CSC4130
Introduction to Human-Computer Interaction

Lecture 11
Visual Encoding and Information Visualization

Outline

- Marks and channels
- Introduction to information visualization
- Tips for designing visual forms

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- Marks and channels
- Introduction to information visualization
- Tips for designing visual forms

Visual encoding

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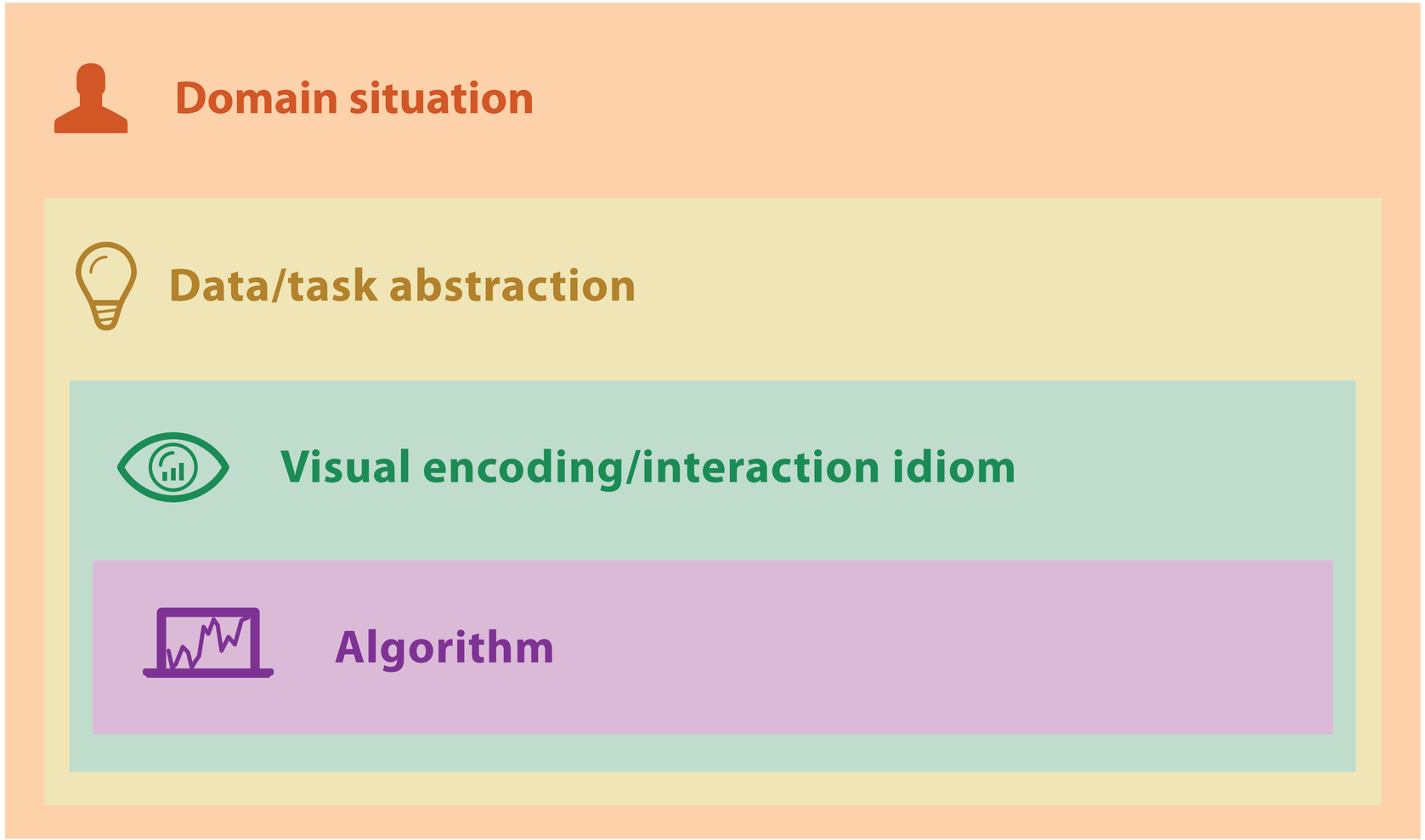
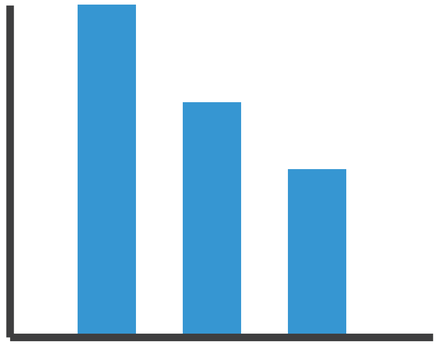
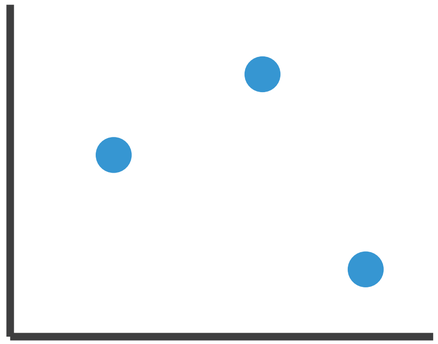
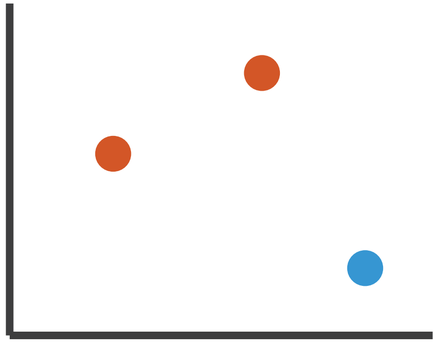
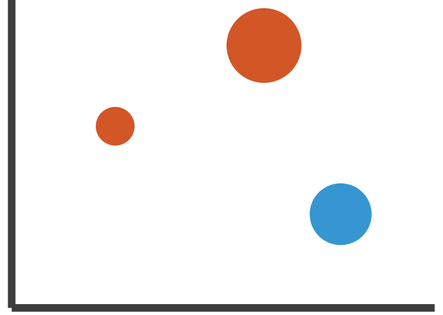
- How to systematically analyze idiom structure?



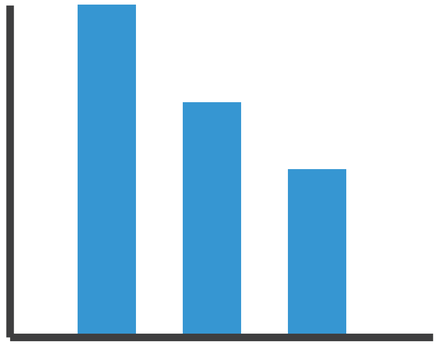
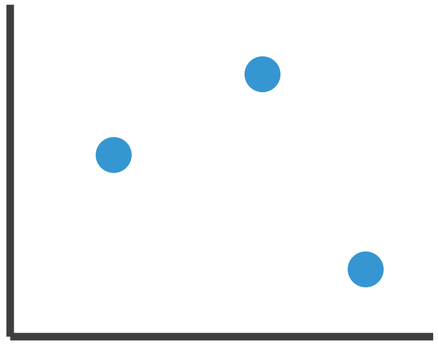
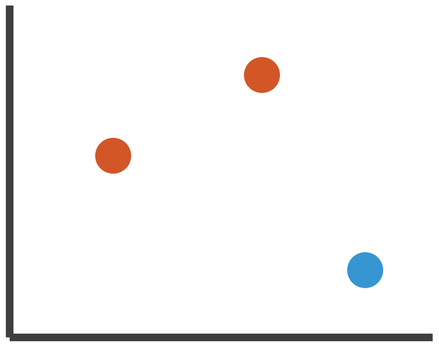
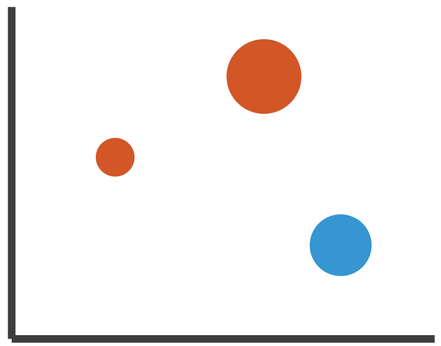
Visual encoding

- How to systematically analyze idiom structure?

Visual encoding

- How to systematically analyze idiom structure?

- Marks and channels
- Marks: represent items or links
- Channels: change appearance of marks based on attributes

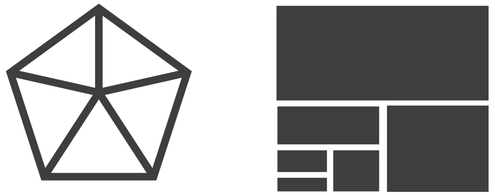
Marks for items

- Basic geometric elements

Points

Lines

Areas



- 3D mark: volume, rarely used

Marks for links

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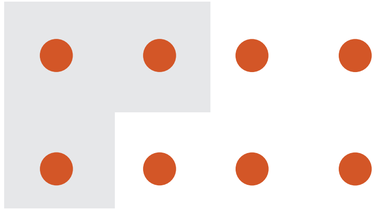
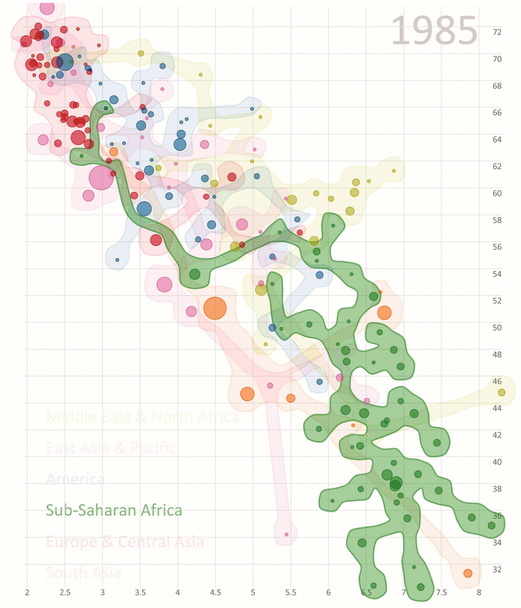
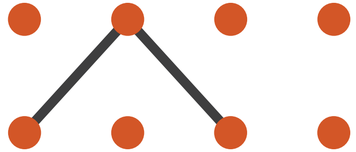
Containment

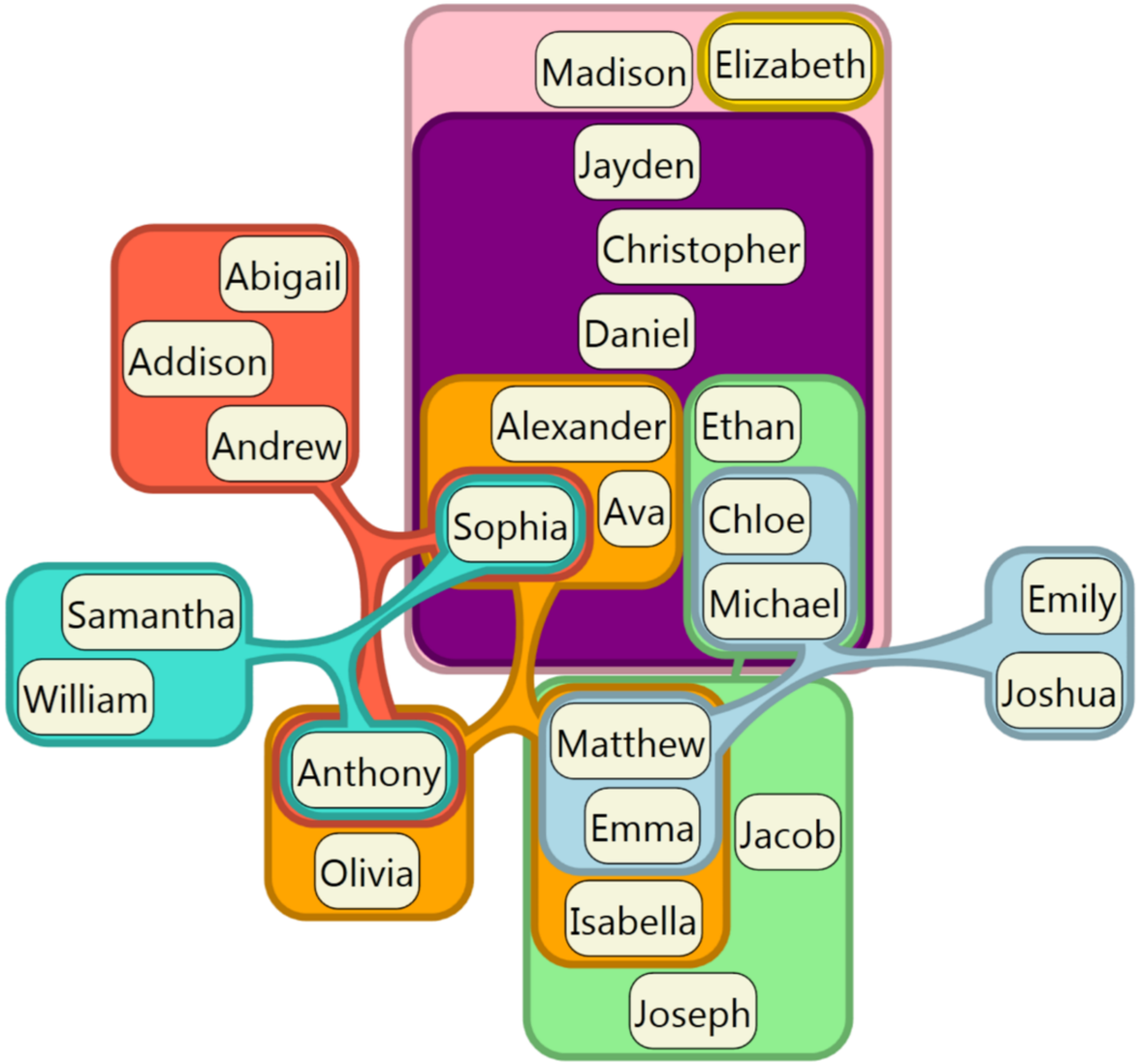




Connection



Containment can be nested

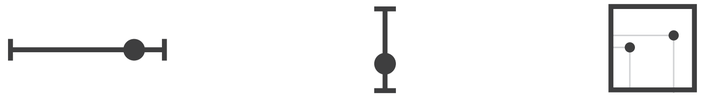


Channels

- Control appearance of marks
  - Proportional to or based on attributes

Position

→ Horizontal → Vertical → Both



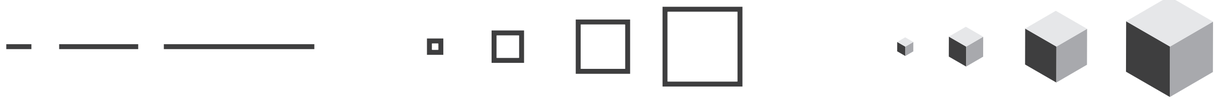
Color

Shape

Tilt

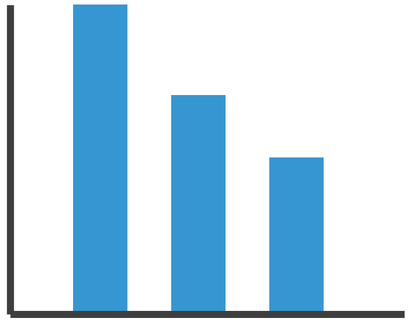
Size

→ Length → Area → Volume



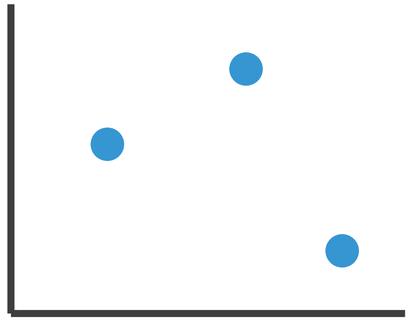
Visual encoding

- Analyze idiom structure as combination of marks and channels



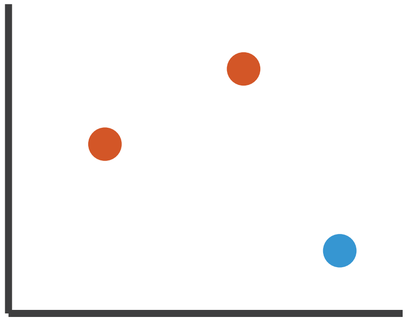
1:
vertical position

mark: line



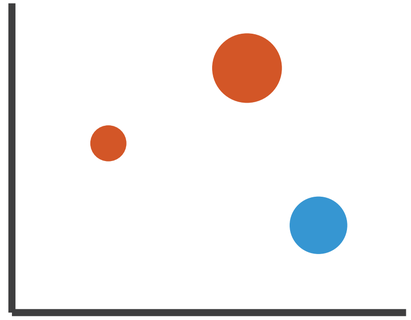
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point

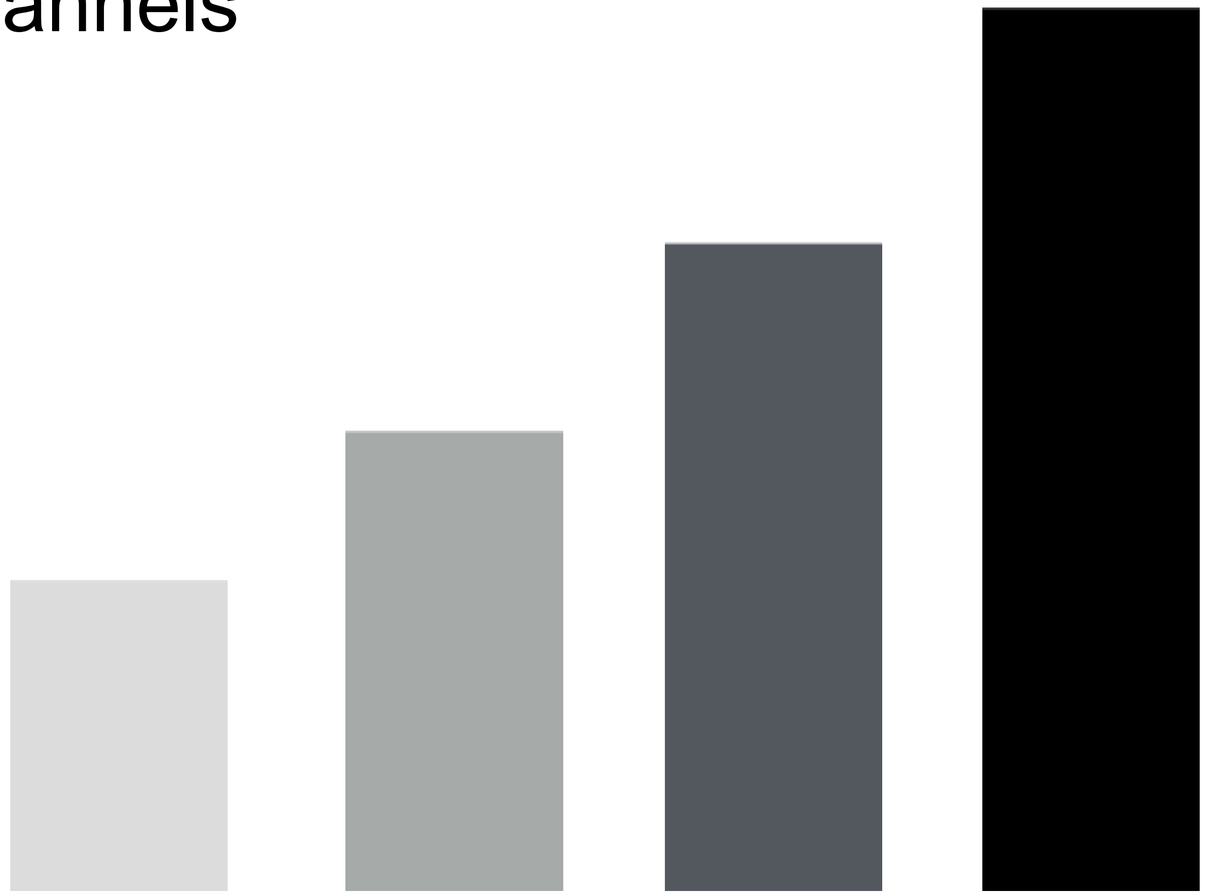


4:
vertical position
horizontal position
color hue size (area)

mark: point

Redundant encoding

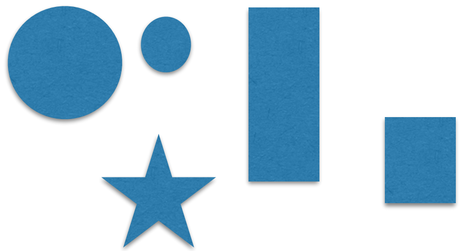
- Multiple channels
  - Send stronger message
  - But use up channels



