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0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

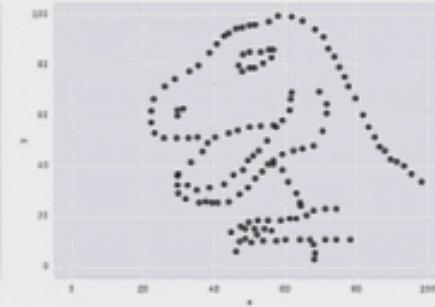
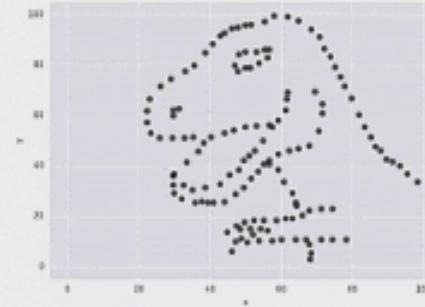
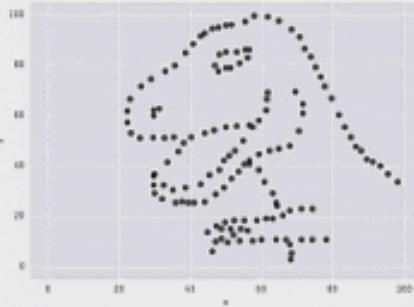
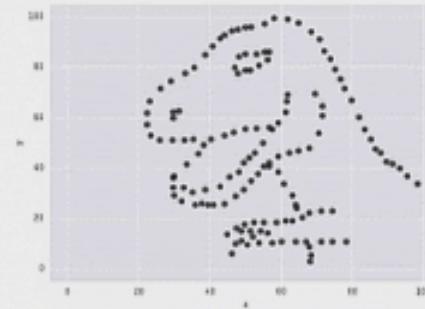
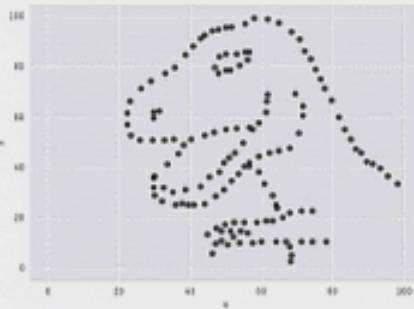
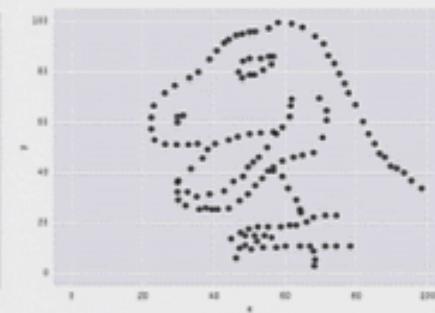
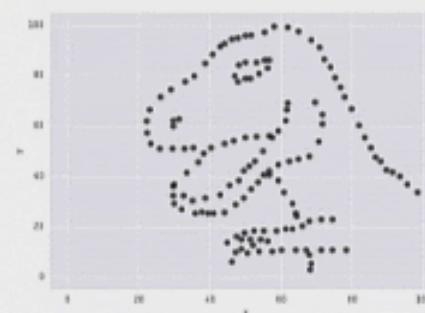
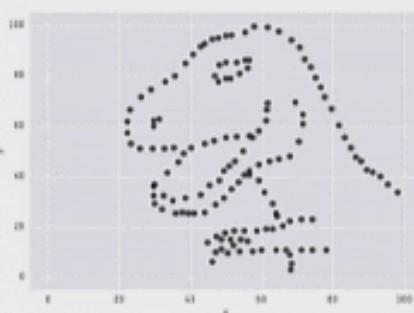
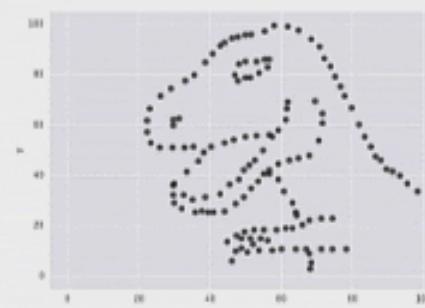
Mean of x	9.0
Variance of x	11.0
Mean of y	7.5
Variance of y	4.12
Correlation between x and y	0.816
Linear regression line	$y = 3 + 0.5x$

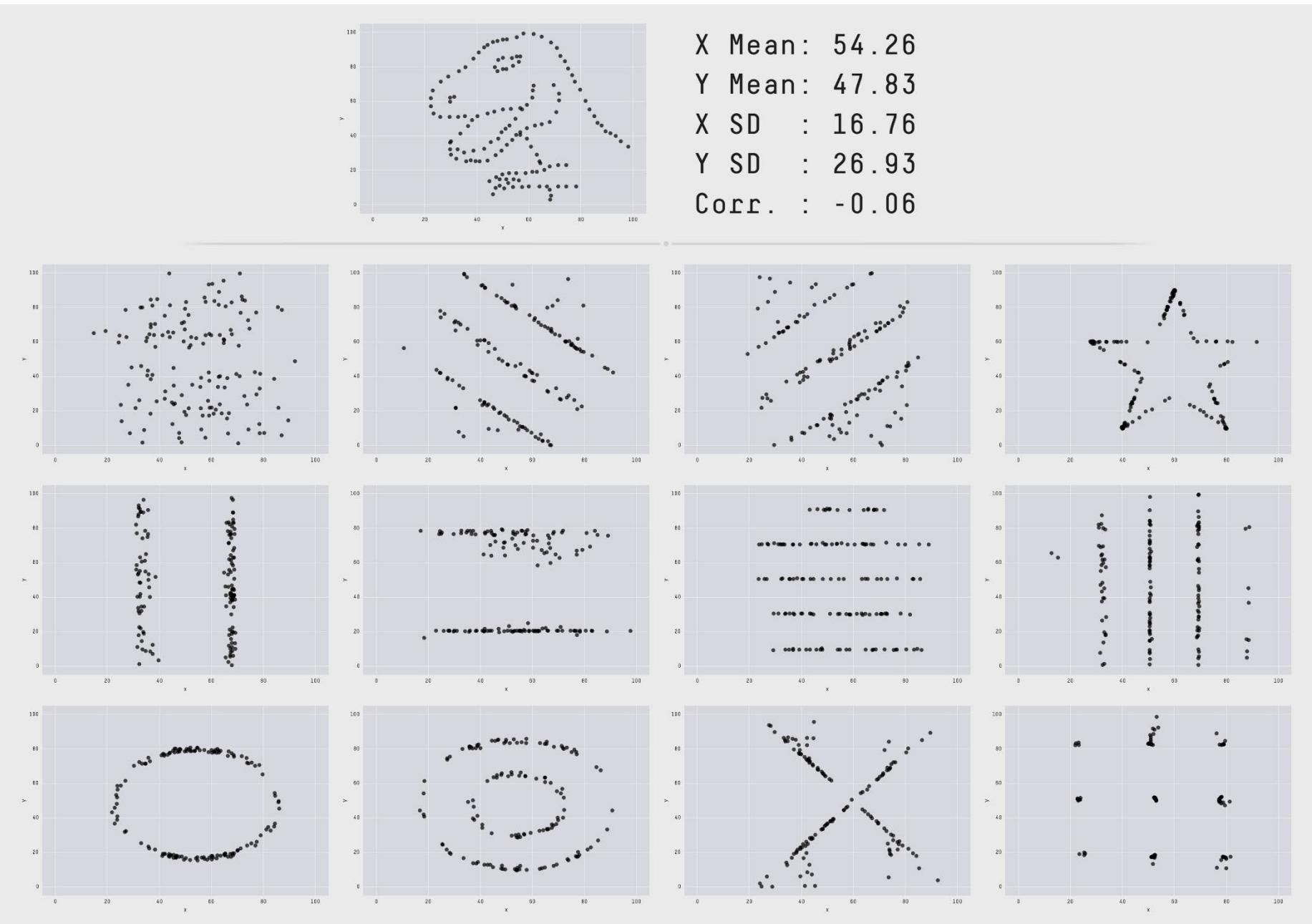
VISUAL REPRESENTATION OF THE DATA

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



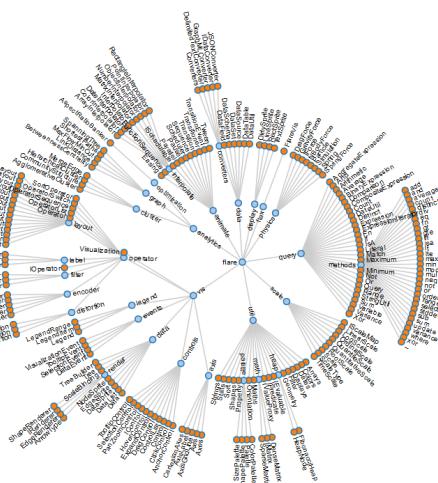




Why visual data representations?

- 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

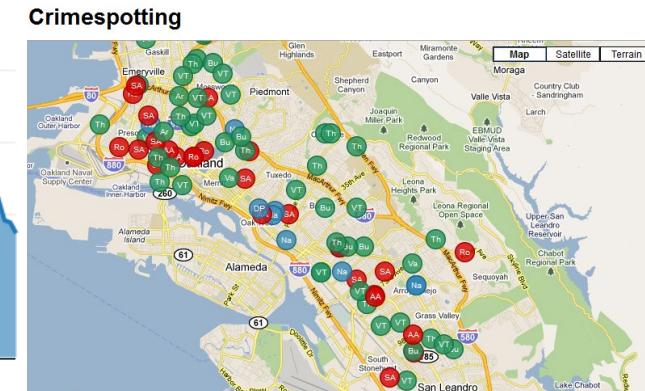
common examples:



graphs / hierarchies



charts



maps

Other benefits of visualization

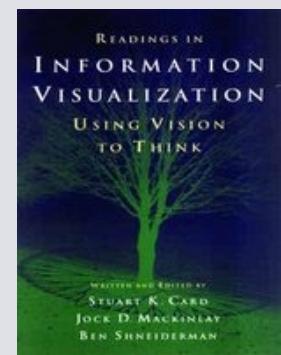
- expand human working memory
 - offload cognitive resources to the visual system,
- reduce search
 - by representing a large amount of data in a small space,
- enhance the recognition of patterns
 - by making them visually explicit
- aid monitoring of a large number of potential events
- provides a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

Visualization

- Create visual representation
- Includes interaction

Official Definition:

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

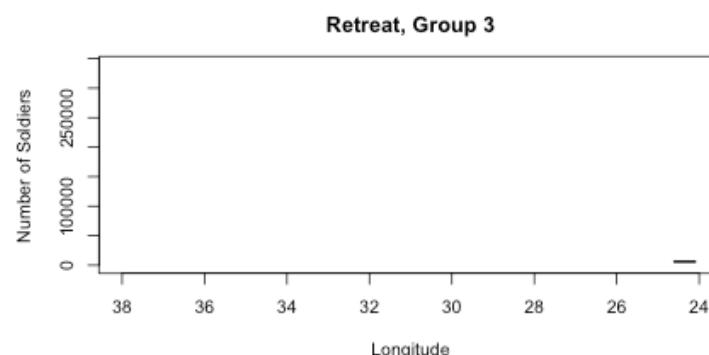
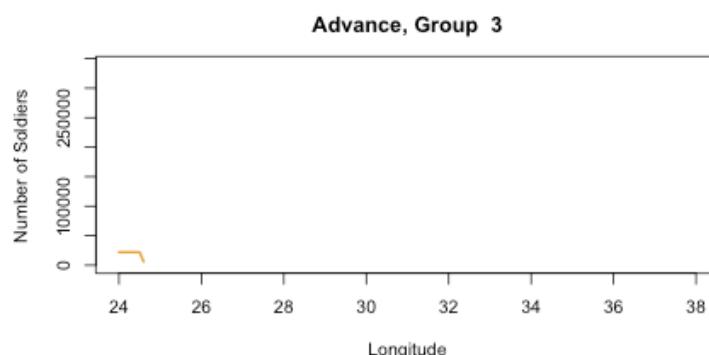
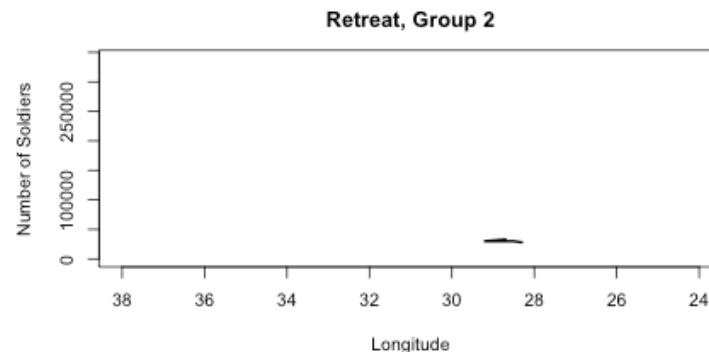
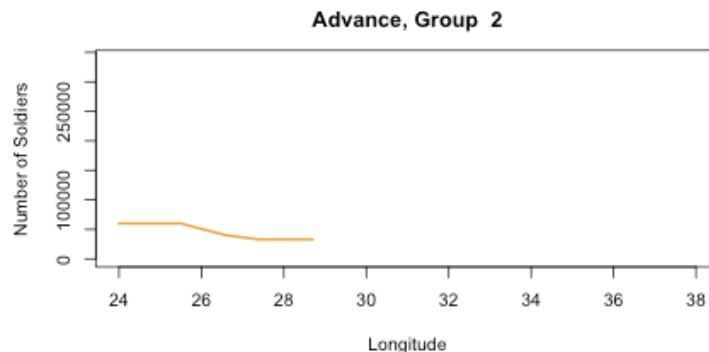
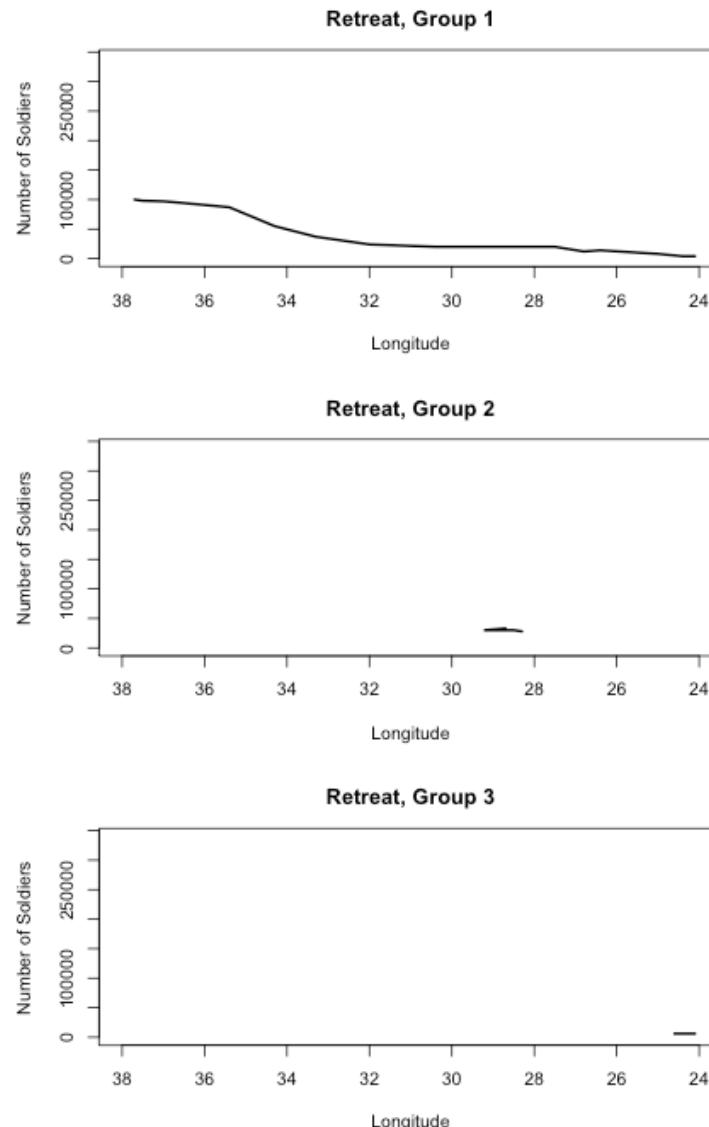
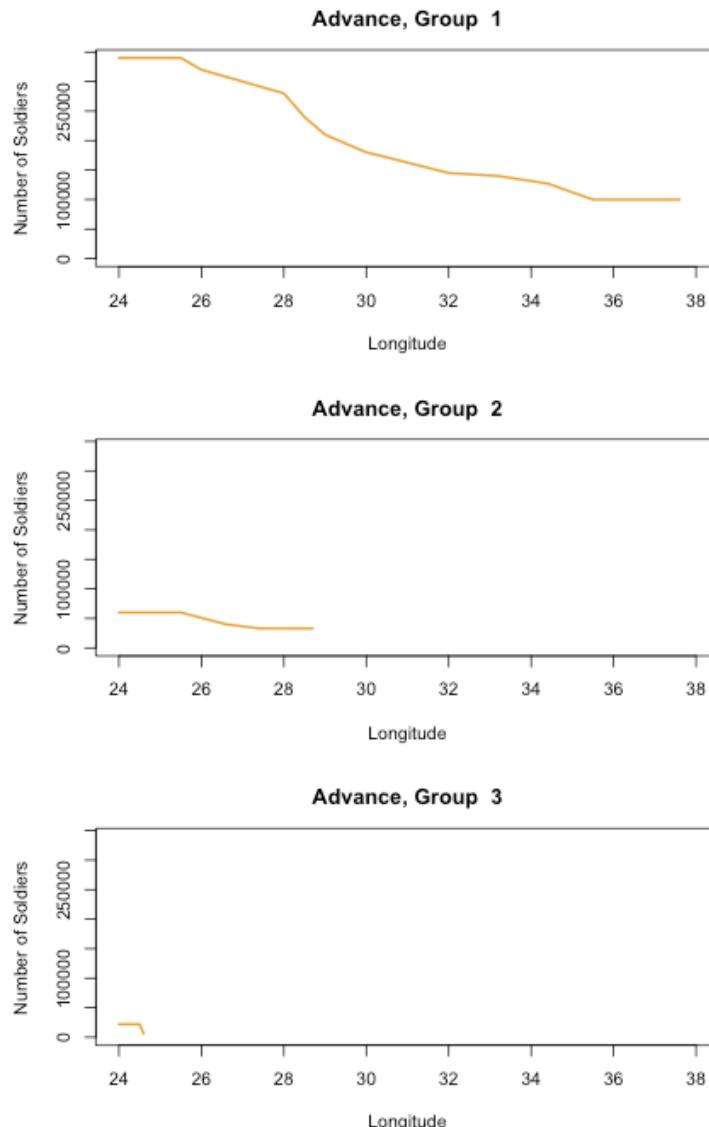


