

Visualization Analysis & Design

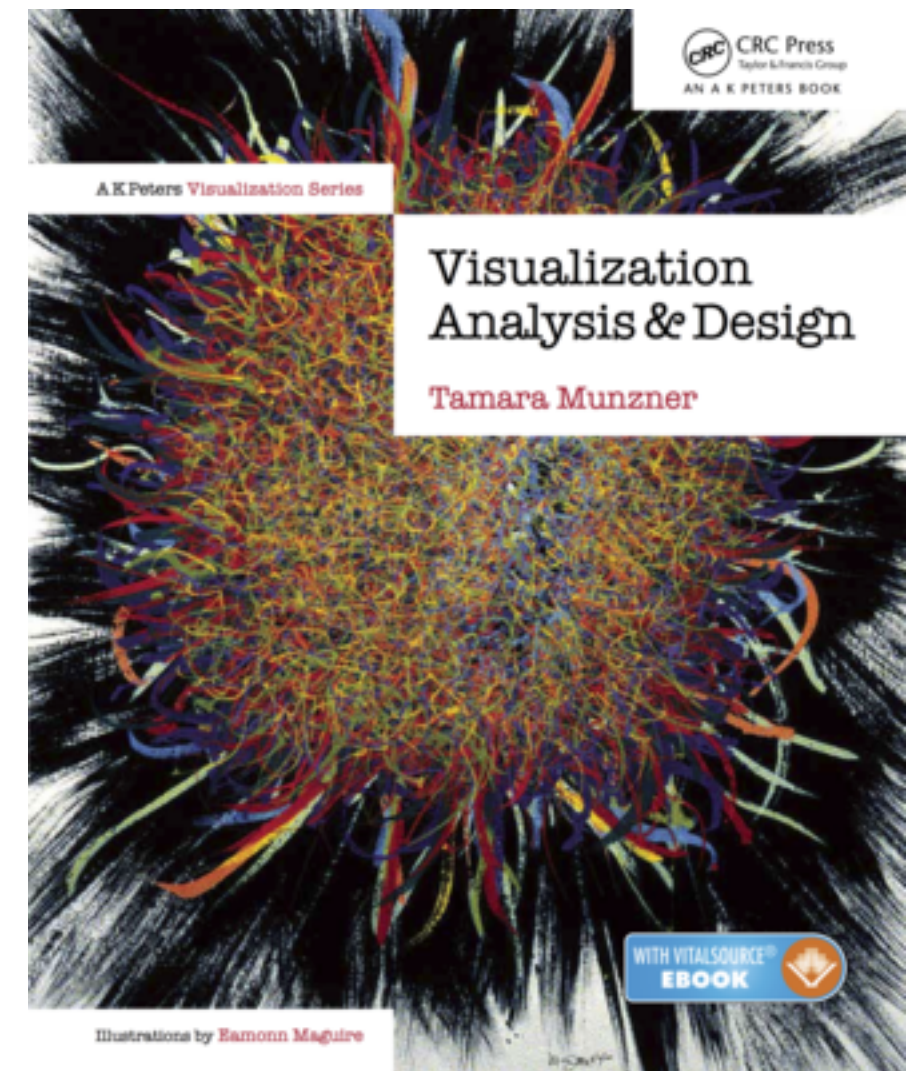
All Book/Teaching Slides

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All Book/Teaching Slides
Last change: 4 Oct 2021

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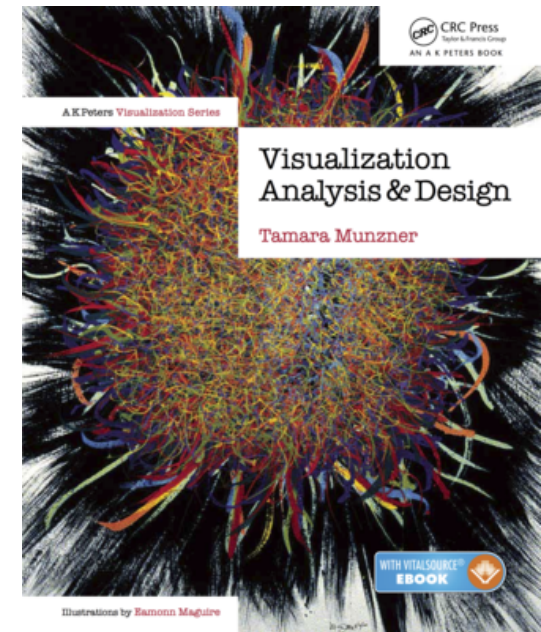
Visualization Analysis & Design

What's Vis, and Why Do It? (Ch 1)

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Defining visualization (vis)

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

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Why?...

Why have a human in the loop?

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Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

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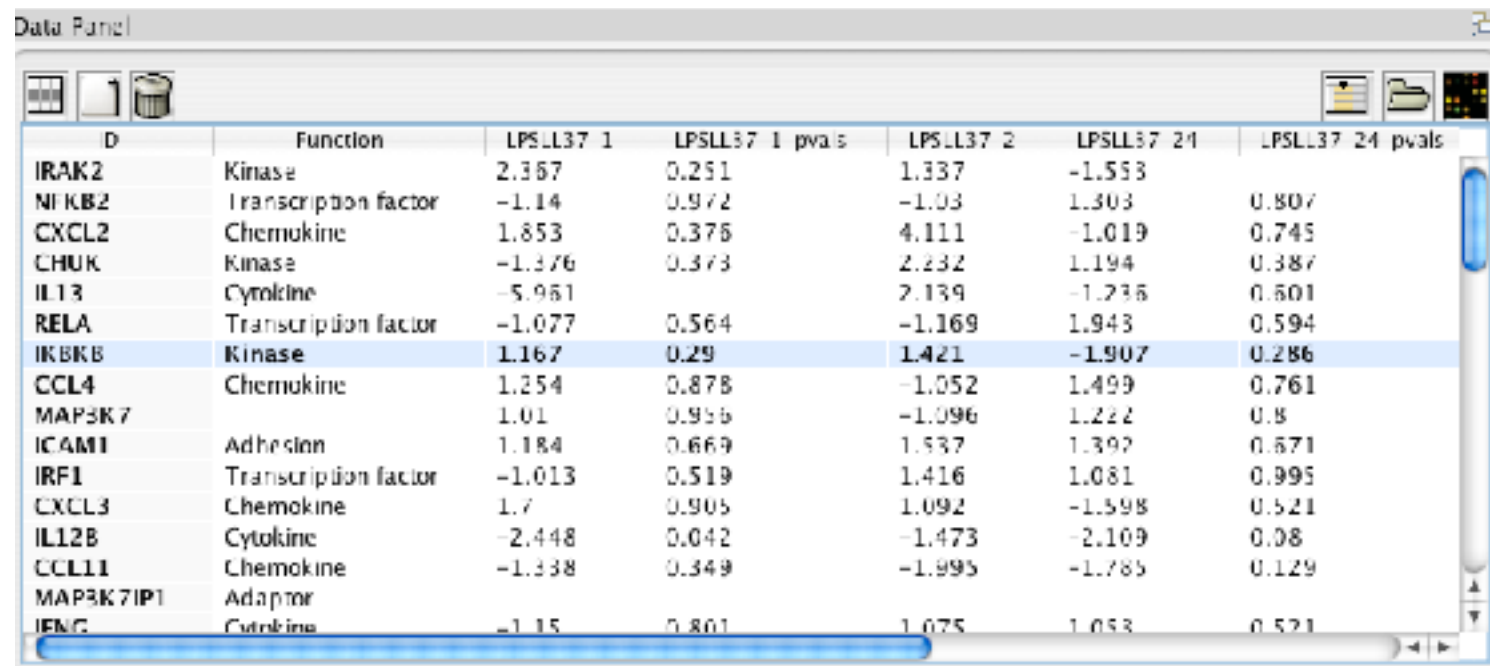
Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

- don't need vis when fully automatic solution exists and is trusted
- many analysis problems ill-specified
 - don't know exactly what questions to ask in advance
- possibilities
 - long-term use for end users (ex: exploratory analysis of scientific data)
 - presentation of known results (ex: New York Times Upshot)
 - stepping stone to assess requirements before developing models
 - help automatic solution developers refine & determine parameters
 - help end users of automatic solutions verify, build trust

Why use an external representation?