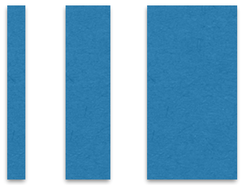
Marks as constraints

- Math view: geometric primitives have dimensions
- Constraint view: mark type constrains what else can be encoded
  - points: 0 constraints on size, can encode more attributes w/ size & shape
  - lines: 1 constraint on size (length), can still size code other way (width)
  - interlocking areas: 2 constraints on size (length/width), cannot size or shape code

Points 0D



Lines 1D



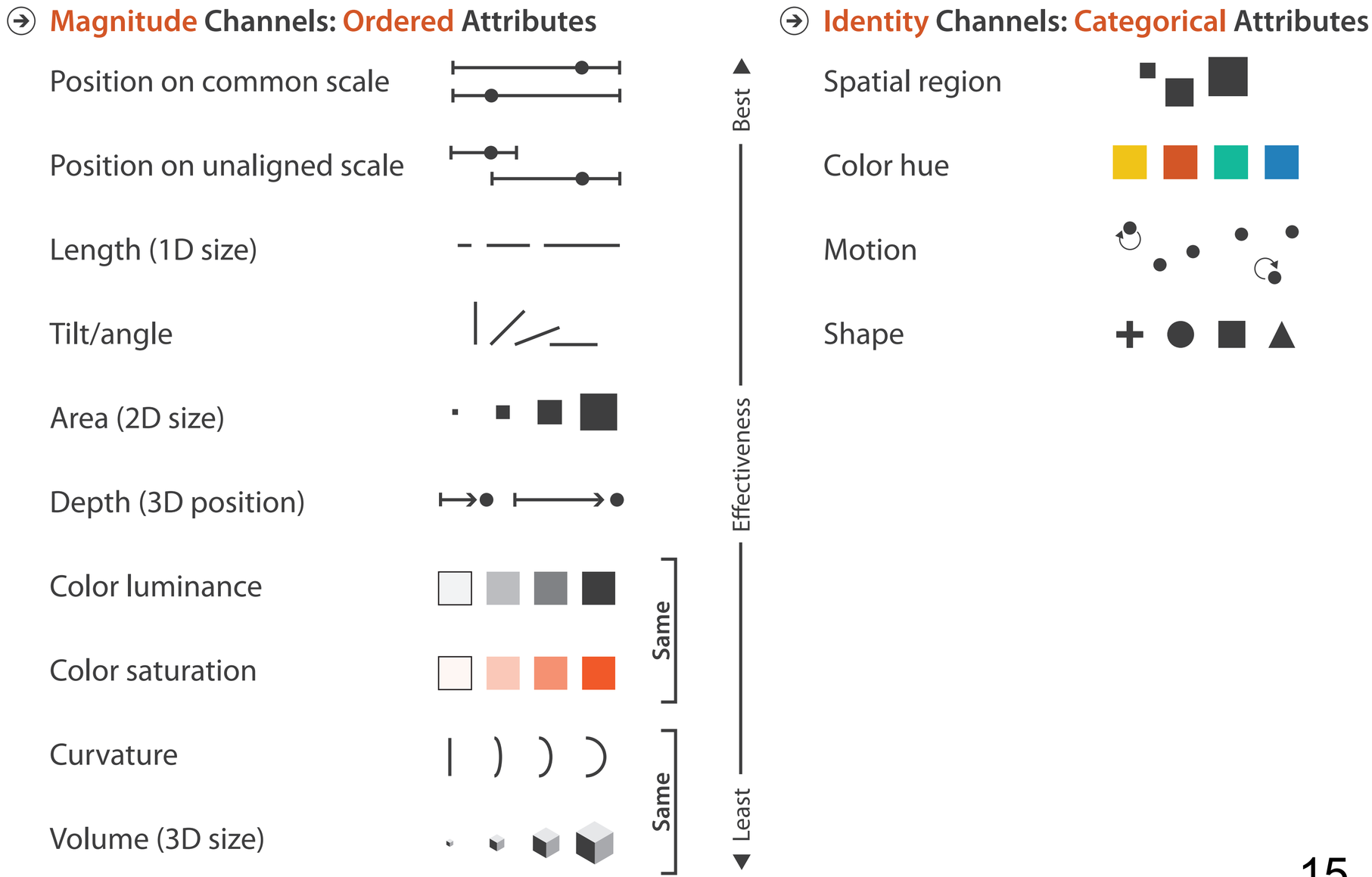
Interlocking Areas 2D

When to use which channel

- Expressiveness
  - Match channel type to data type
- Effectiveness
  - Some channels are better than others

Channel rankings

- Expressiveness
  - Match channel and data characteristics
- Effectiveness
  - Channels differ in accuracy of perception



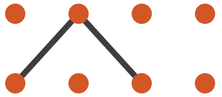
Grouping

- Containment
- Connection
- Proximity
  - Same spatial region
- Similarity
  - Same values as other categorical channels

Marks as Links

Containment

Connection



Identity Channels: Categorical Attributes

Spatial region

Color hue

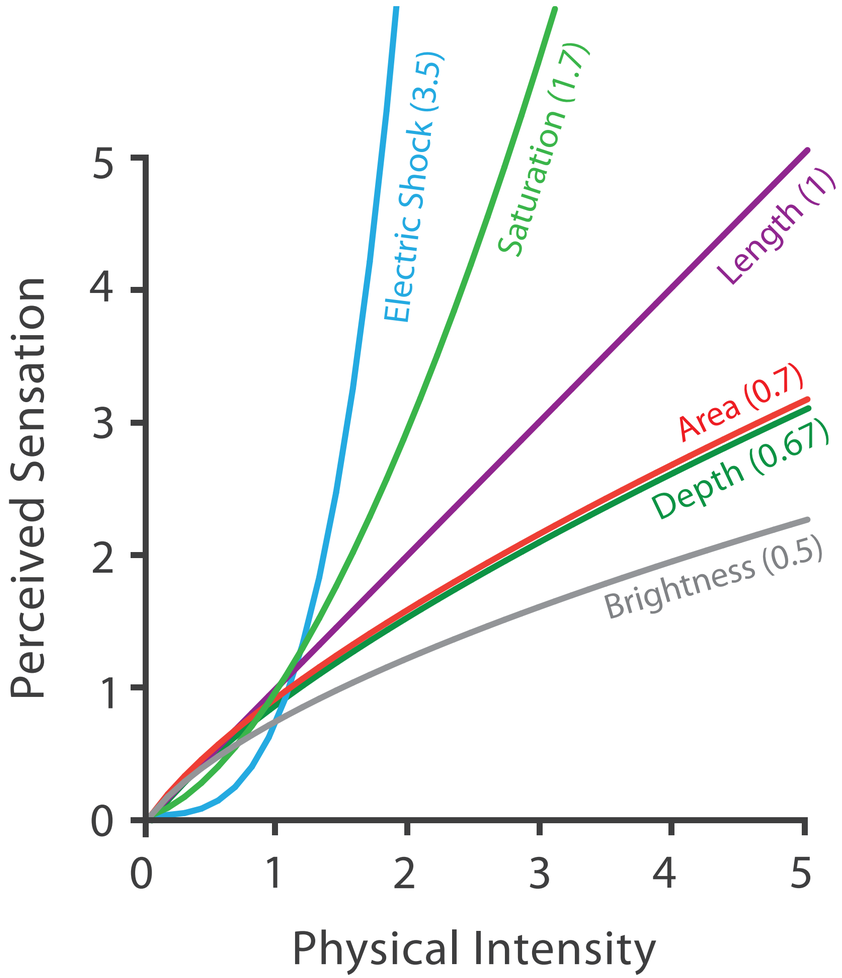
Motion

Shape

Channel effectiveness

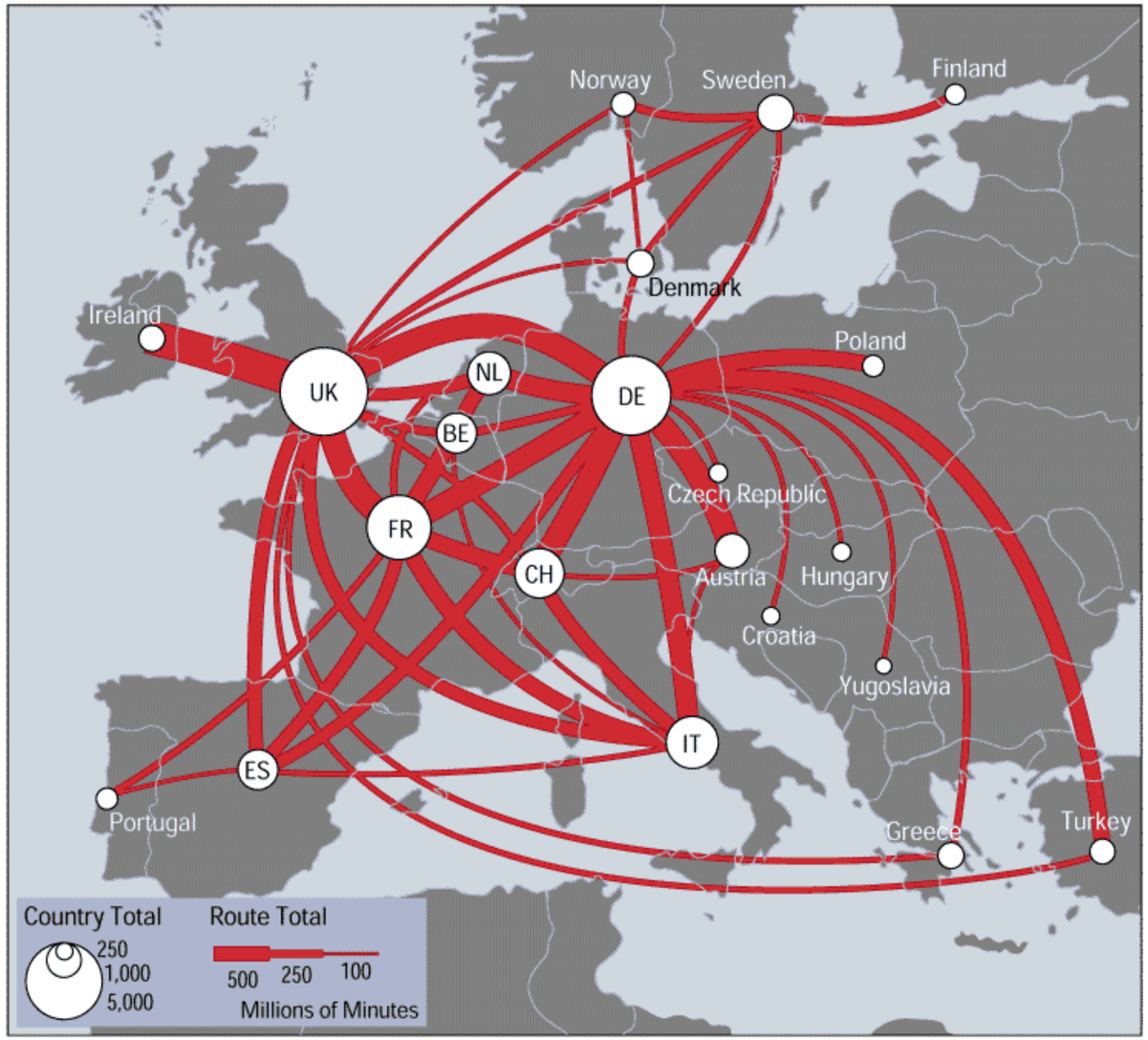
- Accuracy: how precisely can we tell the difference between encoded items?

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



Channel effectiveness

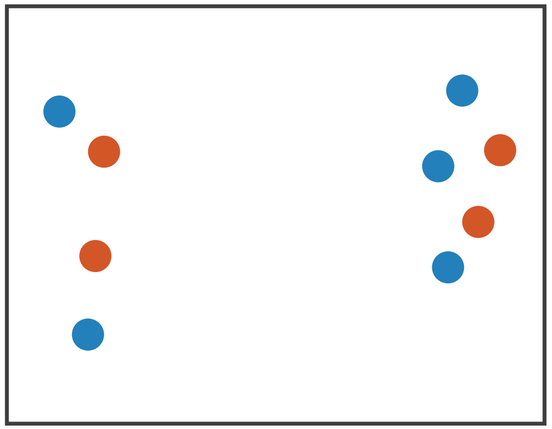
- Discriminability: how many unique steps can we perceive?



Channel effectiveness

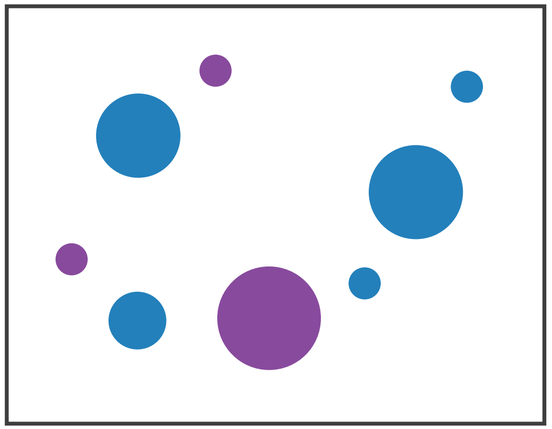
- Separability: is our ability to use this channel affected by another one?

Position
+ Hue (Color)



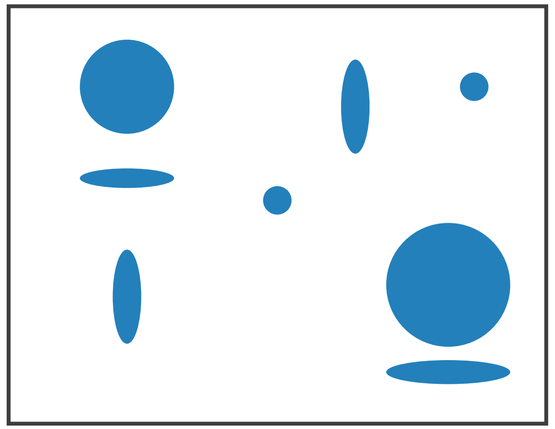
Fully separable

Size
+ Hue (Color)



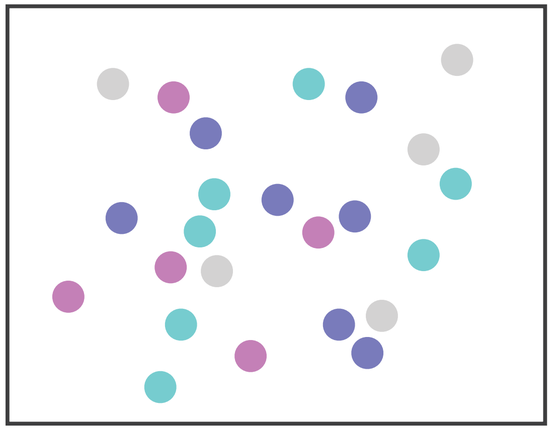
Some interference

Width
+ Height



Some/significant interference

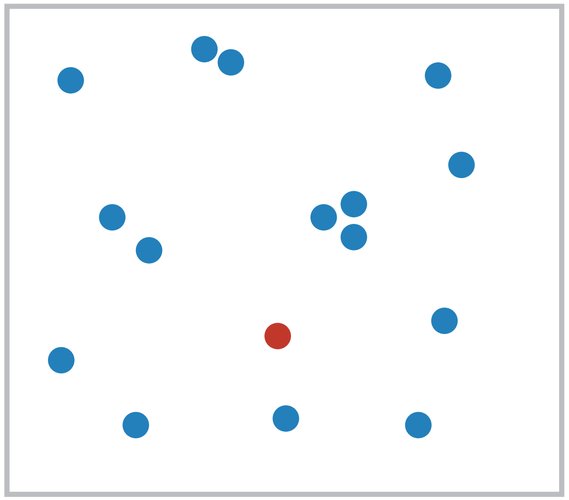
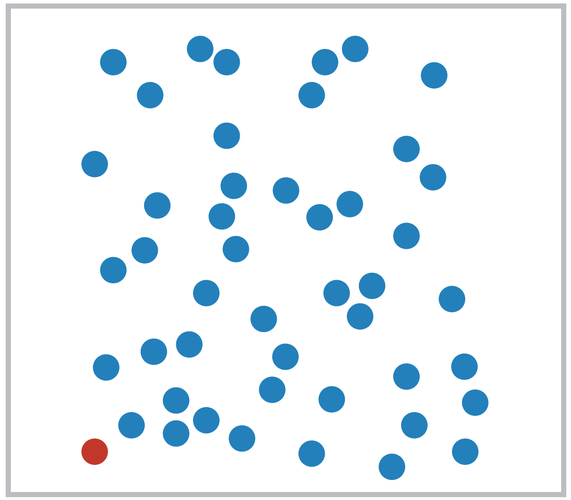
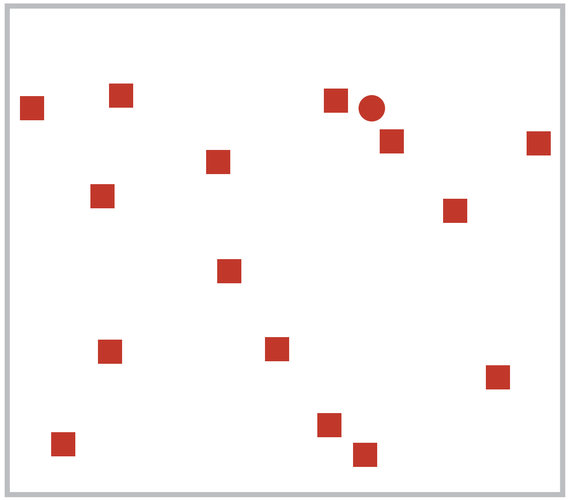
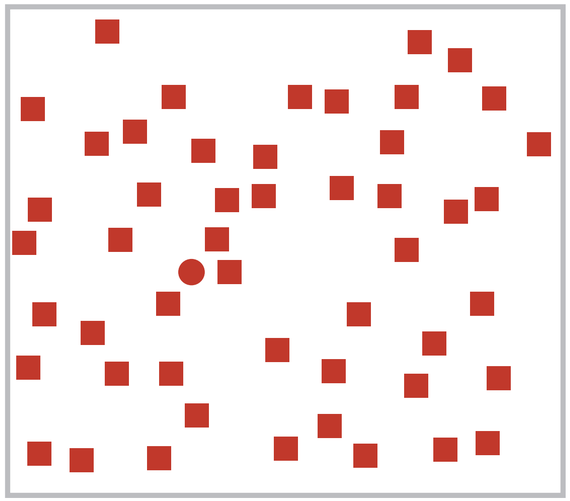
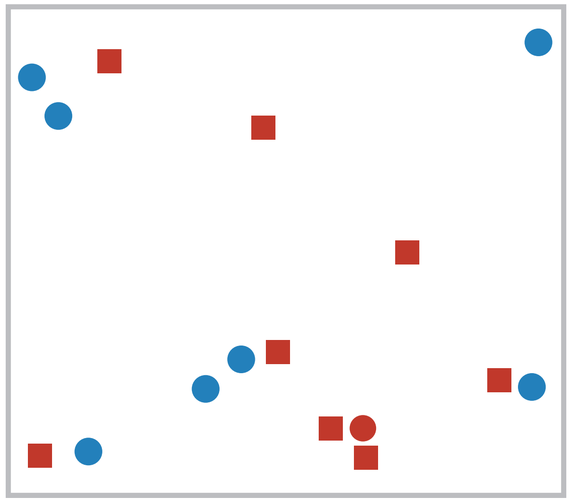
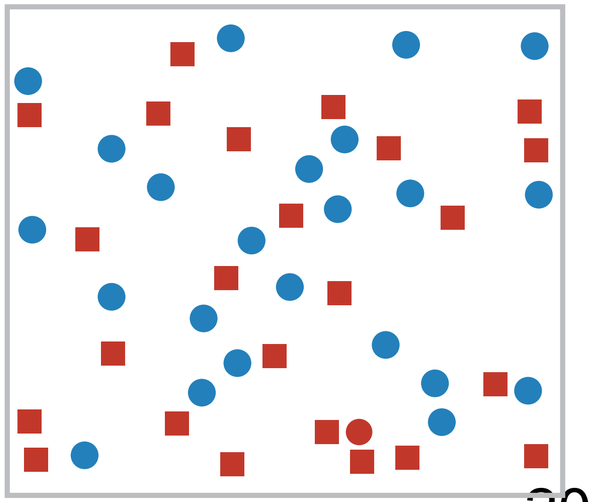
Red
+ Green



Major interference

Channel effectiveness

- Popout: can things jump out using this channel?

