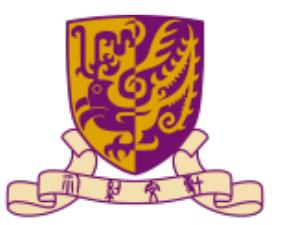

CSC4130

Introduction to Human-Computer Interaction

Lecture 11

Visual Encoding and Information Visualization



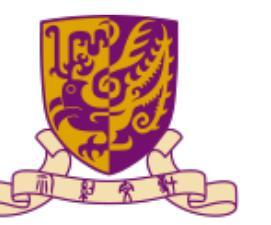


香港中文大學(深圳)

The Chinese University of Hong Kong, Shenzhen

Outline

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

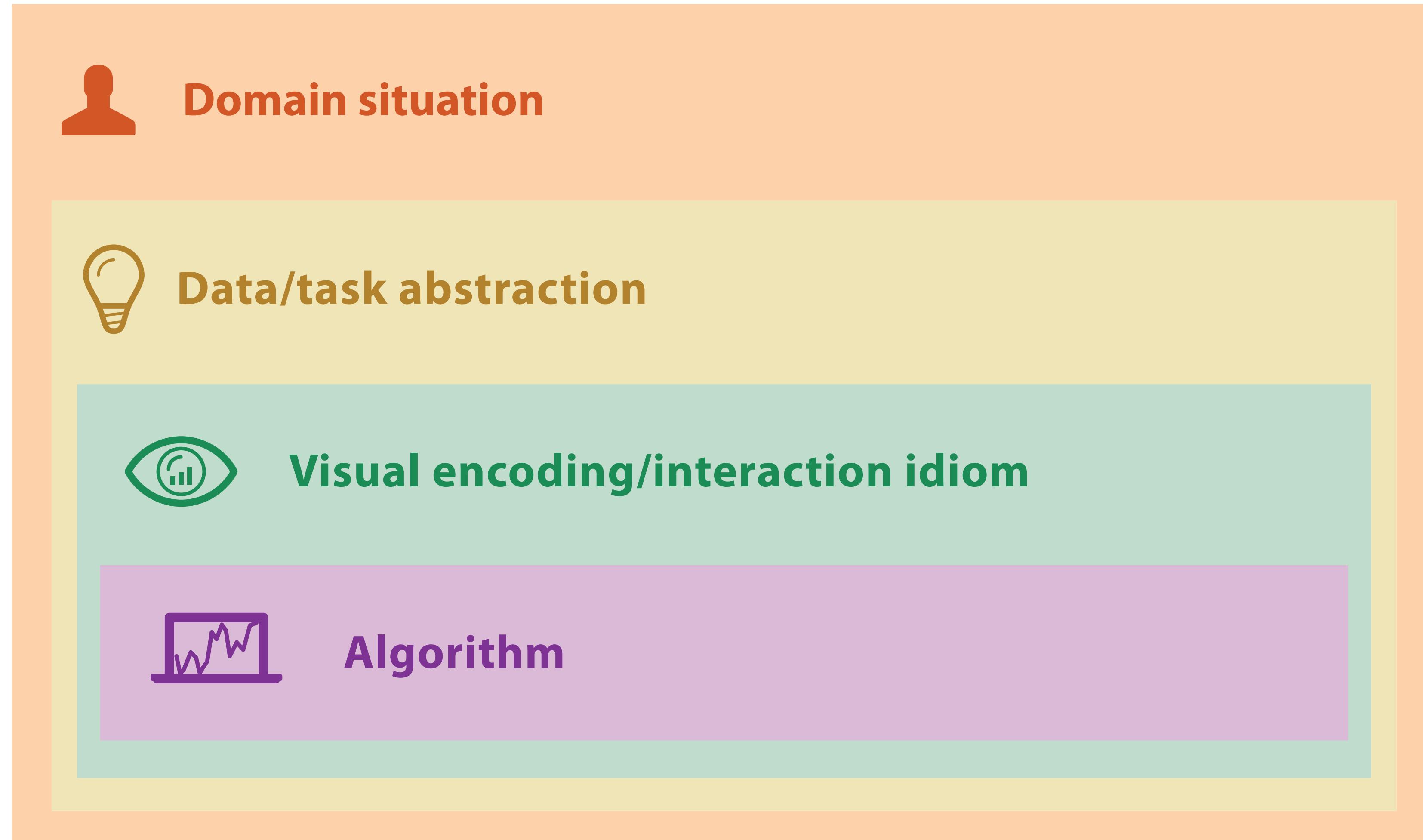


Outline

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

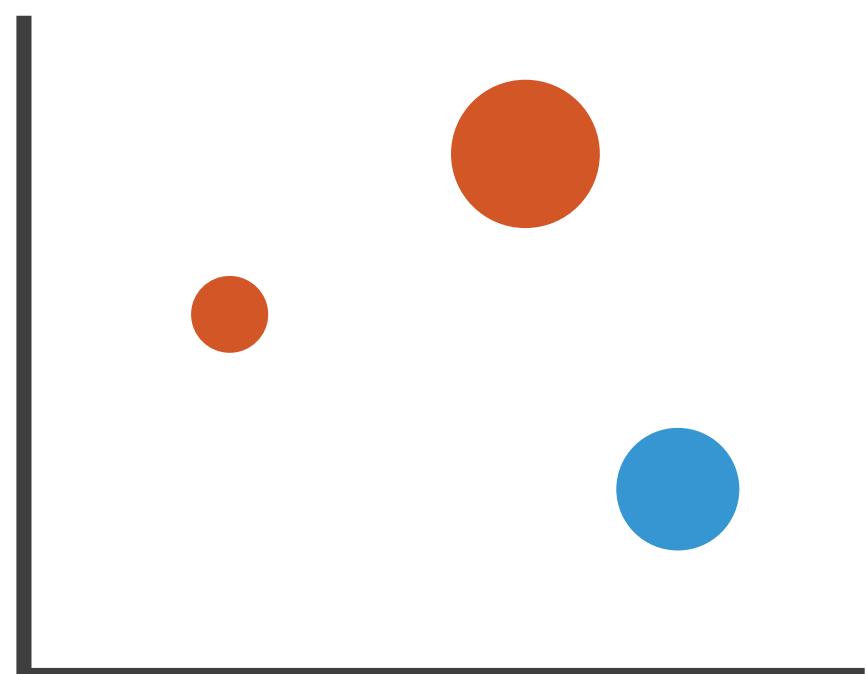
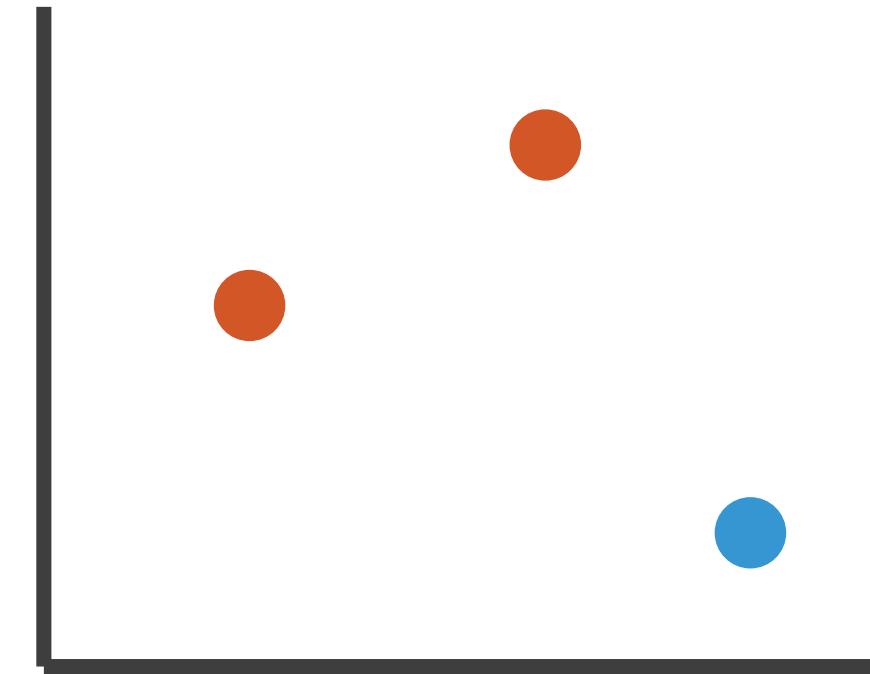
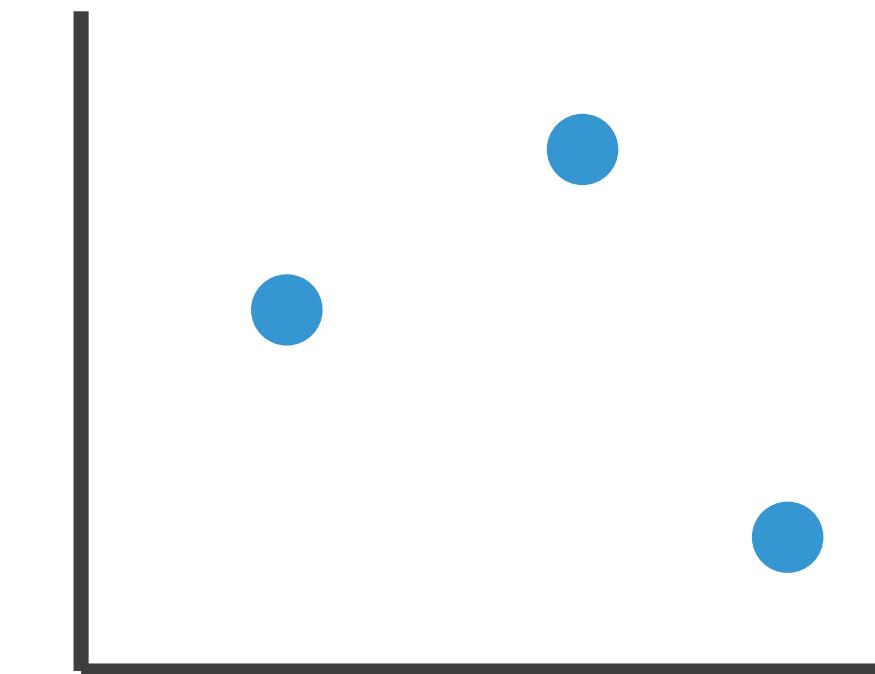
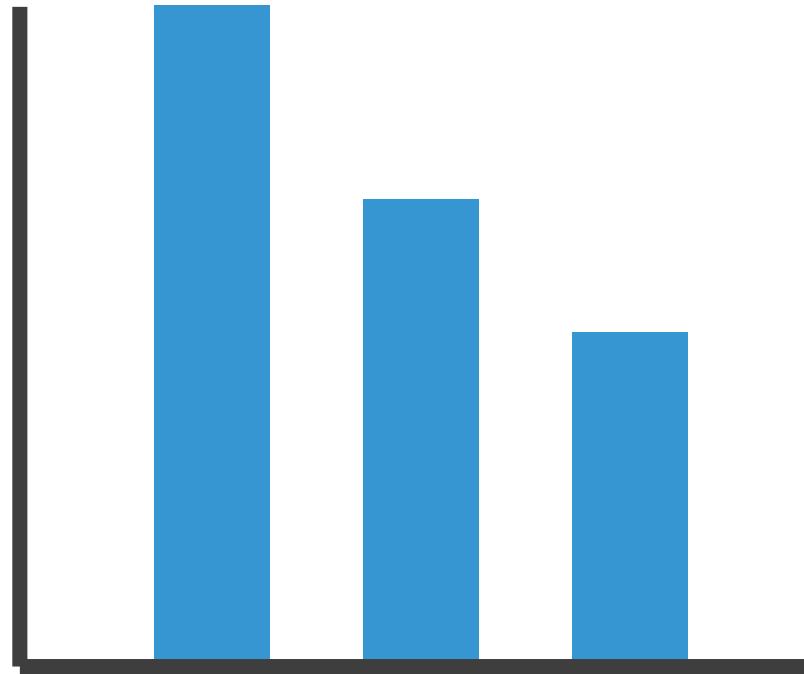
Visual encoding

- How to systematically analyze idiom structure?



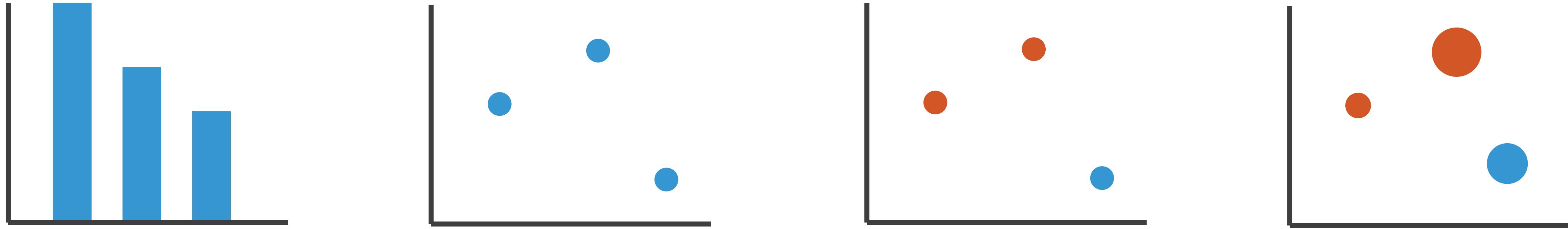
Visual encoding

- How to systematically analyze idiom structure?



Visual encoding

- How to systematically analyze idiom structure?

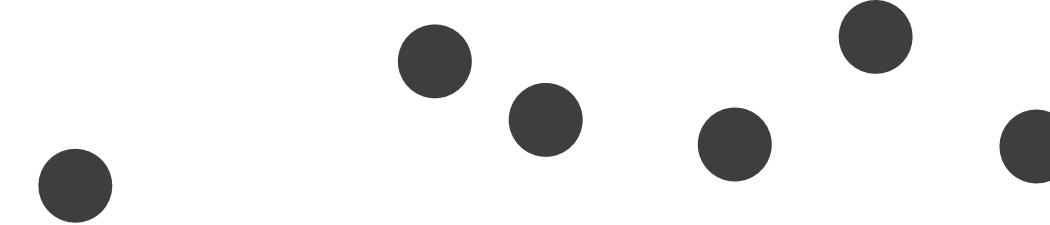


- Marks and channels
- Marks: represent items or links
- Channels: change appearance of marks based on attributes

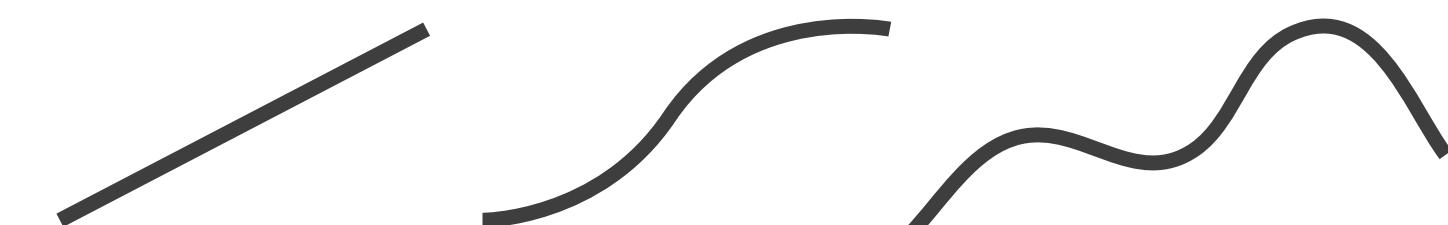
Marks for items

- Basic geometric elements

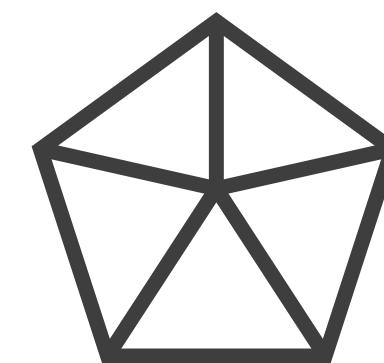
→ Points



→ Lines



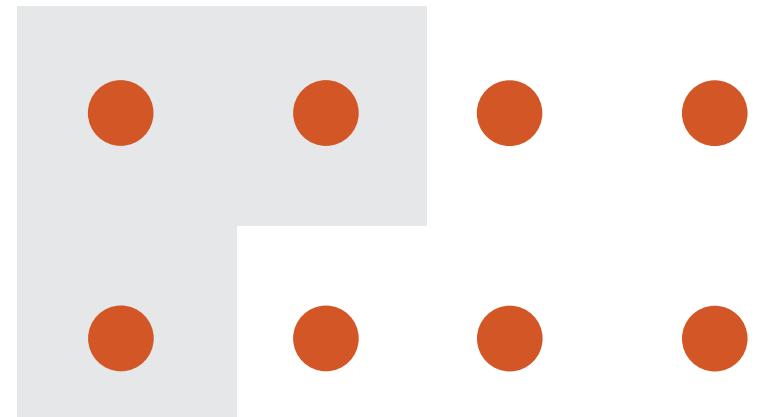
→ Areas



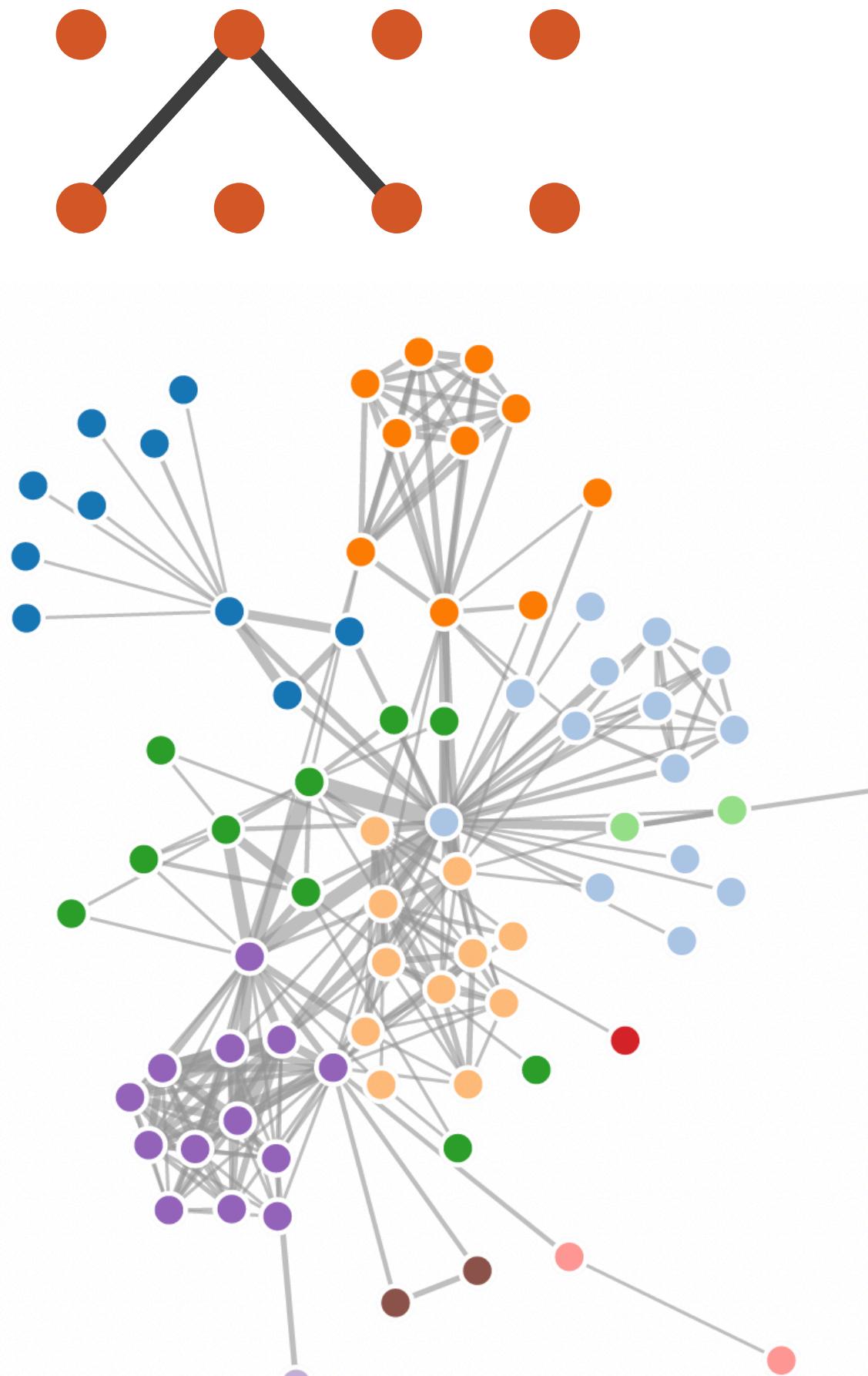
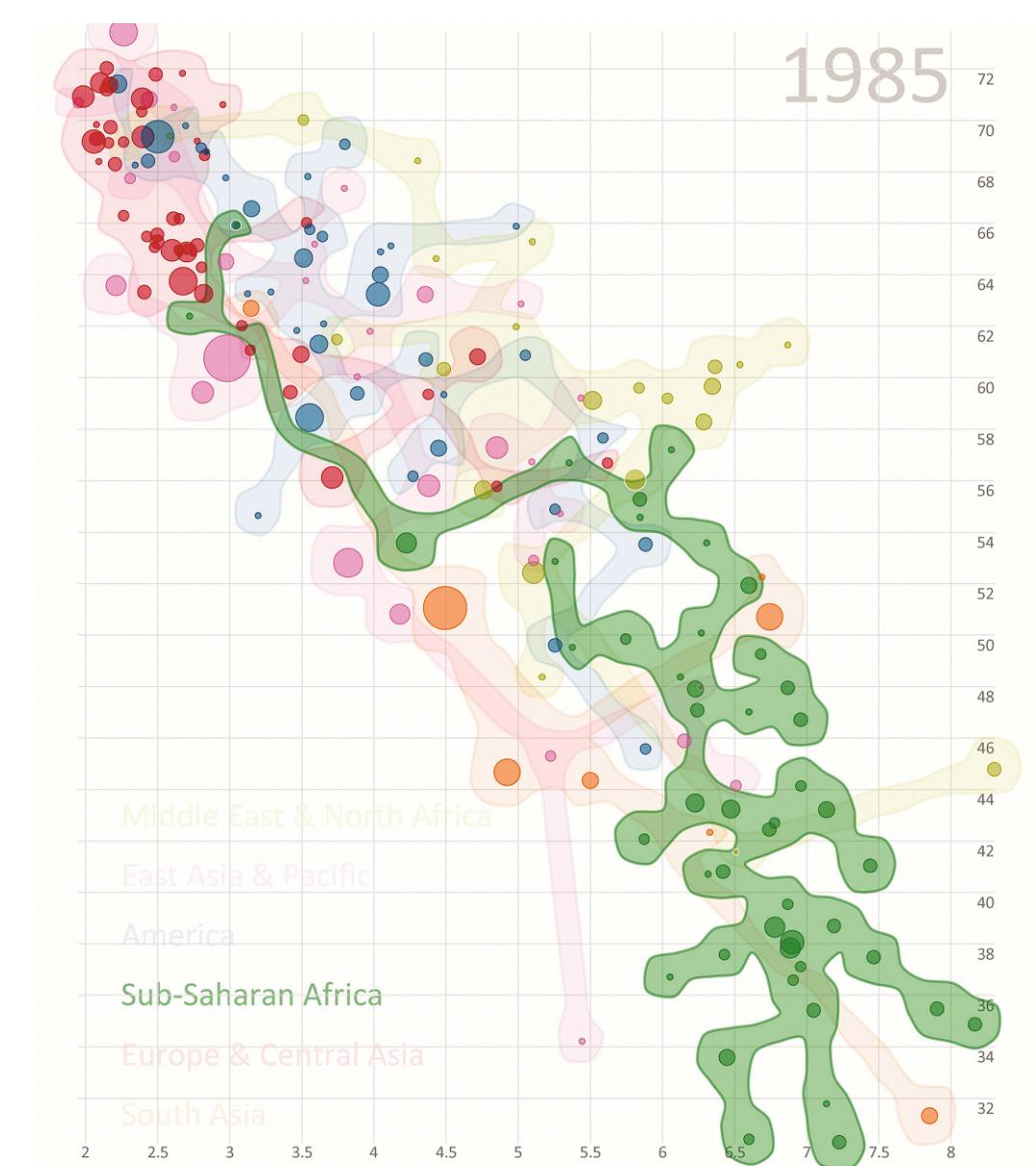
- 3D mark: volume, rarely used

Marks for links

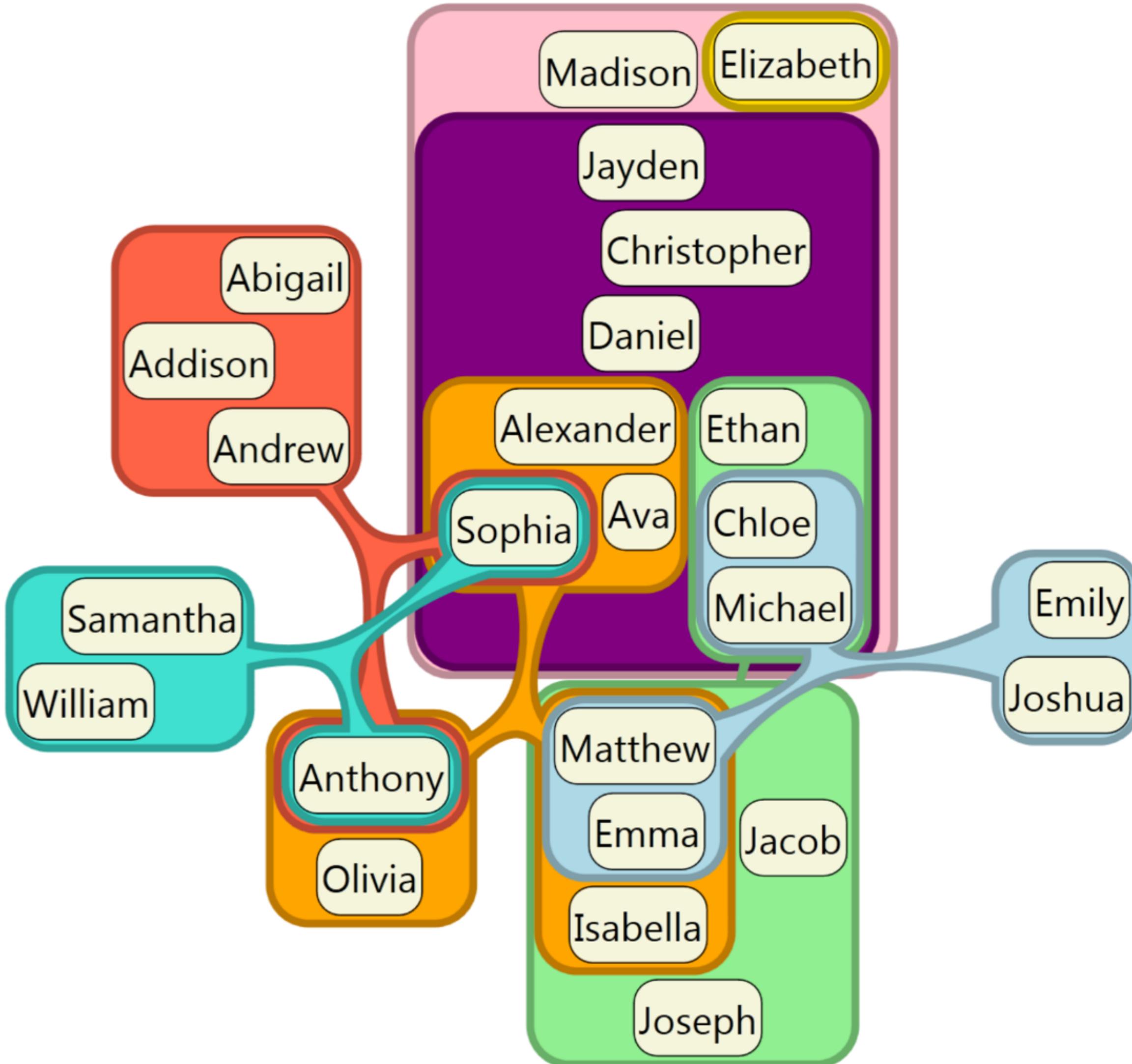
→ Containment



→ Connection



Containment can be nested



Channels

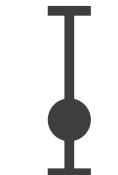
- Control appearance of marks
 - Proportional to or based on attributes

