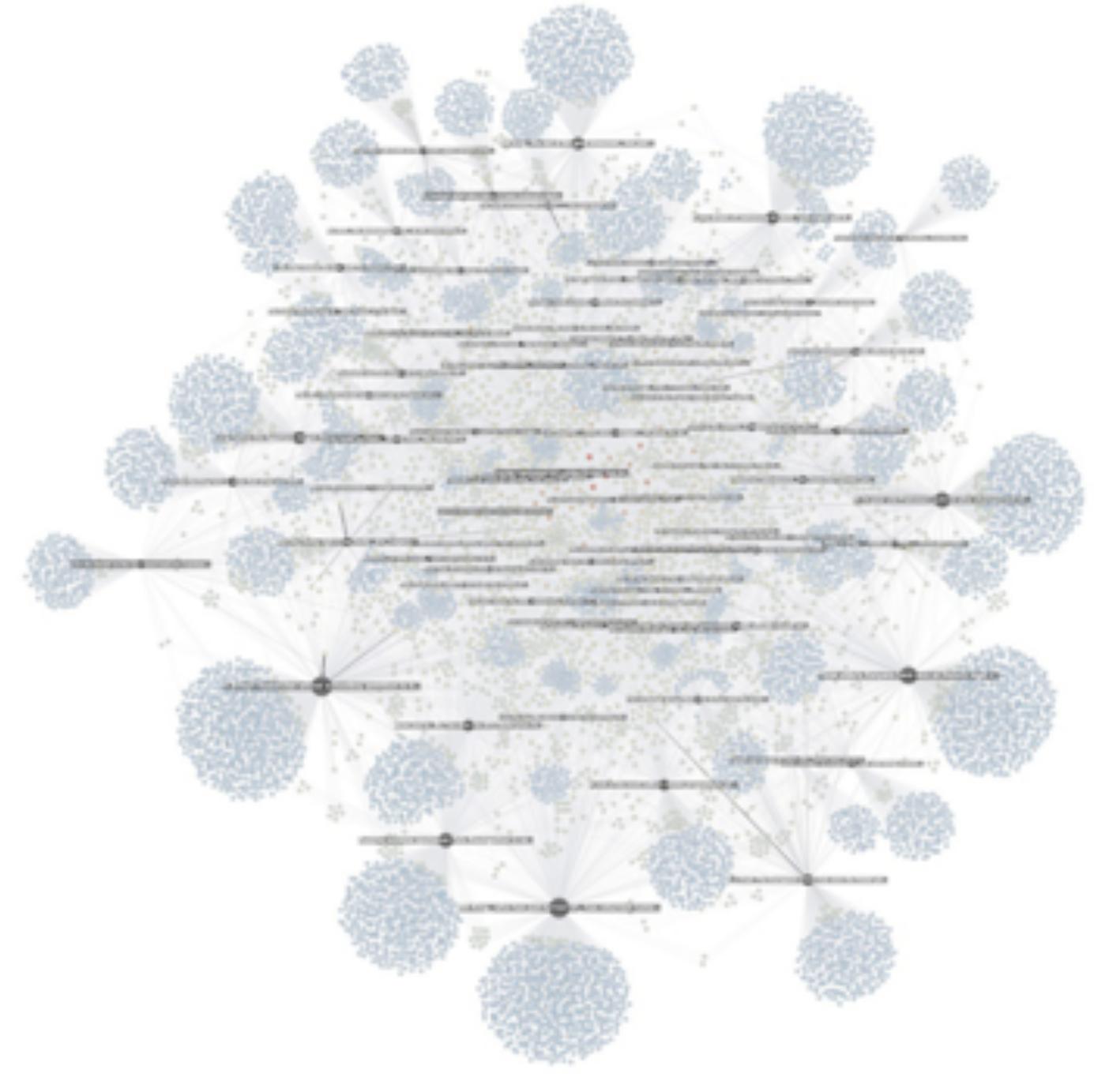
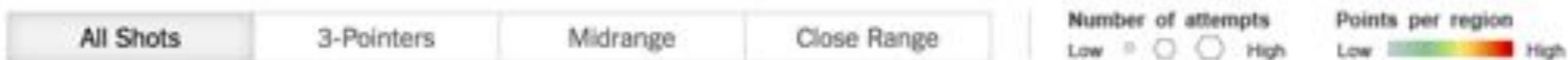


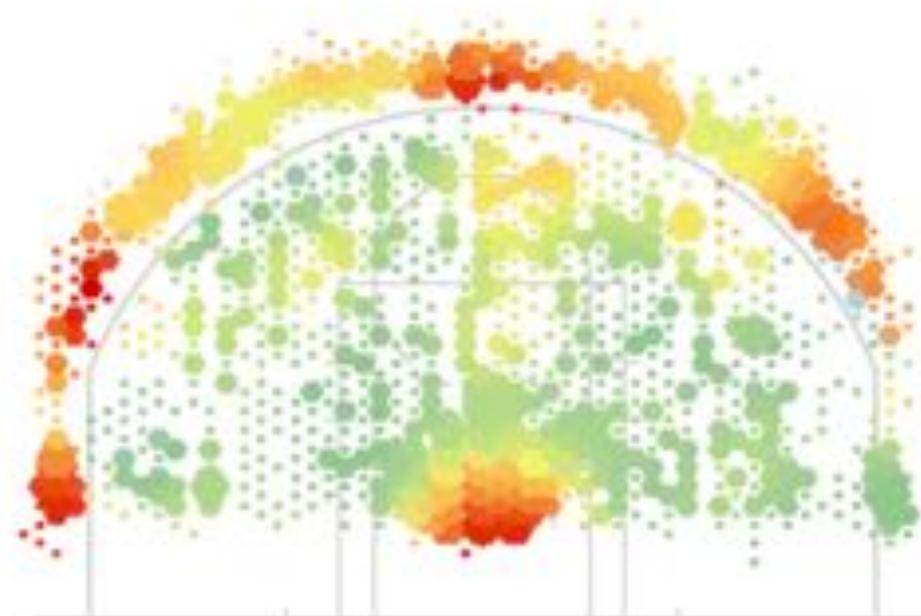
Multimodal User Interfaces

Information Visualization - 2019

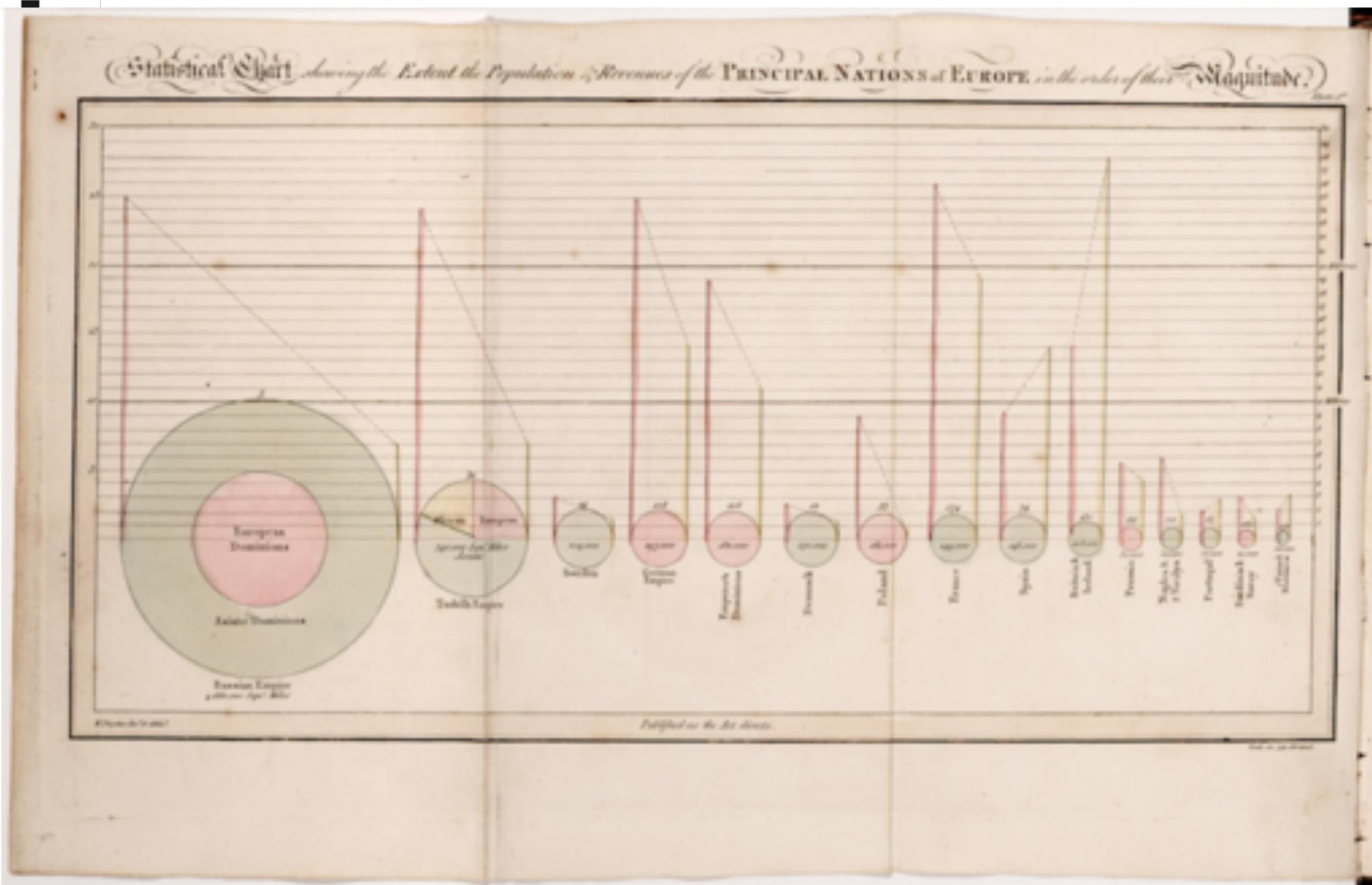


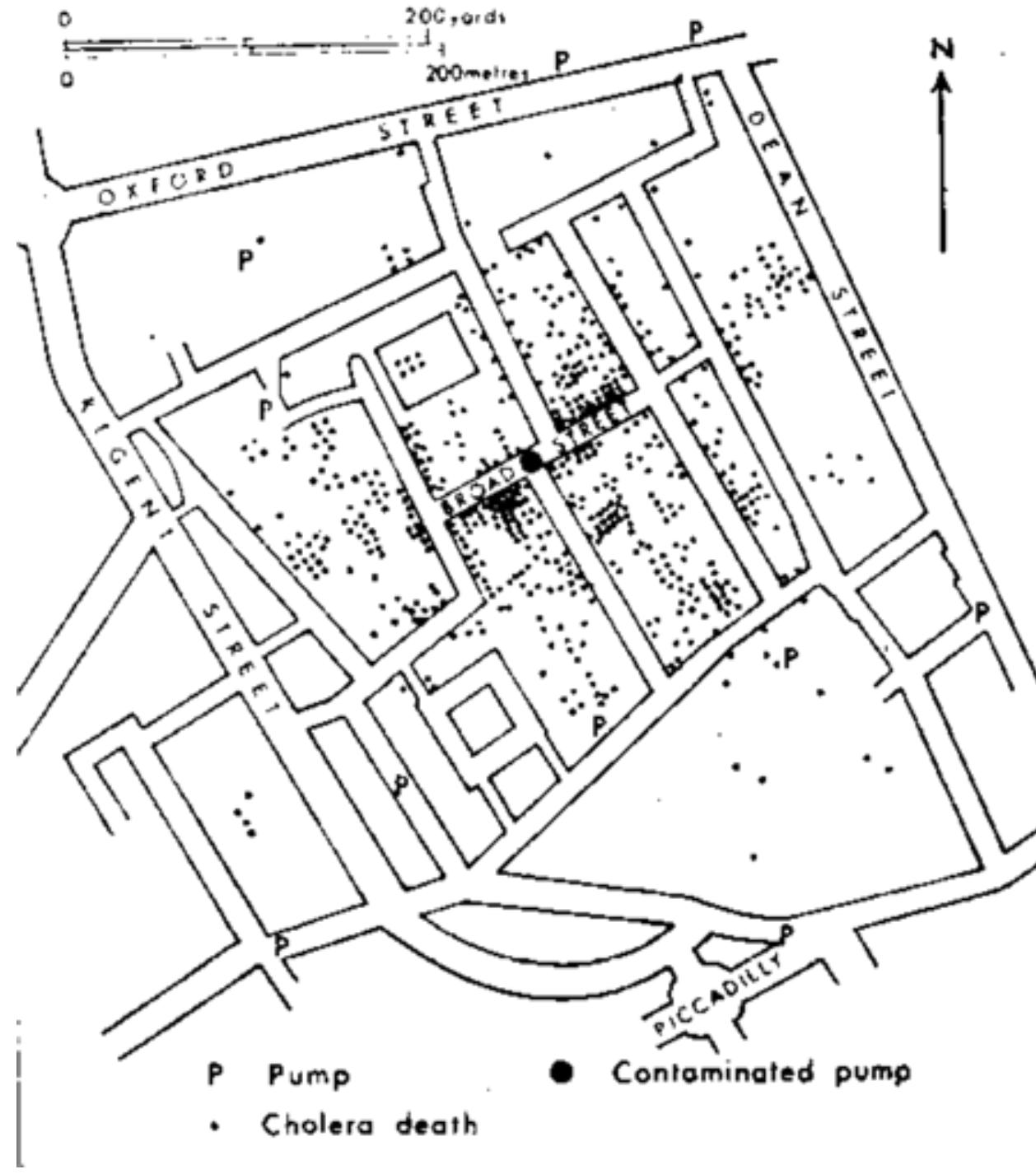
**Miami Heat**TOTAL SHOTS **5,209** | POINTS PER SHOT **1.01** | F.G. PERCENT **47%**

The Heat rely on player positioning to create isolation plays for LeBron James and Dwyane Wade, often on the left side. The Heat take many fewer 3-point shots than the Thunder.

Oklahoma City ThunderTOTAL SHOTS **5,228** | POINTS PER SHOT **1.03** | F.G. PERCENT **47.1%**

The Thunder are effective from almost any area on the court and shoot many more 3-point shots than the league average. Kevin Durant and James Harden are potent from the top of the arc.





Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.
Dessin par N. Minard, Imprimé à Paris au Chasseray en octobre

Paris, le 25 Novembre 1869.

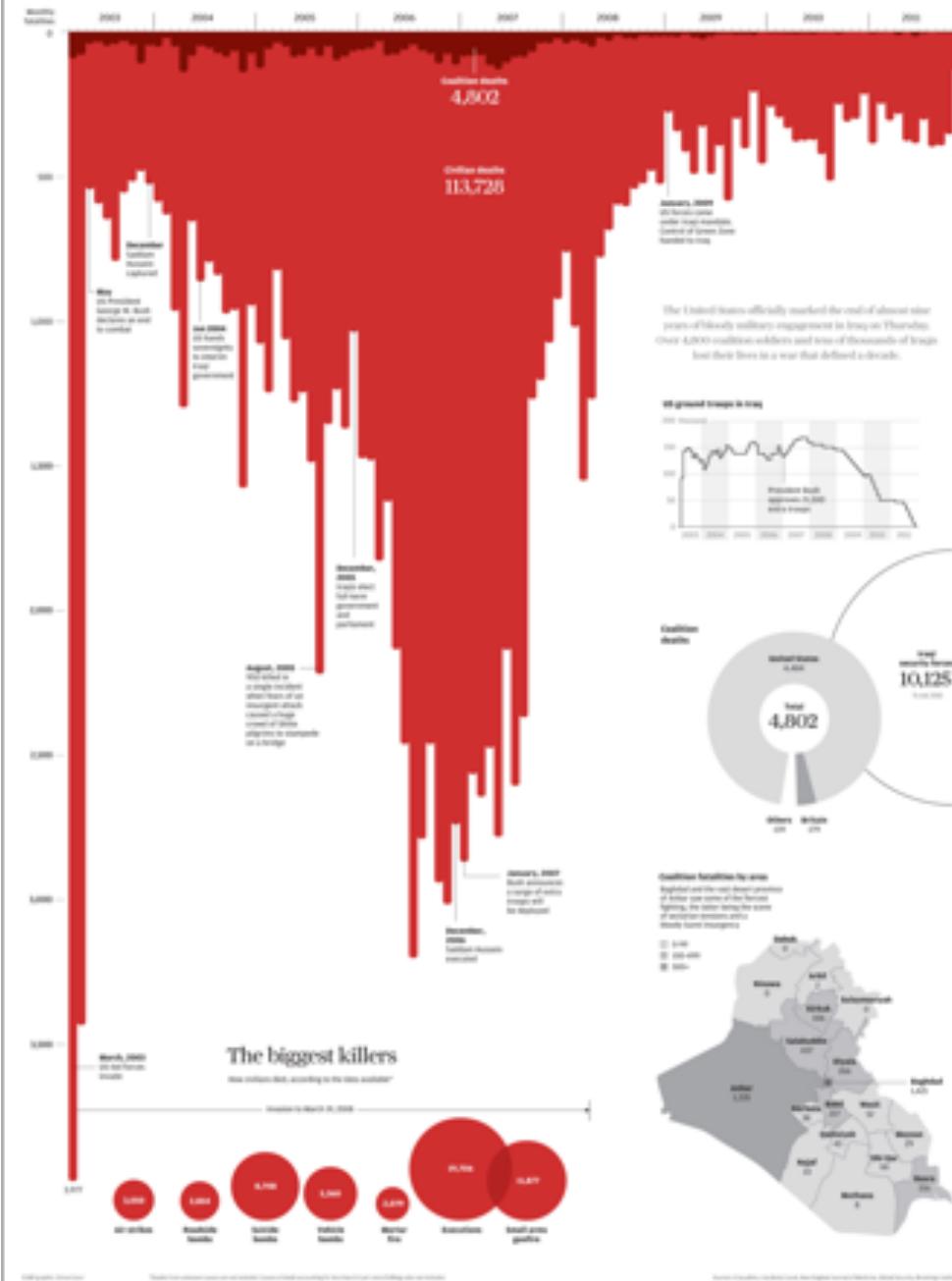
Les courbes bleues présentent les pertes subies par les divisions du général bleu à raison d'un millième pour six mille hommes. Le noir, le plus évident en dessous des bleus. Le rouge, lorsque les hommes qui restent, en Russie, le sont assez pour se débrouiller. — Les hachures qui entourent les courbes indiquent les mouvements qui ont abouti à faire le constat du précédent.

Sur cette carte je juge à tout le moins que l'armée française a été vaincue à Borodino par le général bleu, qui a vaincu le général noir, et que l'armée rouge a vaincu l'armée bleue, mais toujours aussi sur l'assaut.