Hint: but there is more to it

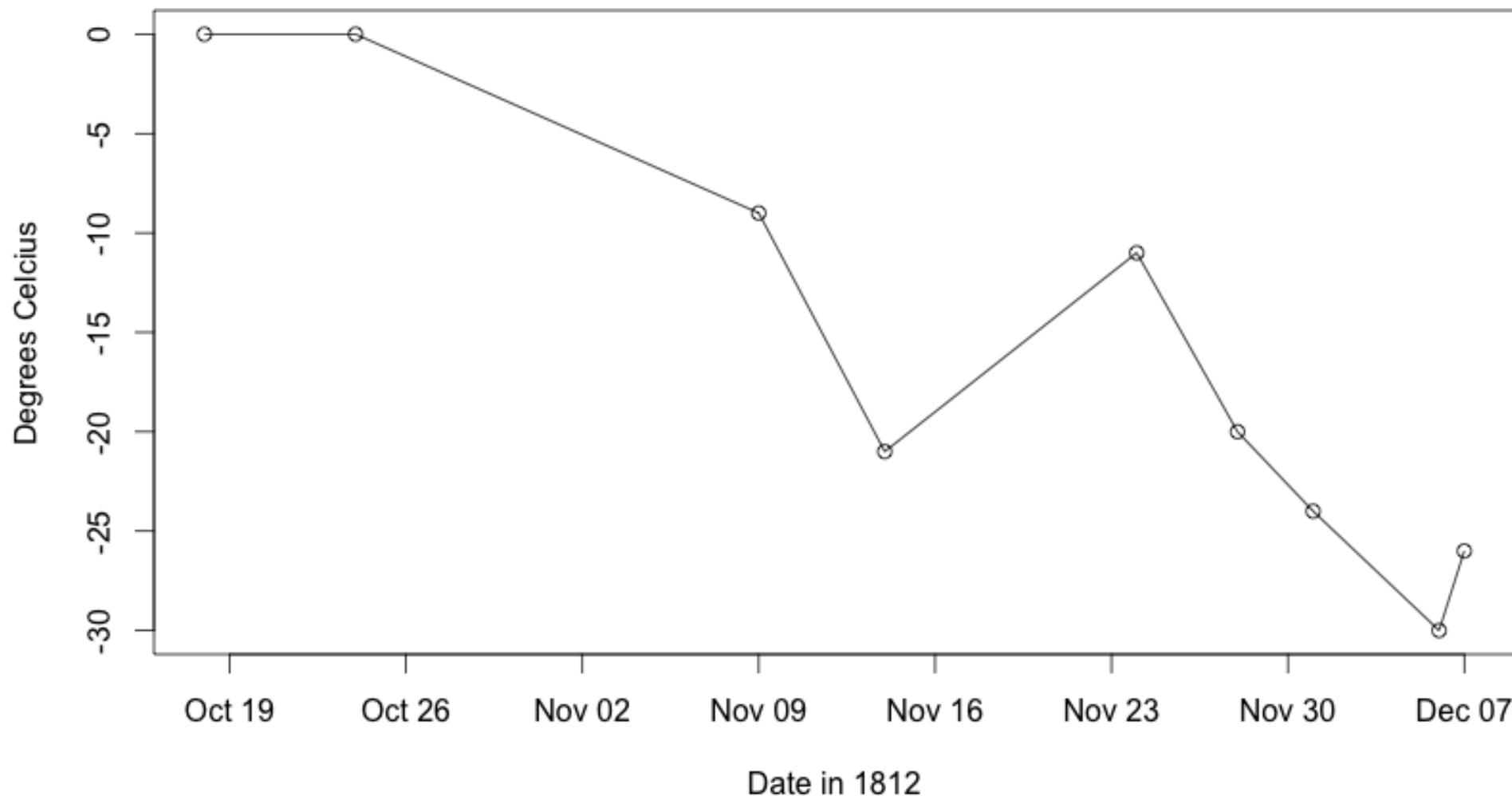
HISTORICAL EXAMPLES

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

NAPOLEON'S MARCH ON MOSCOW



Temperature During The Retreat

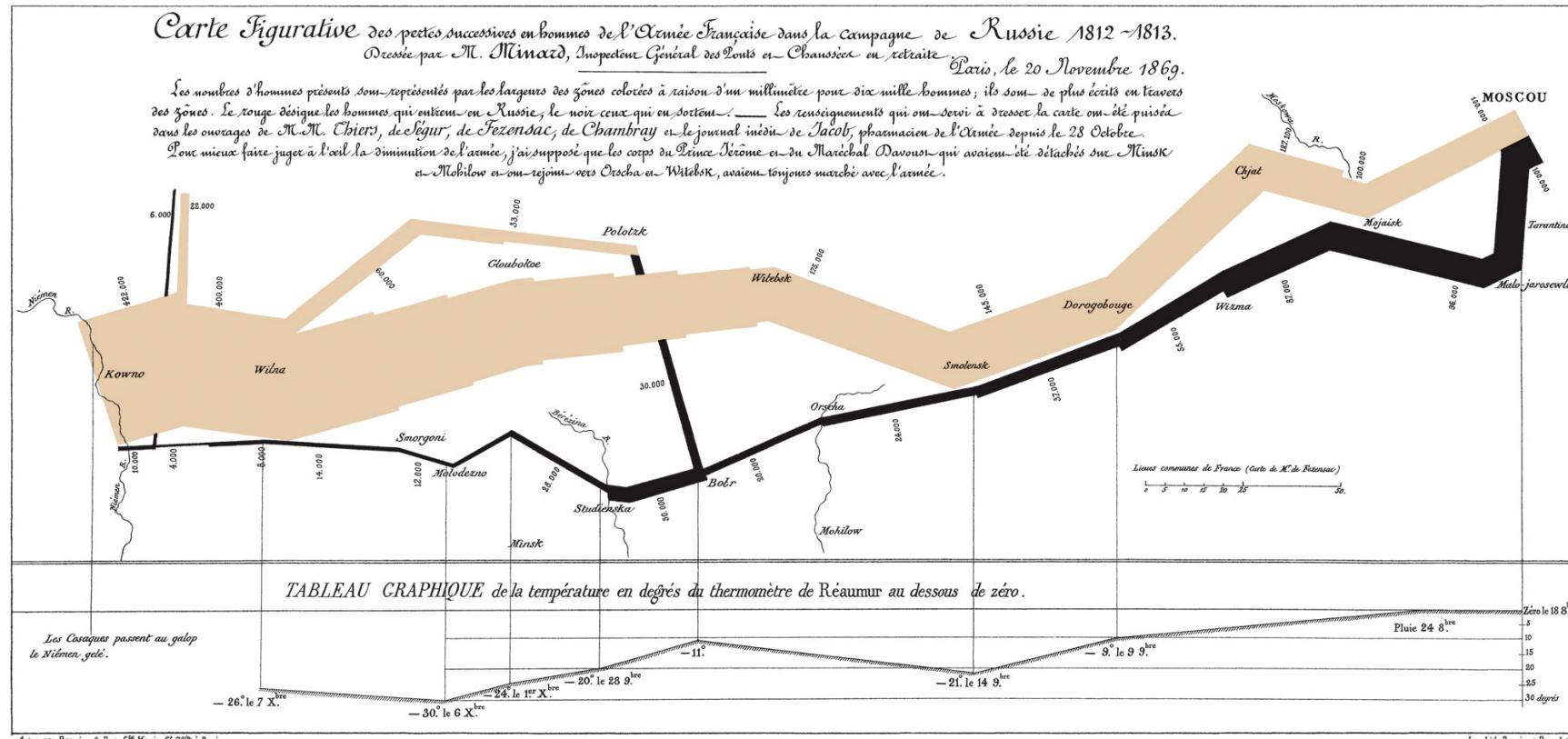




NAPOLEON'S MARCH ON MOSCOW

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



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 zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zones. 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. Chiers, 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 Davout qui avaient été détachés sur Minsk et Mobilow et qui rejoignirent vers Orscha et Witebsk, avaient toujours marché avec l'armée.

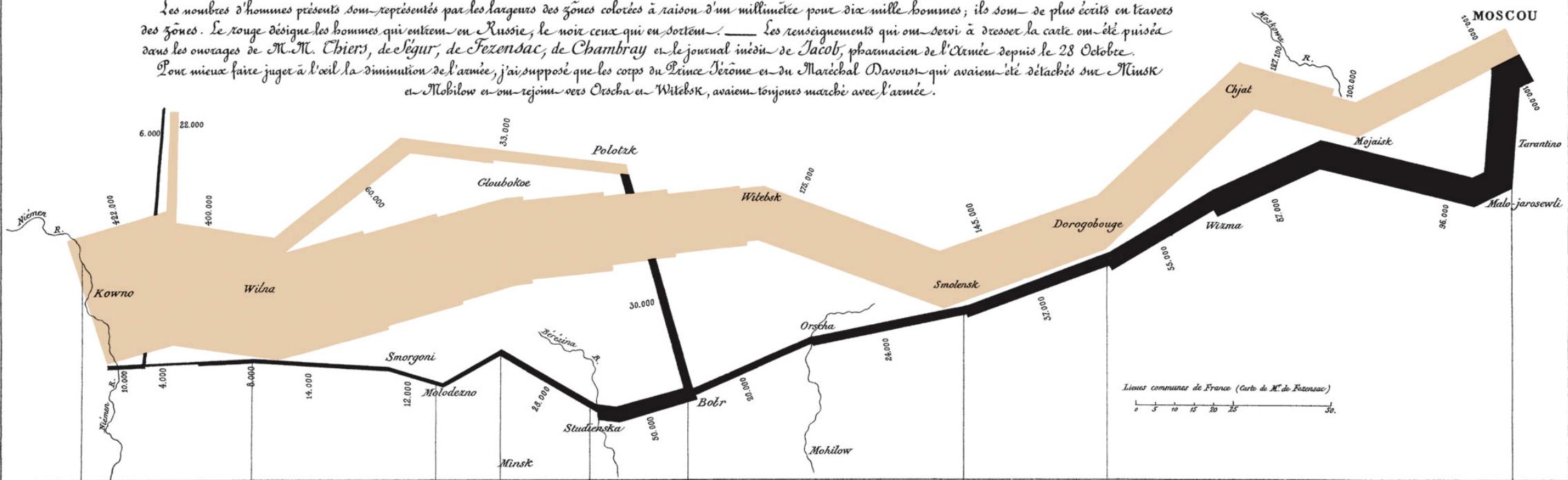
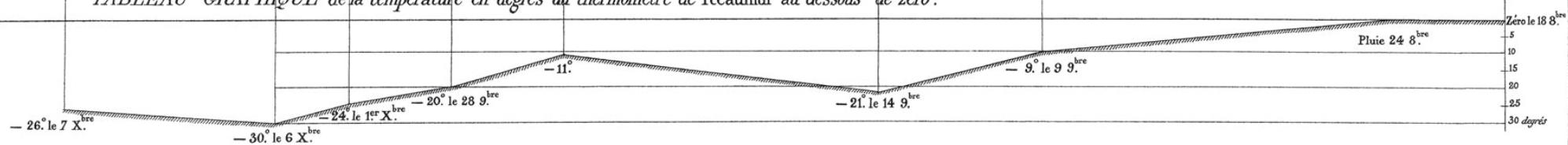


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les Cosaques passent au galop
le Niémen gelé.



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





TODAY

Visualizations are done by many people...



KANTAR Information is Beautiful Awards 2019

About News Awards Entry Showcase Sponsor Attend the Awards ceremony

Awards Challenges

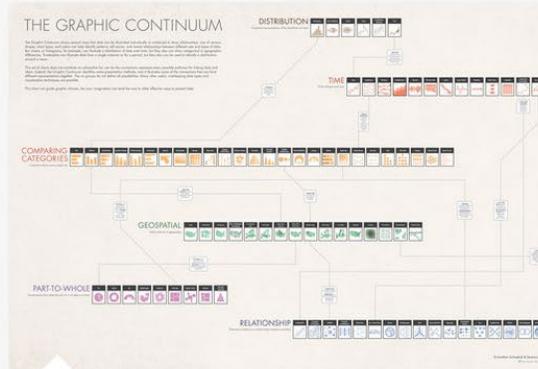
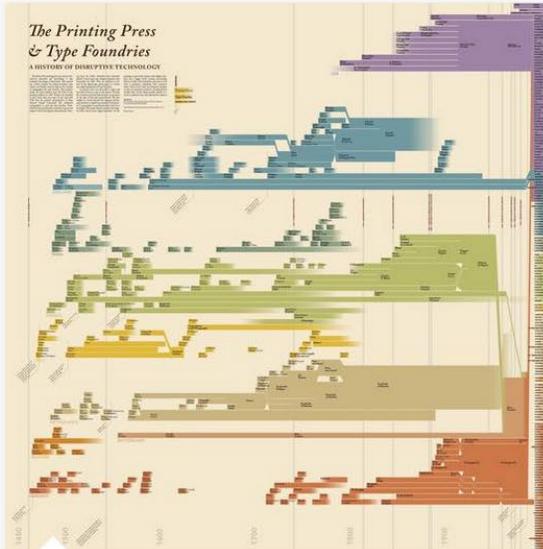
All 2019 2018 2017 2016 2015 2014 2013 2012

Google for beautiful examples

Gold Silver Bronze Rising Star Outstanding Individual Best-Non-English-Language Outstanding Outfit Student

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...

Enthusiasts, freelancer, ...

Where Have All the Houses Gone?

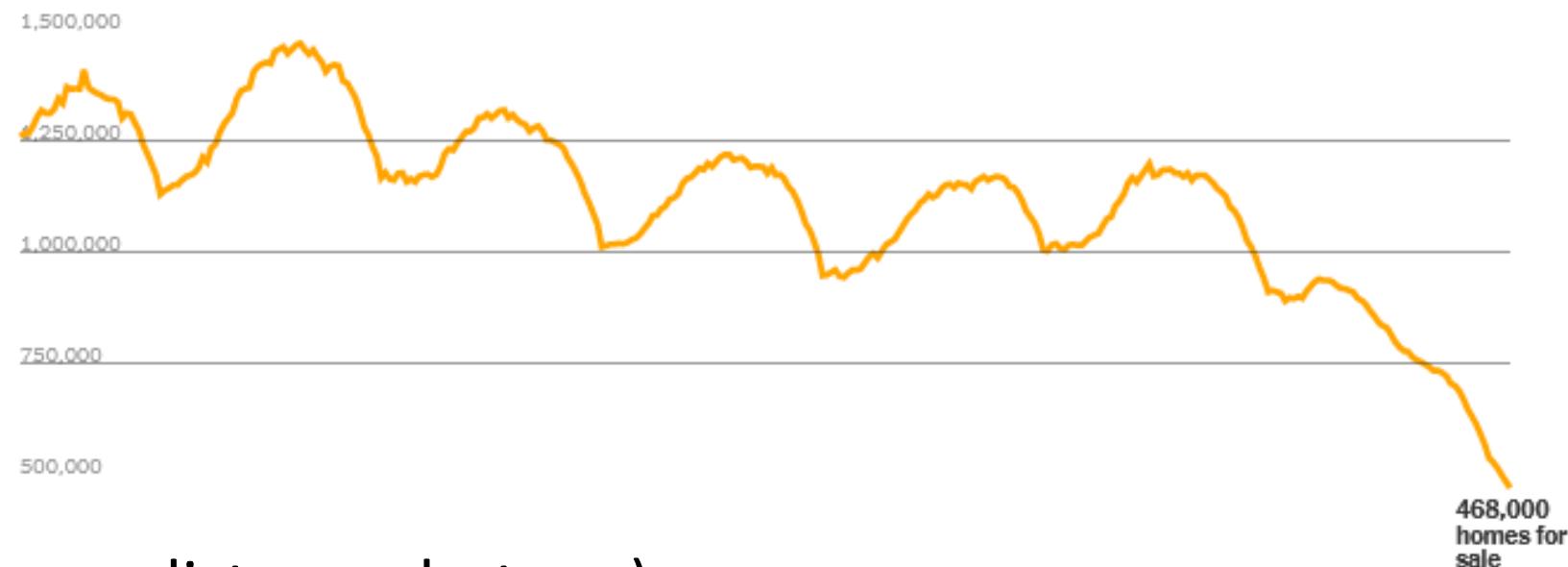
The inventory of homes for sale is startlingly low. The pandemic is part of the reason, but it's not the whole story.



By [Emily Badger](#) and [Quoc Trung Bui](#)

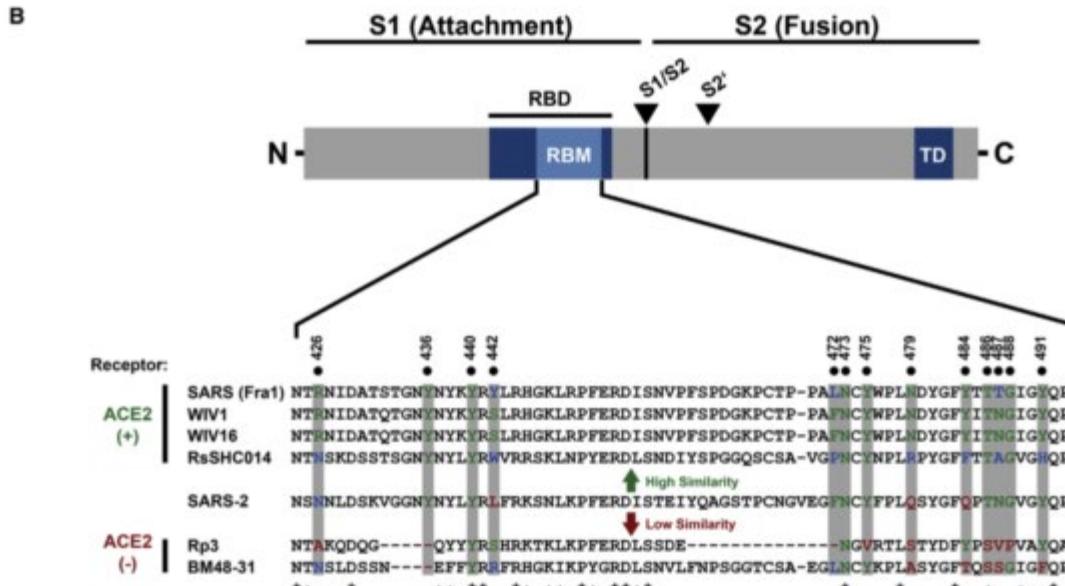
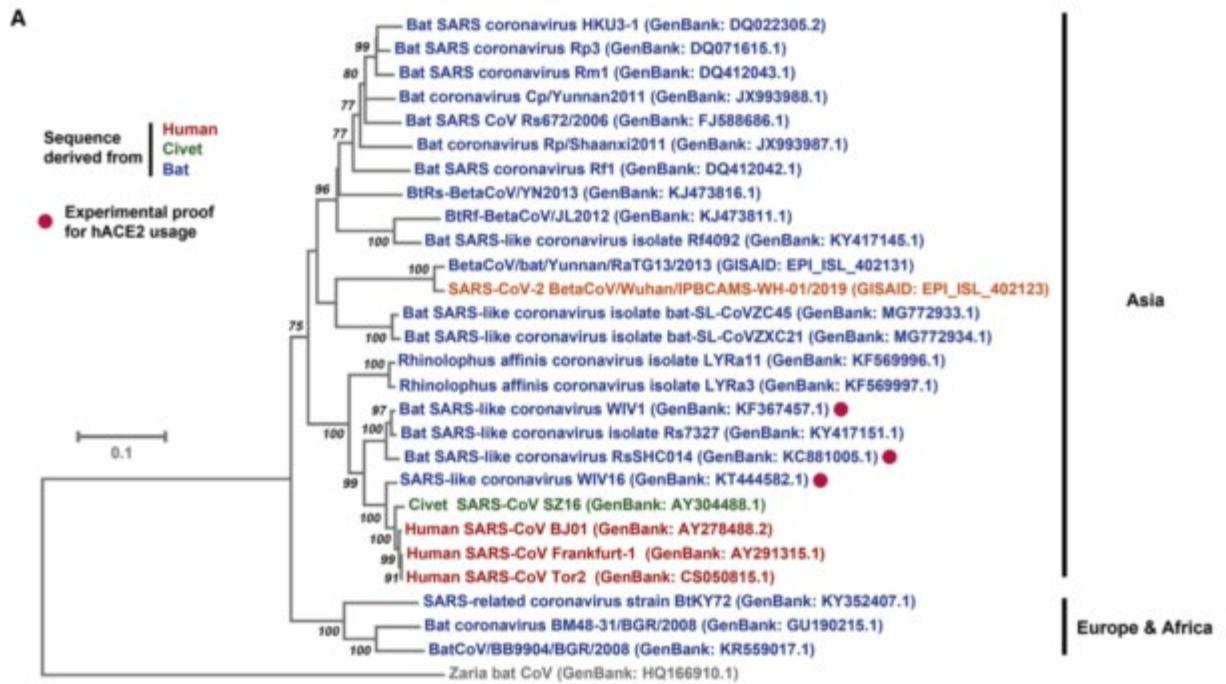
Published Feb. 26, 2021 Updated March 2, 2021

The number of homes for sale nationally has plummeted



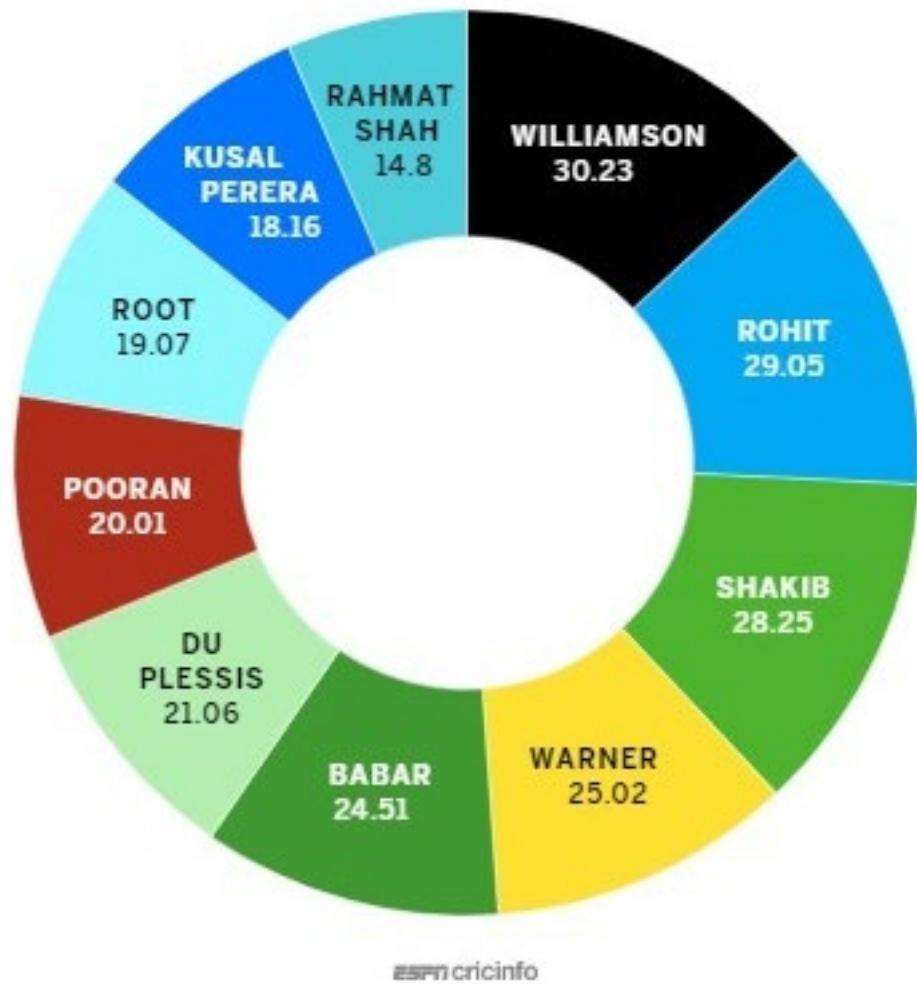
Professionals (journalists, analysts, ...)