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

- external representation: replace cognition with perception



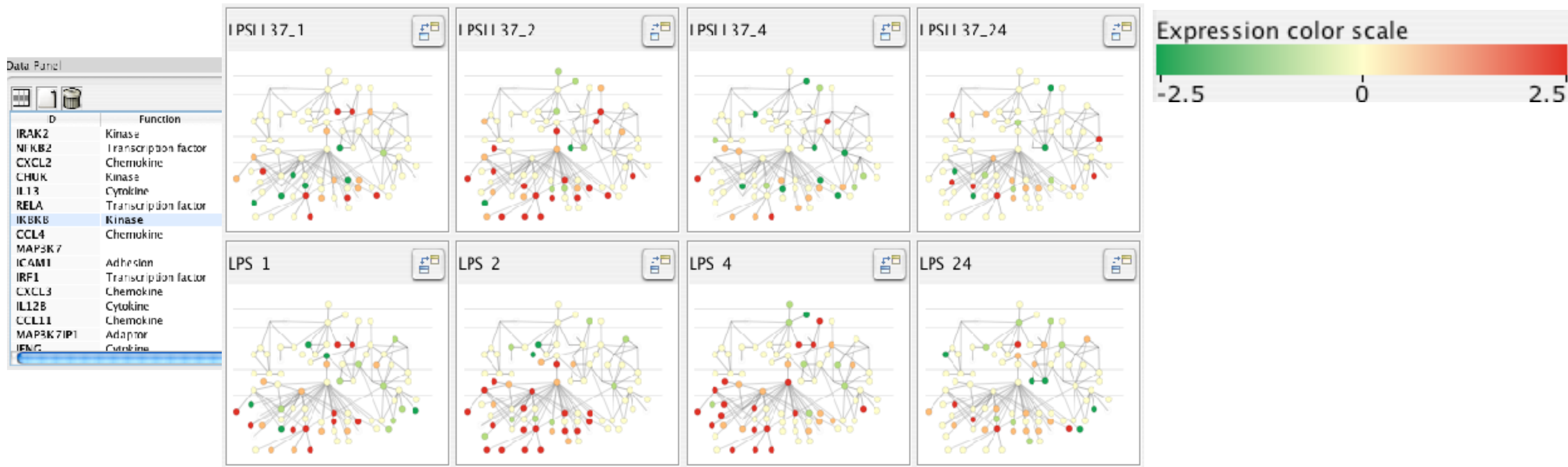
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IRAK2	Kinase	2.357	0.251	1.337	-1.553	
NIK2	Transcription factor	-1.14	0.972	-1.03	1.303	0.807
CXCL2	Chemokine	1.853	0.376	4.111	-1.019	0.745
CHUK	Kinase	-1.376	0.373	2.232	1.194	0.387
IL13	Cytokine	-5.961		2.139	-1.236	0.601
RELA	Transcription factor	-1.077	0.564	-1.169	1.943	0.594
IKKKB	Kinase	1.167	0.29	1.421	-1.907	0.286
CCL4	Chemokine	1.254	0.878	-1.052	1.499	0.761
MAP3K7		1.01	0.956	-1.096	1.222	0.8
ICAM1	Adhesion	1.184	0.669	1.537	1.392	0.671
IRF1	Transcription factor	-1.013	0.519	1.416	1.081	0.995
CXCL3	Chemokine	1.7	0.905	1.092	-1.598	0.521
IL12B	Cytokine	-2.448	0.042	-1.473	-2.109	0.08
CCL11	Chemokine	-1.338	0.349	-1.995	-1.785	0.129
MAP3K7IP1	Adaptor					
IFNG	Cytokine	-1.15	0.801	1.075	1.053	0.521

[Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE TVCG (Proc. InfoVis) 14(6):1253-1260, 2008.]

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Why depend on vision?

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

- human visual system is high-bandwidth channel to brain
 - overview possible due to background processing
 - subjective experience of seeing everything simultaneously
 - significant processing occurs in parallel and pre-attentively
- sound: lower bandwidth and different semantics
 - overview not supported
 - subjective experience of sequential stream
- touch/haptics: impoverished record/replay capacity
 - only very low-bandwidth communication thus far
- taste, smell: no viable record/replay devices

Why represent all the data?

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

- summaries lose information, details matter
 - confirm expected and find unexpected patterns
 - assess validity of statistical model

Anscombe's Quartet

Identical statistics	
x mean	9
x variance	10
y mean	7.5
y variance	3.75
x/y correlation	0.816

Why represent all the data?

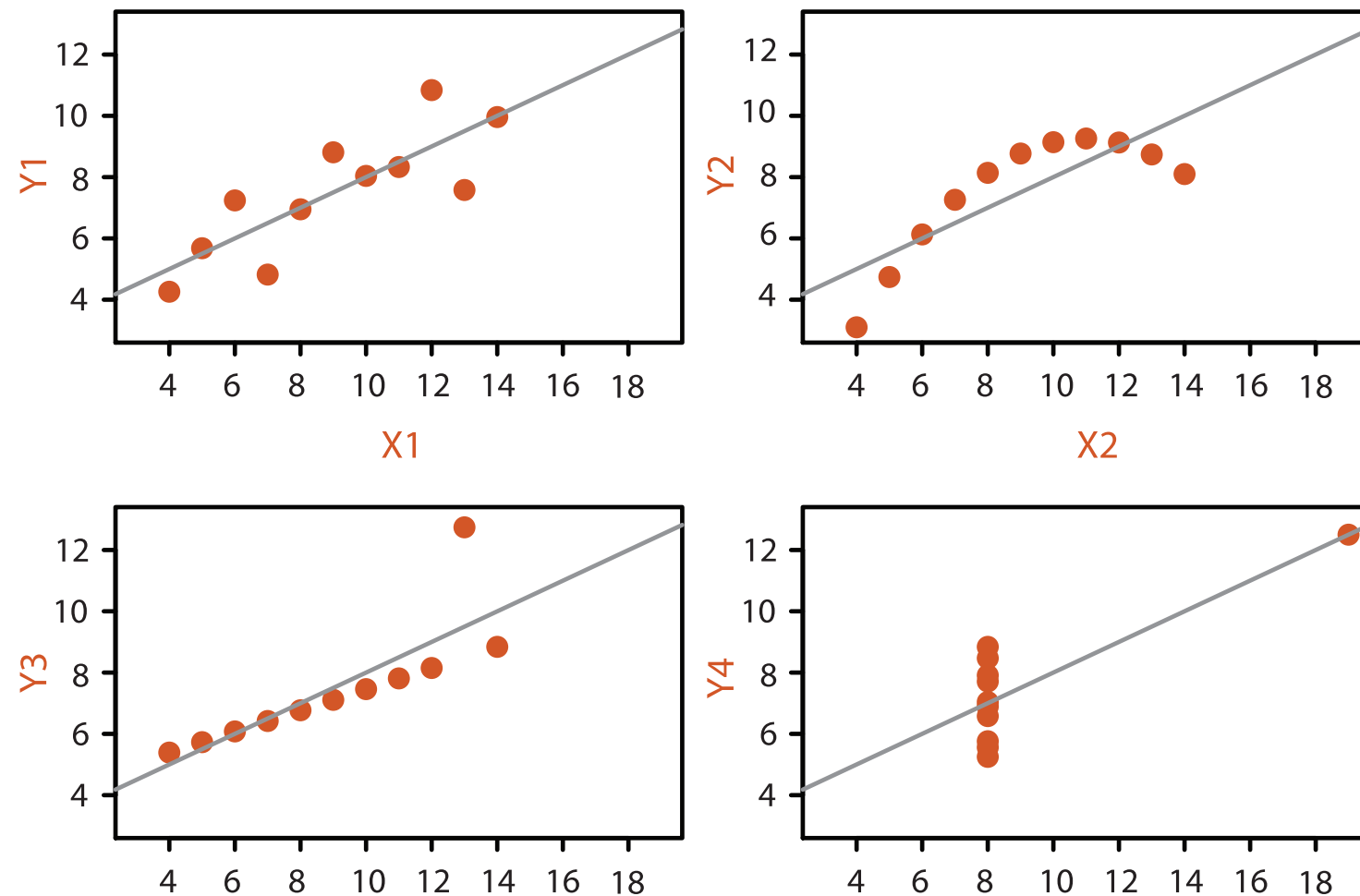
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Anscombe's Quartet