→ Position

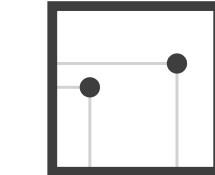
→ Horizontal



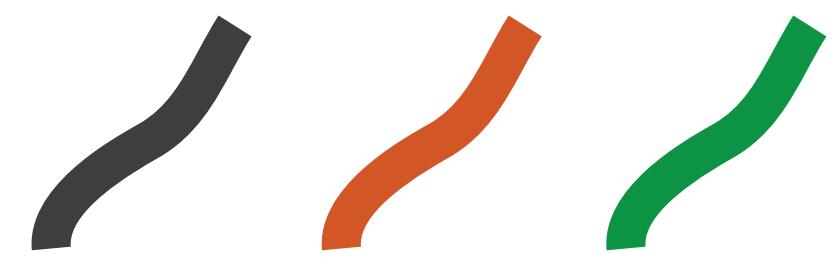
→ Vertical



→ Both



→ Color



→ Shape



→ Tilt

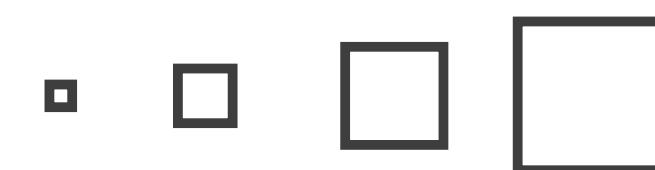


→ Size

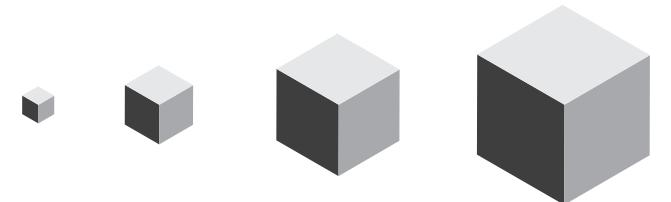
→ Length



→ Area

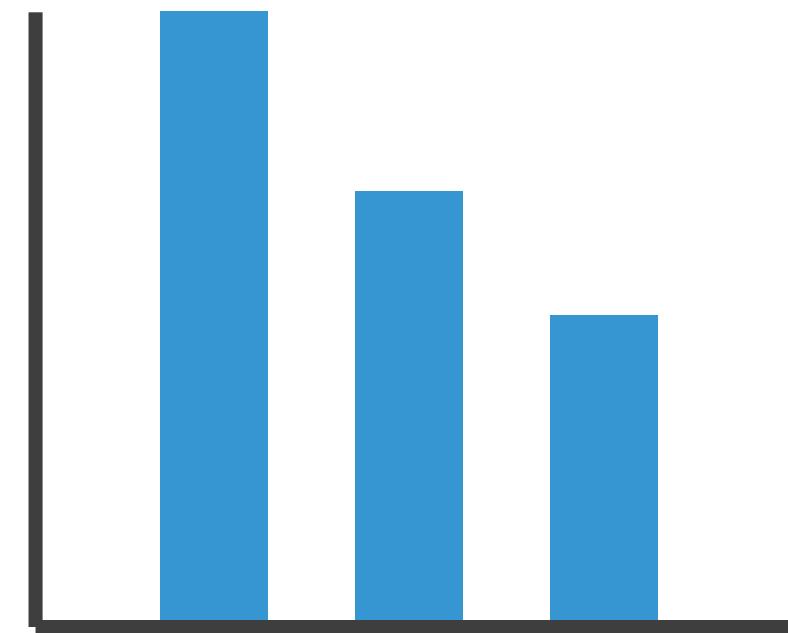


→ Volume



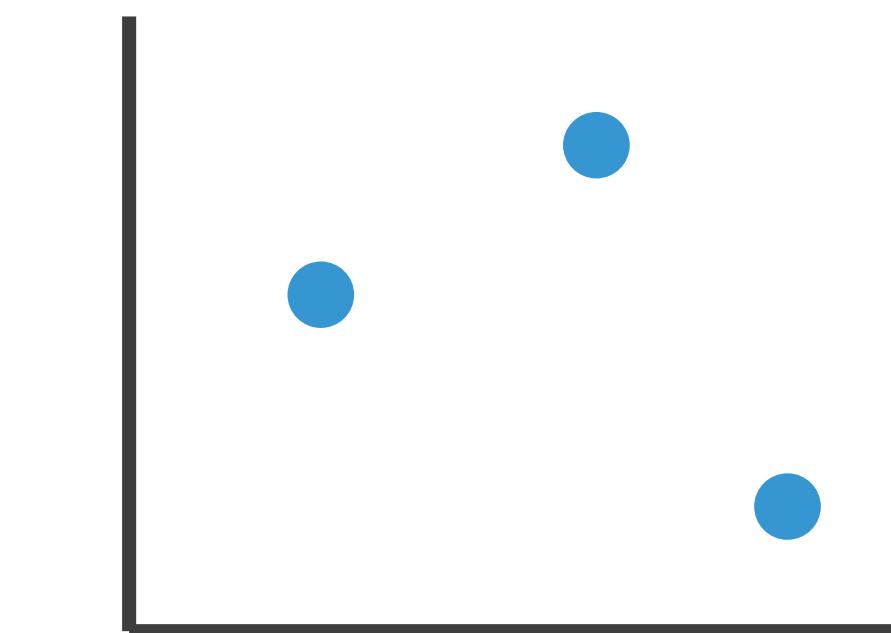
Visual encoding

- Analyze idiom structure as combination of marks and channels



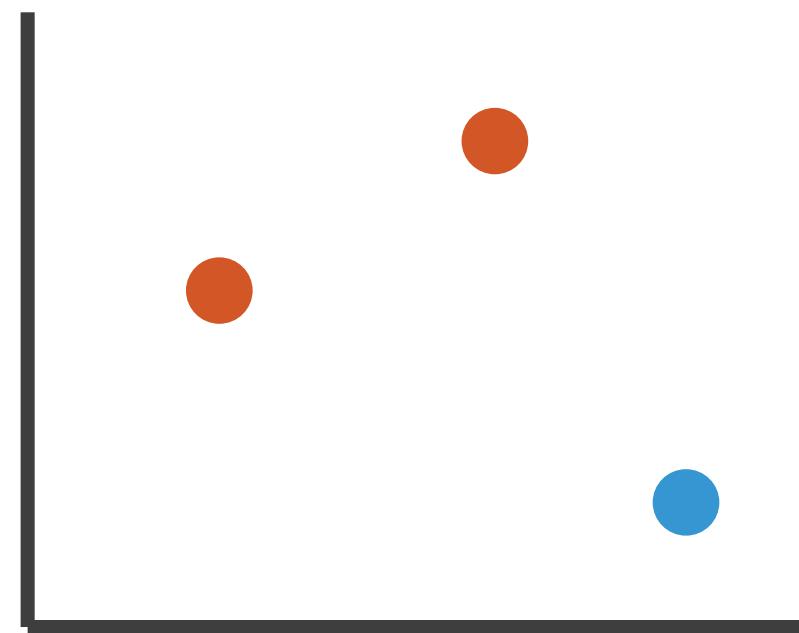
1:
vertical position

mark: line



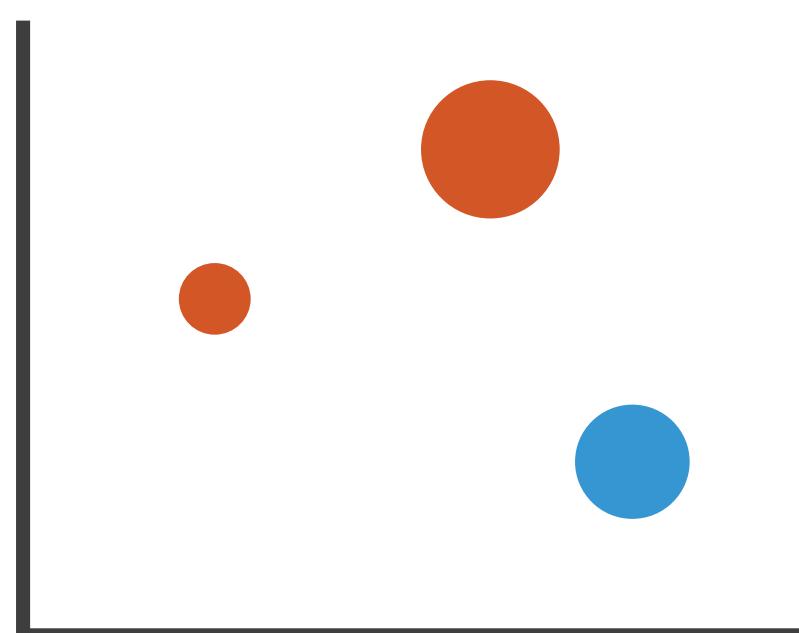
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point

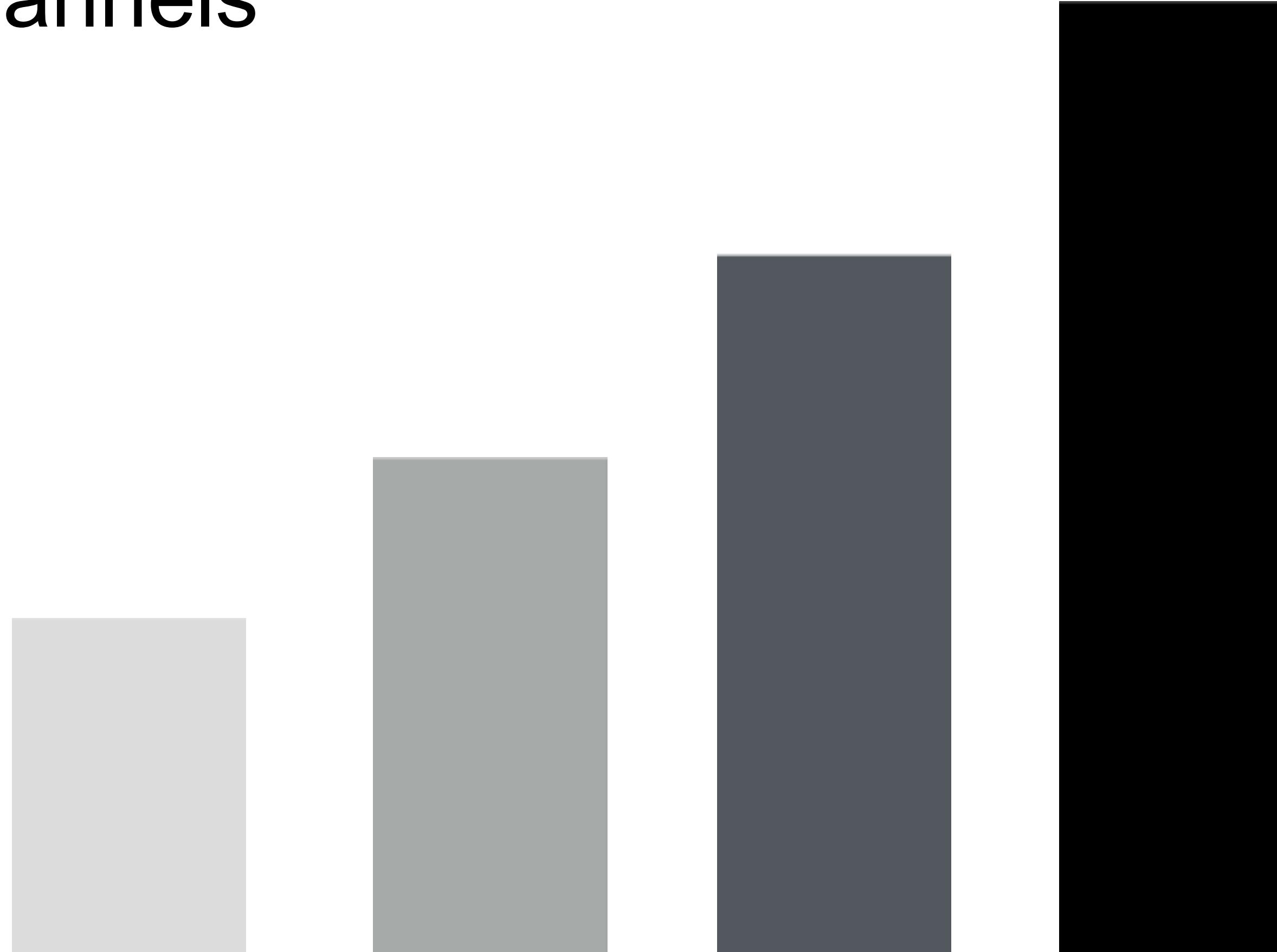


4:
vertical position
horizontal position
color hue size (area)

mark: point

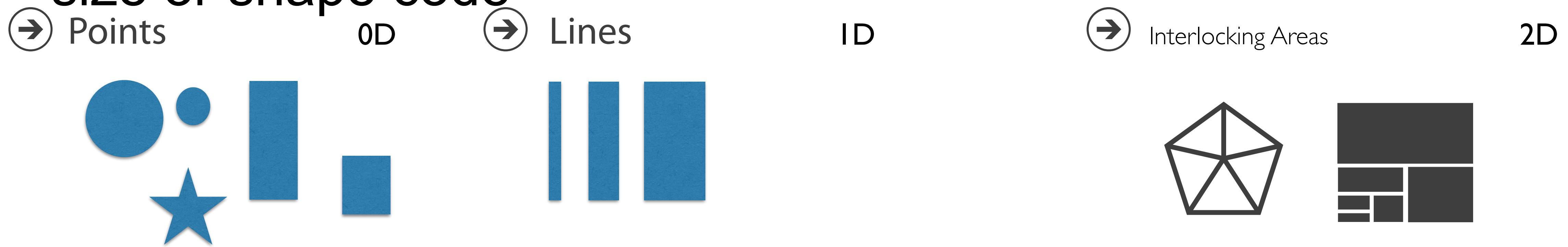
Redundant encoding

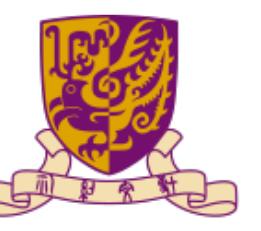
- Multiple channels
 - Send stronger message
 - But use up channels



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



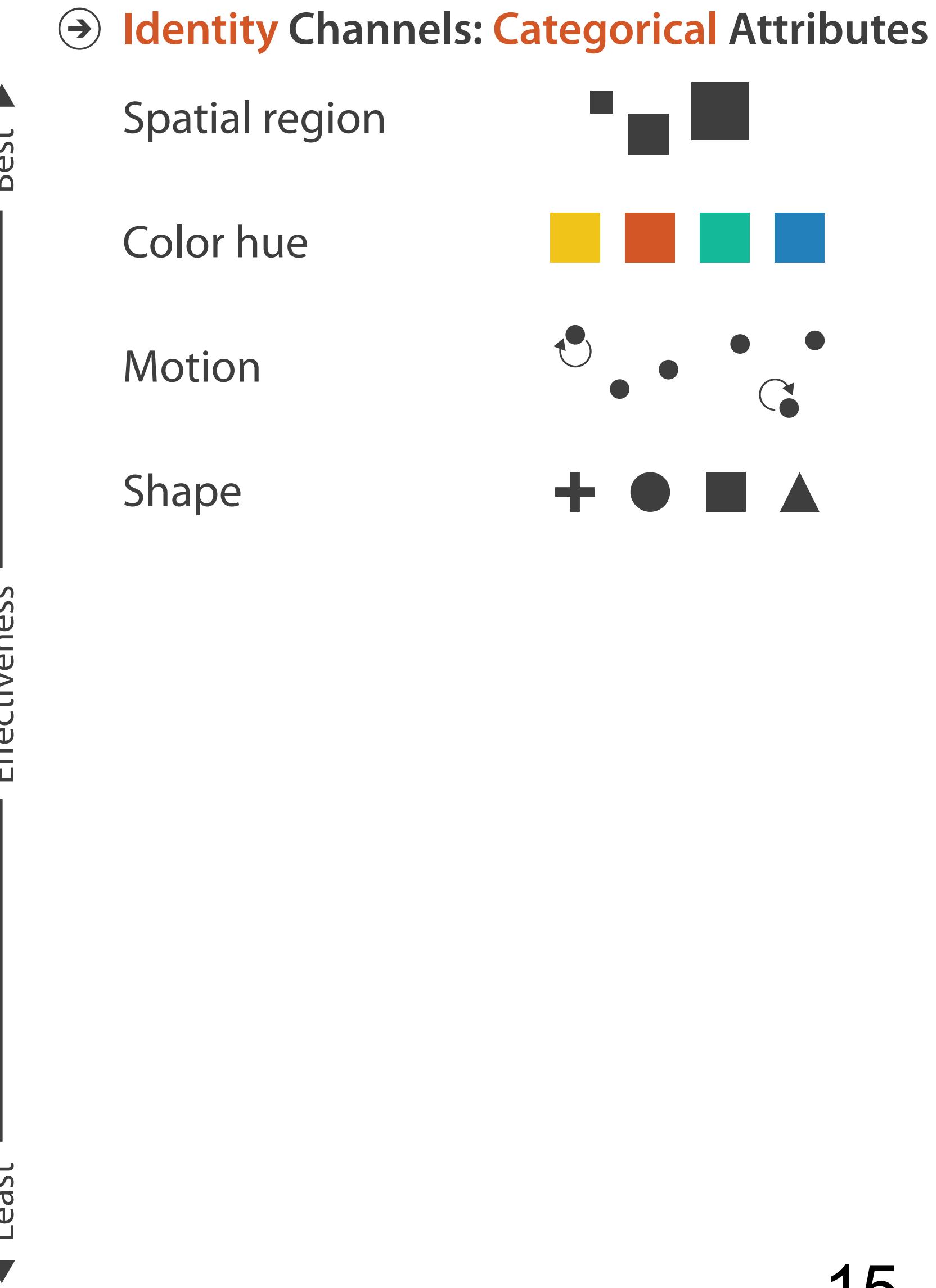
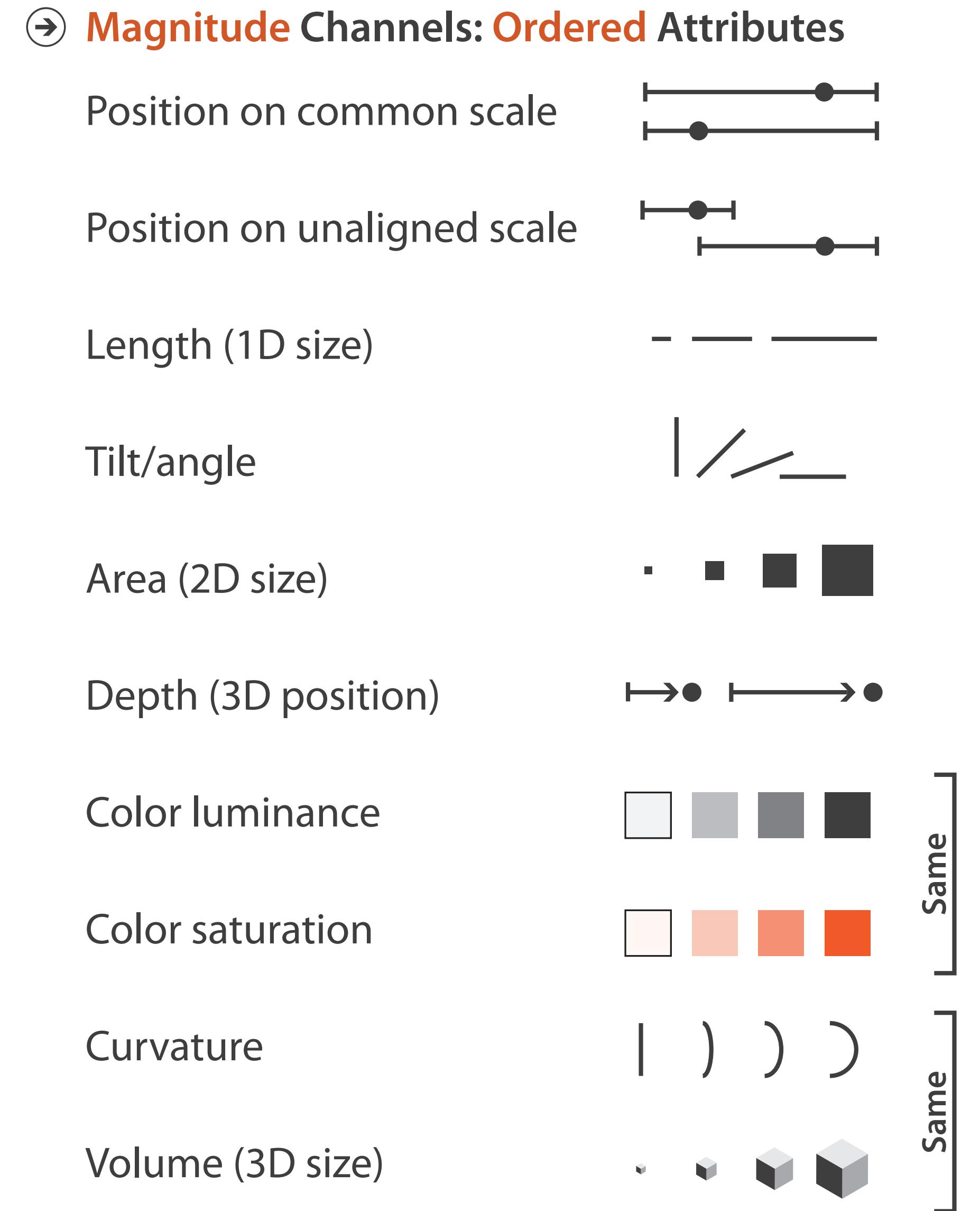


When to use which channel

- 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

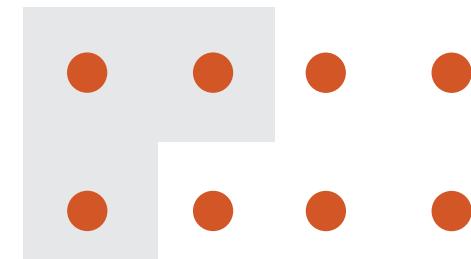


Grouping

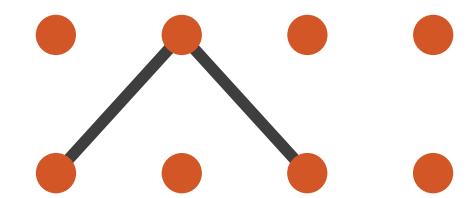
- Containment
- Connection
- Proximity
 - Same spatial region
 - Similarity
 - Same values as other categorical channels

Marks as Links

→ Containment



→ Connection



→ Identity Channels: Categorical Attributes

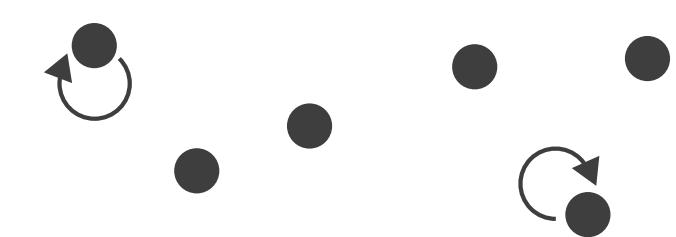
Spatial region



Color hue



Motion



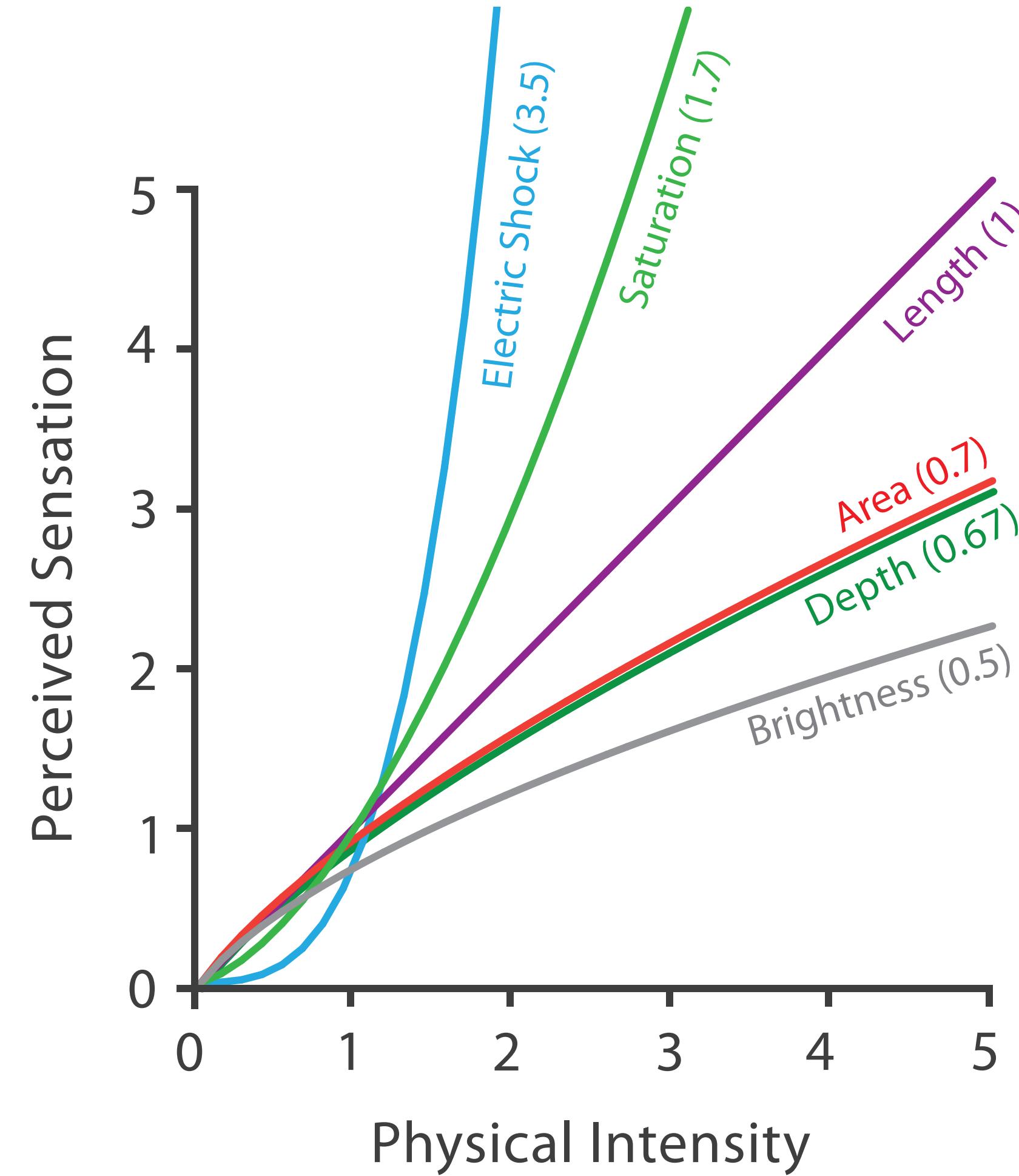
Shape



Channel effectiveness

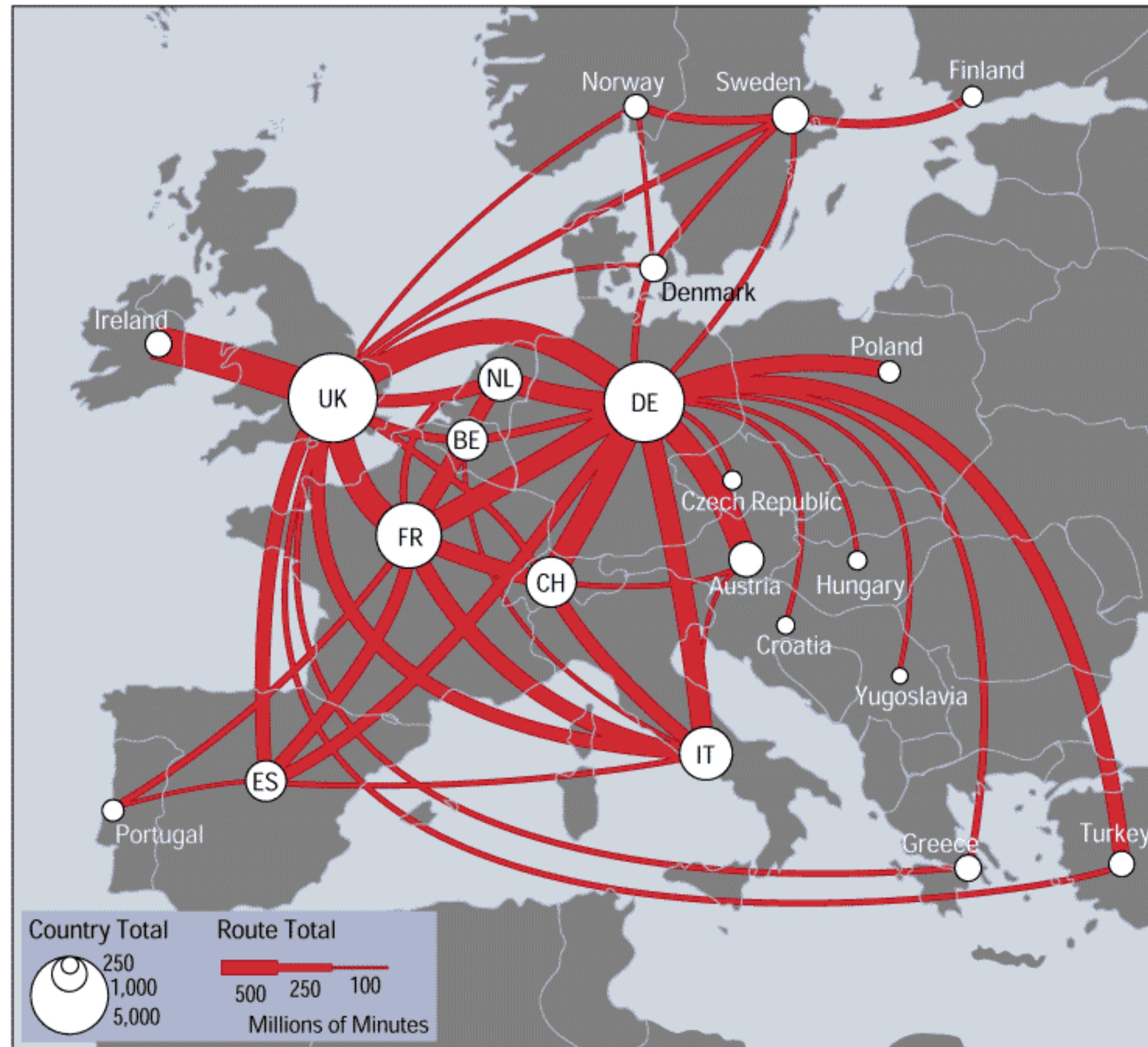
- Accuracy: how precisely can we tell the difference between encoded items?

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



Channel effectiveness

- Discriminability: how many unique steps can we perceive?