Popout

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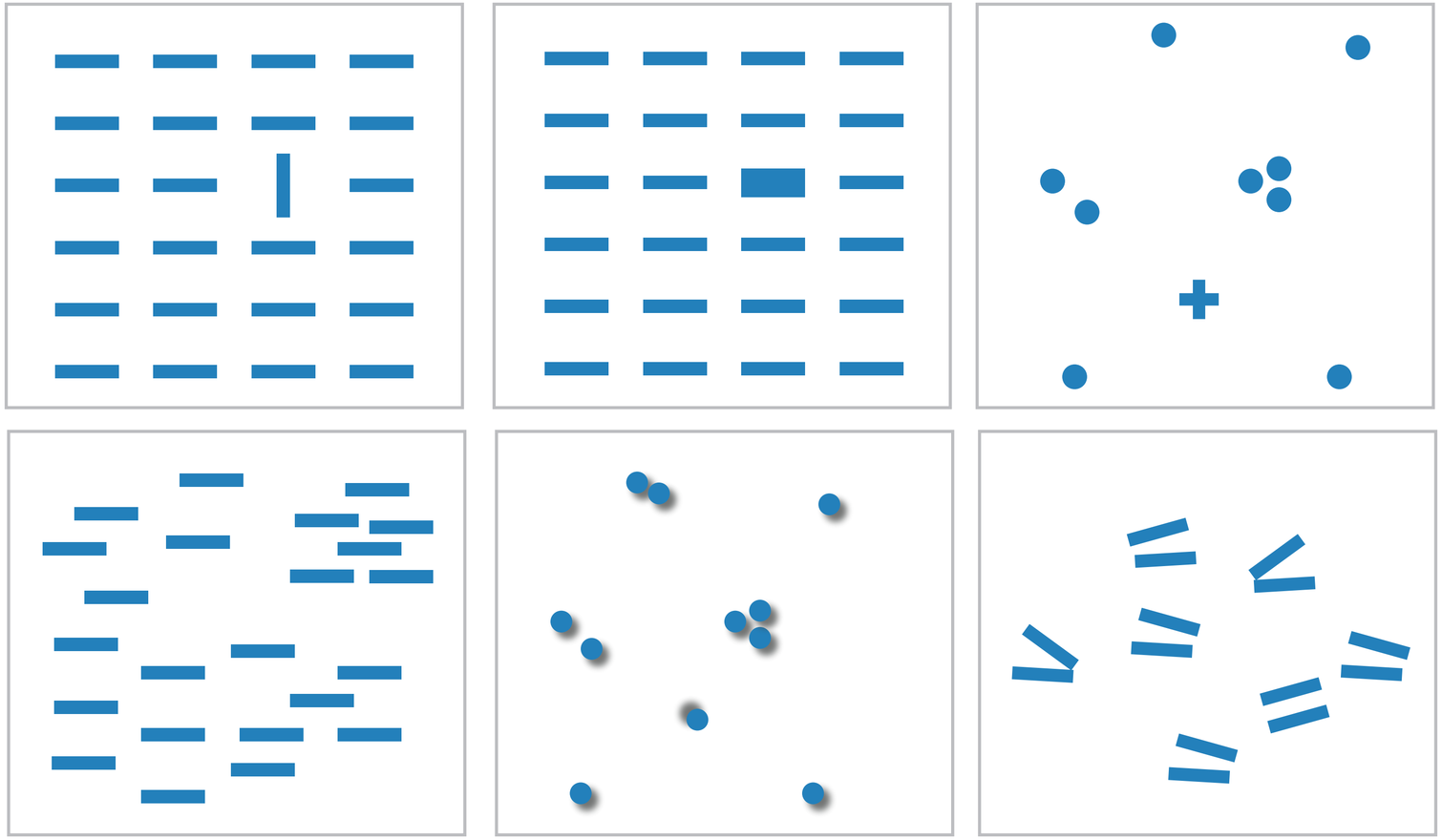
- Many channels
  - Tilt, size, shape, direction, …



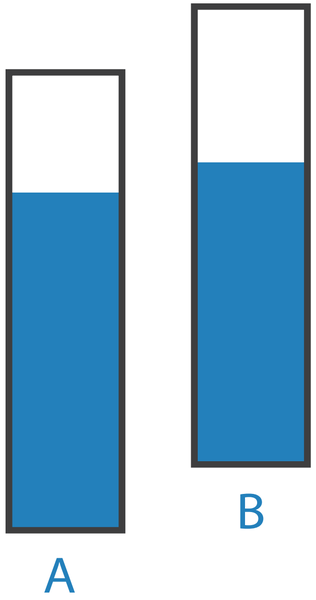
Factor affecting accuracy

- Alignment
- Distractors
- Distance
- Common scale

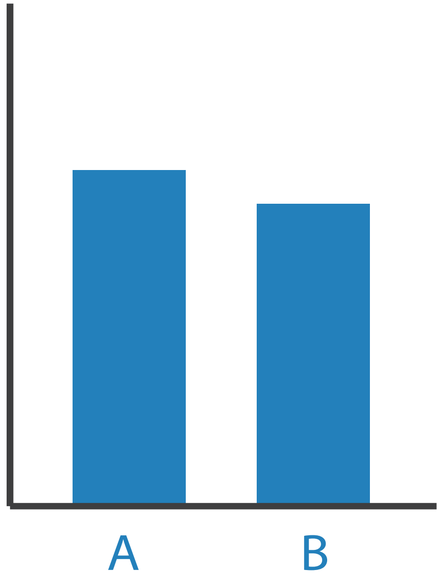
Relative vs. absolute judgements

- Perceptual system mostly operates with relative judgements, not absolute

length



position along unaligned common



position along aligned scale

Relative luminance judgements

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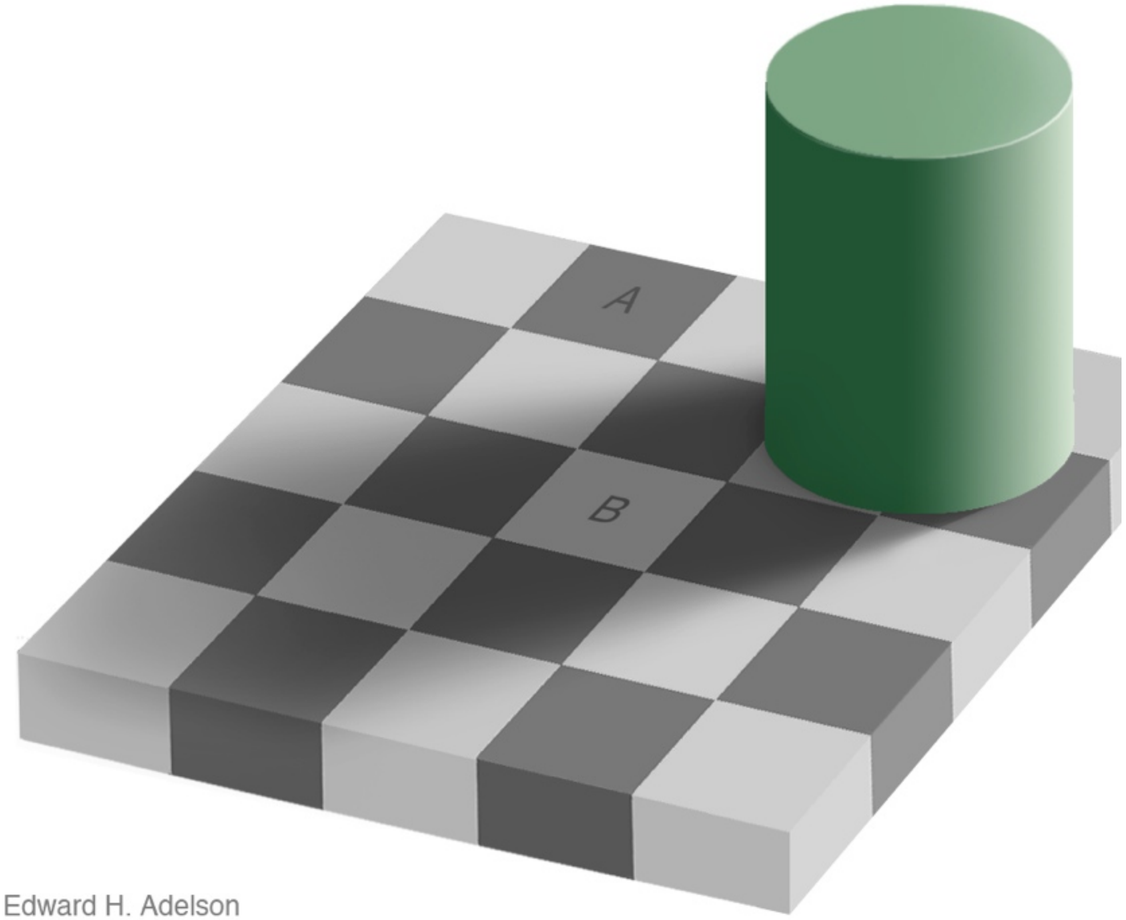
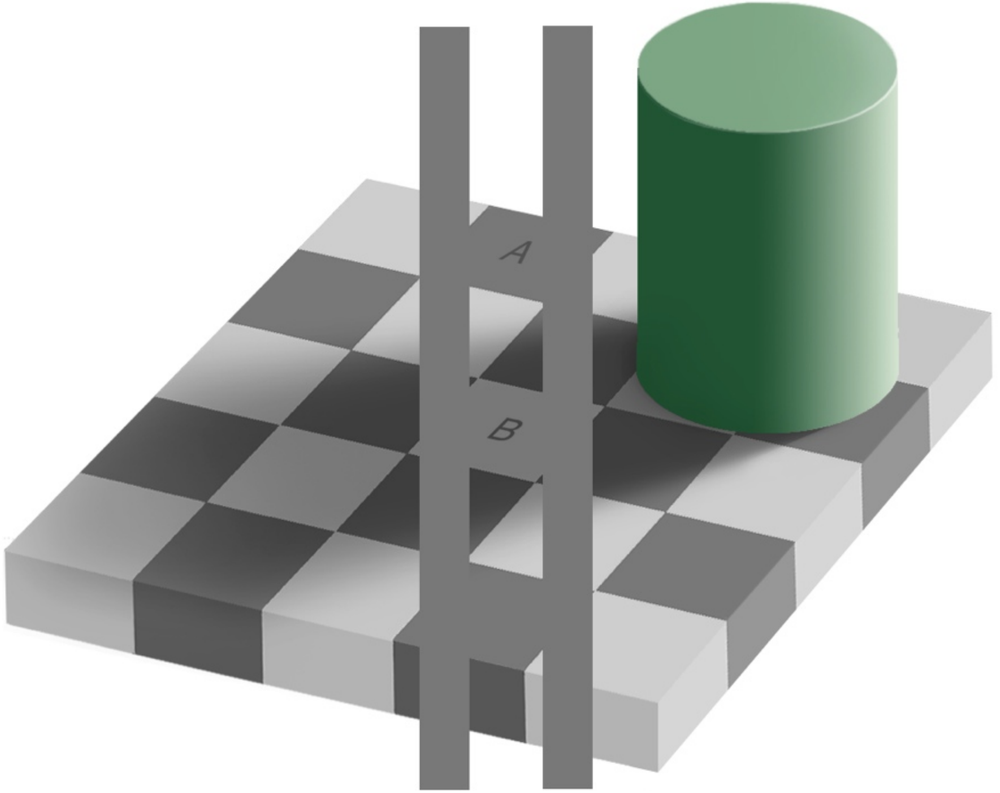
- Perception of luminance is contextual based on contrast with surroundings



Edward H. Adelson



Relative color judgements

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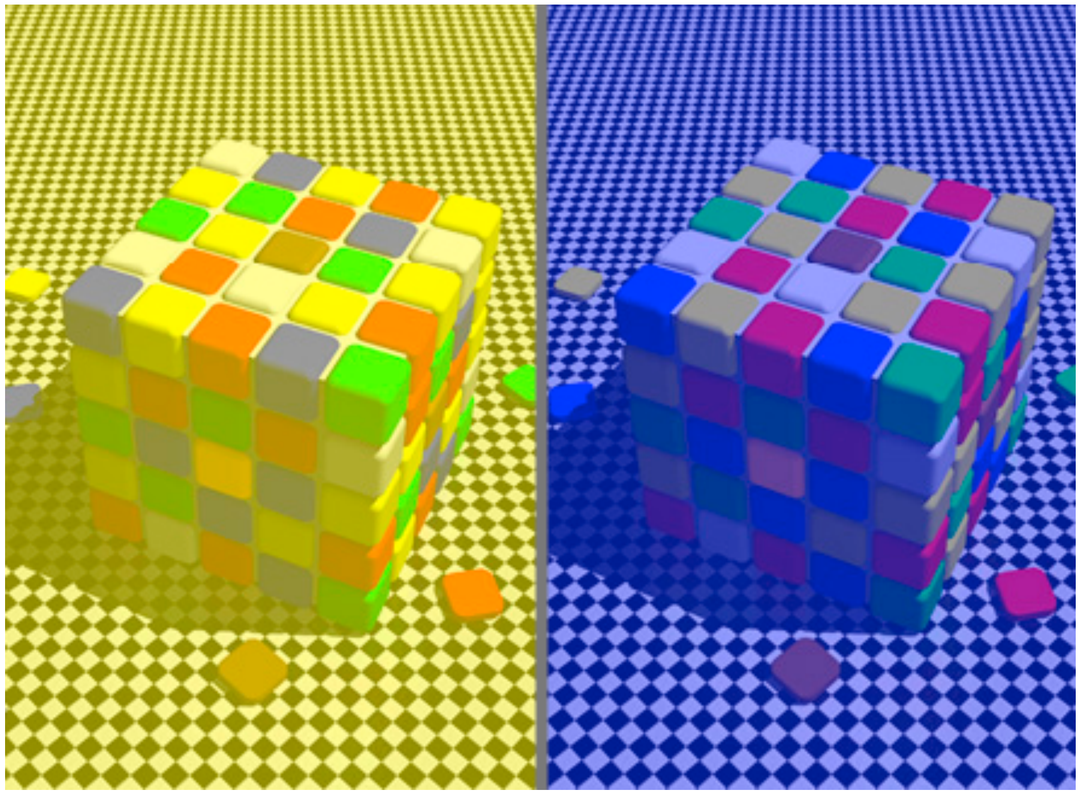
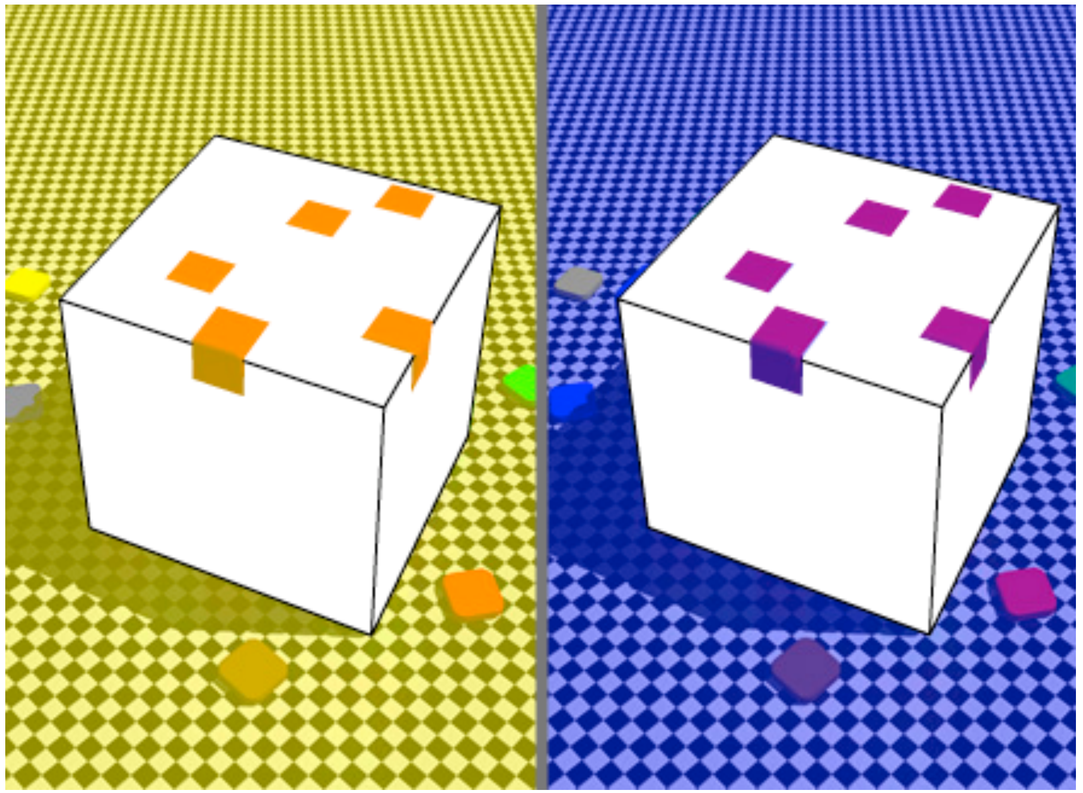
- Color constancy across broad range of illumination conditions