See http://en.wikipedia.org/wiki/Charles_Joseph_Minard

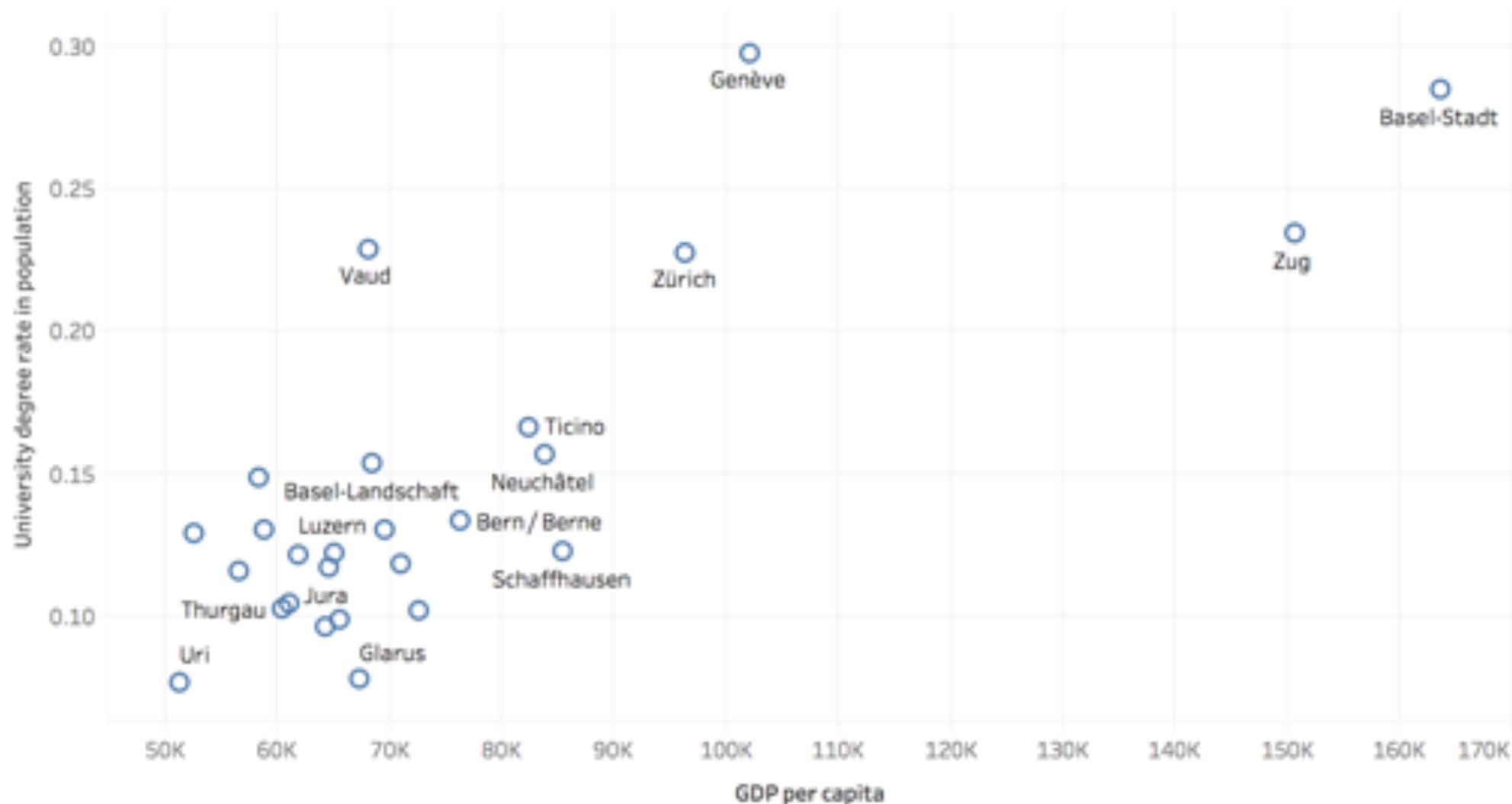
Iraq's bloody toll



		Uni degree %	GDP per capita
	Zürich	23%	96'411
	Bern / Berne	13%	76'307
	Luzern	12%	65'119
	Uri	8%	51'332
	Schwyz	13%	58'788
	Obwalden	10%	64'253
	Nidwalden	13%	69'559
	Glarus	8%	67'379
	Zug	23%	150'613
	Fribourg / Freiburg	15%	58'369
	Solothurn	10%	65'588
	Basel-Stadt	28%	163'632
	Basel-Landschaft	15%	68'537
	Schaffhausen	12%	85'529
	Appenzell Ausserrhoden	12%	56'663
	Appenzell Innerrhoden	10%	61'067
	St. Gallen	10%	72'624
	Graubünden / Grigioni / Grischun	12%	70'968
	Aargau	12%	61'959
	Thurgau	10%	60'533
	Ticino	17%	82'438
	Vaud	23%	68'084
	Valais / Wallis	13%	52'532
	Neuchâtel	16%	83'835
	Genève	30%	102'113
	Jura	12%	64'606

- Which state has lowest GDP per capita?
- Which state has the highest university degree rate in the population?
- Is there a relationship between GDP per capita and education?

		Uni degree %	GDP per capita
Zürich	23%	96'411	
Bern / Berne	13%	76'307	
Luzern	12%	65'119	
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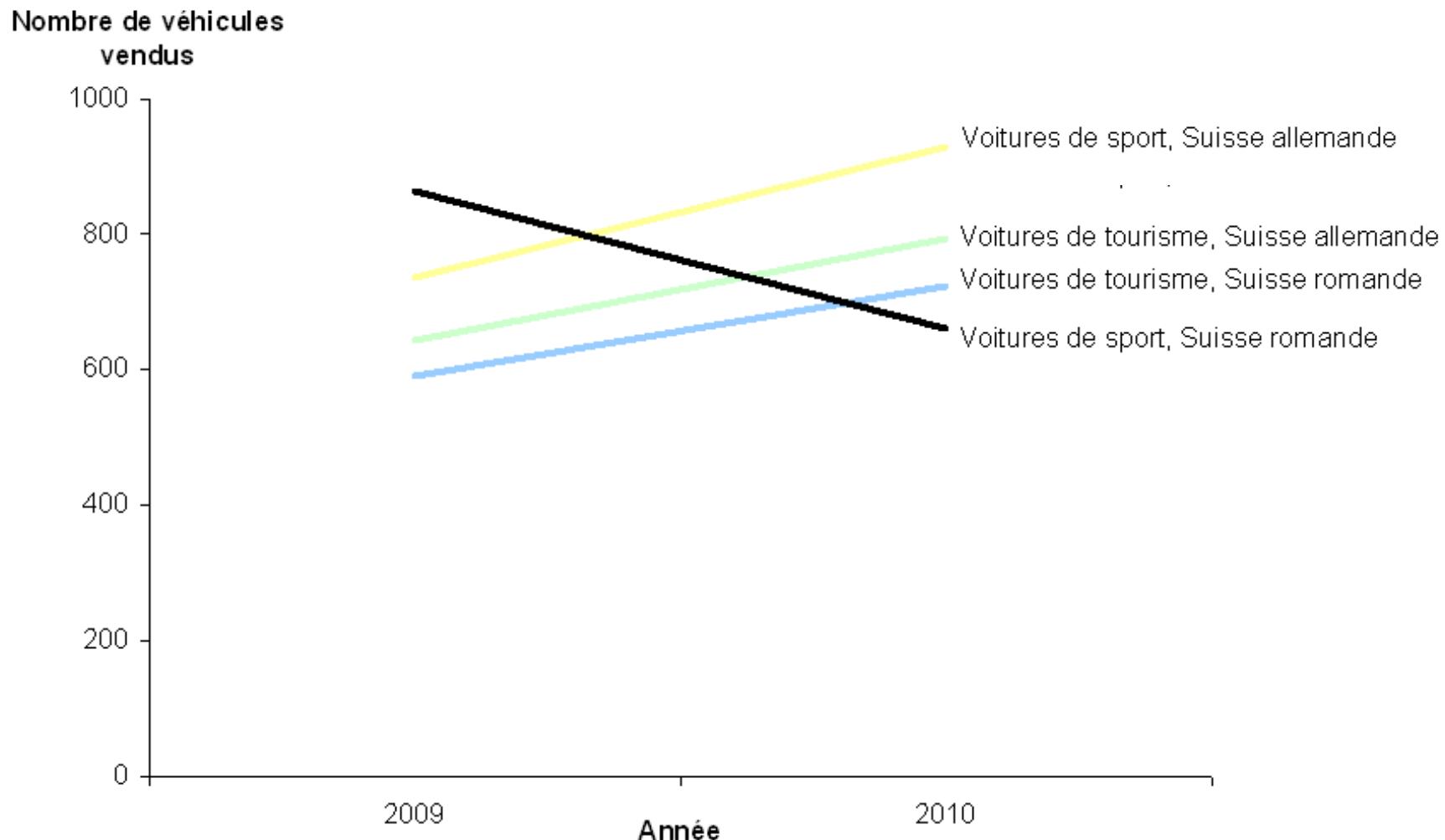


«Visualization is useful only for complex data»
Are you sure ?

Nombre de véhicules vendus par type, région et année

Type	Suisse allemande		Suisse romande	
	2009	2010	2009	2010
Voitures de tourisme	643	793	590	724
Voitures de sport	735	928	863	662

Nombre de véhicules vendus par type, région et année



Why visualize data?

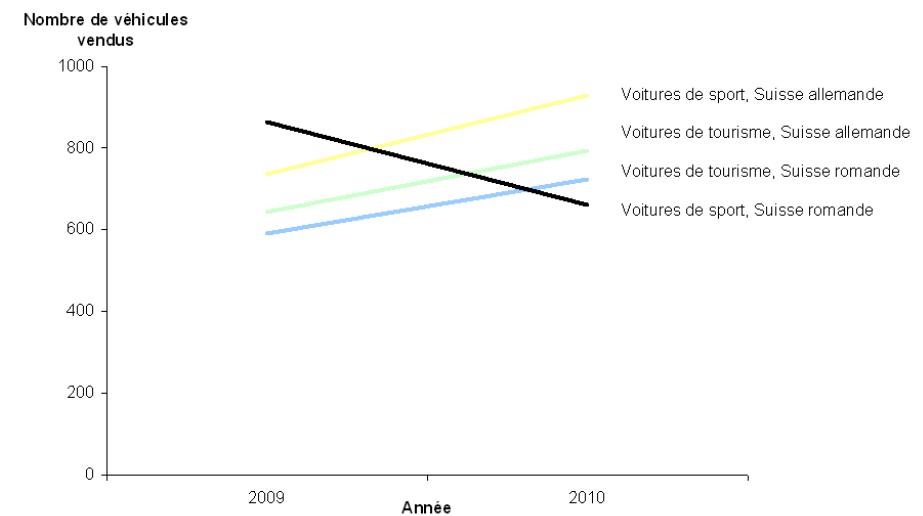
Replace cognition with perception

« Eye beats Memory »

Nombre de véhicules vendus par type, région et année

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Nombre de véhicules vendus par type, région et année



Why visualize data?

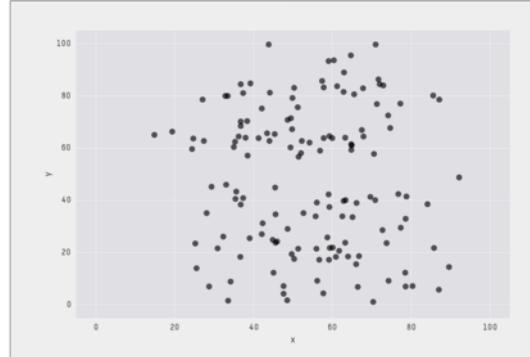
- Exploration
 - Prerequisite: domain knowledge
 - Outcome: new hypothesis
- Confirmation
 - Prerequisite: hypothesis
 - Outcome: confirmation/rejection (new hypothesis)
- Communication
 - Prerequisite: confirmed hypothesis
 - Outcome: clear message

[Keim KDD'02]

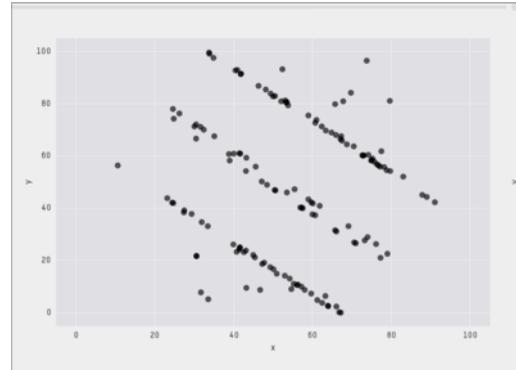
Exploration: approaching a new dataset

- To get a first idea about a dataset, we often use descriptive statistics
 - Mean
 - Standard deviation
 - Pairwise correlation
- With this we hope to get a basic overview of how the data looks like

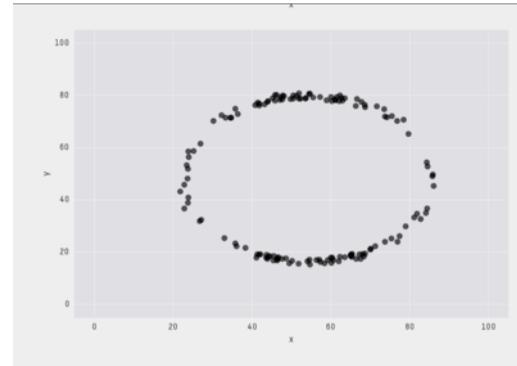
X Mean:	54.26
Y Mean:	47.83
X SD :	16.76
Y SD :	26.93
Corr. :	-0.06



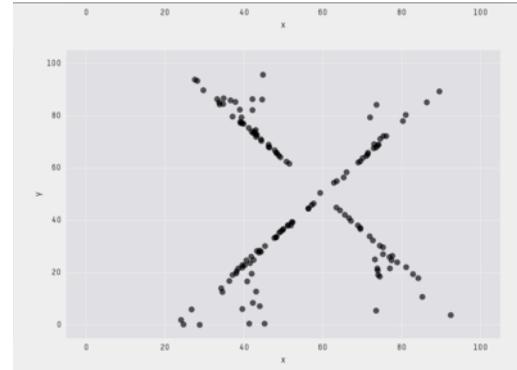
X Mean:	54.26
Y Mean:	47.83
X SD :	16.76
Y SD :	26.93
Corr. :	-0.06



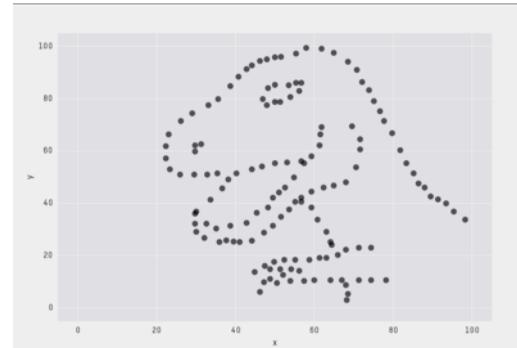
X Mean: 54.26
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X SD : 16.76
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X Mean: 54.26
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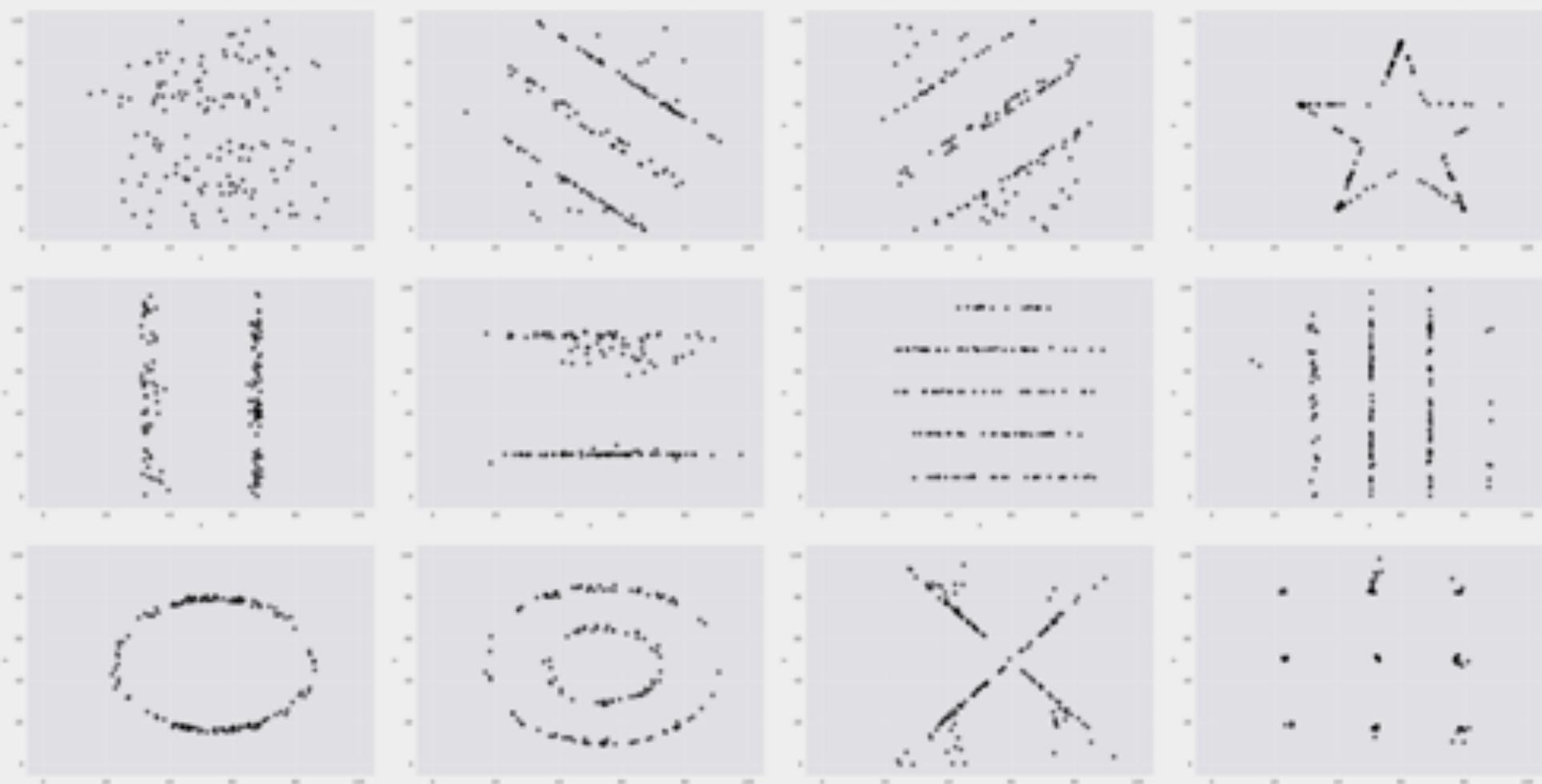
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X Mean: 54.26
Y Mean: 47.83
X SD : 16.76
Y SD : 26.93
Corr. : -0.06



‘Datasaurus’ dozen dataset

Justin Matejka and George Fitzmaurice. 2017. Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (CHI '17). ACM, New York, NY, USA, 1290-1294. DOI: <https://doi.org/10.1145/3025453.3025912>

WHY USING VISUAL REPRESENTATIONS OF DATA ? - 2

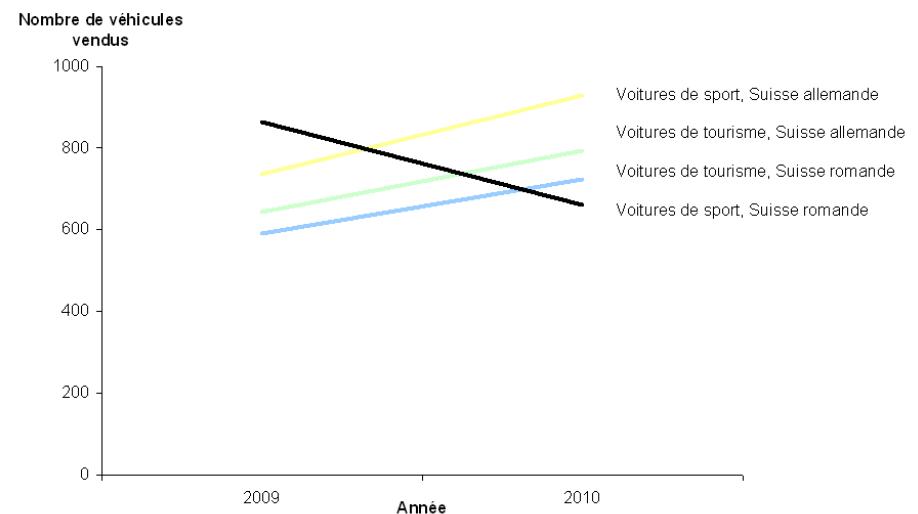
Replace cognition with perception

« Eye beats Memory »

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Nombre de véhicules vendus par type, région et année



WHY IS VISUALIZATION USEFUL?