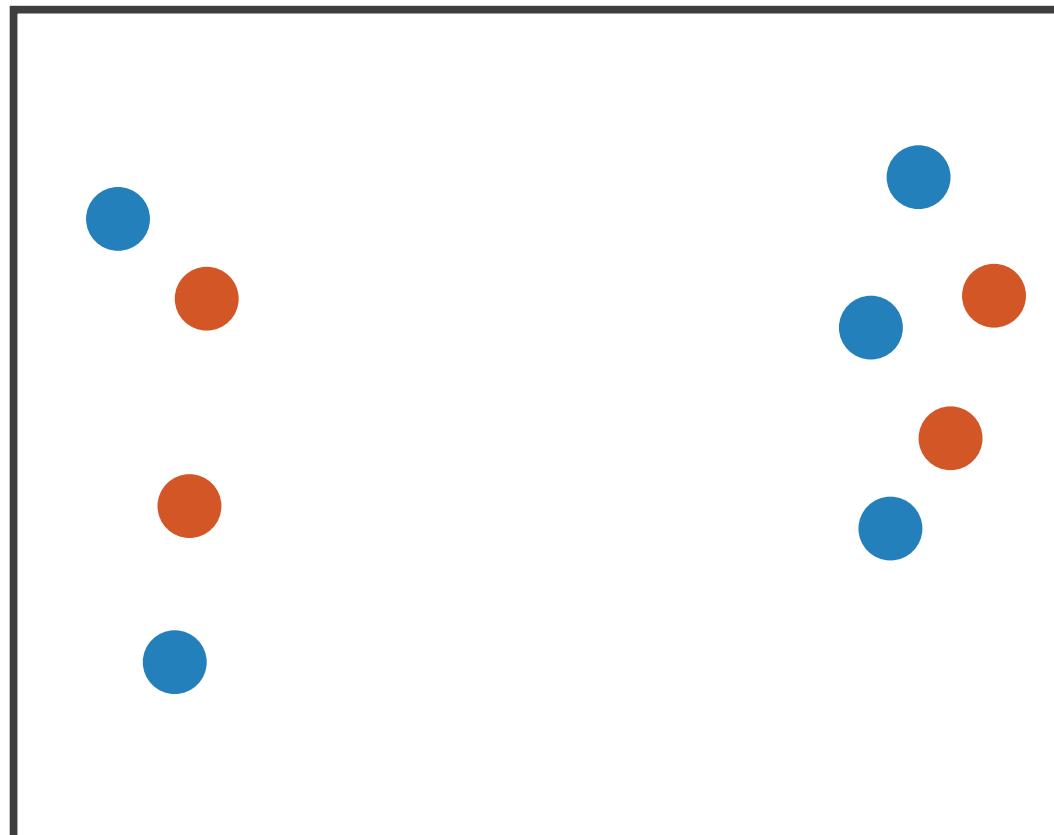


Channel effectiveness

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

Position

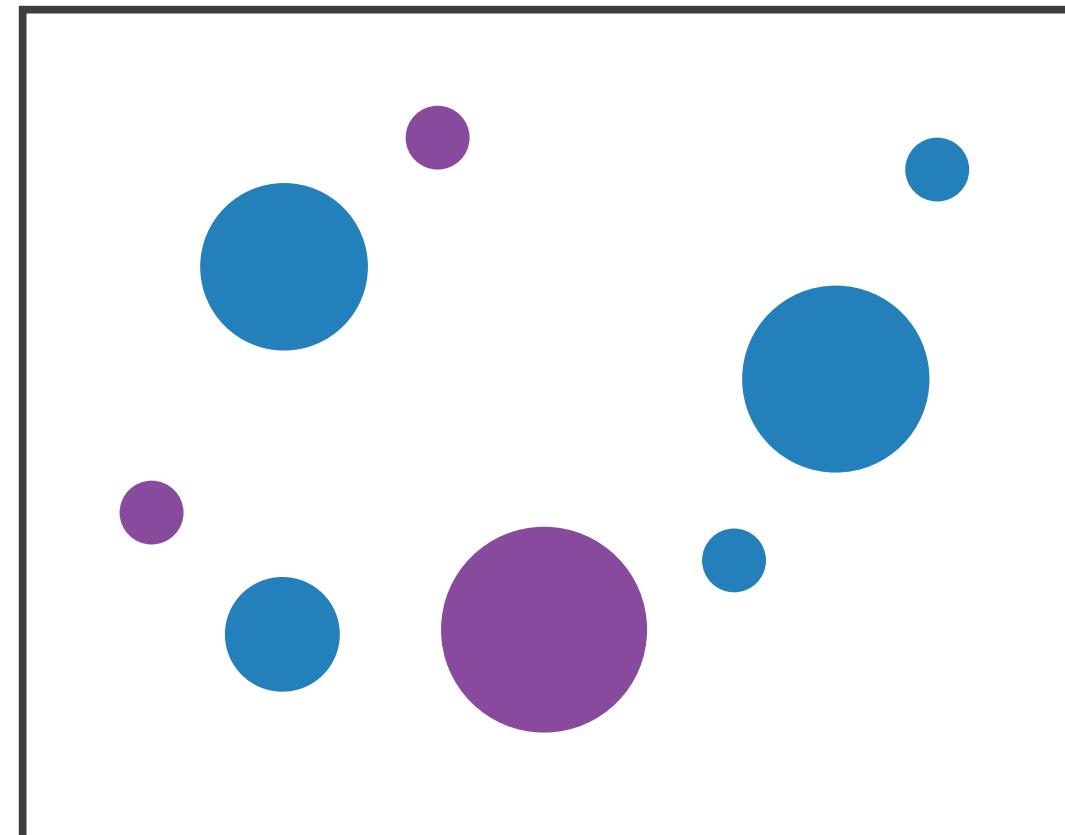
+ Hue (Color)



Fully separable

Size

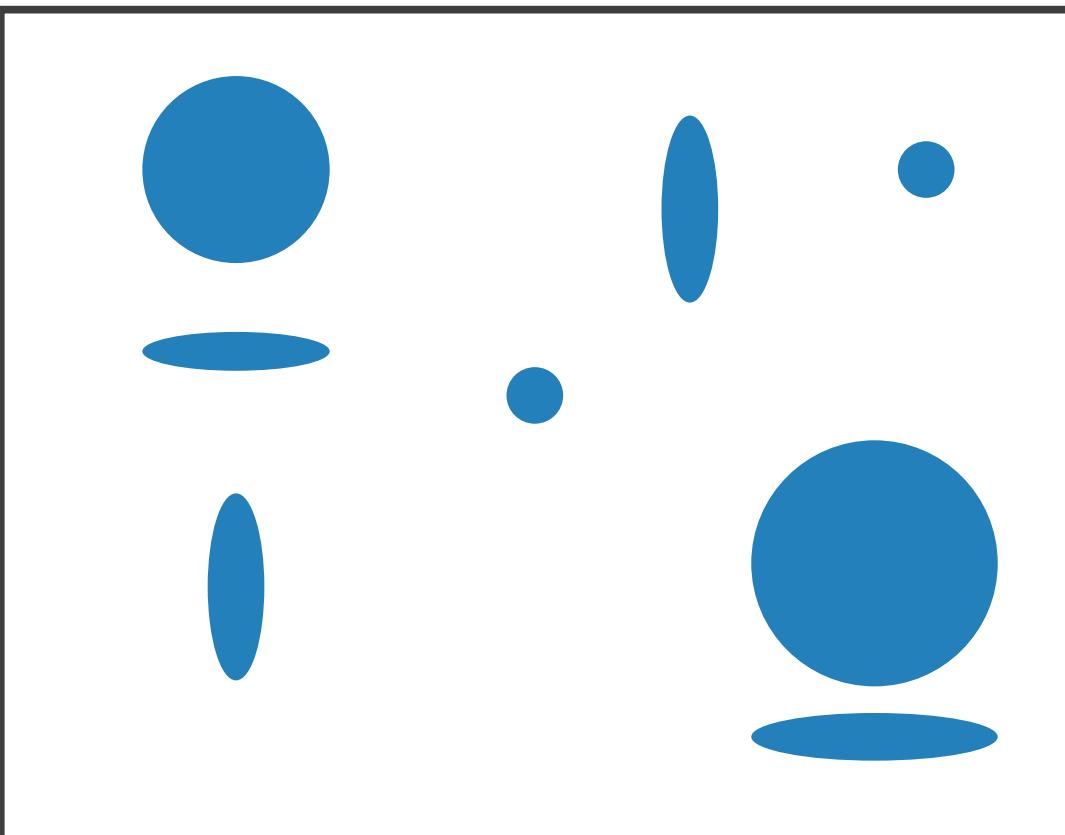
+ Hue (Color)



Some interference

Width

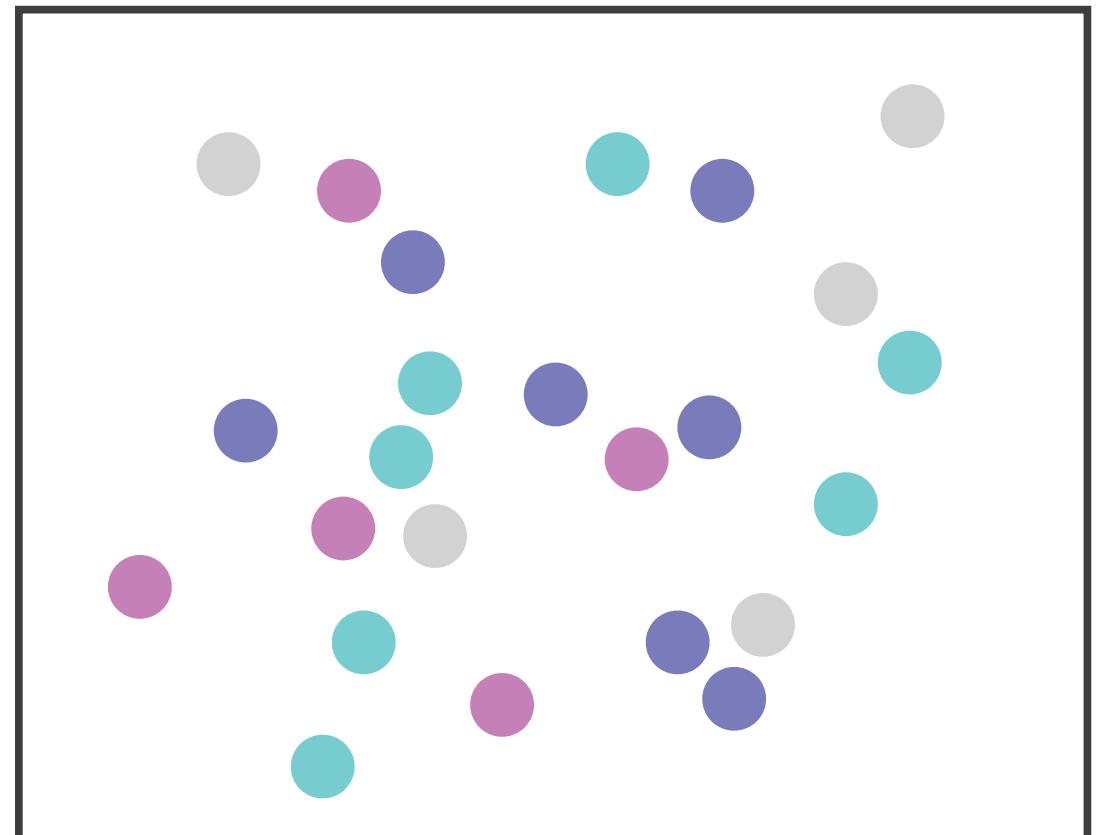
+ Height



Some/significant
interference

Red

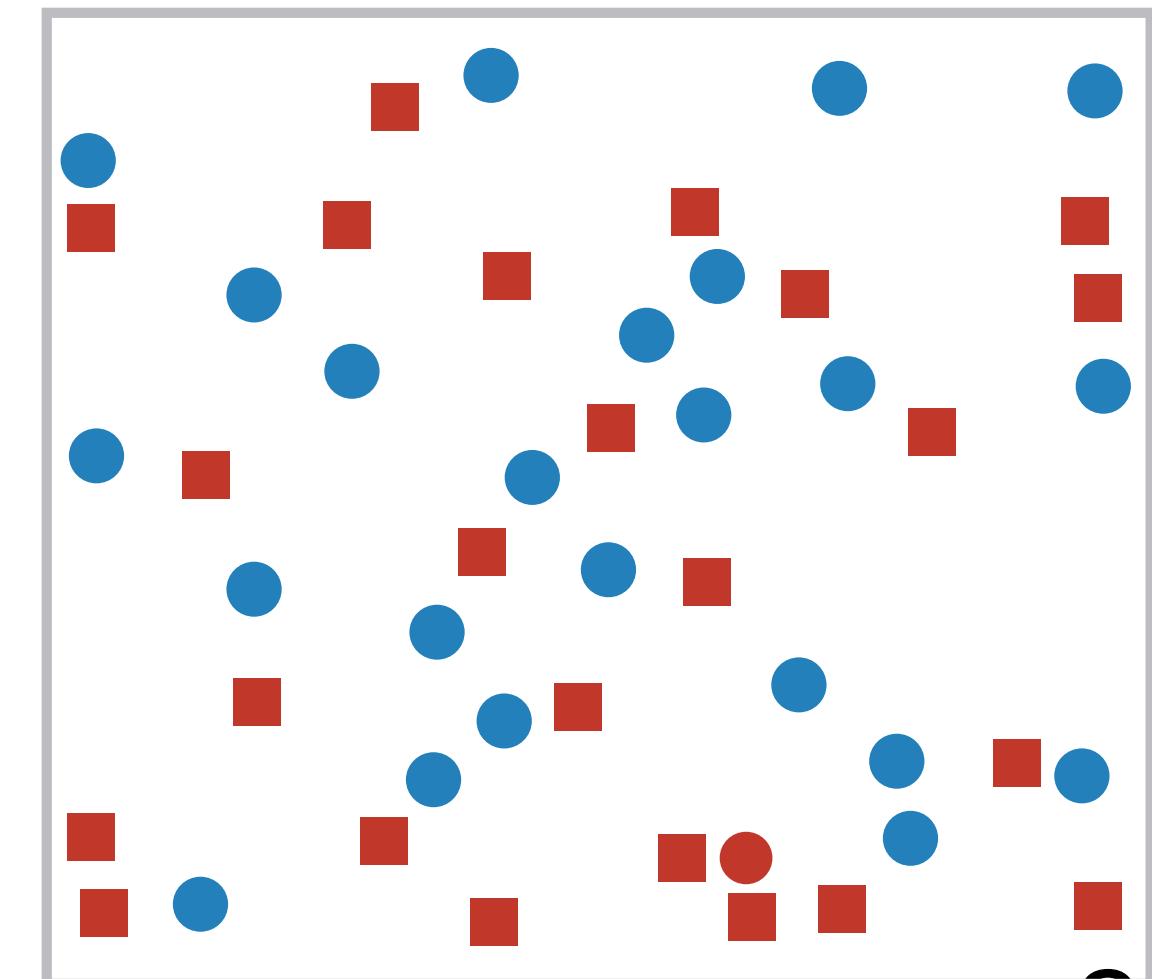
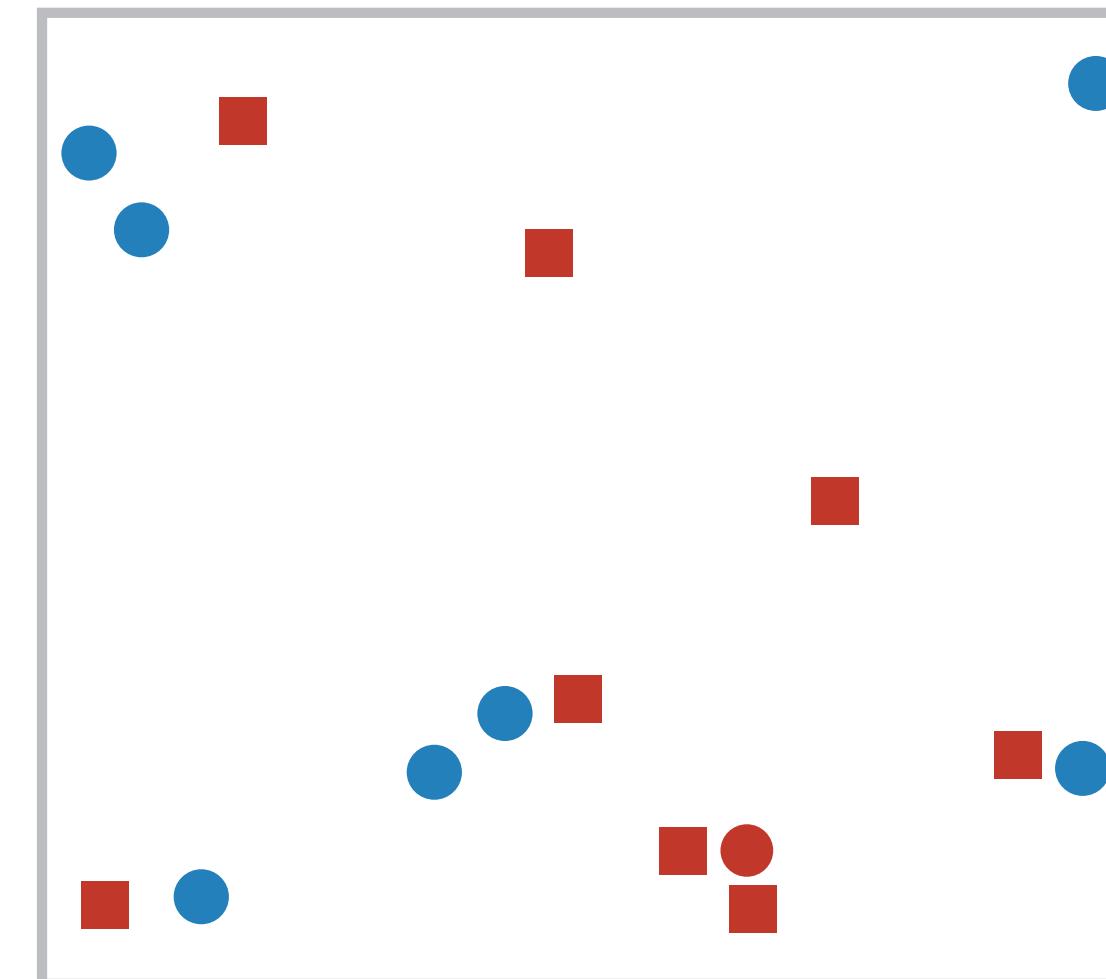
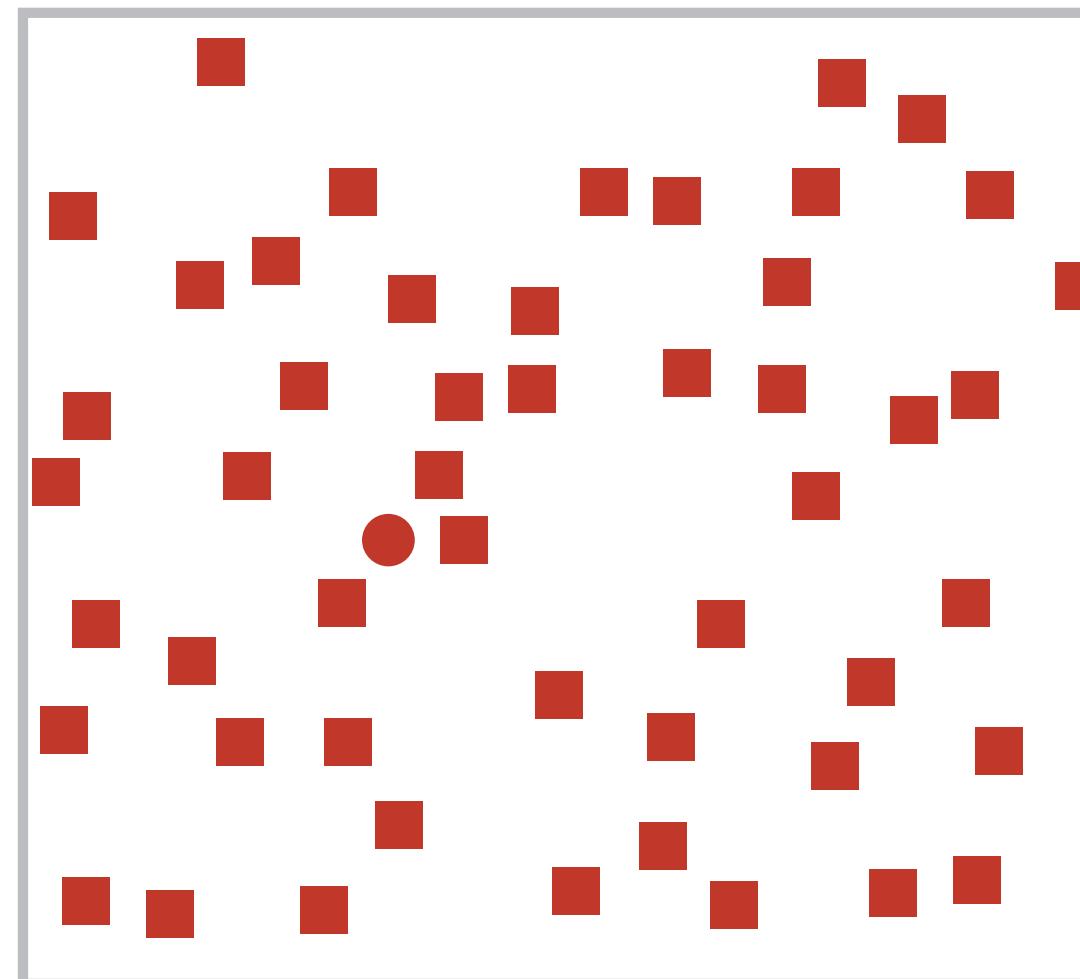
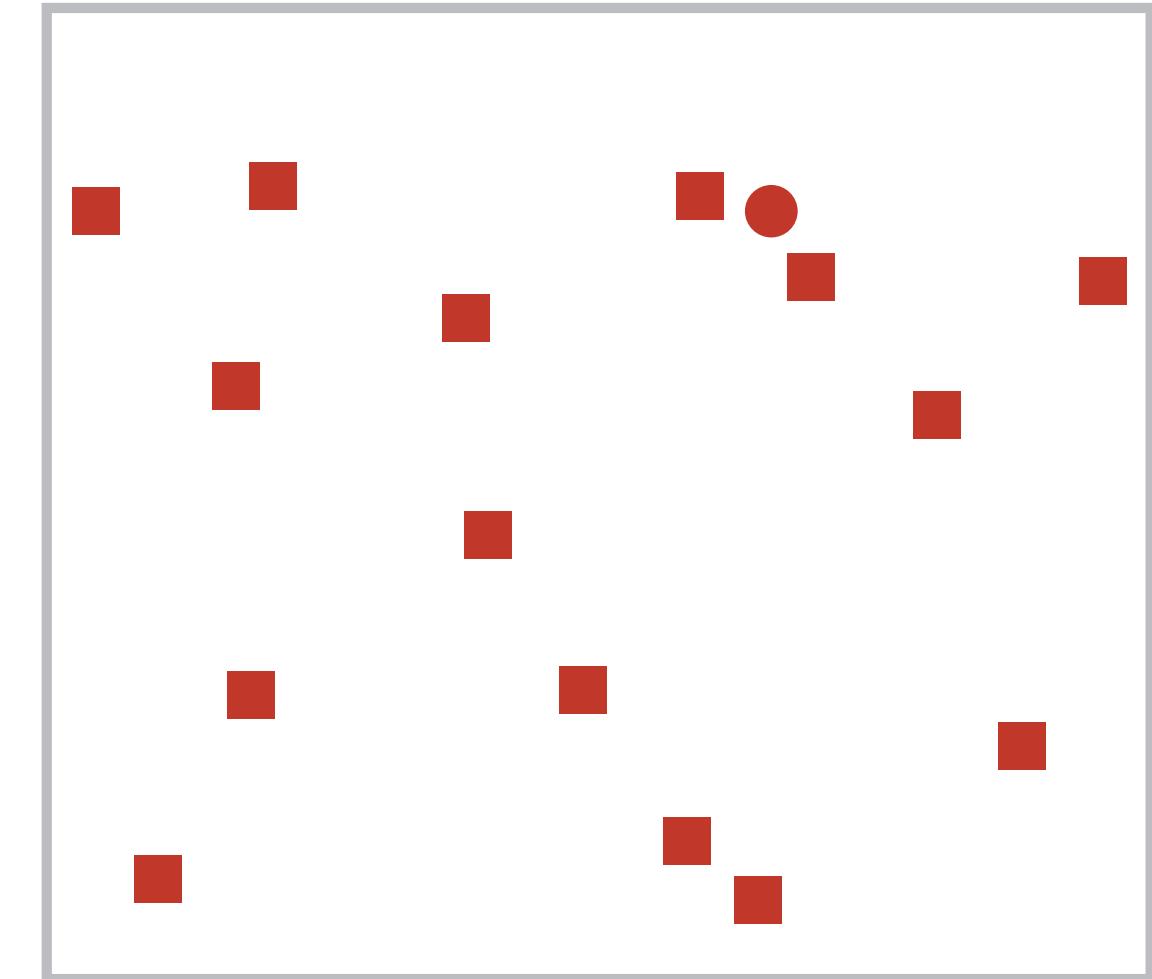
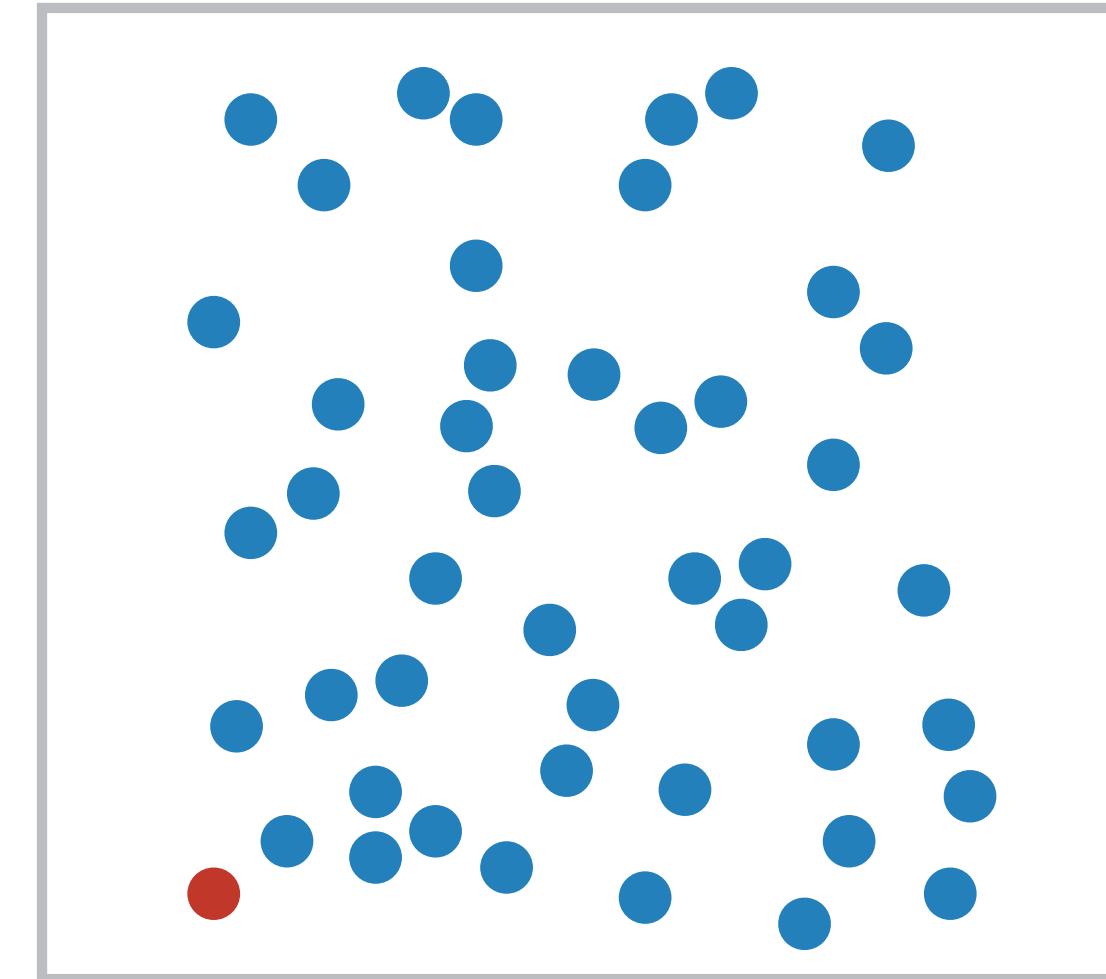
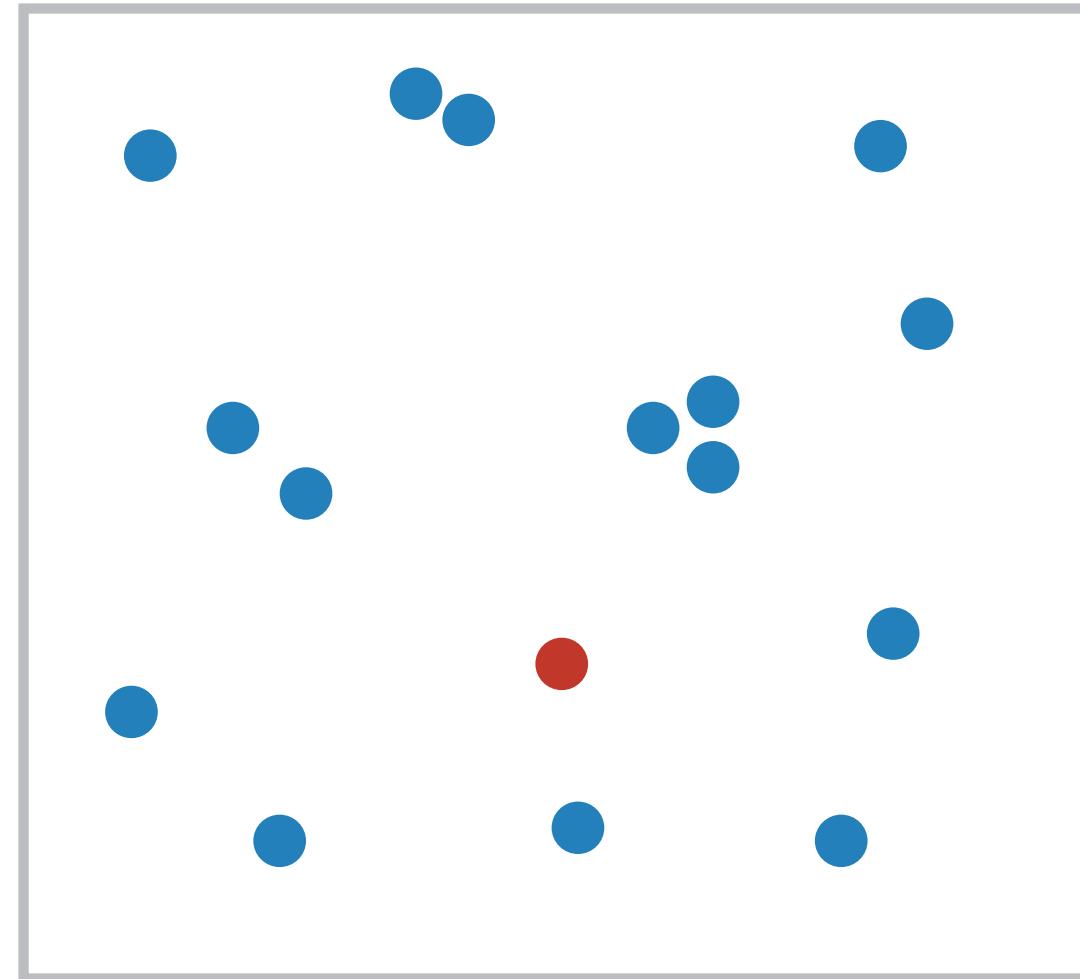
+ Green



Major interference

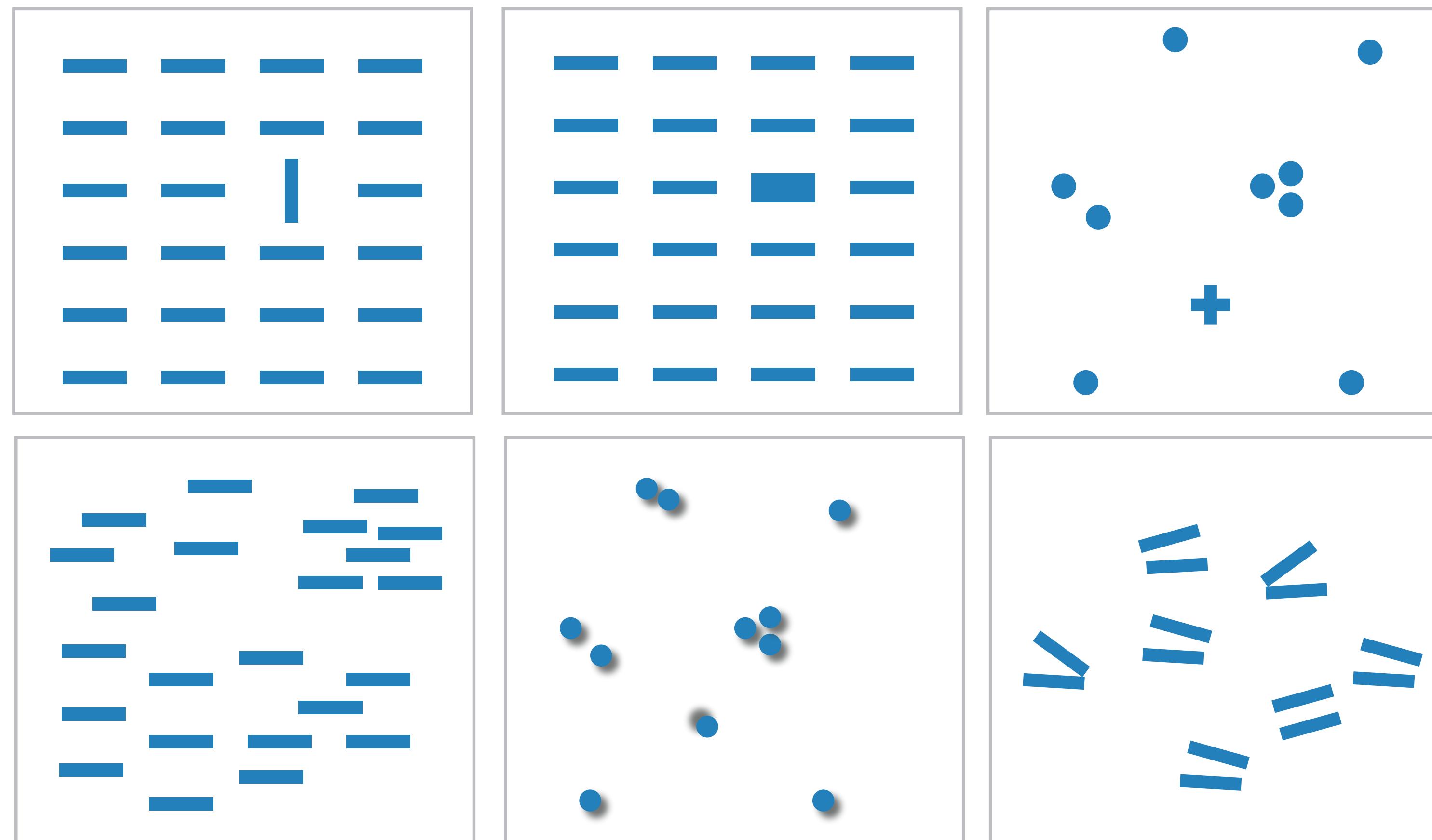
Channel effectiveness

- Popout: can things jump out using this channel?



