

# Visual data analysis

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# What is visual data analysis?

# Definitions

- Oxford English Dictionary:

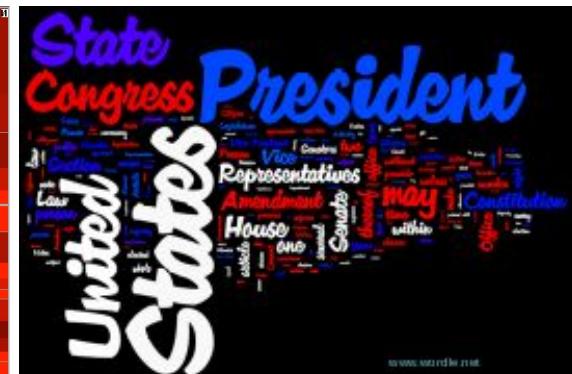
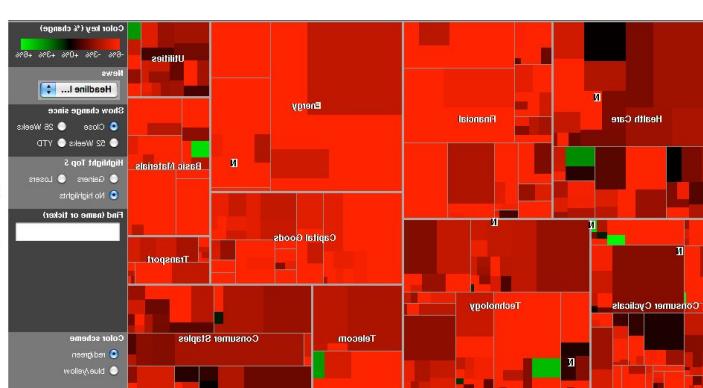
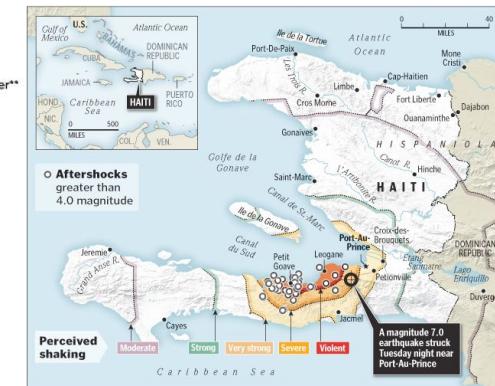
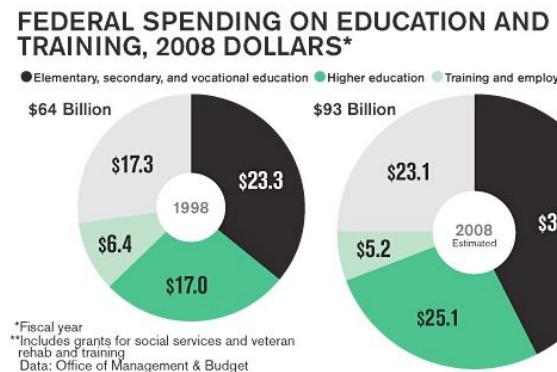
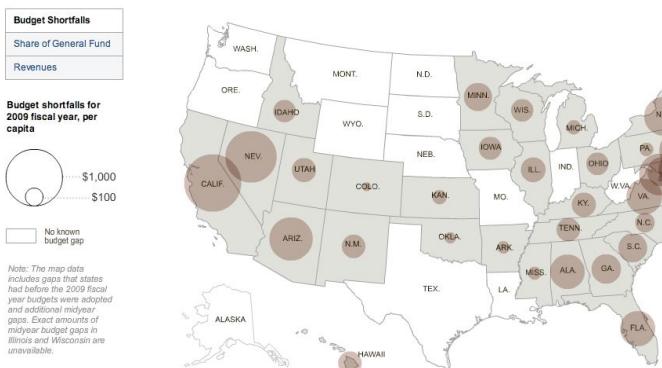
to **visualize**:

form a mental vision, image, or picture of  
(something not visible or present to sight, or of an  
abstraction);

to make visible to the mind or imagination.

# Data visualization

To convey information through visual representations



# Definitions

- Tamara Munzner:

Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.

T. Munzner: ***Visualization Design and Analysis: Abstractions, Principles, and Methods***, AK Peters, 2014

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# Definitions

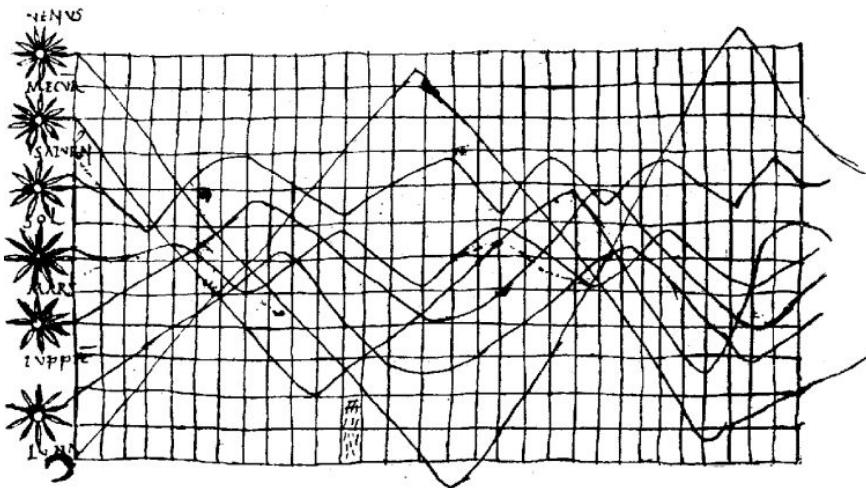
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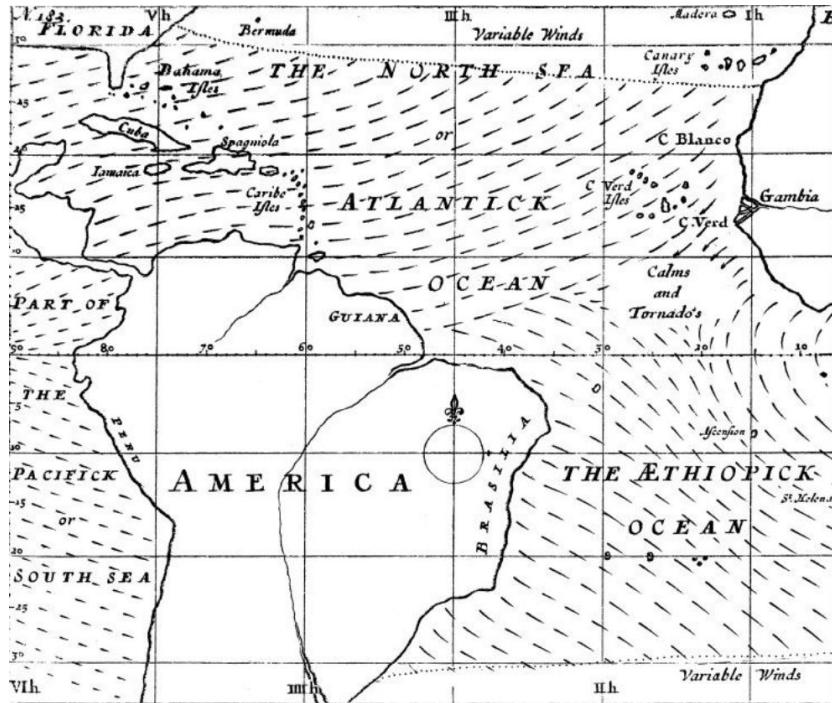
T. Munzner: ***Visualization Design and Analysis: Abstractions, Principles, and Methods***, AK Peters, 2014

# Visualization Goals

# Map



Planetary Movement Diagram, c. 950



Halley's Wind Map, 1686

# Discover

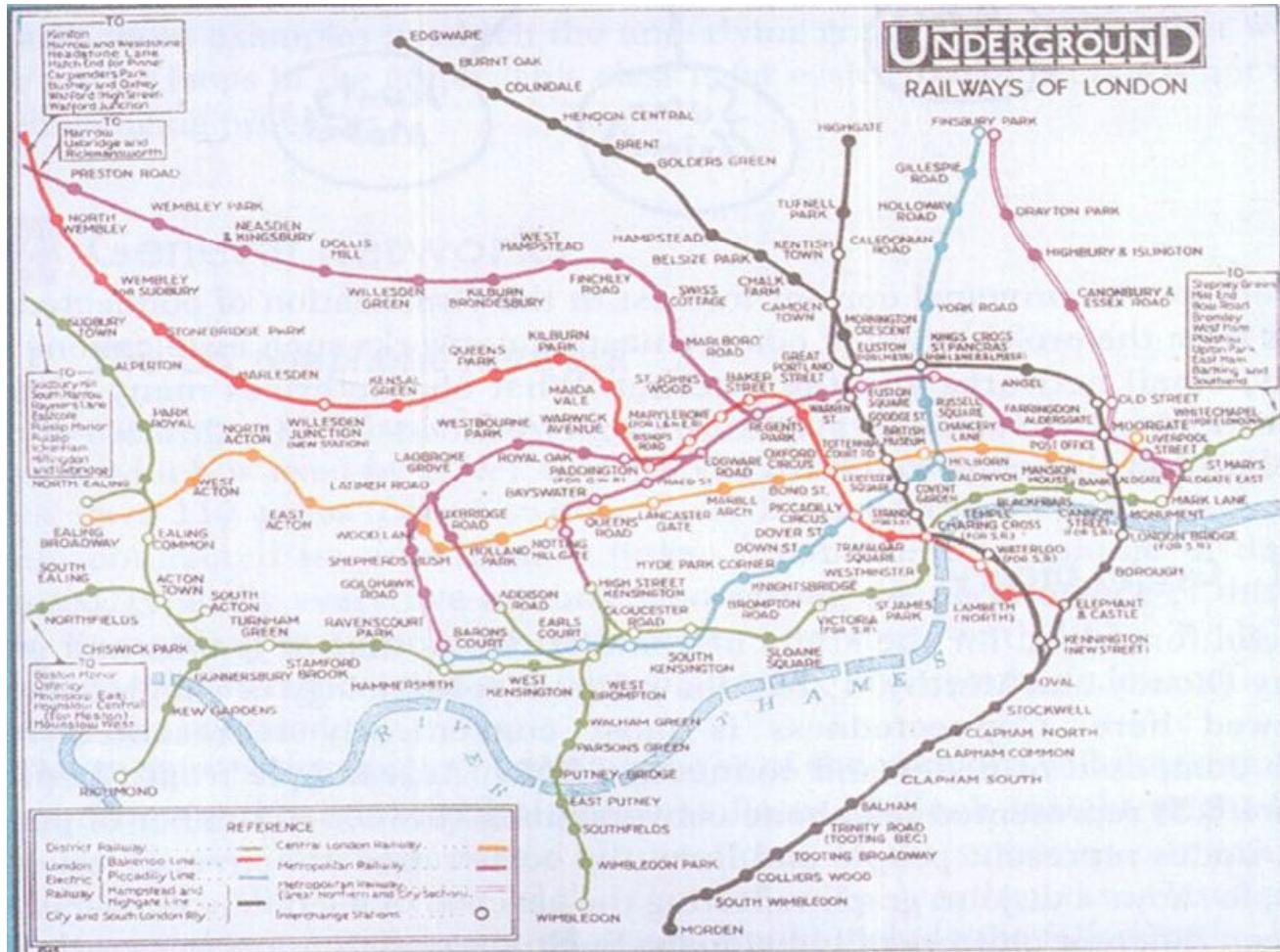


© E. Tufte, Visual Explanations, 1997

John Snow, 1854

© Munzner/Möller

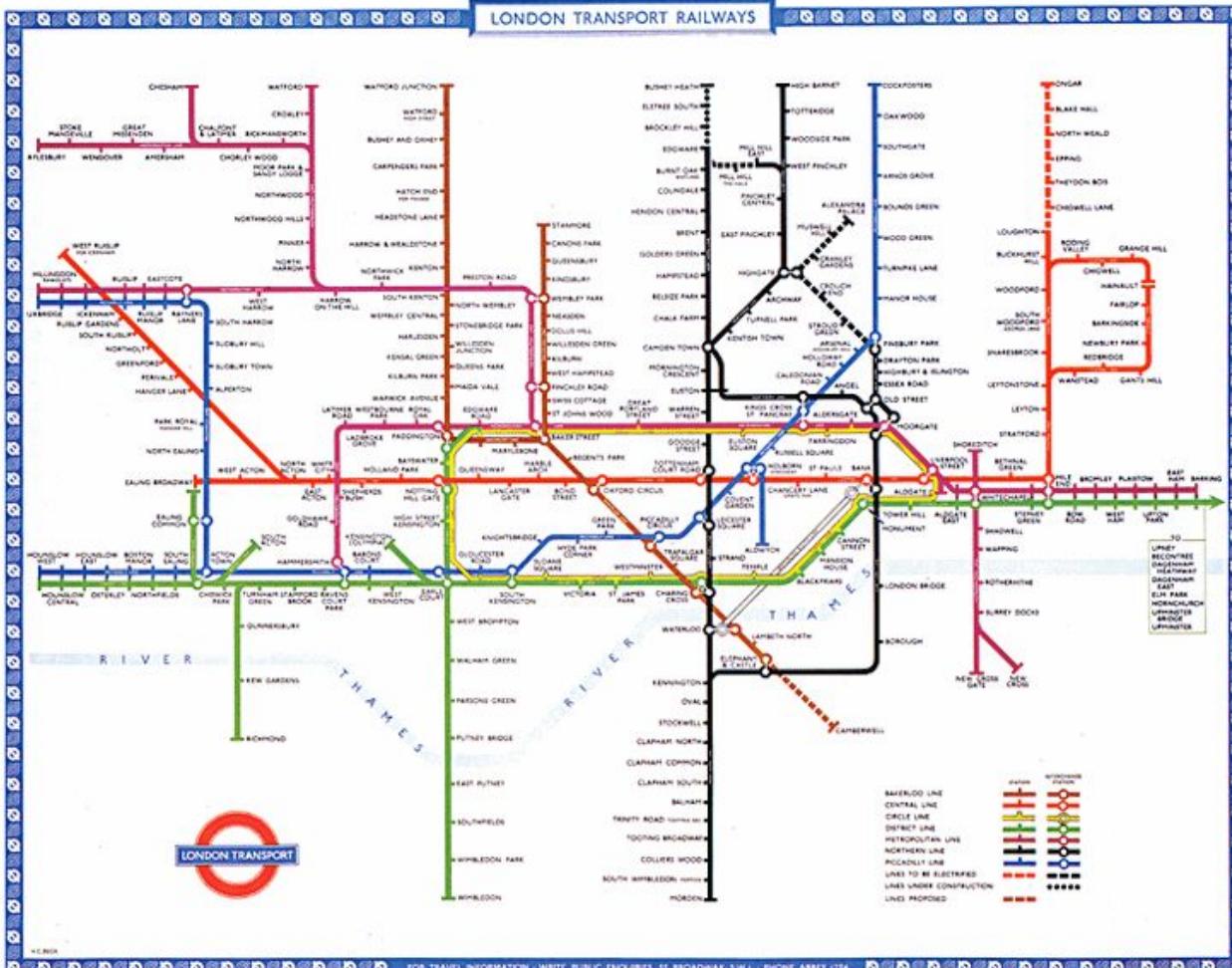
# Clarify



## London Subway Map, 1927

© Munzner/Möller

# Clarify



Harry Beck, 1933

© Munzner/Möller

# Communicate

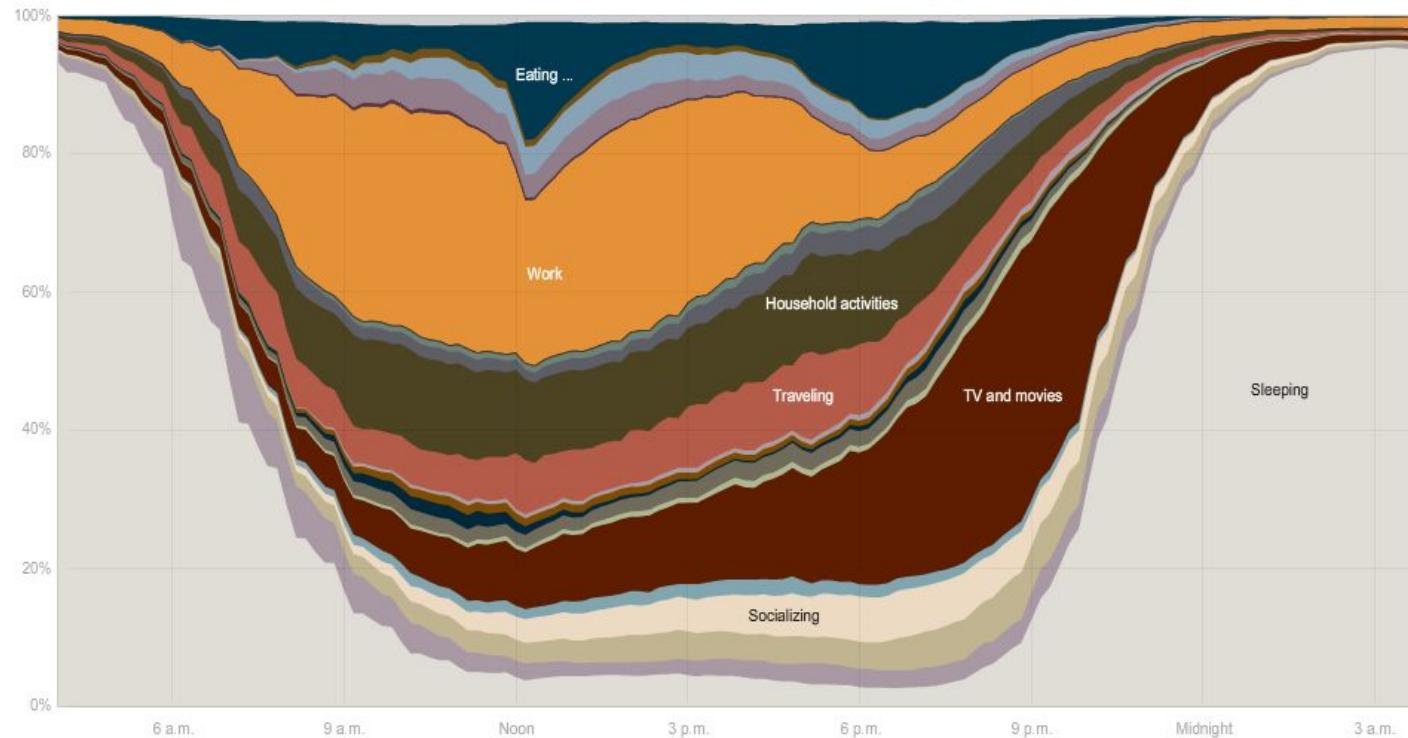
## How Different Groups Spend Their Day

The American Time Use Survey asks thousands of American residents to recall every minute of a day. Here is how people over age 15 spent their time in 2008. [Related article](#)

### Everyone

Sleeping, eating, working and watching television take up about two-thirds of the average day.