Outline

- Marks and channels
- Introduction to information visualization
- Tips for designing visual forms

What is information visualization

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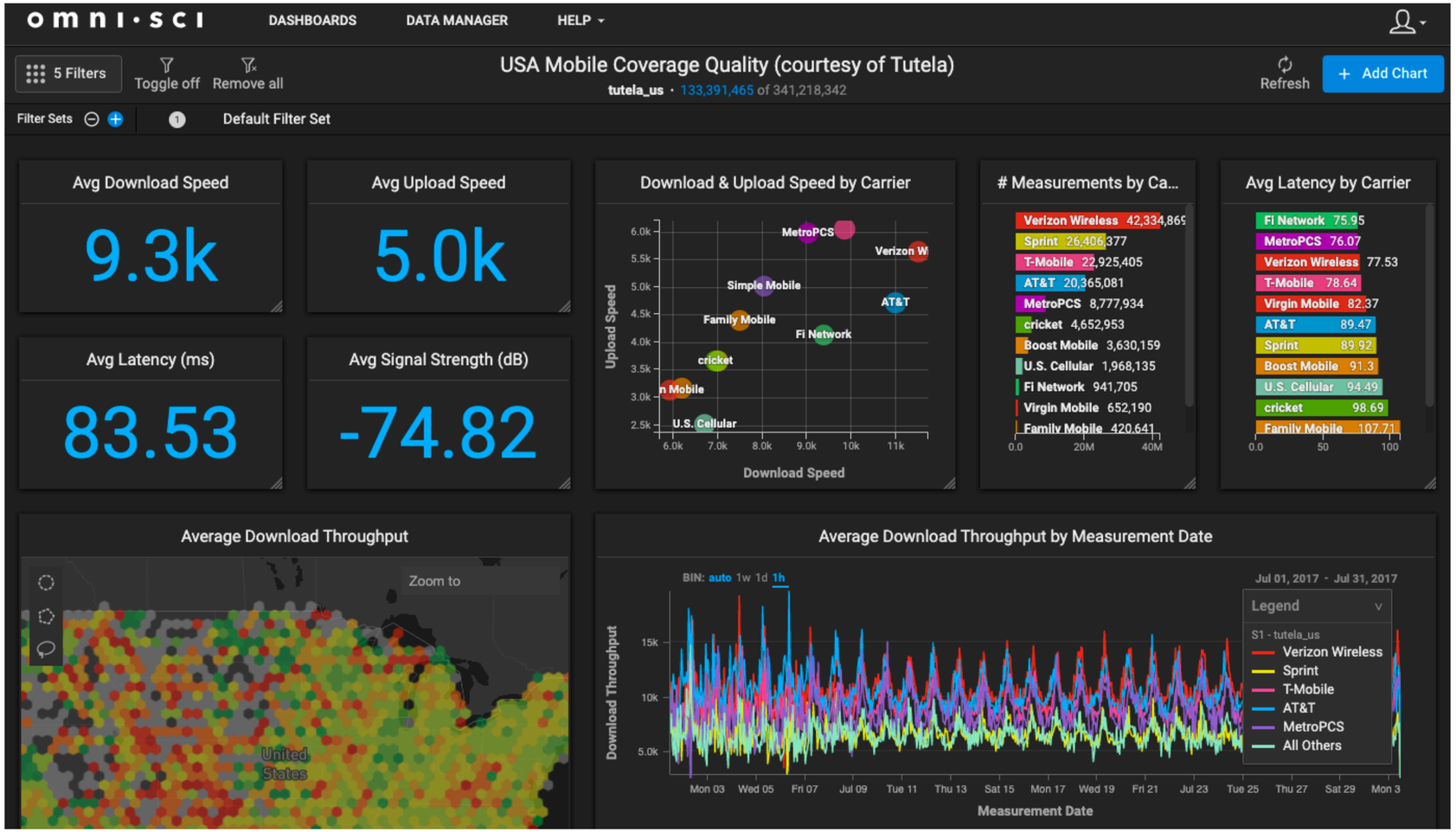
- The practice of representing data in a meaningful, visual way that users can interpret and easily comprehend



Definition

Computer-based visualization systems provide visual representations of **datasets** designed to help people carry out tasks more effectively.

Example

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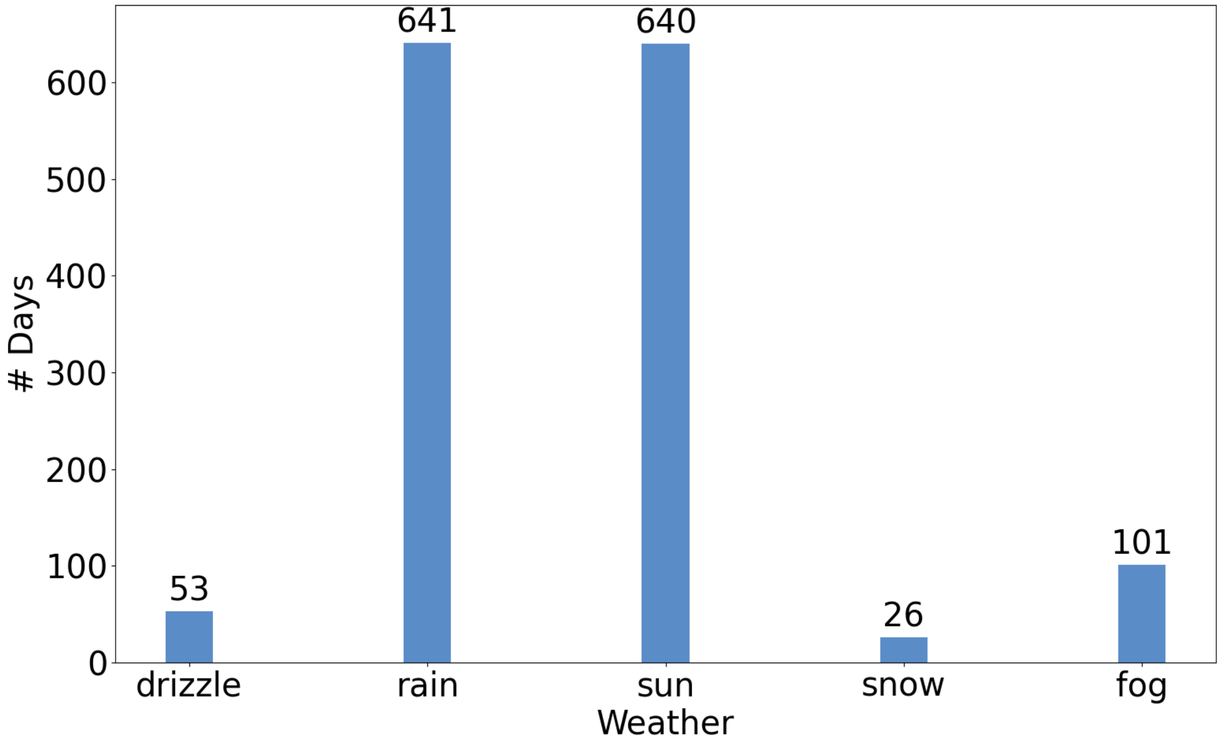
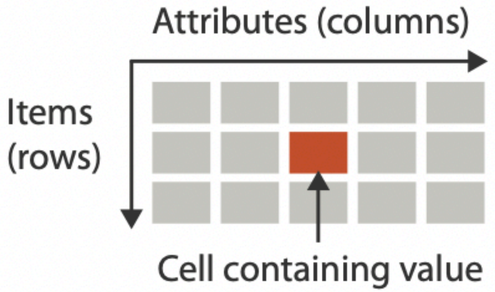
location	date	precipitation	temp_max	temp_min	wind	weather
Seattle	2012-01-01	0.0	12.8	5.0	4.7	drizzle
Seattle	2012-01-02	10.9	10.6	2.8	4.5	rain
Seattle	2012-01-03	0.8	11.7	7.2	2.3	rain
Seattle	2012-01-04	20.3	12.2	5.6	4.7	rain
Seattle	2012-01-05	1.3	8.9	2.8	6.1	rain
Seattle	2012-01-06	2.5	4.4	2.2	2.2	rain
Seattle	2012-01-07	0.0	7.2	2.8	2.3	rain
Seattle	2012-01-08	0.0	10.0	2.8	2.0	sun
Seattle	2012-01-09	4.3	9.4	5.0	3.4	rain
Seattle	2012-01-10	1.0	6.1	0.6	3.4	rain
Seattle	2012-01-11	0.0	6.1	-1.1	5.1	sun
Seattle	2012-01-12	0.0	6.1	-1.7	1.9	sun
Seattle	2012-01-13	0.0	5.0	-2.8	1.3	sun
Seattle	2012-01-14	4.1	4.4	0.6	5.3	snow
Seattle	2012-01-15	5.3	1.1	-3.3	3.2	snow
Seattle	2012-01-16	2.5	1.7	-2.8	5.0	snow
Seattle	2012-01-17	8.1	3.3	0.0	5.6	snow
Seattle	2012-01-18	19.8	0.0	-2.8	5.0	snow

find interesting patterns

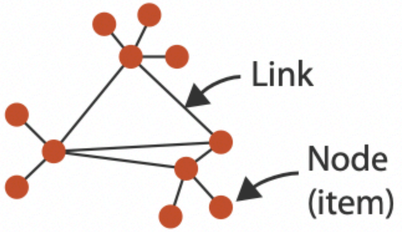


Data types

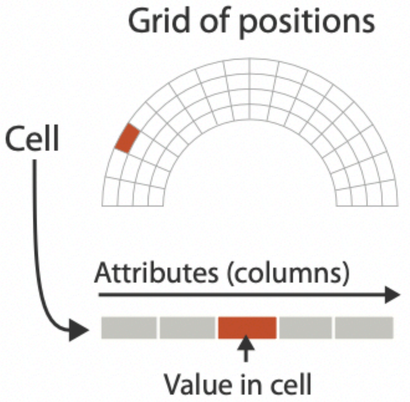
➔ Tables



➔ Networks

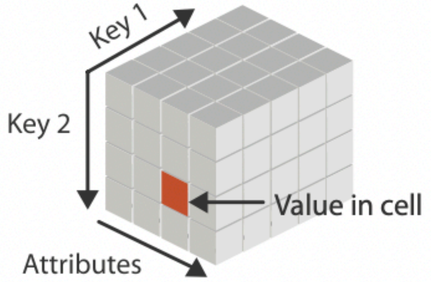


➔ Fields (Continuous)



➔ Geometry (Spatial)

➔ *Multidimensional Table*



➔ *Trees*

+ Sets
+ Text

Data items and attributes

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A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box		7/17/07
32	7/16/07	2-High	Medium Box		7/18/07
32	7/16/07	2-High	Medium Box		7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/6/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/6/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

attribute

item

Attribute types

→ Categorical

→ Ordered

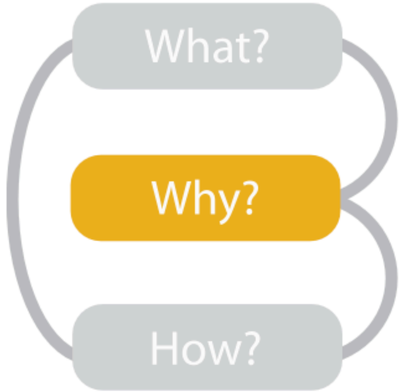
→ *Ordinal*

→ *Quantitative*

Definition

Computer-based visualization systems provide visual representations of datasets designed to help people carry out **tasks** more effectively.

Tasks



Why?

Actions

Analyze

- Consume
  - Discover
  - Present
  - Enjoy
- Produce
  - Annotate
  - Record
  - Derive

Search

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

Query

- Identify
- Compare
- Summarize

Targets

All Data

- Trends
- Outliers
- Features

Attributes

- One
  - Distribution
  - Extremes
- Many
  - Dependency
  - Correlation
  - Similarity

Network Data

- Topology
- Paths

Spatial Data

- Shape

Visualization for consumption

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- Discover new knowledge
  - Generate new hypothesis or verify existing one
  - Designer doesn’t know what users need to see
  - "why doesn't dictate how"
- Present known information
  - Presenter already knows what the data says
  - Wants to communicate this to an audience
  - May be static but not limited to that
- Enjoy
  - Similar to discover, but without concrete goals
  - May be enjoyed differently than the original purpose

Definition

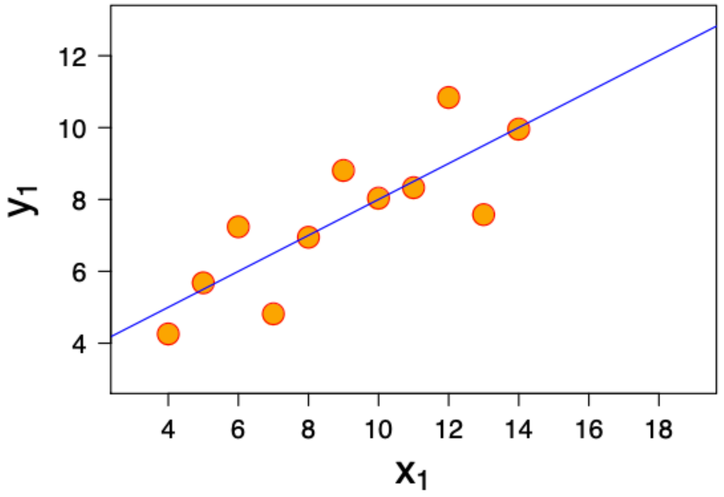
Computer-based visualization systems provide **visual** representations of datasets designed to help people carry out tasks more effectively.

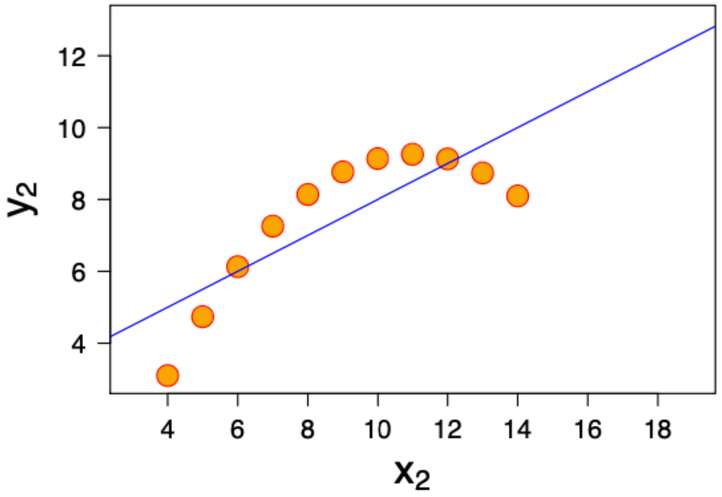
Why visual

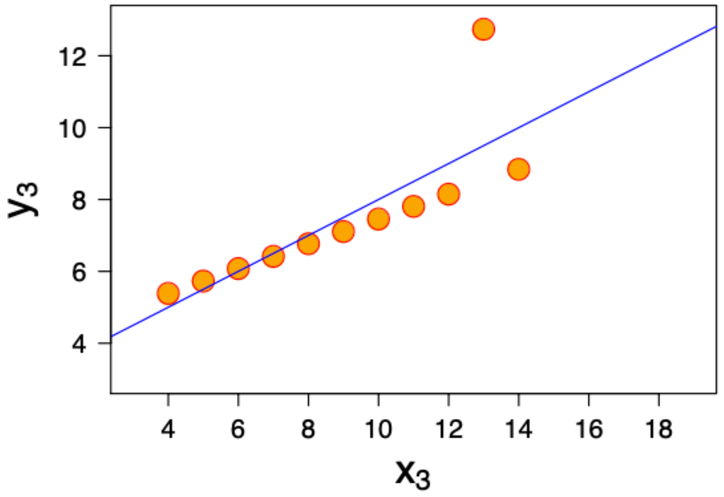
I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0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

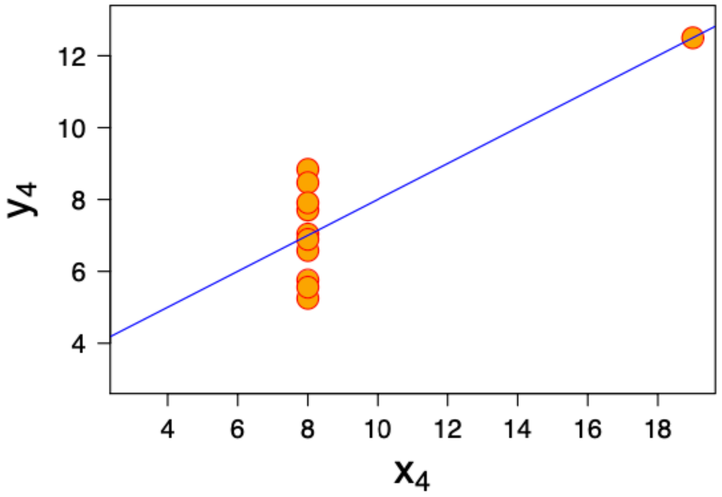
Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

Why visual









Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

Definition

Computer-based visualization systems provide visual representations of datasets **designed** to help people carry out tasks more effectively.