Popout

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



Factor affecting accuracy

- Alignment
- Distractors
- Distance
- Common scale

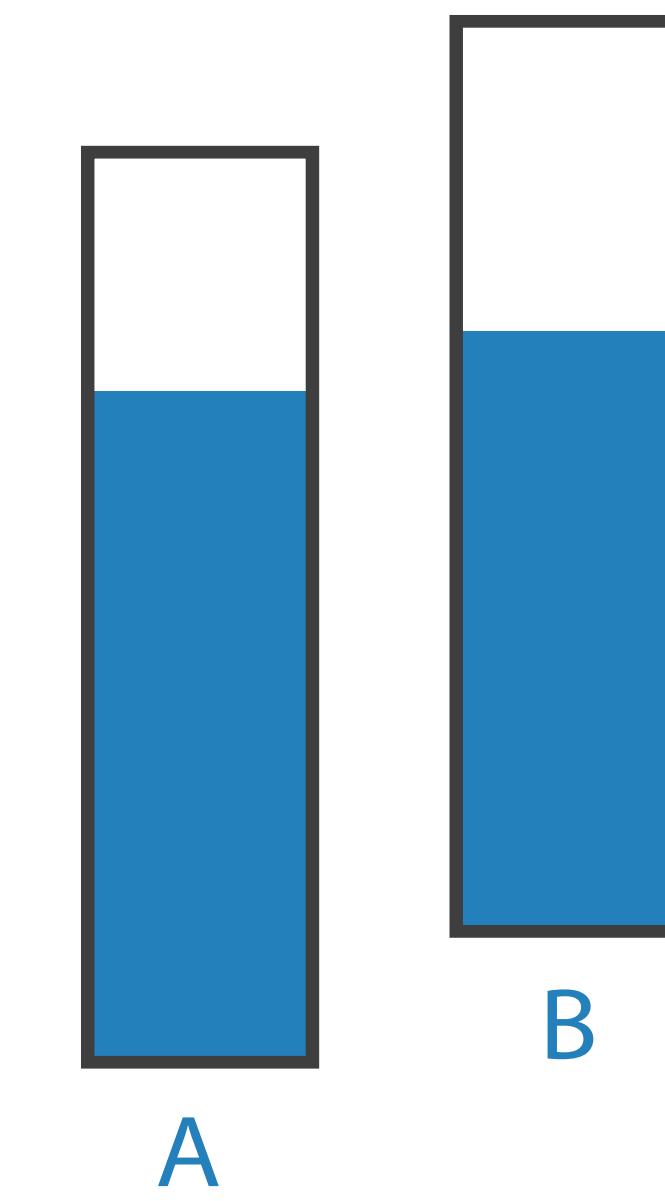


Relative vs. absolute judgements

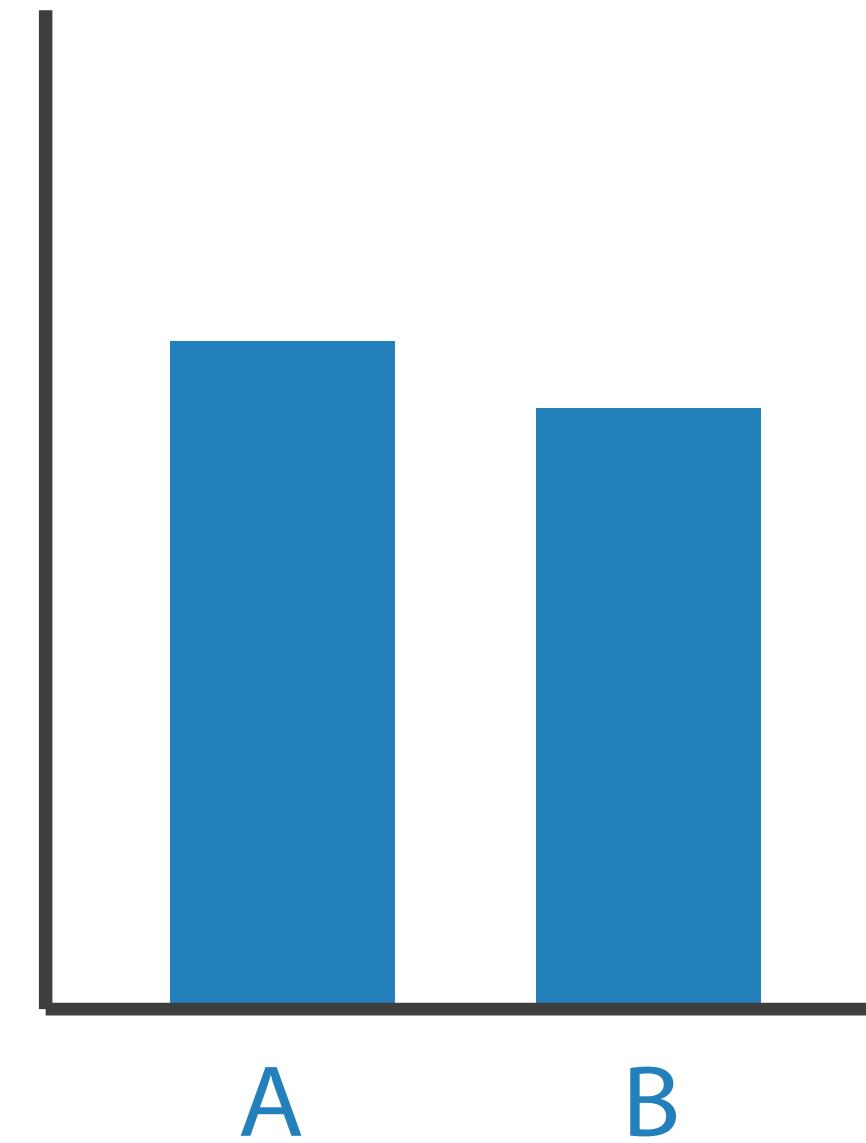
- Perceptual system mostly operates with relative judgements, not absolute



length



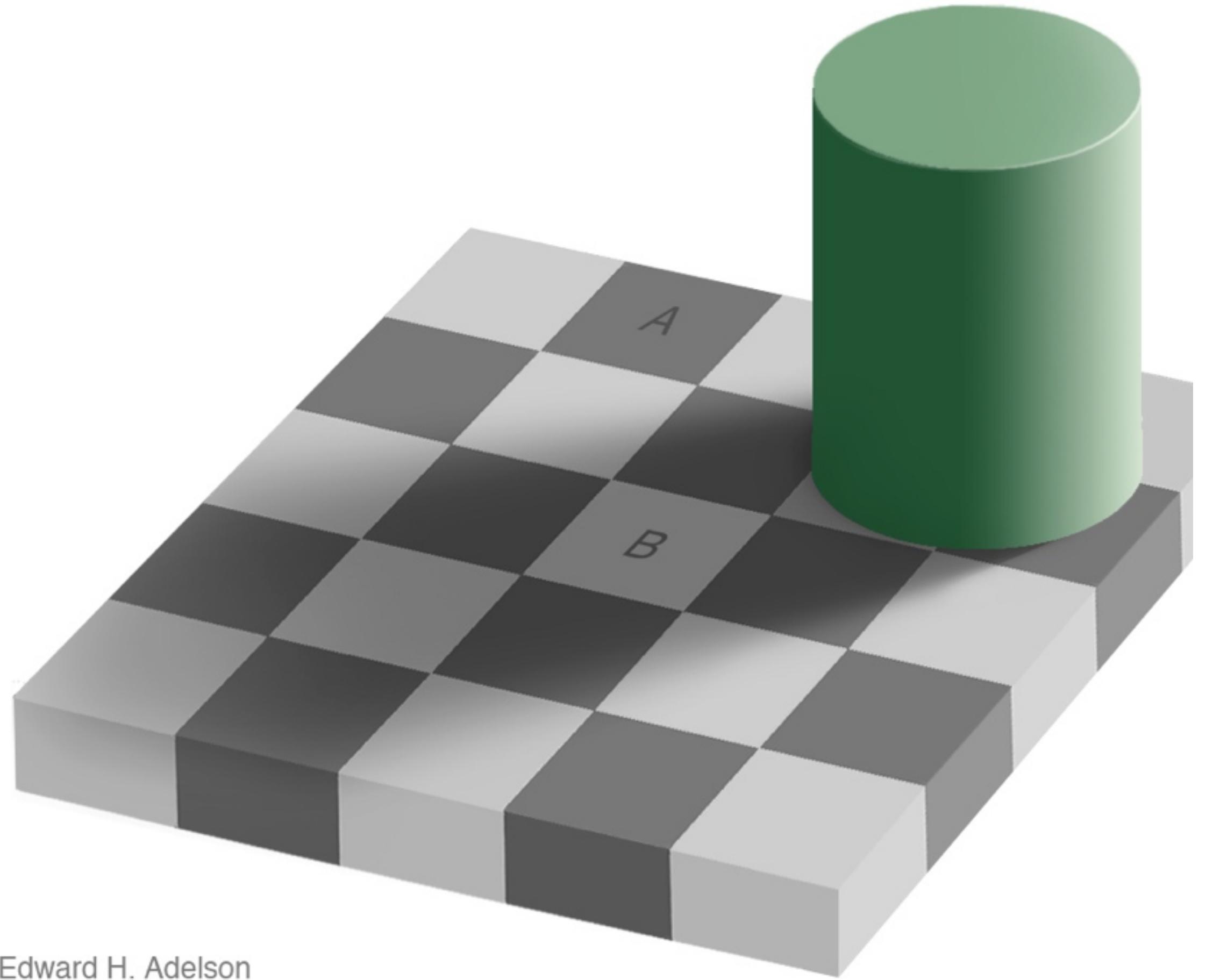
position along
unaligned common



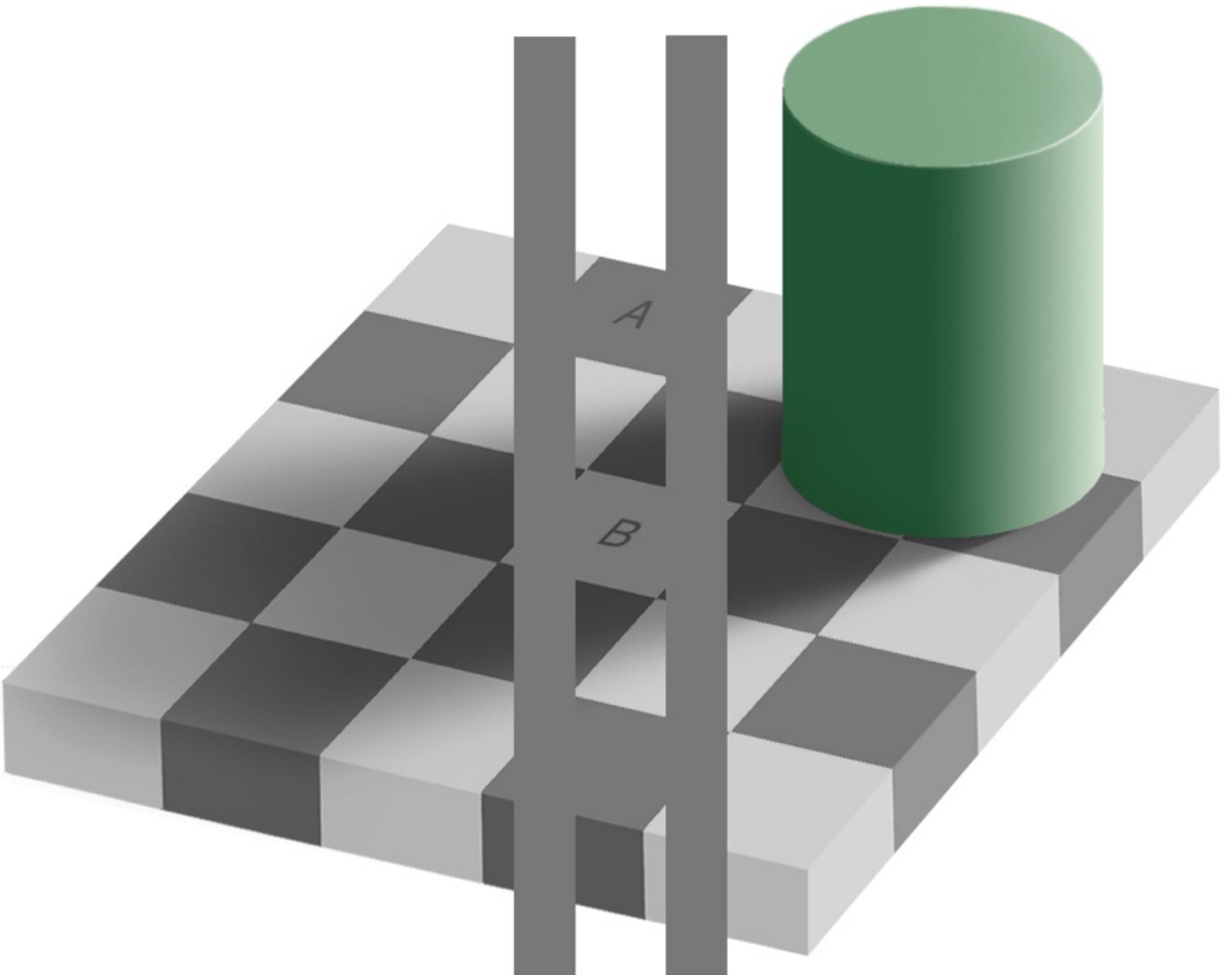
position along
aligned scale

Relative luminance judgements

- Perception of luminance is contextual based on contrast with surroundings

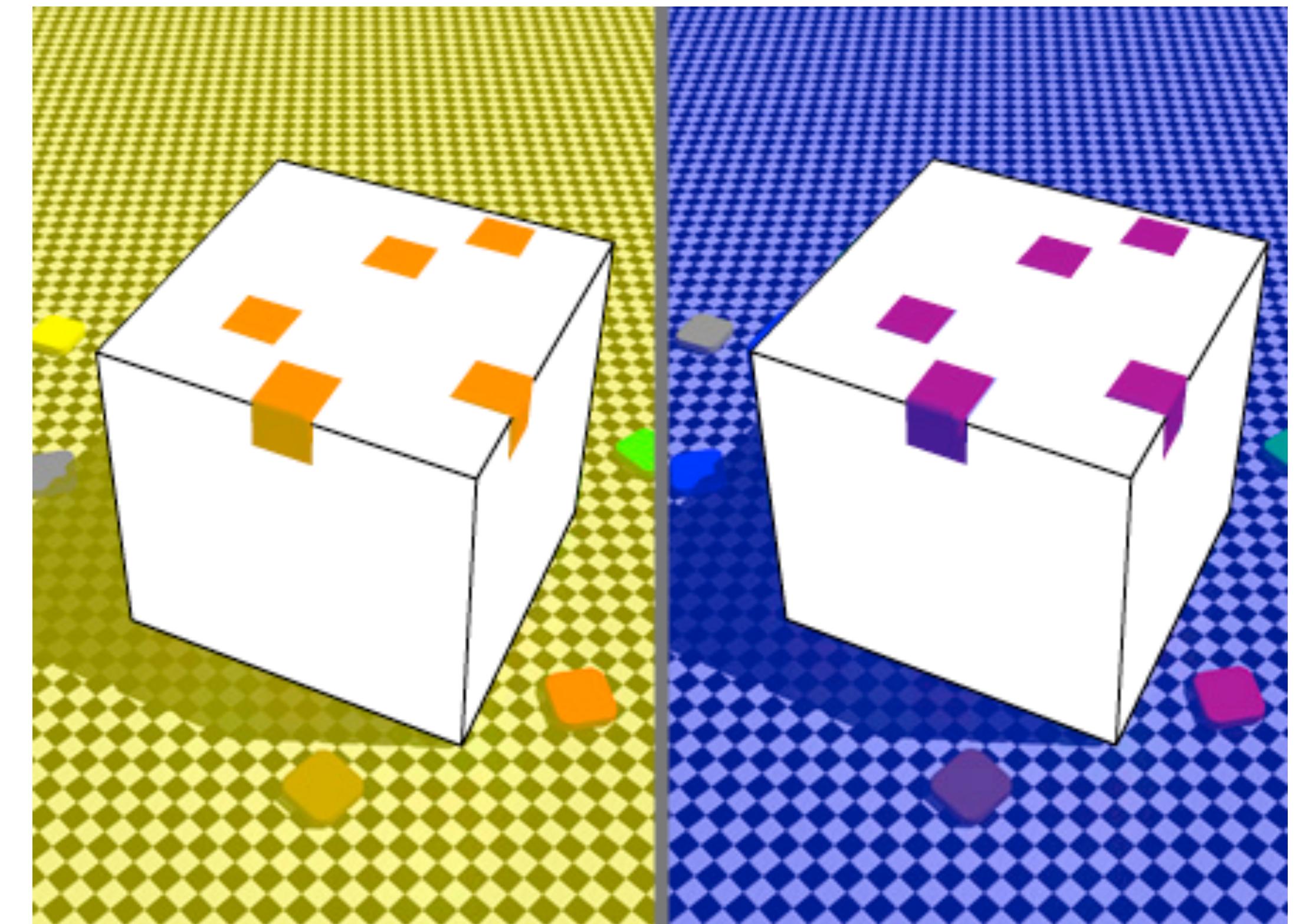
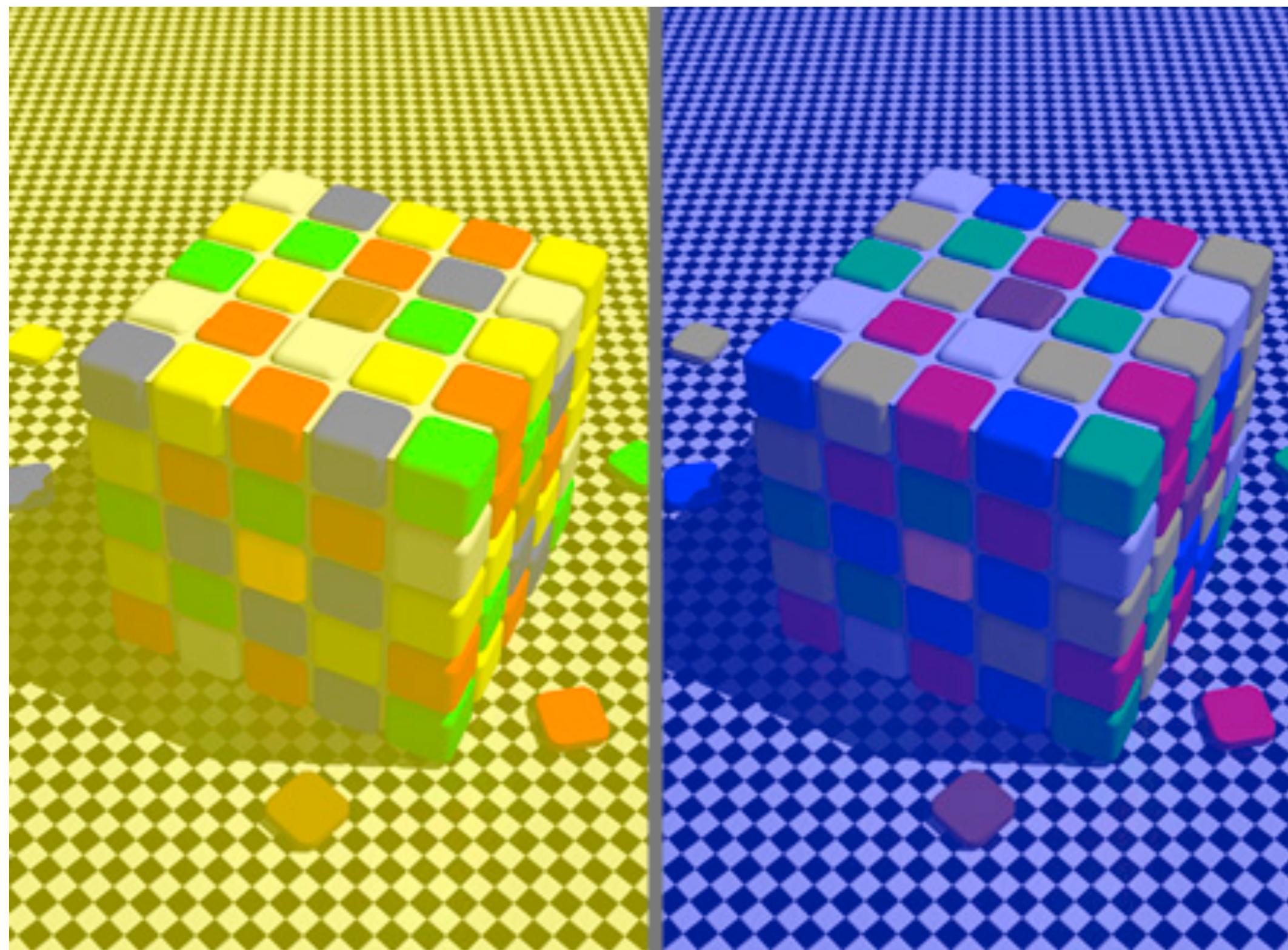


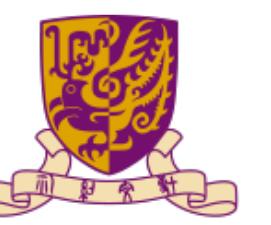
Edward H. Adelson



Relative color judgements

- Color constancy across broad range of illumination conditions



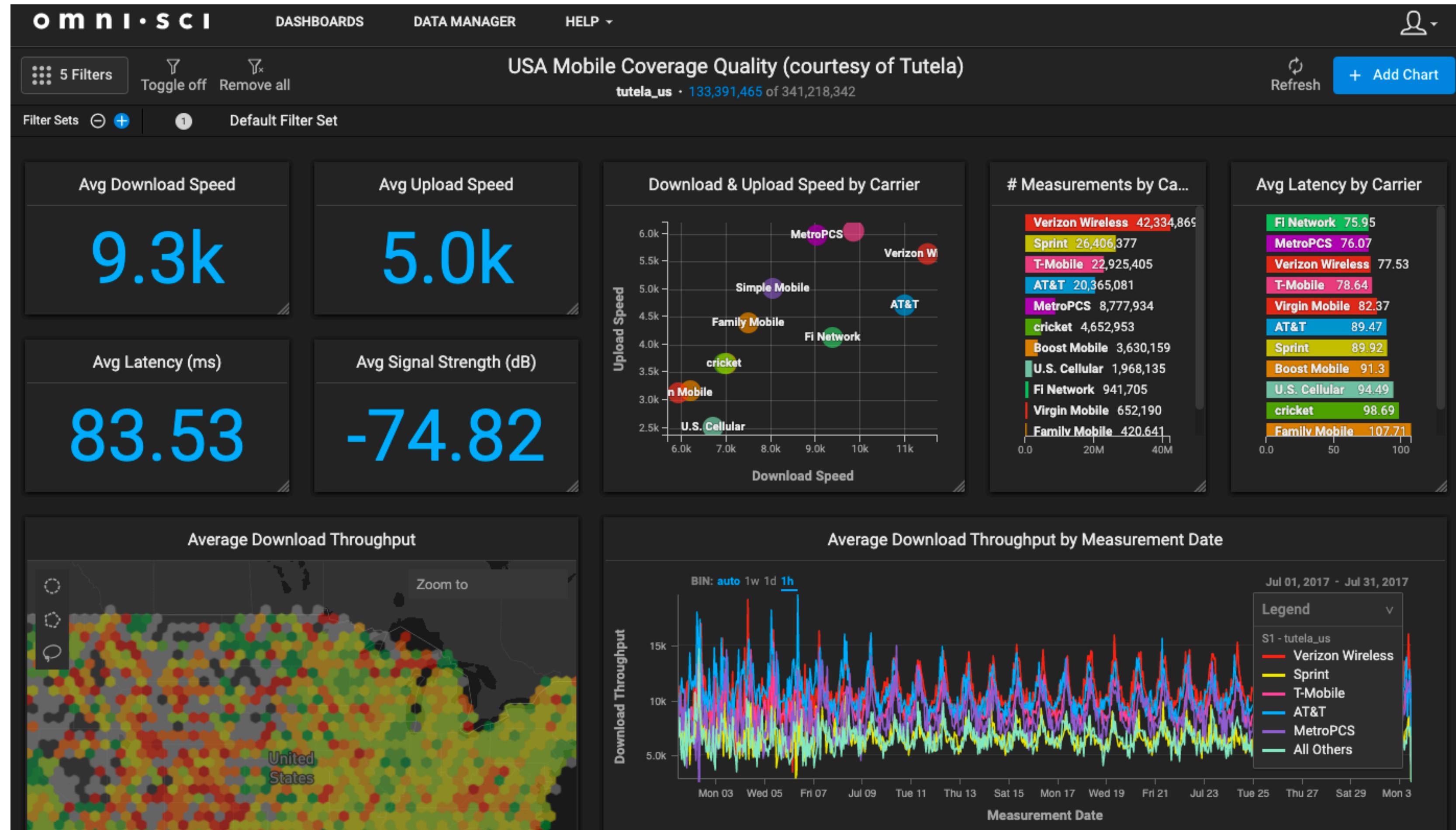


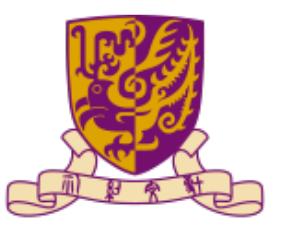
Outline

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

What is information visualization

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





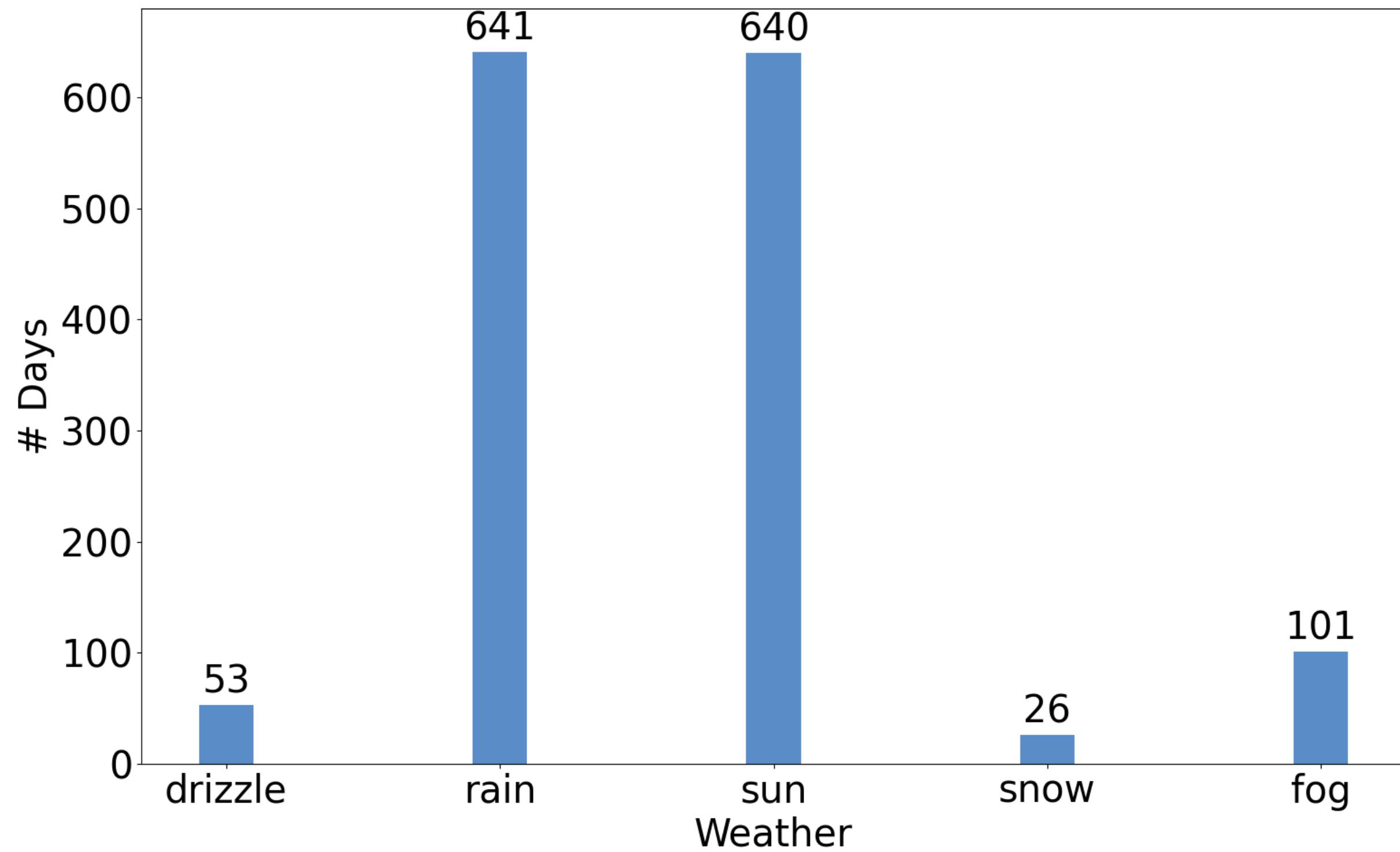
Definition

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

Example

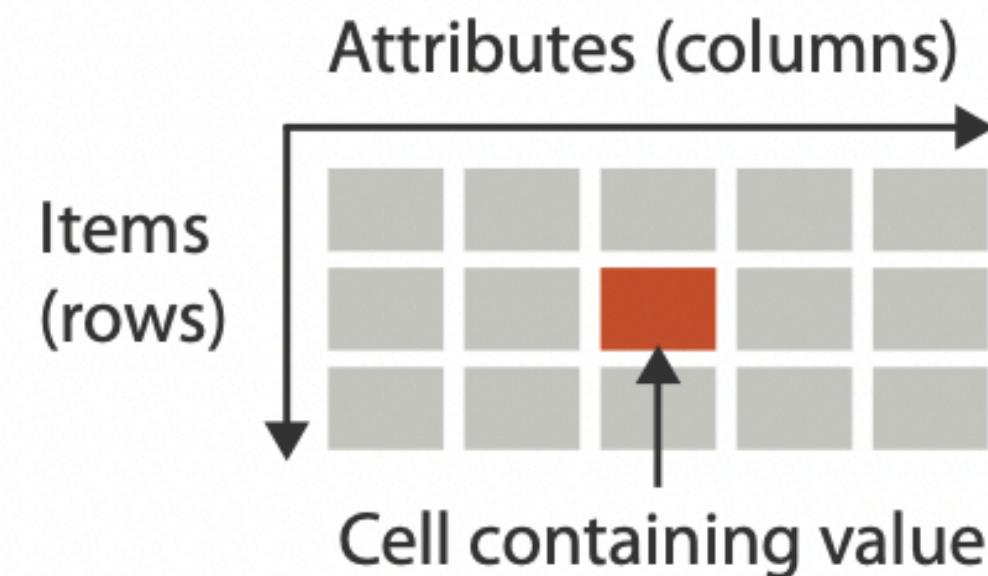
location	date	precipitation	temp_max	temp_min	wind	weather
Seattle	2012-01-01	0.0	12.8	5.0	4.7	drizzle
Seattle	2012-01-02	10.9	10.6	2.8	4.5	rain
Seattle	2012-01-03	0.8	11.7	7.2	2.3	rain
Seattle	2012-01-04	20.3	12.2	5.6	4.7	rain
Seattle	2012-01-05	1.3	8.9	2.8	6.1	rain
Seattle	2012-01-06	2.5	4.4	2.2	2.2	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