Everyone	Employed	White	Age 15-24	H.S. grads	No children
Men	Unemployed	Black	Age 25-64	Bachelor's	One child
Women	Not in lab...	Hispanic	Age 65+	Advanced	Two+ children



# Goals

- Insight and analysis
  - Extract the information content
  - Make things/connections visible that are not apparent
- Communication
  - Allow the non-expert to understand
  - Guide the expert into the right direction
- Exploration
  - Interactively explore the (unknown) data content

# Overview

- Design principles
- Data types and semantics
- Visual encoding principles
- Tasks
- Arrange tables & spatial data
- Arrange networks and trees
- Multiple views, interaction & human centered design
- Evaluation
- Design Studies
- Reduce: Items and Attributes
- Embed: Focus + Context
- TextVis
- Visual Data Science
- Visual Analysis and Communication of Cultural Collections
- The Data in the Visualization
- Ethics in Vis

# Overview

- Design principles
- Data types and semantics
- Visual encoding principles
- Tasks

Check out our course website at

<http://vda.univie.ac.at/Teaching/Vis/21w/schedule.html>

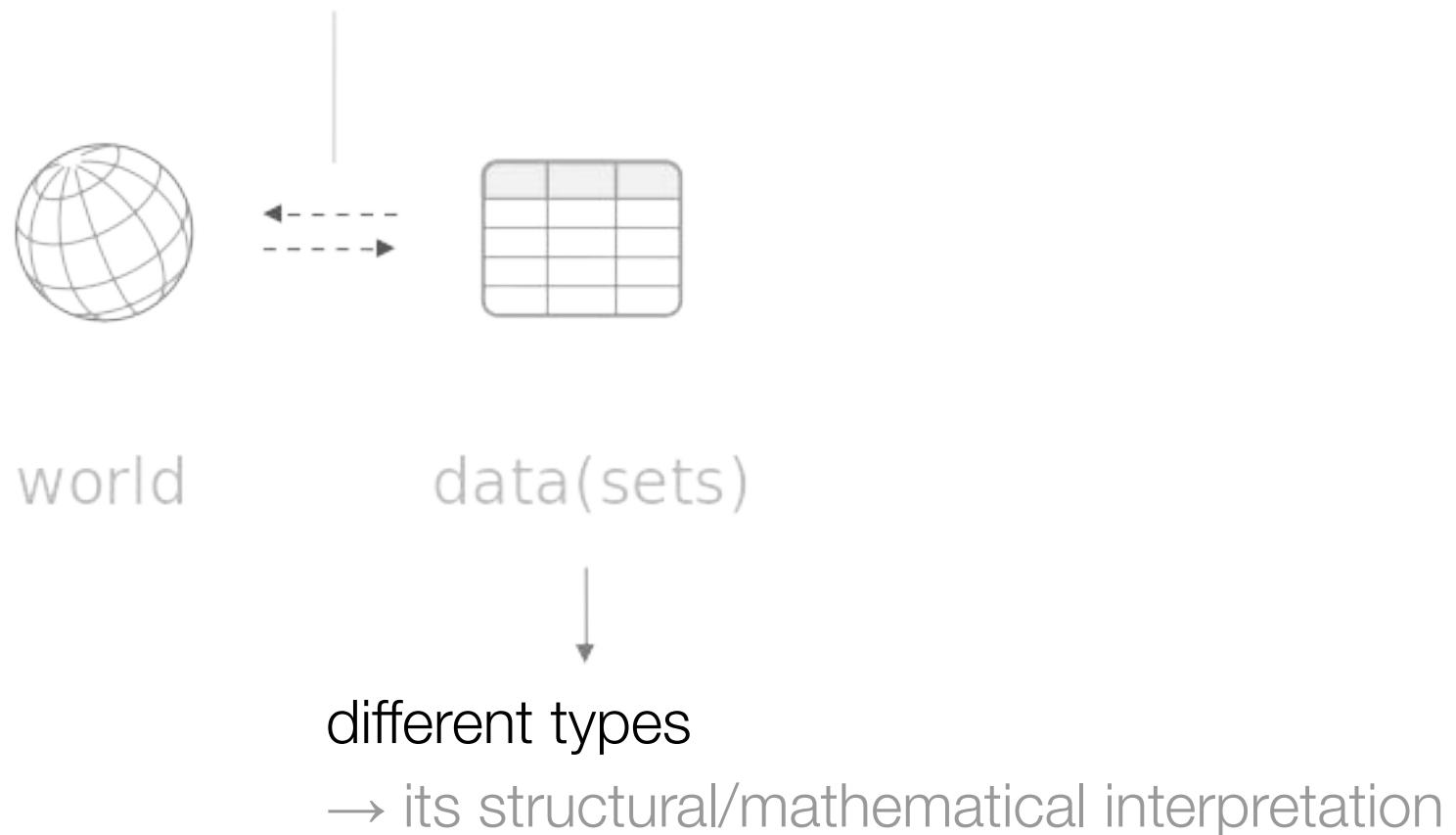
- Embed: Focus + Context
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# Data types and semantics

From real world meaning to  
abstract classification

# Semantics vs. Type

Semantics of data → its real world meaning



# Tabular data

32

7/16/07 2-High

Medium Box

0.6

7/18/07

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
32	7/16/07	2-High	Medium Box	0.6	7/18/07

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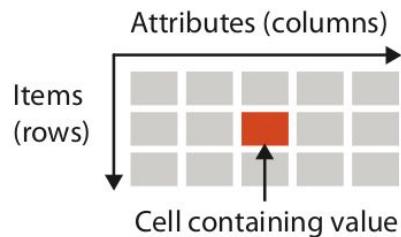
Record/Item

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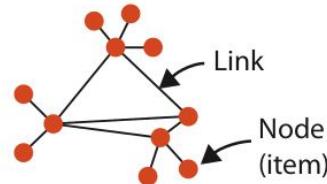
Dimension/  
Attribute

# Dataset types

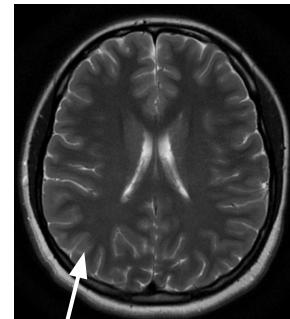
## → Tables



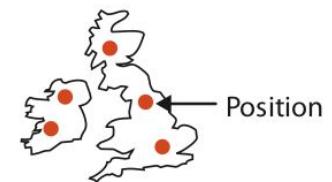
## → Networks



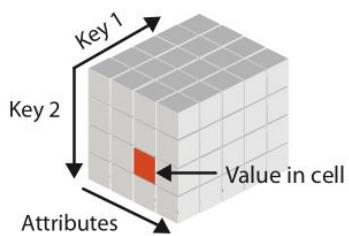
## → Fields



## → Geometry (Spatial)



## → Multidimensional Table



## → Trees



# Attribute types

- Ordered
  - Quantitative  
10 inches, 23cm, etc.
  - Ordinal  
Small, medium, large
- Categorical (Nominal, Qualitative)  
Apples, oranges, bananas, etc.

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1 = Quantitative  
 2 = Ordinal  
 3 = Nominal

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Apples, oranges, bananas, etc.
- 
- The diagram illustrates three types of ordering directions:
- Sequential:** Represented by a horizontal line with three segments and two tick marks. A bracket to its right is labeled with a circular arrow icon and the text "Ordering Direction".
  - Diverging:** Represented by a horizontal line with three segments and two tick marks, with arrows pointing away from a central point. A bracket to its right is labeled with a double-headed arrow icon and the text "Diverging".
  - Cyclic:** Represented by a circle with an arrow pointing clockwise. A bracket to its right is labeled with a circular arrow icon and the text "Cyclic".
- 
- The diagram shows four icons representing categorical attributes:
- A plus sign (+)
  - A solid black circle (●)
  - A solid black square (■)
  - A solid black triangle (▲)



+ a b l e a u

# Visual encoding principles

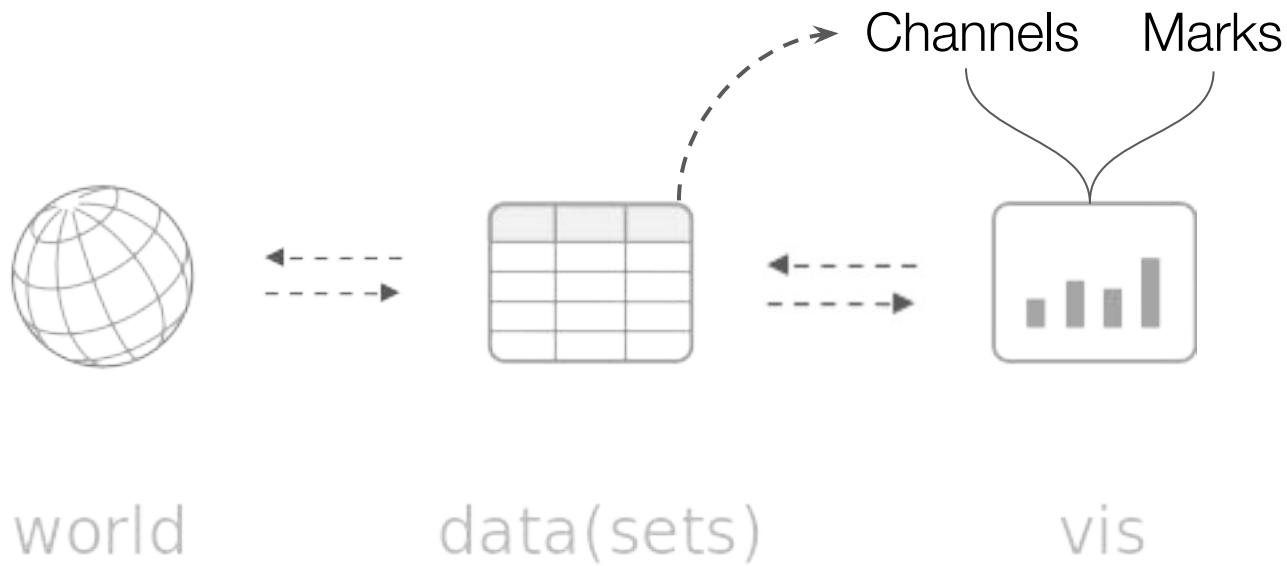
Basic building blocks of a visualization