Identical statistics

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What resource limitations are we faced with?

Vis designers must take into account three very different kinds of resource limitations: those of computers, of humans, and of displays.

- computational limits
 - computation time, system memory
- display limits
 - pixels are precious & most constrained resource
 - **information density**: ratio of space used to encode info vs unused whitespace
 - tradeoff between clutter and wasting space
 - find sweet spot between dense and sparse
- human limits
 - human time, human memory, human attention

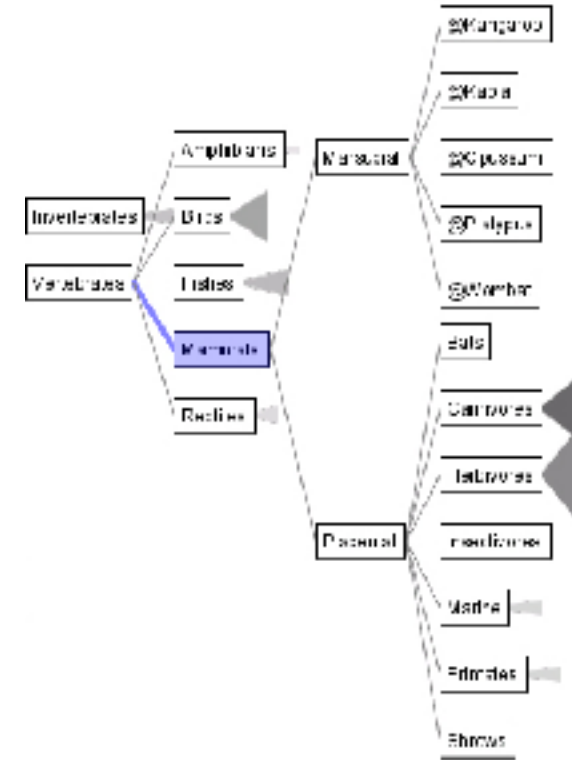
Why analyze?

- imposes structure on huge design space
 - scaffold to help you think systematically about choices
 - analyzing existing as stepping stone to designing new
 - most possibilities ineffective for particular task/data combination

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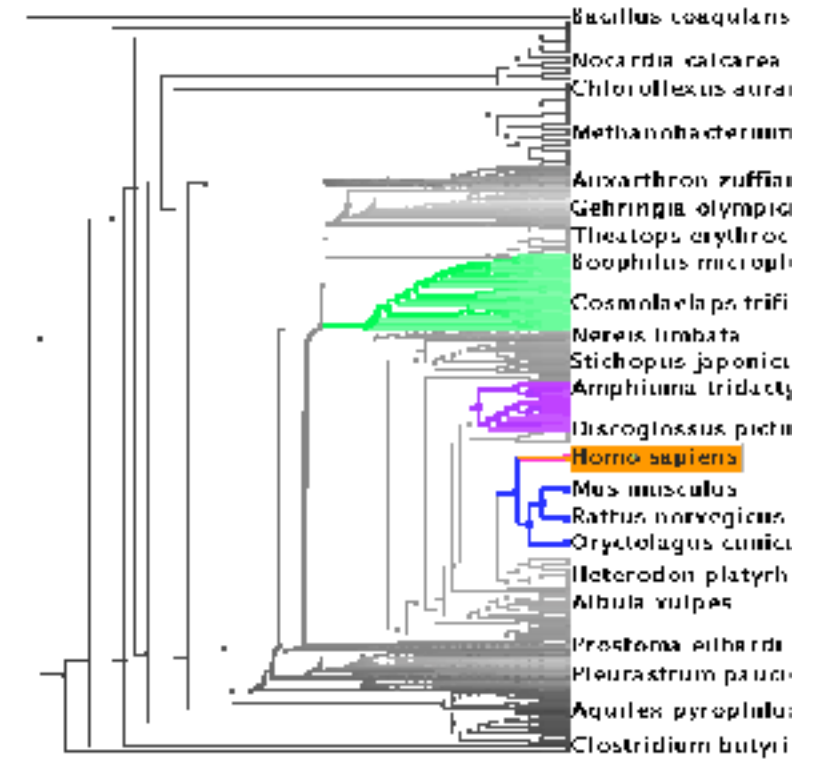
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SpaceTree