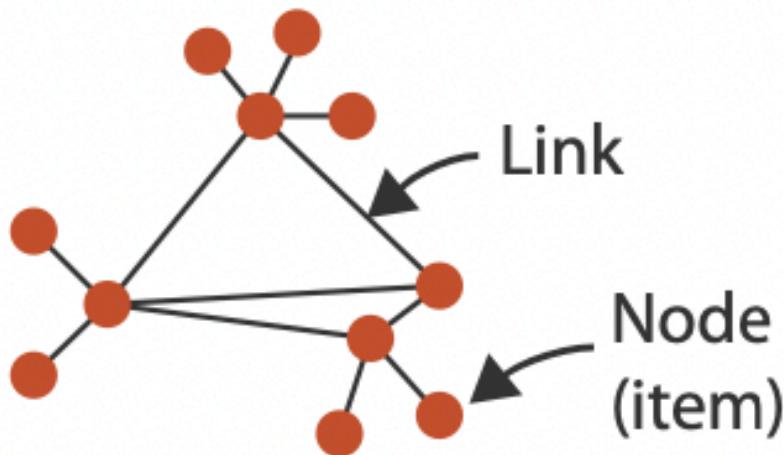


Data types

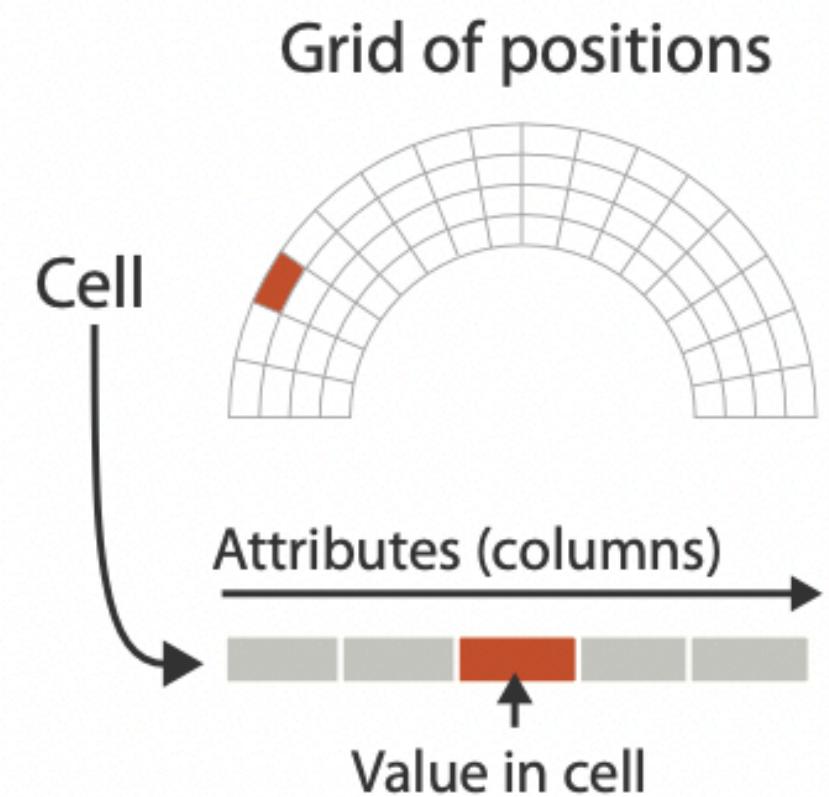
→ Tables



→ Networks



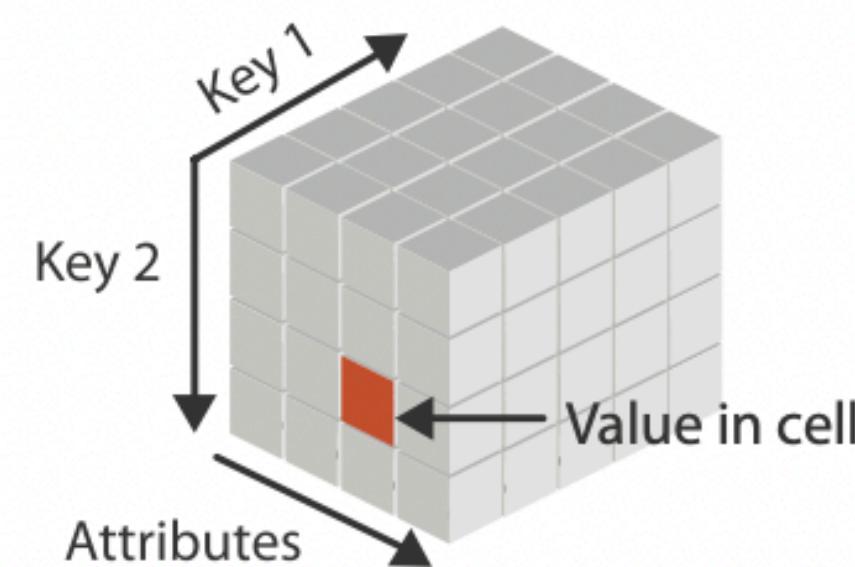
→ Fields (Continuous)



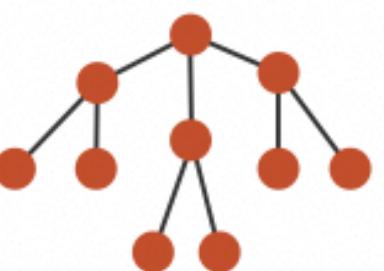
→ Geometry (Spatial)



→ Multidimensional Table



→ Trees



+ Sets
+ Text

Data items and attributes

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	0.65	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	item	5 4-Not Specified	Small Pack	0.44	6/6/05
69		5 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 types

→ Categorical

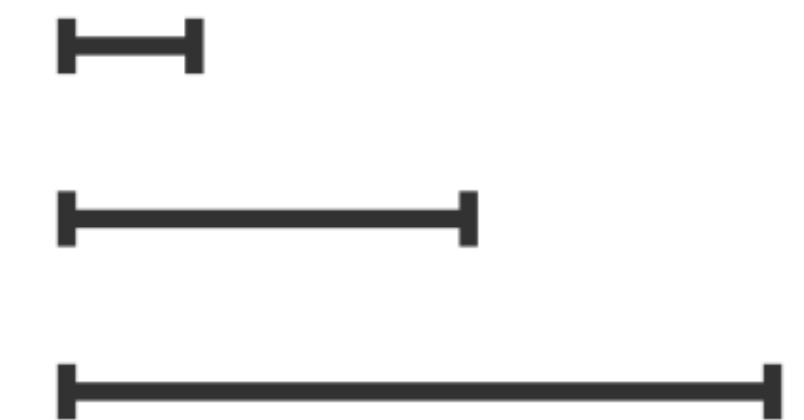


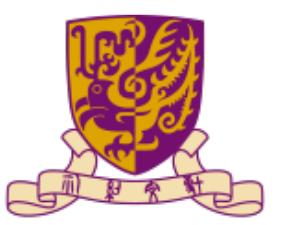
→ Ordered

→ *Ordinal*



→ *Quantitative*

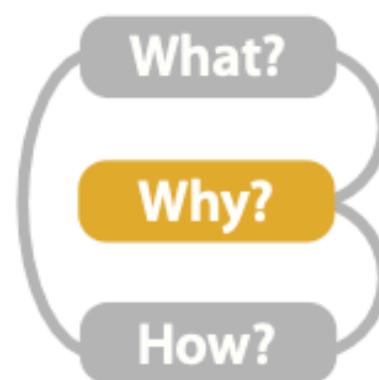
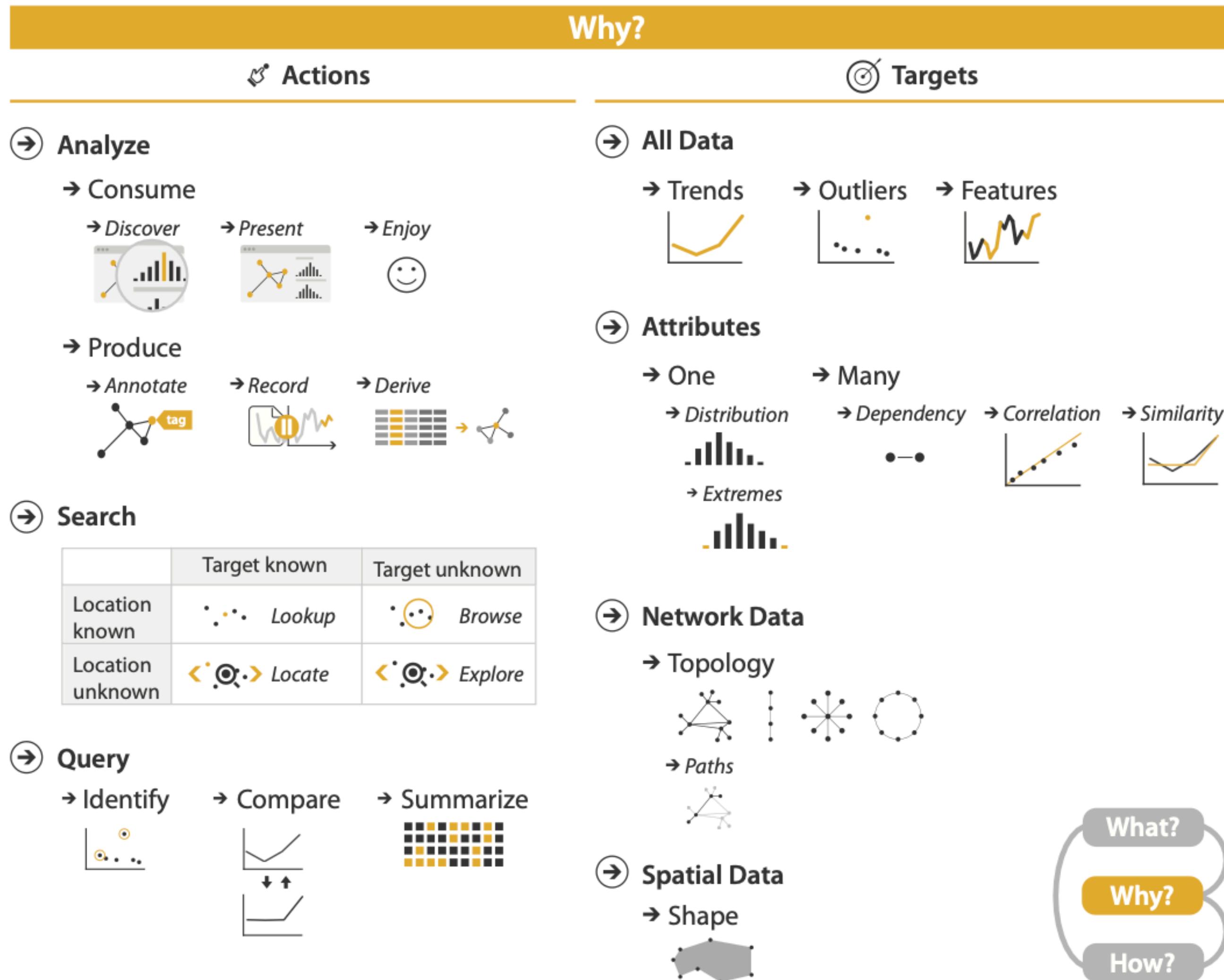
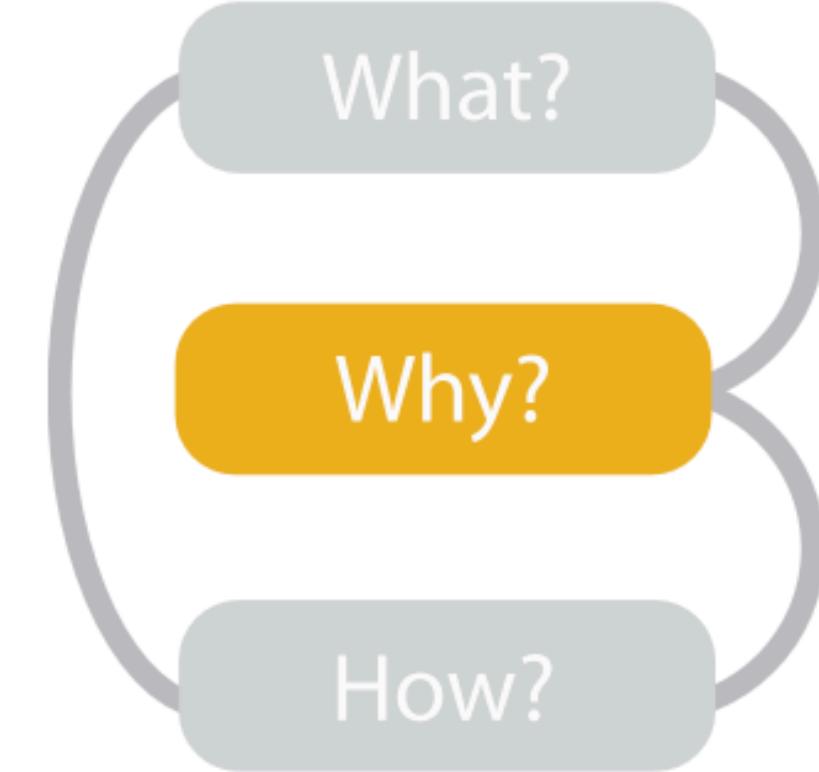




Definition

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

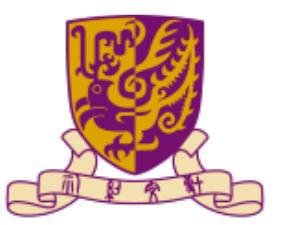
Tasks





Visualization for consumption

- 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

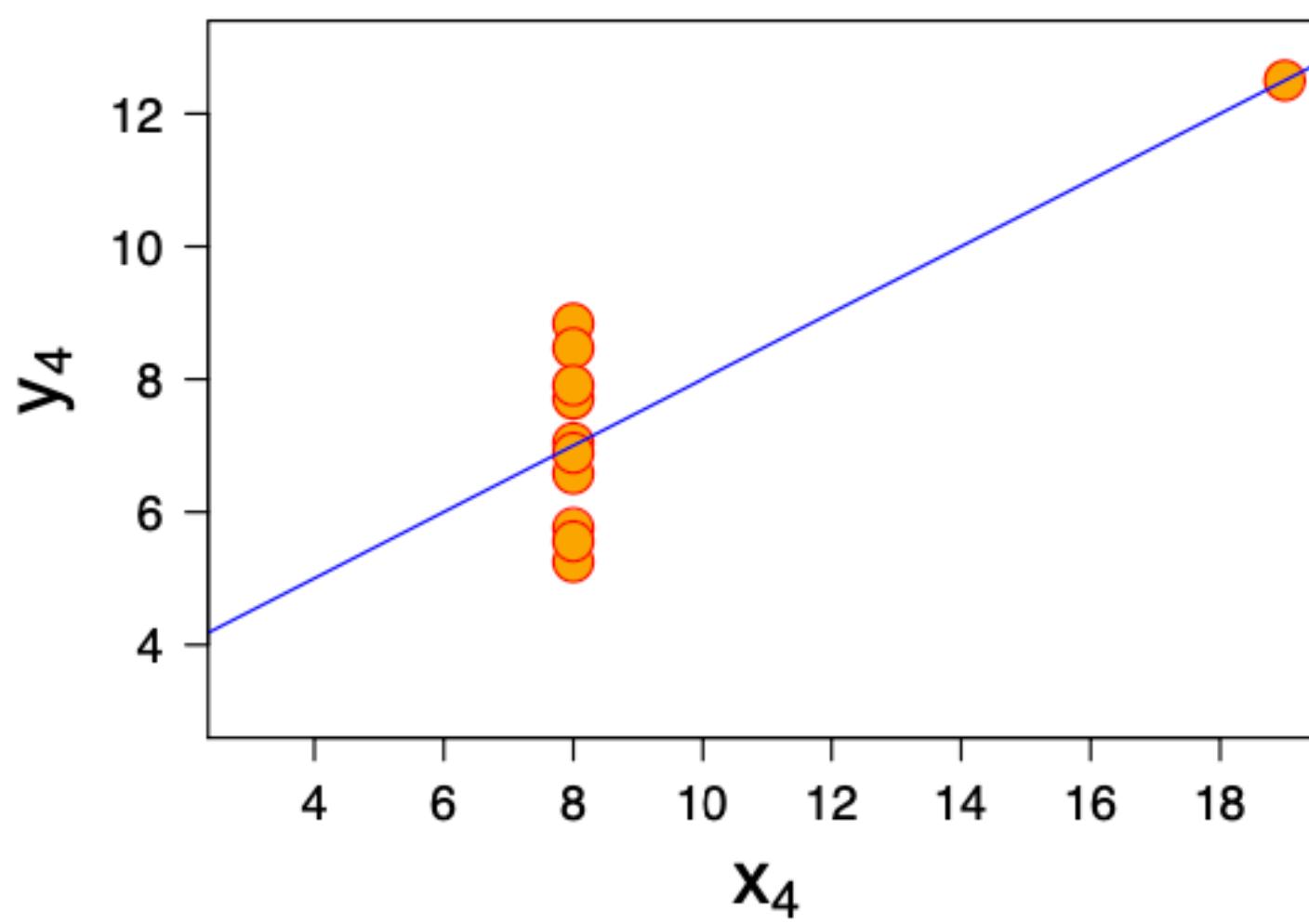
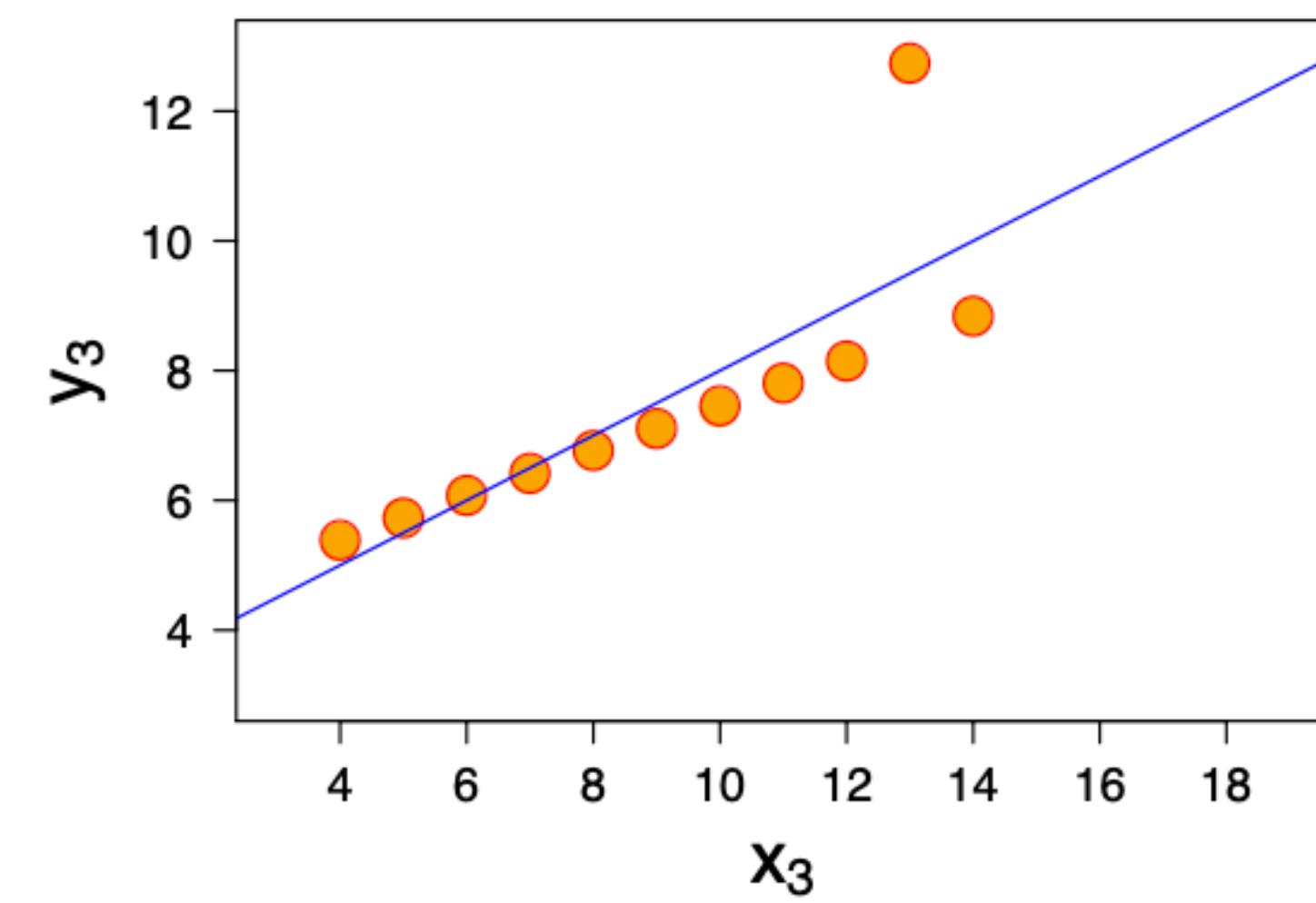
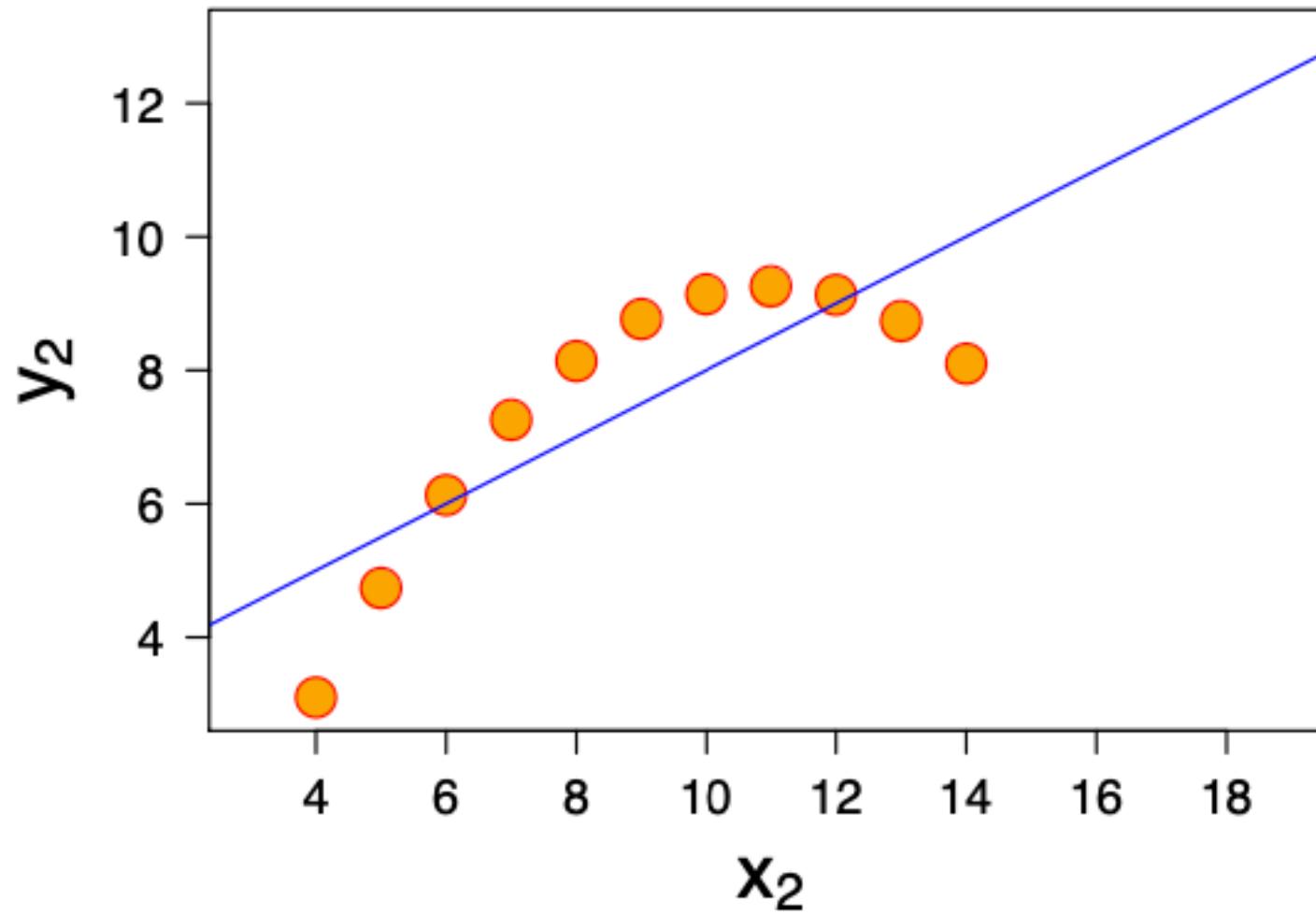
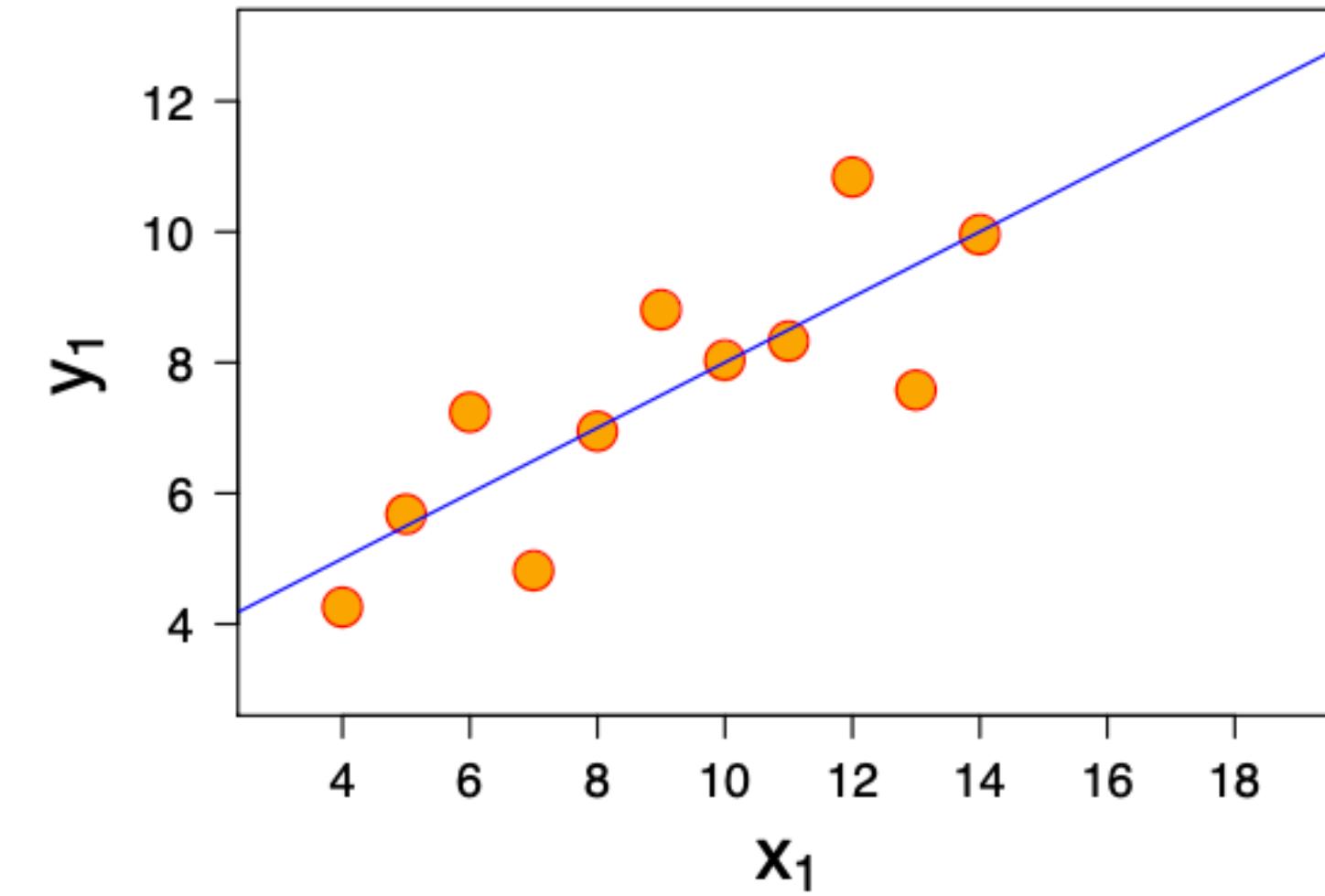
Computer-based visualization systems provide **visual** representations of datasets designed to help people carry out tasks more effectively.