# Visual analysis pipeline\*

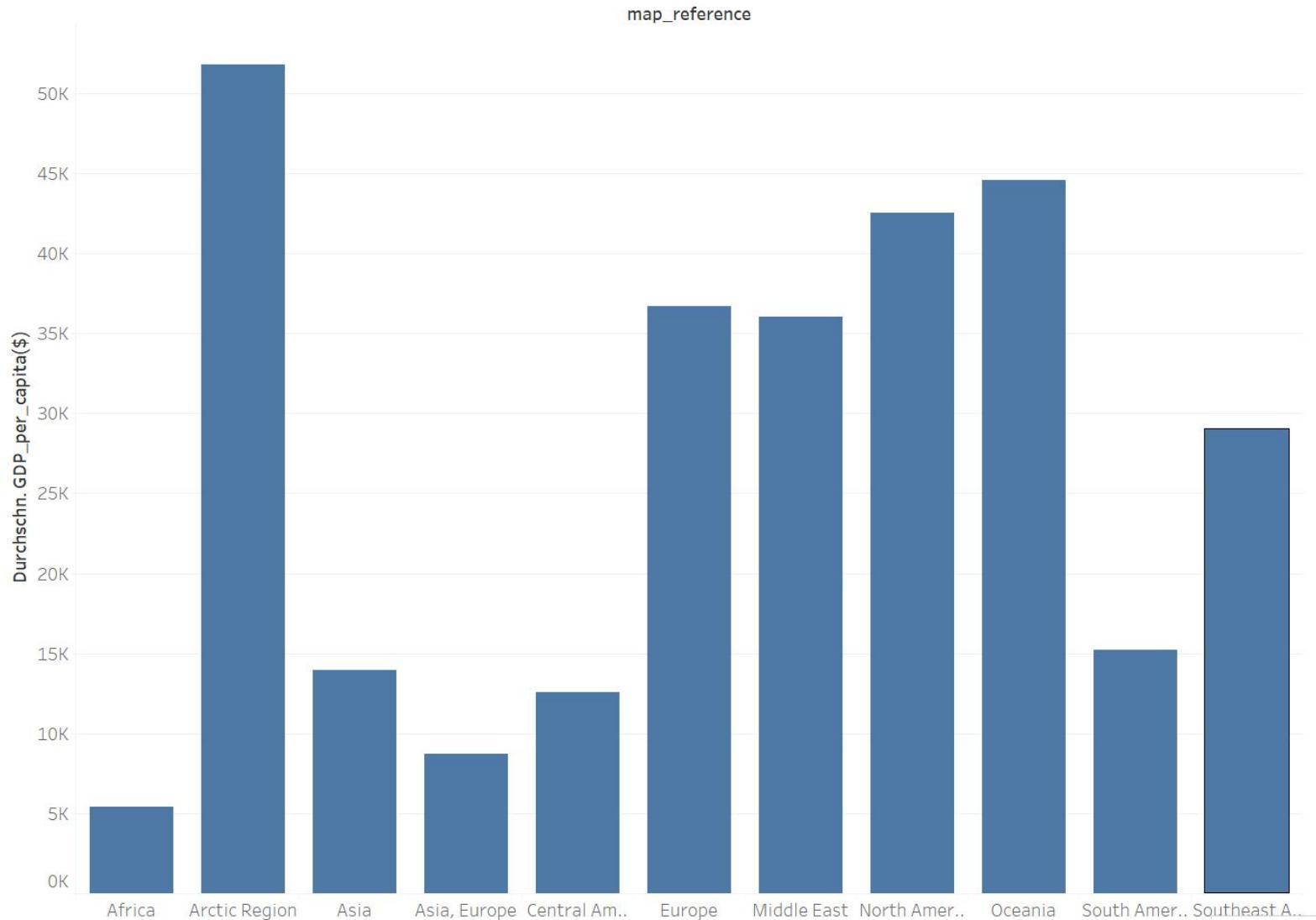


\* parts of the pipeline

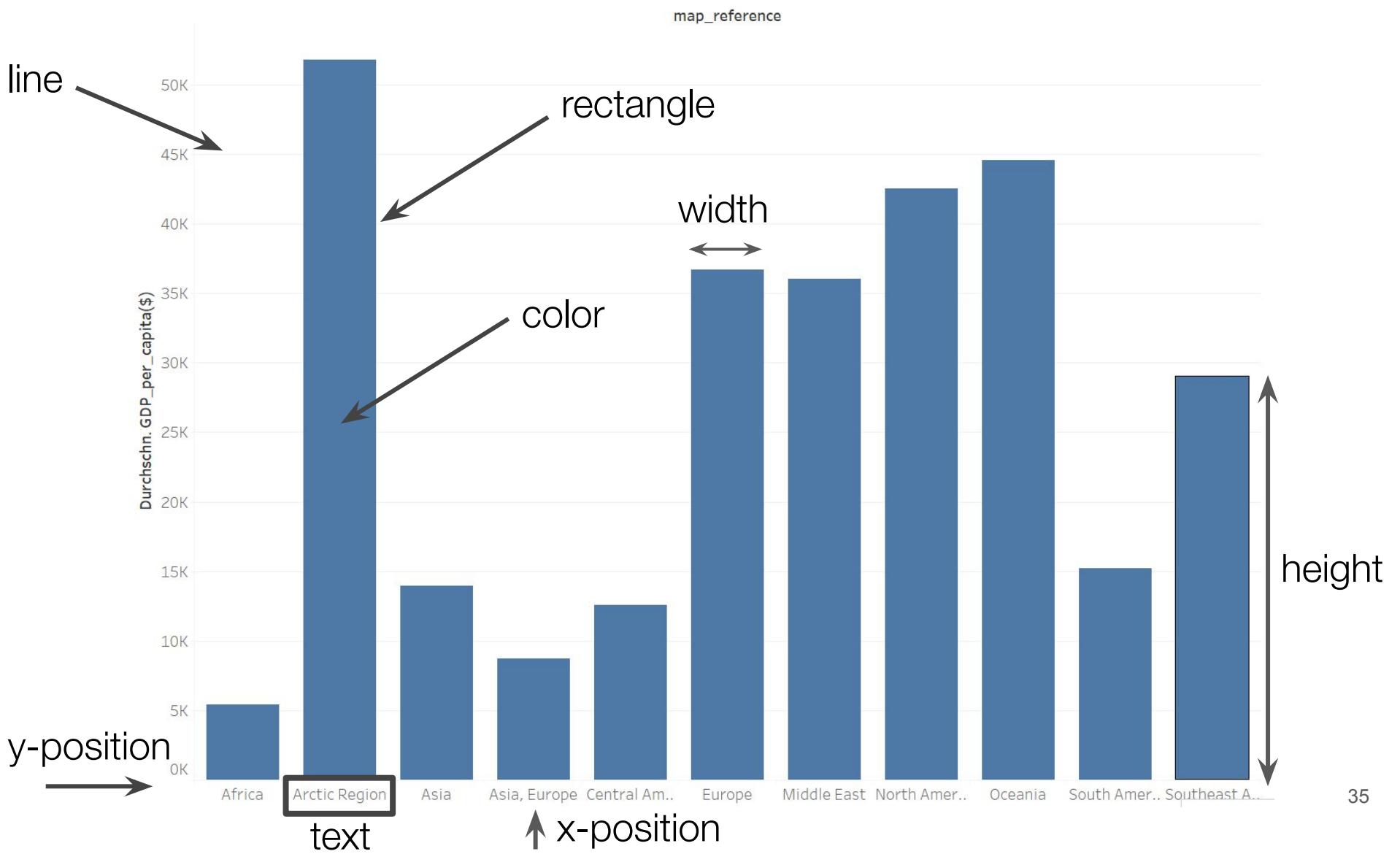
# Marks & Channels



# Parts of a visualization



# Parts of a visualization



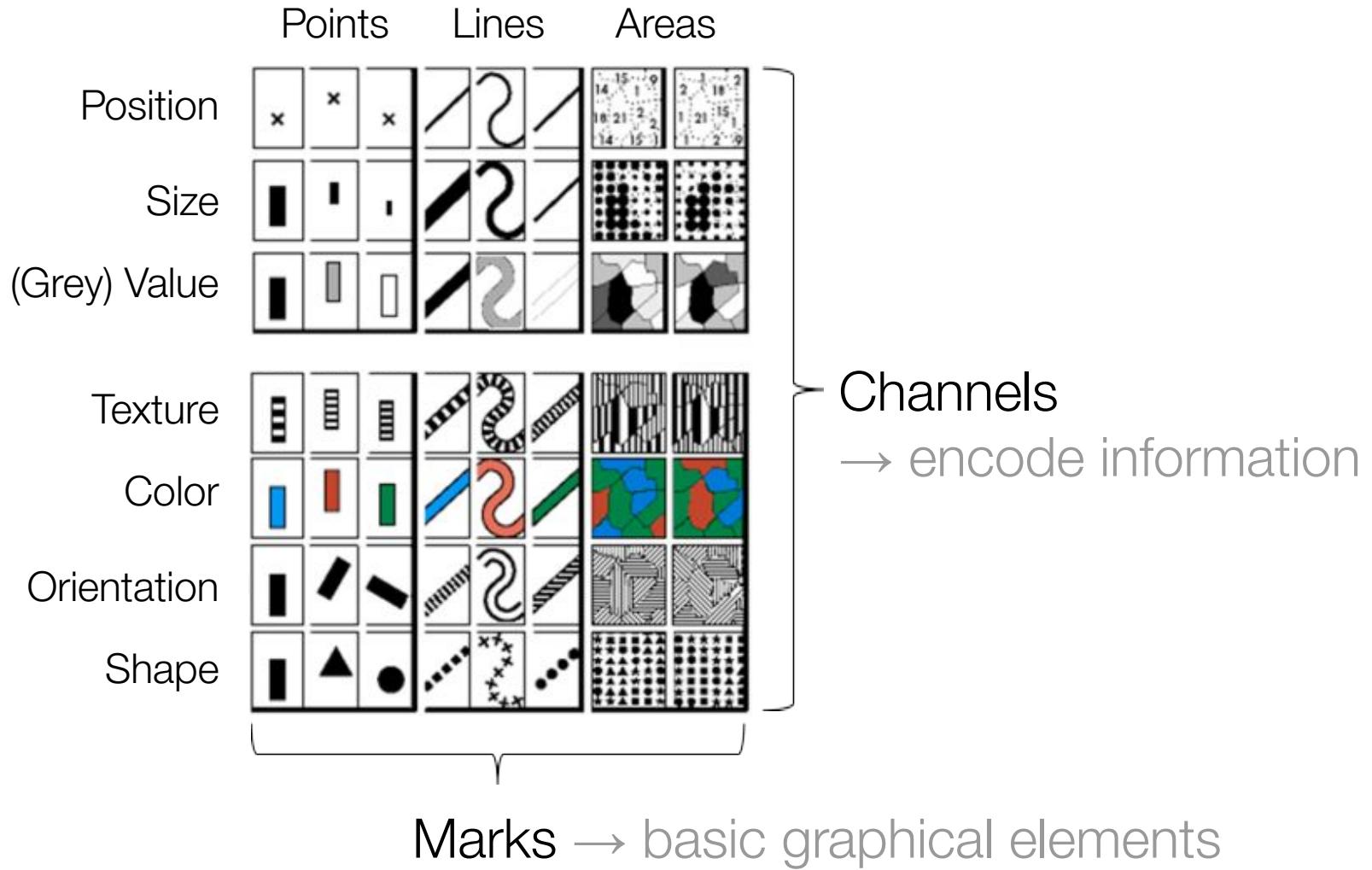
# Parts of a visualization

- Image perceived as a set of signs
- Sender encodes information in signs
- Receiver decodes information from signs
- Jacques Bertin
  - French cartographer [1918-2010]
  - Semiology of Graphics [1967]
  - Theoretical principles for visual encodings



Bertin, Semiology of Graphics, 1983

# According to Bertin...



# Marks

## Points



## Lines



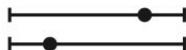
## Areas



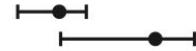
# Channels

## → Magnitude Channels: Ordered Attributes

Position on common scale



Position on unaligned scale



Length (1D size)



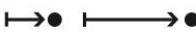
Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



## → Identity Channels: Categorical Attributes

Spatial region



Color hue



Motion



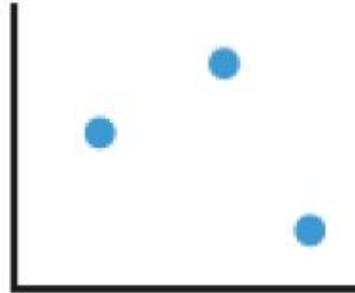
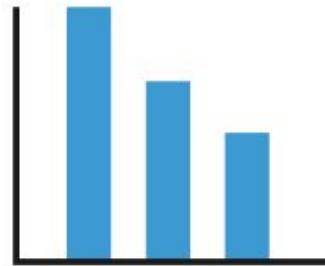
Shape



Same

# Parts of a visualization

- Bar charts
  - Marks: lines
  - Channels: length
- Scatterplots
  - Marks: points
  - Channels: position



# Choice of marks and channels

## **Expressiveness principle**

The visual encoding should express all of (and only) the information in the dataset attributes.

e.g., ordered data are seen as ordered

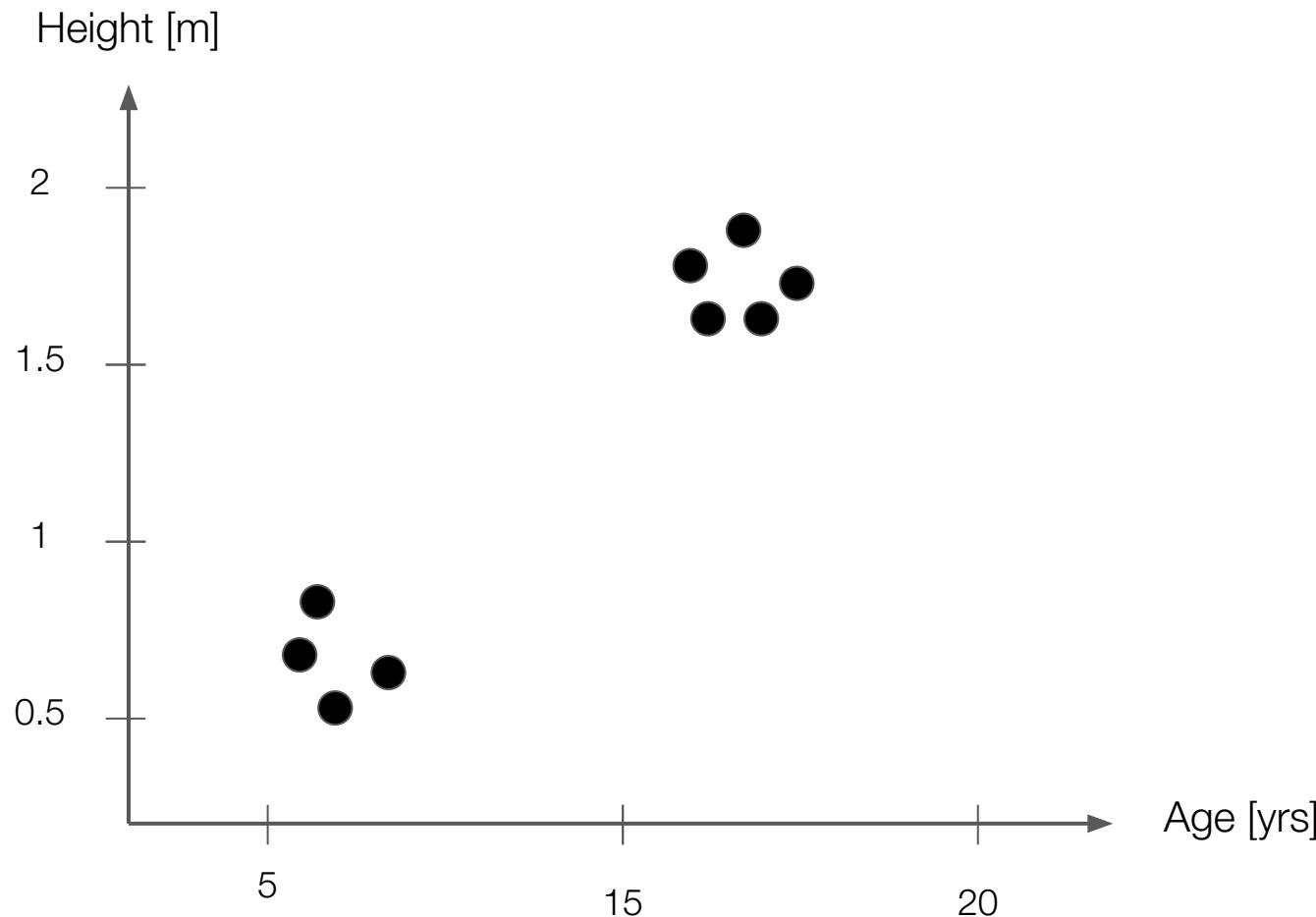
## **Effectiveness principle**

The most important attributes should be encoded with the most effective channels in order to be most noticeable.

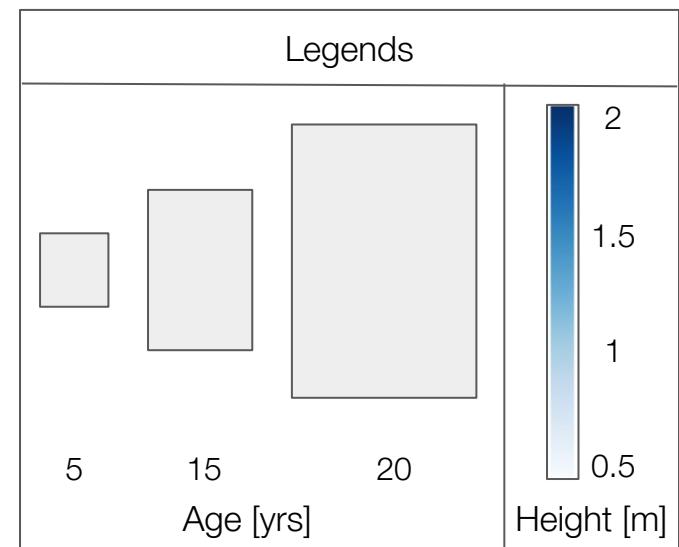
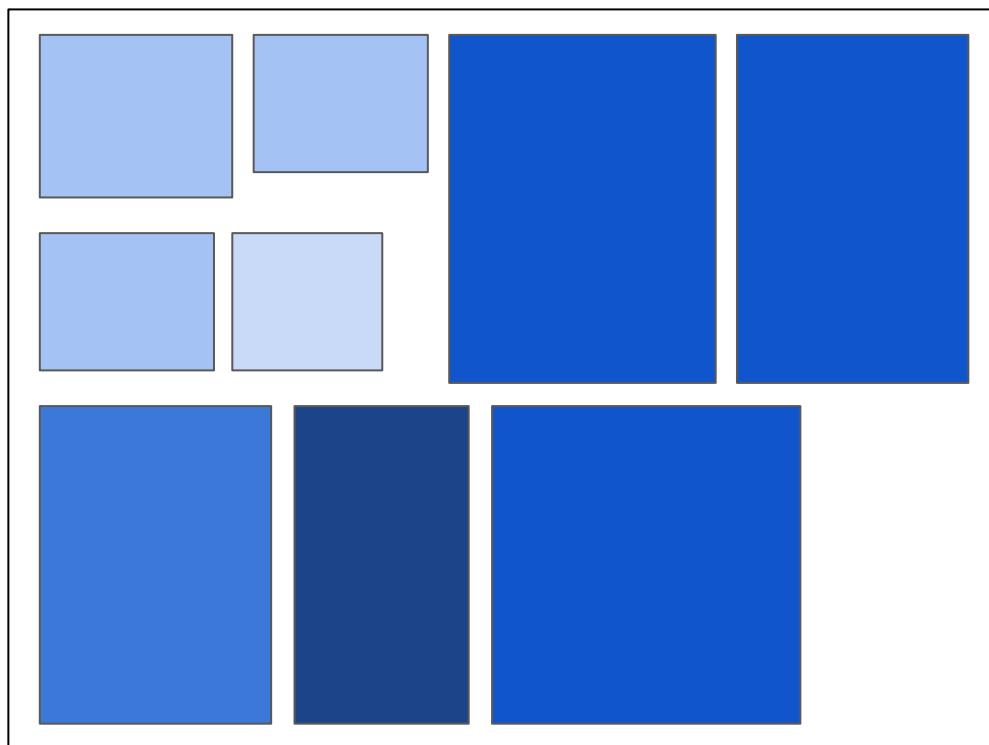
e.g., important information is made most noticeable

What do you think is the “best” visualization for the following data?