- **Visualization helps in *making sense* of phenomena observed through derived data, when raw data alone is difficult to understand**
- **Visualization enables open-ended exploration, including when one does not know what to look for (vague goal)**
- **Other approaches to data analysis make *exploration* difficult**
 - **Statistics:**
 - (+) *strong verification*
 - (-) *does not support exploration and vague goals*
 - **Data mining:**
 - (+) *actionable and reliable*
 - (-) *black box style, not interactive (question-response)*

INFORMATION VISUALIZATION DEFINITION

« The use of computer-supported, interactive,
visual representations of abstract data to
amplify cognition »

[Card et al., 1999]

Information visualization = data visualization

INFORMATION VISUALIZATION VS INFOGRAPHICS

« The use of computer-supported, interactive,
visual representations of abstract data to
amplify cognition »

[Card et al., 1999, modified]

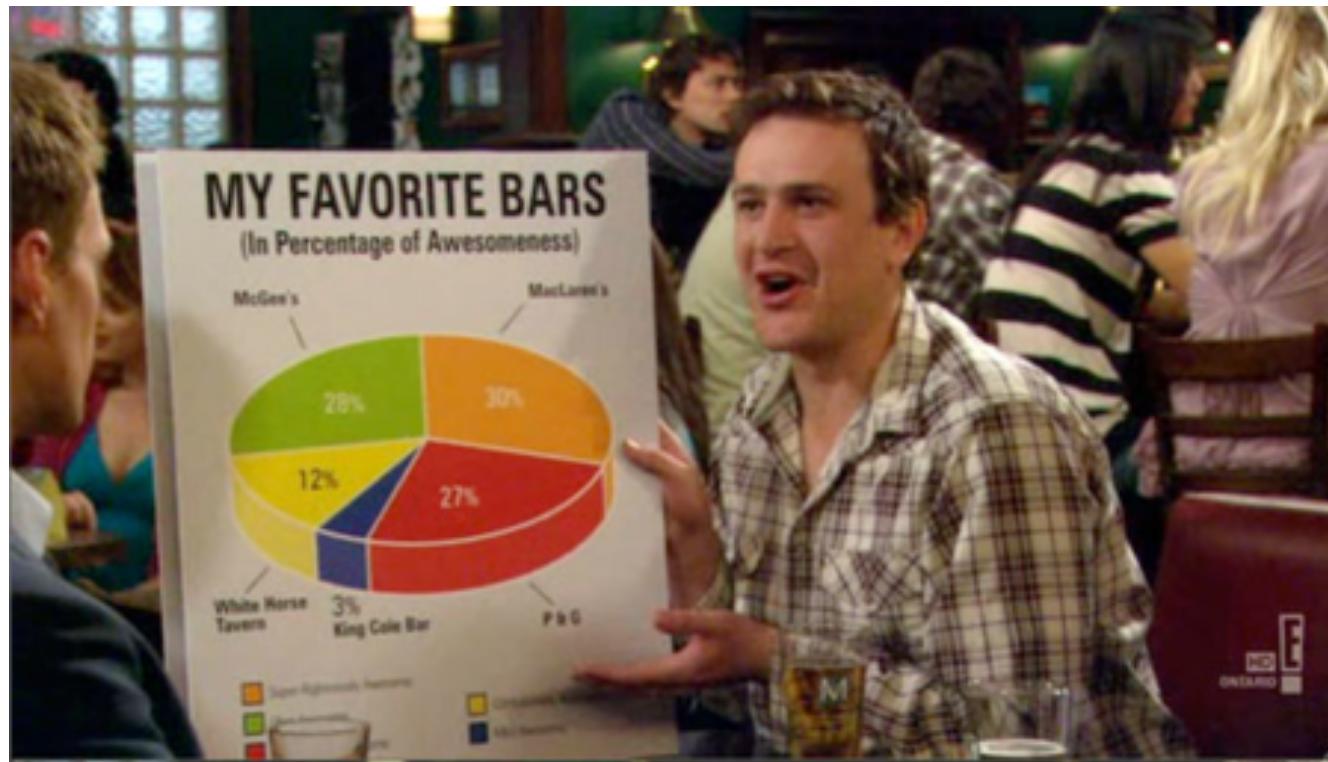
Aka infographics, static visualization, charts ...

HOW – VISUALIZATION IDIOMS - BASIC CHARTS



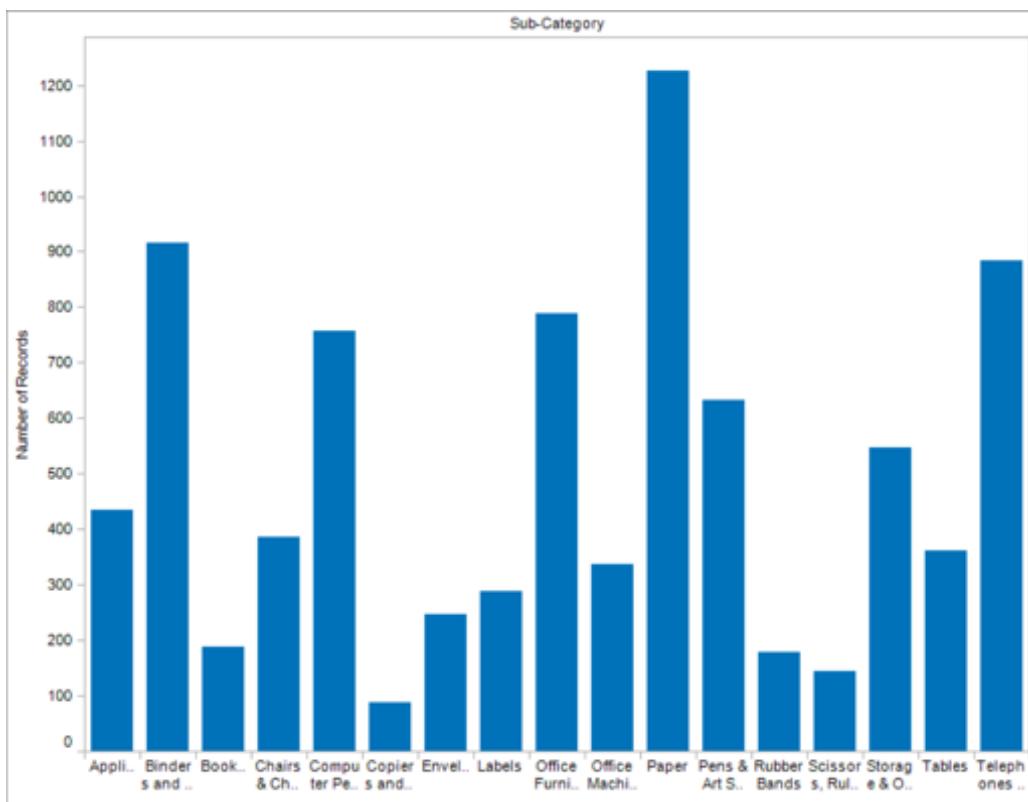
UNI
FR
UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

UNIVERSITÉ DE FRIBOURG / UNIVERSITÄT FREIBURG | HUMAN-IST RESEARCH CENTER



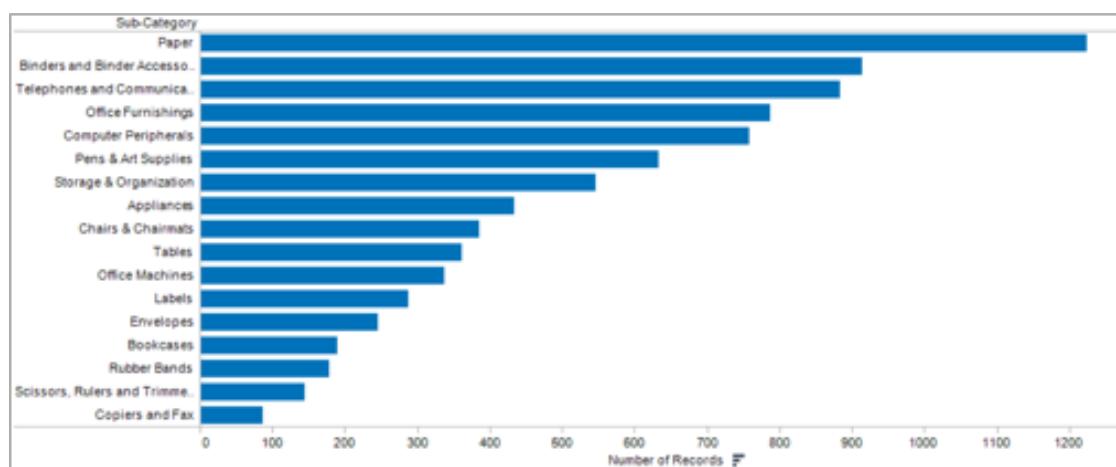
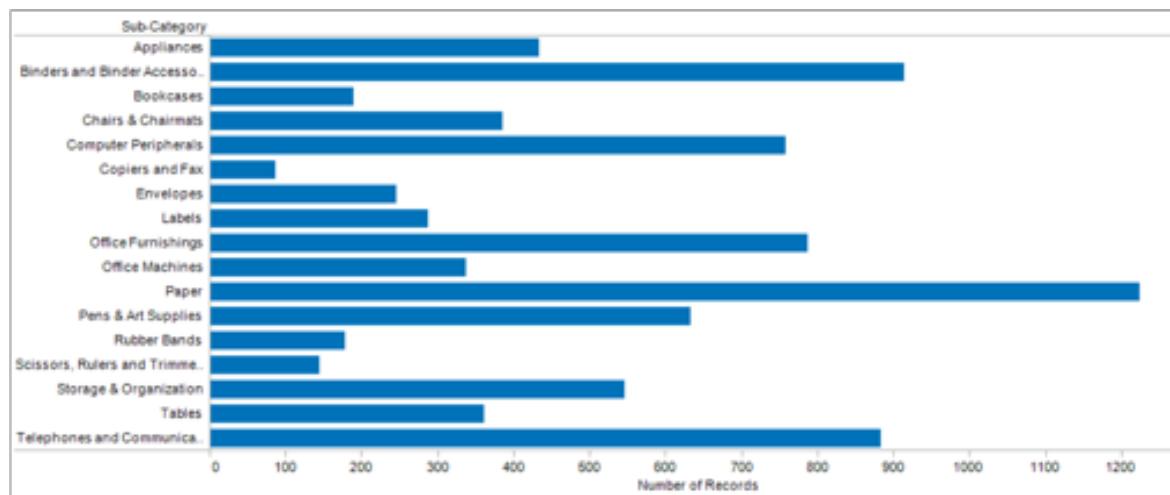
BAR CHART

Bar charts encode a relationship between categorical/nominal information and a quantity.



**Product Category
(categorical)
by
Number of Products
(quantity)**

BAR CHART



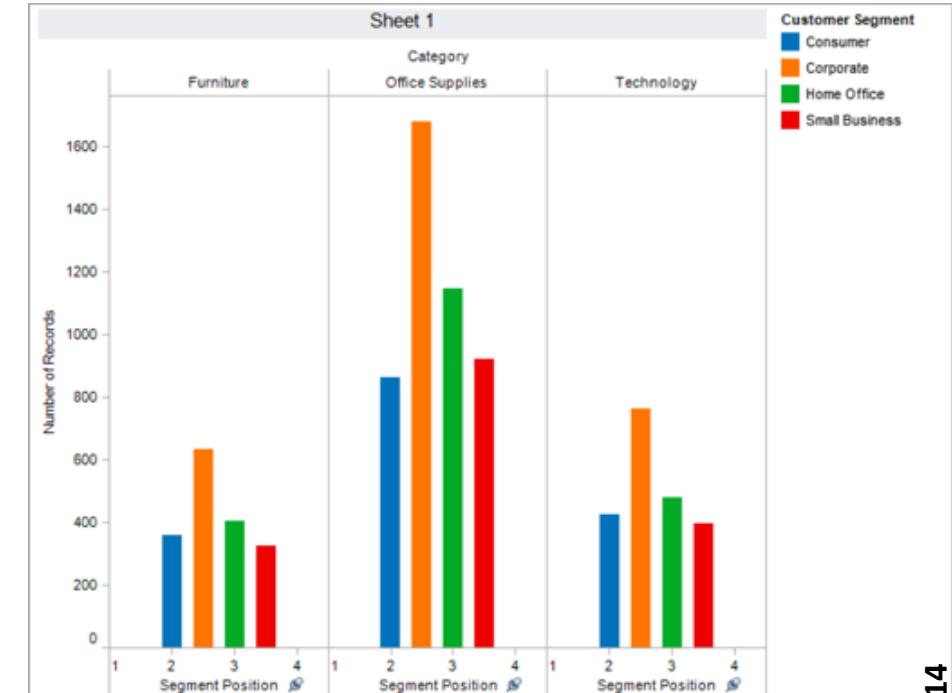
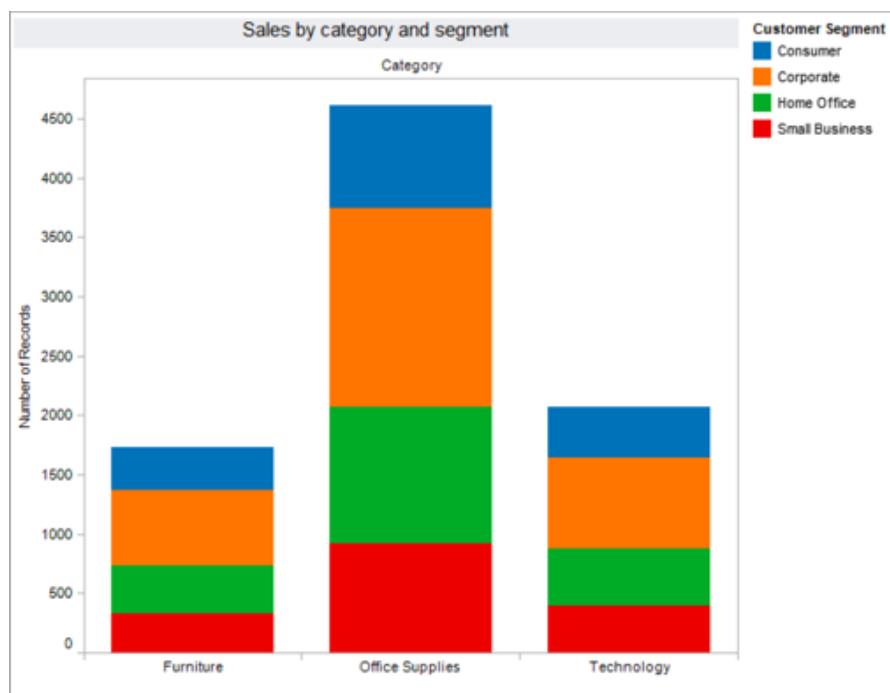
Source: Bertini, 2014

How about encoding the relationship between **two categorical attributes** and a **quantity**?

For instance, “*product sales by category of product and customer segment*”.