Why visual

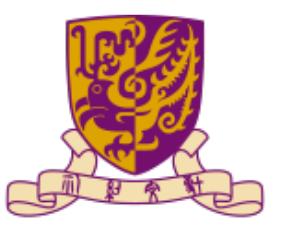
I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0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

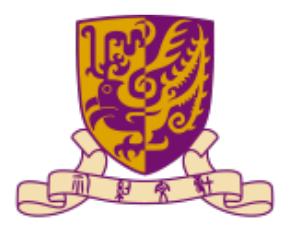


Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816



Definition

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



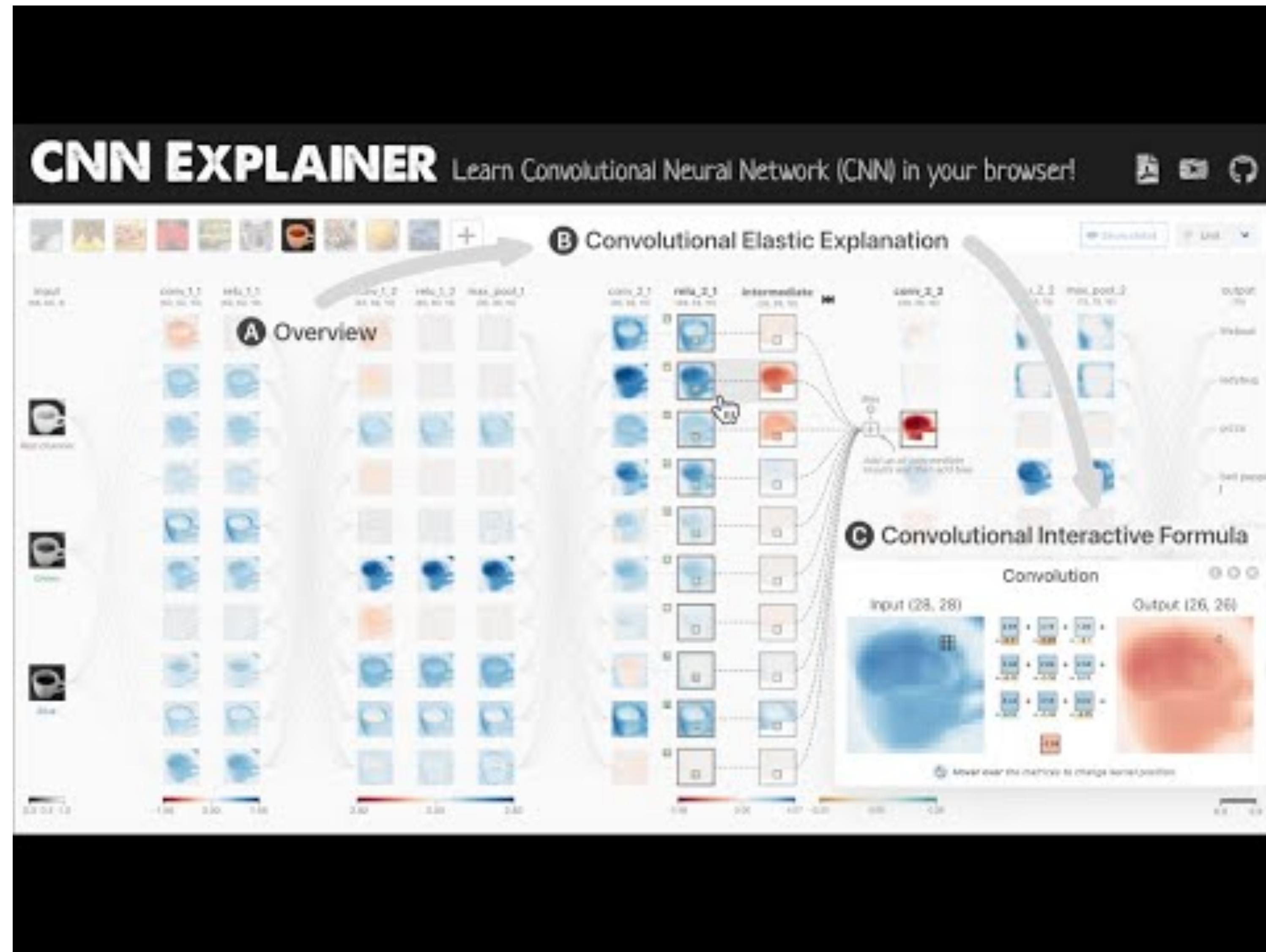
香港中文大學(深圳)

The Chinese University of Hong Kong, Shenzhen

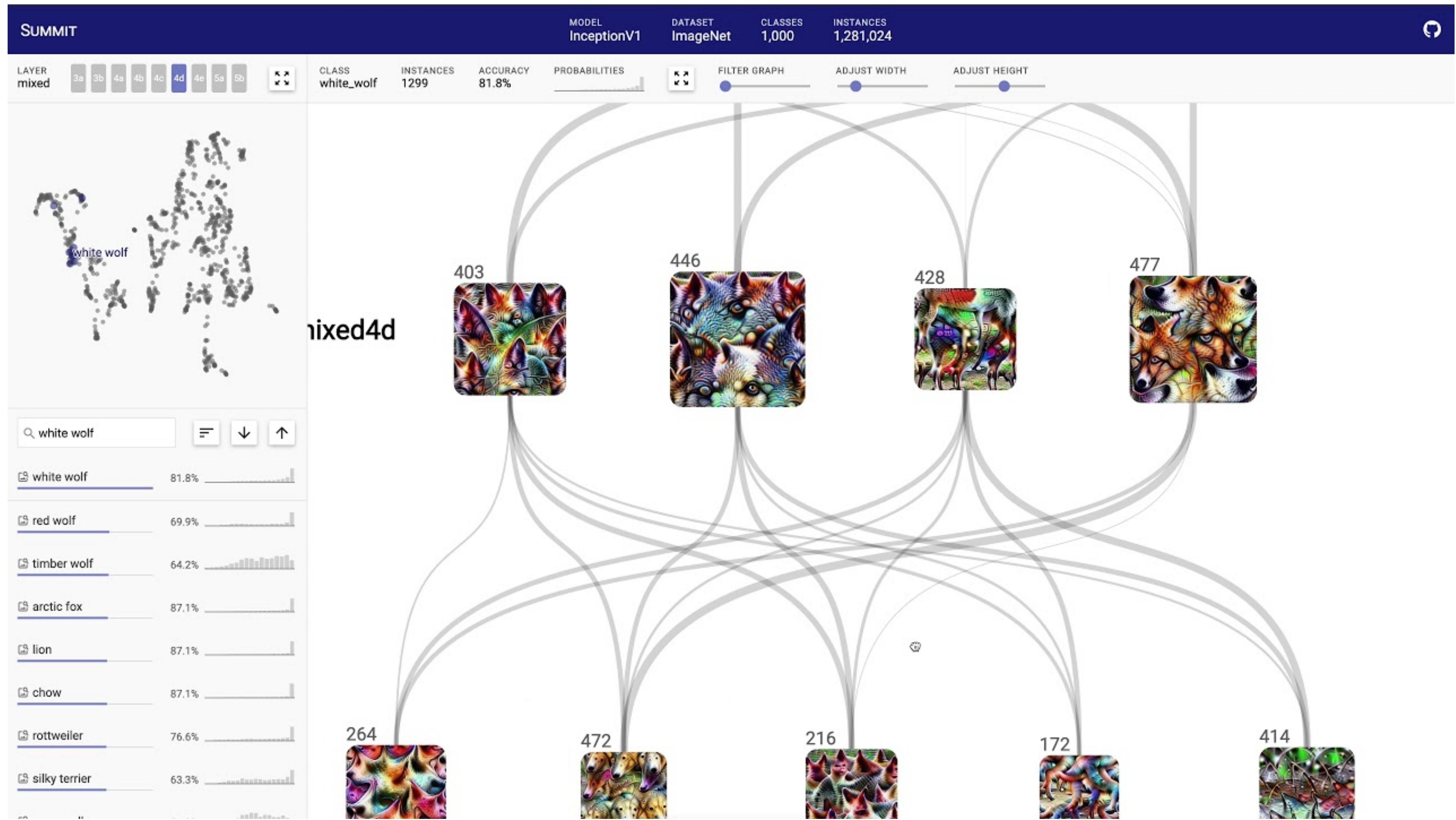
Design example

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

Design example



Design example





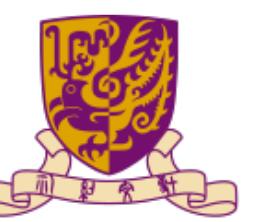
Definition

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

How do we do visualization

How?

Encode	Manipulate	Facet	Reduce	
<p>④ Arrange</p> <p>→ Express ↔</p> <p>→ Separate </p> <p>→ Order </p> <p>→ Use </p> <div style="border: 1px solid #ccc; border-radius: 10px; padding: 5px; margin-top: 10px;"> What? </div> <div style="border: 1px solid #ccc; border-radius: 10px; padding: 5px; margin-top: 10px;"> Why? </div> <div style="background-color: #009640; color: white; border-radius: 10px; padding: 5px; margin-top: 10px;"> How? </div>	<p>④ Map from categorical and ordered attributes</p> <p>→ Color → <i>Hue</i> → <i>Saturation</i> → <i>Luminance</i> </p> <p>→ Size, Angle, Curvature, ... </p> <p>→ Shape + ● ■ ▲</p> <p>→ Motion <i>Direction, Rate, Frequency, ...</i> </p>	<p>④ Change </p> <p>④ Select </p> <p>④ Navigate </p>	<p>④ Juxtapose </p> <p>④ Partition </p> <p>④ Superimpose </p>	<p>④ Filter </p> <p>④ Aggregate </p> <p>④ Embed </p>



香港中文大學(深圳)

The Chinese University of Hong Kong, Shenzhen

Visual encoding



Maps

FACTS

TEACH

ABOUT



HOW TO USE

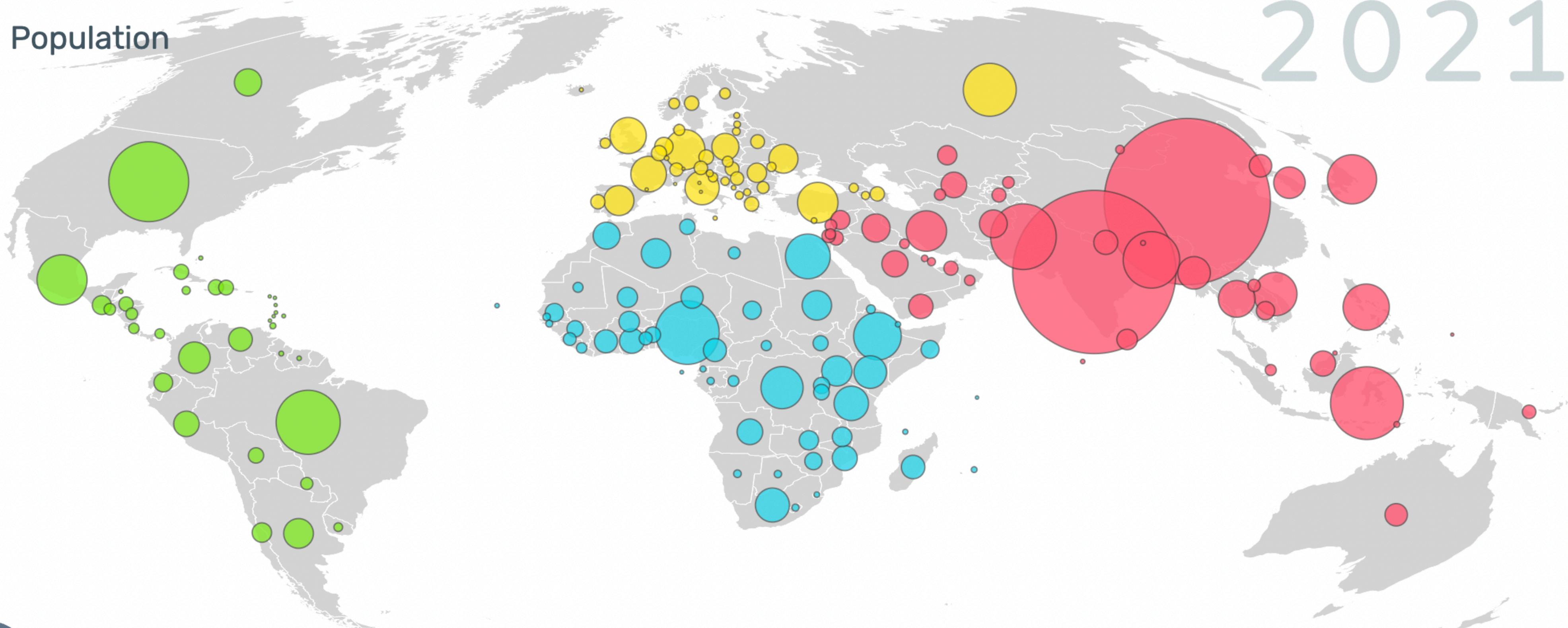
Share



English



Population



2021

Color

World Regions



Select

Search...