Markus Hoffmann, Hannah Kleine-Weber, Simon
 Schroeder, Nadine Krüger, Tanja Herrler, Sandra
 Erichsen, Tobias S. Schiergens, Georg Herrler, Nai-Huei
 Wu, Andreas Nitsche, Marcel A. Müller, Christian
 Drosten, Stefan Pöhlmann,
 SARS-CoV-2 Cell Entry Depends on ACE2 and TMPRSS2
 and Is Blocked by a Clinically Proven Protease Inhibitor,
Cell,
 Volume 181, Issue 2,
 2020,



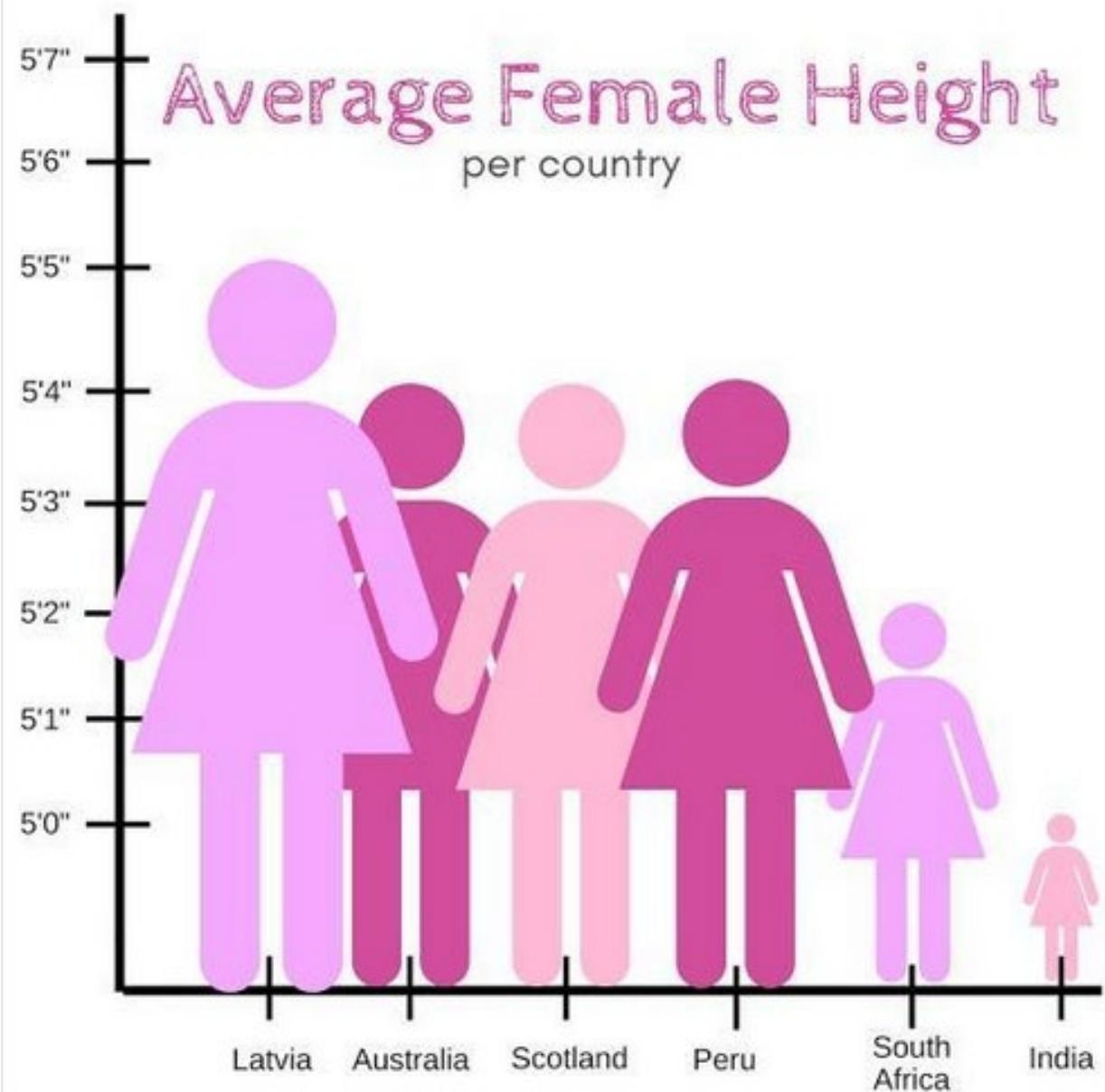
THE WORLD CUP'S BIG GUNS

% OF TEAM'S RUNS SCORED BY TOP SCORER



Average Female Height

per country



People who shouldn't

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/>
 - <https://badvisualisations.tumblr.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)

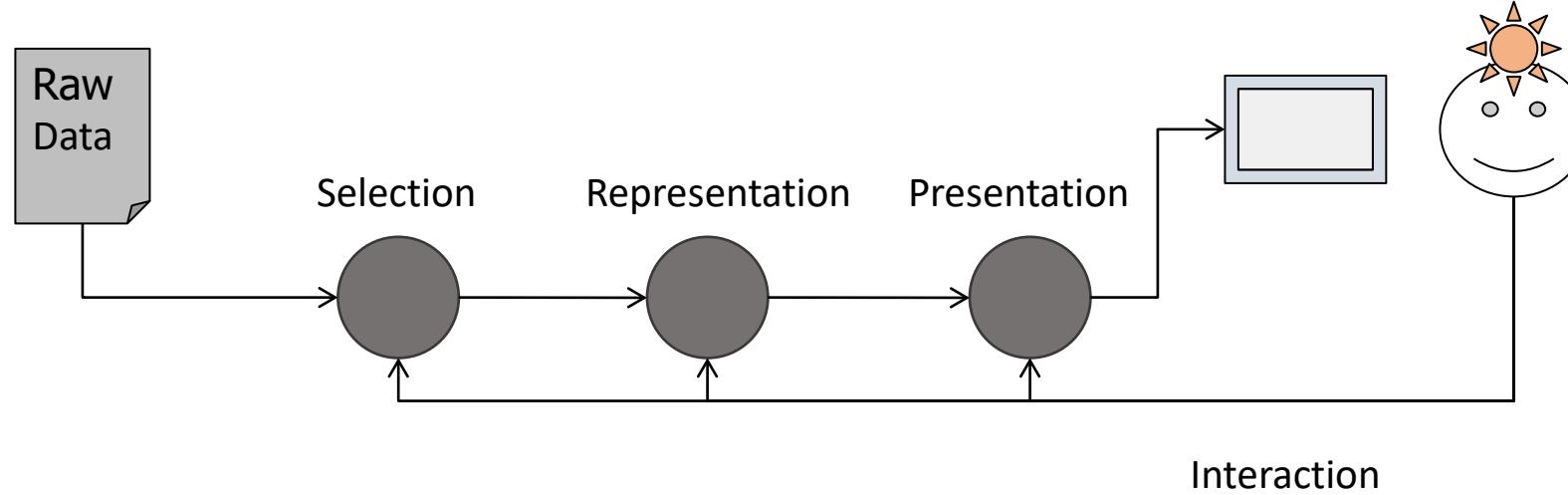
It is difficult to create

good ↑

VISUALIZATIONS



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

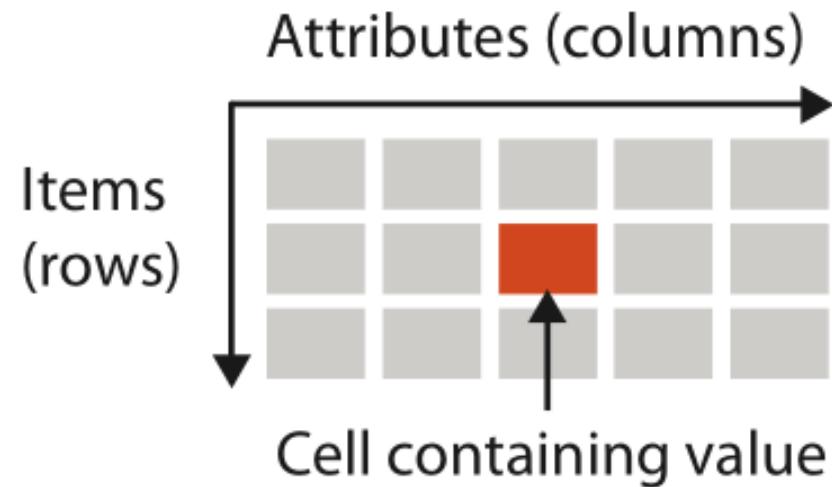
DATA

- 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

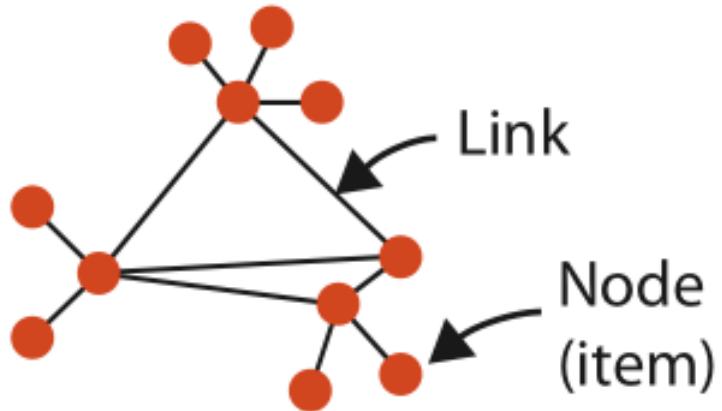


Example:

Items: drinks

Attributes: color, calories, name, ...

NETWORKS



Example:

Item = nodes: people

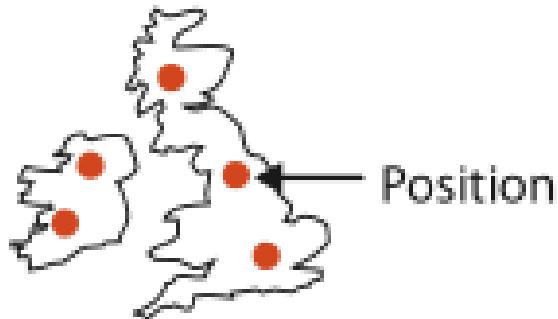
Item = links: co-authorship

Node attributes: name, experience, ...

Link attributes: #of papers

GEOMETRY (SPATIAL)

Specifies information about the shape of items with explicit spatial position



Item = countries

Positions = location on the planet

ATTRIBUTE TYPES

Data types, column types

- Nominal (sometimes called categorical)

- Fruits: apples, oranges



- Can be compared =, ≠

- Ordered

- Ordinal

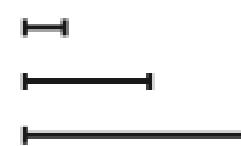
- T-shirt sizes: S, M, L, XL



- Can be compared & ordered, but not measured: =, ≠, <, >

- Quantitative

- Counts and amounts, 5kg / 10kg



- you can do =, ≠, <, >, - , +, ×, ÷

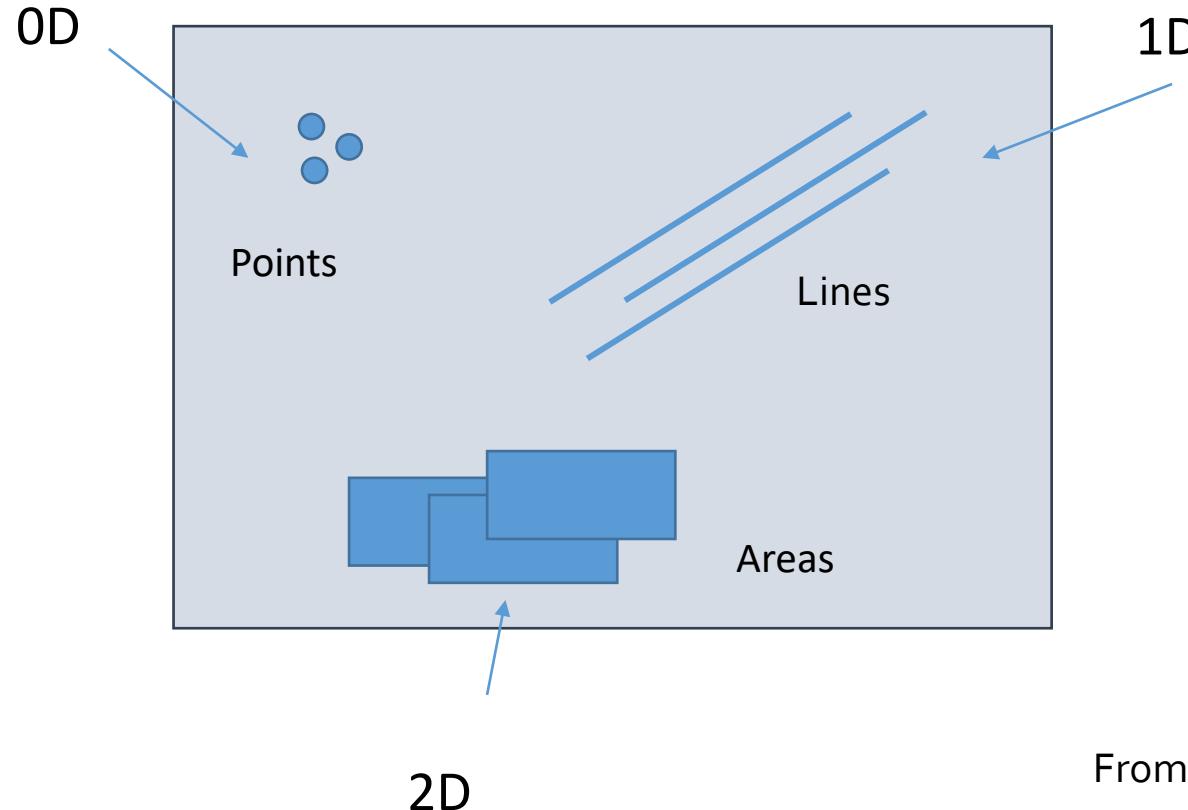
WHY IS THIS IMPORTANT?

- 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

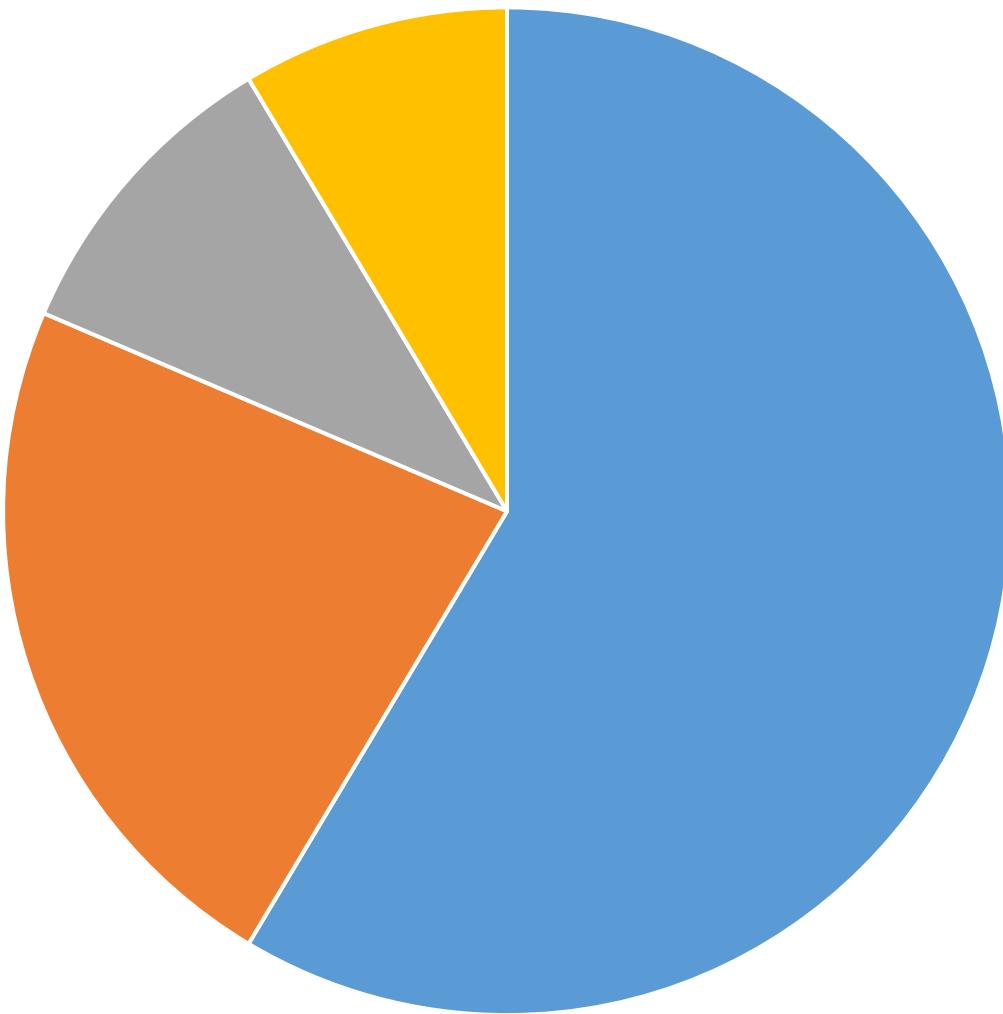
Basic geometric element data depict items or links



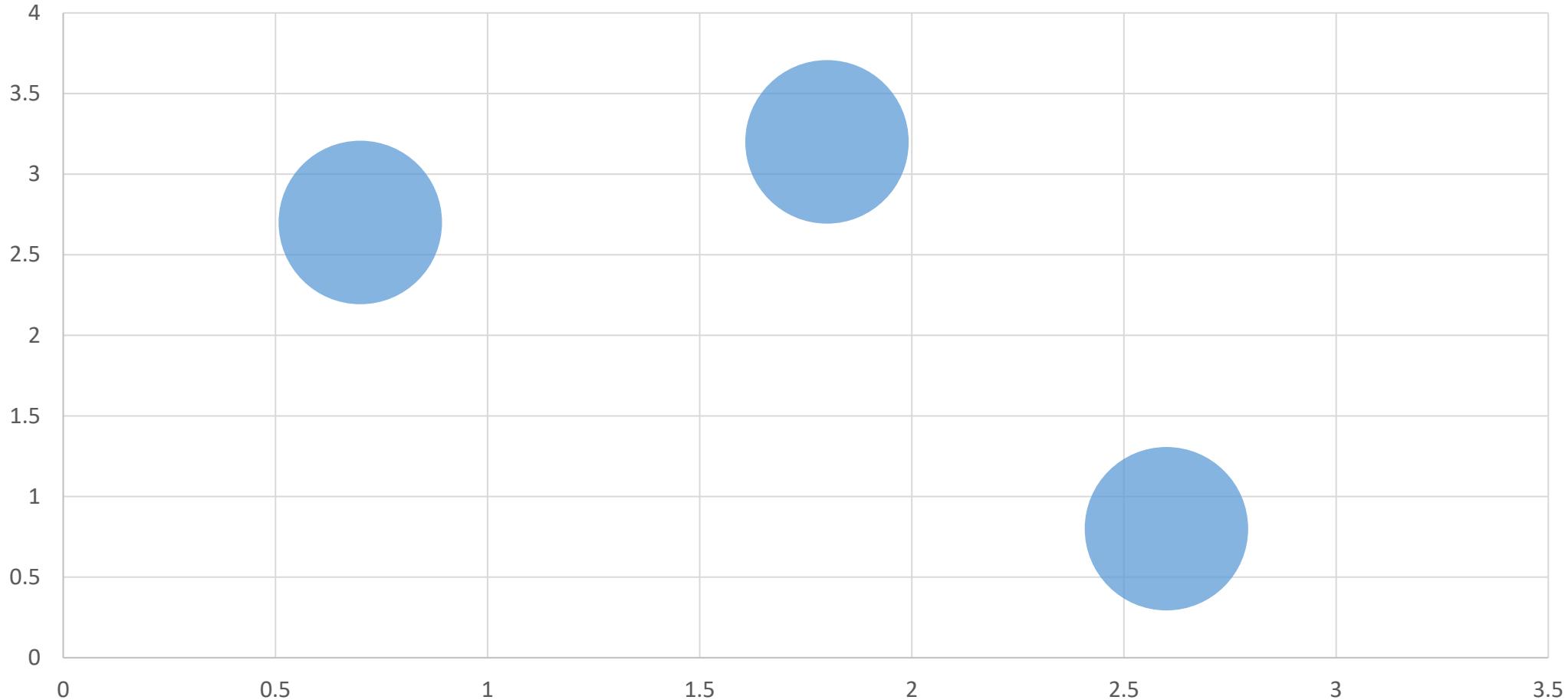
which marks do you see?



which marks do you see?



which marks do you see?