# VIS 1

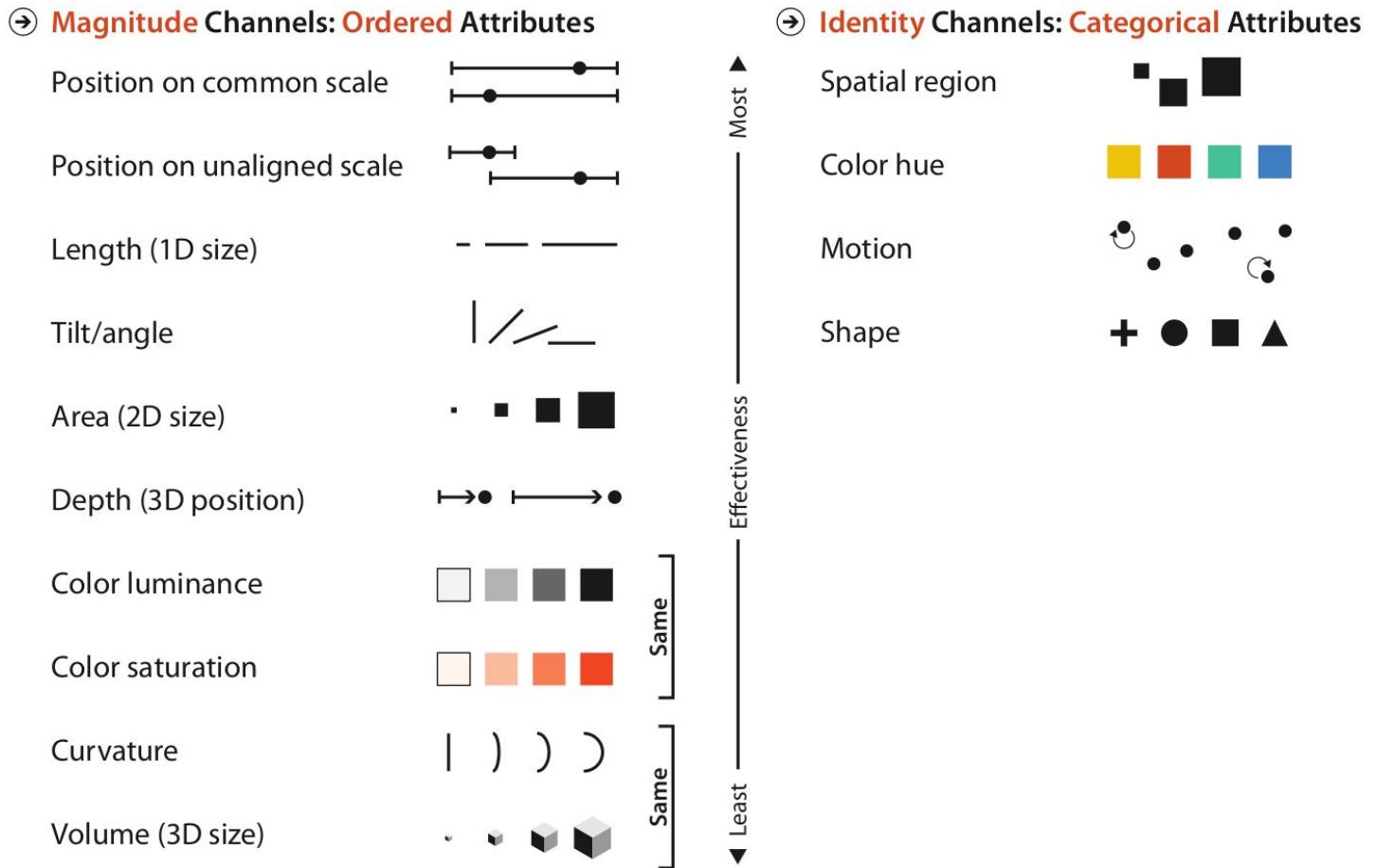


# VIS 2



What do you think is the “best” visualization for the following data?

# Channels



# Choice effectiveness ranking

- How do we determine the ranking above?
  - Accuracy
  - Discriminability
  - Separability
  - Popout

# Channel accuracy

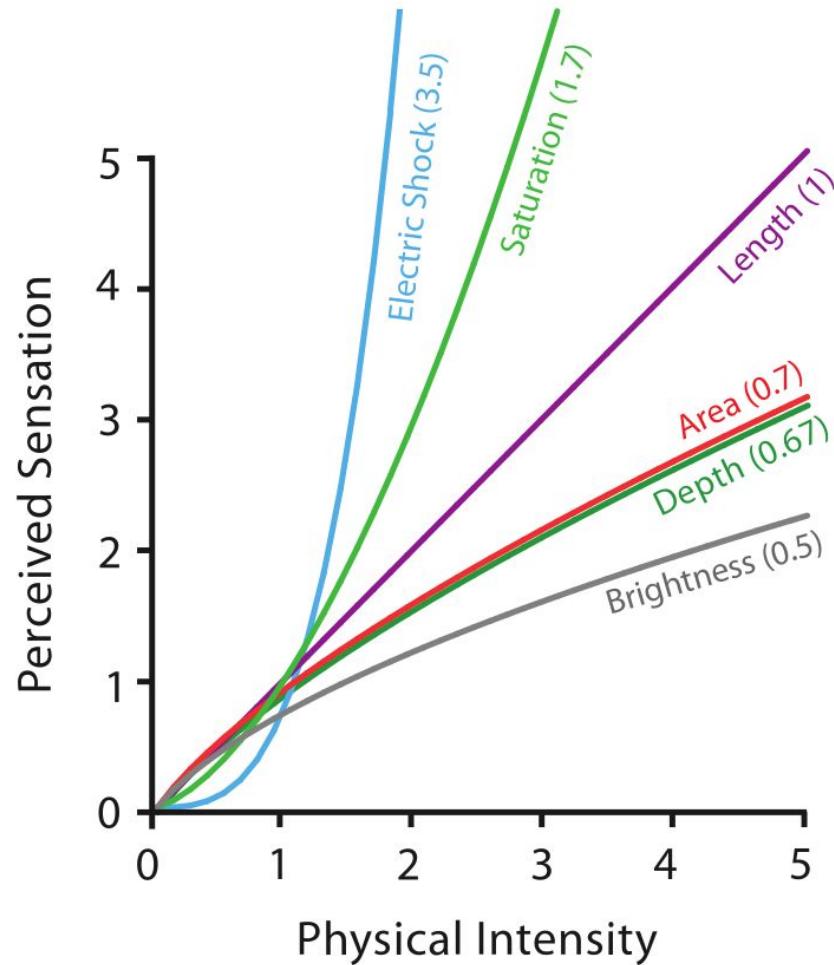
- How close is human perceptual judgment to some objective measurement of the stimulus?
- Our responses to sensory experience follows a power law

$$S = I^n$$

S...perceived sensation

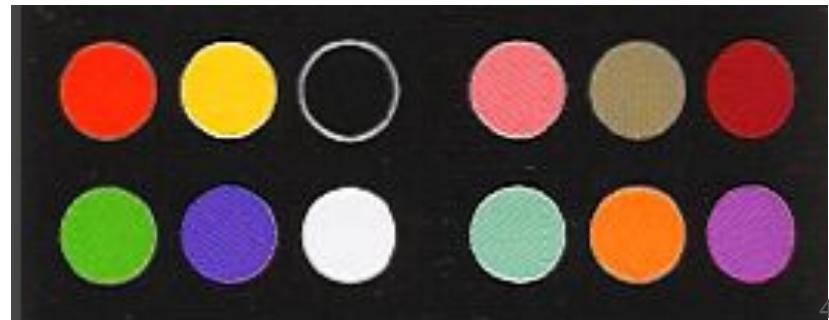
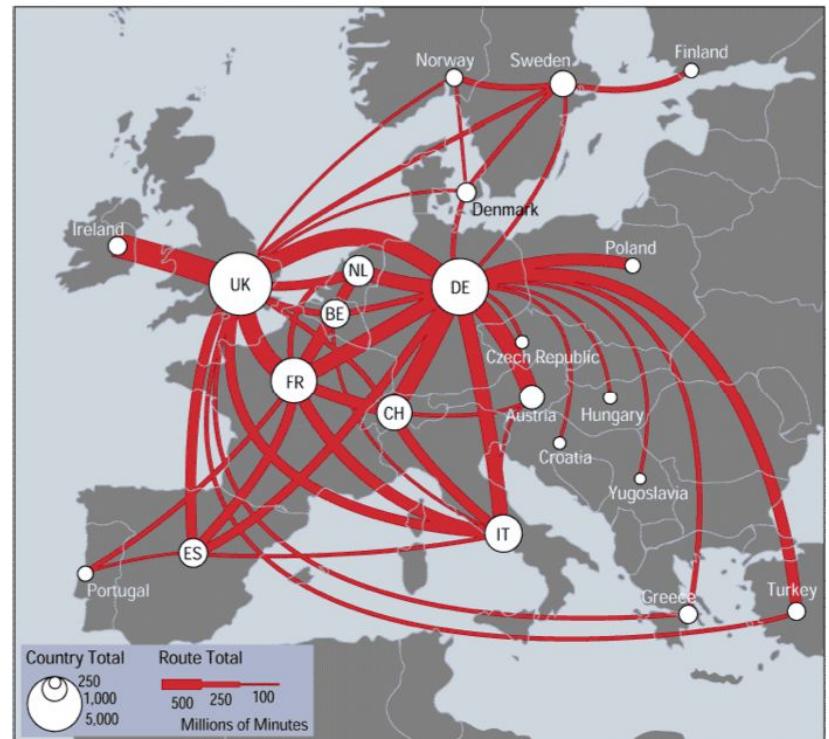
I...physical intensity

# Steven's psychophysical Law



# Discriminability

- How many distinguishable levels (bins) in the channel?
  - Linewidth works well for 3 or 4 levels
  - Color hue works for ~8-14

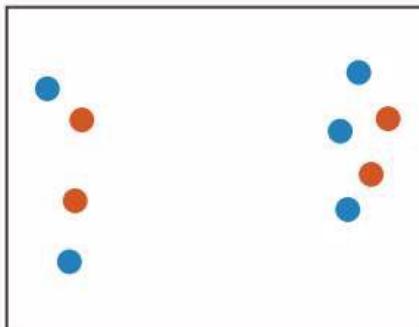


# Separability

- Not all channels are independent

Position

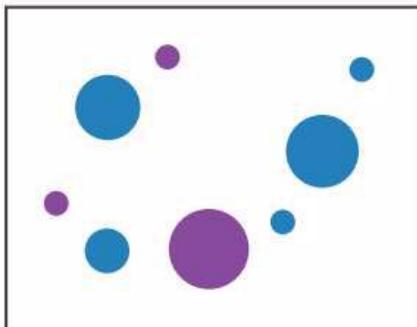
+ Hue (Color)



Fully separable

Size

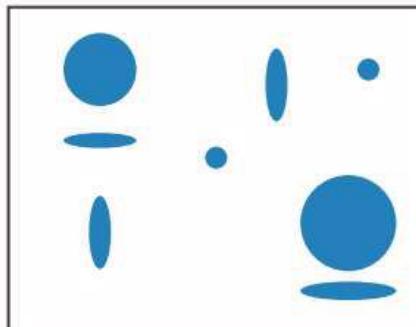
+ Hue (Color)



Some interference

Width

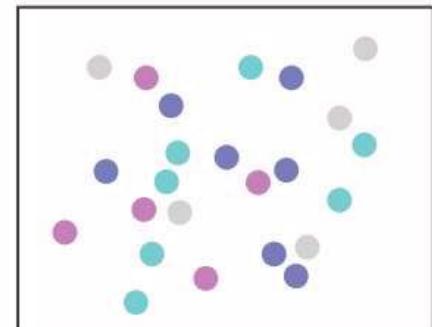
+ Height



Some/significant  
interference

Red

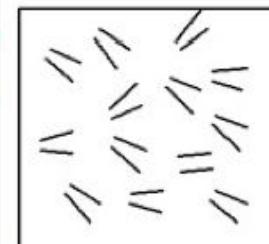
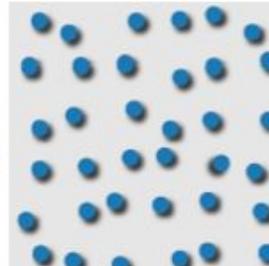
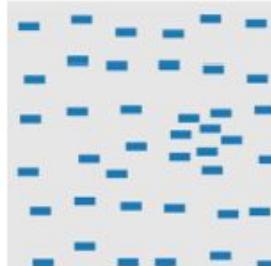
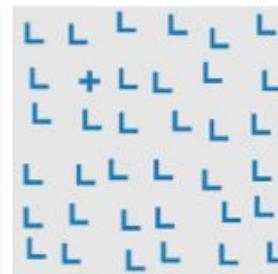
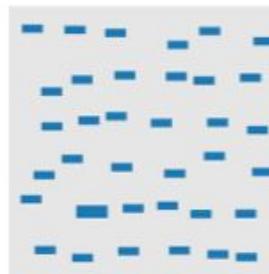
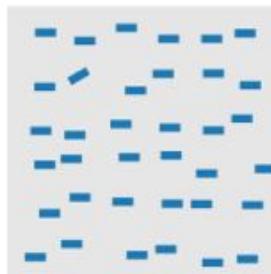
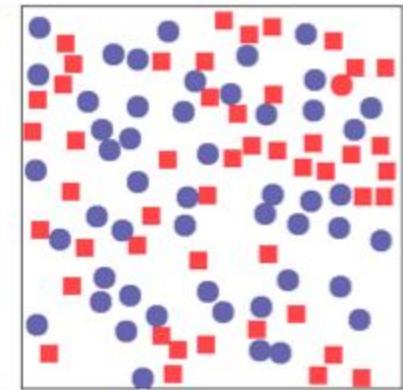
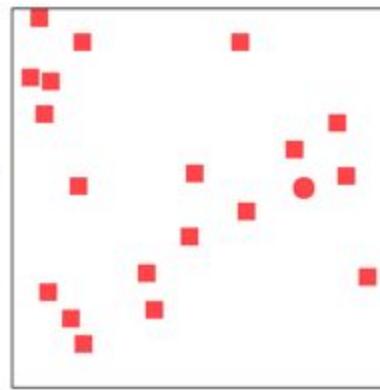
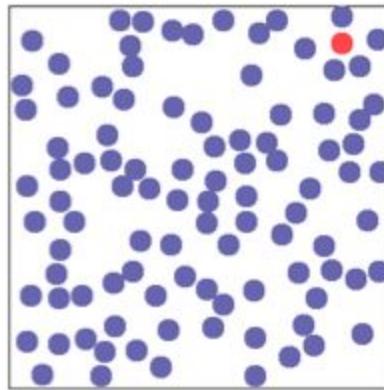
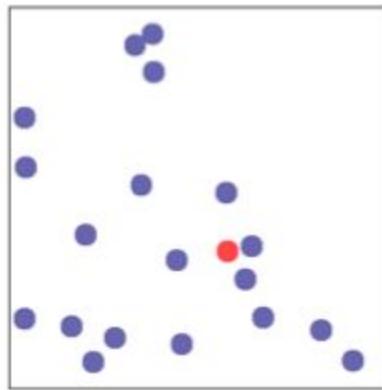
+ Green



Major interference

# Popout

- Distinct items stand out



# Marks

## → Points



## → Lines



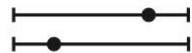
## → Areas



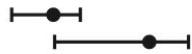
# Channels

## → Magnitude Channels: Ordered Attributes

Position on common scale



Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



## → Identity Channels: Categorical Attributes

Spatial region



Color hue



Motion



Shape



▲ Most

Effectiveness

▼ Least

Same



+ a b l e a u

# Multiple Views & Interaction

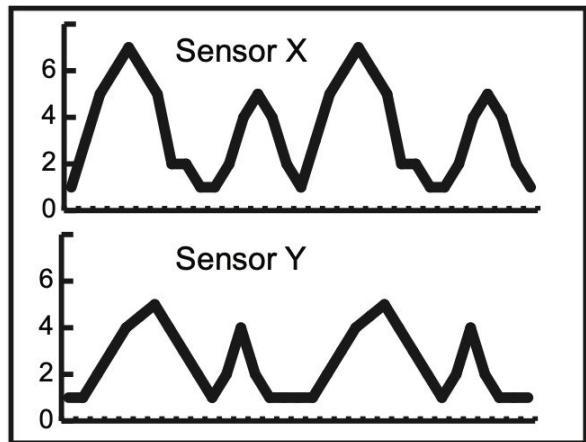
# What is Faceting?