- Afghanistan
- Albania
- Algeria
- Andorra
- Angola
- Antigua and Barbuda

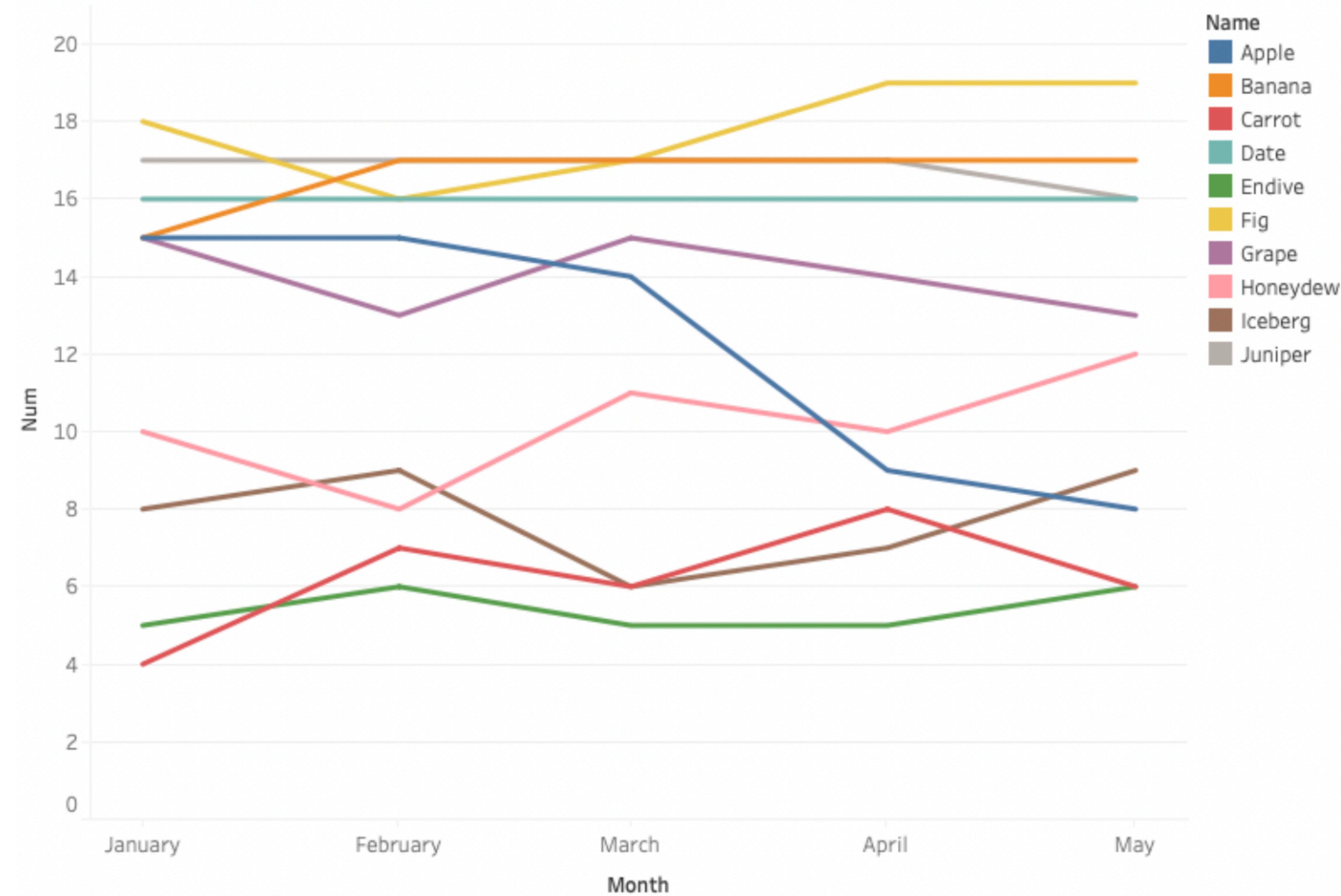
Size

Population



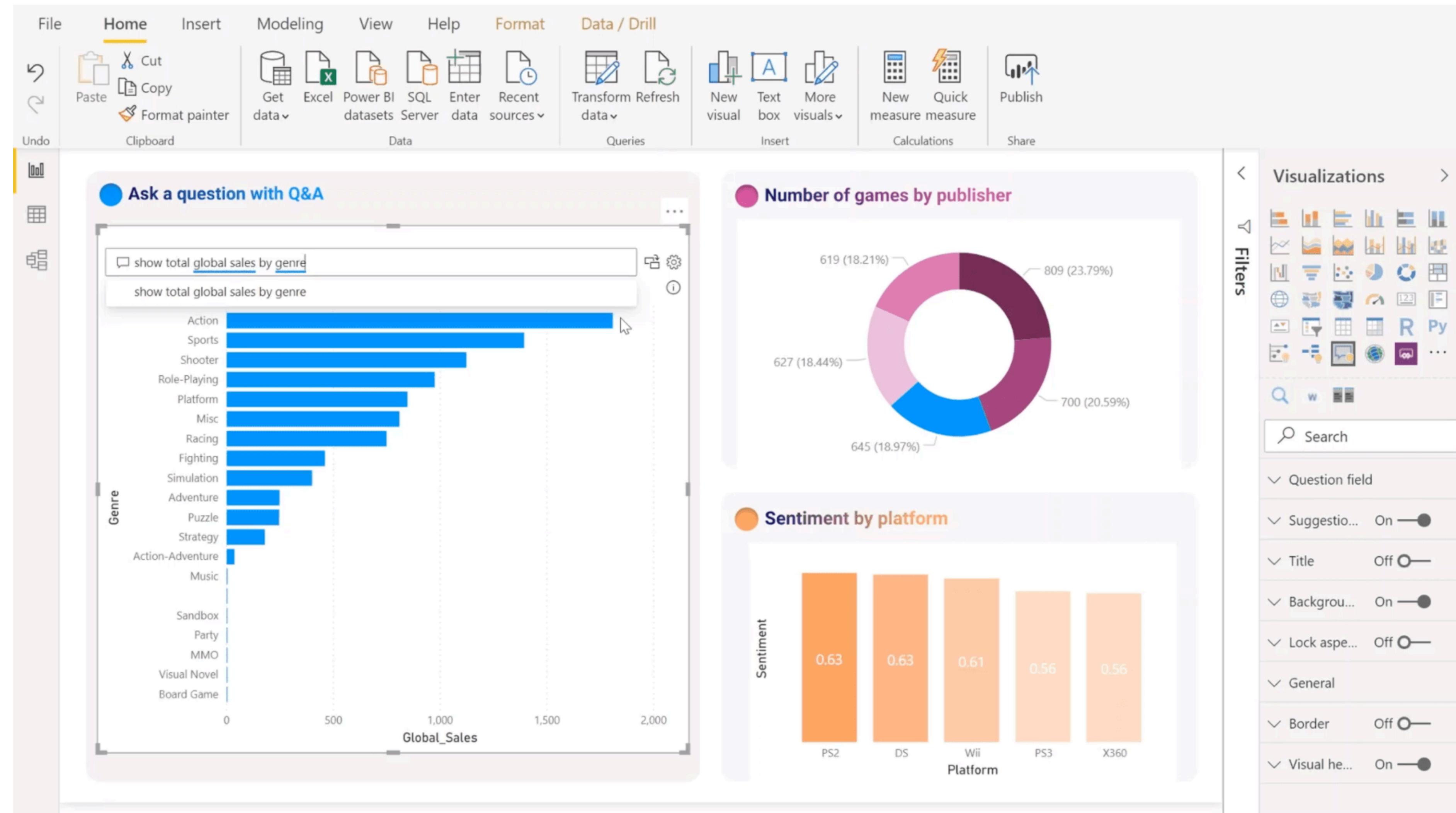
Tools

- Tableau



Tools

- 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

④ Express Values



⑤ Separate, Order, Align Regions

→ Separate



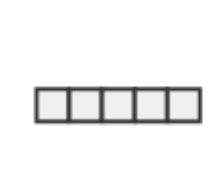
→ Order



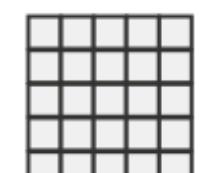
→ Align



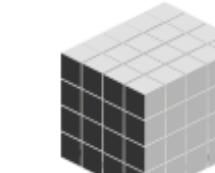
→ 1 Key
List



→ 2 Keys
Matrix



→ 3 Keys
Volume



→ Many Keys
Recursive Subdivision



⑥ Axis Orientation

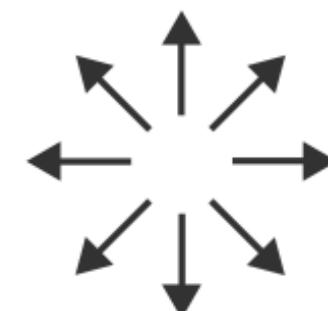
→ Rectilinear

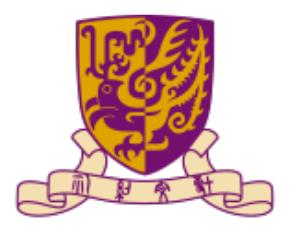


→ Parallel



→ Radial

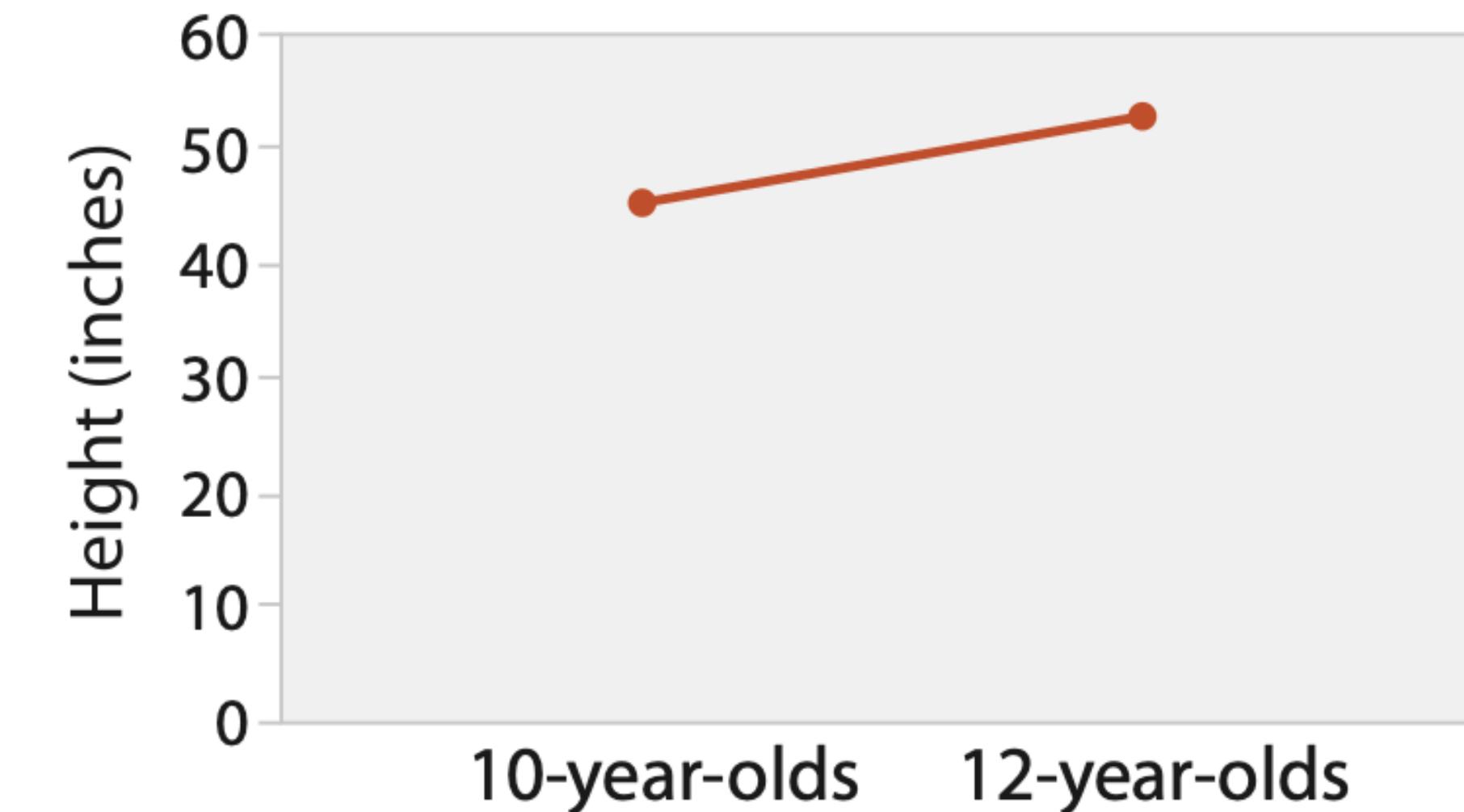
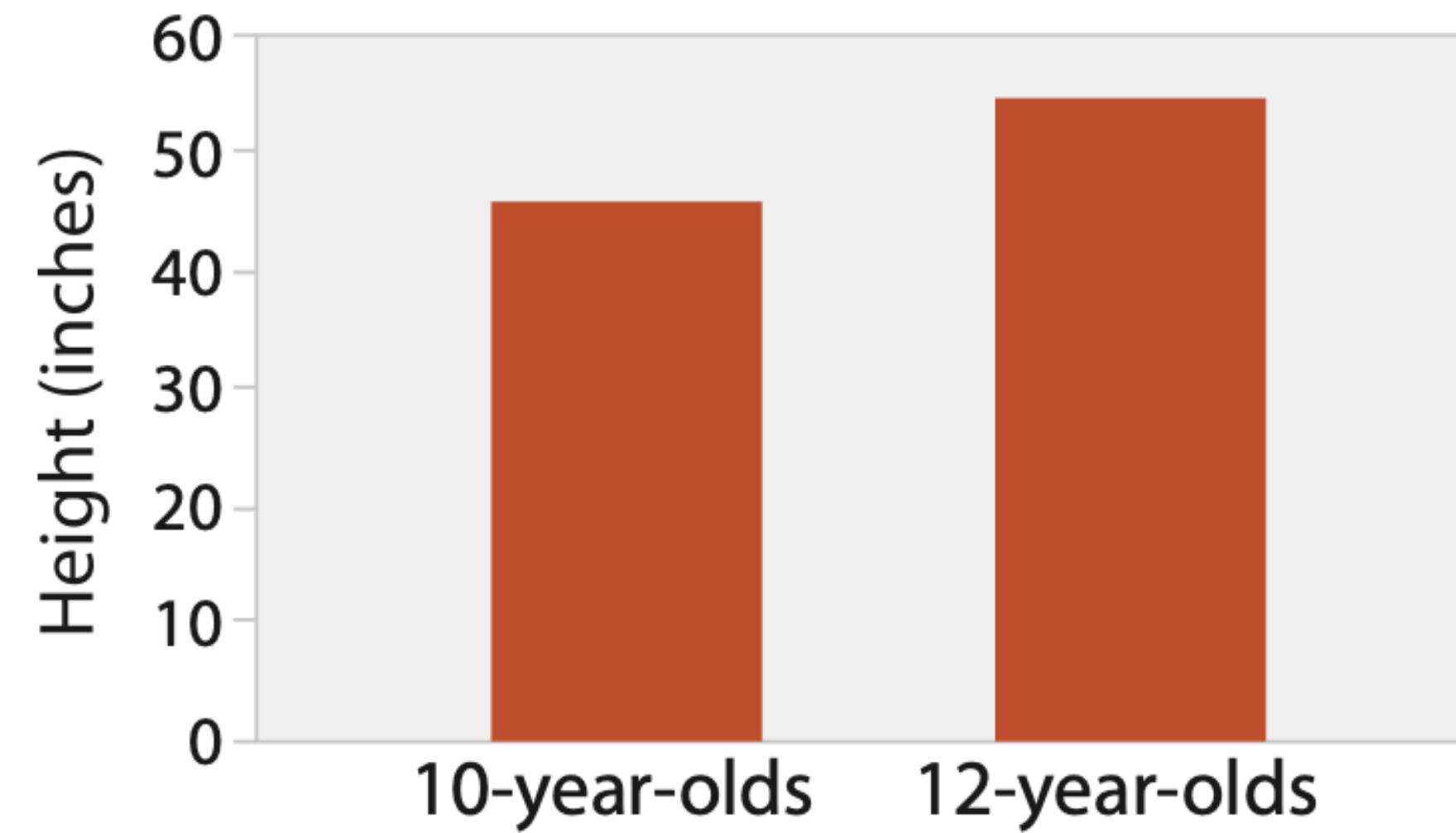
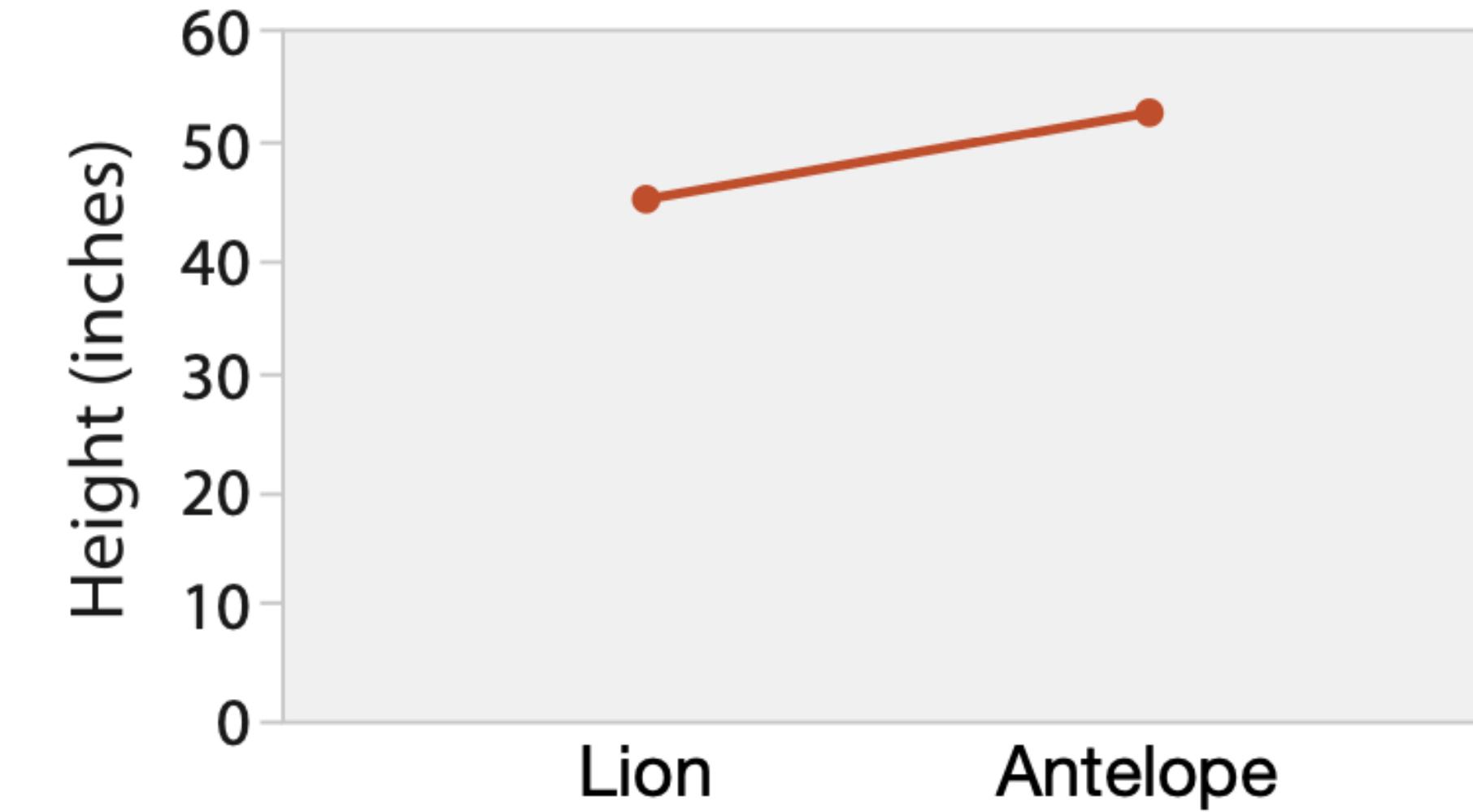
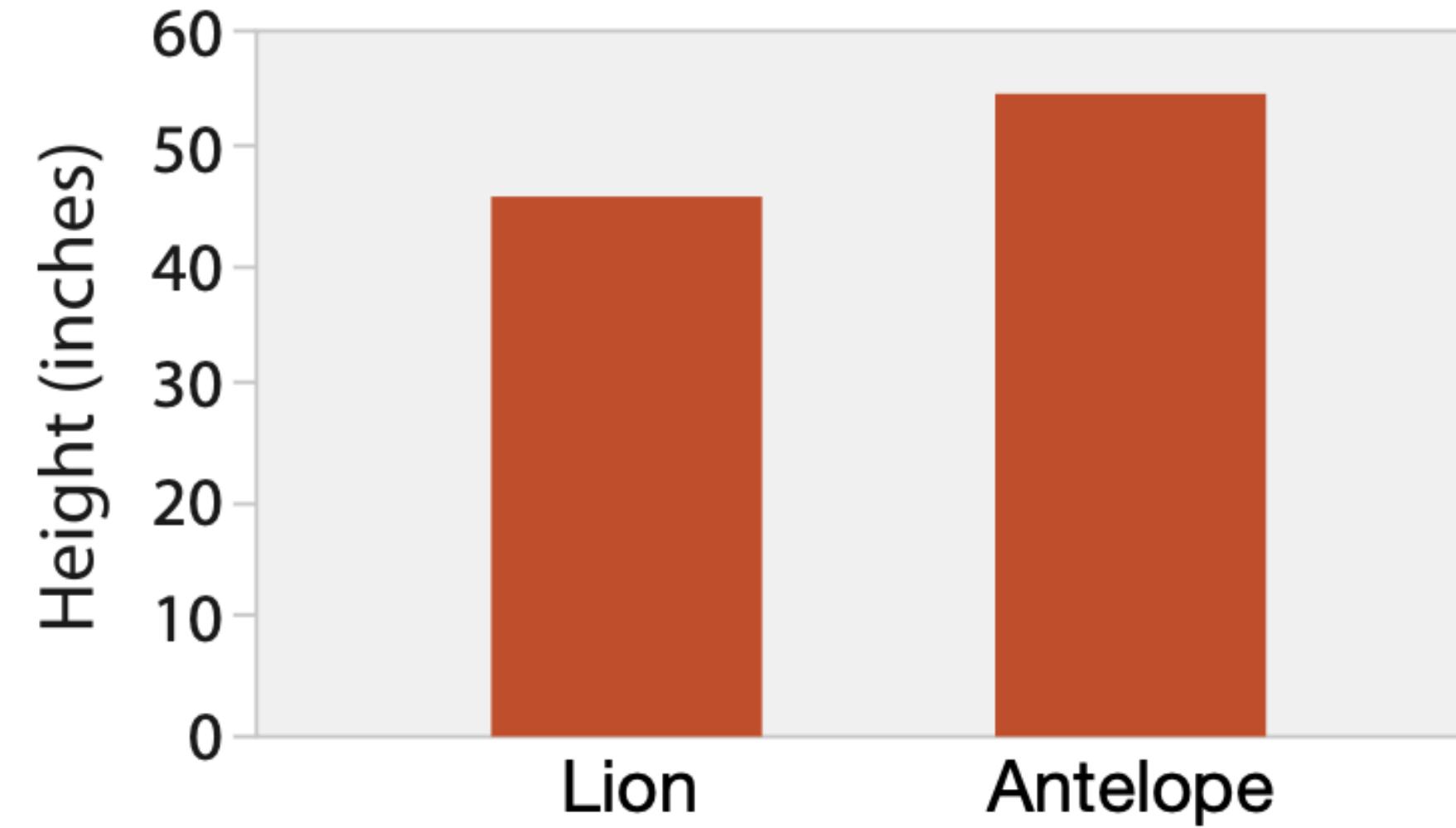




Basic visualization charts

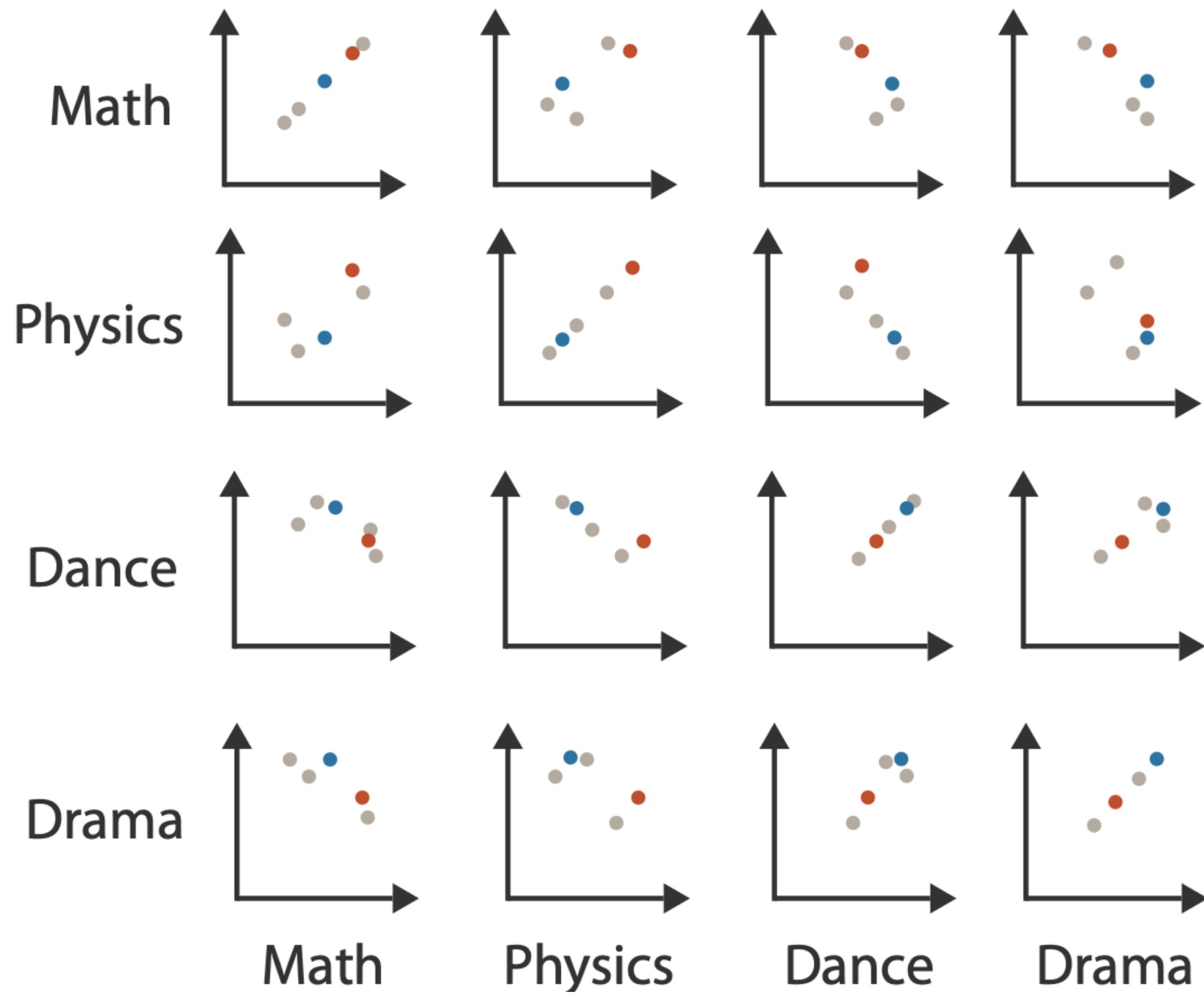
- Line chart
- Bar chart
- Scatter plot matrices
- Parallel coordinates
- Pie chart
- Categorical map
- Tree visualization
- Set visualization
- Graph visualization

Line and bar charts

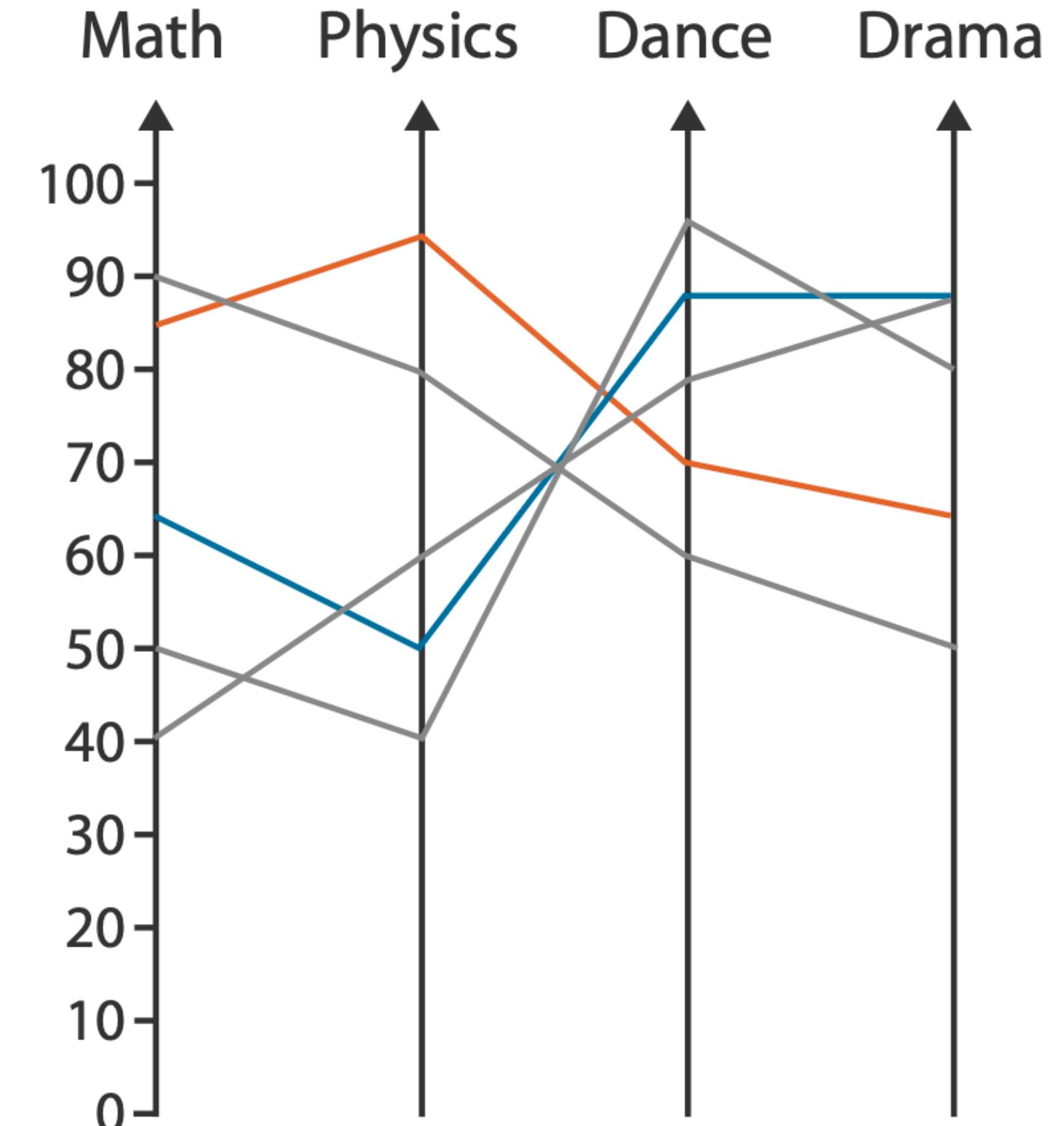


Scatter plot matrices and parallel coordinates

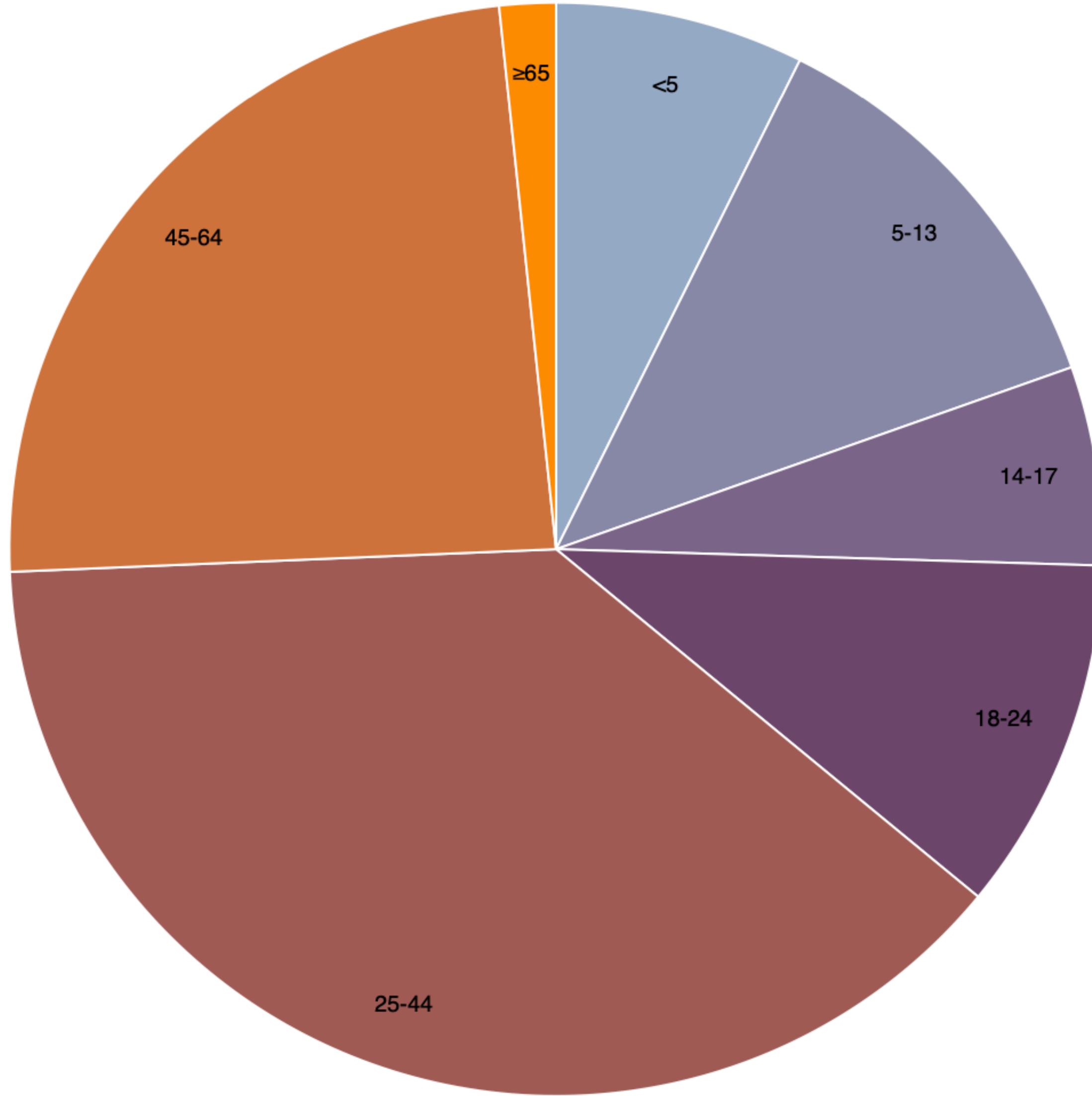
Scatterplot Matrix



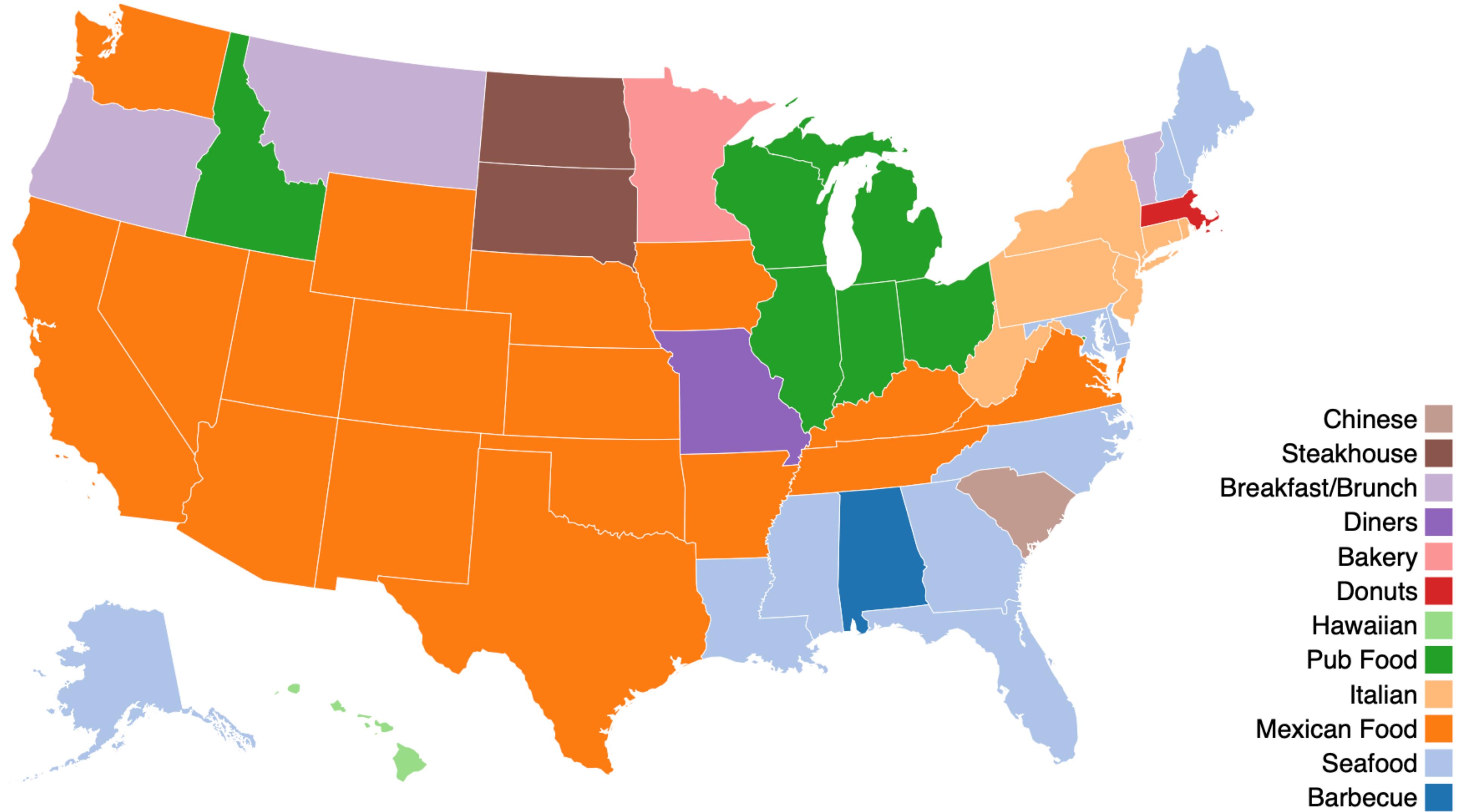
Parallel Coordinates



Pie chart

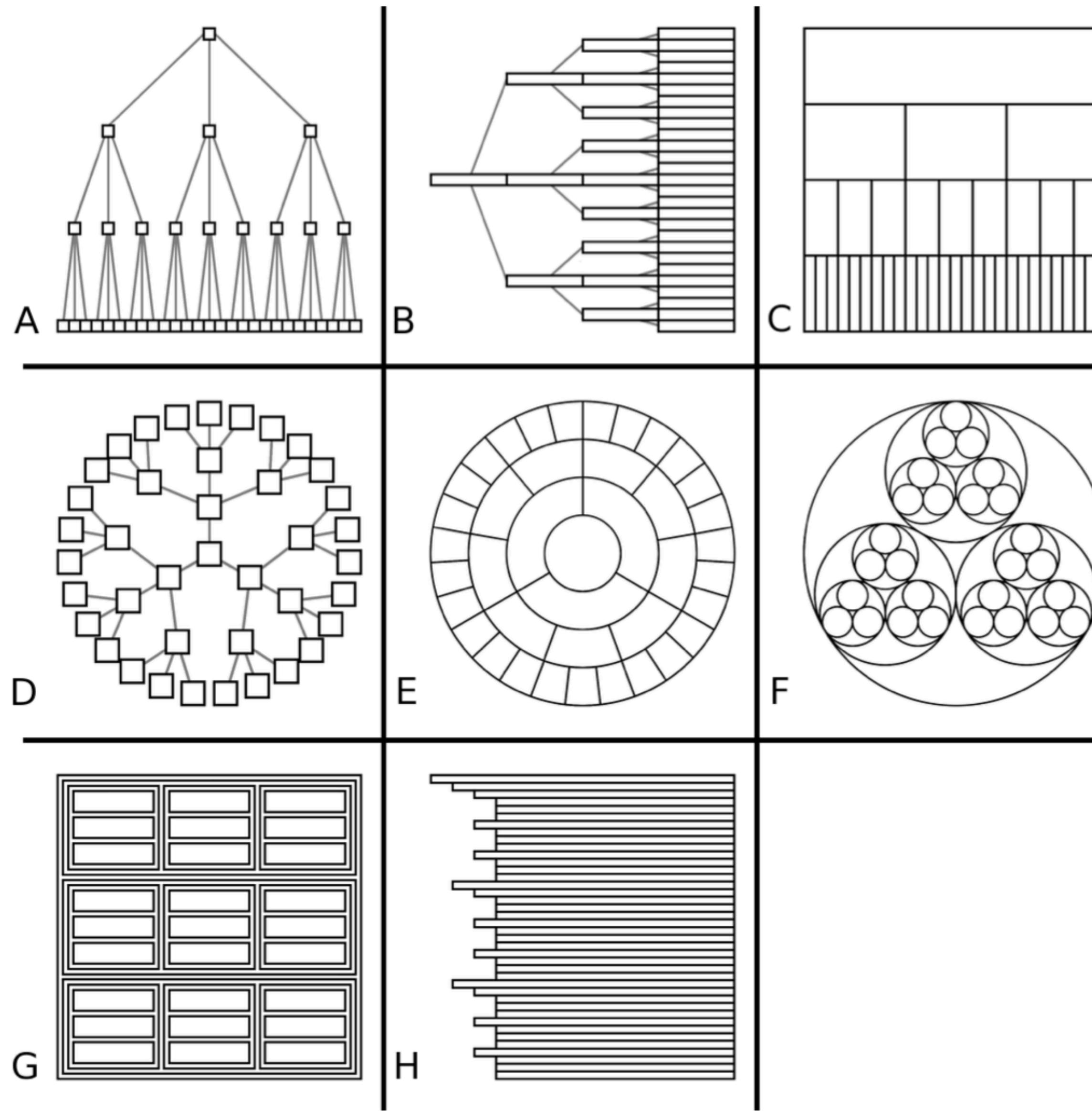


Categorial map

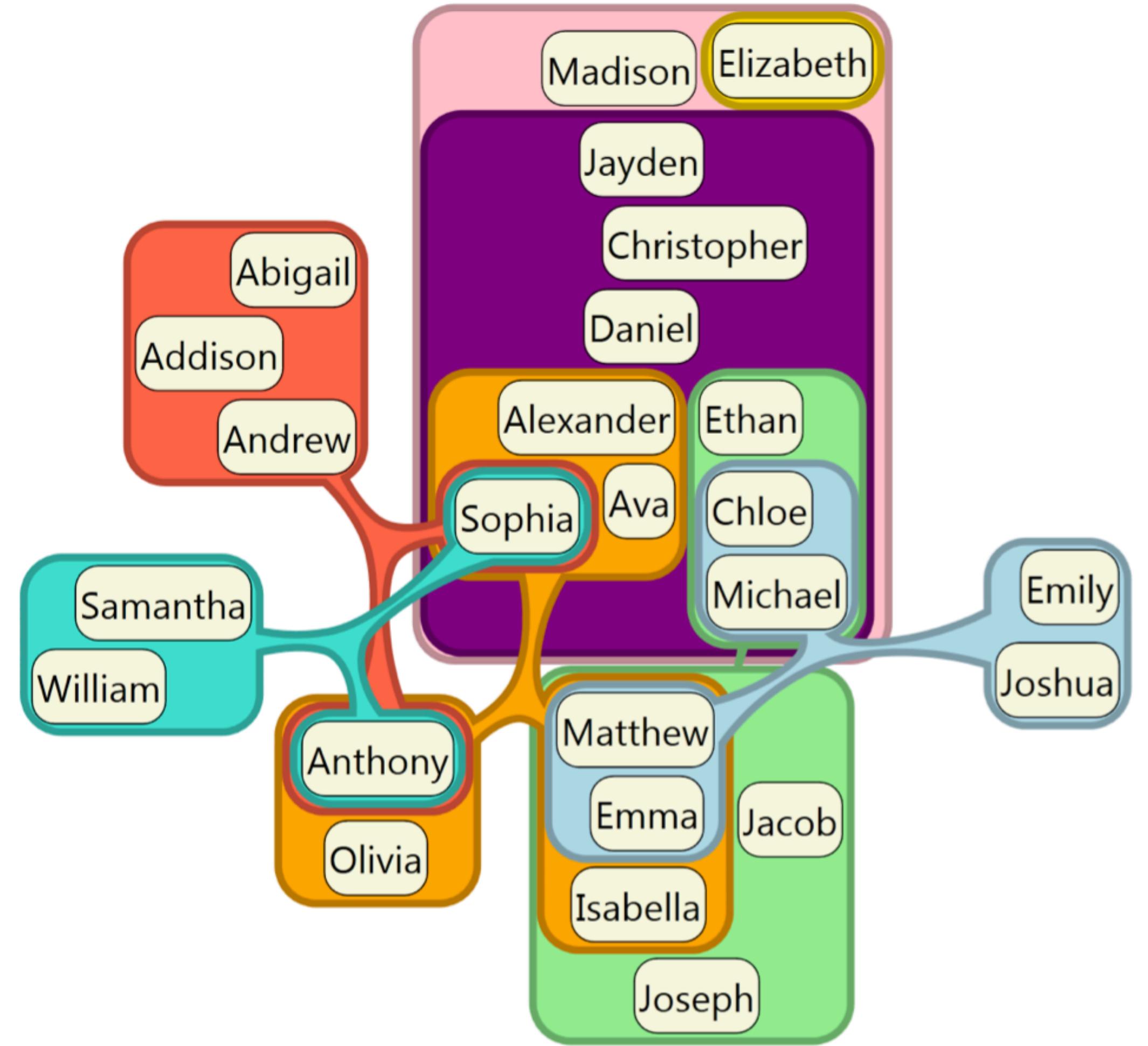
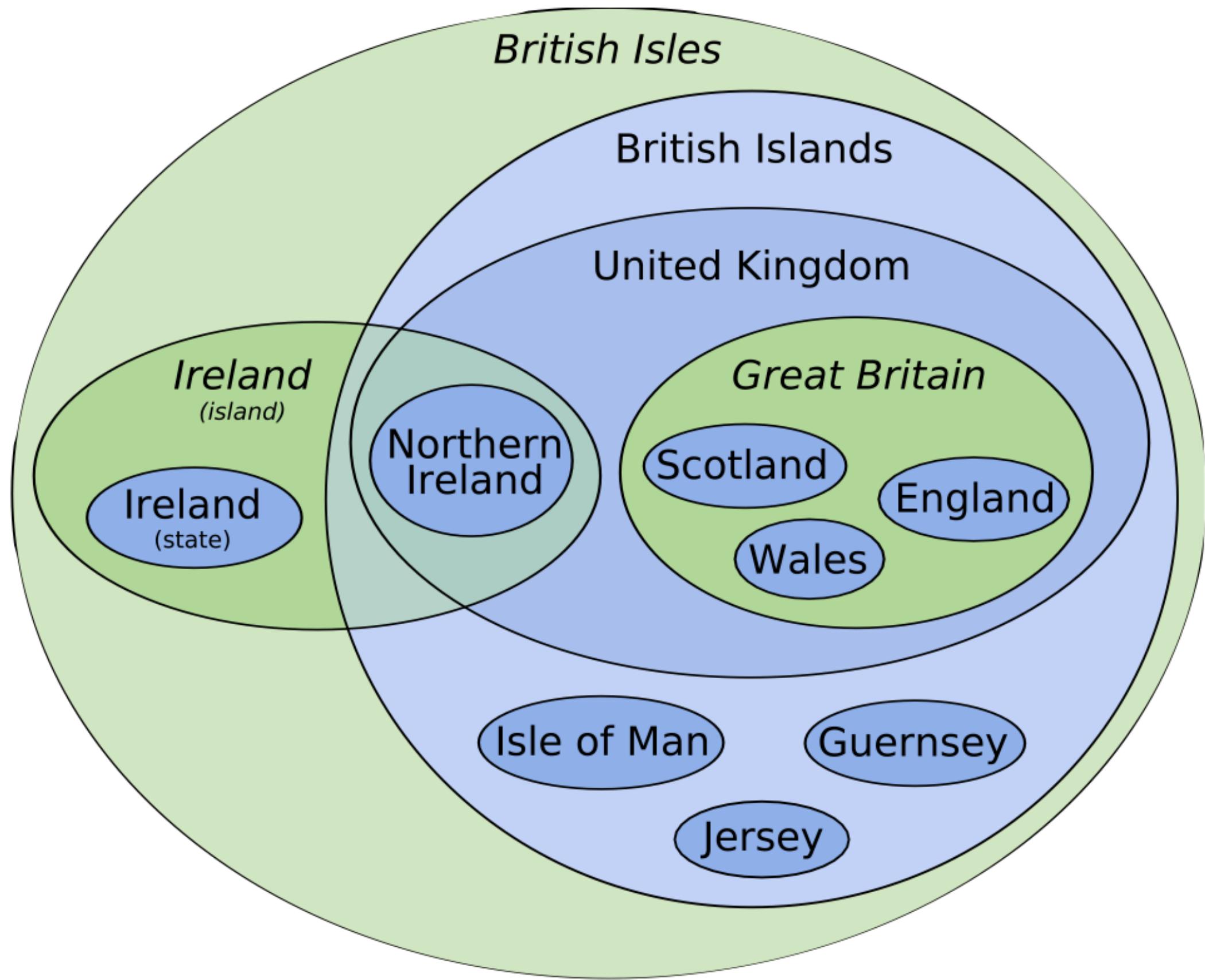