[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

TreeJuxtaposer

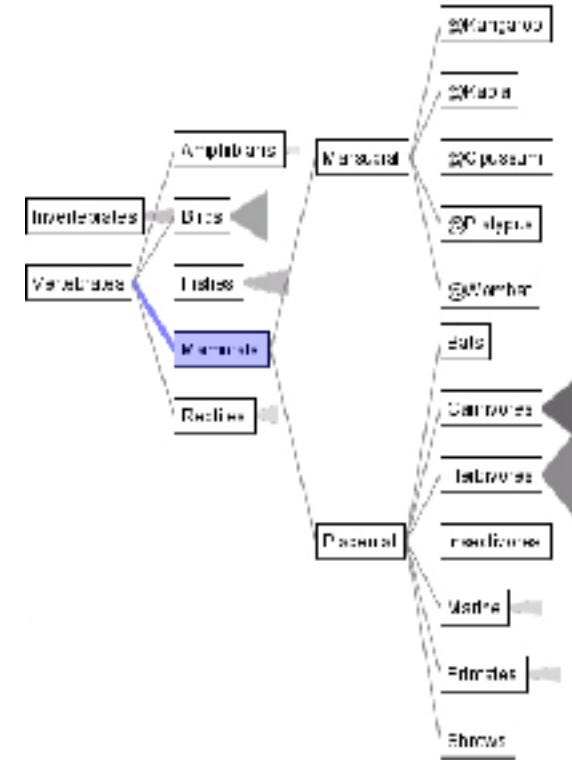


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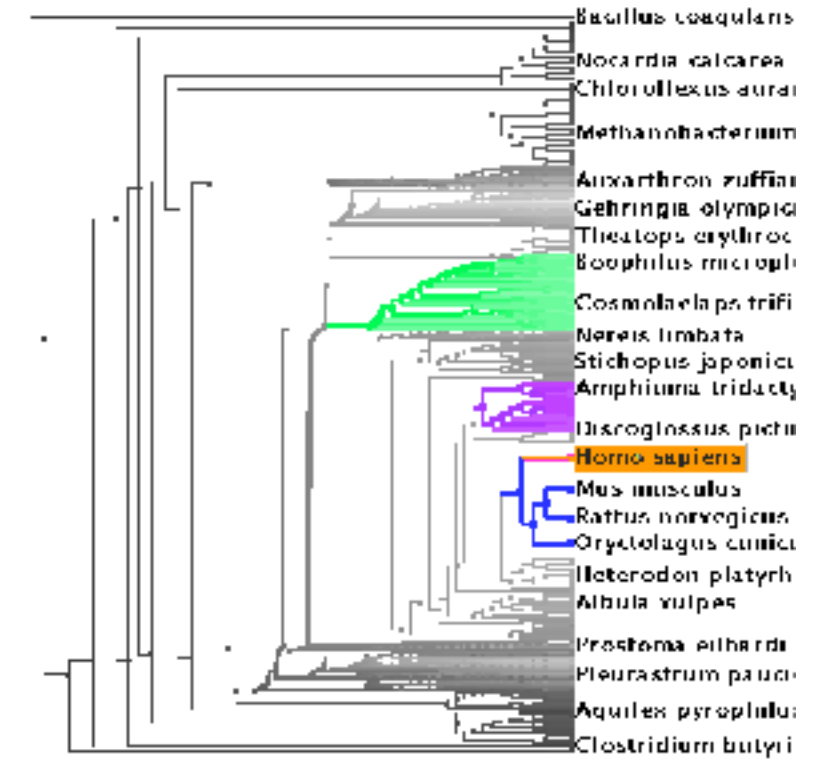
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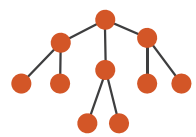
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What?

Why?

How?

→ Tree



→ Actions

→ Present → Locate → Identify



→ Targets

→ Path between two nodes



→ SpaceTree

→ Encode → Navigate → Select → Filter → Aggregate



→ TreeJuxtaposer

→ Encode → Navigate → Select → Arrange



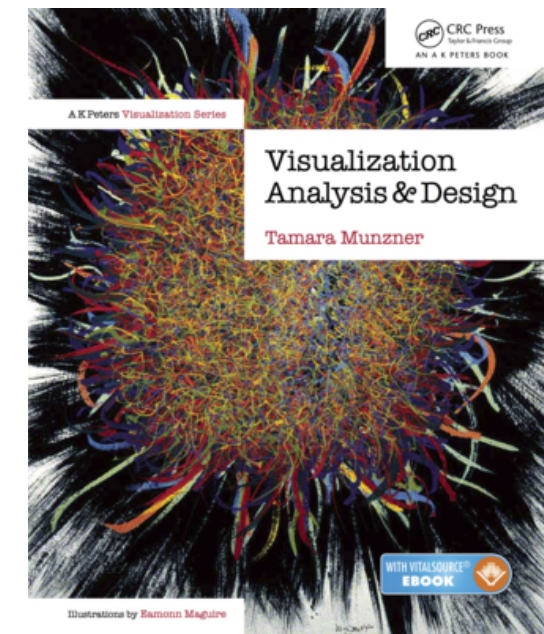
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Analysis: Nested Model (Ch 4)

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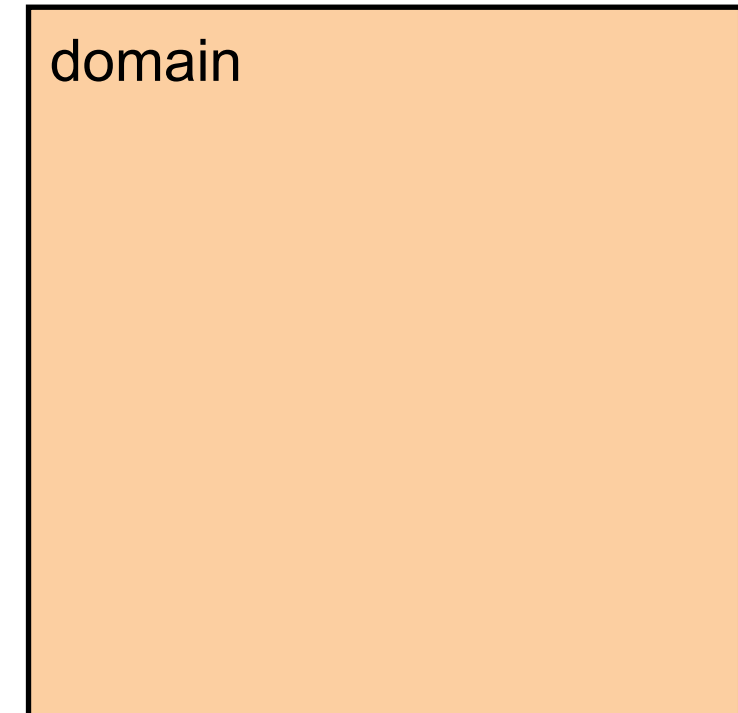
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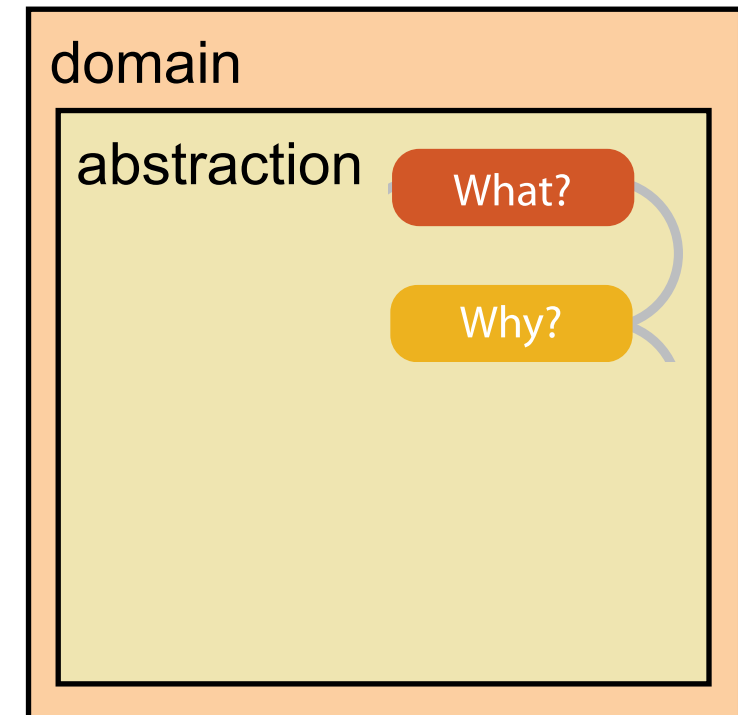
Analysis framework: Four levels, three questions

- *domain situation*
 - who are the target users?