- to facet (verb): to split
- one of the five major approaches to handling visual complexity. They are:
  - **juxtaposing coordinated views side by side**
  - deriving new data and including it in the view
  - changing single view over time
  - reducing amount of data shown in a view
  - embedding focus and context within the same view

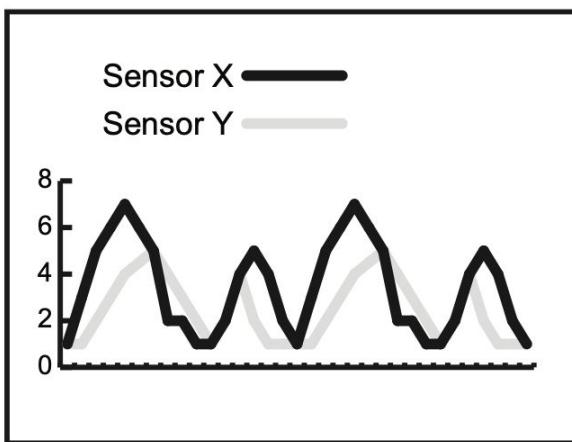
# Combining Views

- Often information is too complex for a single view
- Show multiple views side by side
- **Eyes Over Memory:** two simultaneous views have lower cognitive load than remembering previous view
- Real-estate trade-off: popup view vs. static side-by-side
- OR – single view that is changed through interaction (filtering aggregation, navigation)

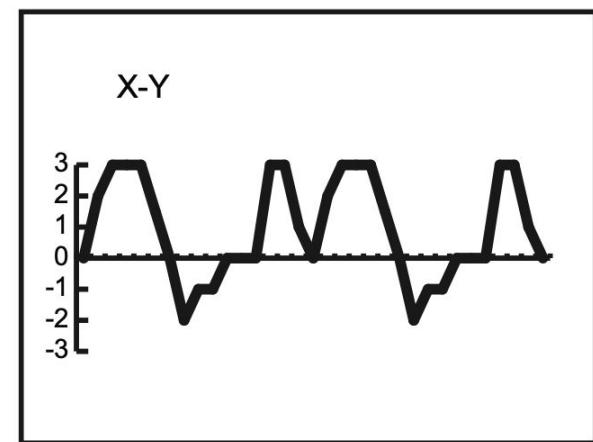
# How to show multiple views



a) Juxtaposition



b) Superposition

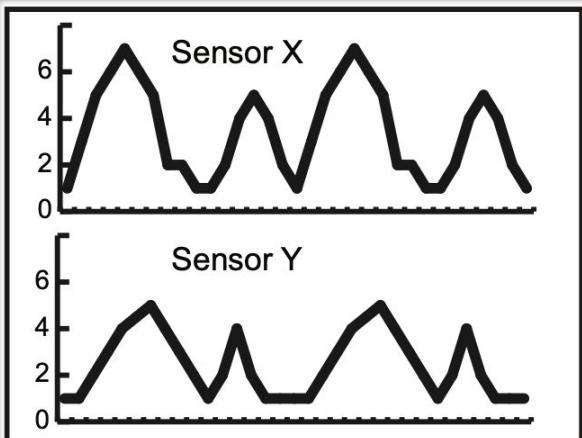


c) Explicit Encoding:  
Difference

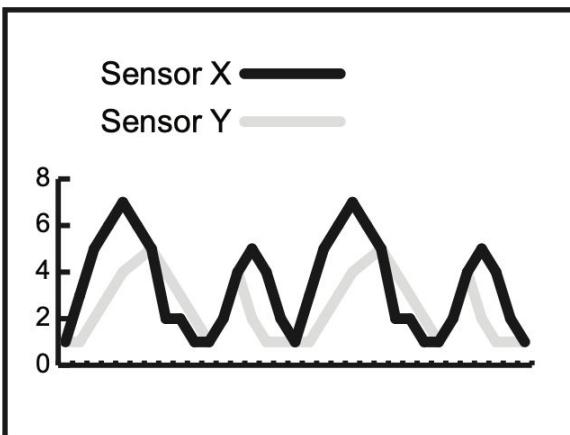
Visual Comparison for Information Visualization , Gleicher et al. 2011

© Munzner/Möller

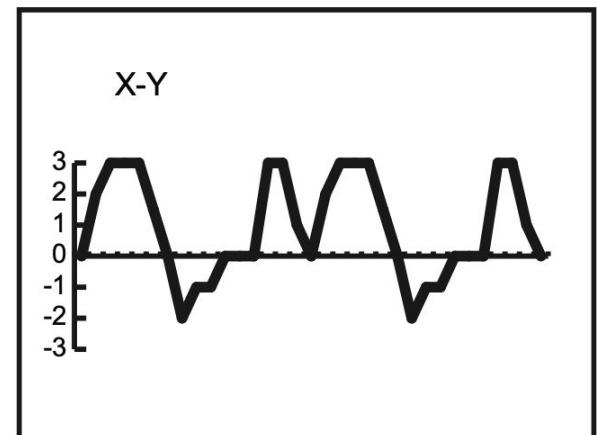
# Partitioning



a) Juxtaposition



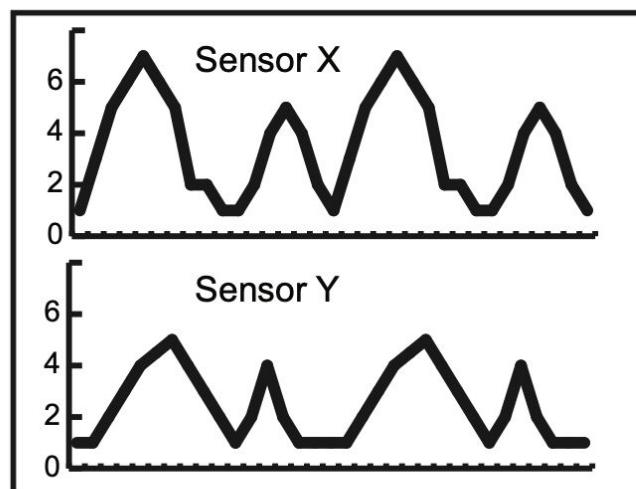
b) Superposition



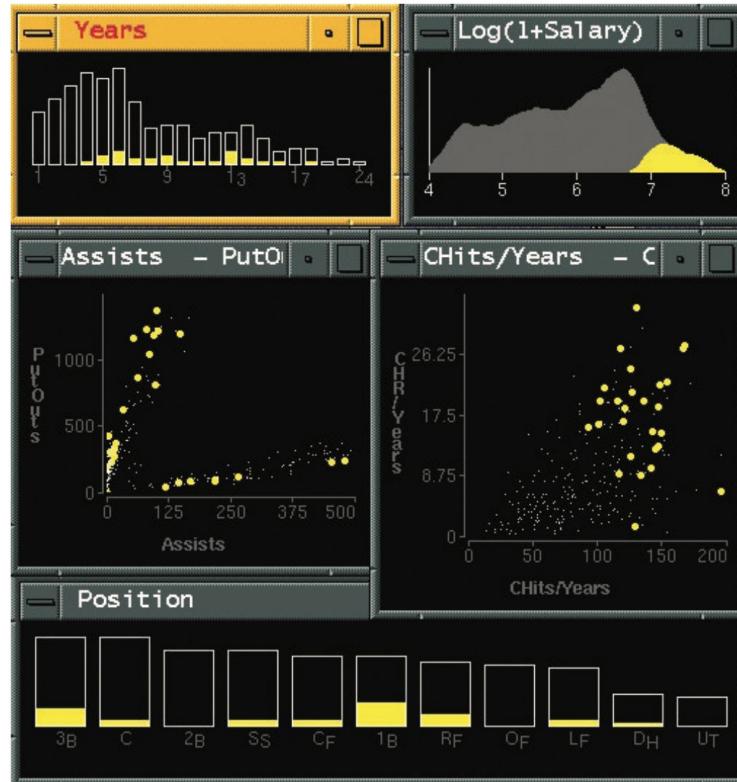
c) Explicit Encoding:  
Difference

# Juxtapose and Coordinate Views

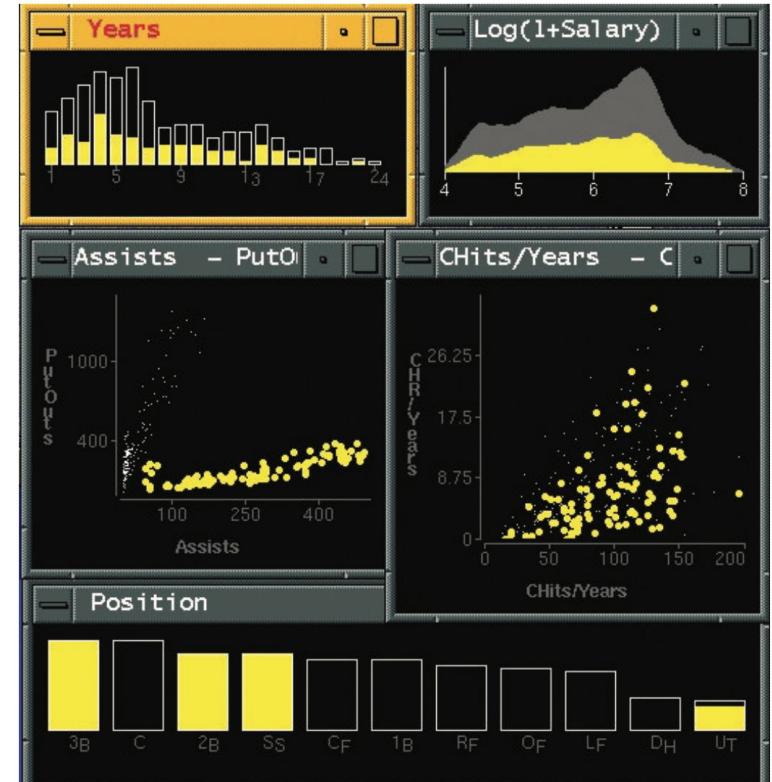
- juxtapose: place or deal with close together for contrasting effect
- Linked views, multiple views, coordinated views, coordinated multiple views, and coupled views: synonyms for the same fundamental idea



# Linked Highlighting



(a)



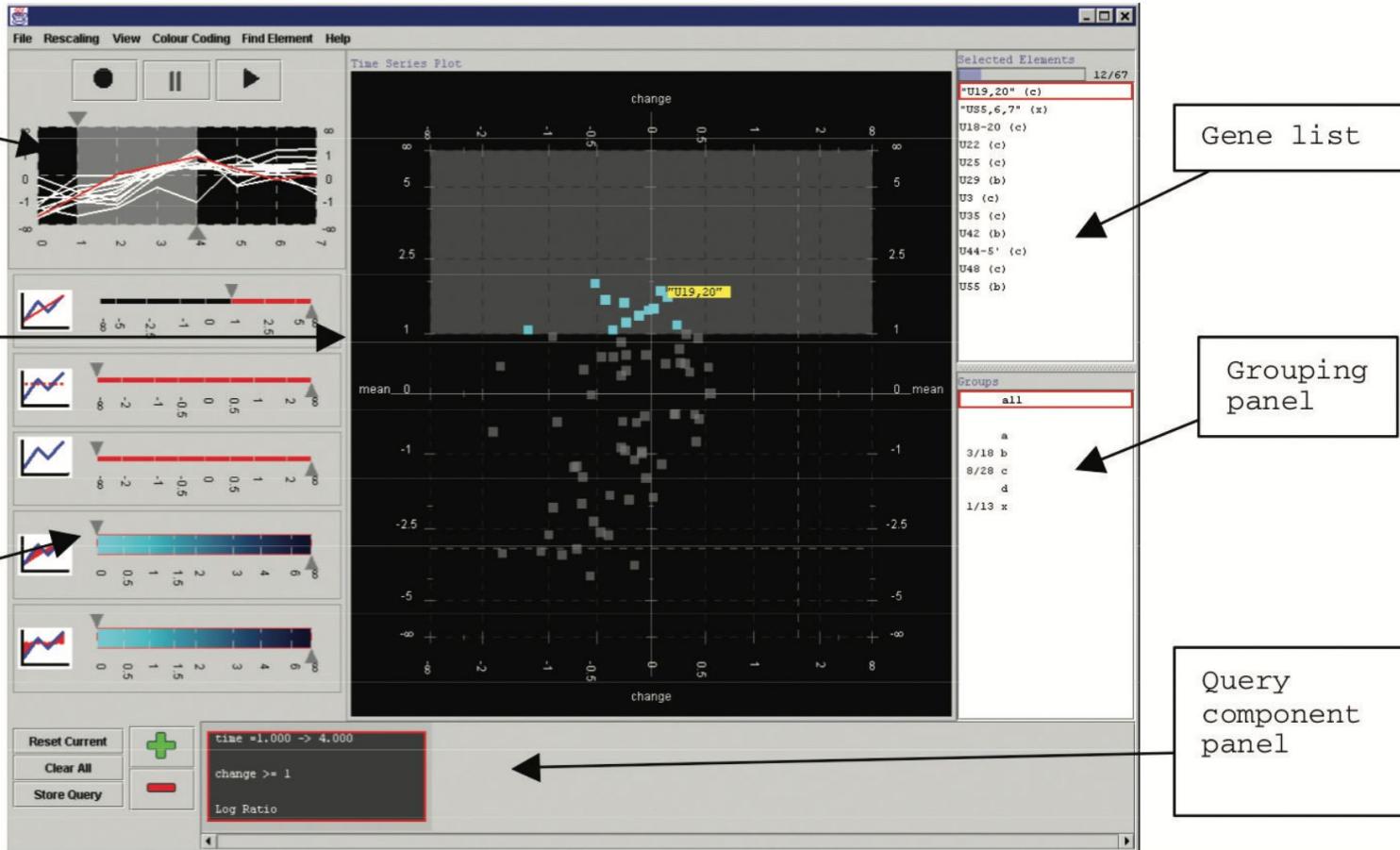
(b)

# Overview-Detail

Graph view for time period specification.

Scatter-plot detail view of a selected time-period

Range sliders



Coordinated Graph and Scatter-Plot Views for the Visual Exploration of Microarray Time-Series Data,  
Craig and Kennedy. 2003

# Visual Information Seeking Mantra

*“Overview first,  
zoom and filter,  
then details-on-demand!”*

Ben Shneiderman



Source: [http://www.cs.umd.edu/users/ben/ben\\_pic\\_proper-color.jpg](http://www.cs.umd.edu/users/ben/ben_pic_proper-color.jpg) [Accessed: June 10th, 2022]

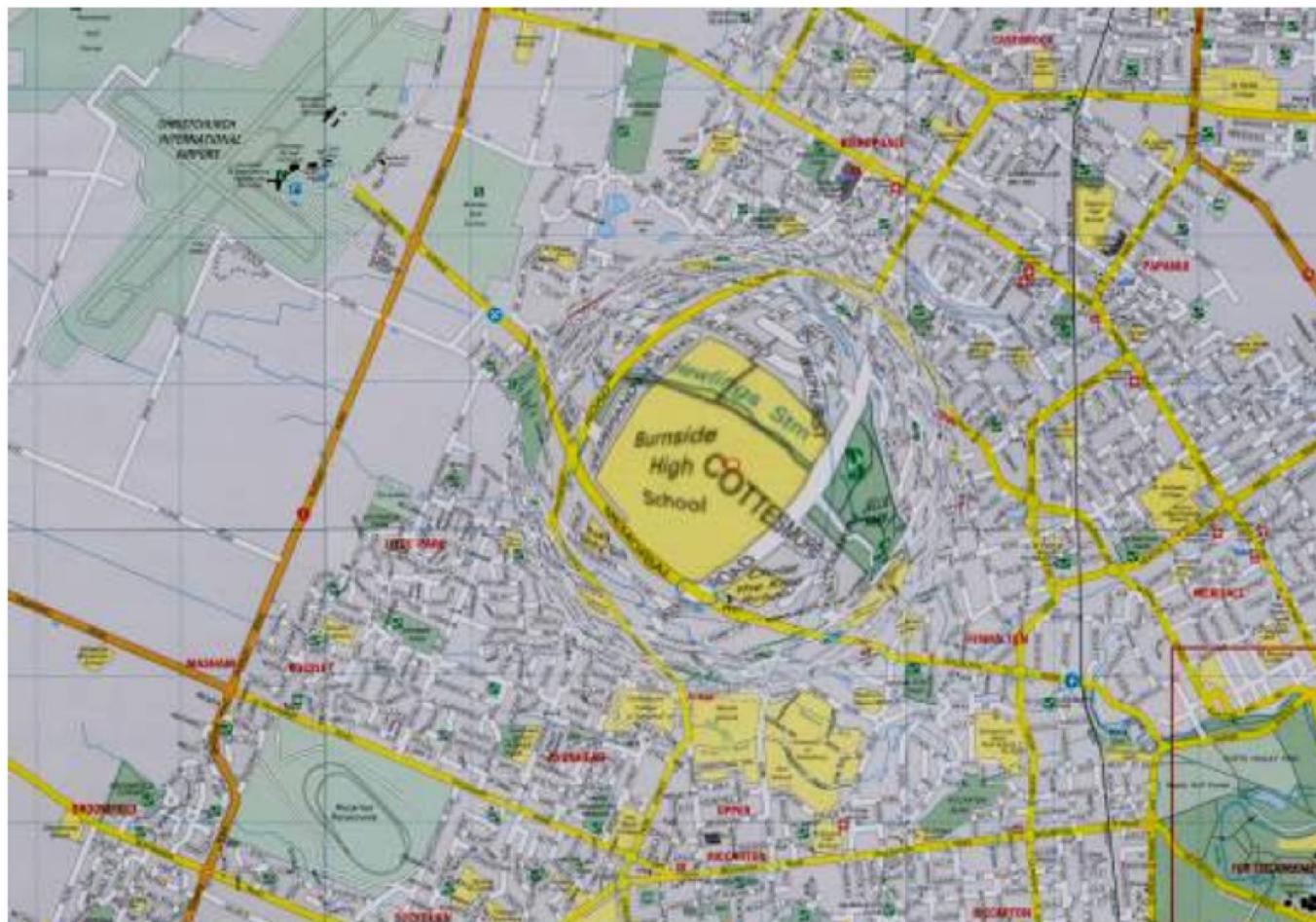
# Overview-and-detail

- Example: tooltips -- show details about a data item on demand (*detail-on-demand*)
- Example: Geographic birdseye