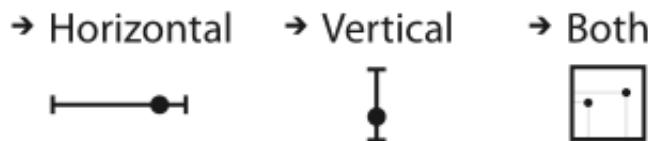


VISUAL CHANNELS

Also often called visual variables

Modify marks
independent of the
dimensionality of the
mark

④ Position



④ Color



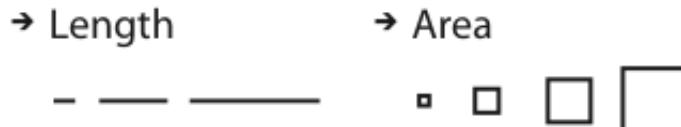
④ Shape



④ Tilt / angle

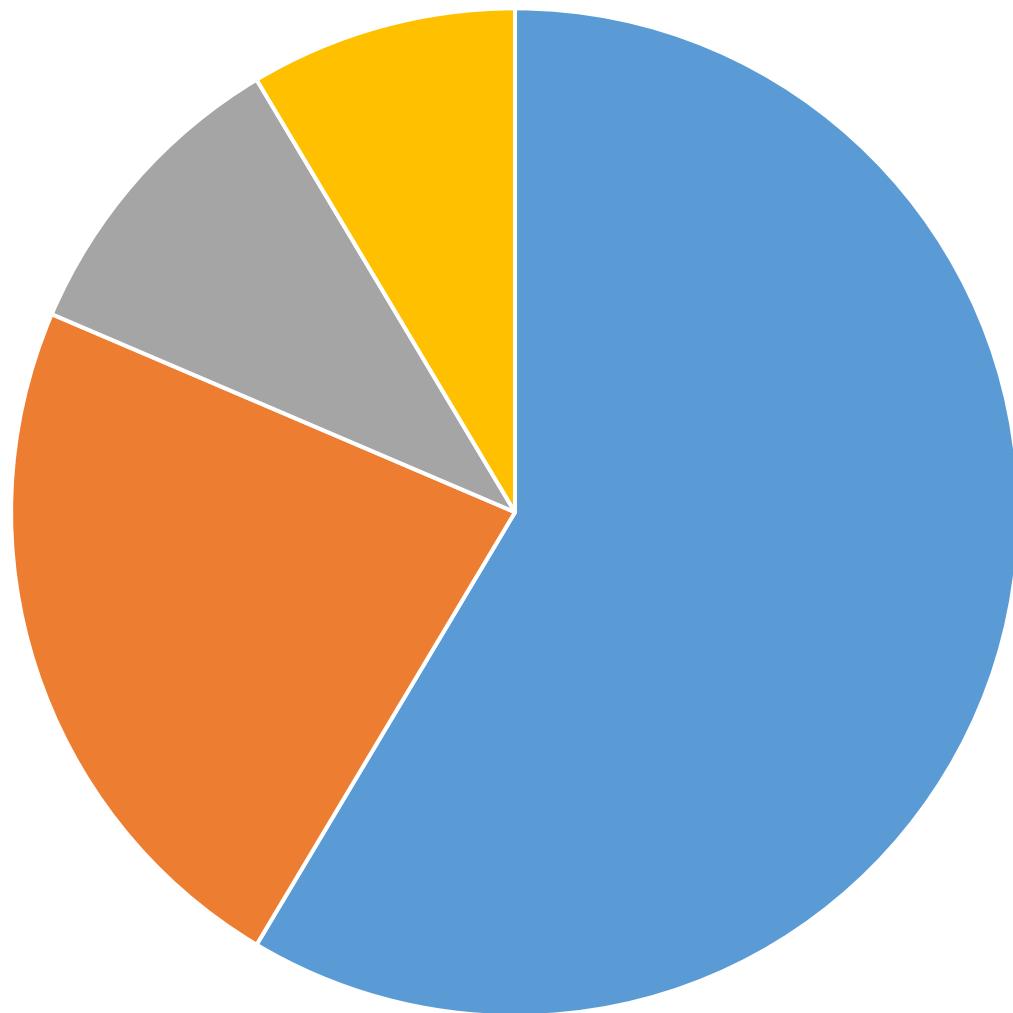


④ Size



These are the most common but there are more

which visual channels encode data?



↪ Position

- Horizontal
 - Vertical
 - Both
-

↪ Color



↪ Shape



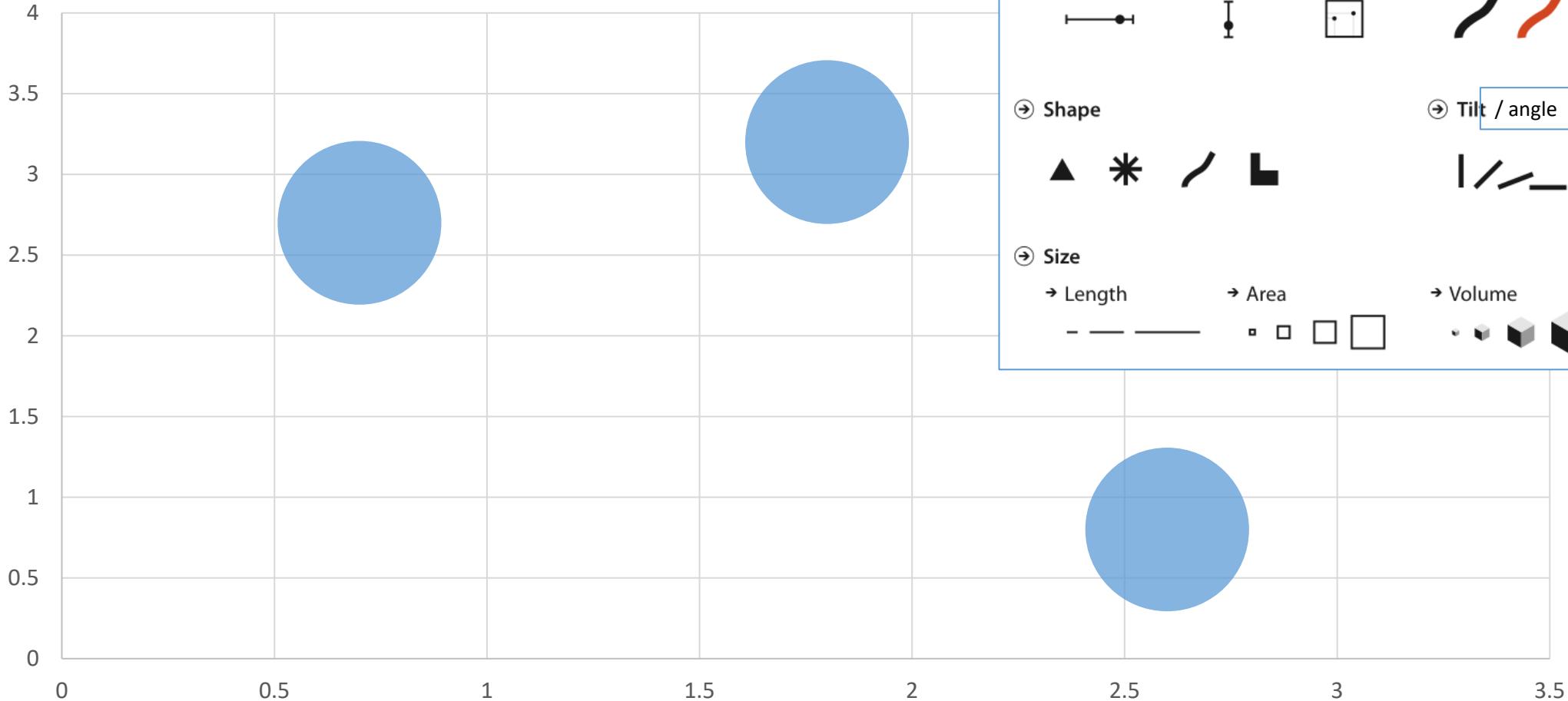
↪ Tilt / angle



↪ Size

- Length
 - Area
 - Volume
-

which visual channels encode data?



ADDITIONAL CHANNELS

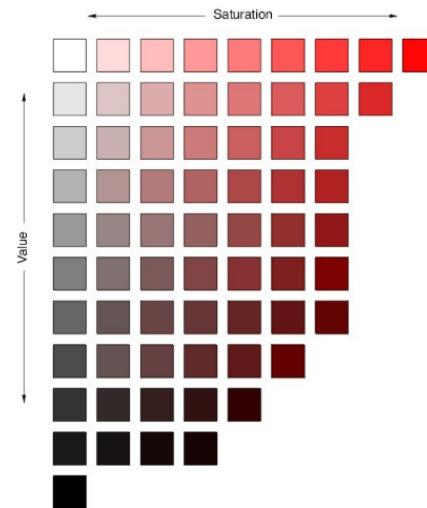
- **motion**

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



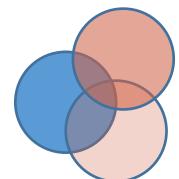
- **saturation**

- 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 of, and only**, the information in the attributes
(nothing more, nothing less) (columns)

Example:

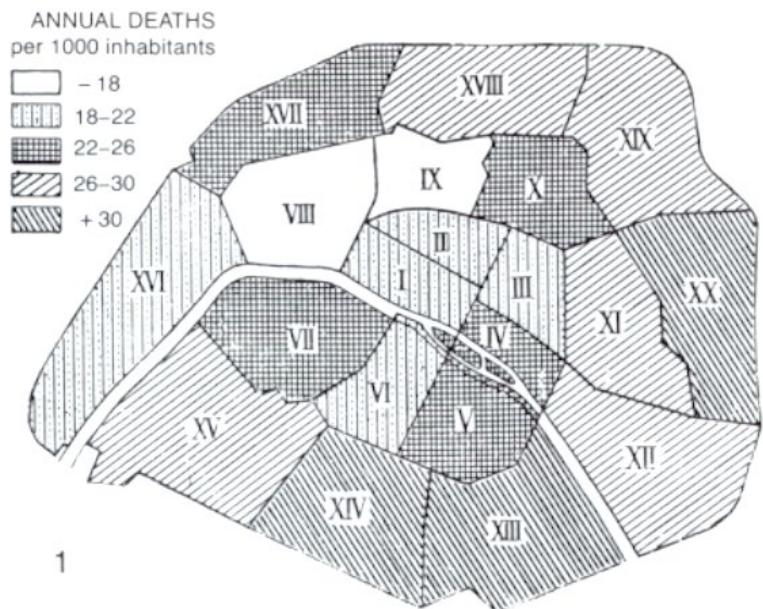
*an ordered attribute needs to look ordered,
an unordered attribute should not*



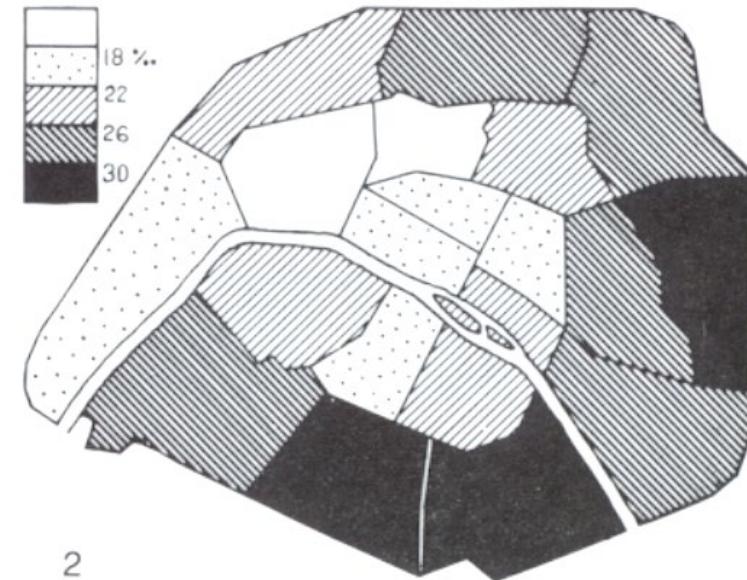
This mismatch is a common beginner's mistake

EXPRESSIVENESS

luminance is ordered, cannot be reordered



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

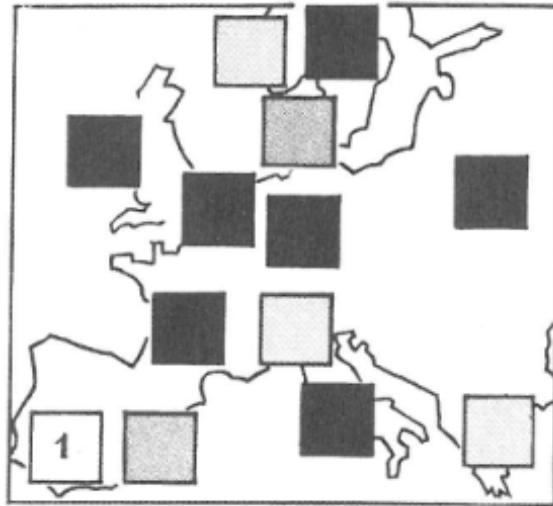


Values ordered correctly
Image much more useful

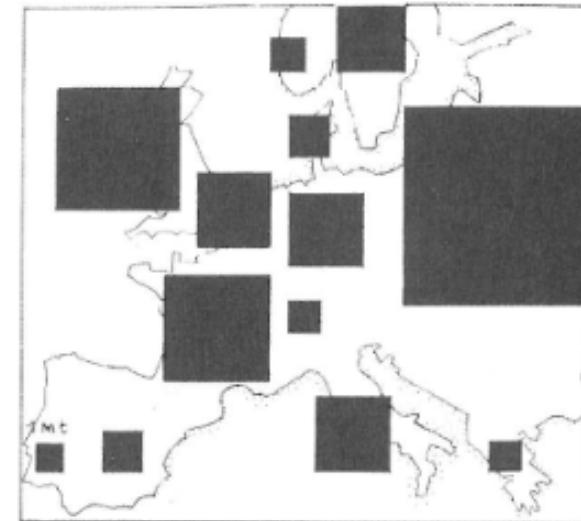
annual deaths per 1000 inhabitants, Paris

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.

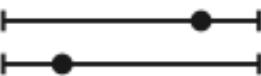
Separability: How much interaction there is with multiple encodings.

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

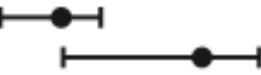
Grouping: How good a channel is in conveying groups.

→ **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



Same □ Same □ Same □ Same □

Color saturation



Curvature



Volume (3D size)



→ **Identity Channels: Categorical Attributes**

Spatial region



Color hue



Motion



Shape



▲ Most

Effectiveness

▼ Least

We will look at effectiveness a lot more throughout the lectures

VISUALIZATION TOOLS AND PARADIGMS



UNIVERSITY OF
CALGARY

Slides adapted from Wesley Willett

**HOW CAN WE GENERATE GRAPHICAL
REPRESENTATIONS?**

**WHAT TOOLS ARE CURRENTLY THE
MOST INTERESTING?**

**WHEN & WHY TO CHOOSE DIFFERENT
APPROACHES?**

DRAW USE CODE

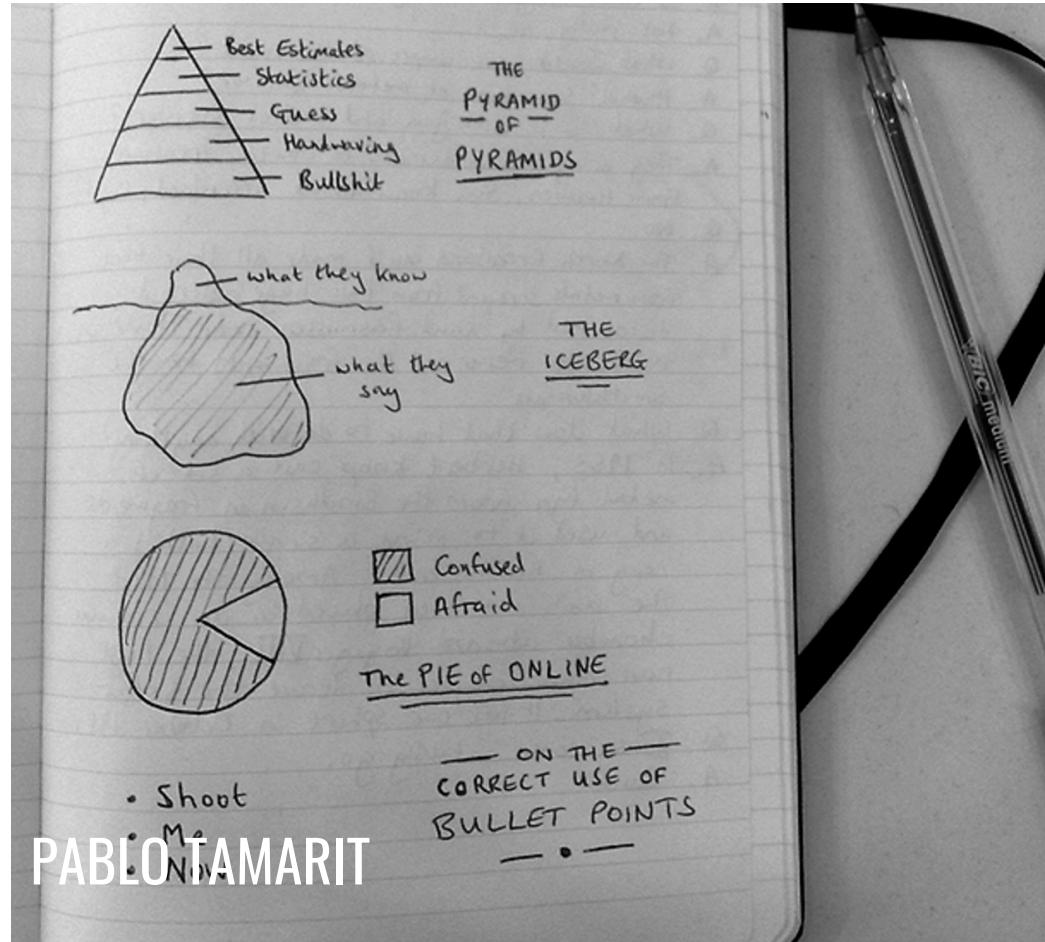
BRET VICTOR



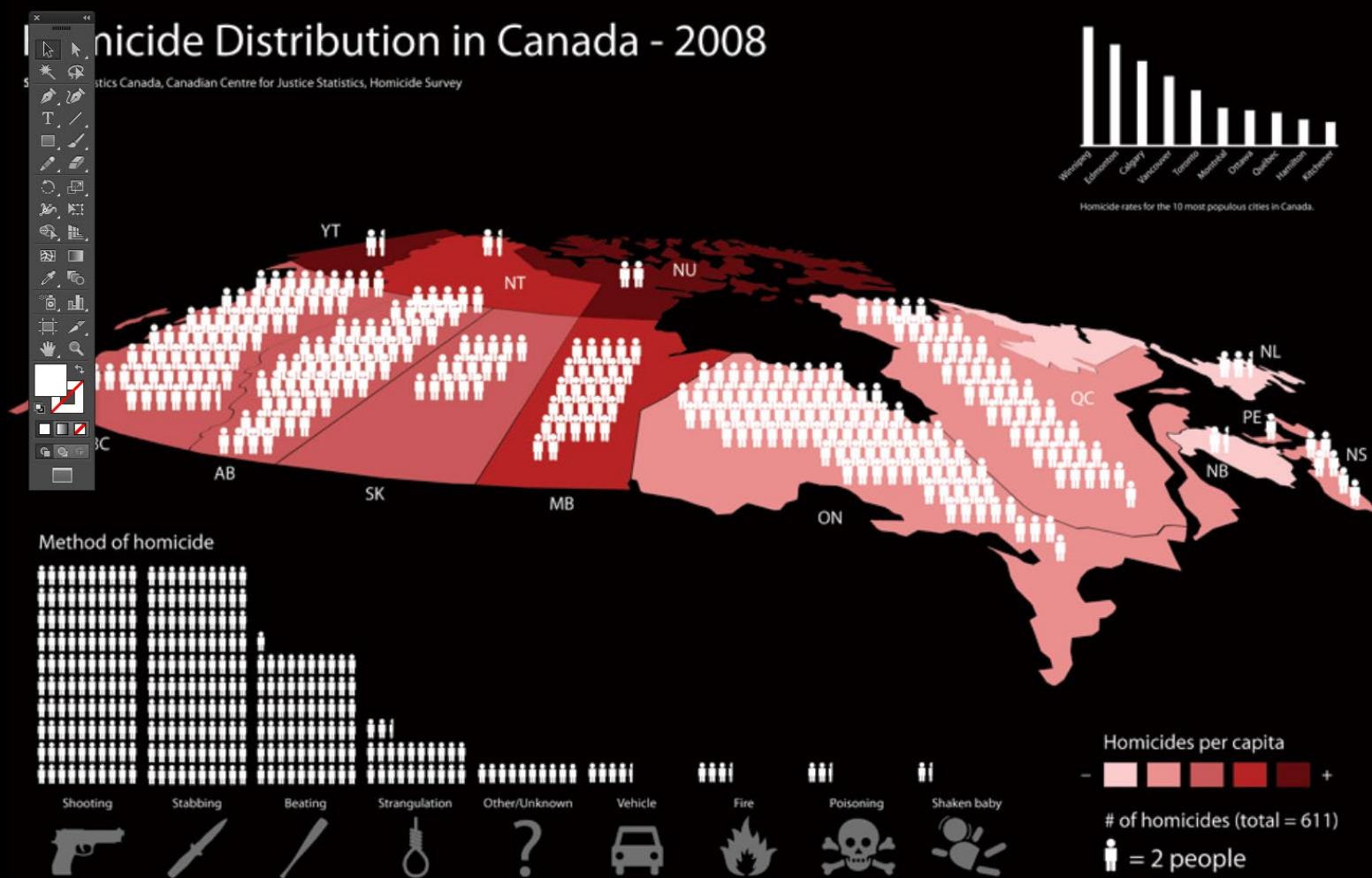
DRAWING DYNAMIC VISUALIZATIONS
<https://vimeo.com/66085662>