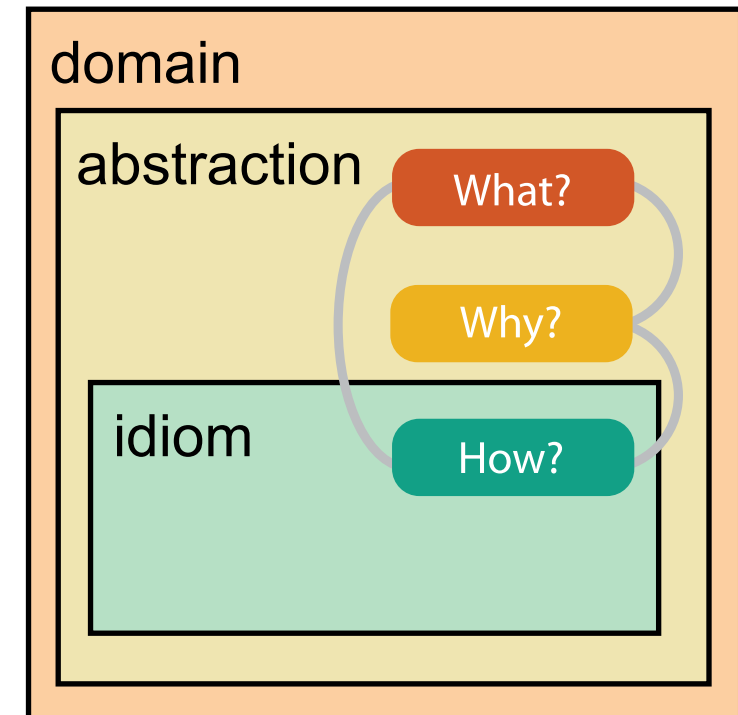
Analysis framework: Four levels, three questions

- *domain situation*
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- *abstraction*
 - translate from specifics of domain to vocabulary of vis
 - **what** is shown? **data** abstraction
 - **why** is the user looking at it? **task** abstraction



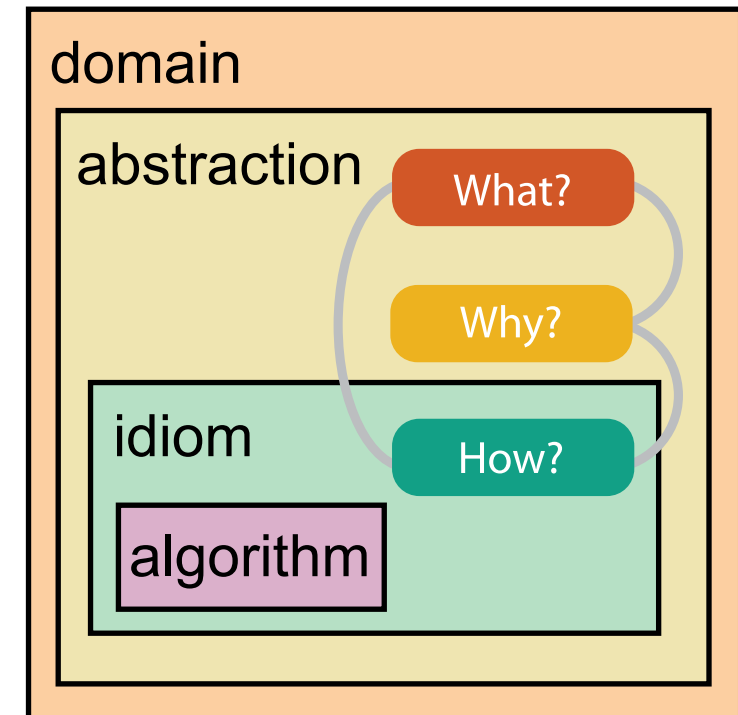
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- *idiom*
 - **how** is it shown?
 - **visual encoding** idiom: how to draw
 - **interaction** idiom: how to manipulate



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 - **visual encoding** idiom: how to draw
 - **interaction** idiom: how to manipulate
- *algorithm*
 - efficient computation

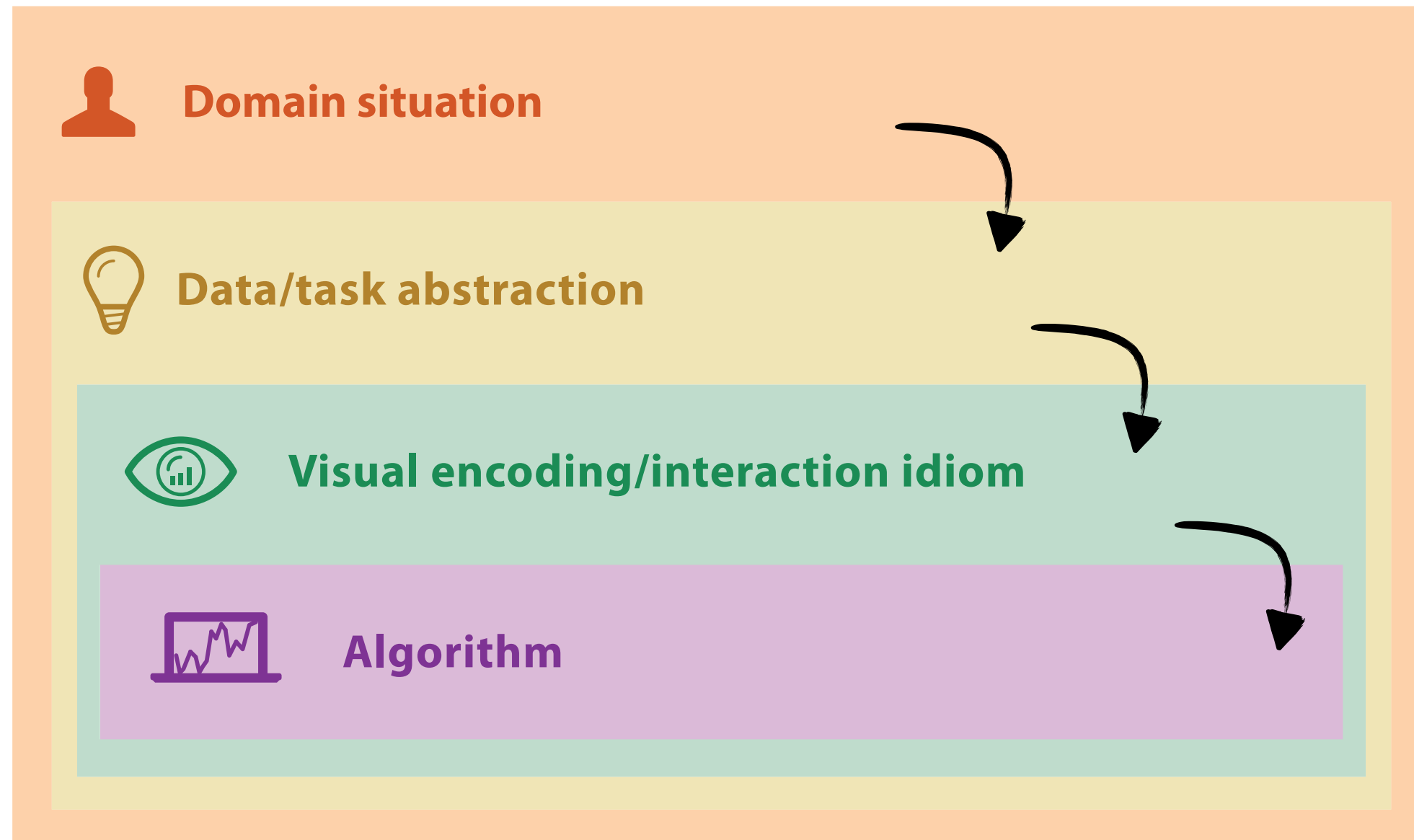


[A Multi-Level Typology of Abstract Visualization Tasks. Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]