Design example

Design a visual system for understanding the decision process of convolutional neural network

Design example

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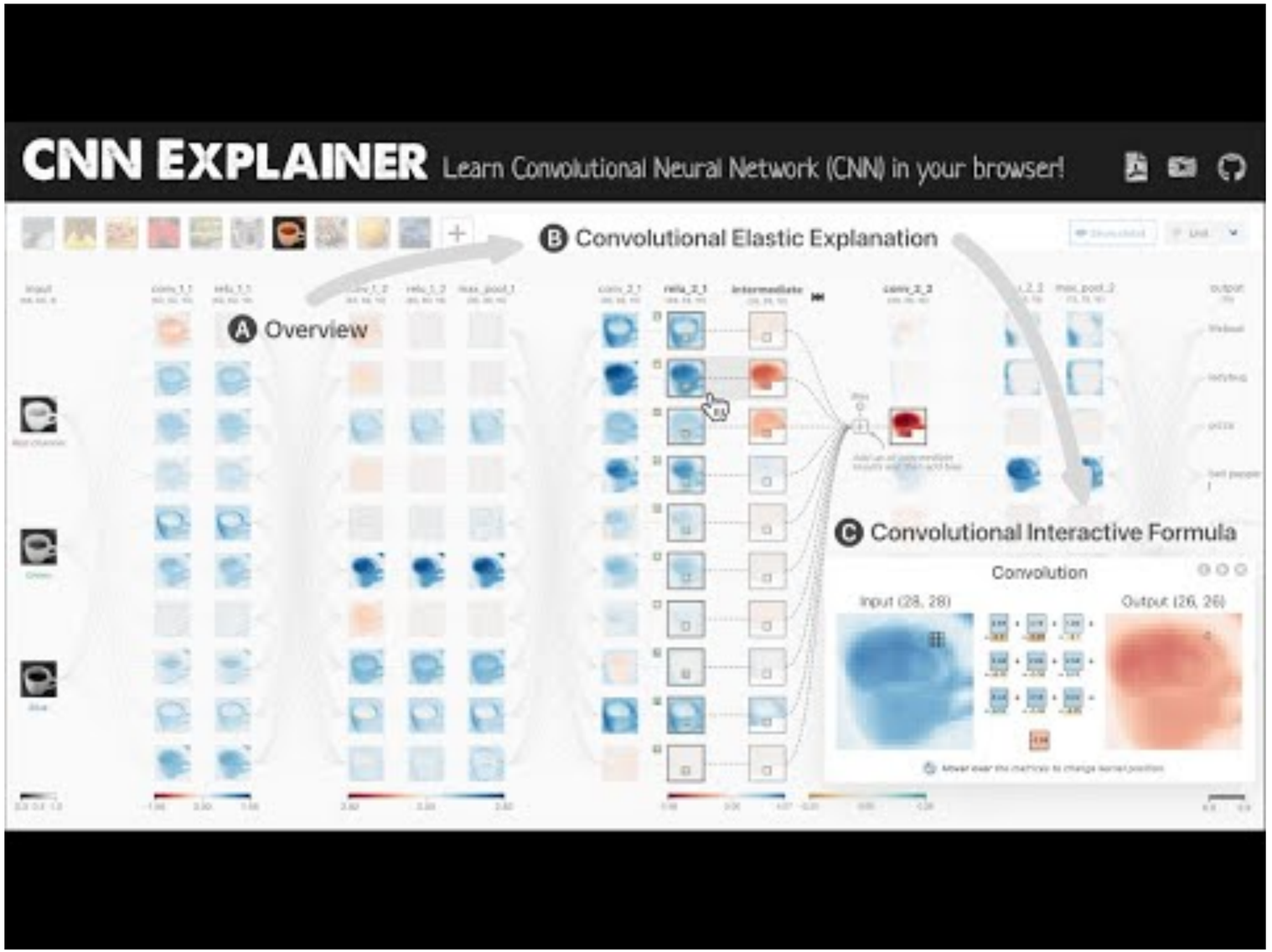

Design example

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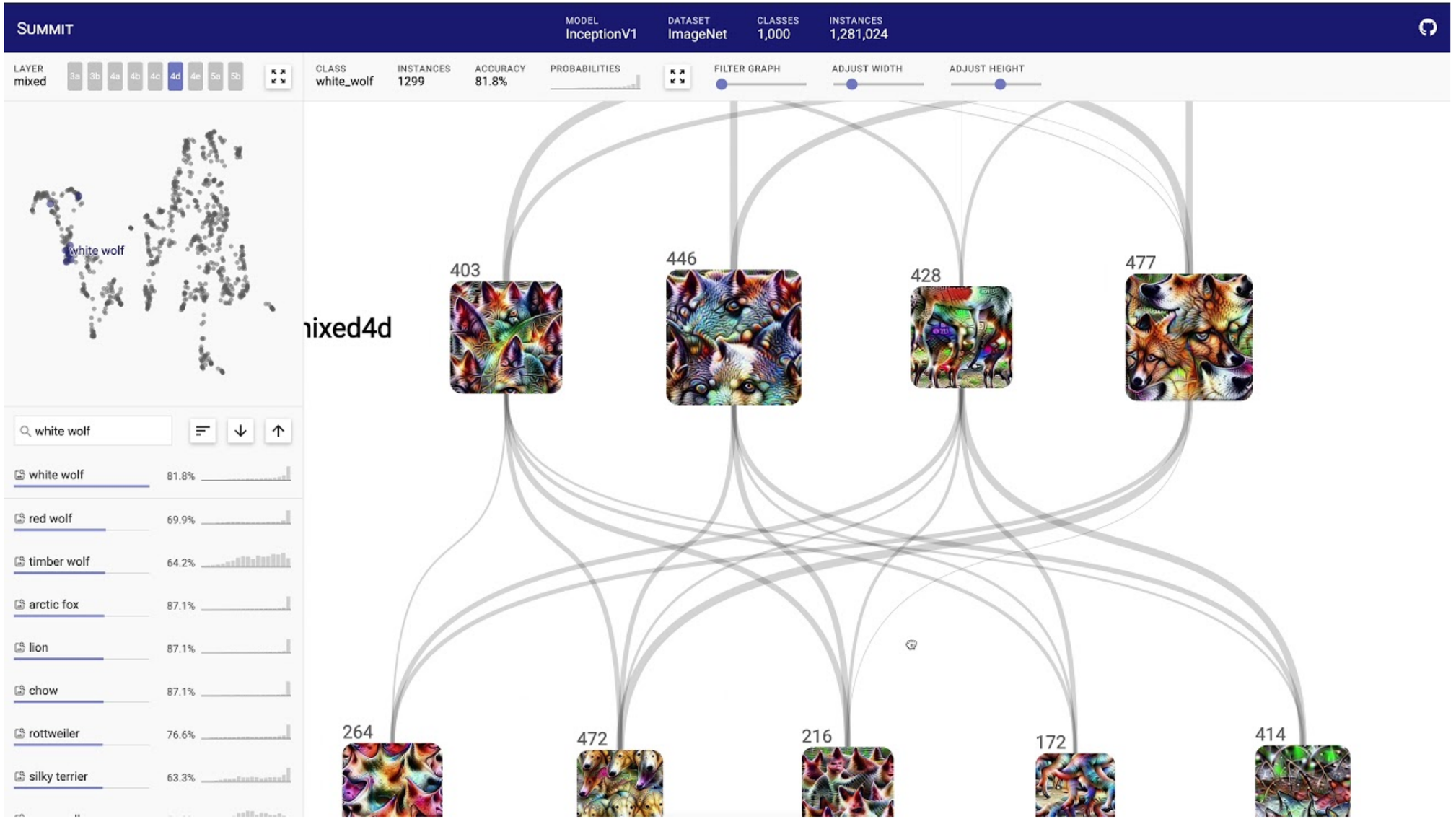
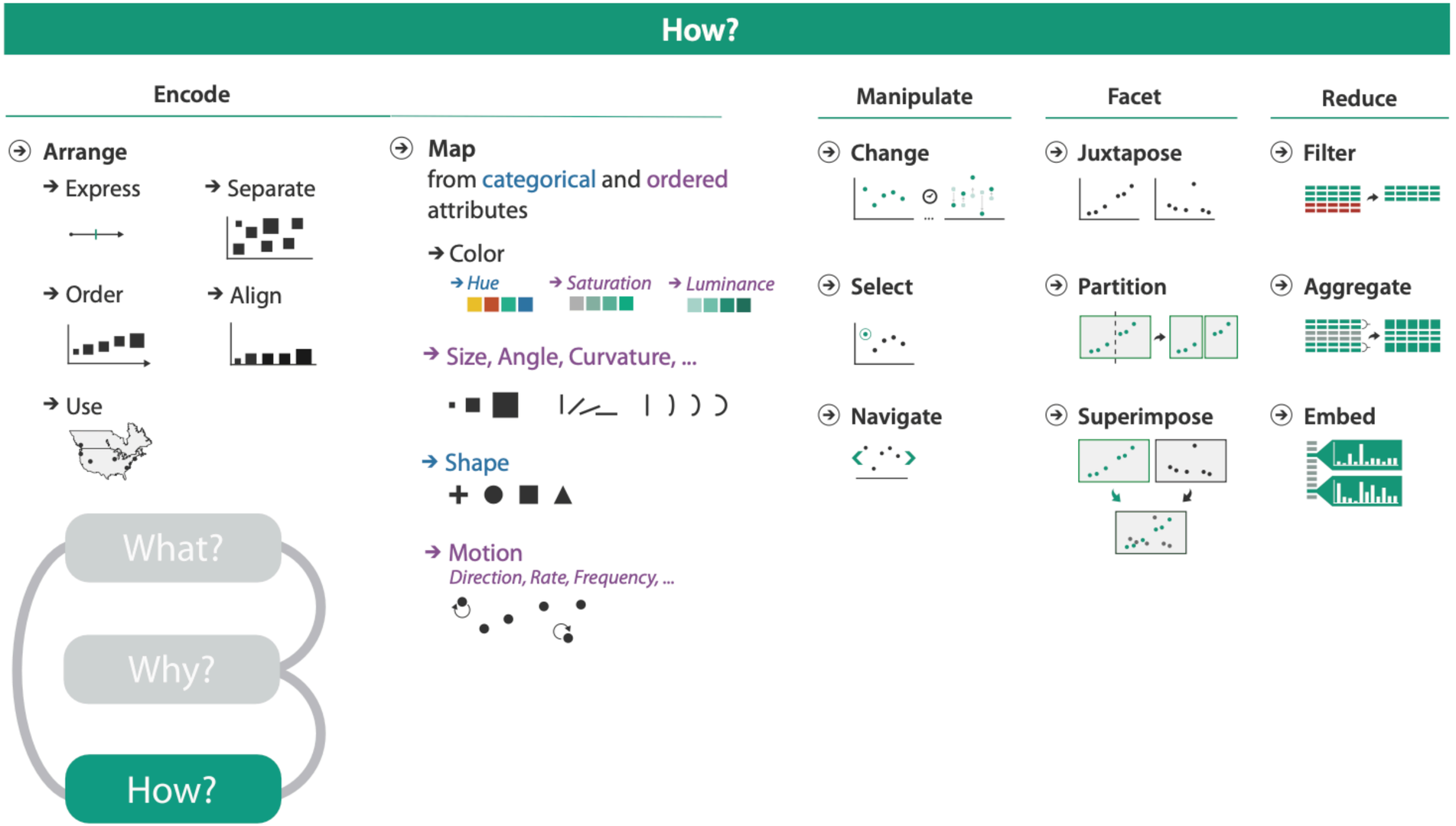


Definition

Computer-based visualization systems provide visual representations of datasets designed to **help** people carry out tasks more effectively.

How do we do visualization



Visual encoding

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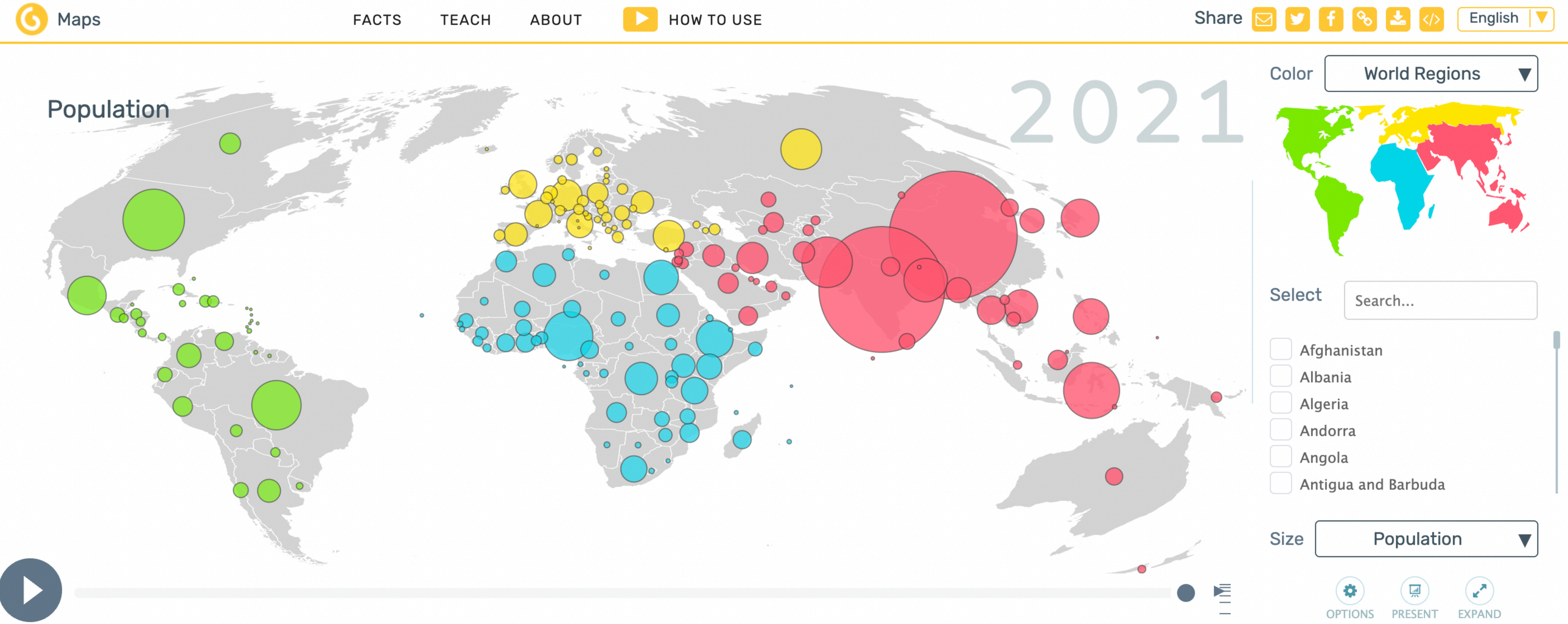

Tools

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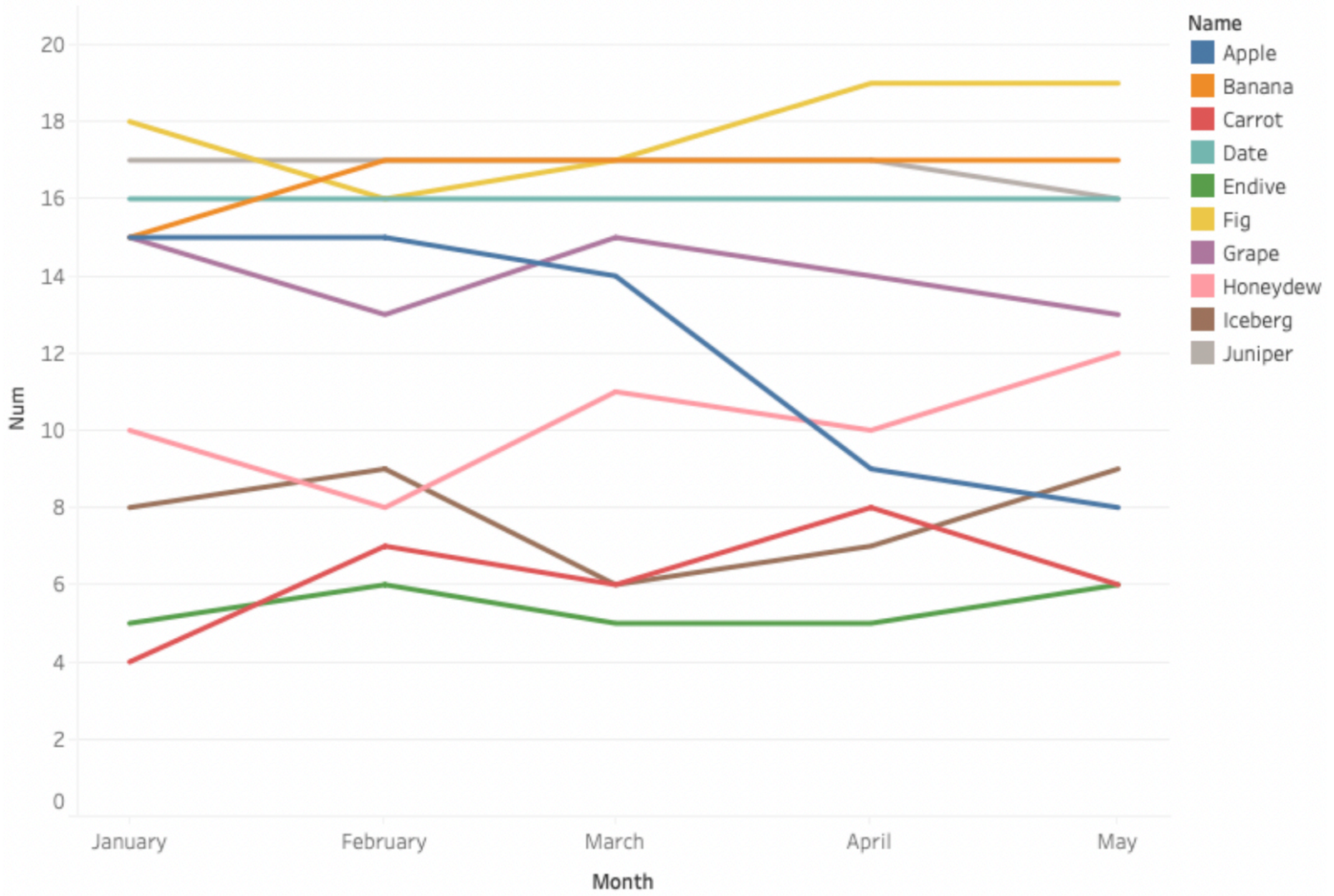
- Tableau



Tools

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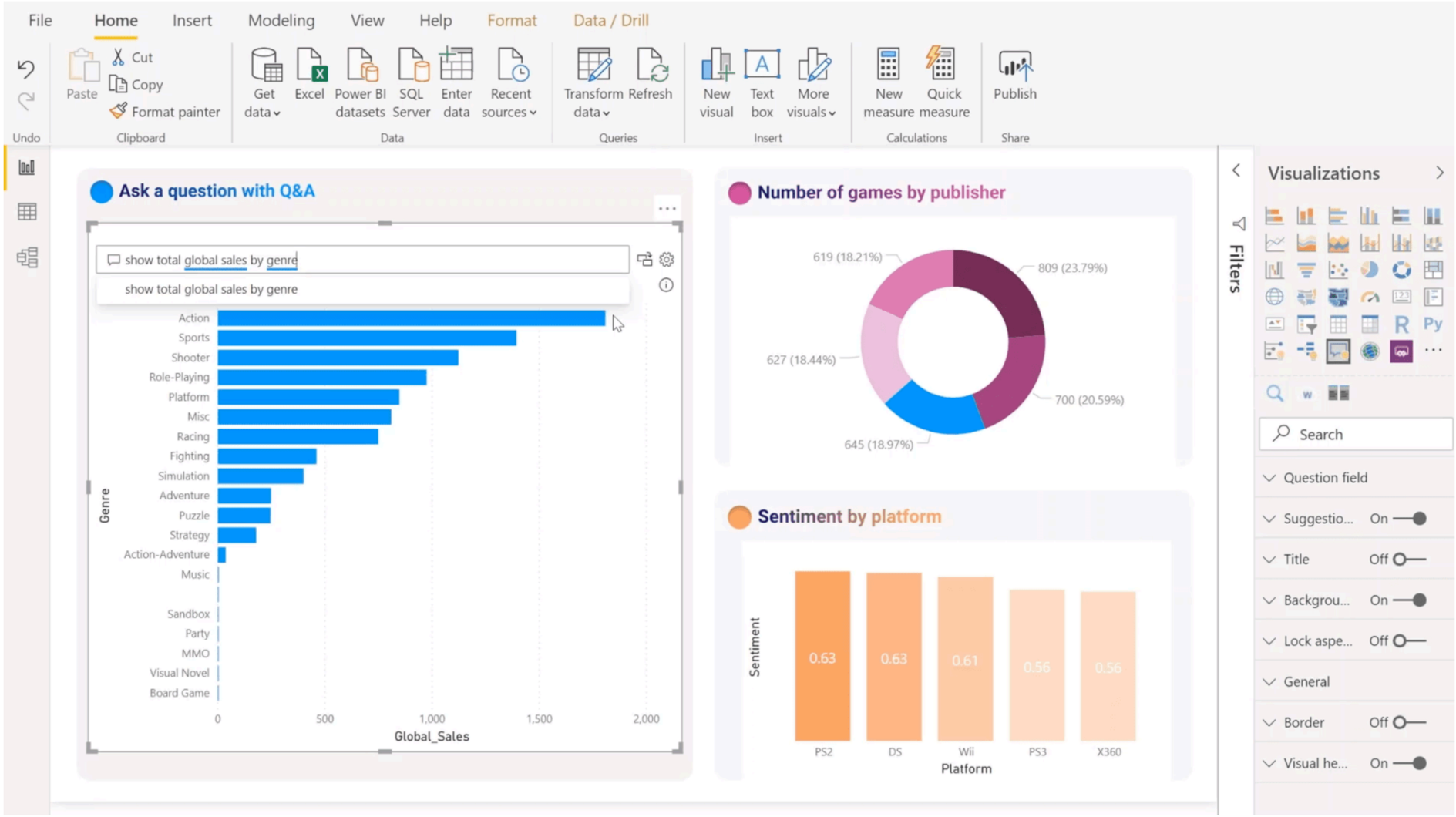
- PowerBI