DRAW

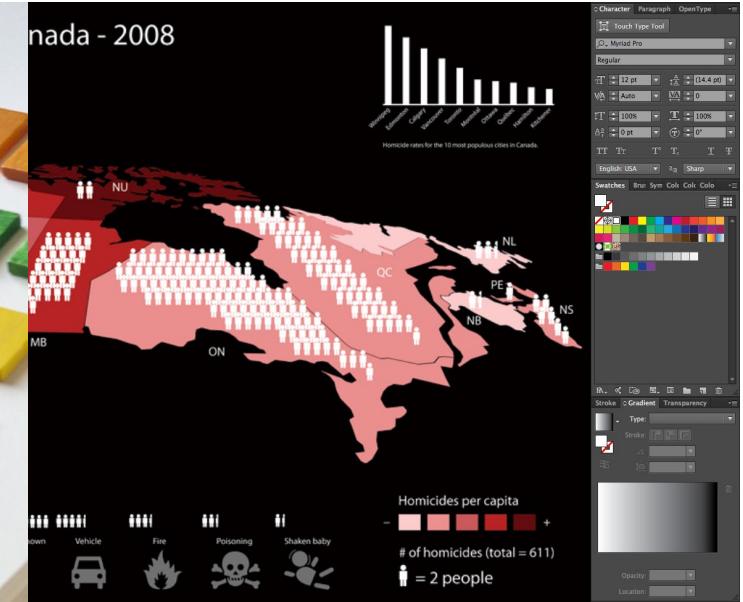
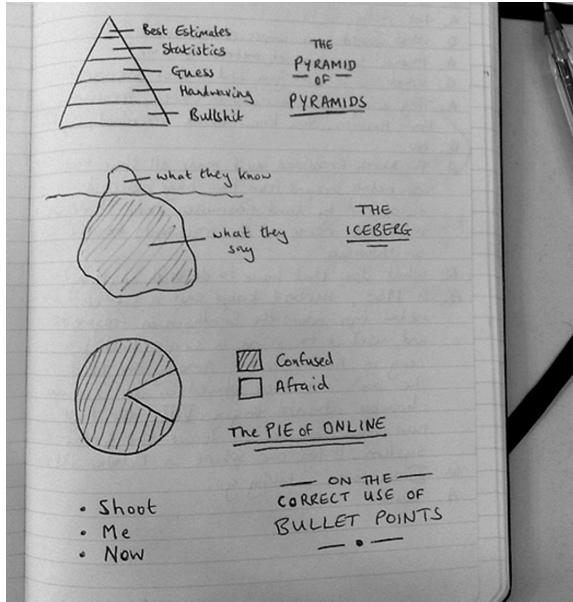
SKETCHING / CONSTRUCTING BY HAND



GRAPHIC DESIGN SOFTWARE (ILLUSTRATOR, PHOTOSHOP, ETC.)



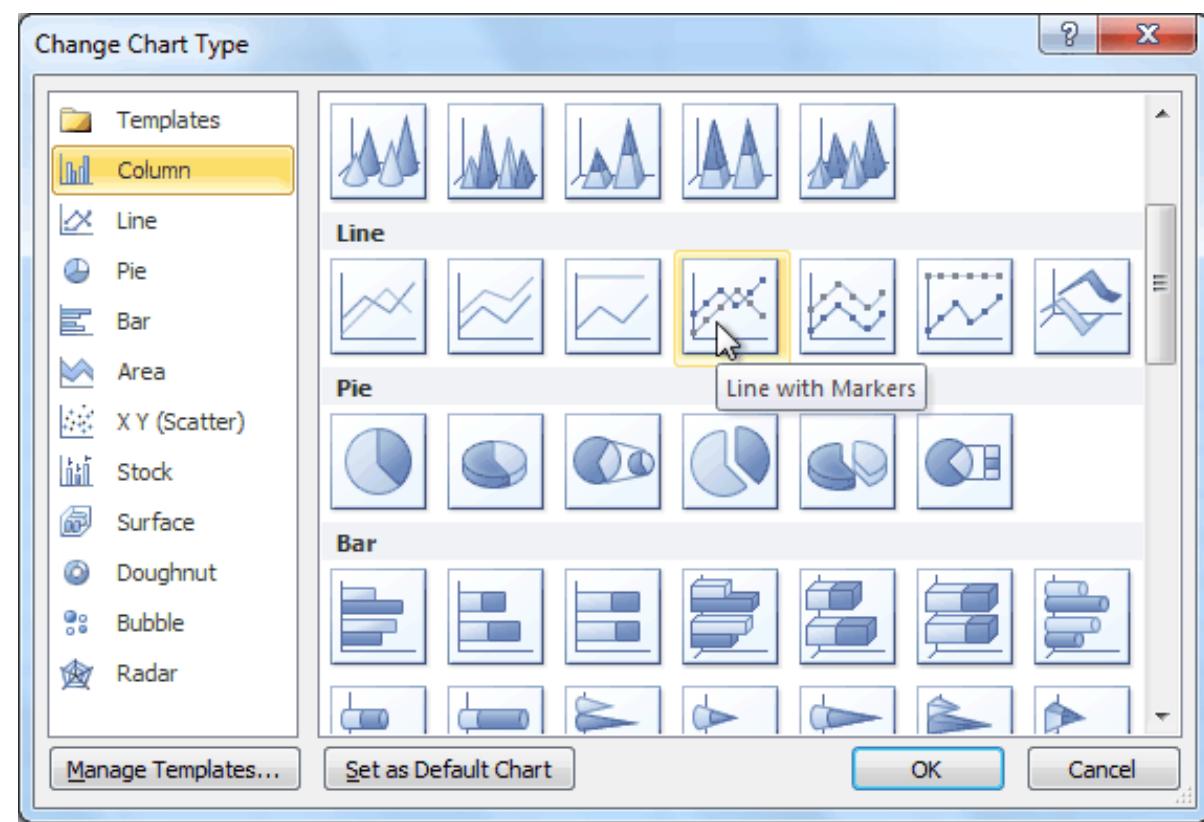
<http://www.kristinaneuman.com/>



DRAW
+ FLEXIBLE & EXPRESSIVE
- SCALES BADLY
- DESIGNS ARE ONE-OFFS

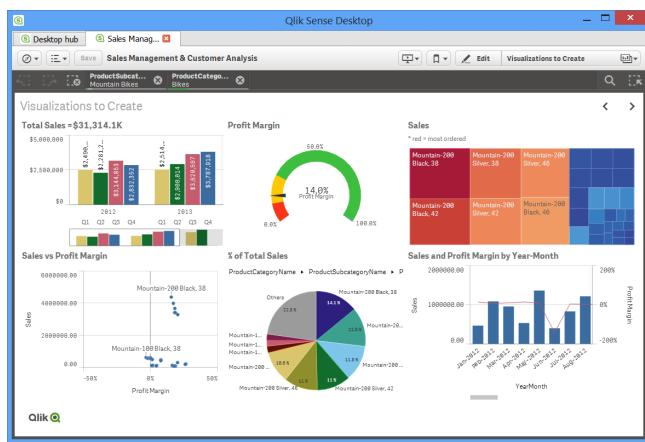
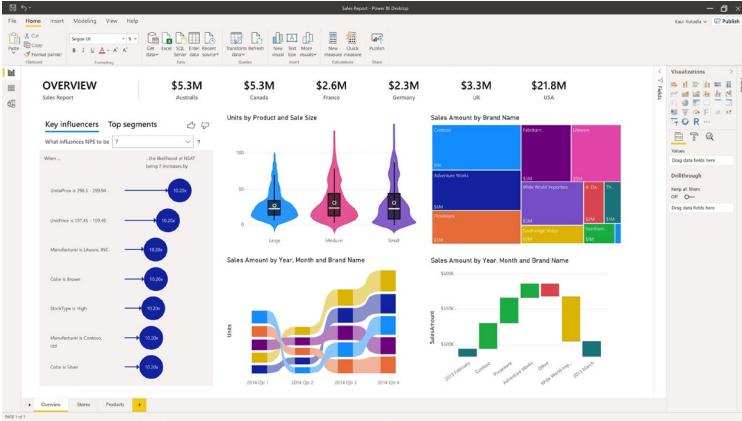


USE

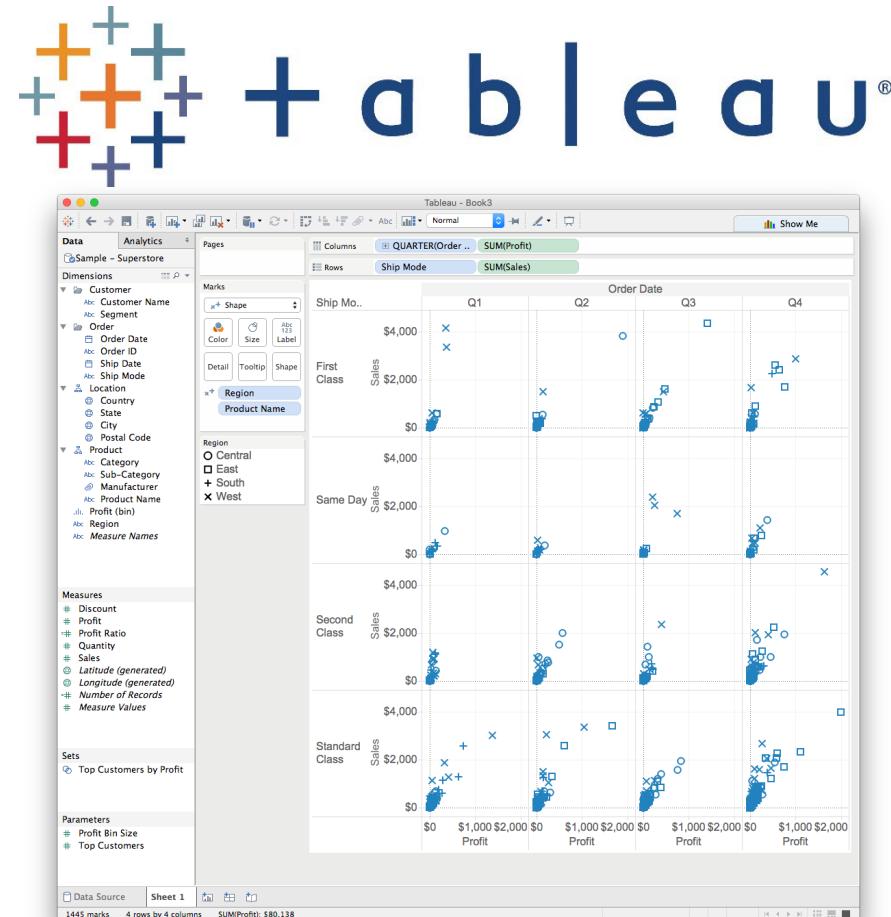


INTERACTIVE TOOLS

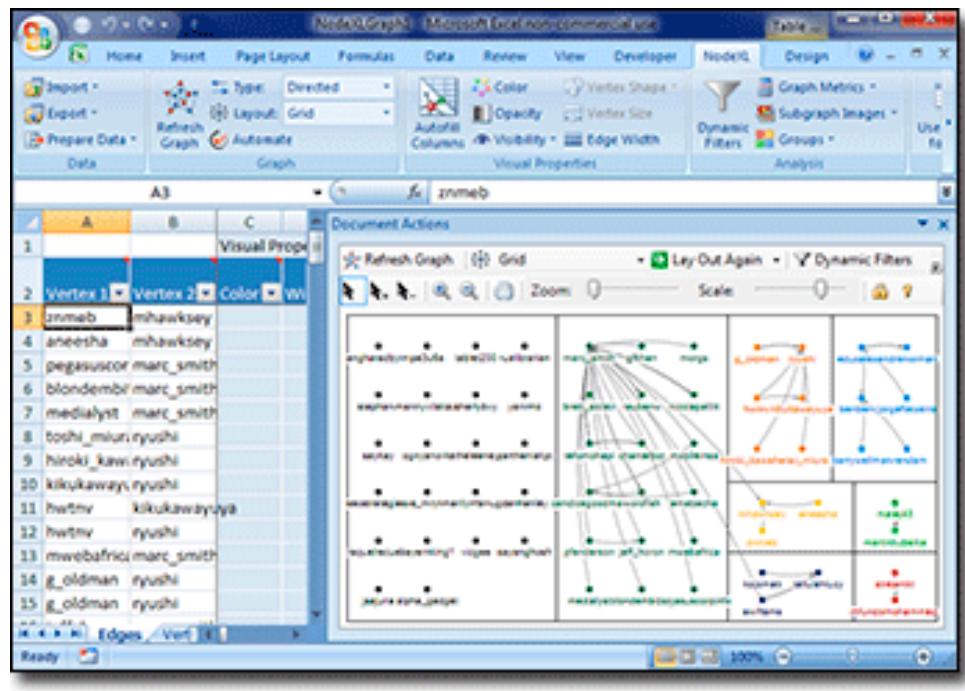
Power BI



Qlik



NETWORK AND GRAPH DATA



NodeXL

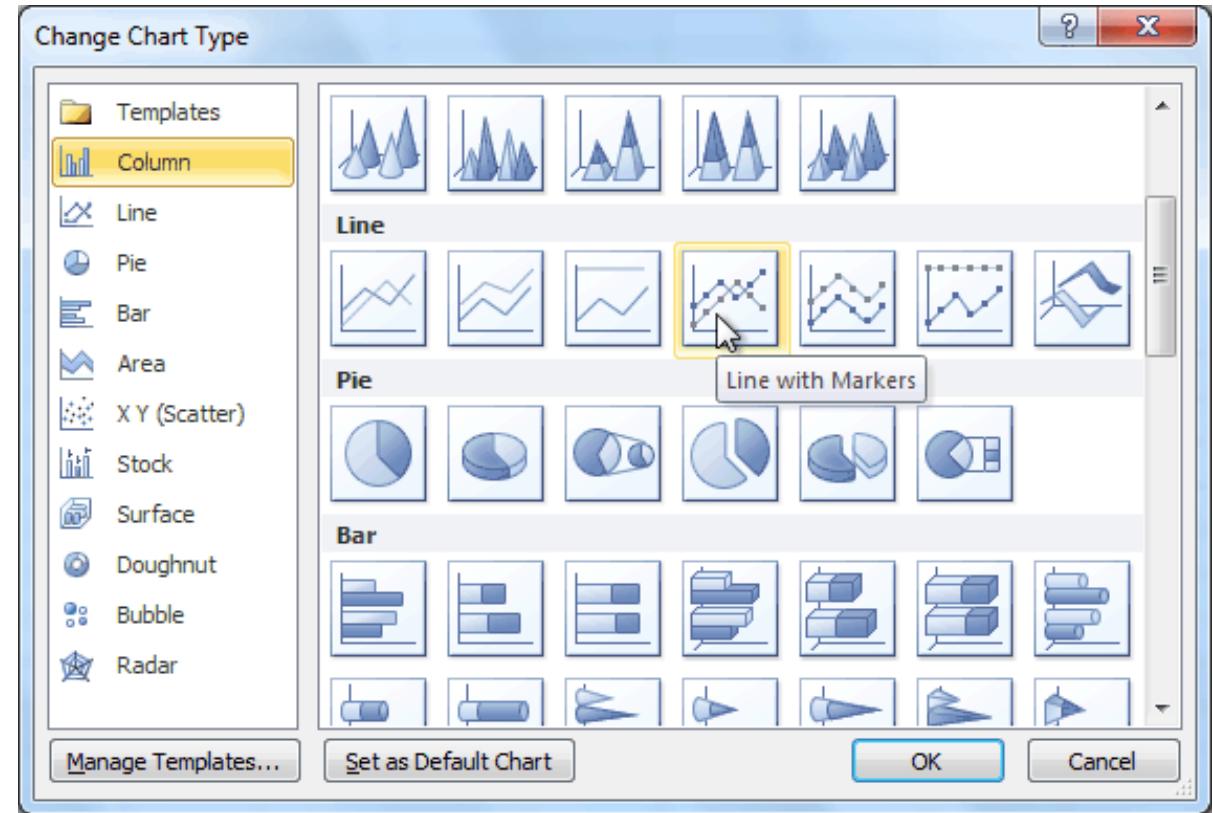


Gephi

USE

- + EASY
- + SCALABLE

- LIMITED FLEXIBILITY
- LIMITED EXPRESSIVENESS
- WHAT IF I NEED A NEW CHART TYPE?