- Chinese
- Steakhouse
- Breakfast/Brunch
- Diners
- Bakery
- Donuts
- Hawaiian
- Pub Food
- Italian
- Mexican Food
- Seafood
- Barbecue

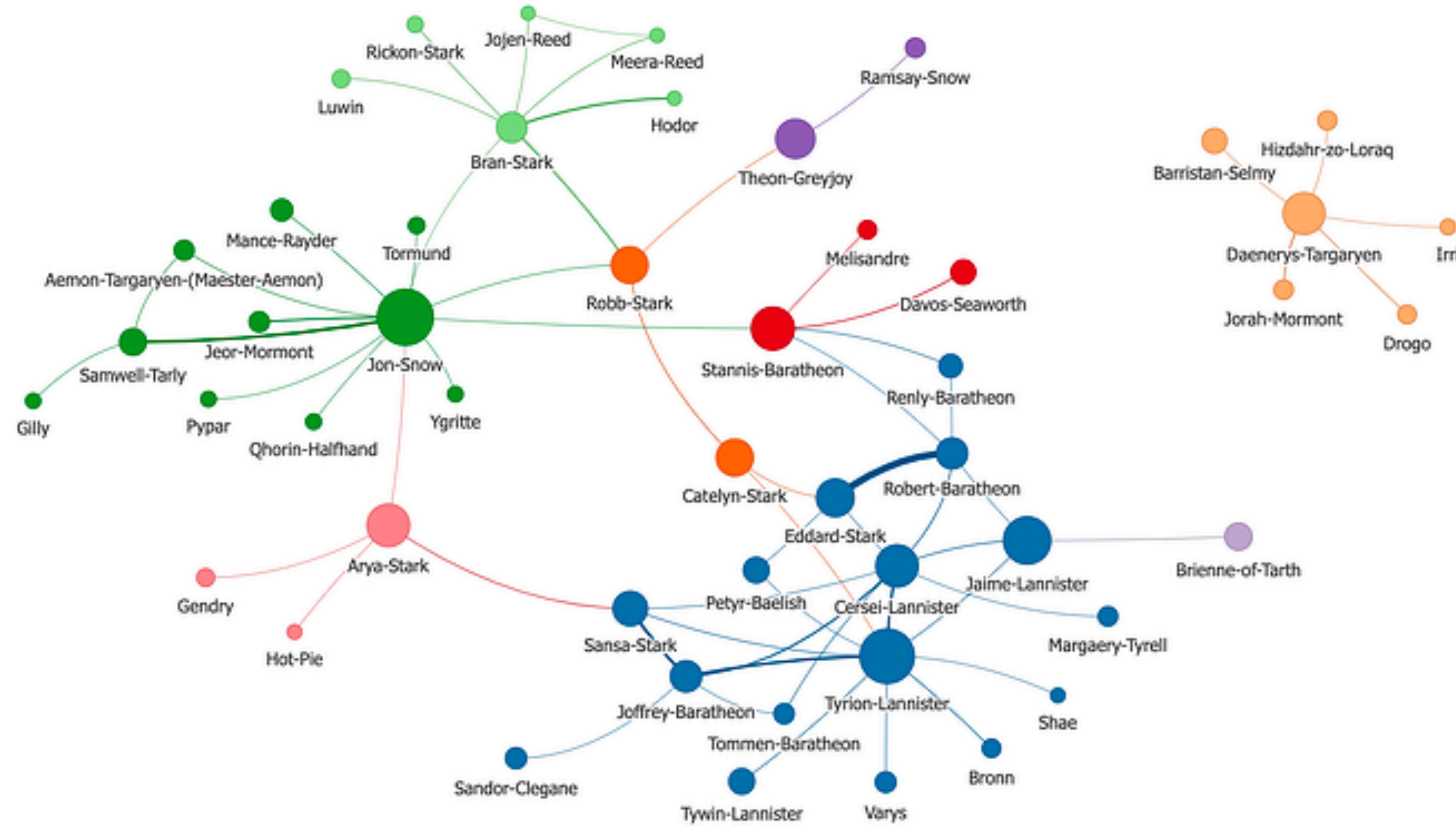
Tree visualization



Set visualization

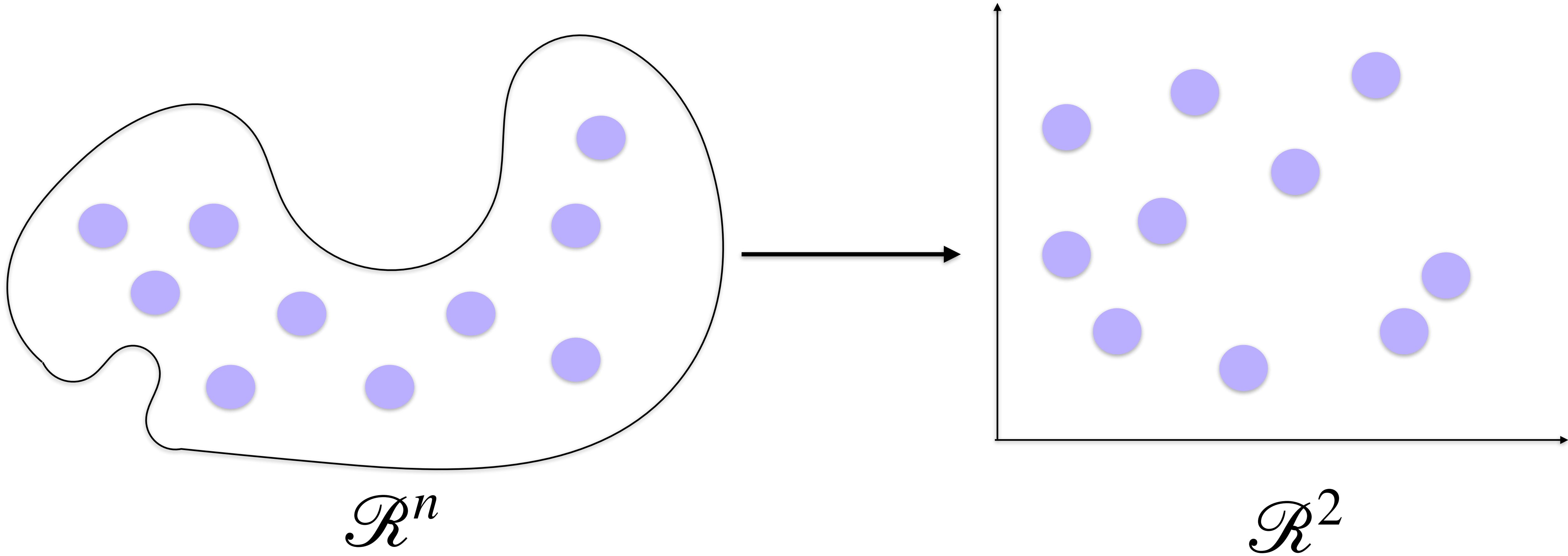


Graph visualization

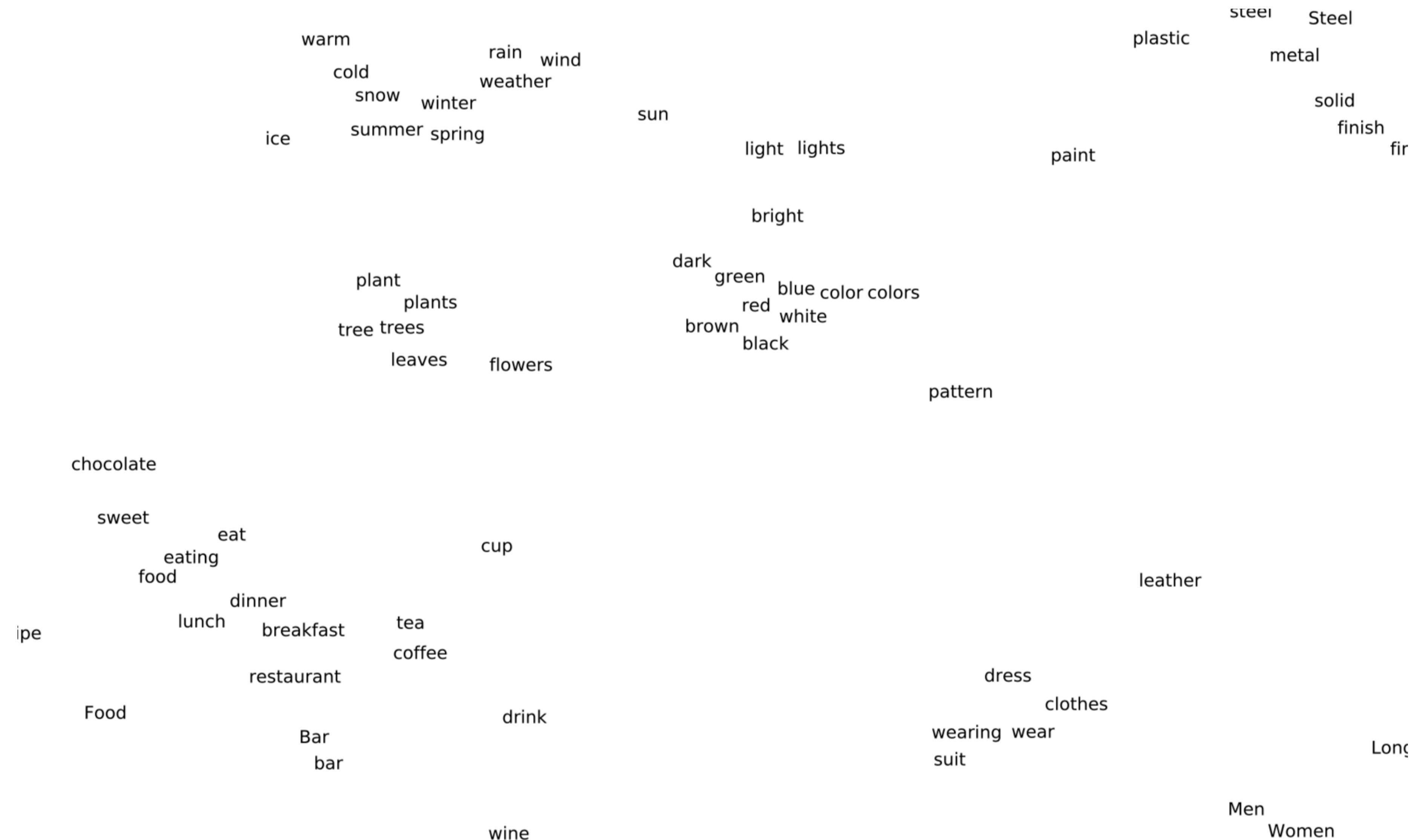


Other topics

- High-dimensional data visualization



Word embedding visualization



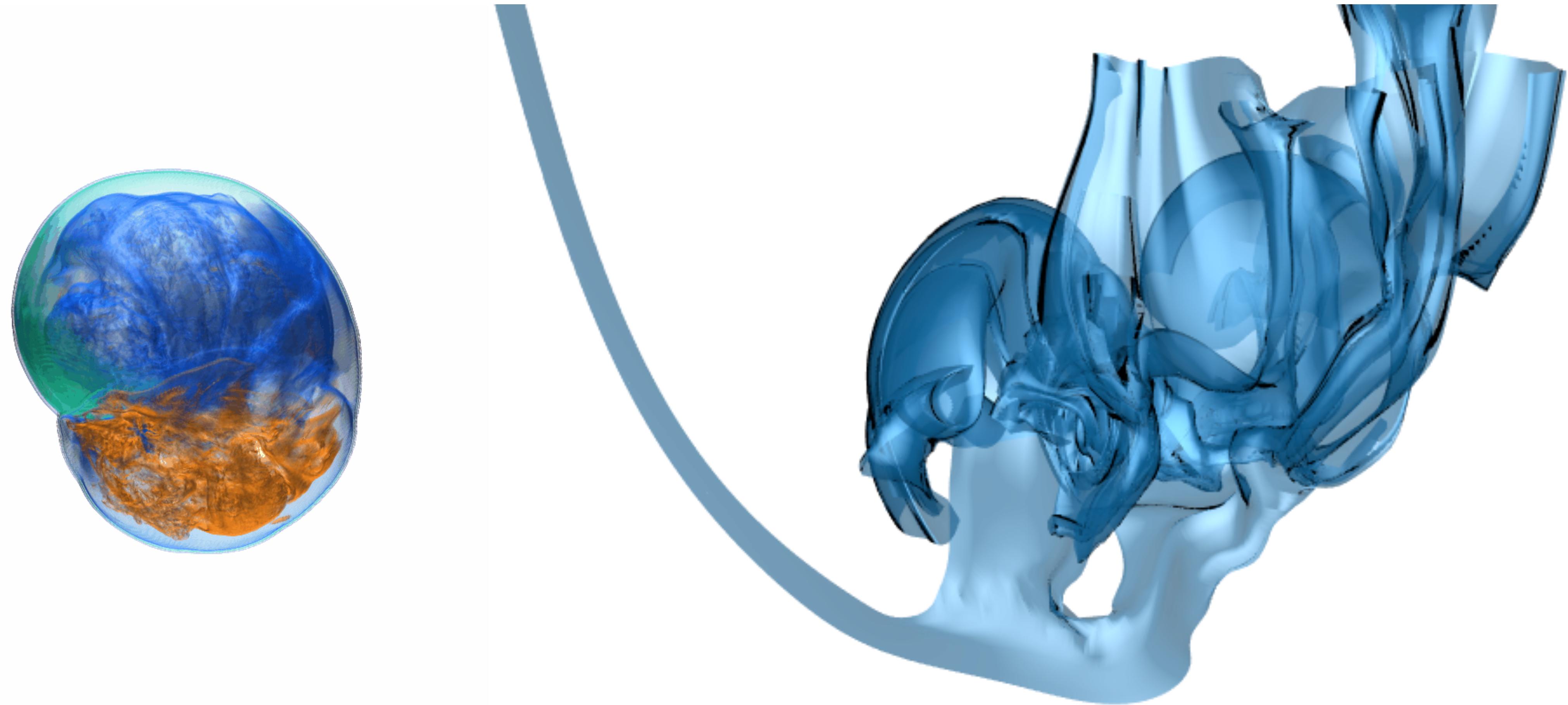
Other topics

- Text visualization



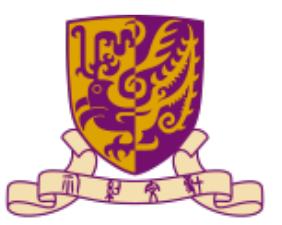
Other topics

- Volume and flow visualization



direct volume rendering

stream surface rendering



香港中文大學(深圳)

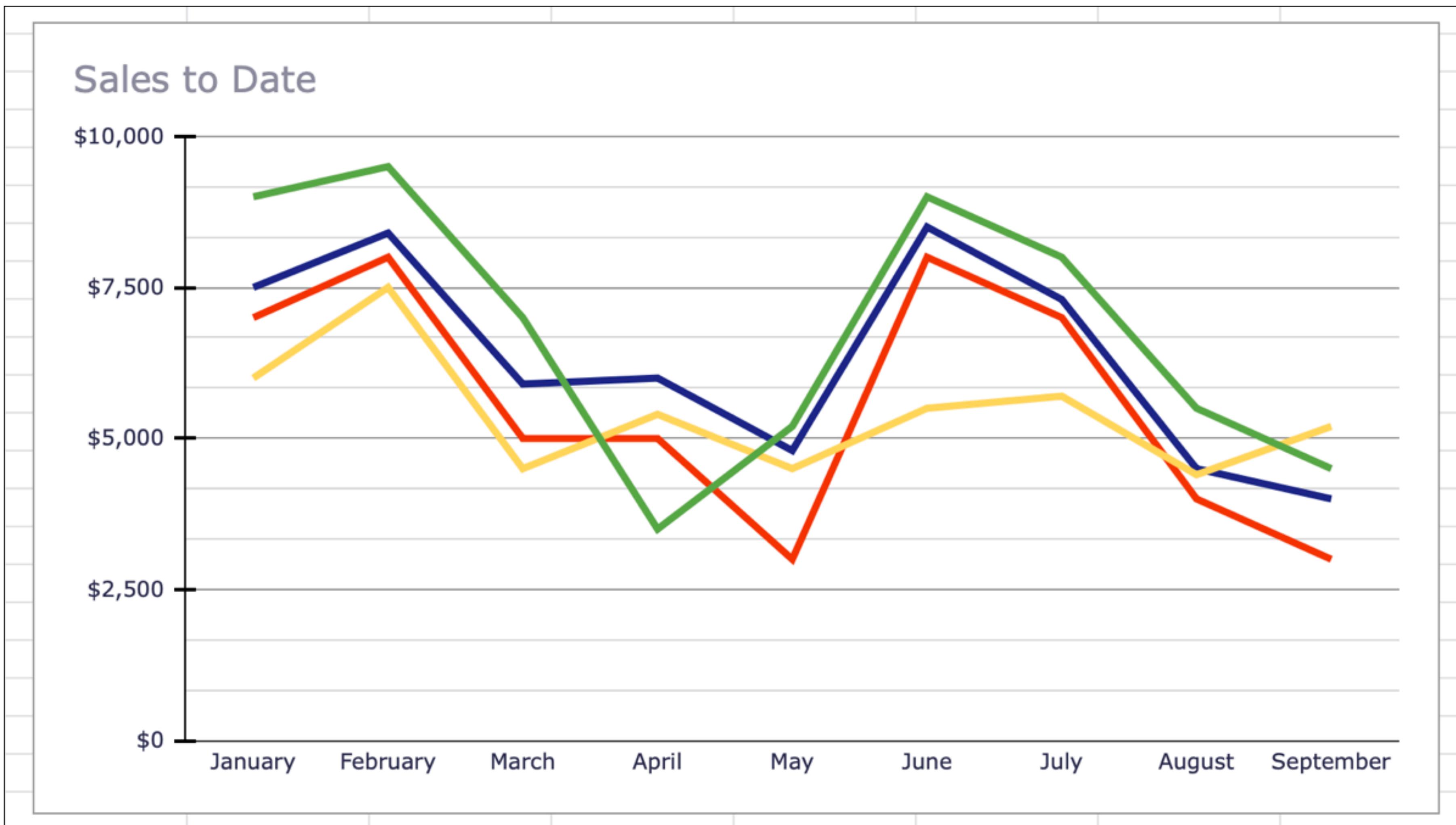
The Chinese University of Hong Kong, Shenzhen

Outline

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

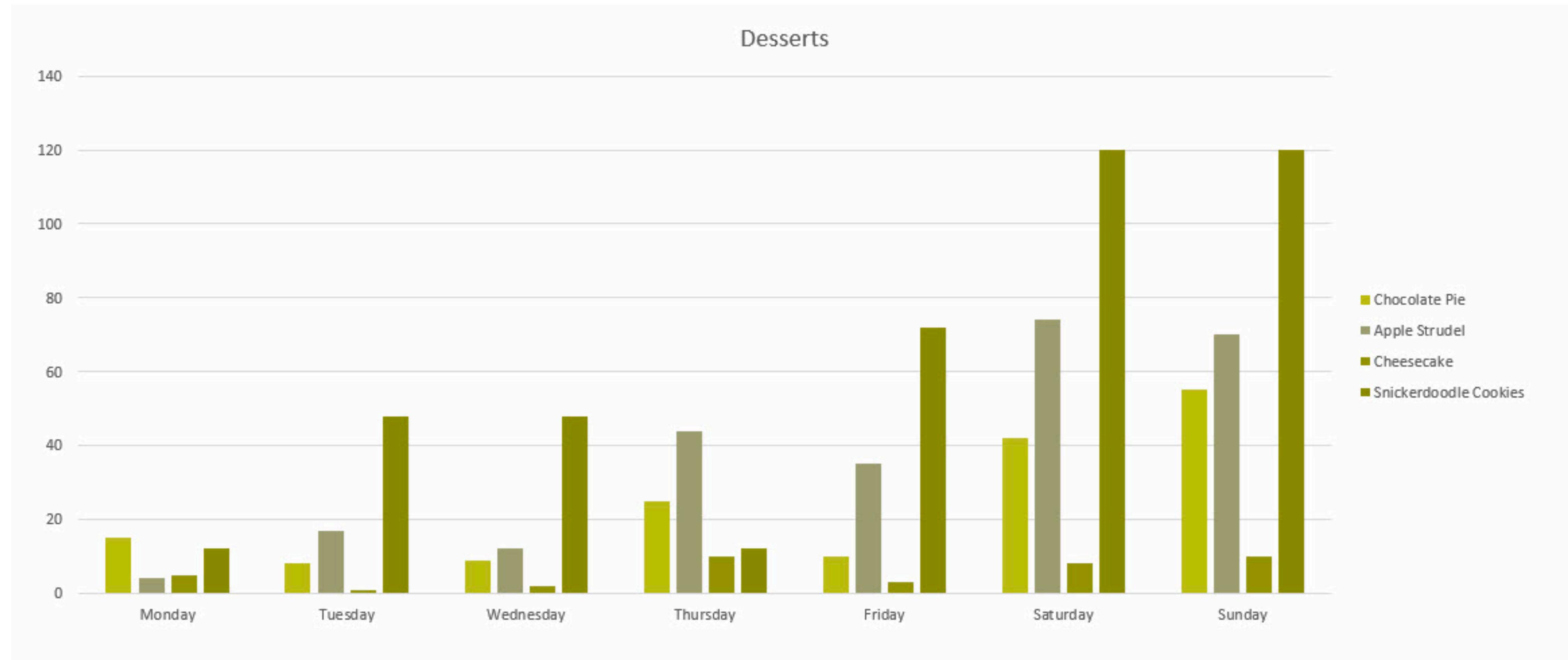
What is a poor visual form

- Missing legend



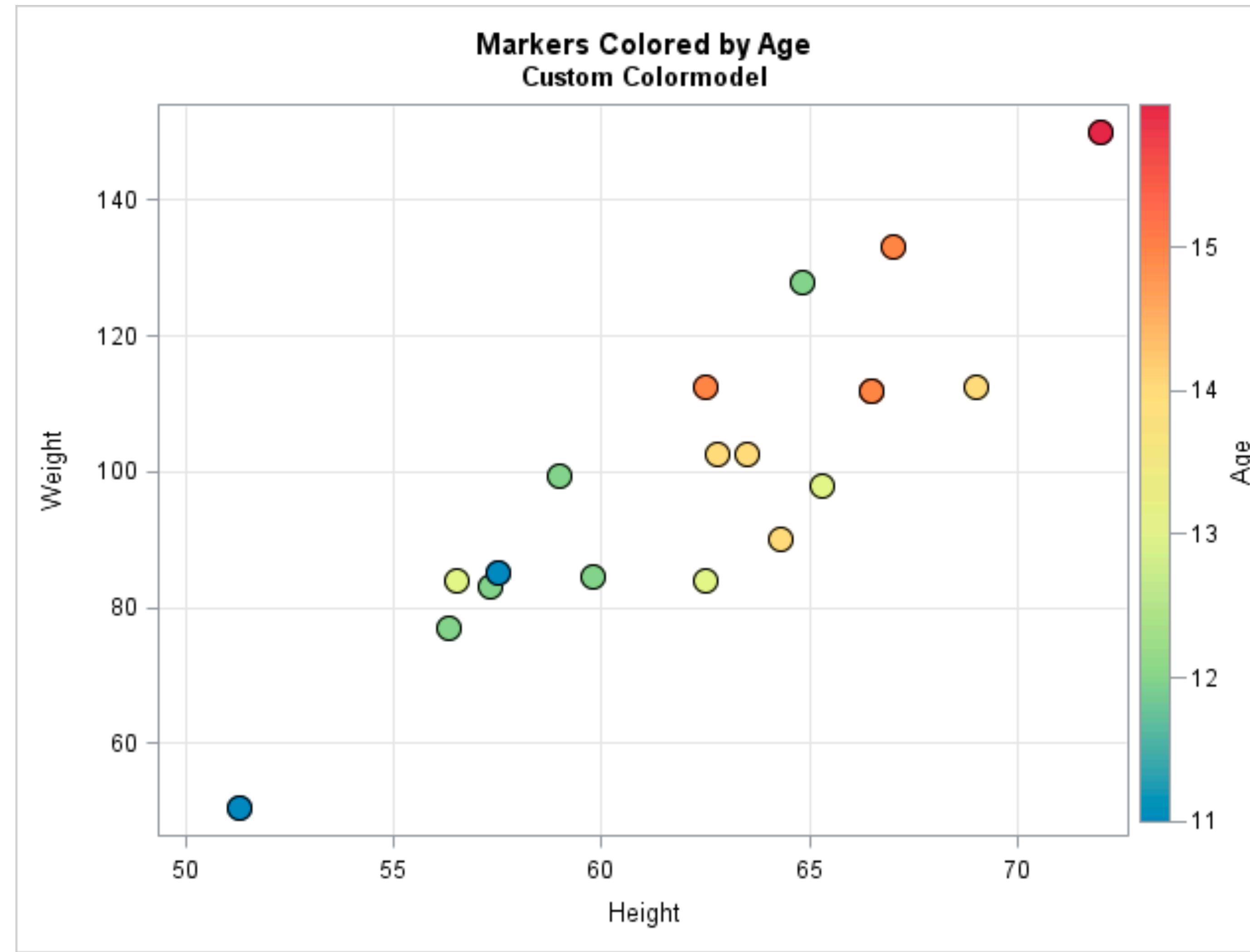
What is a poor visual form

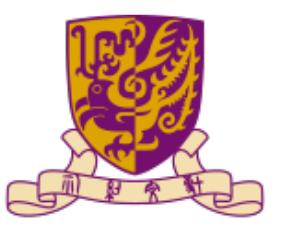
- Poor color choice



What is a poor visual form

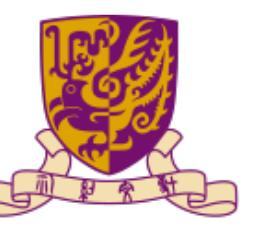
- Non-optimal marker





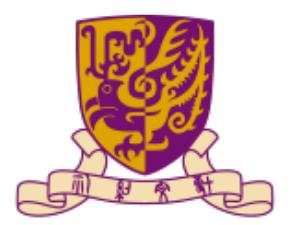
What is a poor visual form

- 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.



香港中文大學(深圳)

The Chinese University of Hong Kong, Shenzhen

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