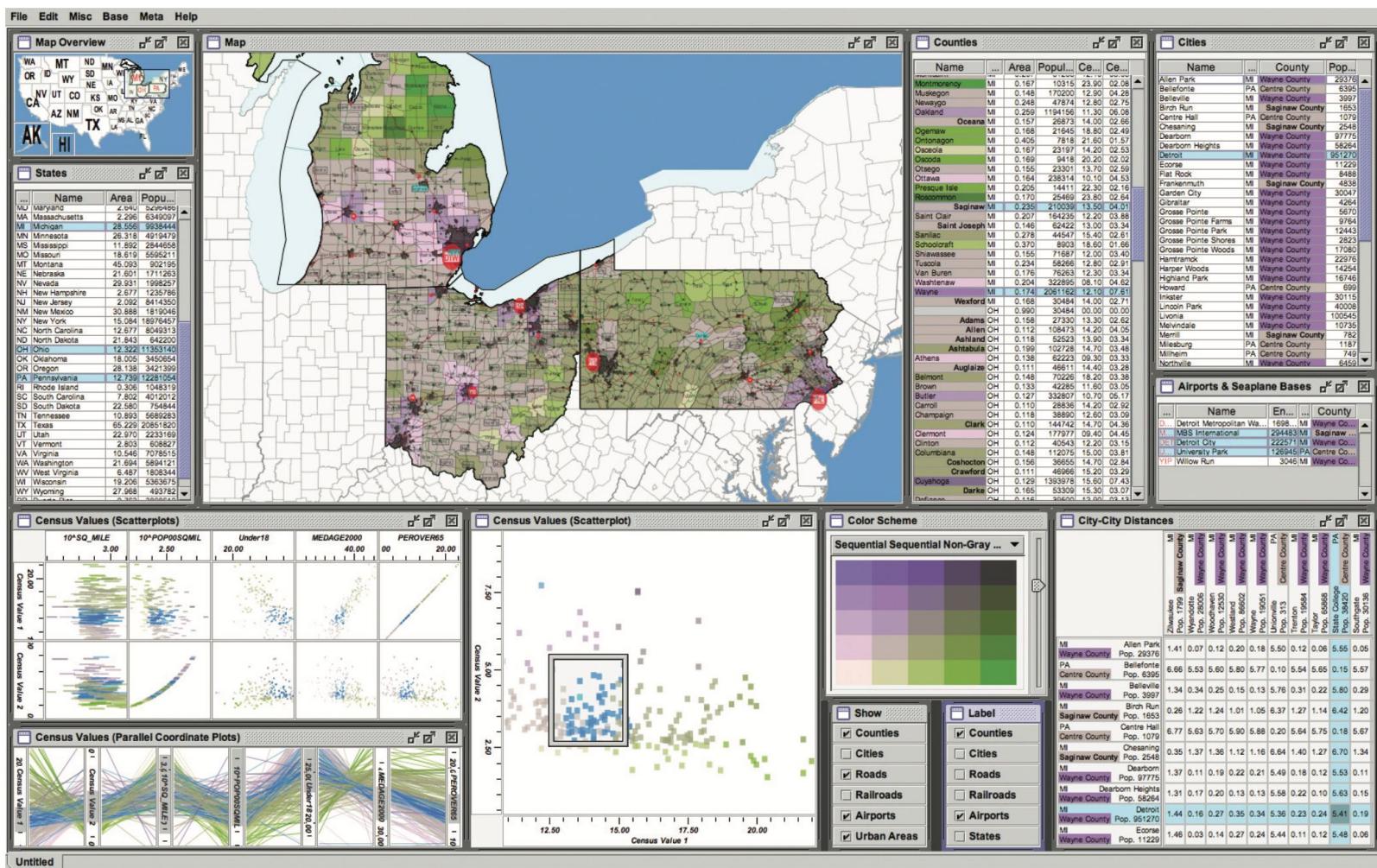


# Overview-and-detail

- fisheye lens technique



# Combinations



## The Improvise toolkit, Weaver.

© Munzner/Möller

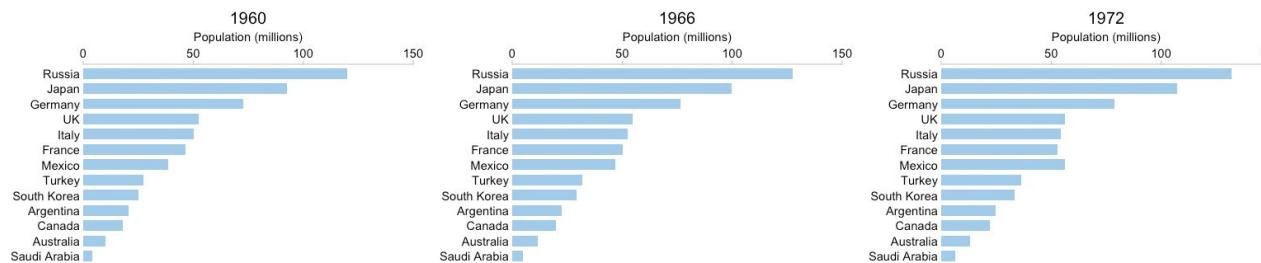
# Multiple side-by-side views

		Data		
		All	Subset	None
Encoding	Same	Redundant		
	Different			No Linkage

© Munzner/Möller

# Small multiple

- shared encoding, different partition
- views have a common reference frame
- facilitates comparison
- often used as a better alternative to animation
- drawback -- screen real-estate



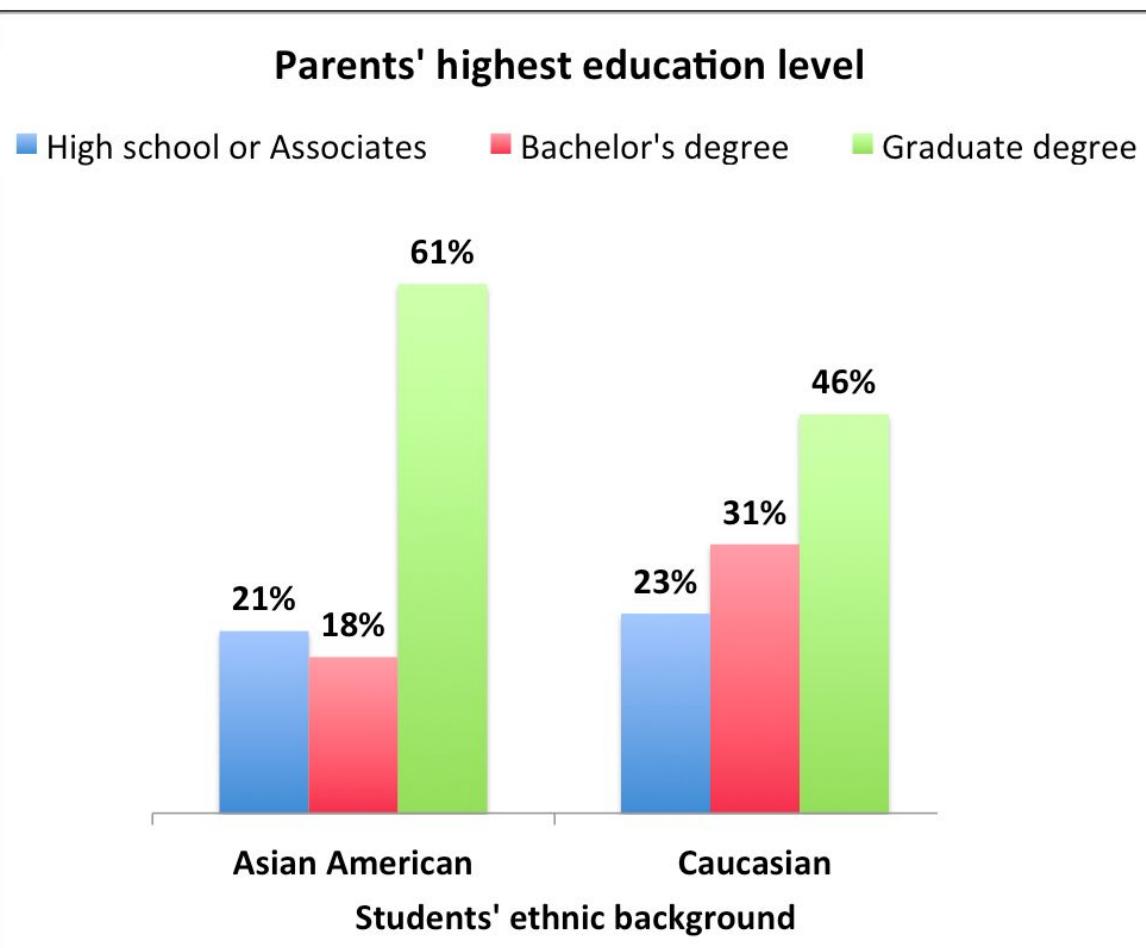
Source: [https://infragistics.com/community/blogs/b/tim\\_brock/posts/an-introduction-to-small-multiples](https://infragistics.com/community/blogs/b/tim_brock/posts/an-introduction-to-small-multiples) [Accessed: June 10th, 2022]

# Animation vs. Small Multiples

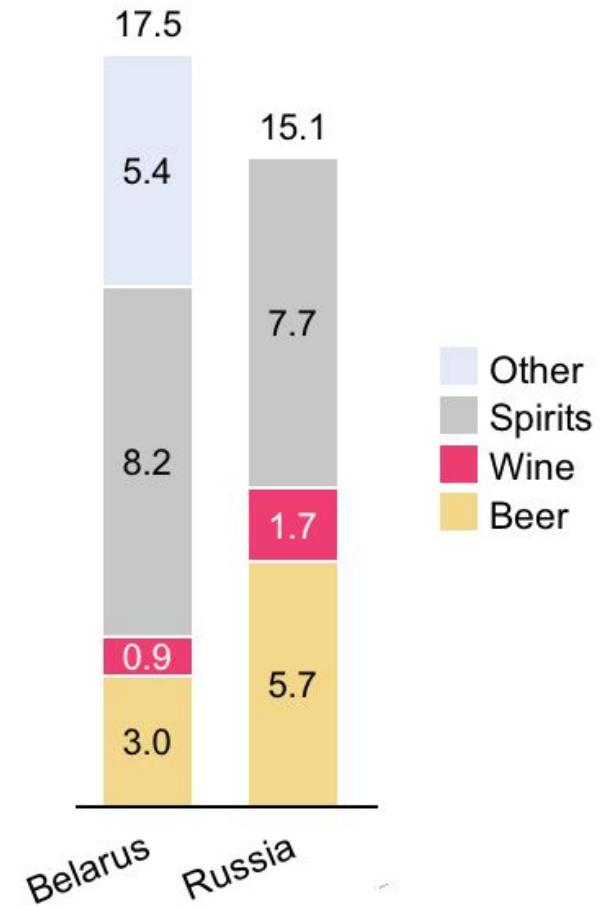
- Tversky argument: intuition that animation helps is wrong
  - meta-review of previous studies
  - often more info shown in animation view so not a fair comparison
  - carefully chosen segmentation into small multiples better than animation if equivalent information shown

[Animation: Can It Facilitate? Barbara Tversky, Julie Morrison, Mireille Betrancourt. International Journal of Human Computer Studies 57:4, pp 247-262, 2002.]

# Partitioning

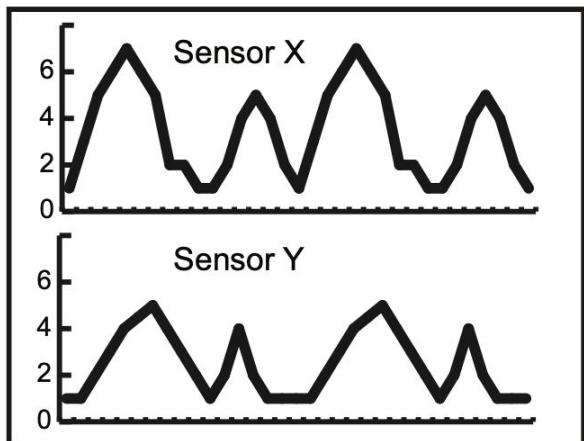


© <https://cra.org/crn/wp-content/uploads/sites/7/2015/06/Feb-2015.png>

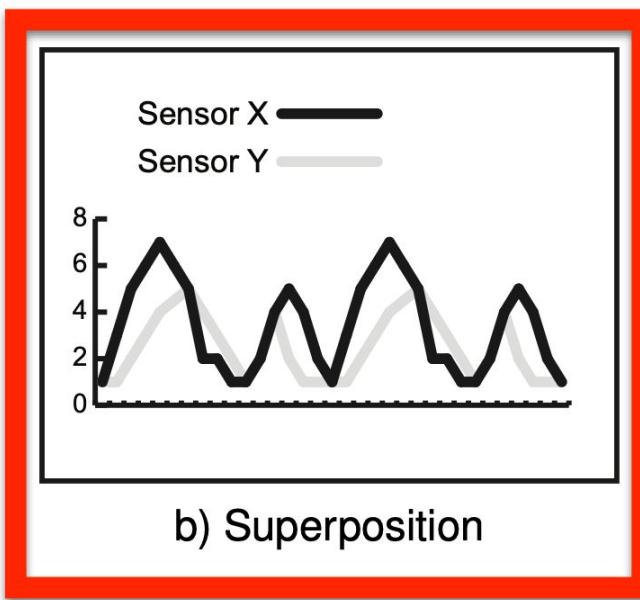


Source: Wikipedia, 2010

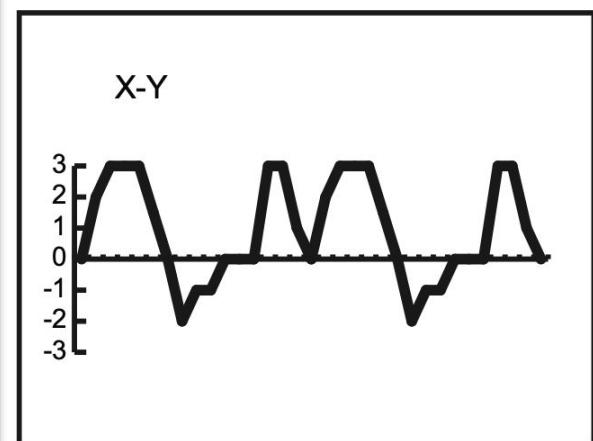
# 4. Superimpose Layers



a) Juxtaposition

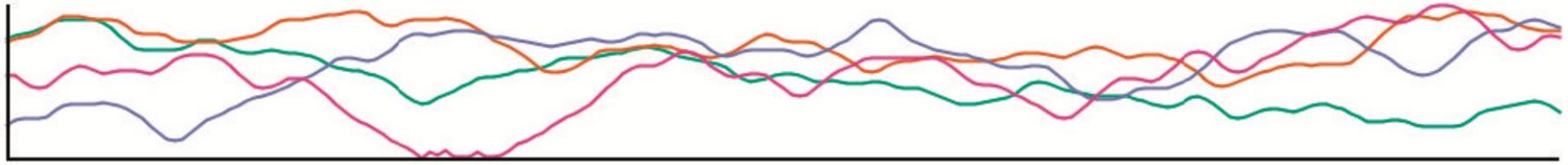


b) Superposition



c) Explicit Encoding:  
Difference

# Superimpose Layers



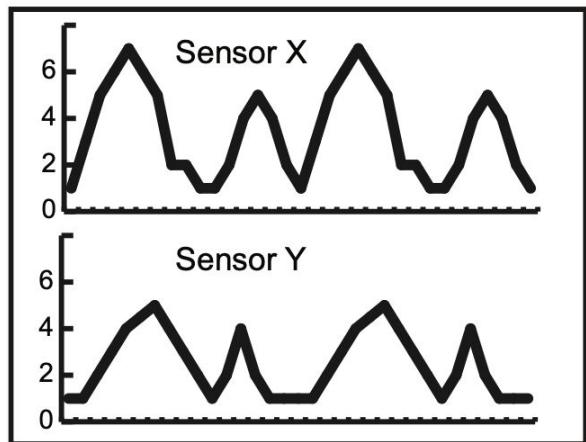
(a)



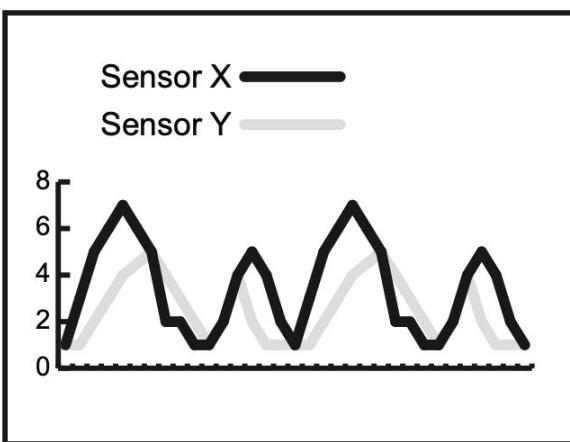
(b)