CODE

+ NEW, REUSABLE DESIGNS

+ SCALABLE

+ DYNAMIC & INTERACTIVE

~ EXPRESSIVE

- HARD

```
var diameter = 960,  
    format = d3.format(",d"),  
    color = d3.scale.category20c();  
  
var bubble = d3.layout.pack()  
  .sort(null)  
  .size([diameter, diameter])  
  .padding(1.5);  
  
var svg = d3.select("body").append("svg")  
  .attr("width", diameter)  
  .attr("height", diameter)  
  .attr("class", "bubble");  
  
d3.json("flare.json", function(error, root) {  
  if (error) throw error;  
  
  var node = svg.selectAll(".node")  
    .data(bubble.nodes(classes(root))  
      .filter(function(d) { return !d.children; }))  
    .enter().append("g")  
    .attr("class", "node")  
    .attr("transform", function(d) { return "translate(" +  
      node.append("title")  
        .text(function(d) { return d.className + ": " + fo  
node.append("circle")  
  .attr("r", function(d) { return d.r; })  
  .style("fill", function(d) { return color(d.packageName); })  
  
node.append("text")  
  .attr("dy", ".3em")  
  .style("text-anchor", "middle")  
  .text(function(d) { return d.className.substring(0, d.r / 3); });  
  
// Returns a flattened hierarchy containing all leaf nodes under the root.  
function classes(root) {  
  var classes = [];  
  
  function recurse(name, node) {  
    if (node.children) node.children.forEach(function(child) { recurse(node.name, child); })  
    else classes.push({packageName: name, className: node.name, value: node.size});  
  }  
  
  recurse(null, root);  
  return {children: classes};  
}  
  
d3.select(self.frameElement).style("height", diameter + "px");
```

“BLINDLY
MANIPULATING
SYMBOLS”



SOME DIFFERENT APPROACHES

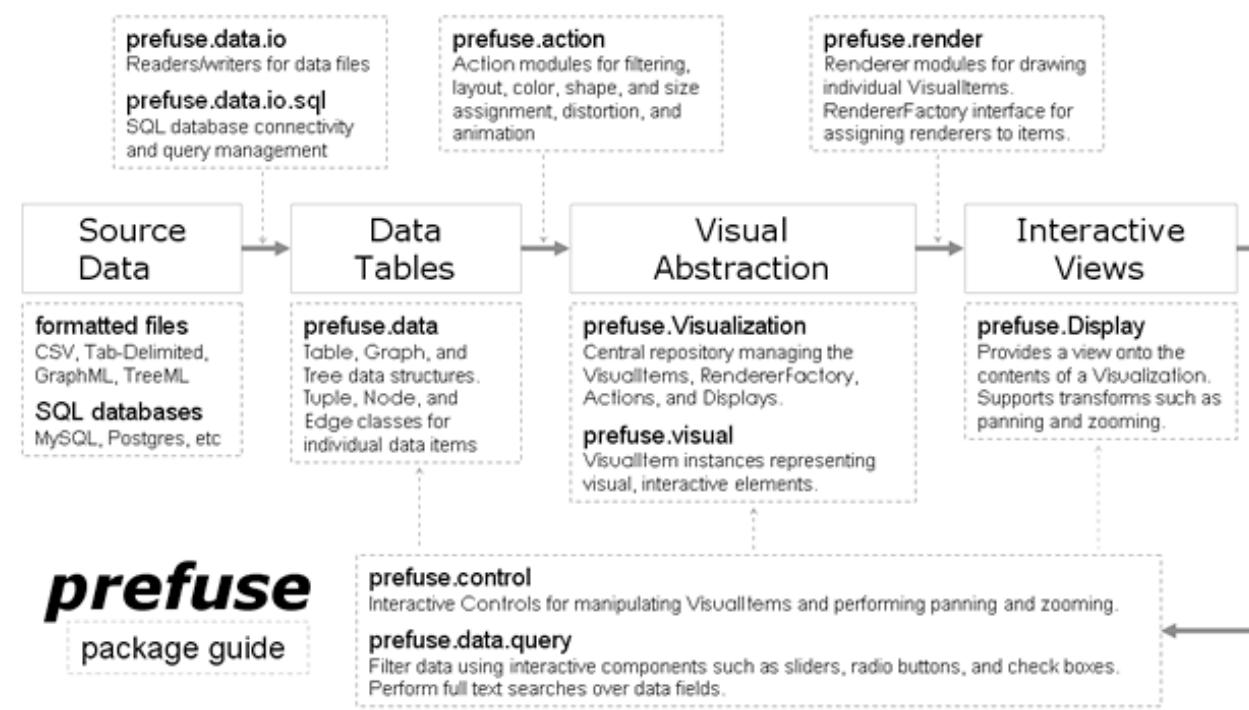
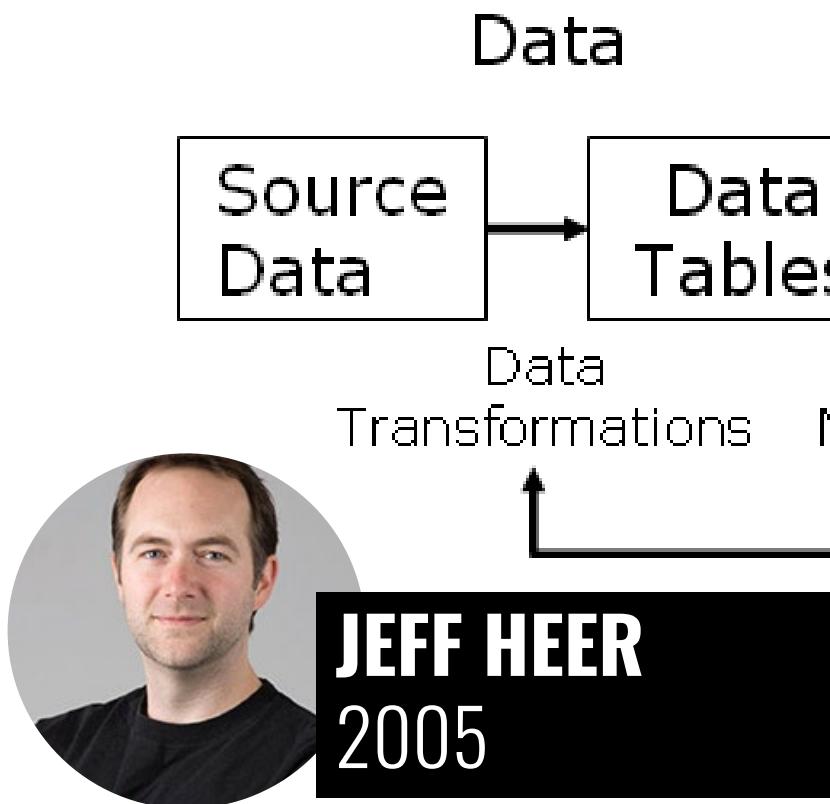
DRAWING PIXELS

```
background(255); // Setting the background to white stroke(0); // Setting the  
outline (stroke) to black fill(150); // Setting the interior of a shape (fill) to grey  
rect(50,50,75,100); // Drawing the rectangle
```



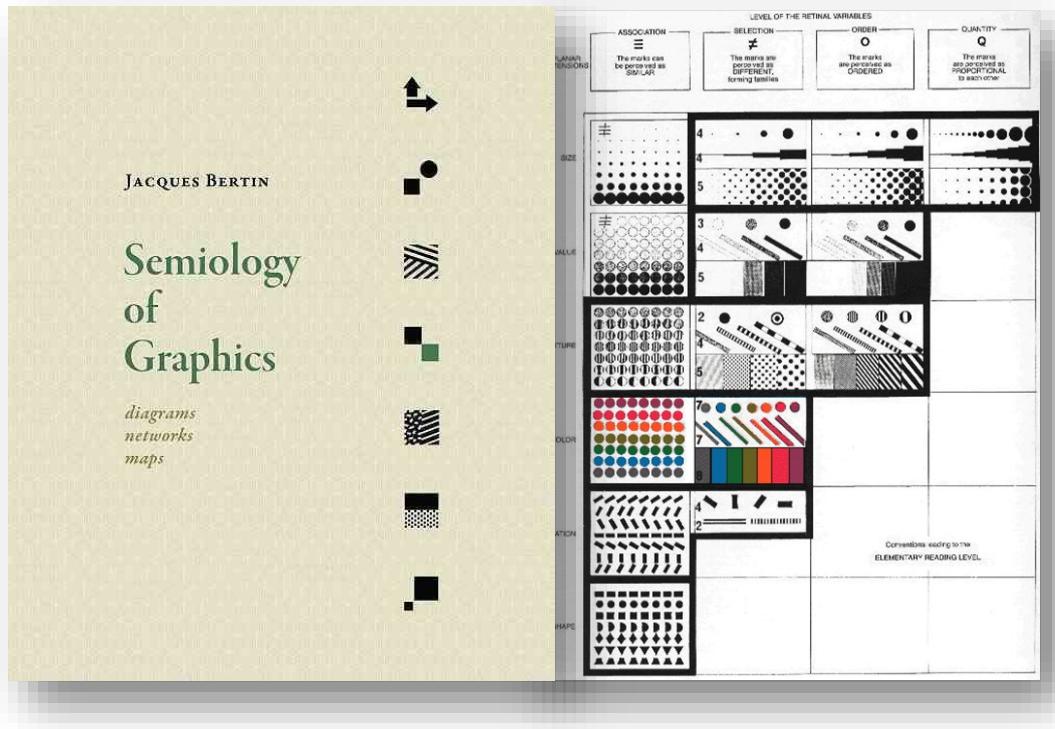
SOME DIFFERENT APPROACHES

COMPUTATIONALLY IMPLEMENTING VISUALIZATION REFERENCE MODEL

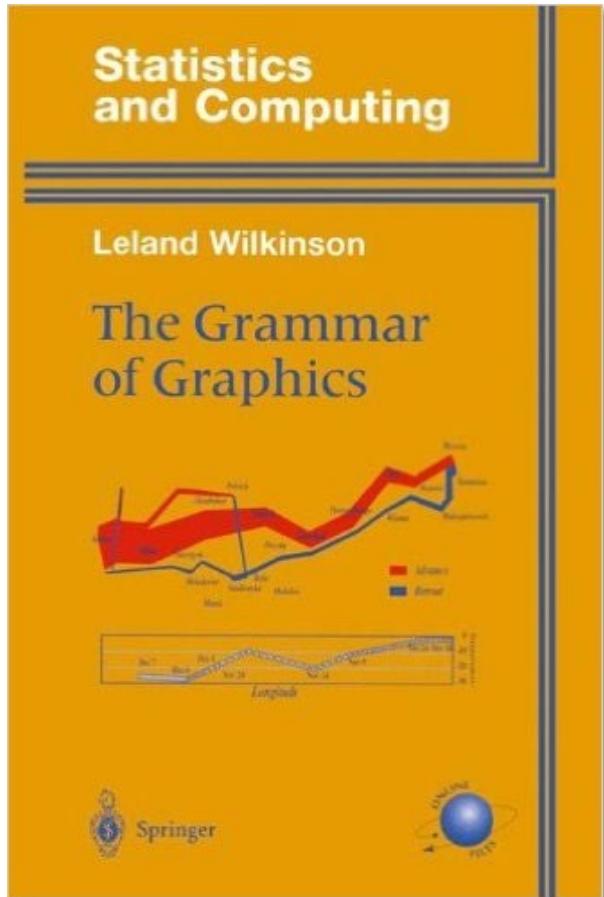


SOME DIFFERENT APPROACHES

DESCRIBING CONCEPTUAL PROPERTIES OF VISUALIZATIONS



JACQUES BERTIN 1963



THE GRAMMAR OF GRAPHICS

LELAND WILKINSON 1999

A FORMAL LANGUAGE
FOR DESCRIBING DATA
GRAPHICS



VizQL & POLARIS

Database Schema:

The user drags fields from the database schema to shelves to define the visual specification.

Layer Tabs:

Each layer has its own tab; different transformations and mappings can be specified for each layer.

Axis Shelves:

The fields placed here determine the structure of the table and the types of graphs in each table pane.

Context Menu:

The context menu provides access to the data transformation and interaction capabilities of Polaris such as sorting, filtering, and aggregation.

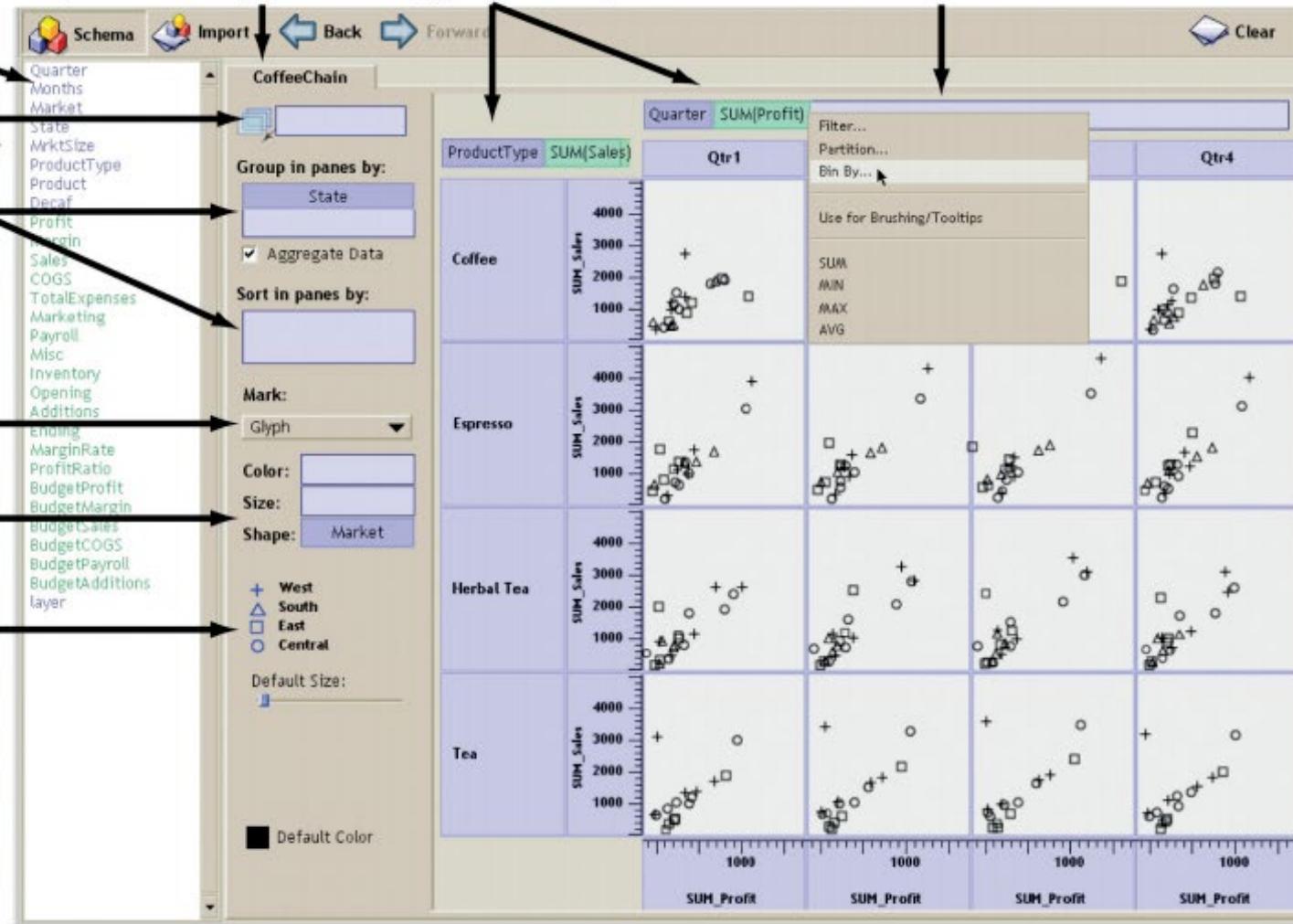
Layer Shelf:
The fields placed here determine how records are partitioned into layers.

Grouping and Sorting Shelves:
The fields placed here determine how records are grouped and sorted within the table panes.

Mark Pulldown:
Relations in each pane are mapped to marks of the selected type.

Retinal Property Shelves:
The fields placed here determine how data is encoded in the retinal properties of the marks.

Legends:
Legends enable the user to see and modify the mappings from data to retinal properties.



$O = \text{Quarter} = \{\text{Qtr1}, \text{Qtr2}, \text{Qtr3}, \text{Qtr4}\} = \text{Qtr1} + \text{Qtr2} + \text{Qtr3} + \text{Qtr4}$:

Qtr1	Qtr2	Qtr3	Qtr4
------	------	------	------

$O + O = \text{Quarter} + \text{Product} = \{\text{Qtr1}, \text{Qtr2}, \text{Qtr3}, \text{Qtr4}, \text{Coffee}, \text{Espresso}, \text{Herbal Tea}, \text{Tea}\}$:

Qtr1	Qtr2	Qtr3	Qtr4	Coffee	Espresso	Herbal Tea	Tea
------	------	------	------	--------	----------	------------	-----

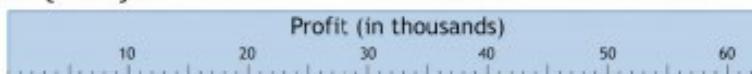
$O \times O = \text{Quarter} \times \text{Product} = \{(\text{Qtr1,Coffee}), (\text{Qtr1,Espresso}), (\text{Qtr1,Herbal Tea}), (\text{Qtr1, Tea}), (\text{Qtr2, Coffee}) \dots (\text{Qtr4, Tea})\}$:

Qtr1				Qtr2				Qtr3				Qtr4			
Coffee	Espresso	Herbal Tea	Tea	Coffee	Espresso	Herbal Tea	Tea	Coffee	Espresso	Herbal Tea	Tea	Coffee	Espresso	Herbal Tea	Tea

$O/O = \text{Quarter} / \text{Month} = \{(\text{Qtr1,Jan}), (\text{Qtr1,Feb}), (\text{Qtr1,Mar}), (\text{Qtr2, Apr}), (\text{Qtr2, May}) \dots (\text{Qtr4, Dec})\}$:

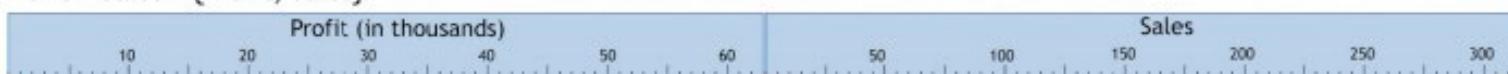
Qtr1			Qtr2			Qtr3			Qtr4		
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

$Q = \text{Profit} = \{\text{Profit}\}$:



The set entry (Qtr4,Nov) corresponds to this column

$Q + Q = \text{Profit} + \text{Sales} = \{\text{Profit, Sales}\}$:



$O \times Q = \text{Quarter} \times \text{Profit} = \{(\text{Qtr1,Profit}), (\text{Qtr2, Profit}), (\text{Qtr3, Profit}), (\text{Qtr4, Profit})\}$:

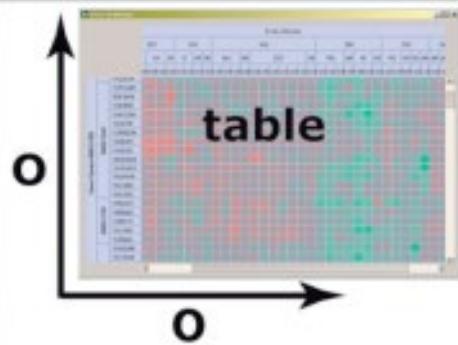
Qtr1	Qtr2	Qtr3	Qtr4
Profit (in thousands) 10 20 30 40 50 60	Profit (in thousands) 10 20 30 40 50 60	Profit (in thousands) 10 20 30 40 50 60	Profit (in thousands) 10 20 30 40 50 60

Ordinal fields partition an axis into columns (or rows)

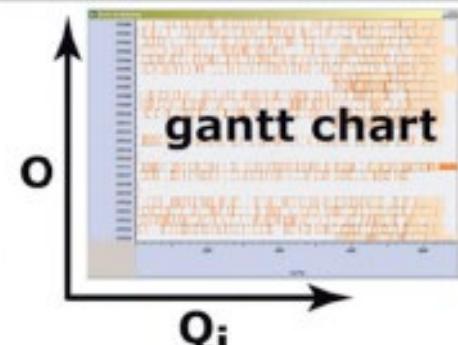
Quantitative fields are spatially encoded as axes

Quantitative fields: Profit, Sales
Ordinal fields: Quarter, Months, Product

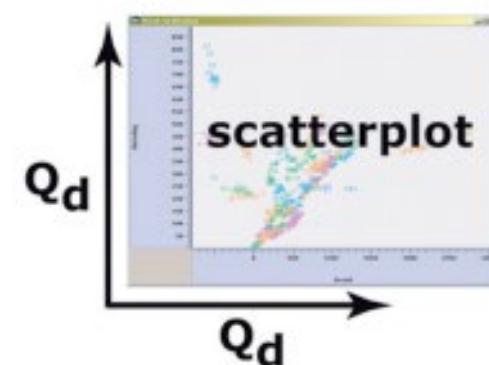
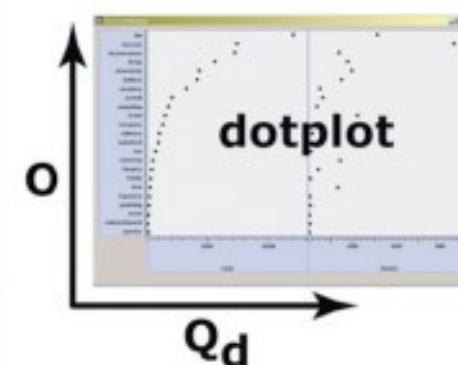
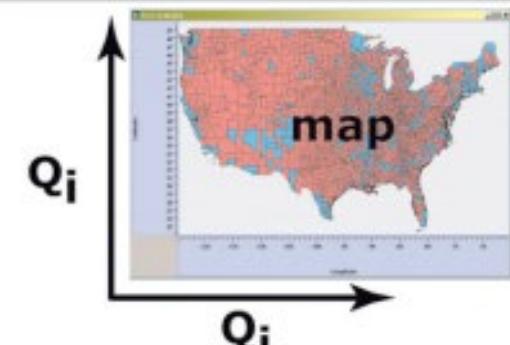
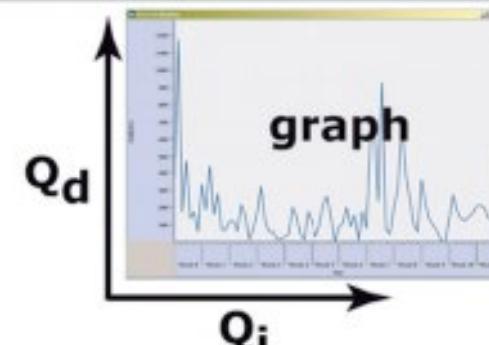
**Ordinal-
Ordinal**