[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

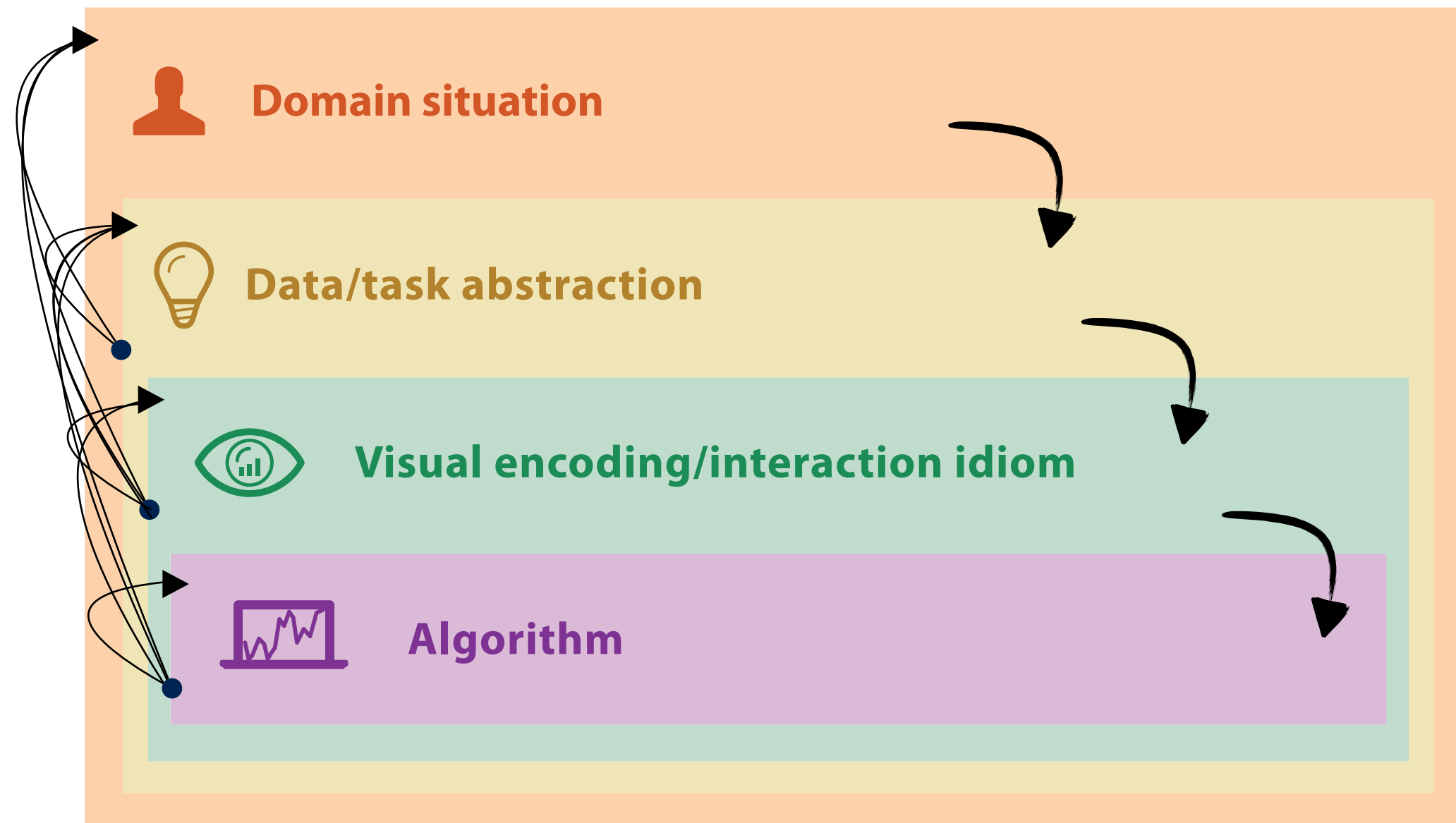
Nested model

- downstream: cascading effects



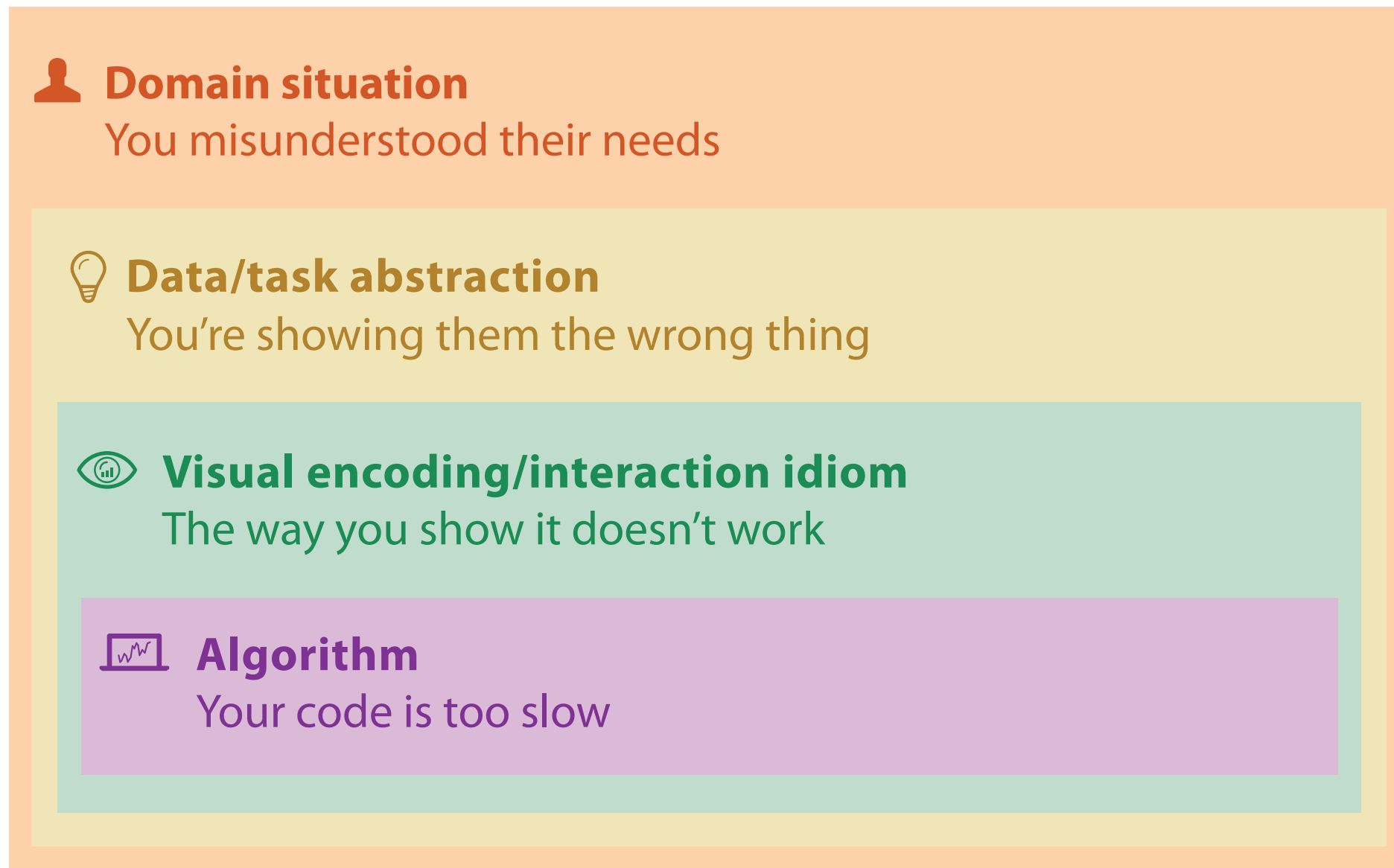
Nested model

- downstream: cascading effects
- upstream: iterative refinement



Why is validation difficult?

- different ways to get it wrong at each level



Why is validation difficult?

- solution: use methods from different fields at each level



Algorithm

Measure system time/memory

Analyze computational complexity

Why is validation difficult?