STACKED VS. GROUPED BAR CHART

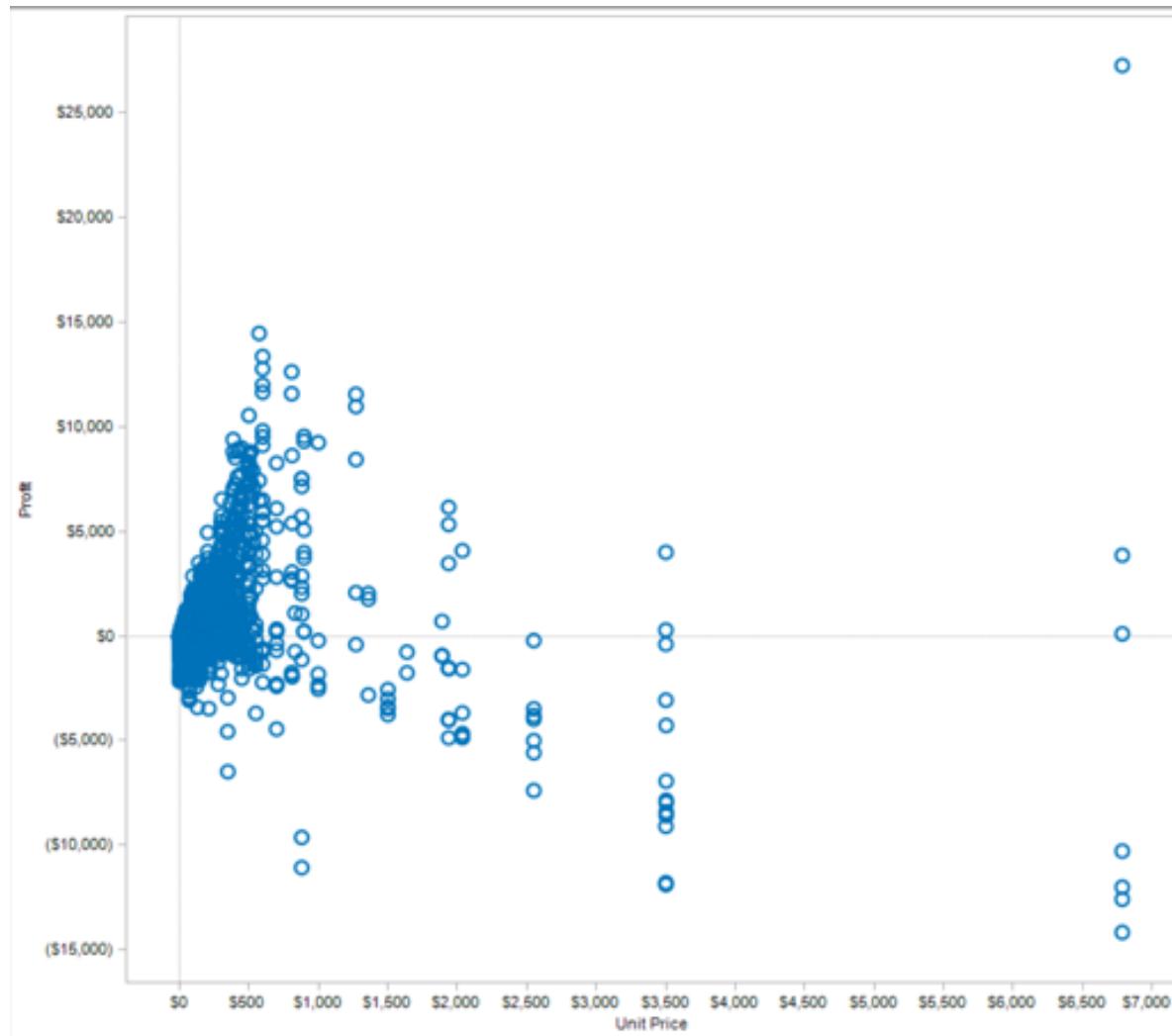


Source: Bertini, 2014

How about encoding the relationship between **two quantities**?

For instance, “*relationship between unit price and profit*”.

SCATTER PLOT

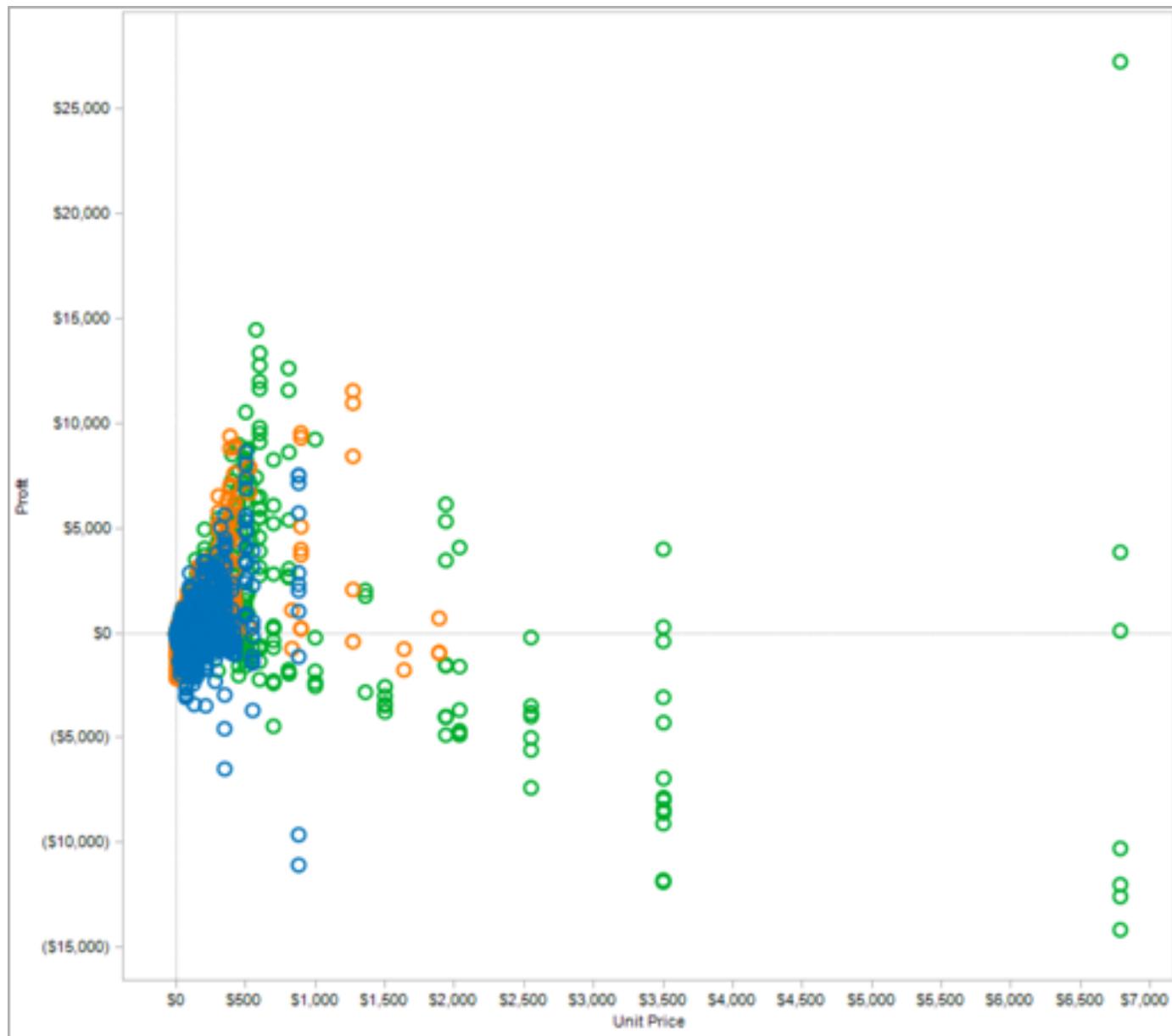


Source: Bertini, 2014



How about the relationship between **two quantities**
and a **categorical** variable?





How about encoding the relationship between **time**
+ a **categorical attribute** + **quantity**?

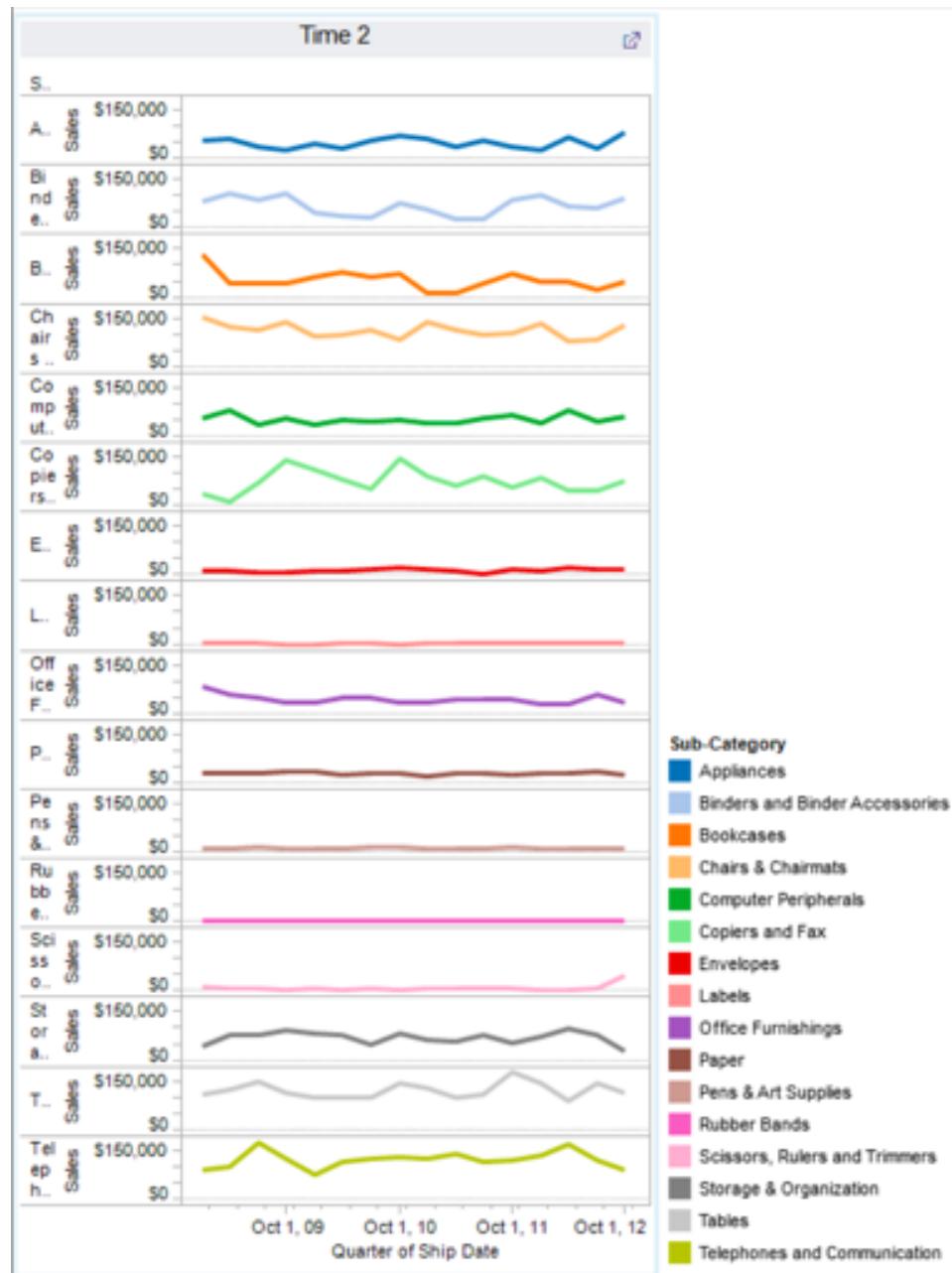


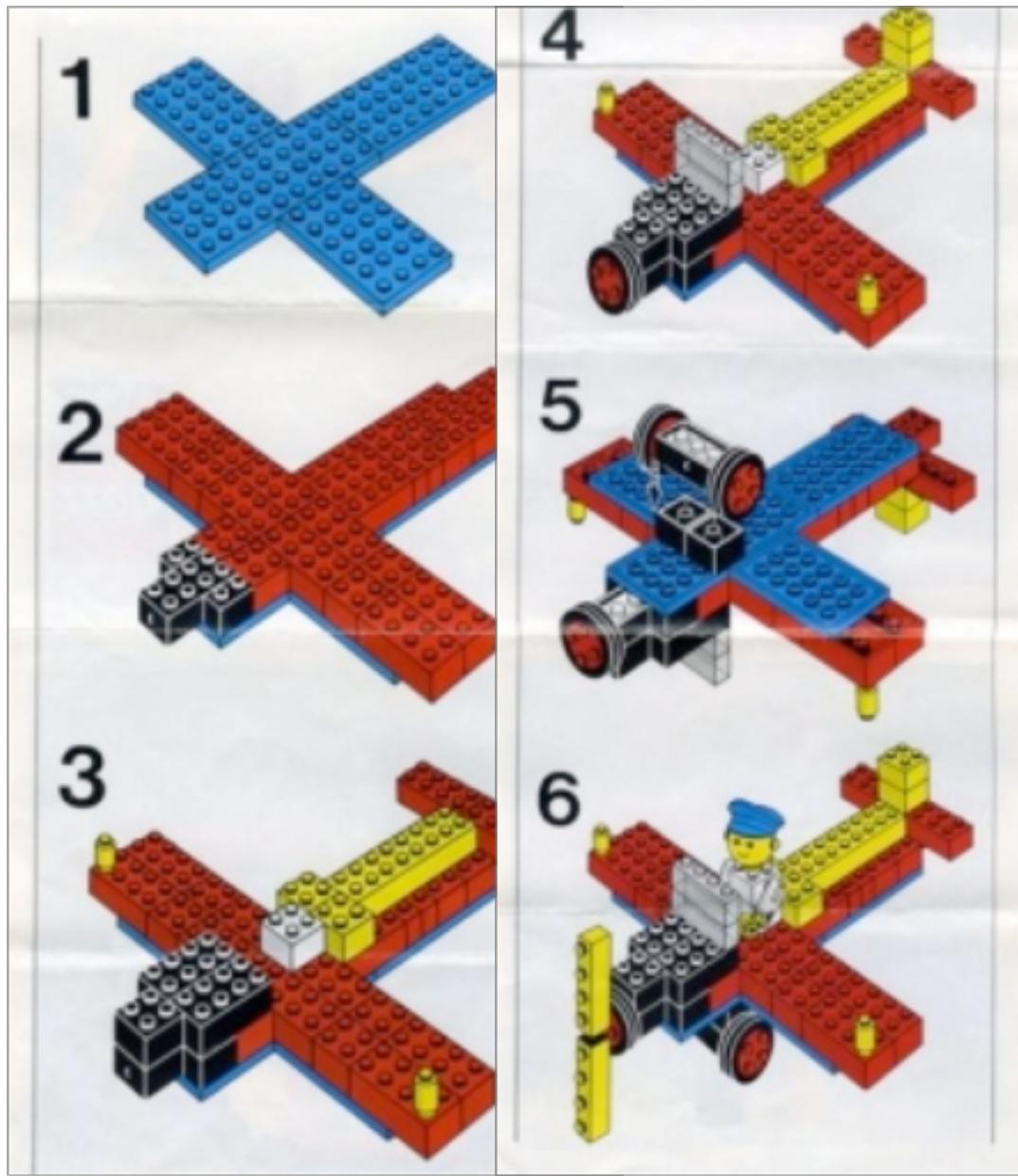
LINE CHARTS



Source: Bertini, 2014

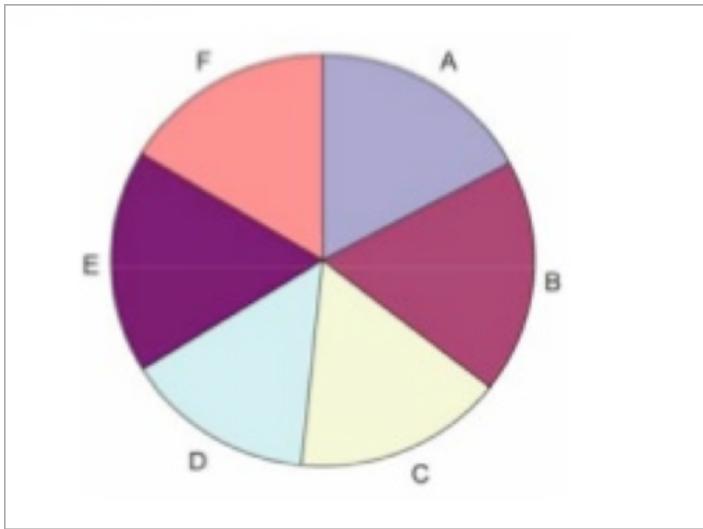
'SMALL MULTIPLES' LINE CHART

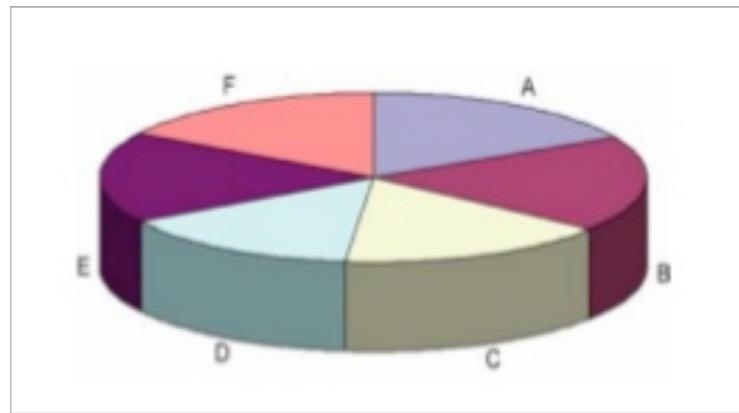


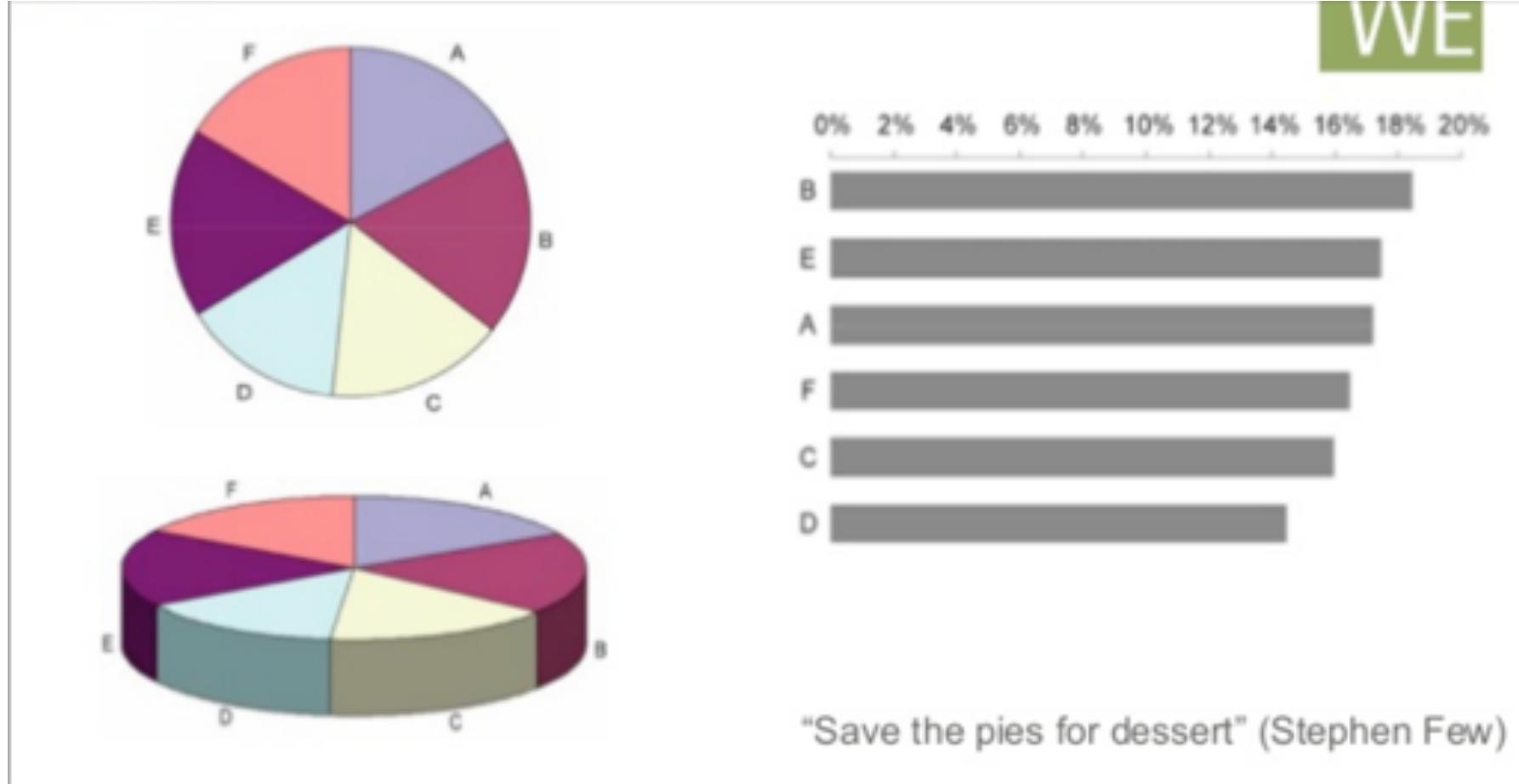


Encode **proportions**, part-to-whole relationship









AREN'T BASIC CHARTS ENOUGH ?