D3

- http://d3js.org/
- Supports data as a core piece of Web elements
  - Correspondence between data and DOM elements
  - Dealing with changing data (joins, enter/update/exit)
  - Data drives the marks and channels
- Selections (similar to CSS) that allow greater manipulation
- Integrated layout algorithms, axes calculations, etc.
- Focus on interaction support
  - Straightforward support for transitions
  - Event handling support for user-initiated changes

Arrange tables

Express Values

Separate, Order, Align Regions

- Separate

- Order

- Align

- *1 Key*
  List

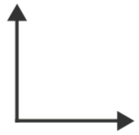
- *2 Keys*
  Matrix

- *3 Keys*
  Volume

- *Many Keys*
  Recursive Subdivision

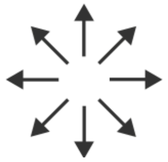
Axis Orientation

- Rectilinear



- Parallel

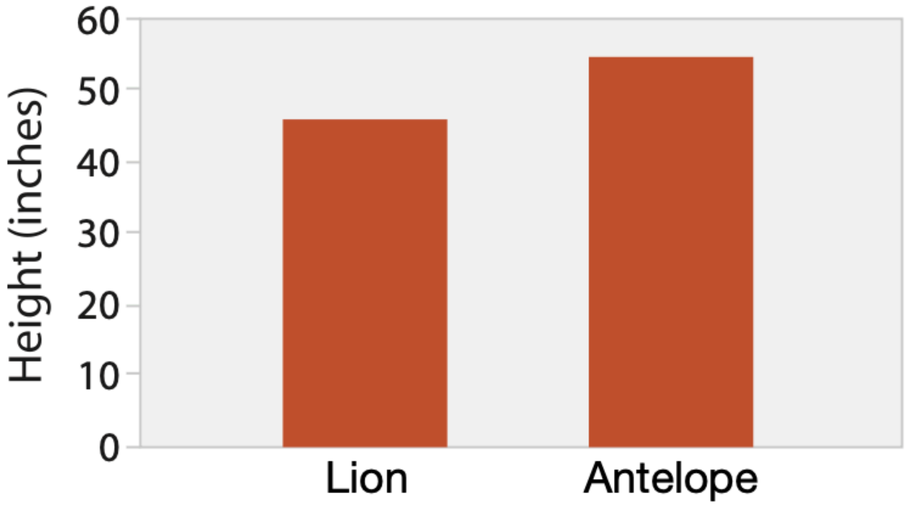
- Radial

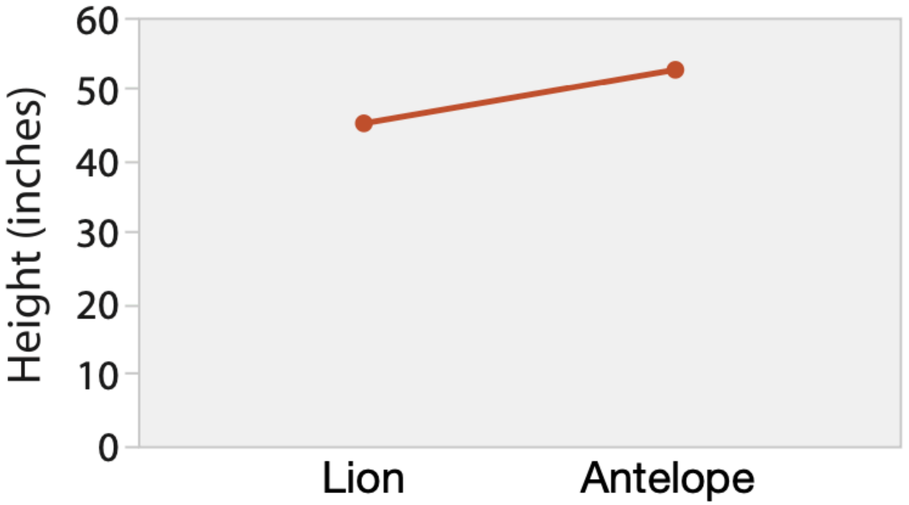


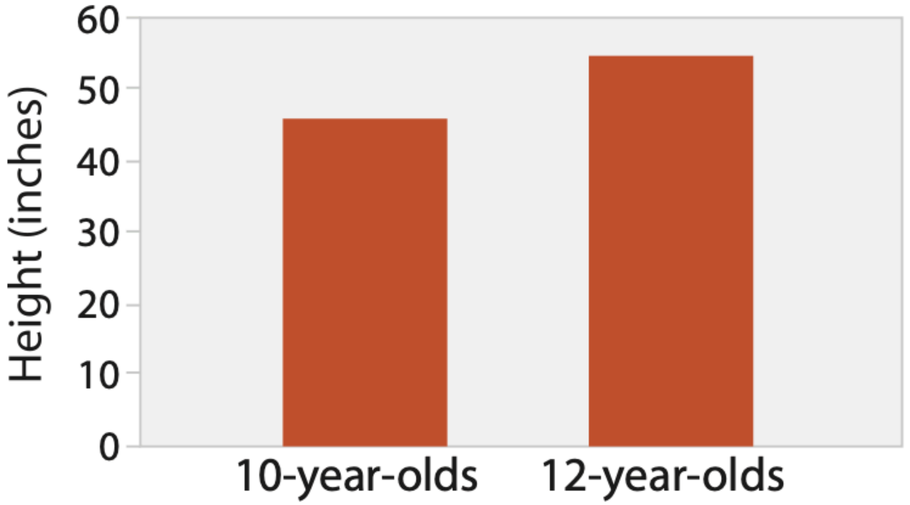
Basic visualization charts

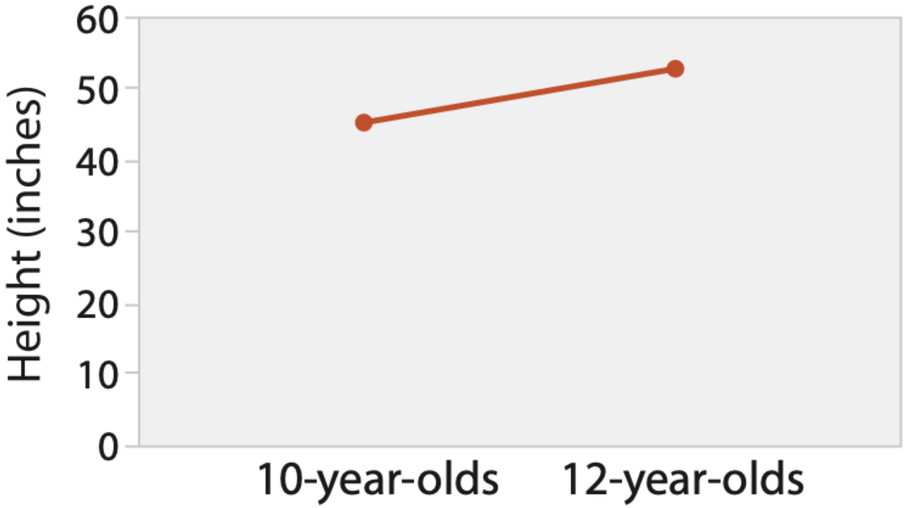
- Line chart
- Bar chart
- Scatter plot matrices
- Parallel coordinates
- Pie chart
- Categorical map
- Tree visualization
- Set visualization
- Graph visualization