- solution: use methods from different fields at each level

computer
science



Algorithm

Measure system time/memory

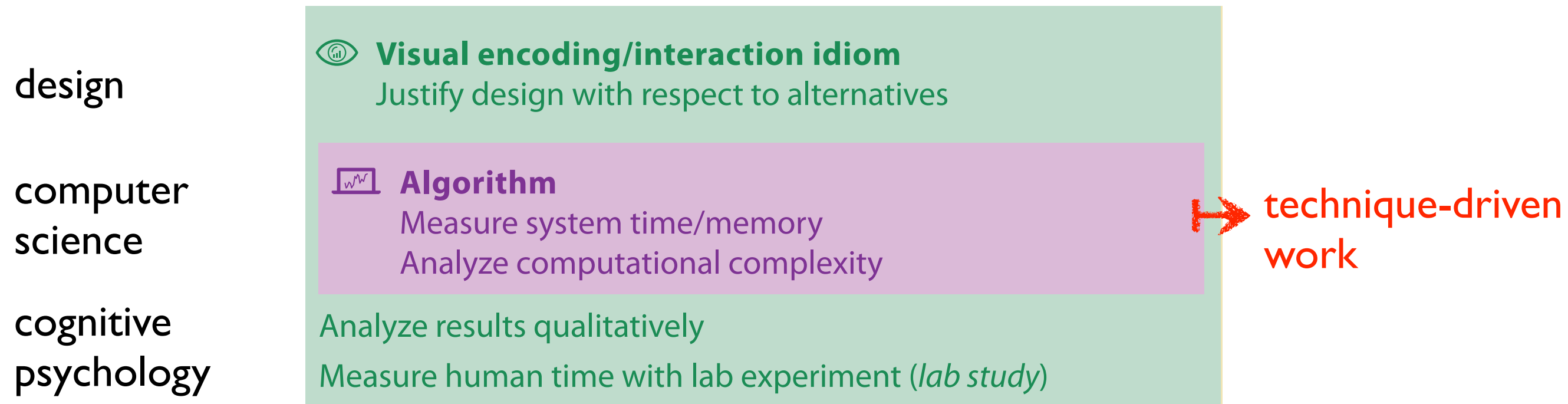
Analyze computational complexity



technique-driven
work

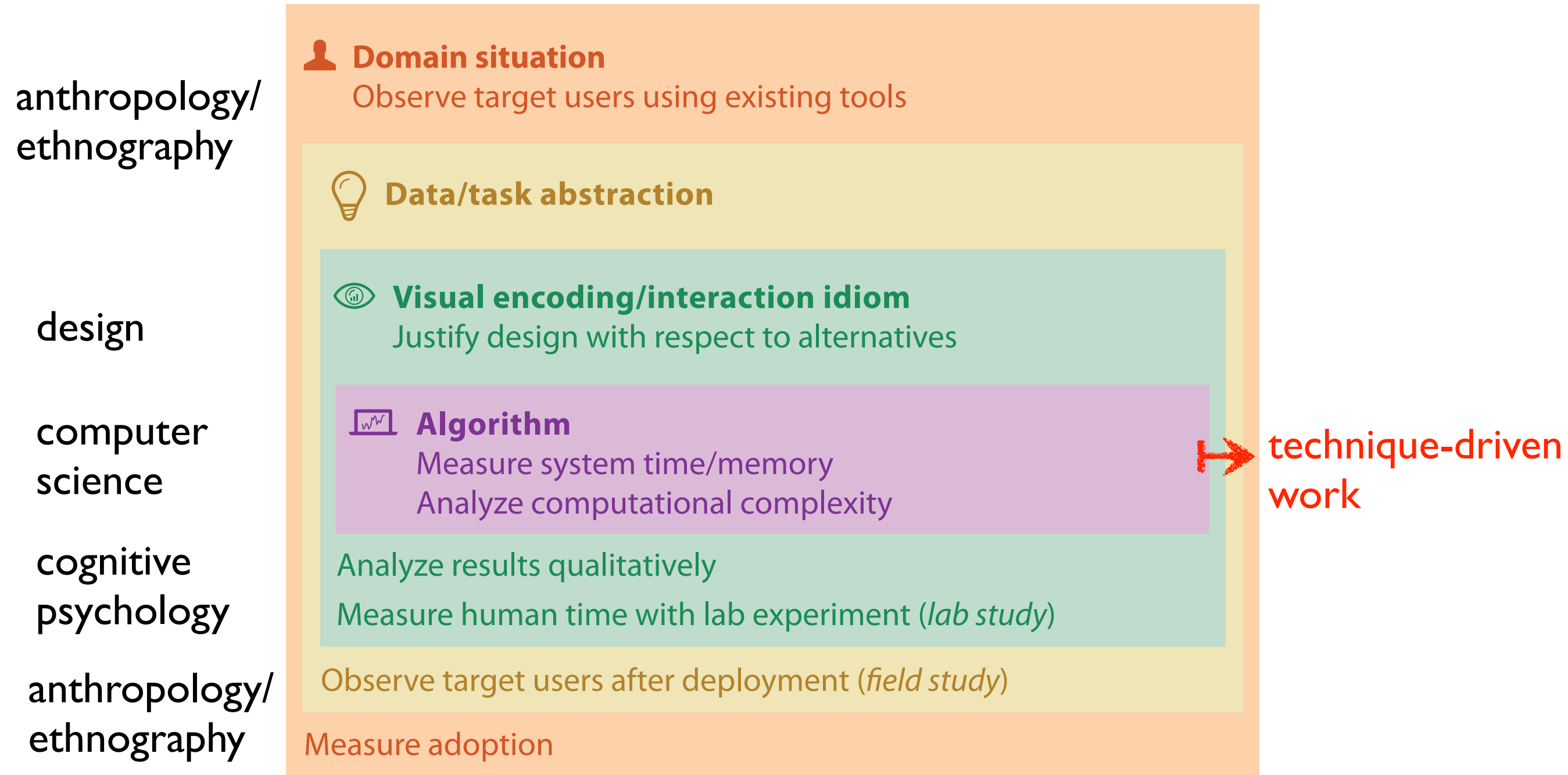