- Basic charts
 - are familiar,
 - are well understood by (almost) everybody
 - are relatively easy to produce with common tools (Excel, ...)
 - designed with care, they are able to represent complex data
- However, they have their limitations
 - support of multidimensional datasets (> 3)
 - support of high-density spaces
 - support of relational data
 - support of geographically-related data
 - ...

VISUALIZATION PARADIGM

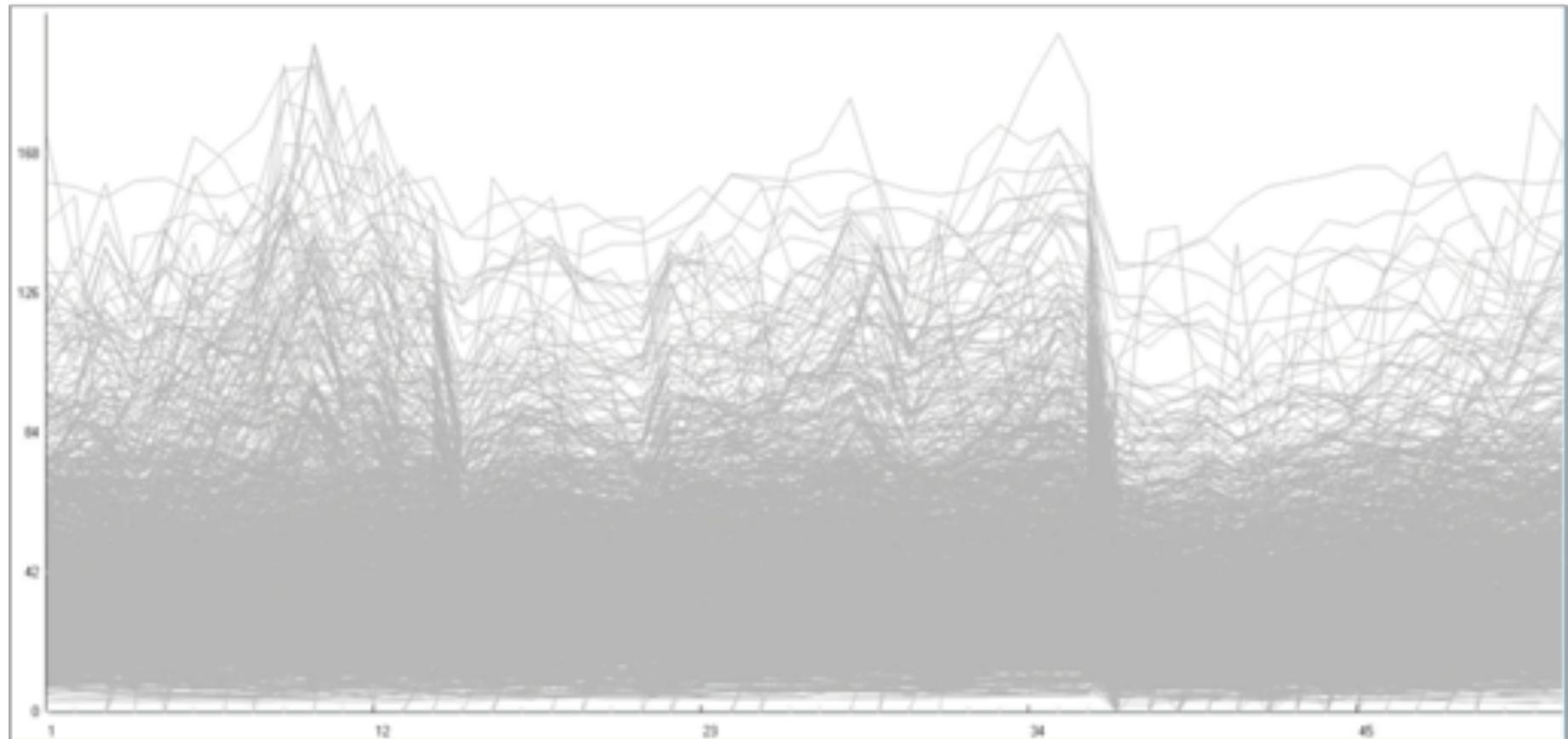
Shneiderman's Information Seeking Mantra: Overview First, Zoom & Filter, Details on Demand

An overview allows people to embrace the whole data set at once.

Many paths are available then, it acts as a “visual index”.

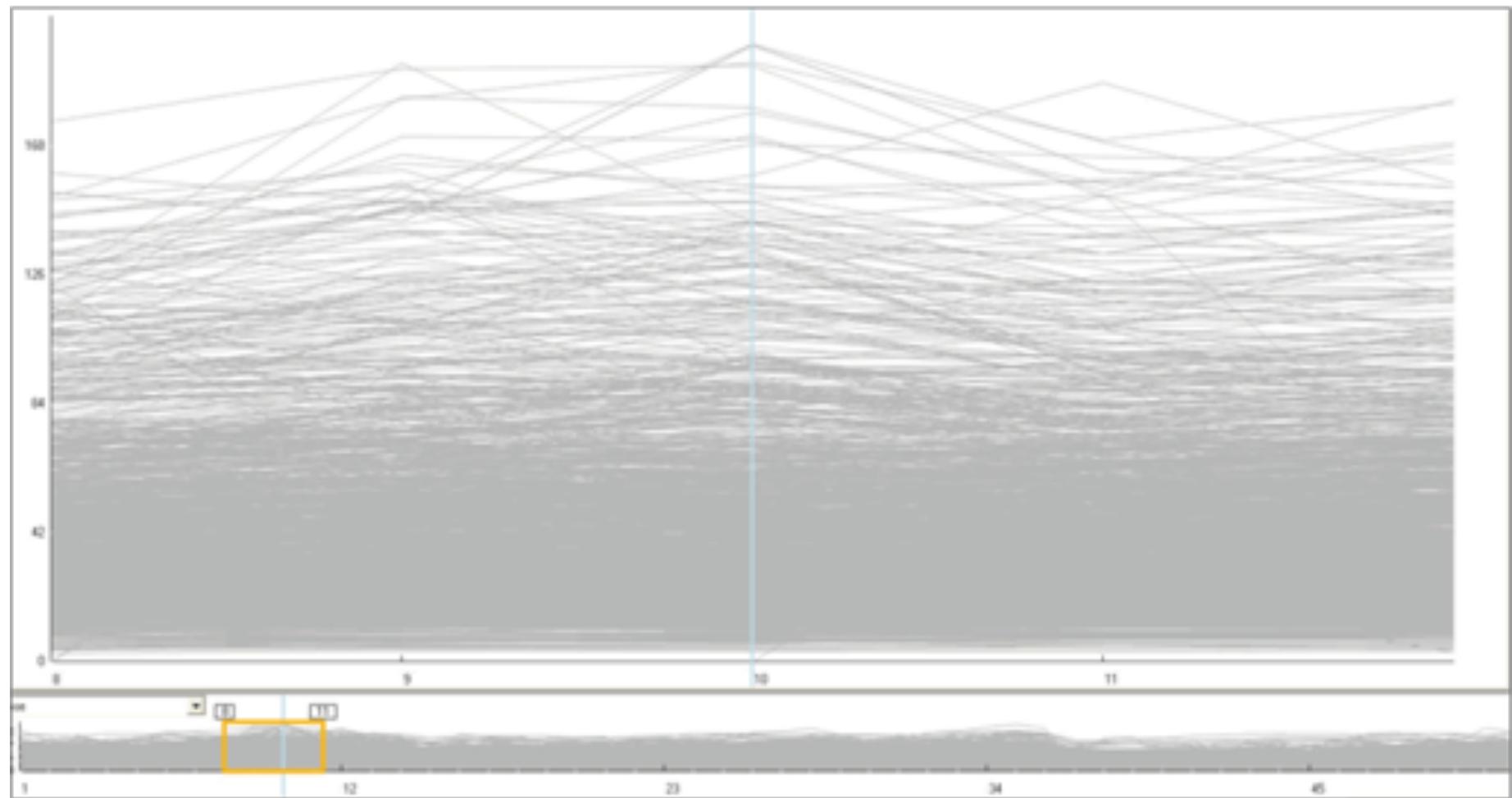
Shneiderman, Ben. "[The eyes have it: A task by data type taxonomy for information visualizations.](#)" *Visual Languages, 1996. Proceedings., IEEE Symposium on.* IEEE, 1996.

INFORMATION SEEKING MANTRA - OVERVIEW



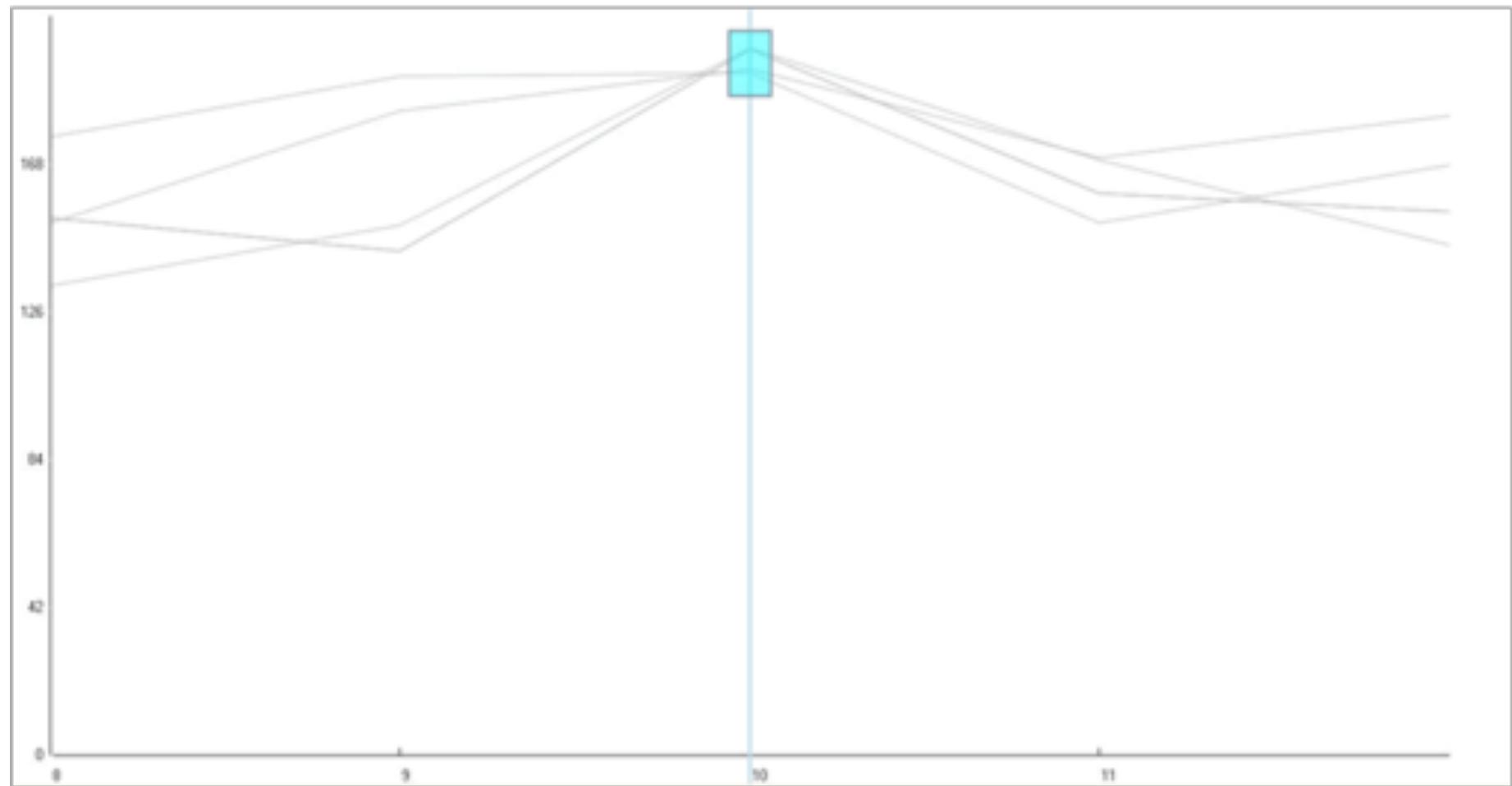
Source: Stephen Few <http://www.b-eye-network.com/view/2674>

INFORMATION SEEKING MANTRA - ZOOM



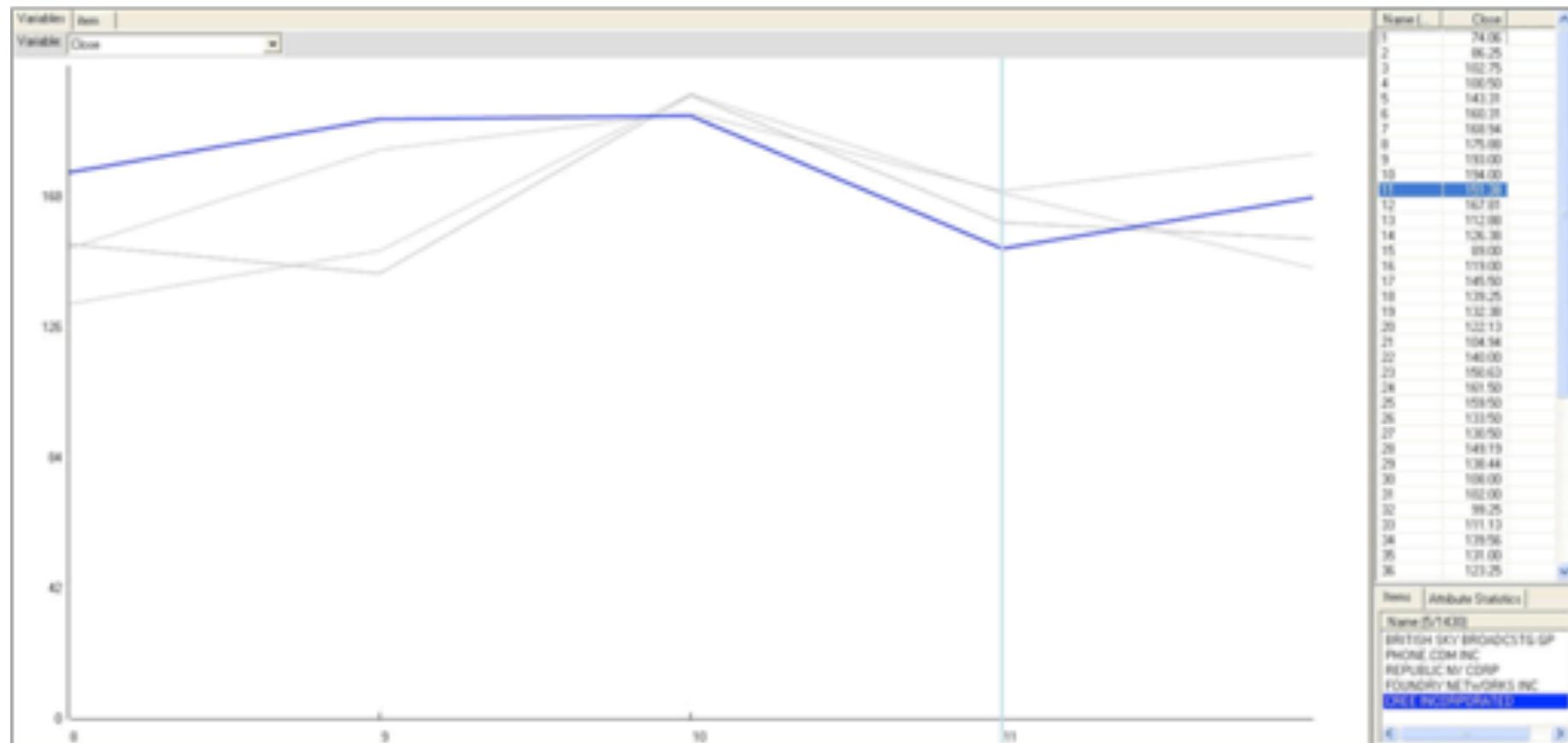
Source: Stephen Few <http://www.b-eye-network.com/view/2674>

INFORMATION SEEKING MANTRA - FILTER



Source: Stephen Few <http://www.b-eye-network.com/view/2674>

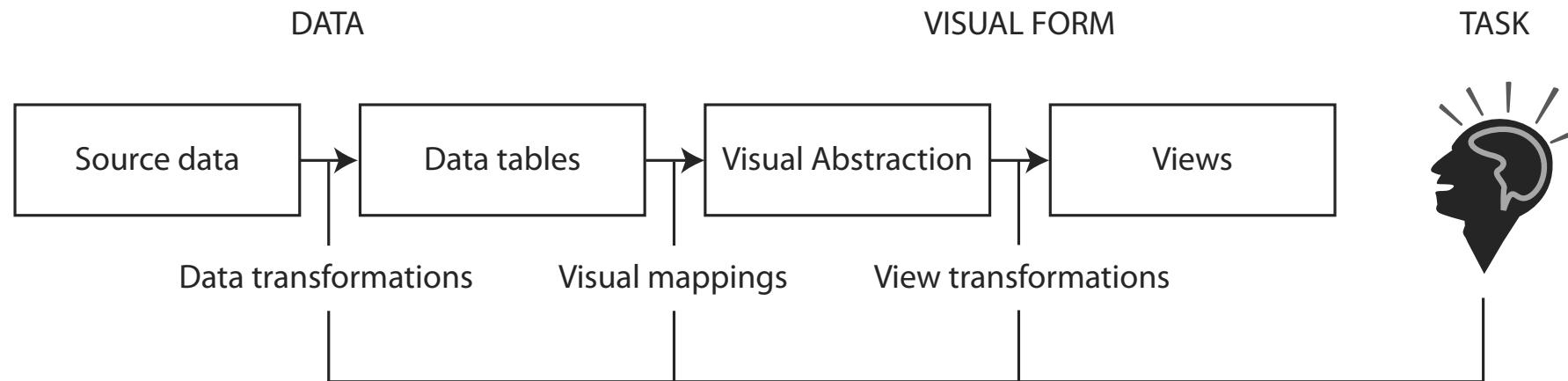
INFORMATION SEEKING MANTRA – DETAILS ON DEMAND



Source: Stephen Few <http://www.b-eye-network.com/view/2674>



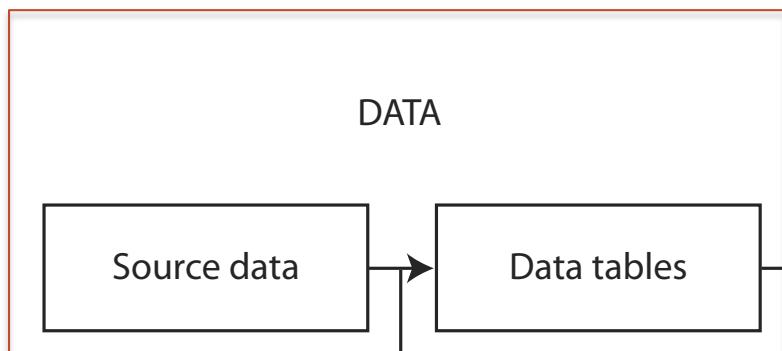
DATA VISUALIZATION PROCESS



Redrawn from Card, Stuart K., Jock D. Mackinlay, and Ben Shneiderman (Editors) (1999). *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA. ISBN 1558605339.