Line and bar charts

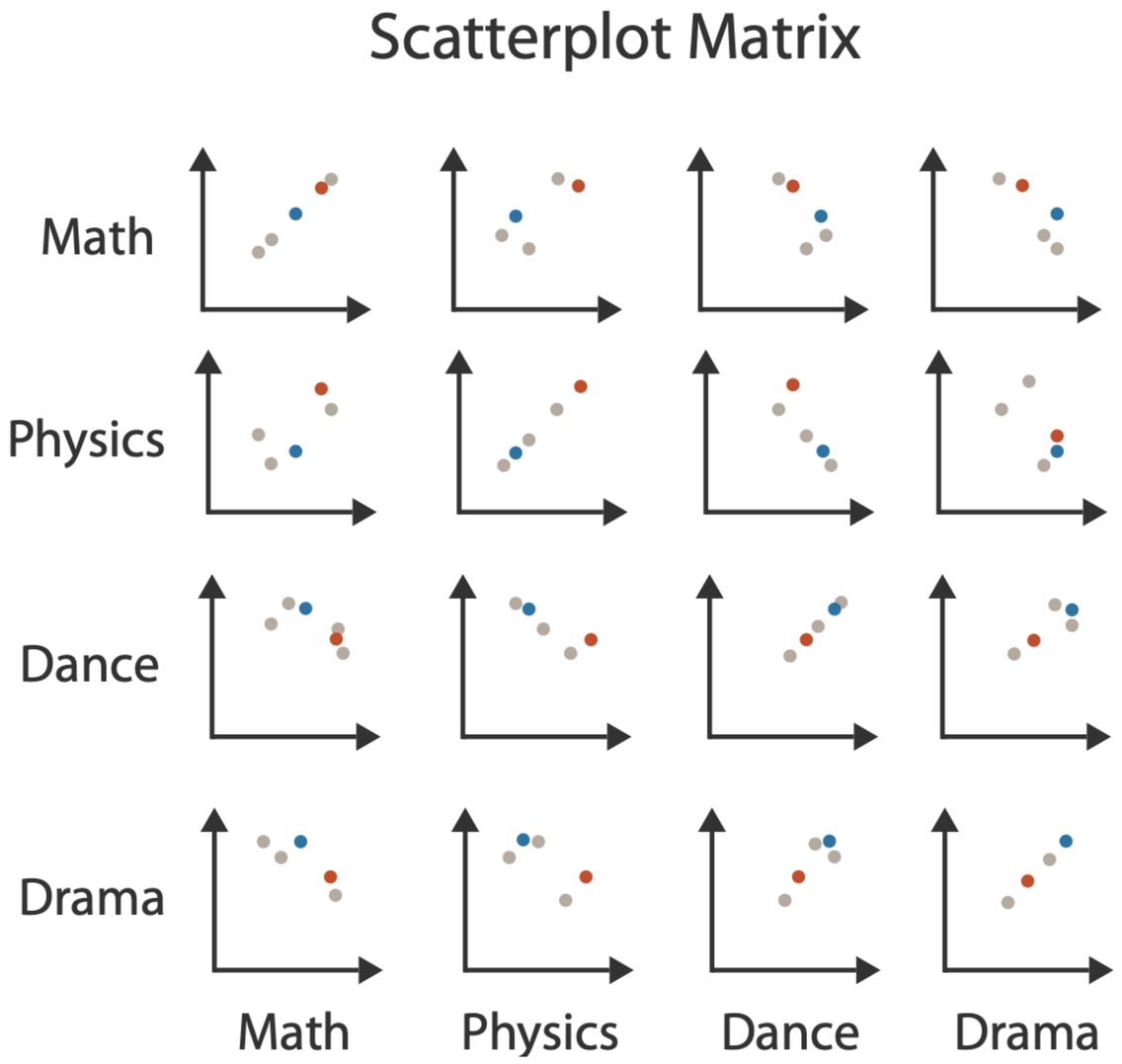


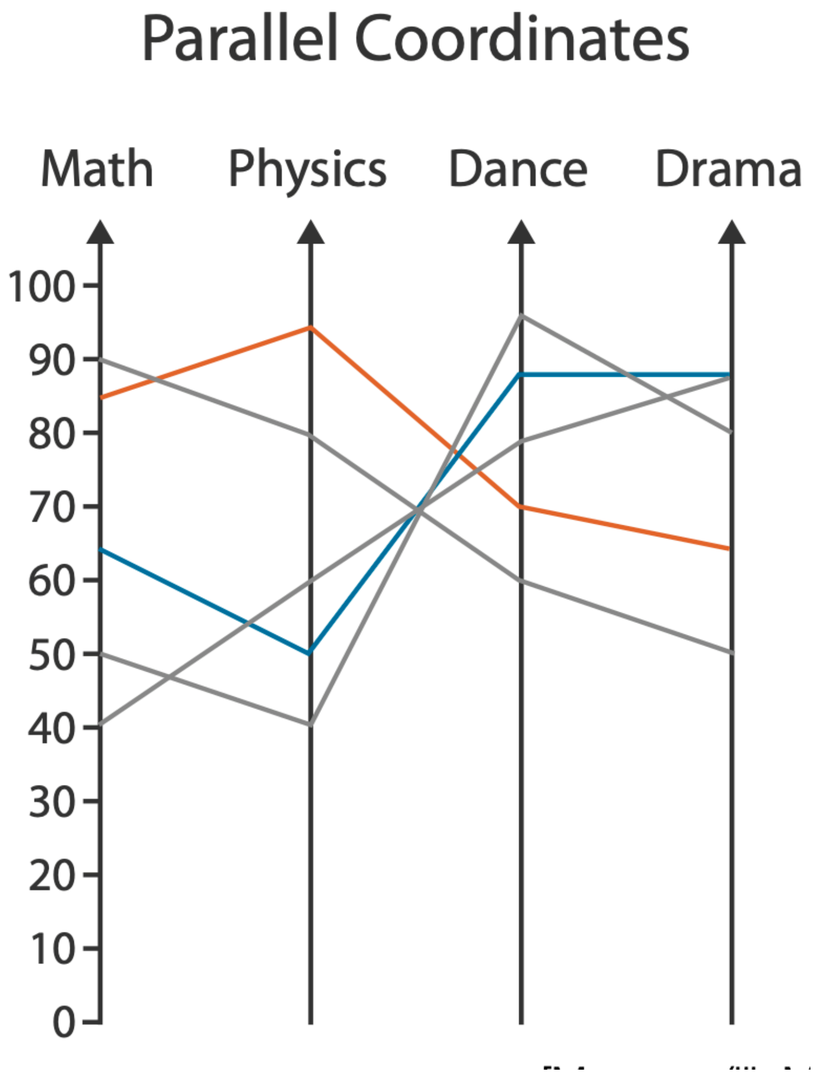




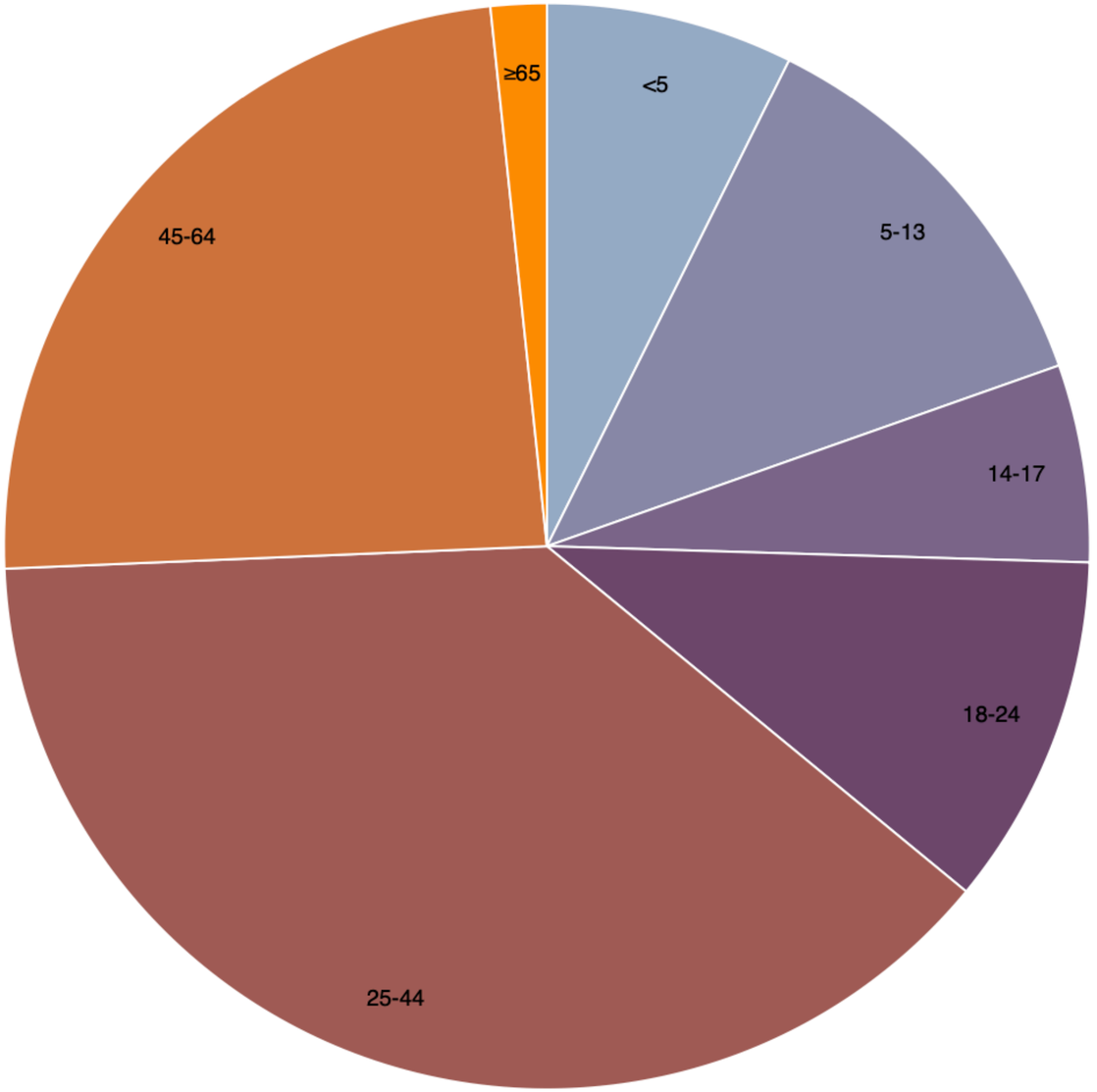


Scatter plot matrices and parallel coordinates





Pie chart



Categorial map

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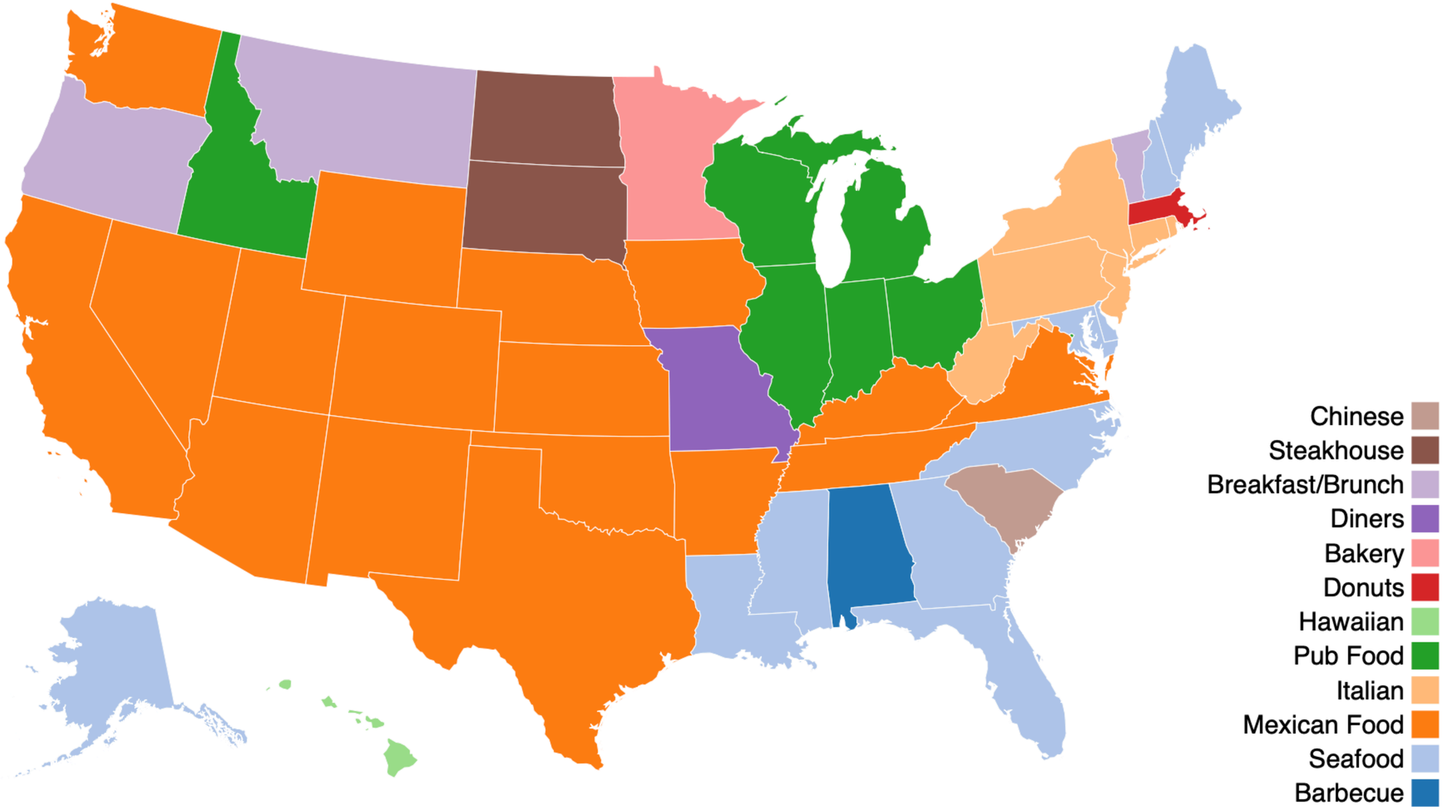
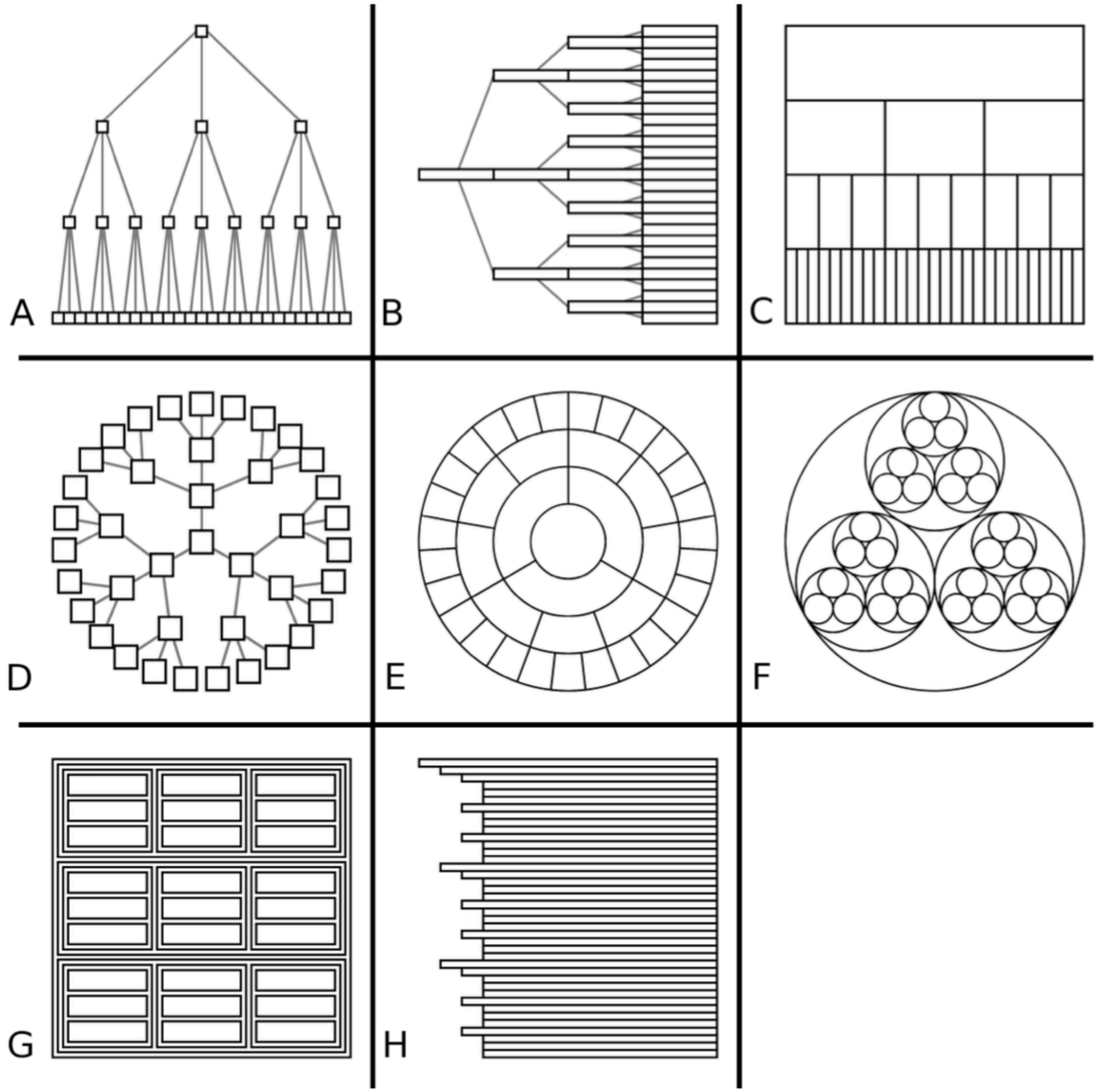
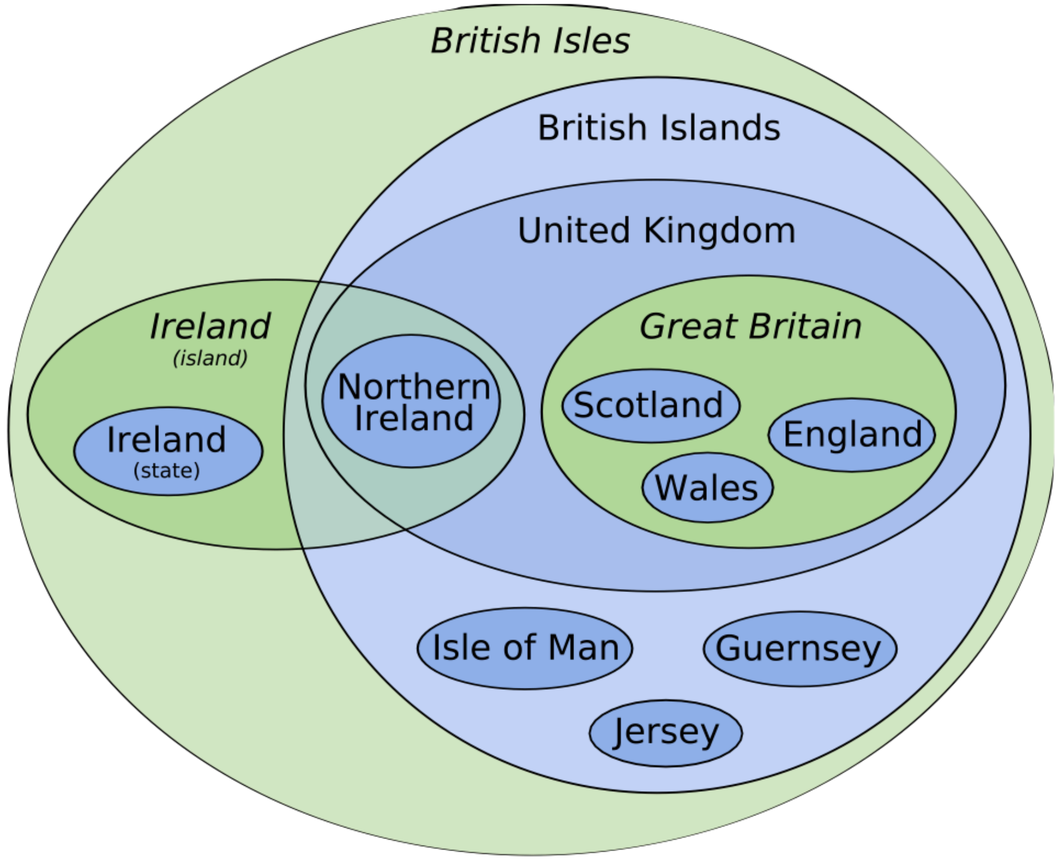
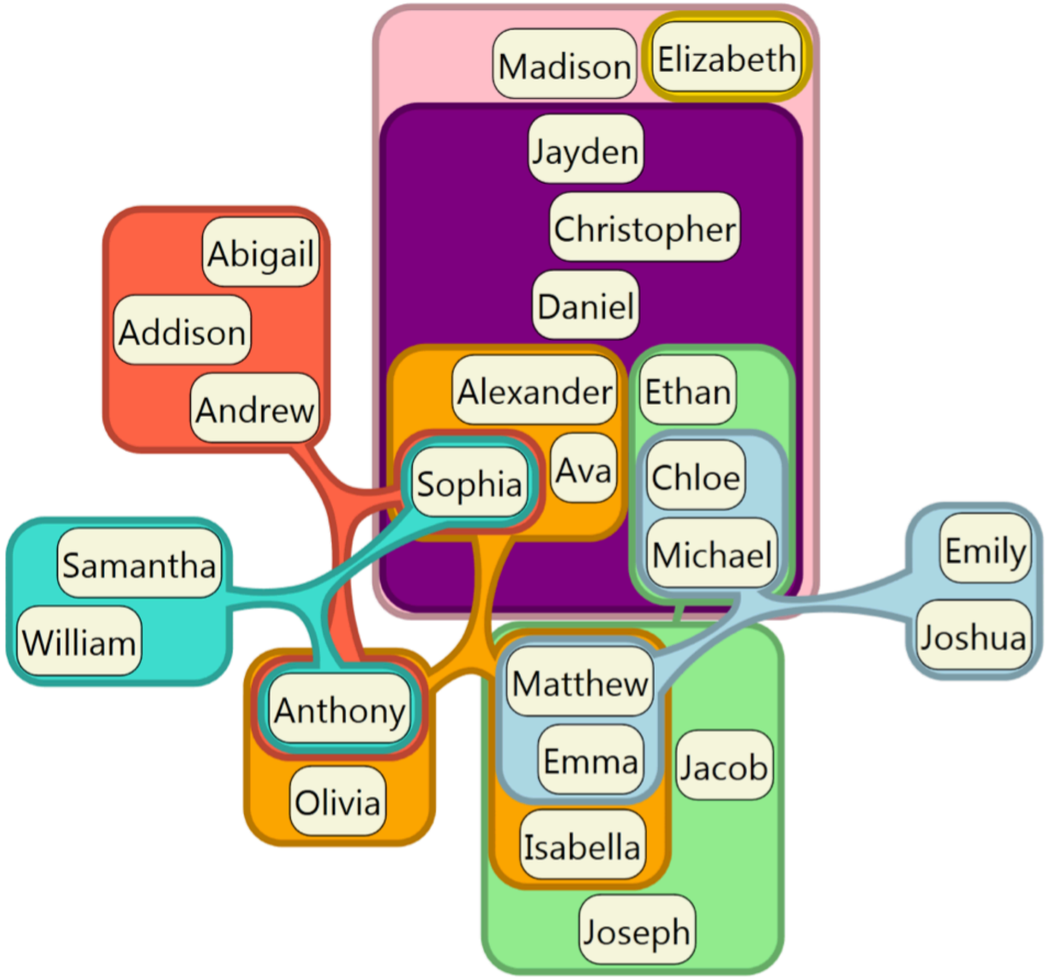