**Ordinal-
Quantitative**



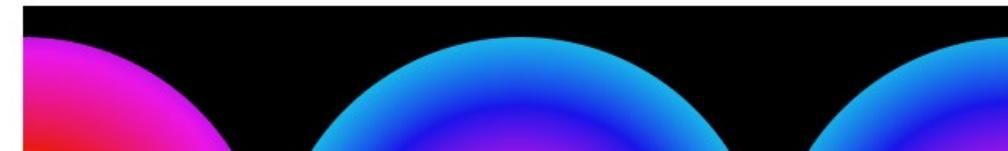
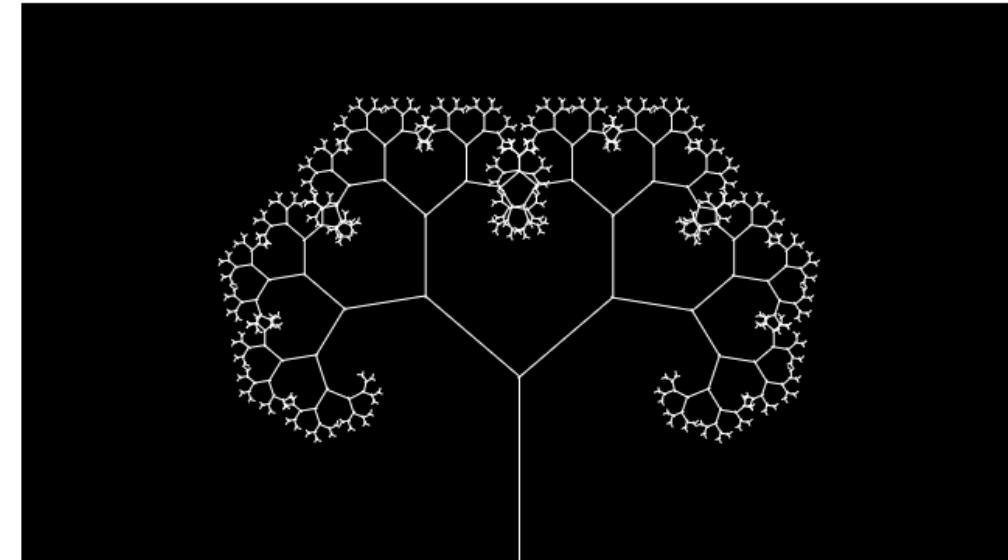
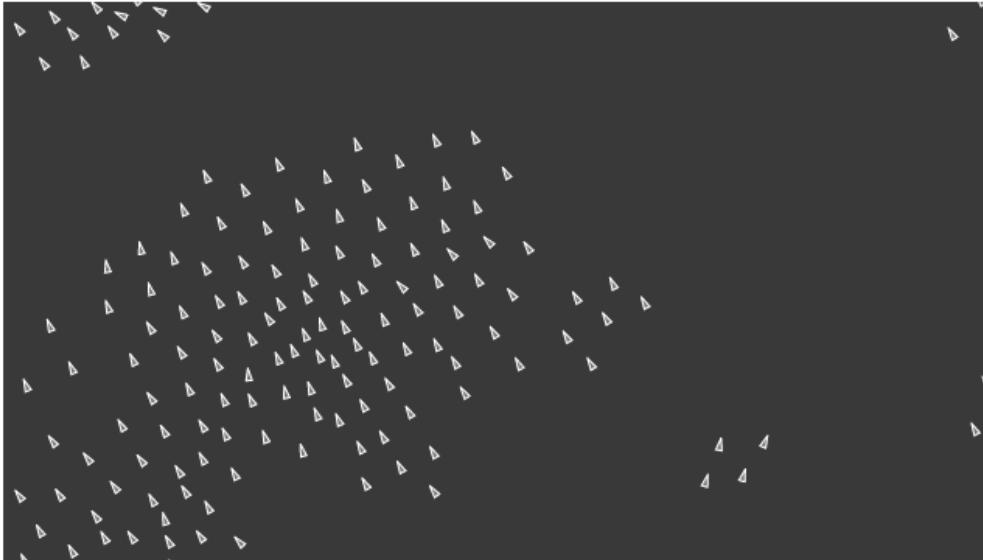
Quantitative-Quantitative



VISUALIZATION LANGUAGES AND TOOLKITS

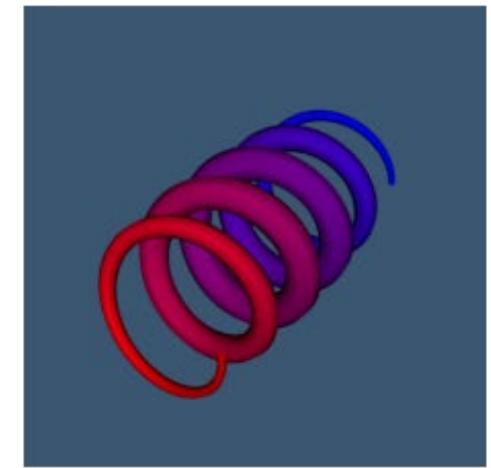
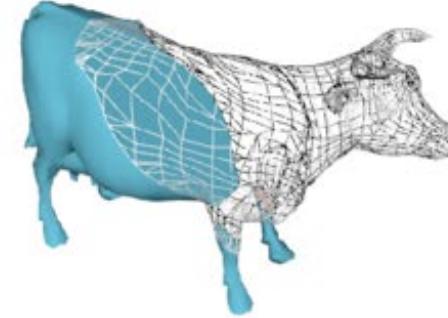
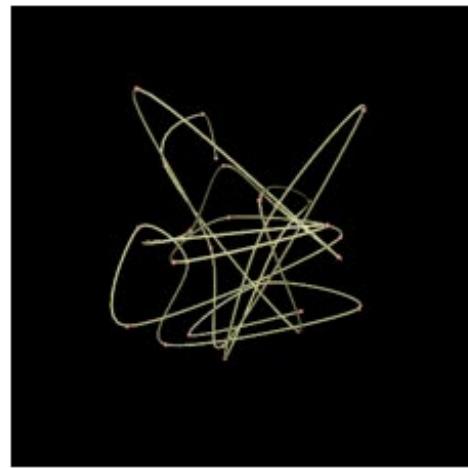
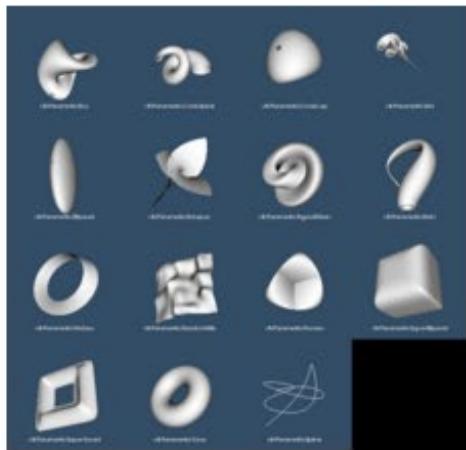
DESKTOP

PROCESSING / P5.js



TARGETED AT ARTISTS & NON-EXPERTS
DESIGNED TO MAKE DRAWING & INTERACTION EASY
NO VISUALIZATION PRIMITIVES

VTK (VISUALIZATION TOOLKIT)

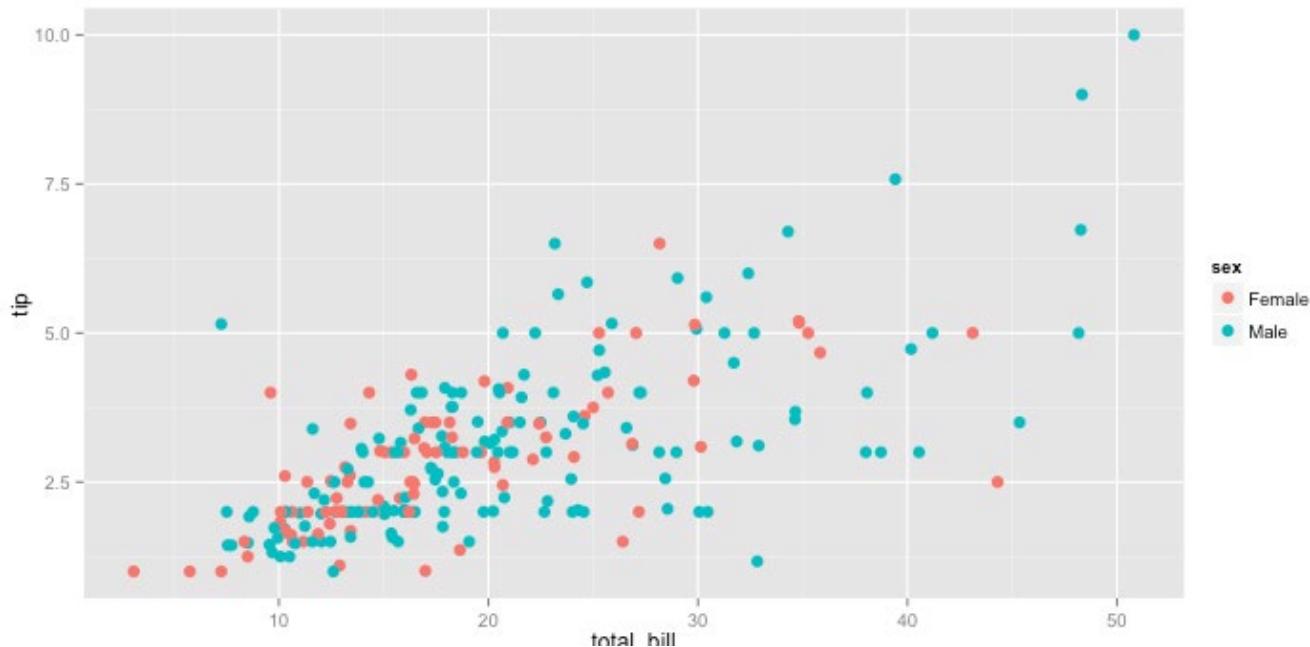


ESPECIALLY COMMON FOR SCIENTIFIC VISUALIZATION
C++ (Python, Java, and Tcl WRAPPERS)

GGPLOT2

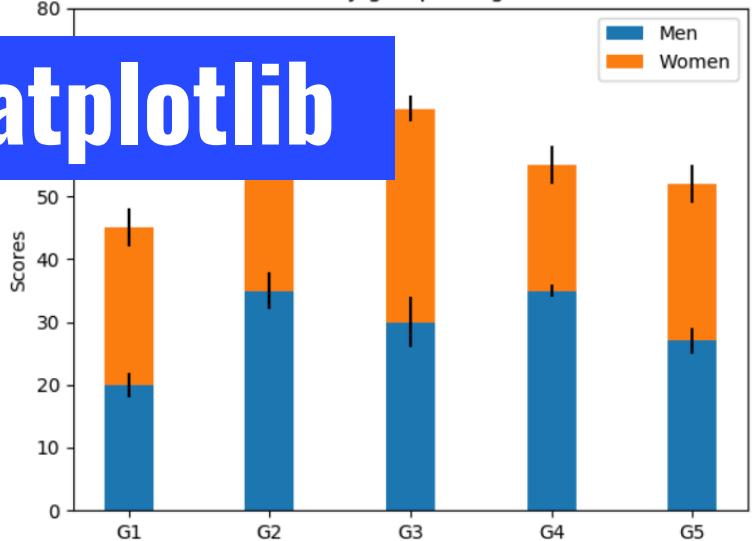
PLOTTING IN R BASED ON THE GRAMMAR OF GRAPHICS

```
layer_point <- geom_point(  
  mapping = aes(x = total_bill, y = tip, color = sex),  
  data = tips,  
  size = 3  
)  
ggplot() + layer_point
```



Matplotlib

Scores by group and gender



```
import numpy as np
import matplotlib.pyplot as plt

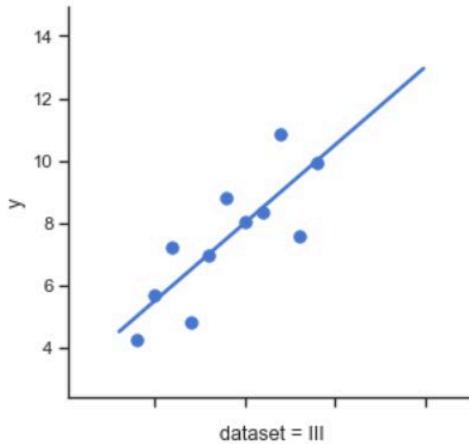
N = 5
menMeans = (20, 35, 30, 35, 27)
womenMeans = (25, 32, 34, 20, 25)
menStd = (2, 3, 4, 1, 2)
womenStd = (3, 5, 2, 3, 3)
ind = np.arange(N)      # the x locations for the groups
width = 0.35            # the width of the bars: can also be len(x) sequence

p1 = plt.bar(ind, menMeans, width, yerr=menStd)
p2 = plt.bar(ind, womenMeans, width,
             bottom=menMeans, yerr=womenStd)

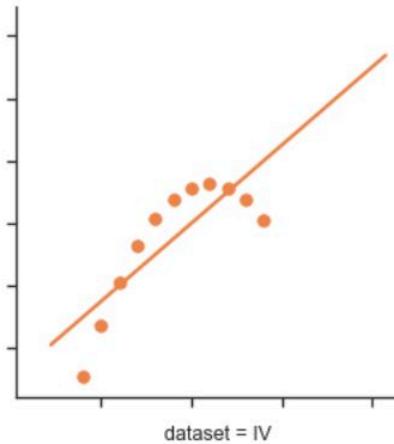
plt.ylabel('Scores')
plt.title('Scores by group and gender')
plt.xticks(ind, ('G1', 'G2', 'G3', 'G4', 'G5'))
plt.yticks(np.arange(0, 81, 10))
plt.legend((p1[0], p2[0]), ('Men', 'Women'))

plt.show()
```

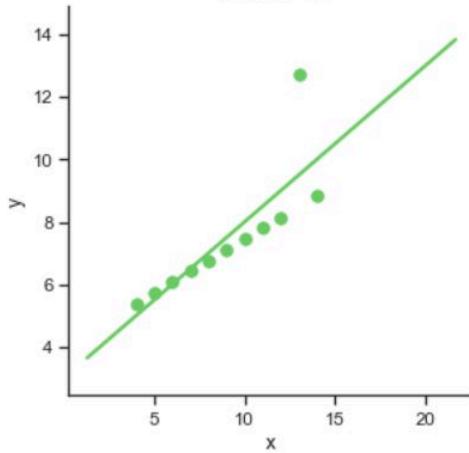
dataset = I



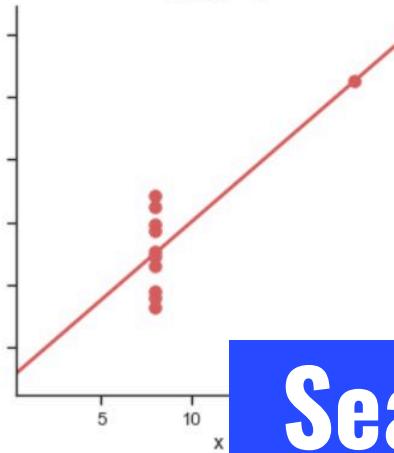
dataset = II



dataset = III



dataset = IV



Seaborn

Python source code: [\[download source: anscombes_quartet.py\]](#)

```
import seaborn as sns
sns.set(style="ticks")

# Load the example dataset for Anscombe's quartet
df = sns.load_dataset("anscombe")

# Show the results of a linear regression within each dataset
sns.lmplot(x="x", y="y", col="dataset", hue="dataset", data=df,
            col_wrap=2, ci=None, palette="muted", height=4,
            scatter_kws={"s": 50, "alpha": 1})
```

VISUALIZATION LANGUAGES AND TOOLKITS

WEB

WHY DEVELOP FOR THE WEB?

NOW THE DOMINANT PLATFORM FOR VIS CONSUMPTION

INTEGRATE VISUALIZATIONS INTO WEB PAGES AND APPLICATIONS

LEVERAGE OTHER HTML5/Javascript LIBRARIES AND TOOLS

DEBUG AND TUNE IN THE BROWSER

GOOGLE CHARTS

EASY TO INSERT PREDEFINED
CHARTS TYPES INTO PAGES AND
STYLE THEM

```
// Callback that creates and populates a data table,
// instantiates the pie chart, passes in the data and
// draws it.
function drawChart() {

    // Create the data table.
    var data = new google.visualization.DataTable();
    data.addColumn('string', 'Topping');
    data.addColumn('number', 'Slices');
    data.addRows([
        ['Mushrooms', 3],
        ['Onions', 1],
        ['Olives', 1],
        ['Zucchini', 1],
        ['Pepperoni', 2]
    ]);

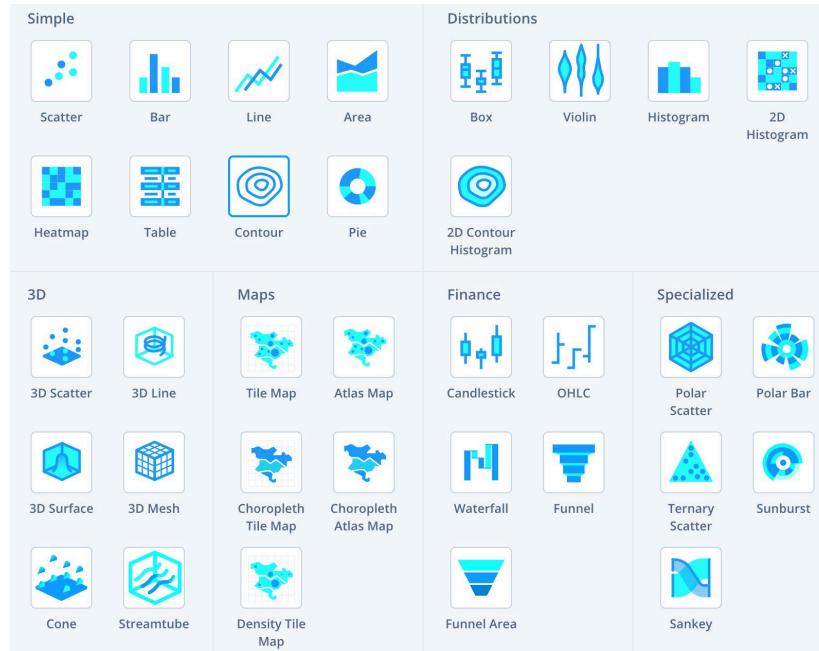
    // Set chart options
    var options = {'title':'How Much Pizza I Ate Last Night',
                  'width':400,
                  'height':300};

    // Instantiate and draw our chart, passing in some options.
    var chart = new google.visualization.PieChart(document.getElementById('chart_div'));
    chart.draw(data, options);
}
```

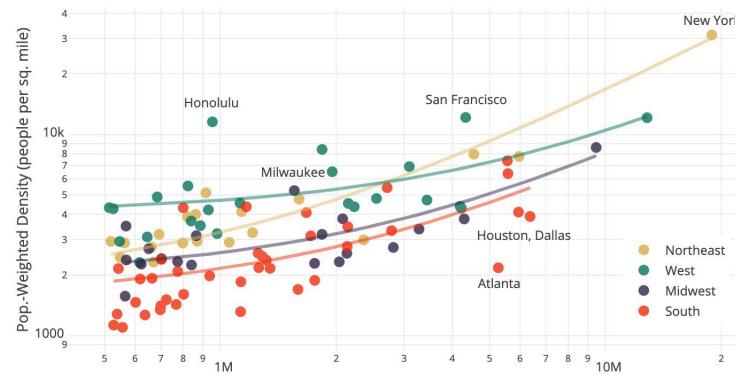


PLOT.LY

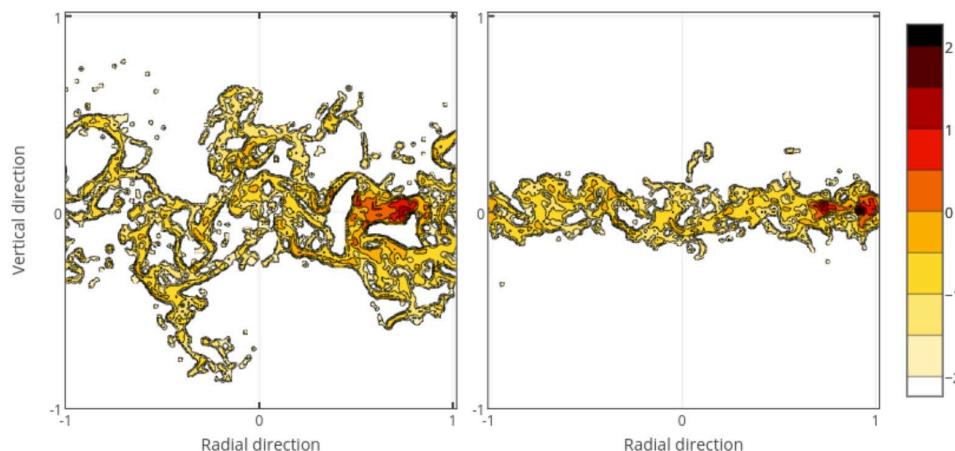
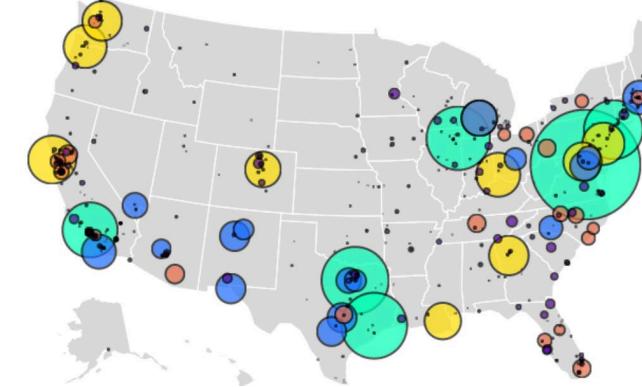
LARGE VOCABULARY OF CHART TEMPLATES + VISUAL INTERFACE + SCRIPTING



Larger US Cities have Higher Population-Weighted Densities



LEED Projects: 1558 - 681
LEED Projects: 681 - 484
LEED Projects: 505 - 266
LEED Projects: 266 - 146
LEED Projects: 146 - 4





D3.js

Data-Driven Documents



D3.JS

JAVASCRIPT / HTML5 / SVG / CSS

DYNAMIC DOCUMENT MANIPULATION AND VISUALIZATION

SUPPORT FOR BINDING DATA TO ELEMENTS,
HANDLING SCALES & LAYOUTS, ANIMATION,
AND MUCH MORE!