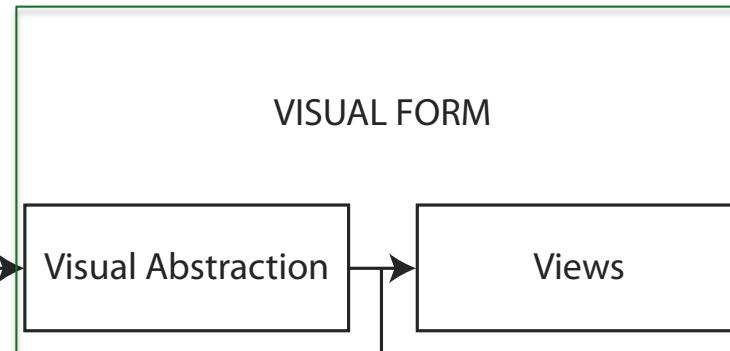
DATA VISUALIZATION PROCESS

what



Data transformations

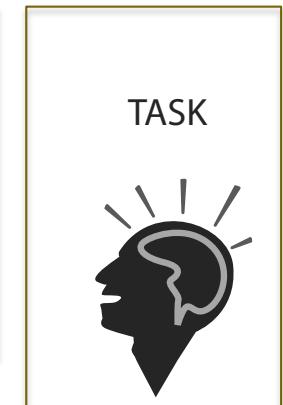
how



Visual mappings

View transformations

why



What?

Why?

How?

VISUALIZATION ANALYSIS & DESIGN: WHAT, WHY, AND HOW

- **what is shown?**
 - **data abstraction**
- **why is the user looking at it?**
 - **task abstraction**
- **how is it shown?**
 - **idiom**: visual encoding and interaction
- **what-why-how analysis framework as scaffold to think systematically about design space**

What?

Datasets

→ Data Types

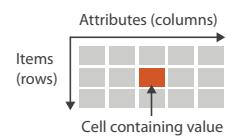
→ Items → Attributes → Links → Positions → Grids

→ Data and Dataset Types

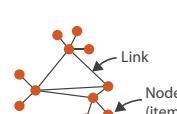
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	

→ Dataset Types

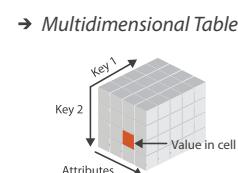
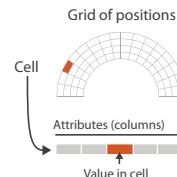
→ Tables



→ Networks



→ Fields (Continuous)



→ Trees



→ Geometry (Spatial)



→ Dataset Availability

→ Static



→ Dynamic



Attributes

→ Attribute Types

→ Categorical



→ Ordered

→ Ordinal



→ Quantitative



→ Ordering Direction

→ Sequential



→ Diverging



→ Cyclic



What?

Why?

How?

Source: Tamara Munzner (see references)



{action, target} pairs

- *discover distribution*
- *compare trends*
- *locate outliers*
- *browse topology*

HIGH-LEVEL ACTIONS: ANALYZE

■ consume

- discover vs present

classic split

aka explore vs explain

aka communicate vs analyze

- enjoy

newcomer

aka casual, social

■ produce

- annotate, record

- derive

crucial design choice



MID-LEVEL ACTIONS: SEARCH, LOW-LEVEL ACTIONS: QUERY

- **what does user know?**
 - target, location
- **how much of the data matters?**
 - one, some, all

➔ Search

	Target known	Target unknown
Location known	 Lookup	 Browse
Location unknown	 Locate	 Explore

➔ Query

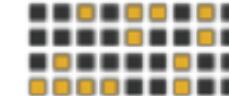
➔ Identify

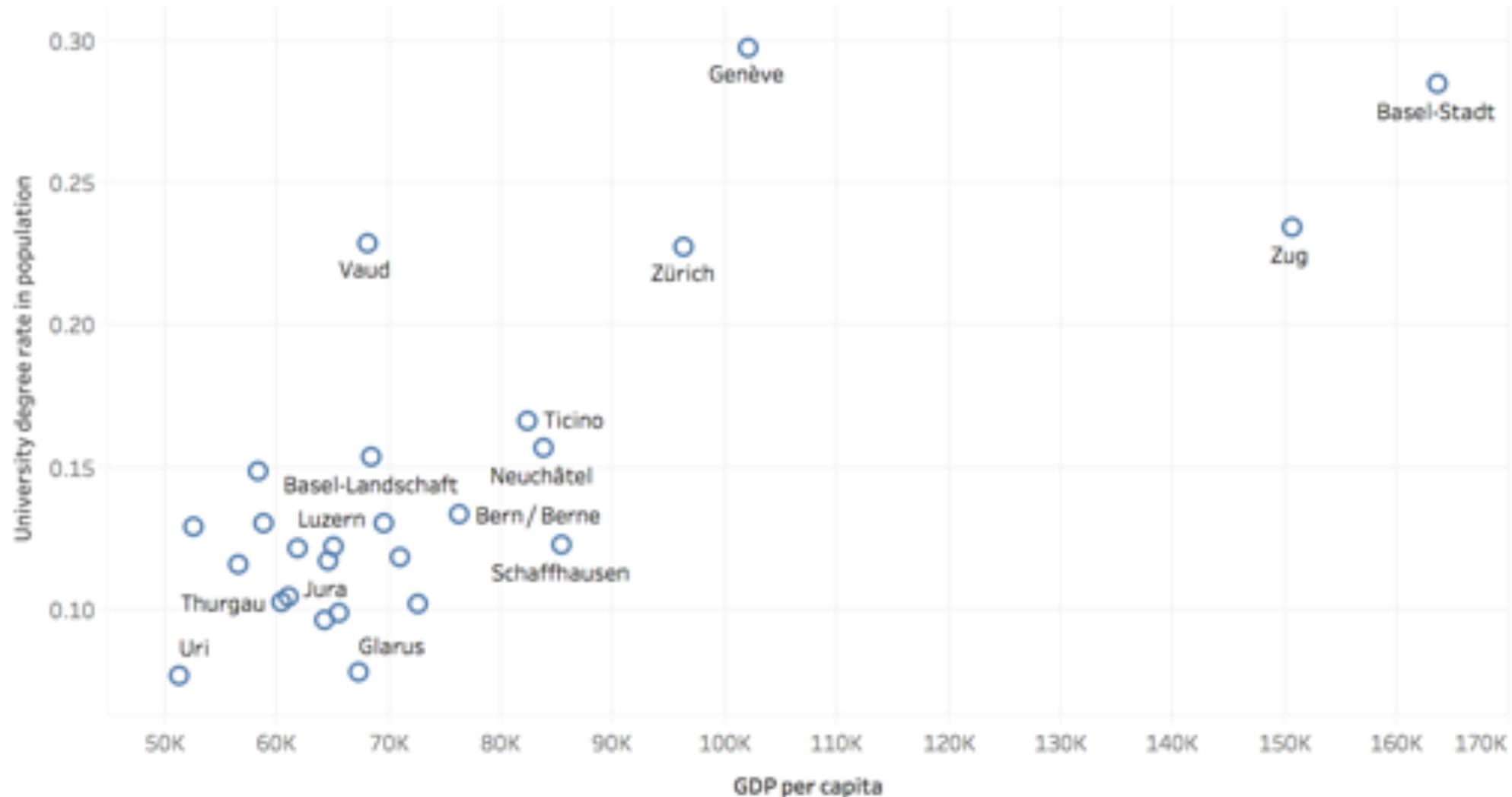


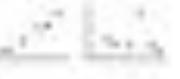
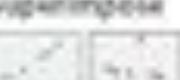
➔ Compare



➔ Summarize





How?			
Encode	Manipulate	Facet	Reduce
<ul style="list-style-type: none"> ⊕ Arrange <ul style="list-style-type: none"> → Express → Separate → Order → Align → Use ⊕ Map <ul style="list-style-type: none"> From categorical and ordered ATTRIBUTES → Color → Size, Angle, Curvature... → Shape → Position 	<ul style="list-style-type: none"> ⊕ Change <ul style="list-style-type: none"> → Swap → Select → Navigate 	<ul style="list-style-type: none"> ⊕ Join/Append <ul style="list-style-type: none"> → Partition → Superimpose 	<ul style="list-style-type: none"> ⊕ Pivot <ul style="list-style-type: none"> → Aggregate → Embed
			
			
			

WORKSHOP

[HTTPS://BIT.LY/2WVS19B](https://bit.ly/2WVS19B)

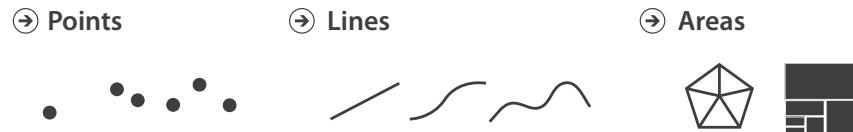
- Choose 2 visualizations from the list on Google Sheet
- Ask yourself
 - **What is the data?**
 - **Why visualizing this data?**
What typical tasks does the visualization support?
 - **How is it visualized?**
What is the meaning of shapes, colors, positions, of visual elements (aka visualization idiom) ?
 - **Do you find the visualization good or not ? Why ?**
- Presentation to the class & Discussion
- 10 minutes preparation
- 5 minutes presentation + discussion / visualization

BUILDING BLOCKS OF VISUALIZATION

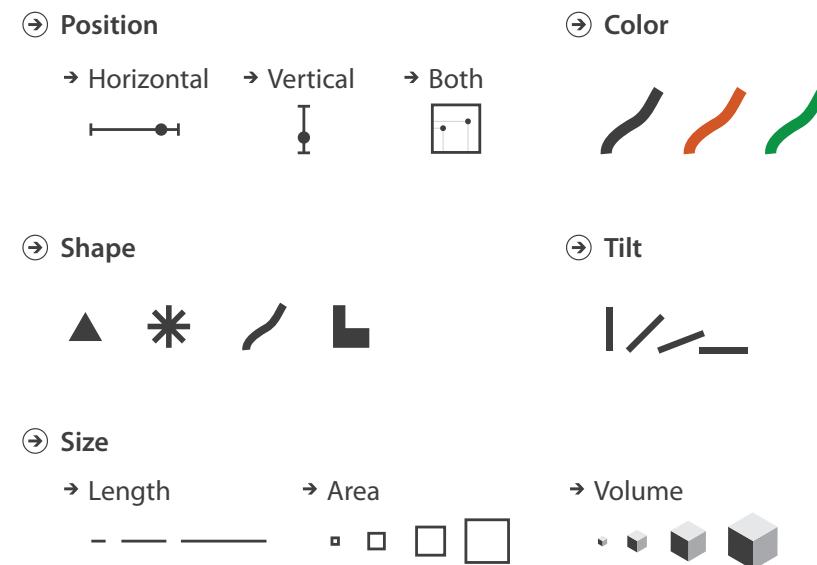
- **Based on those examples, what are the key components of a visualization ?**

HOW – VISUAL ENCODING – MARKS & CHANNELS

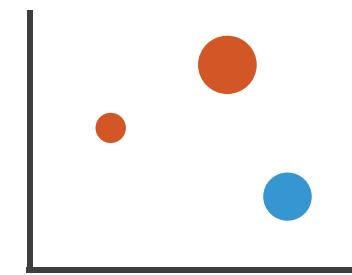
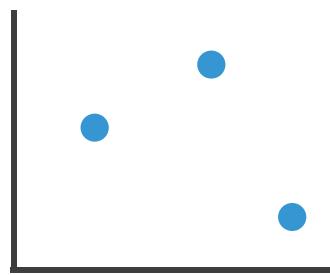
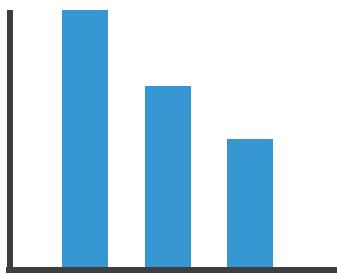
- Marks = graphical elements, geometric primitive objects