Graphical Perception of Multiple Time Series, Javed et al.,  
2010

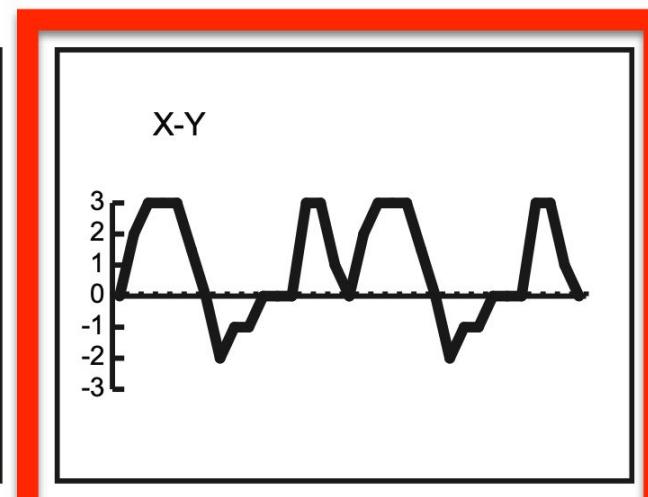
# Difference views



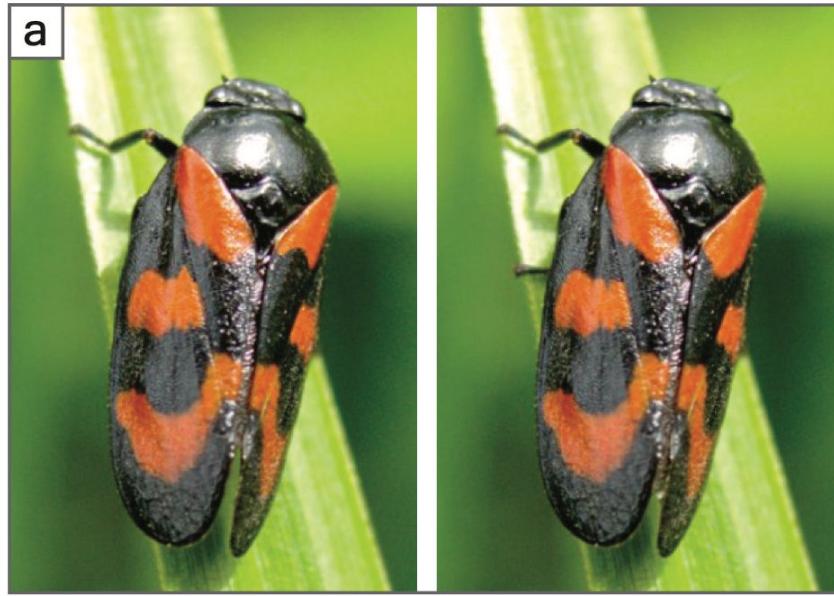
a) Juxtaposition

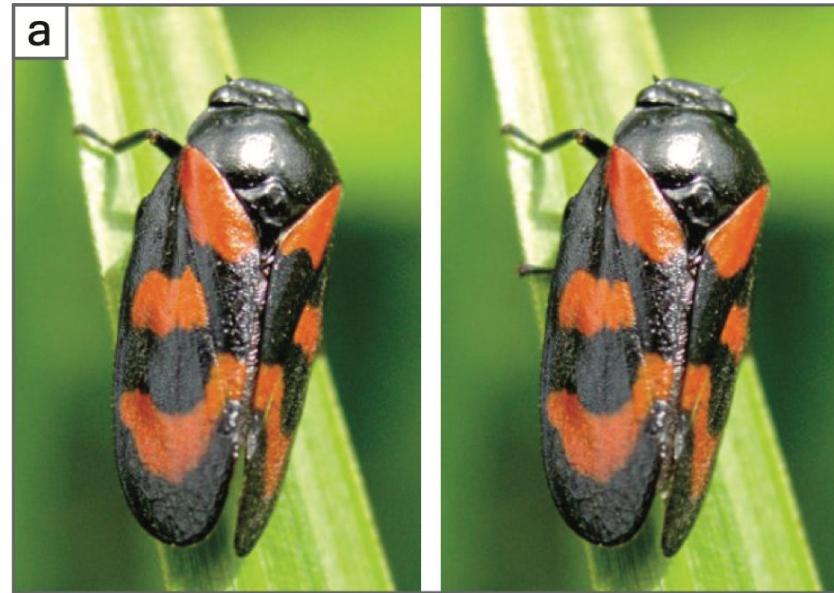


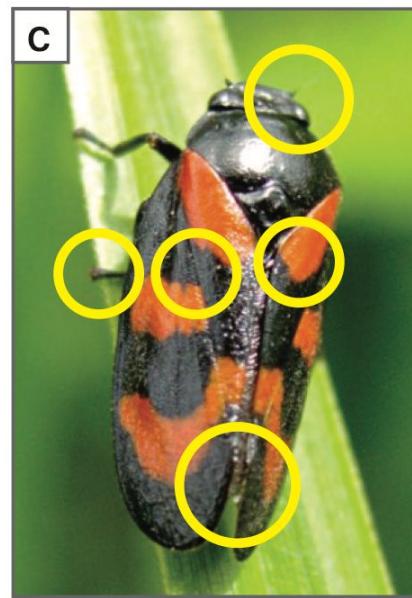
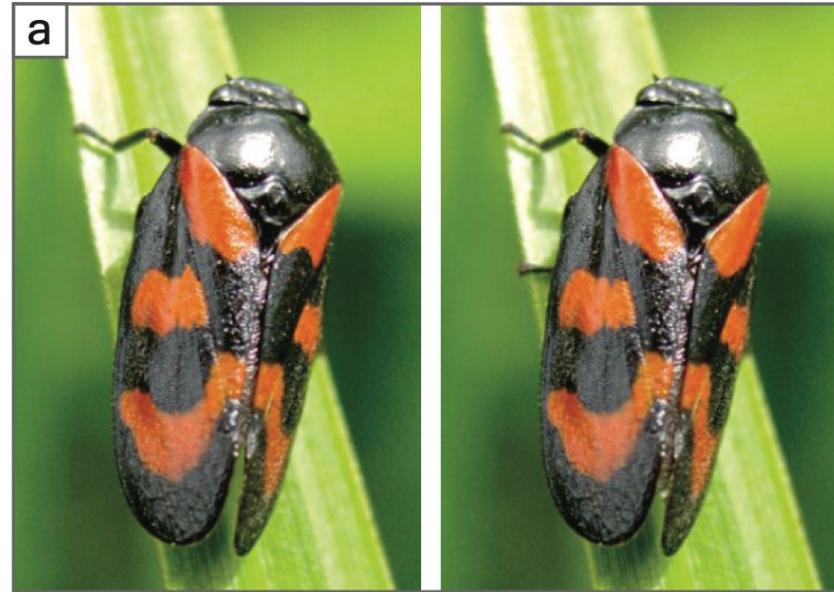
b) Superposition



c) Explicit Encoding:  
Difference





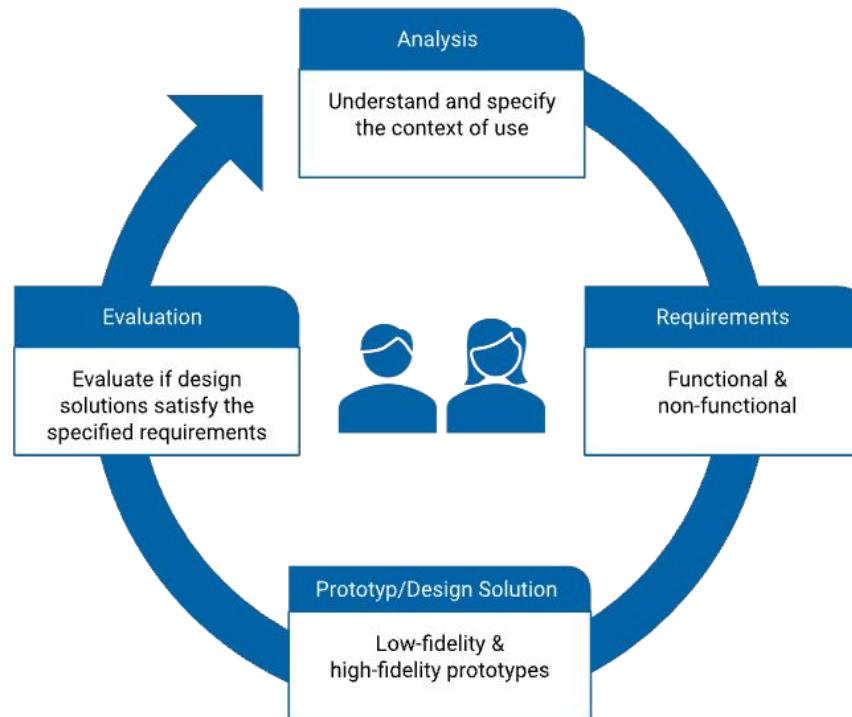




+ a b | e a u

# Human Centered Design

# Human-Centered Design (Participatory Design)

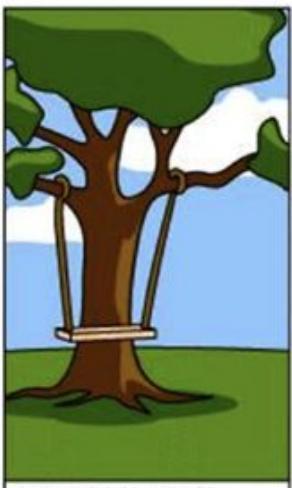


- Success of the system is closely tied to the expectations and needs of the user
- Different stakeholders have different requirements
- Iterative Process
- Future users are included in the whole design and implementation phase

# Risks of Development without Human in the Loop



How the customer explained it



How the Project Leader understood it



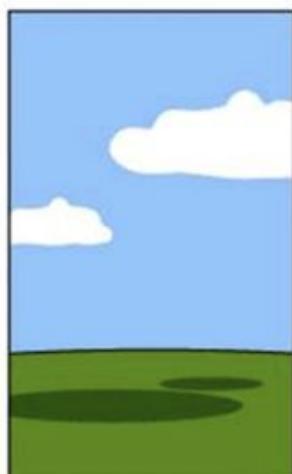
How the Analyst designed it



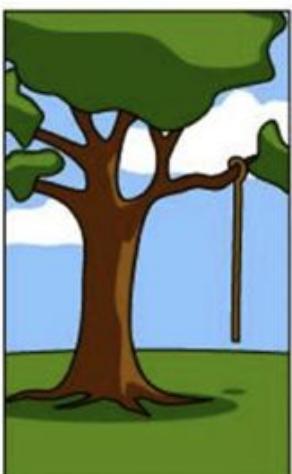
How the Programmer wrote it



How the Business Consultant described it



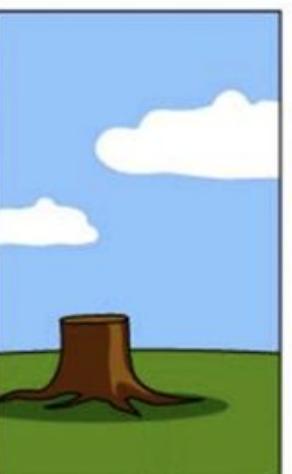
How the project was documented



What operations installed



How the customer was billed



How it was supported

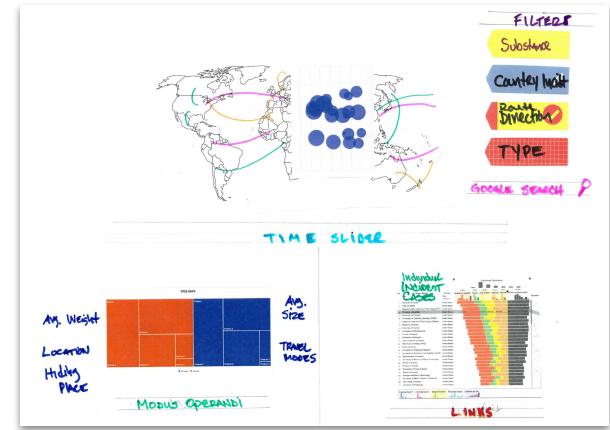


What the customer really needed

# Low-fidelity vs. High-fidelity Prototypes

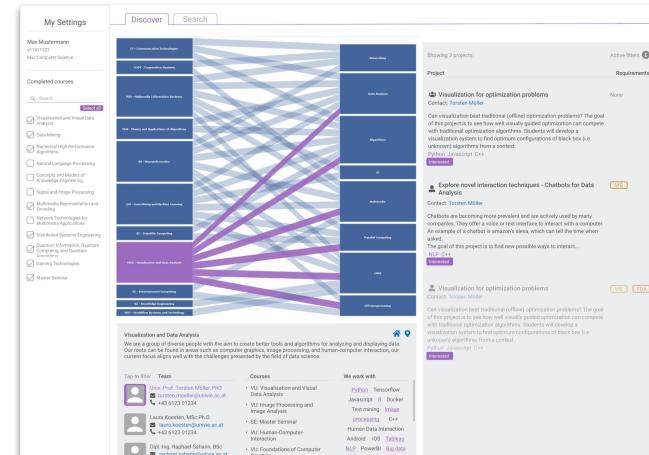
- Prototypes are representations of a design made before final artifacts exist
- Early usability evaluation of an interactive system
- **Low-fidelity prototype:**

- Incomplete and cheap drafts
  - e.g. paper prototypes or mockups (easy to throw away)
- No or very low interactivity
- Pros: Easy and cheap, easy to modify, more honest user feedback, proof of concept



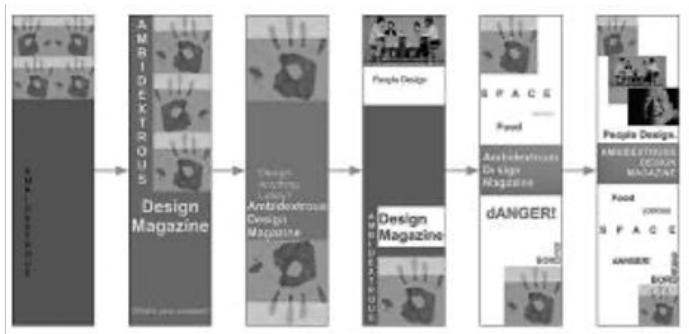
## • High-fidelity prototype:

- Look & feel of the productive interactive system
- Mostly interactive
- Evaluation of selected tasks possible

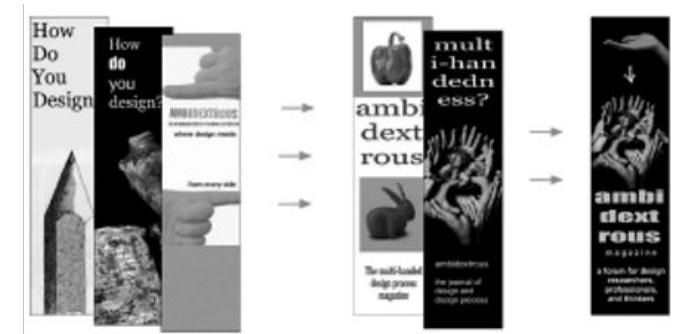


# Parallel Prototyping

- Two or more prototypes are developed and evaluated at the same time
- Allows for comparison between different design solutions
- Less “emotional commitment” to a design solution → more honest user feedback
- “Best of multiple worlds”
- Problems with serial prototyping: Only one prototype is developed, evaluated and iteratively improved → could lead to a bias (priming) since this is the only perspective on the design problem