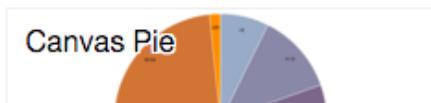
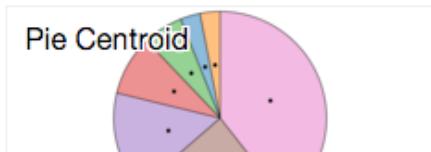
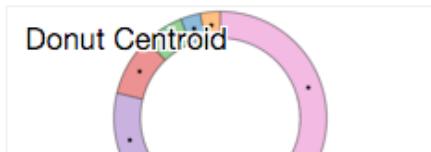
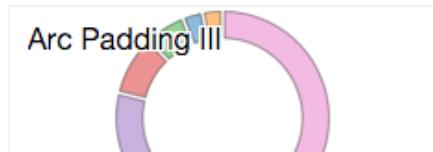
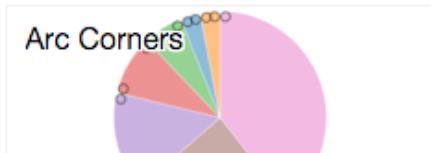
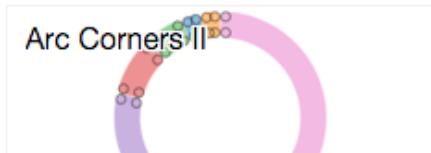
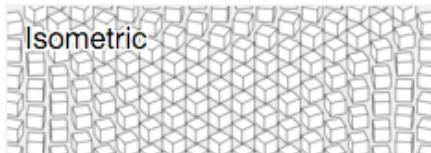
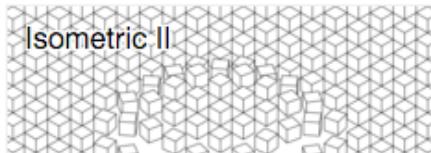
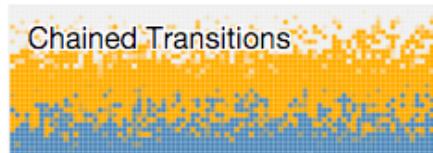
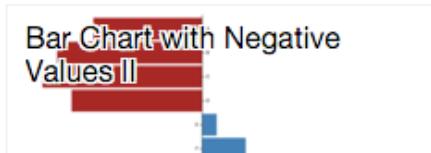
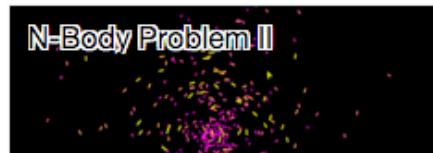
GREAT TUTORIALS & A HUGE LIBRARY OF EXAMPLES

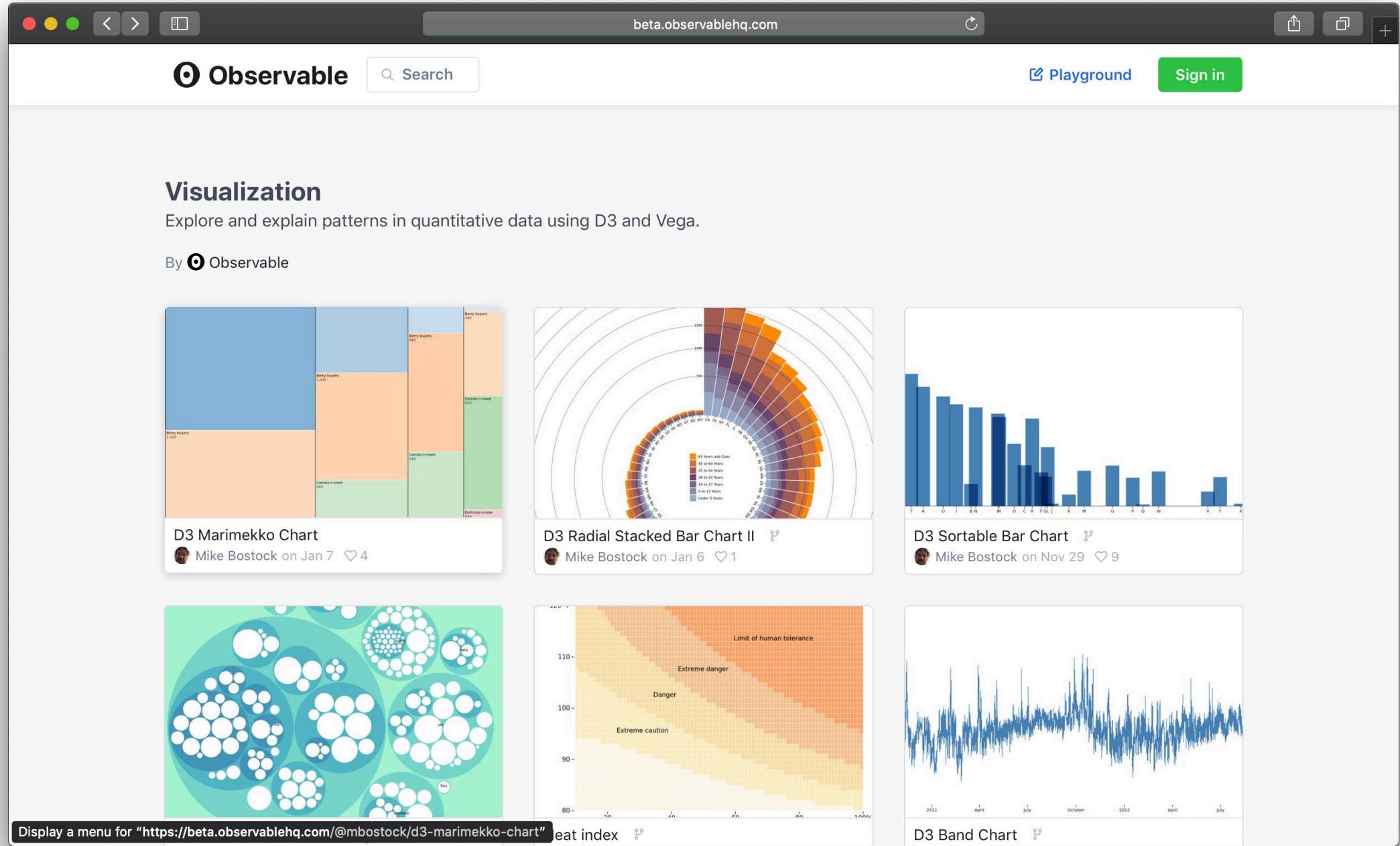


Mike Bostock's Blocks

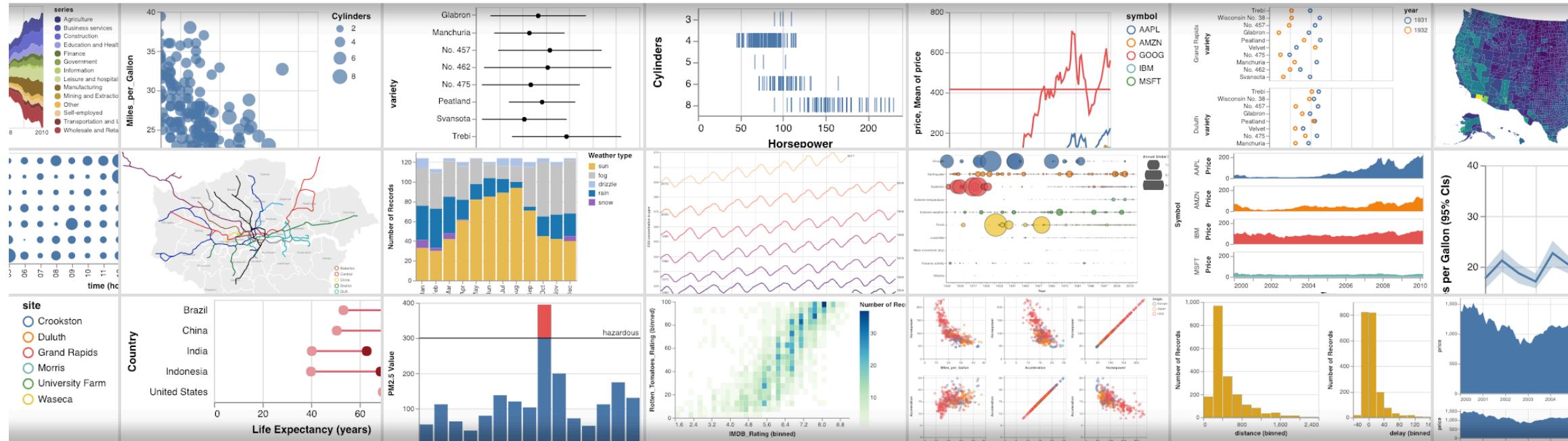
Updated February 25, 2016

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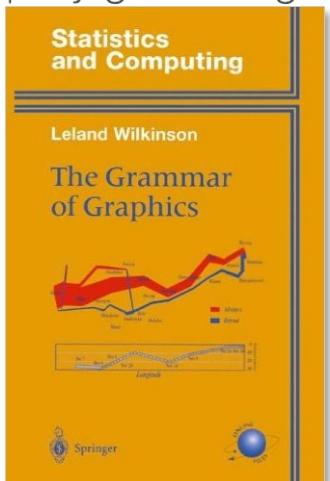


Vega-Lite – A Grammar of Interactive Graphics

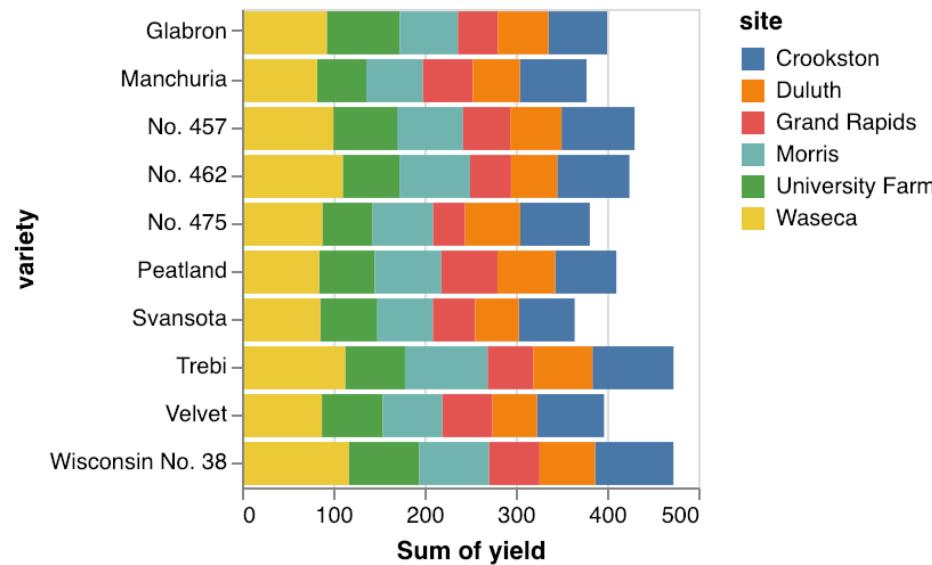


Vega-Lite is a high-level grammar of interactive graphics. It provides a concise JSON syntax for rapidly generating visualizations to support analysis. Vega-Lite specifications can be compiled to [Vega](#) specifications.

A simple, powerful JSON syntax for authoring interactive visualizations inspired by [Wilkinson's Grammar of Graphics](#).



Horizontal Stacked Bar Chart

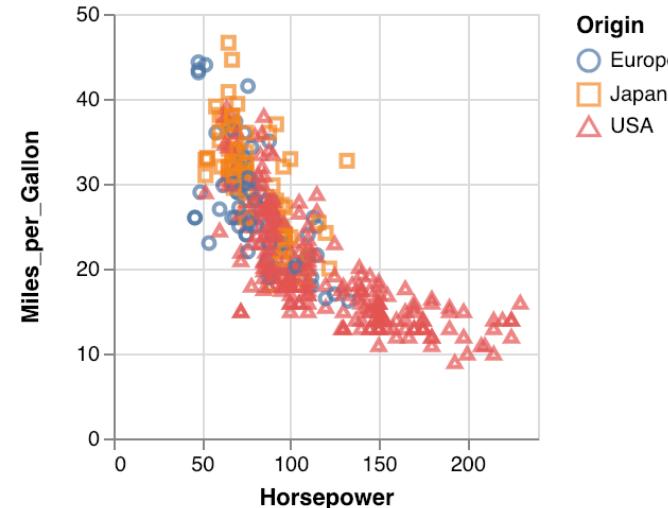


[View this example in the online editor](#)

Vega-Lite JSON Specification

```
{  
  "$schema": "https://vega.github.io/schema/vega-lite/v3.json",  
  "data": {"url": "data/barley.json"},  
  "mark": "bar",  
  "encoding": {  
    "x": {"aggregate": "sum", "field": "yield", "type": "quantitative"},  
    "y": {"field": "variety", "type": "nominal"},  
    "color": {"field": "site", "type": "nominal"}  
  }  
}
```

Colored Scatterplot

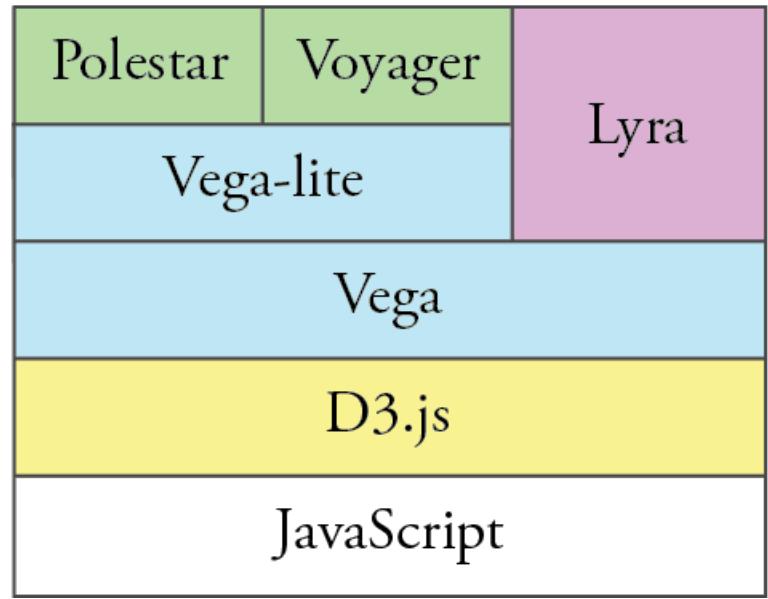


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Vega-Lite JSON Specification

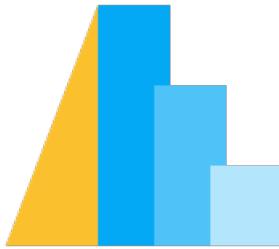
```
{  
  "$schema": "https://vega.github.io/schema/vega-lite/v3.json",  
  "description": "A scatterplot showing horsepower and miles per gallons.",  
  "data": {"url": "data/cars.json"},  
  "mark": "point",  
  "encoding": {  
    "x": {"field": "Horsepower", "type": "quantitative"},  
    "y": {"field": "Miles_per_Gallon", "type": "quantitative"},  
    "color": {"field": "Origin", "type": "nominal"},  
    "shape": {"field": "Origin", "type": "nominal"}  
  }  
}
```

Data Exploration
Visual analysis grammar
Visualization grammar
Visualization kernel



The
D3 - Vega
“Stack”

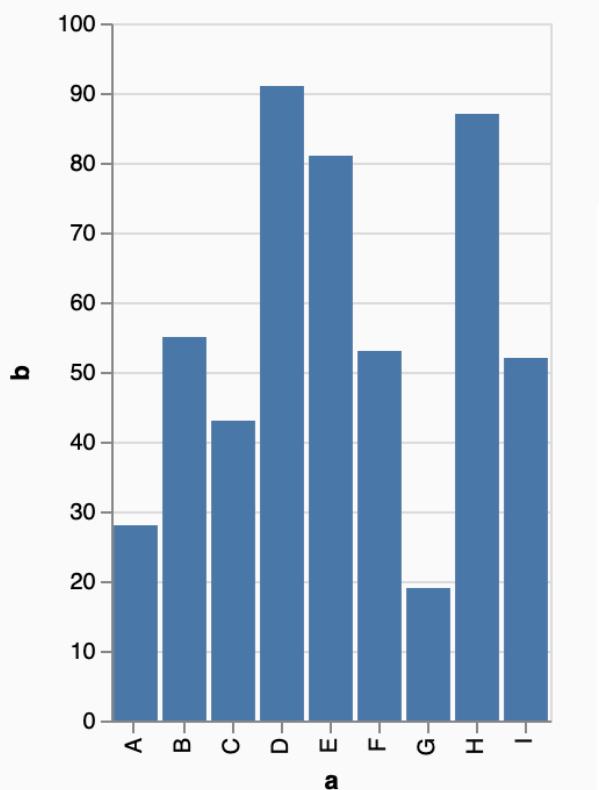
GUI design environment
GUI interface
declarative grammar
library
programming language



Altair

Python wrappers
for Vega-Lite!

Works with Pandas,
Jupyter, etc.



Save as SVG Save as PNG View Source O

```
import altair as alt
import pandas as pd

source = pd.DataFrame({
    'a': ['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I'],
    'b': [28, 55, 43, 91, 81, 53, 19, 87, 52]
})

alt.Chart(source).mark_bar().encode(
    x='a',
    y='b'
)
```

Vega-Lite JSON Specification

```
{
  "$schema": "https://vega.github.io/schema/vega-lite/v3.json",
  "description": "A simple bar chart with embedded data.",
  "data": {
    "values": [
      {"a": "A", "b": 28}, {"a": "B", "b": 55}, {"a": "C", "b": 43},
      {"a": "D", "b": 91}, {"a": "E", "b": 81}, {"a": "F", "b": 53},
      {"a": "G", "b": 19}, {"a": "H", "b": 87}, {"a": "I", "b": 52}
    ]
  },
  "mark": "bar",
  "encoding": {
    "x": {"field": "a", "type": "ordinal"},
    "y": {"field": "b", "type": "quantitative"}
  }
}
```

WHAT TO USE?

There are **many** different visualization tools available.

Need to balance tradeoffs:

- Expressiveness (Can I create the visualization I want/need?)
- Speed & Flexibility (How quickly can I generate, modify, and explore?)
- Reproducibility (Can I re-run the analysis? Re-generate the vis with new data?)
- Presentation (Can I style? Annotate? Share?)
- Interoperability (Can I integrate with other tools and applications?)