- Channels = ways to encode information as properties of marks

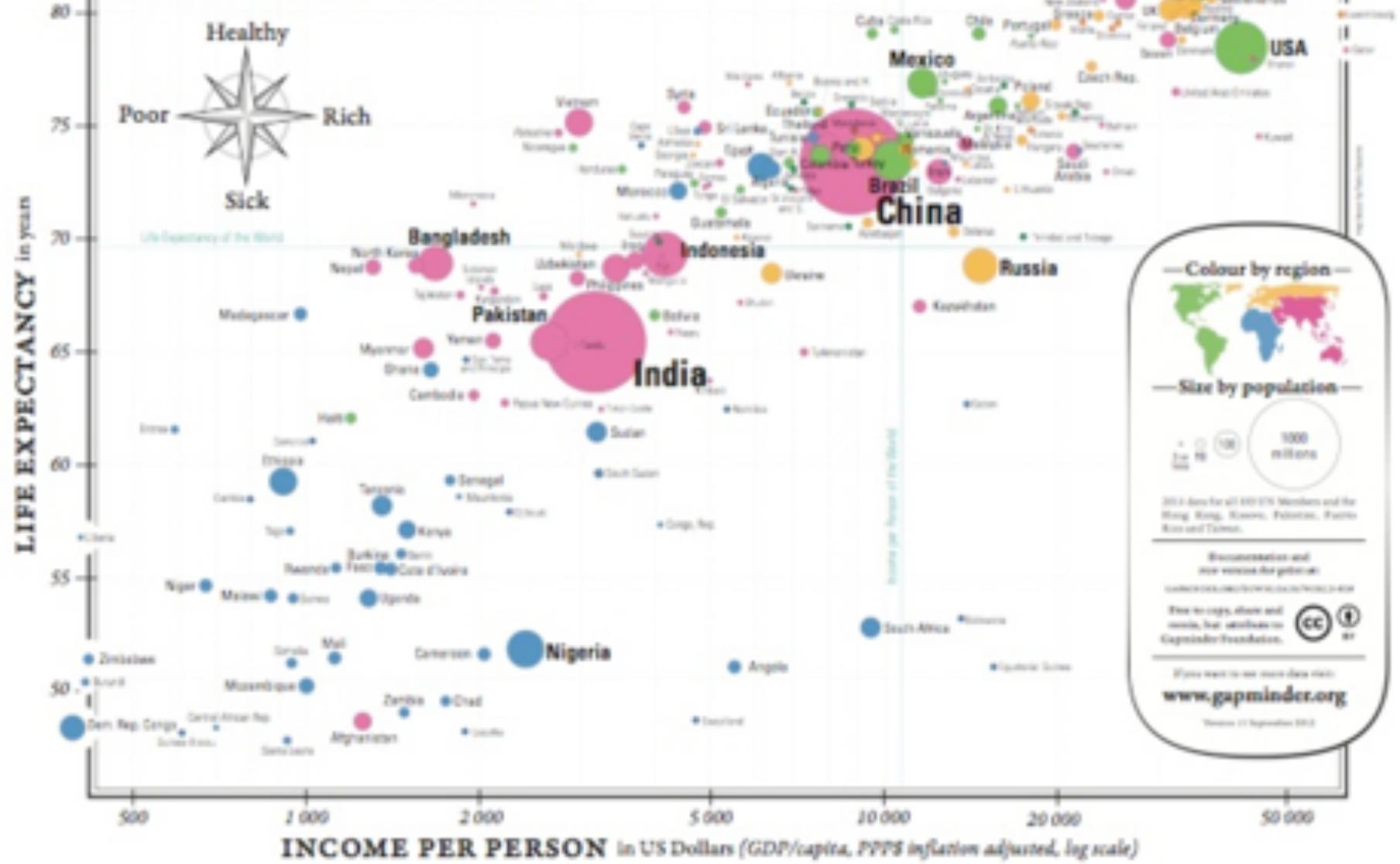


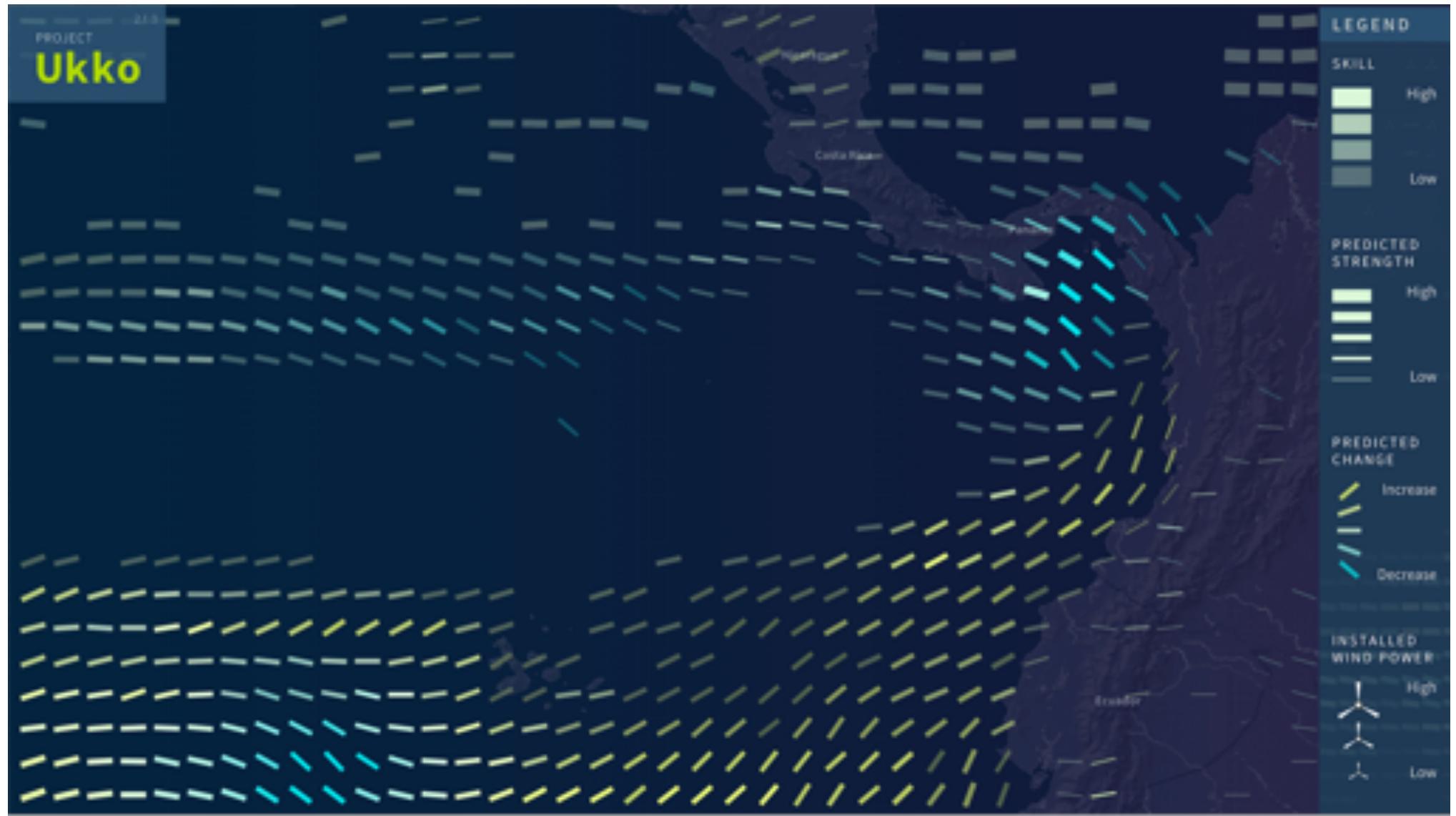
HOW – VISUAL ENCODING – MARKS & CHANNELS - EXAMPLE



GAPMINDER WORLD 2012

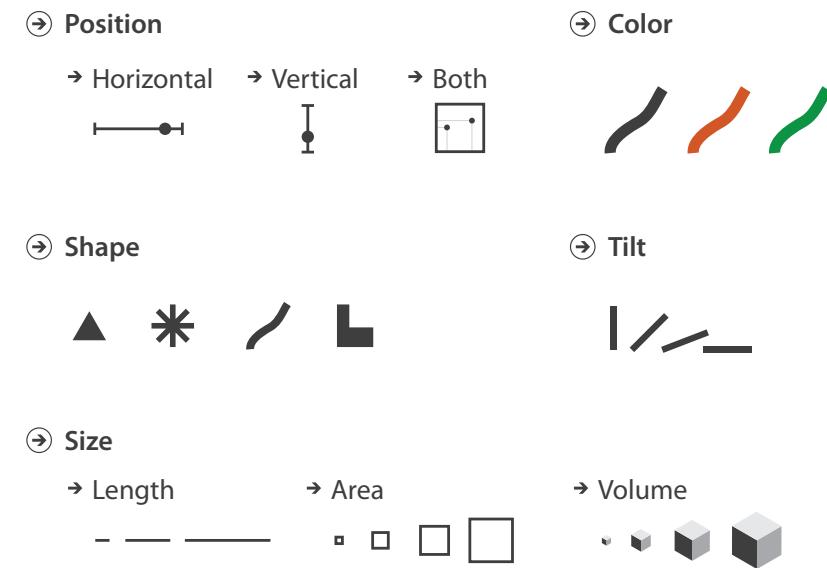
Mapping the Wealth and Health of Nations





CHANNEL EXPRESSIVENESS & EFFECTIVENESS

- **effectiveness principle**
 - encode most important attributes with highest ranked channels
- **expressiveness principle**
 - match channel and data characteristics
- **rankings: where do they come from?**
 - accuracy
 - discriminability
 - separability
 - popout



CHANNEL EXPRESSIVENESS & EFFECTIVENESS

Channels: Expressiveness Types and Effectiveness Marks

+ Magnitude: Channels: Ordered Attributes

Position on continuous scale



Position on unaligned scale



Length (1D size)



Width/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



+ Identity: Channels: Categorical Attributes

Spatial region



Color hue



Rotation

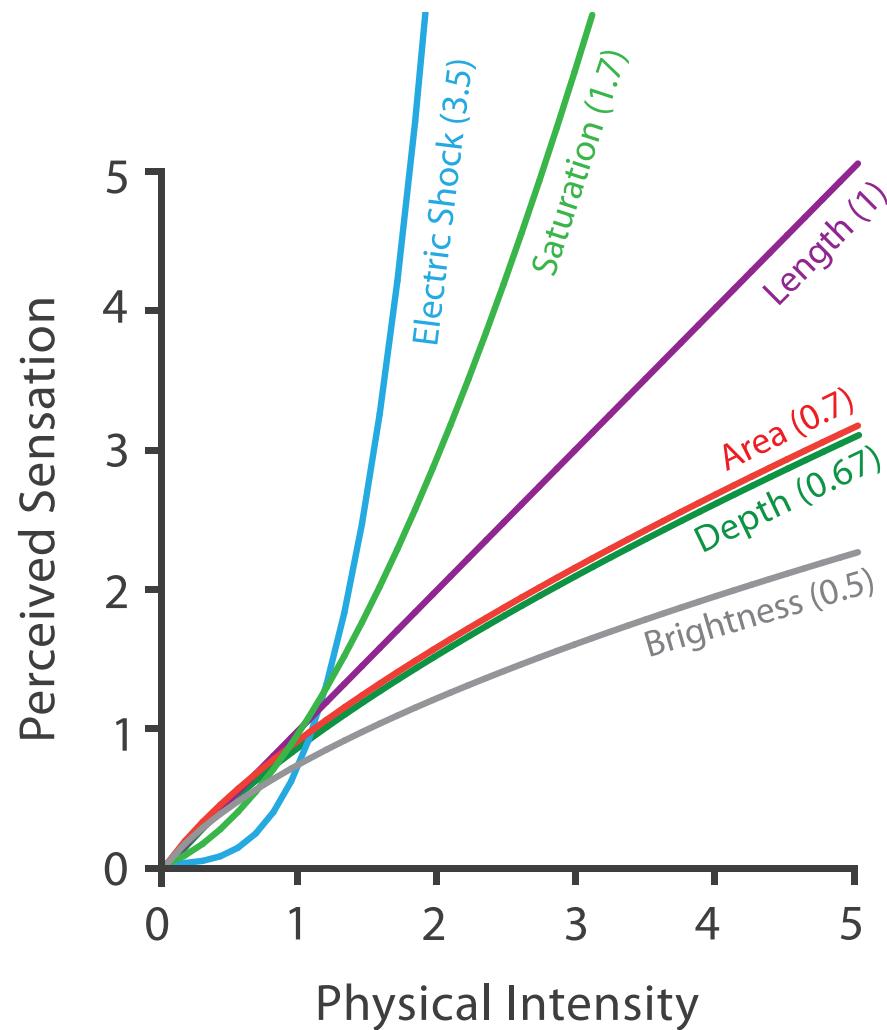


Shape

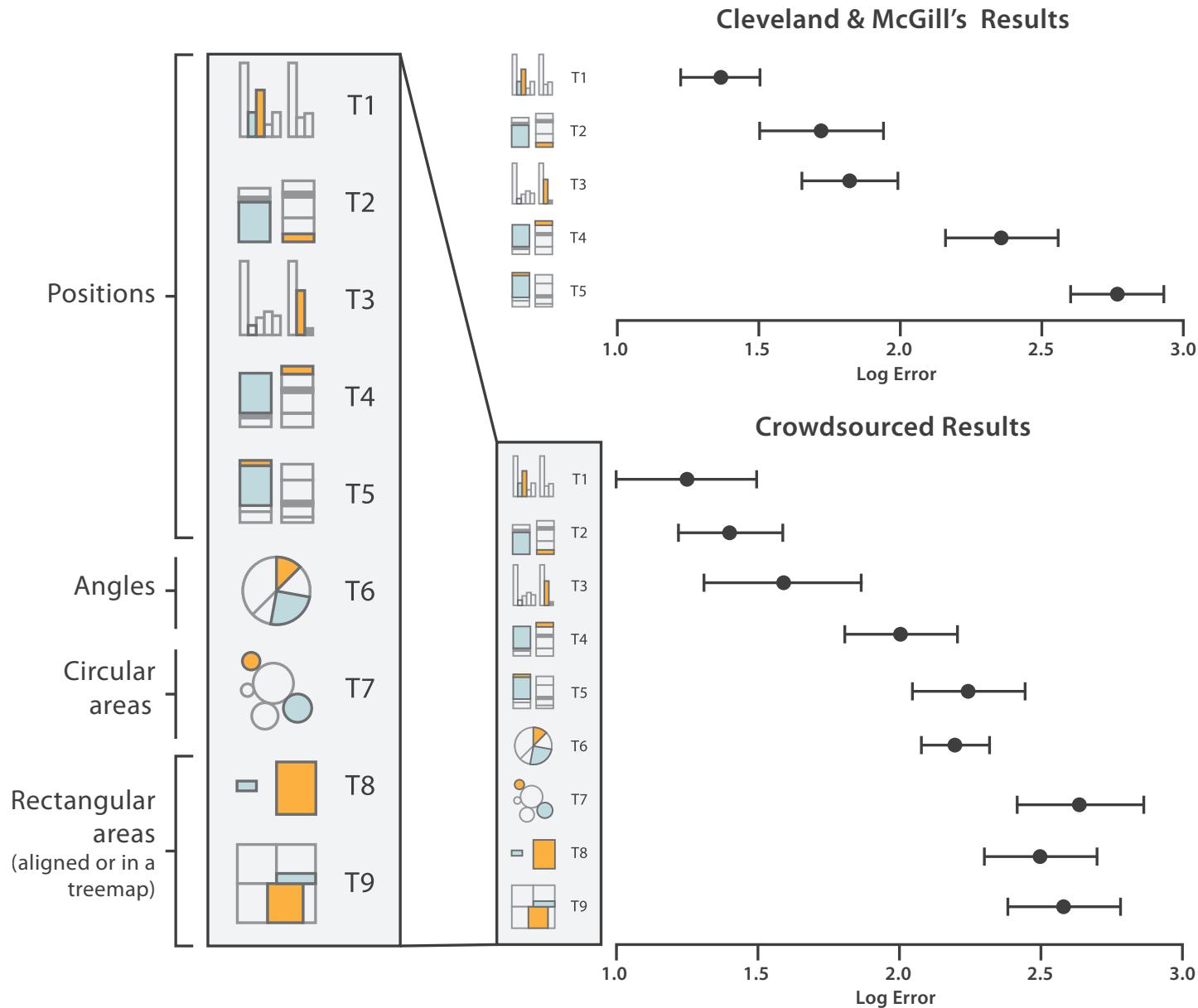


CHANNEL ACCURACY: THEORY

Steven's Psychophysical Power Law: $S = I^n$

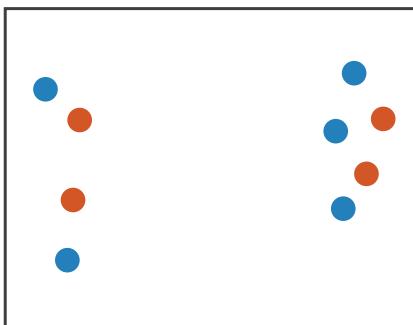


CHANNEL ACCURACY



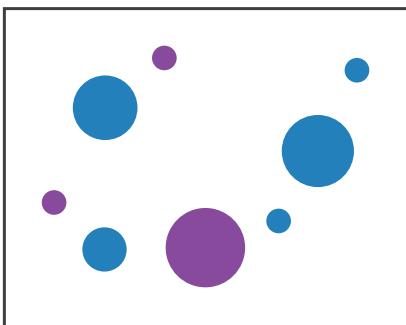
CHANNEL SEPARABILITY

Position
+ Hue (Color)



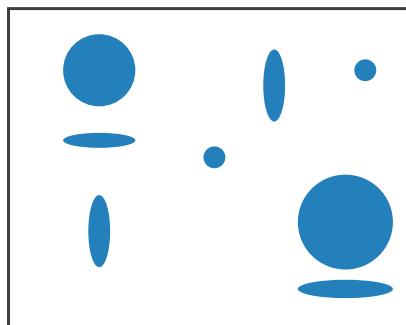
Fully separable

Size
+ Hue (Color)



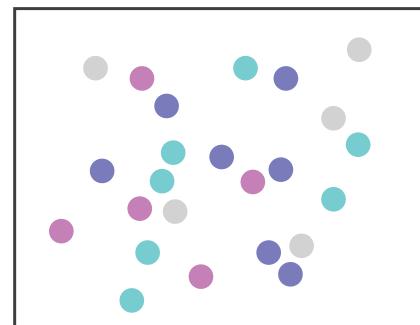
Some interference

Width
+ Height



Some/significant
interference

Red
+ Green



Major interference

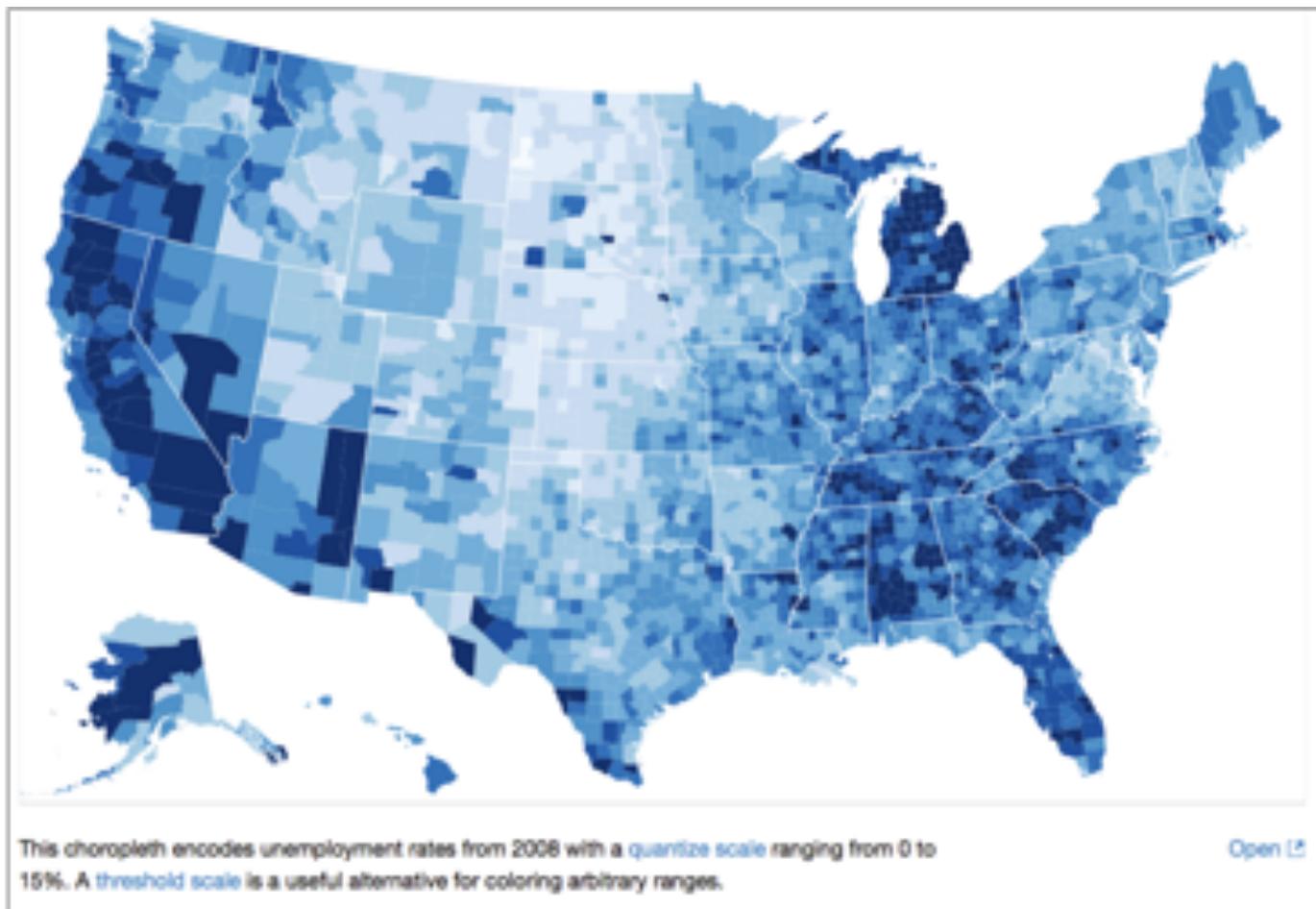
SEQUENTIAL COLOR SCHEME

- Good for mapping numerical / ordinal scales
 - e.g. amount of precipitations



Source: Color Brewer,
<http://bl.ocks.org/mbostock/55770>

SEQUENTIAL COLOR SCHEME - EXAMPLE



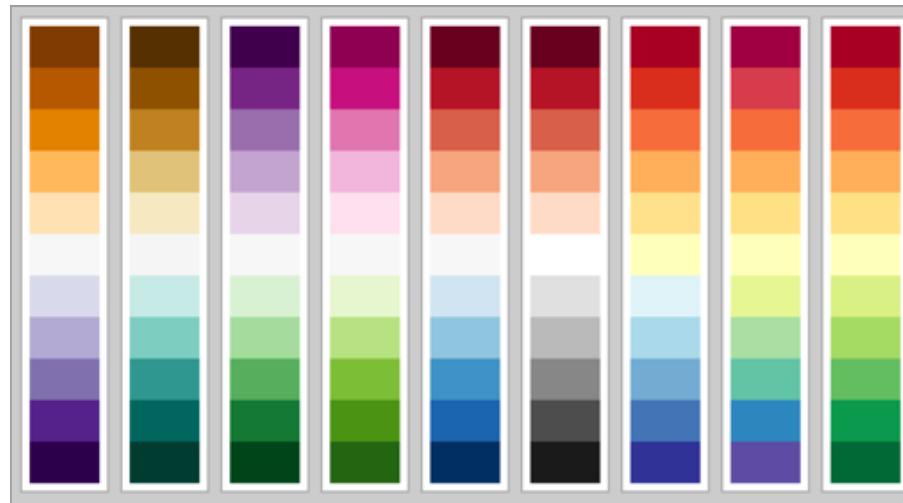
This choropleth encodes unemployment rates from 2008 with a [quantize scale](#) ranging from 0 to 15%. A [threshold scale](#) is a useful alternative for coloring arbitrary ranges.