Tree visualization

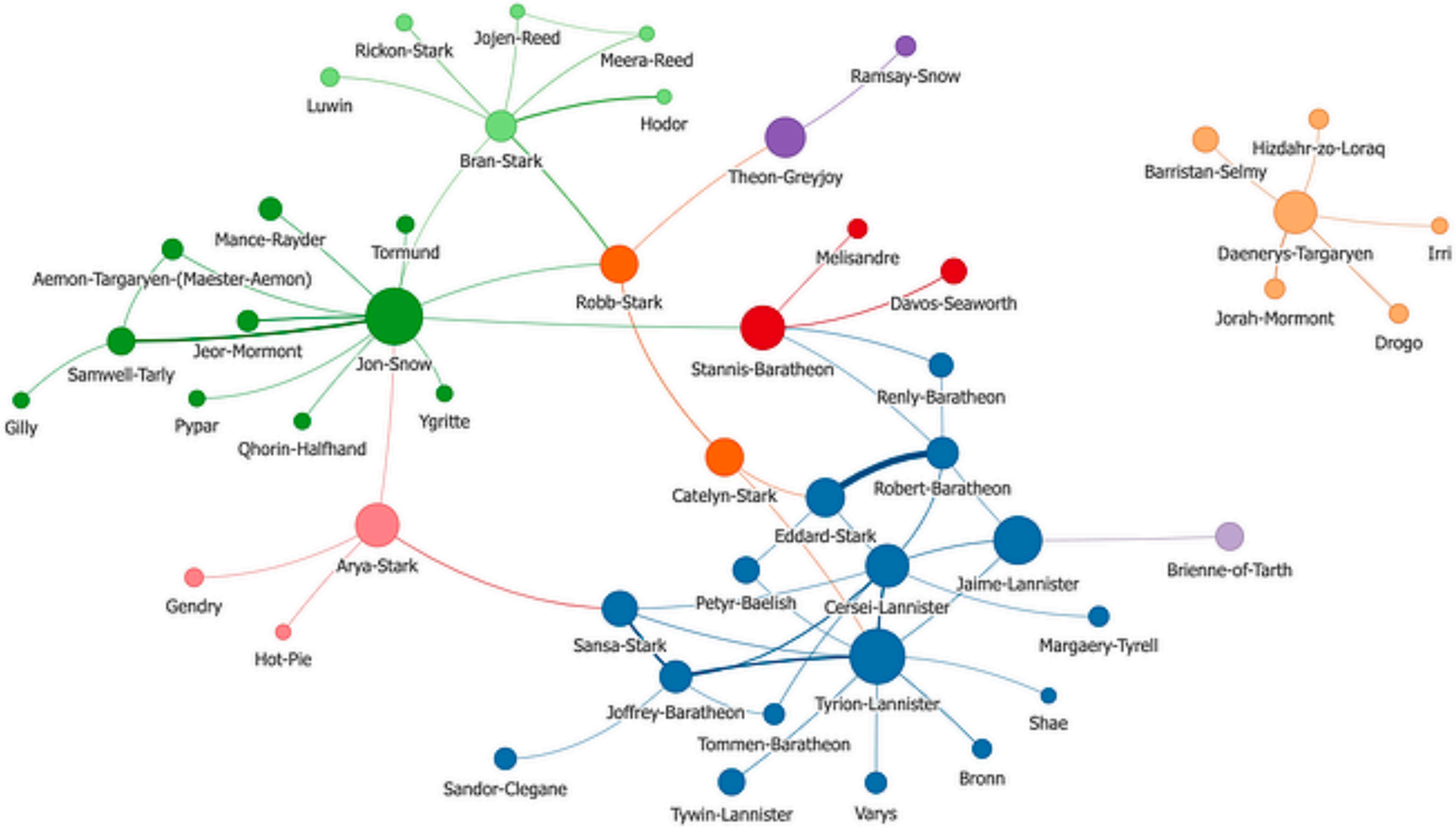


Set visualization



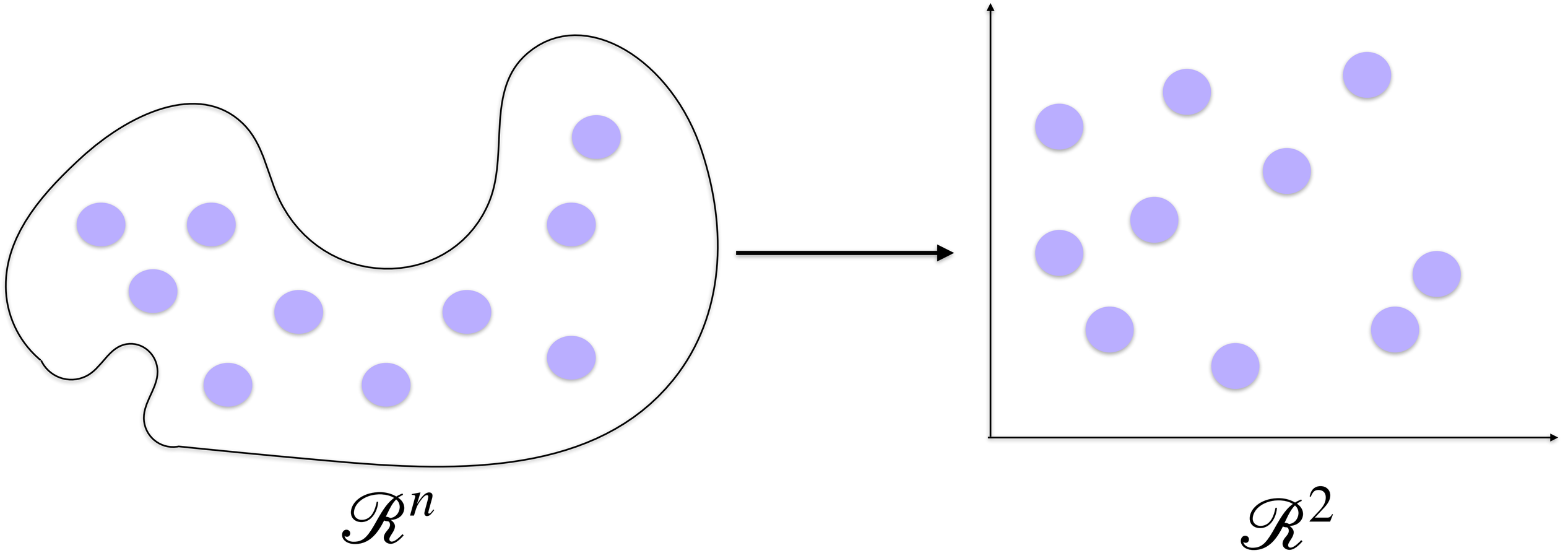


Graph visualization

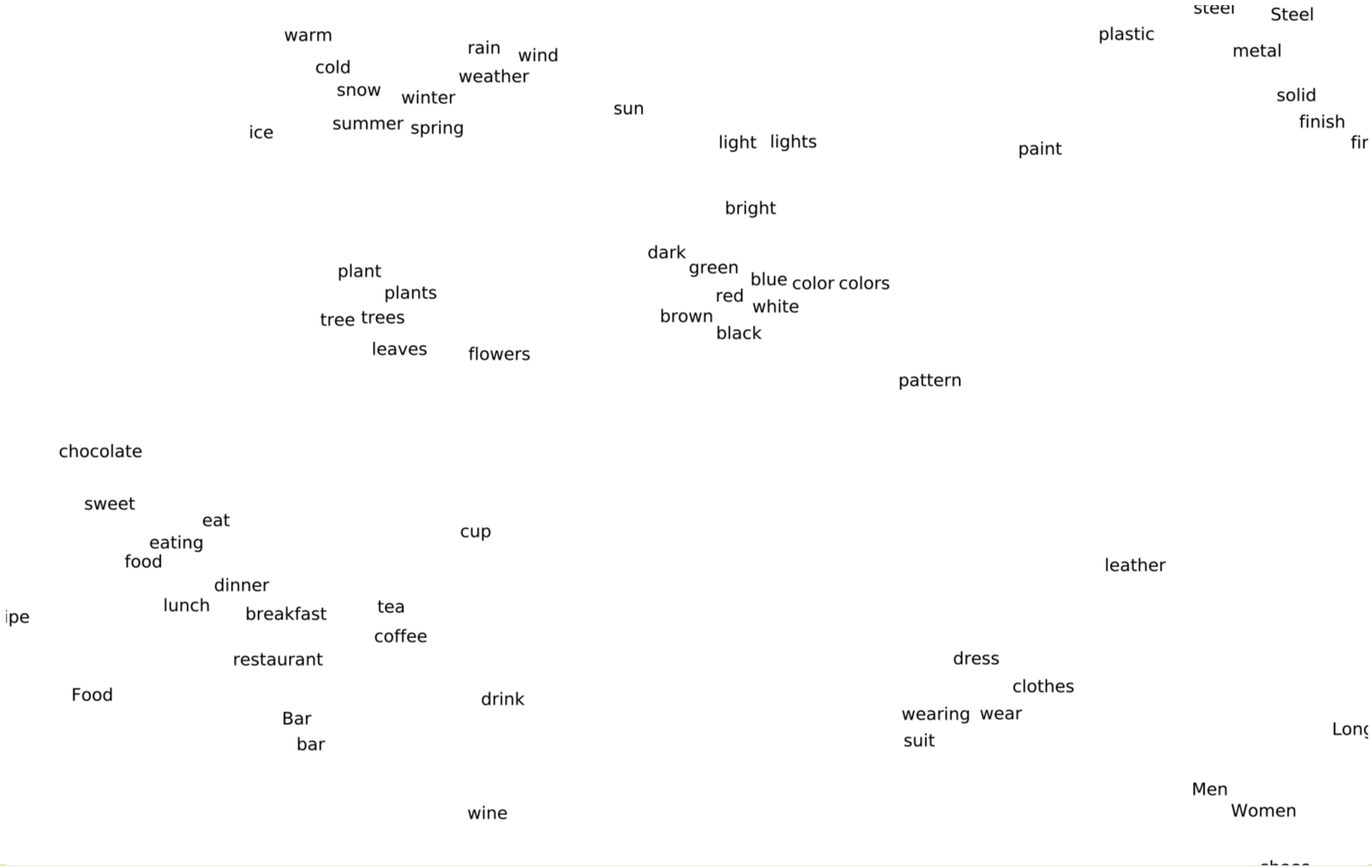


Other topics

- High-dimensional data visualization



Word embedding visualization



Other topics

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- Text visualization

Other topics

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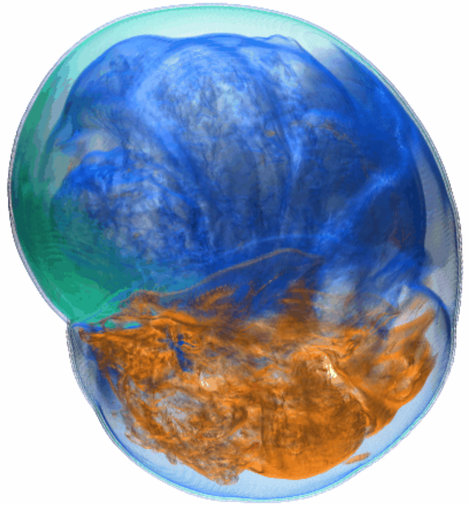
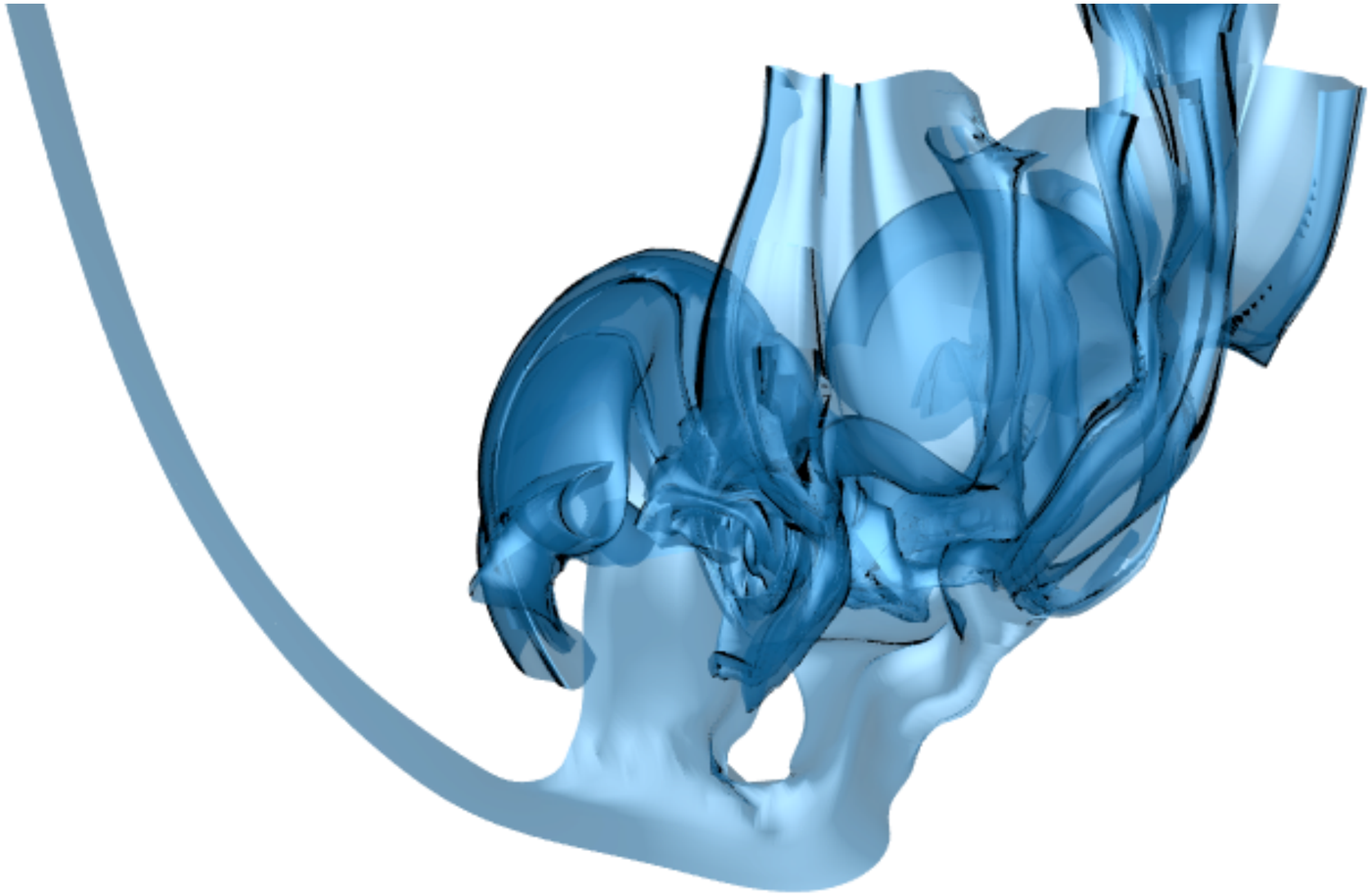
- Volume and flow visualization



direct volume rendering



stream surface rendering

Outline

- Marks and channels
- Introduction to information visualization
- Tips for designing visual forms

What is a poor visual form

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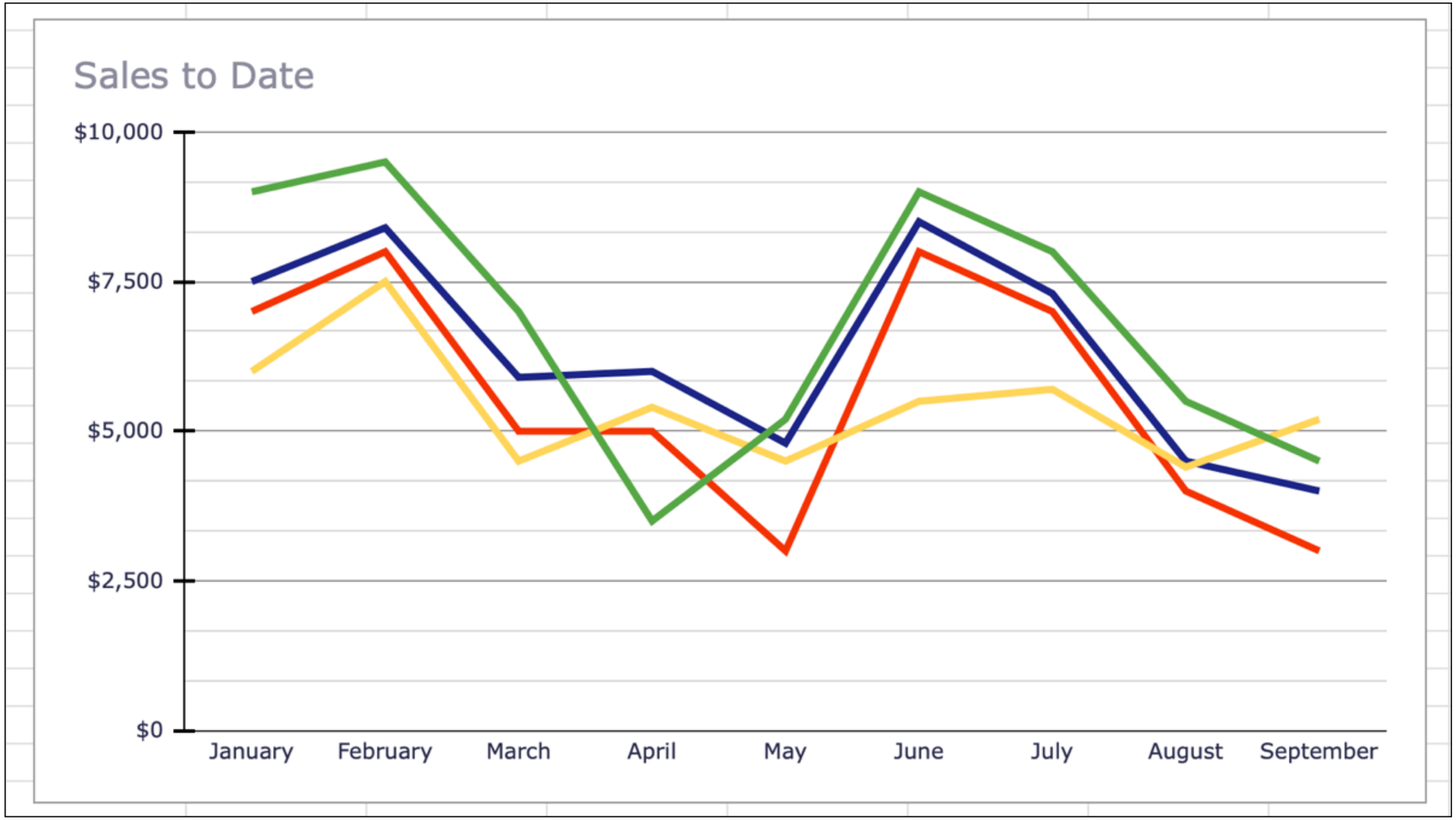
- Missing legend



What is a poor visual form

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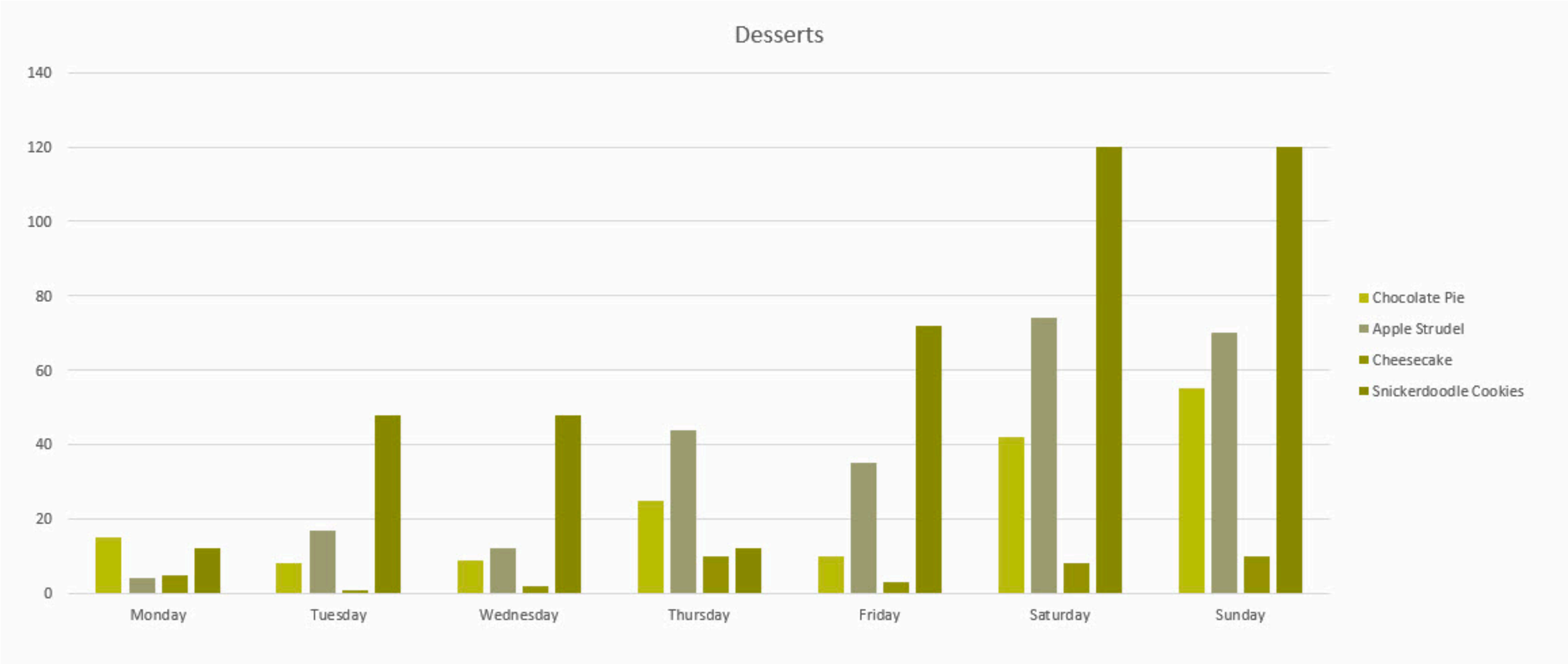
- Poor color choice



What is a poor visual form

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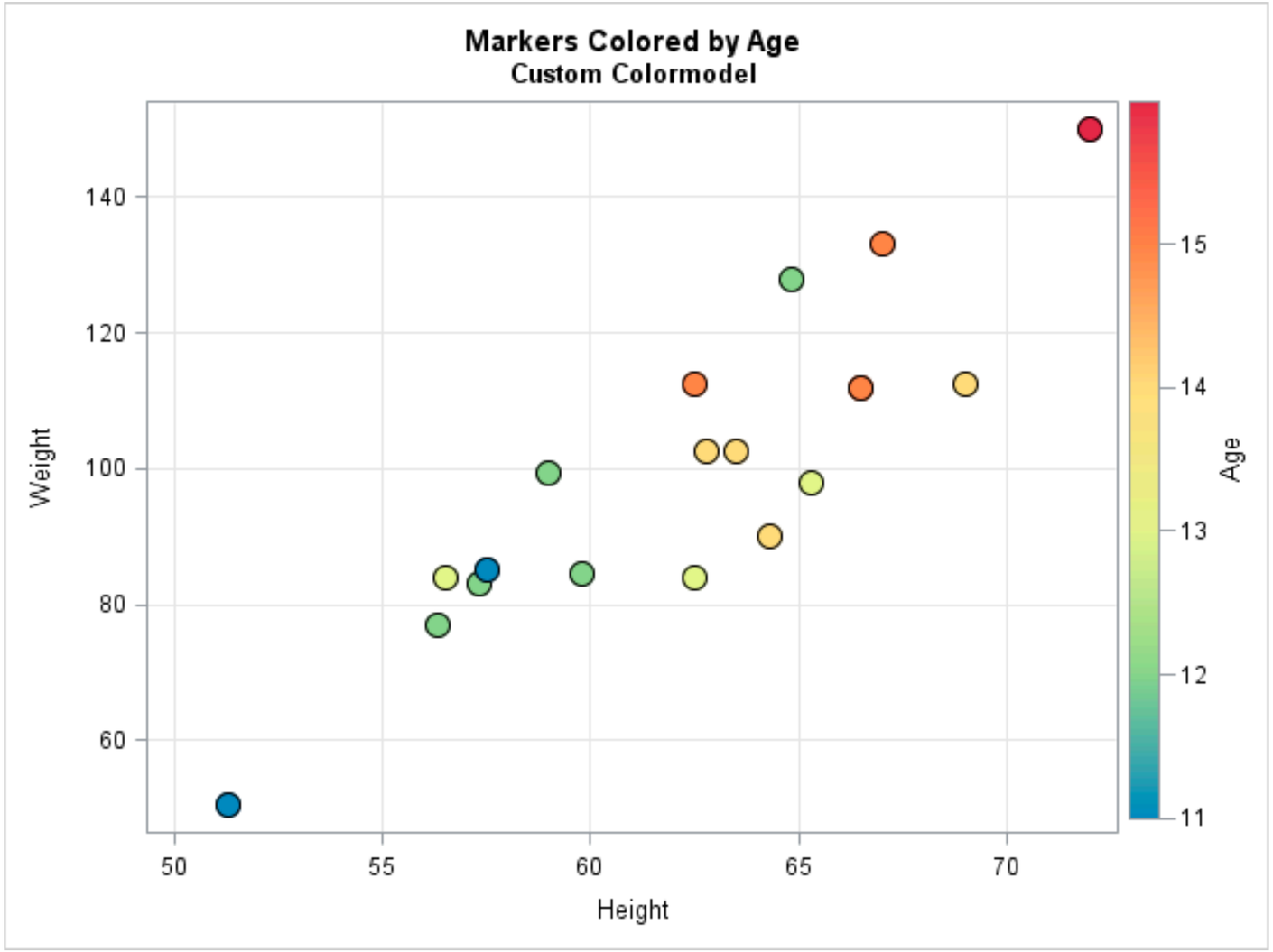
- Non-optimal marker



What is a poor visual form

- Inappropriate ratio
- Misleading bases
- Missing title
- Misleading markers
- etc.

What makes a good visual form

- Choose a good visualization form
- Design non-overlap layout
- Highlight the most important content
- Pick proper colors
- etc.

Thank Prof. Tamara Munzner and Prof. David Koop for many of the slides!