Serial prototyping



Parallel prototyping

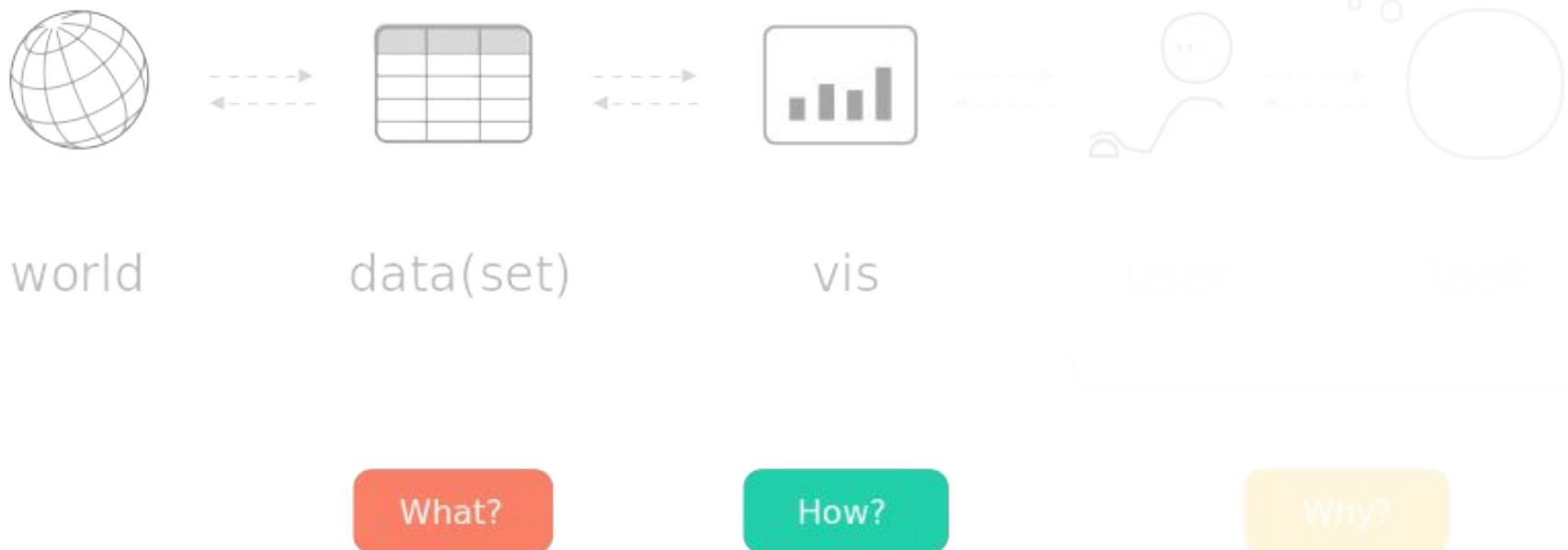


Challenge

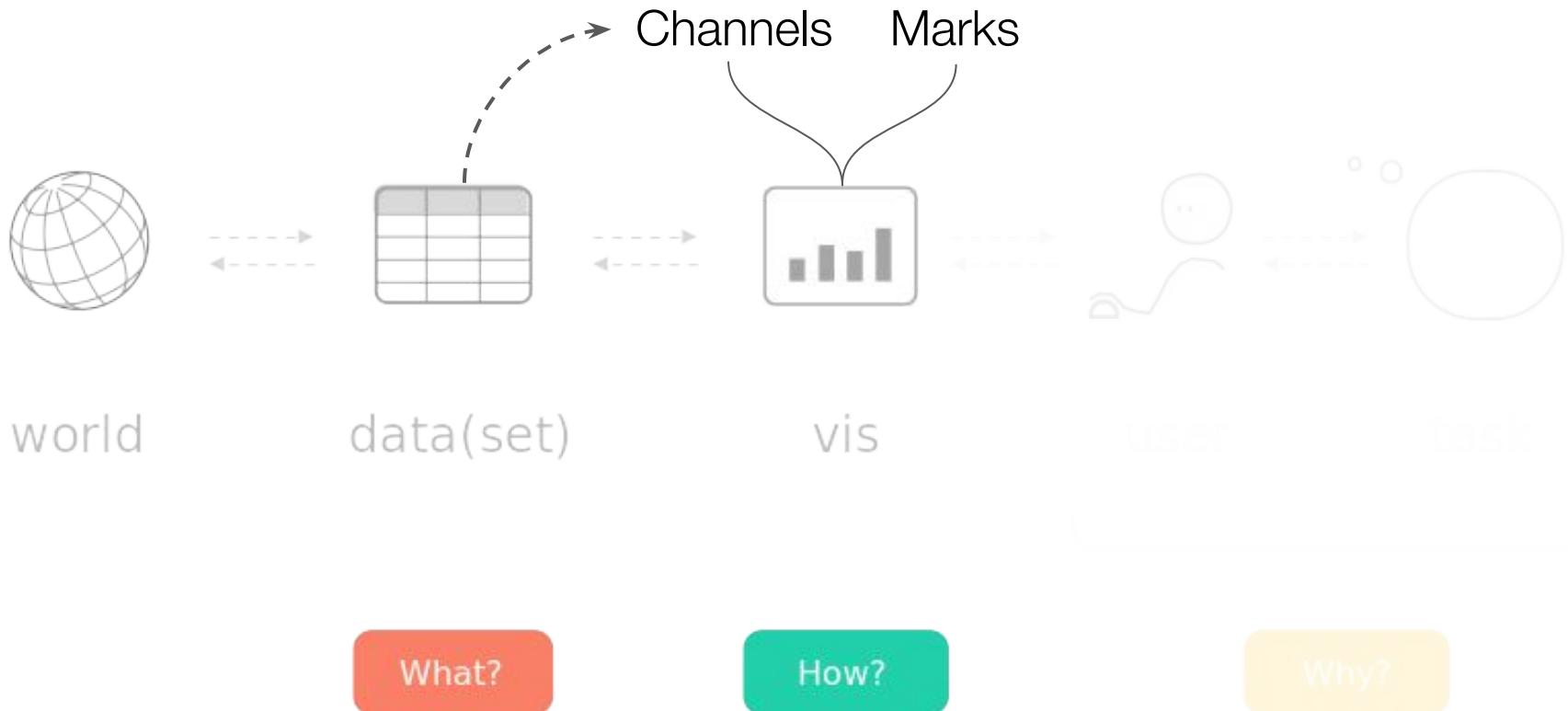


- Which German speaking country has the highest [**Expected years of schooling**]?
- Which English speaking country has the highest [**Expected years of schooling**]?
- Which continent [**map\_reference**] has the highest variance in [**corruption**]?
- Based on the [**corruption**], which is the top and bottom country on that continent?

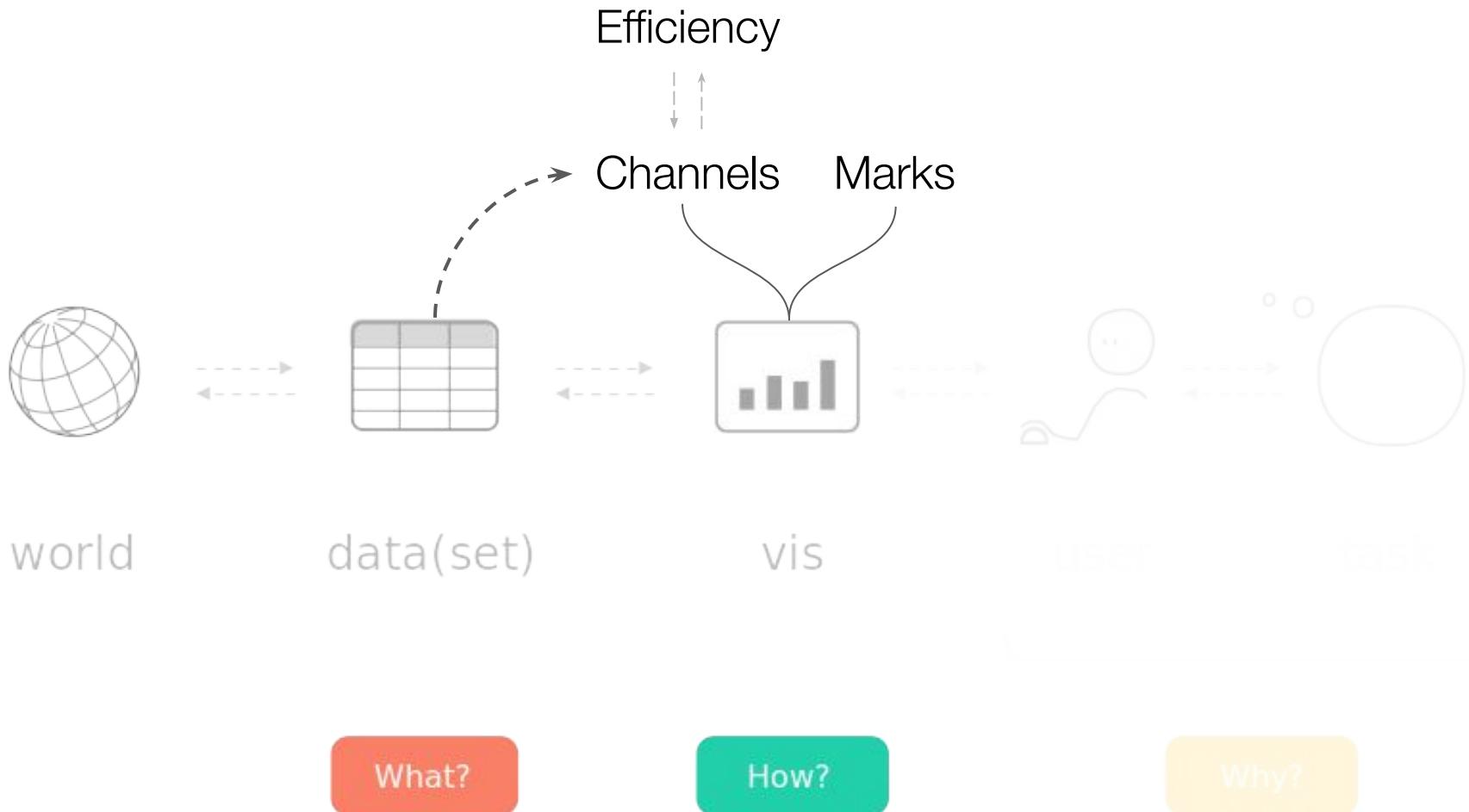
# Conclusion



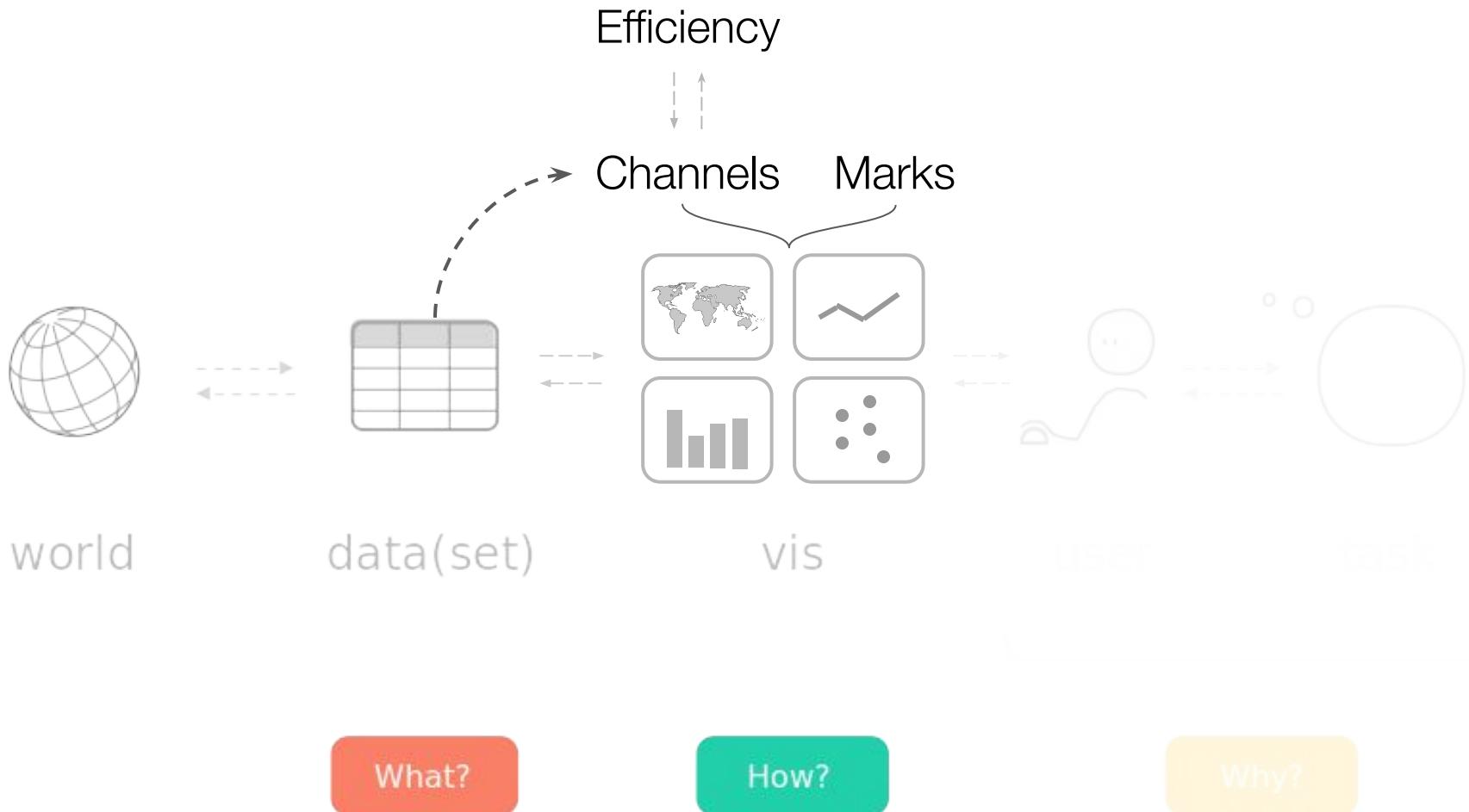
# Conclusion



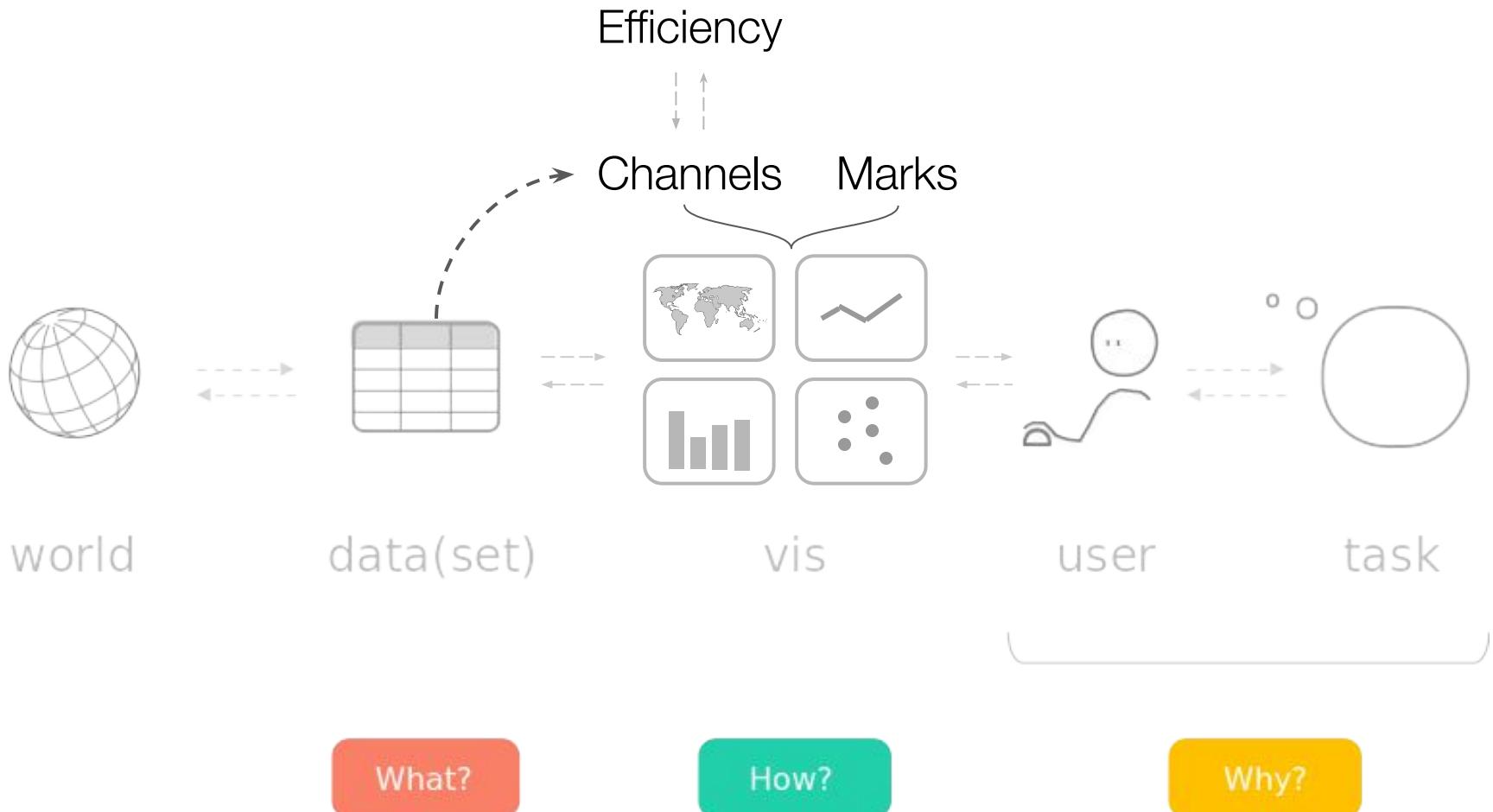
# Conclusion



# Conclusion



# Conclusion



# Thank you!

Check out our course website at

<http://vda.univie.ac.at/Teaching/Vis/21w/schedule.html>