[Open](#)

Source:
<https://bl.ocks.org/mbostock/4060>

DIVERGING SCHEME

- **Ordinal scales with central / threshold value**
 - e.g. amount of profit vs loss, percentage of yes vs no



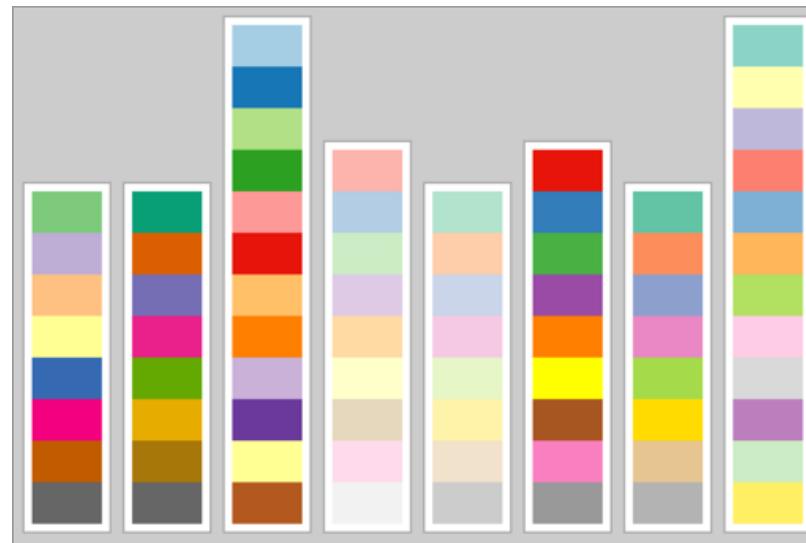
Source: Color Brewer,
<http://bl.ocks.org/mbostock/55770>

DIVERGING SCHEME



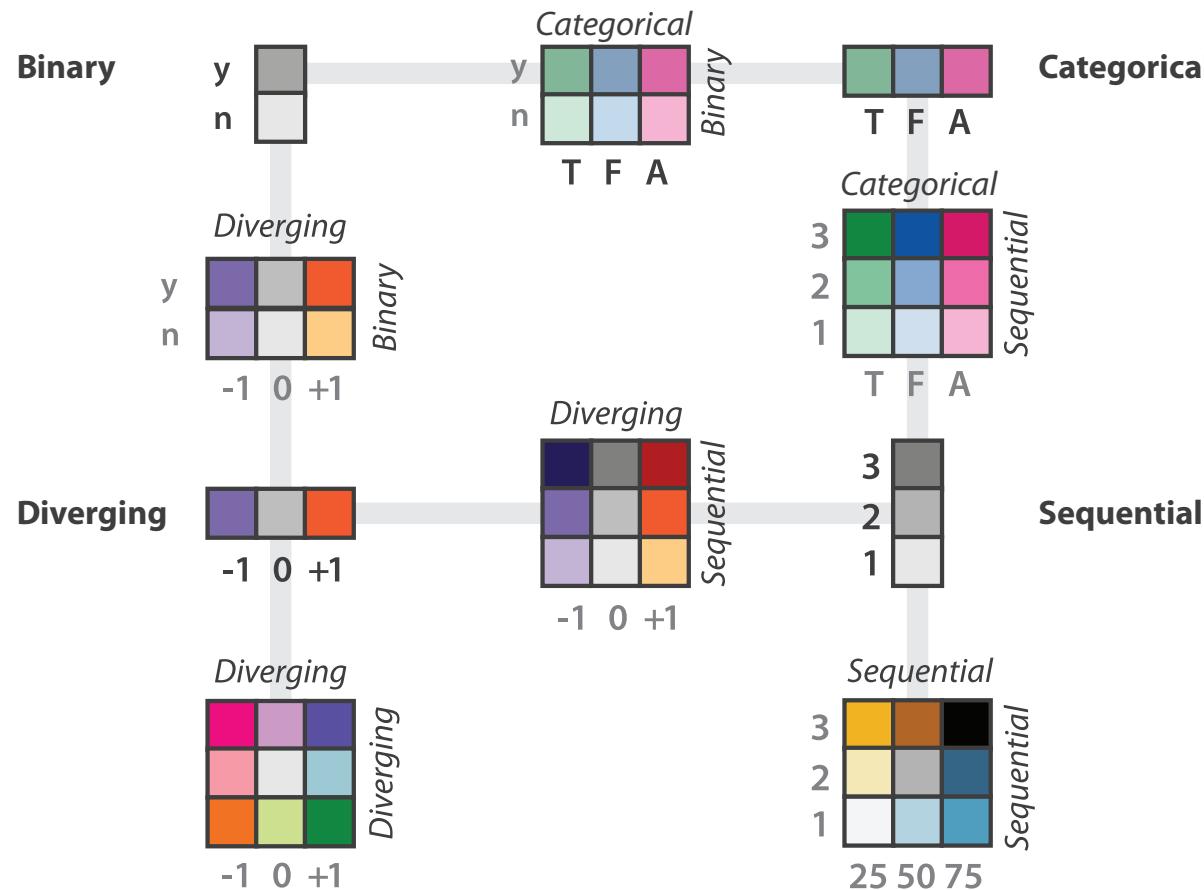
CATEGORICAL SCHEME

- **Different categories**
 - e.g. apples vs bananas vs peaches



Source: Color Brewer,
<http://bl.ocks.org/mbostock/55770>

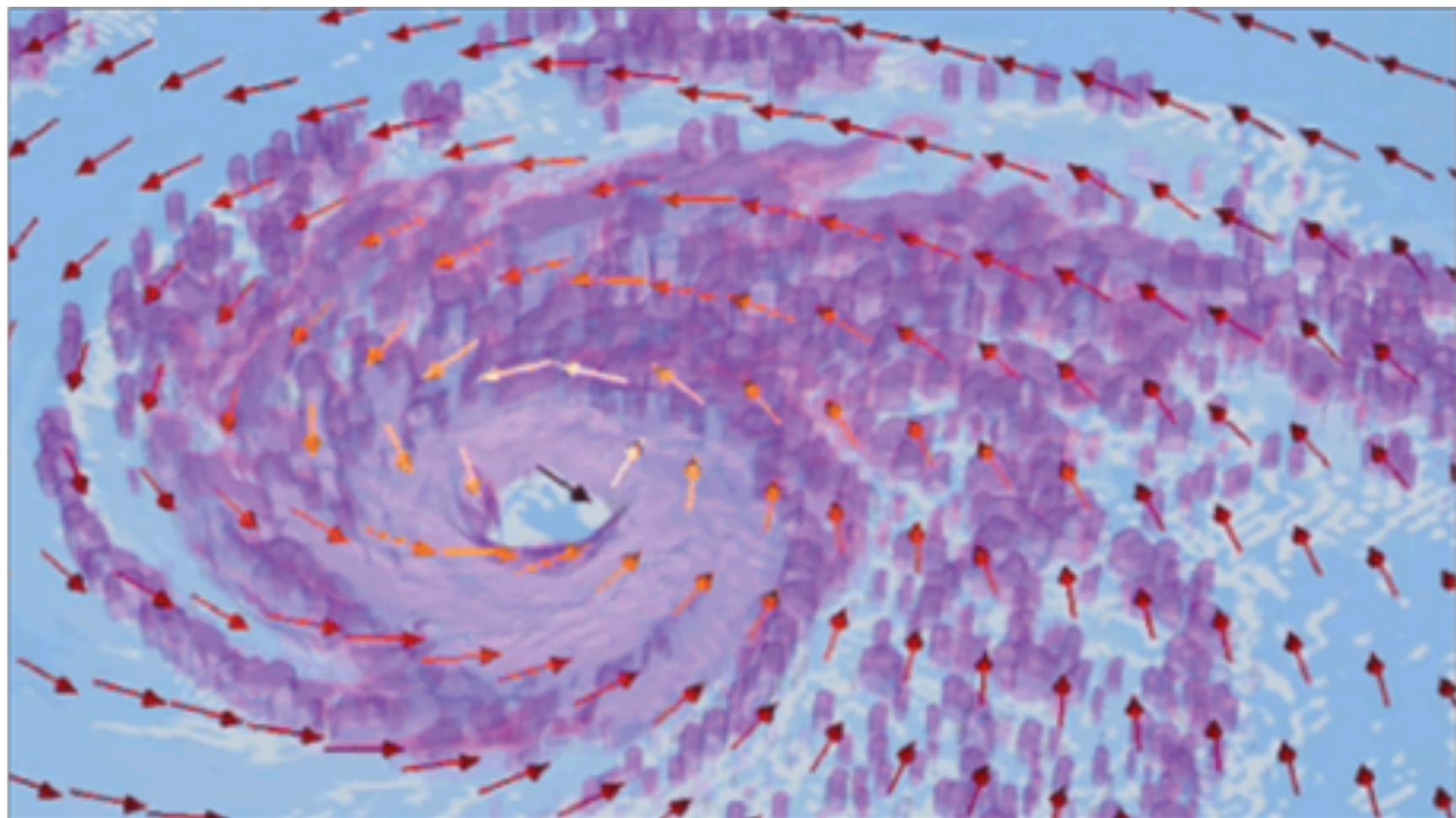
COMBINING COLOR SCHEMES



Source: Munzner VAD (see references)

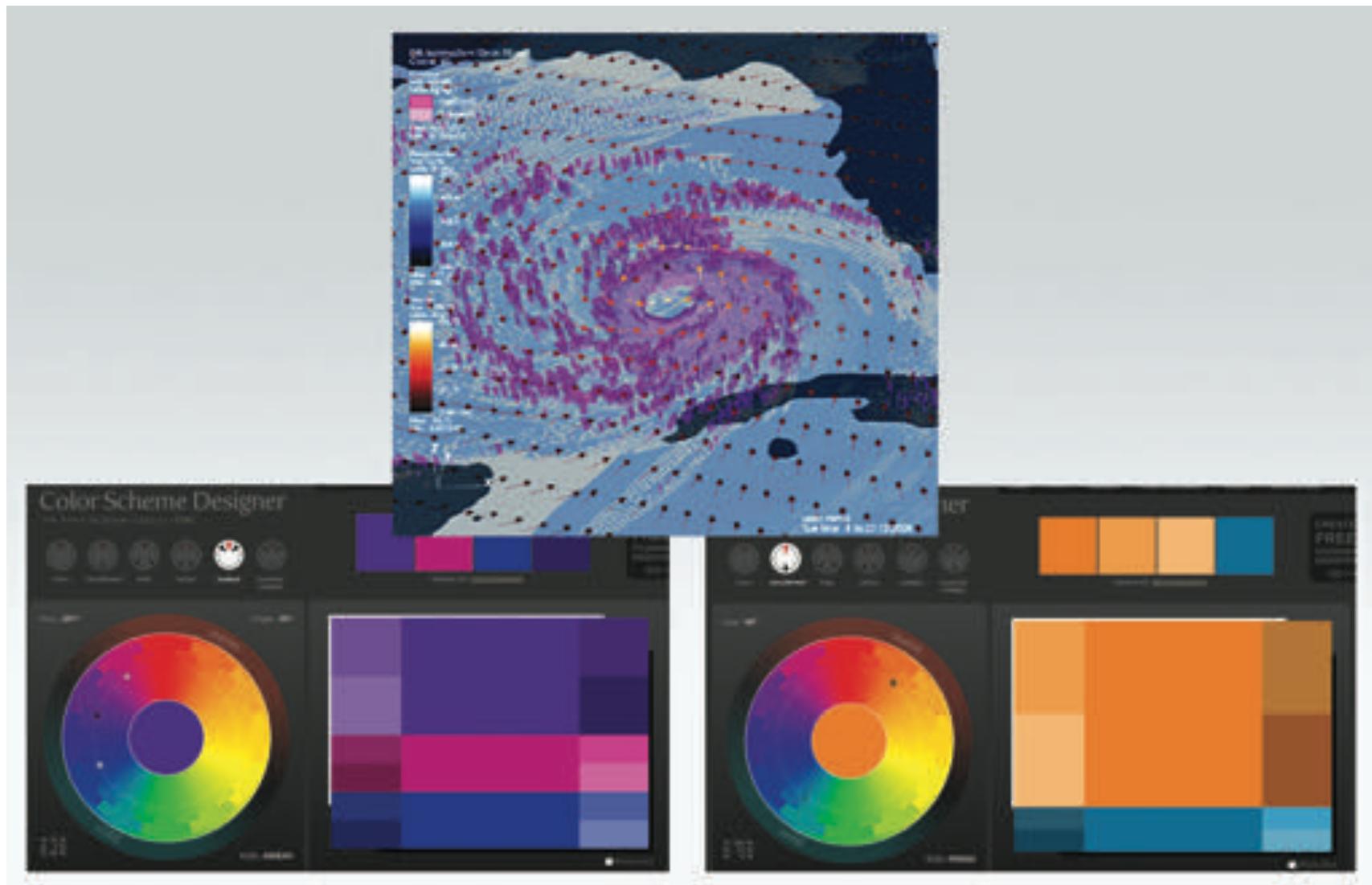


EXAMPLE: COMBINING COLOR SCHEMES

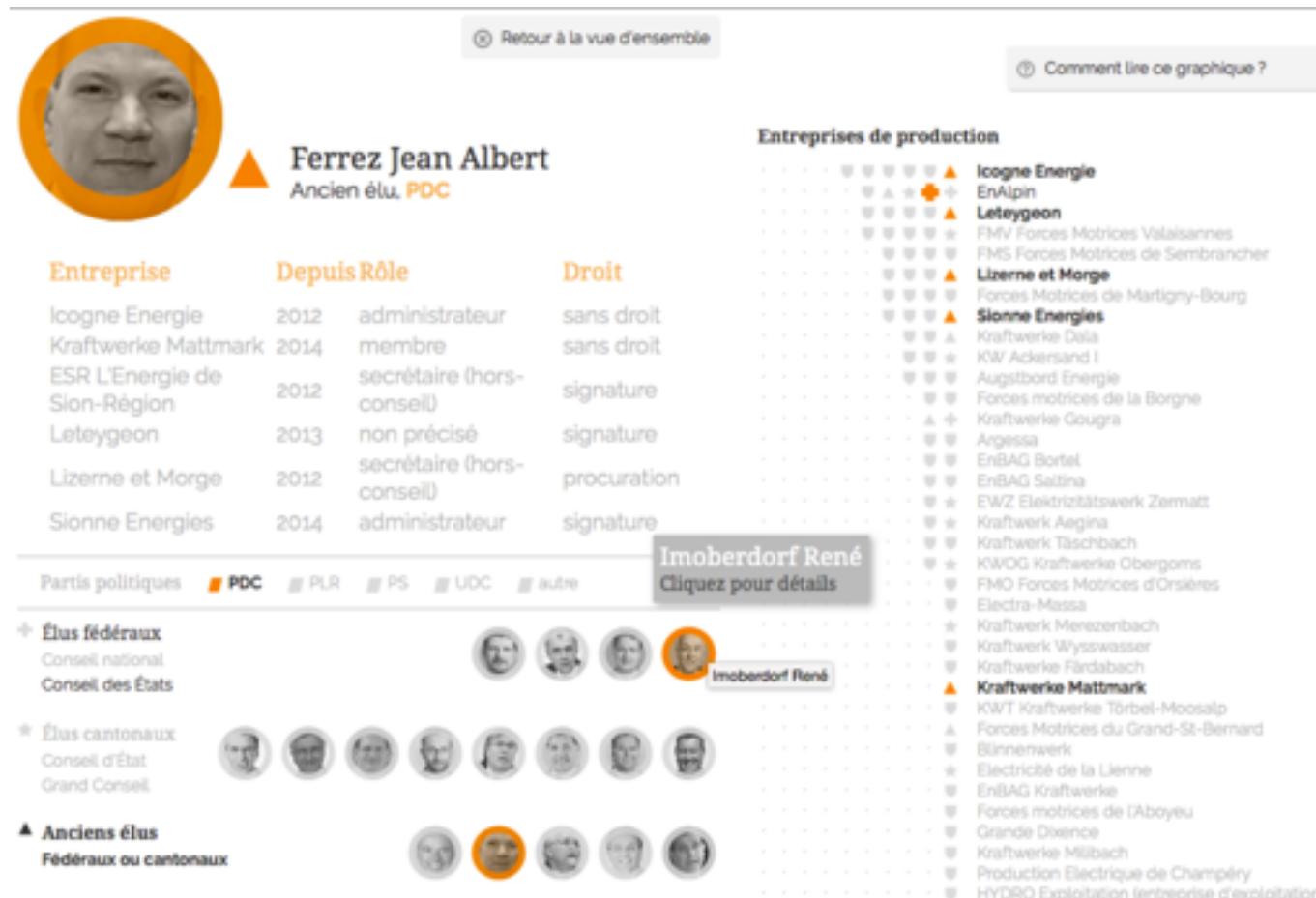


Source: Rhyne, DOI [10.1109/MCG.2011.42](https://doi.org/10.1109/MCG.2011.42)

EXAMPLE: COMBINING COLOR SCHEMES



MARKS & CHANNELS: EXAMPLE



THERE'S MORE TO VISUALIZATION

- **Interaction techniques**
- **Clustering – visual analytics**
- **Visualization & AR/VR**
- **Visualization evaluation**
- ...

TAKE-AWAYS

- **Basic charts vs interactive information visualization**
- **What-why-how framework to think about visualization**
- **Perception studies and human factors in general are key in designing successful visualization**