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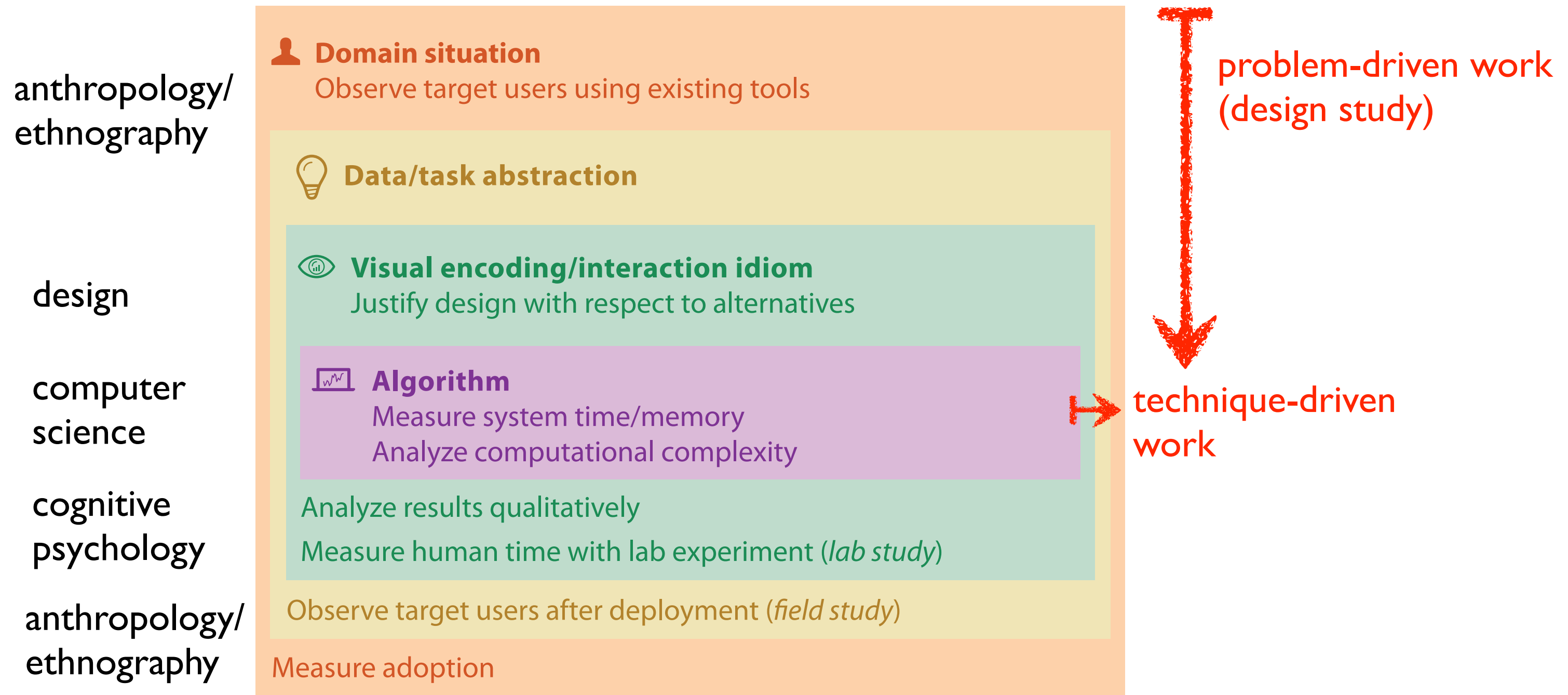
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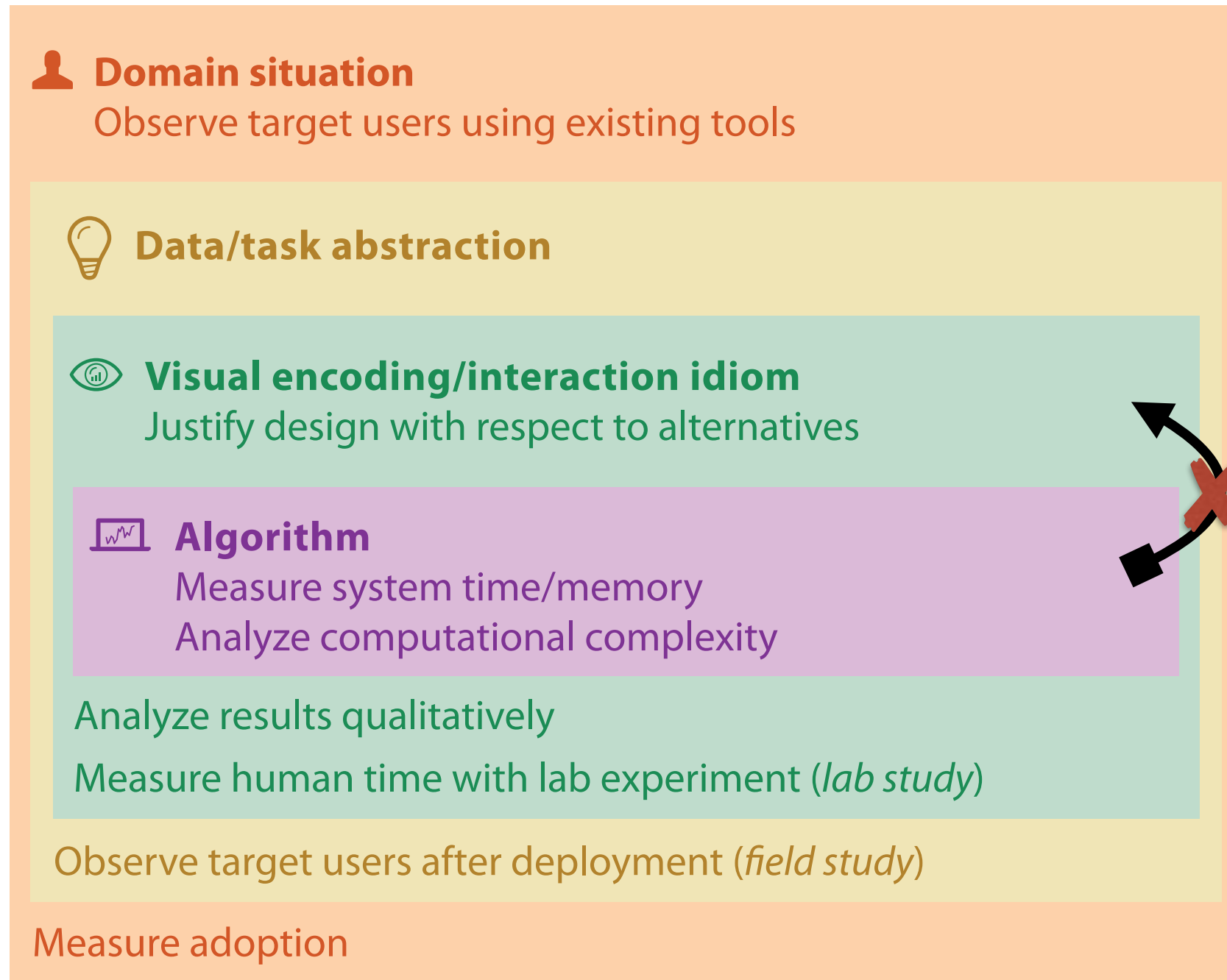


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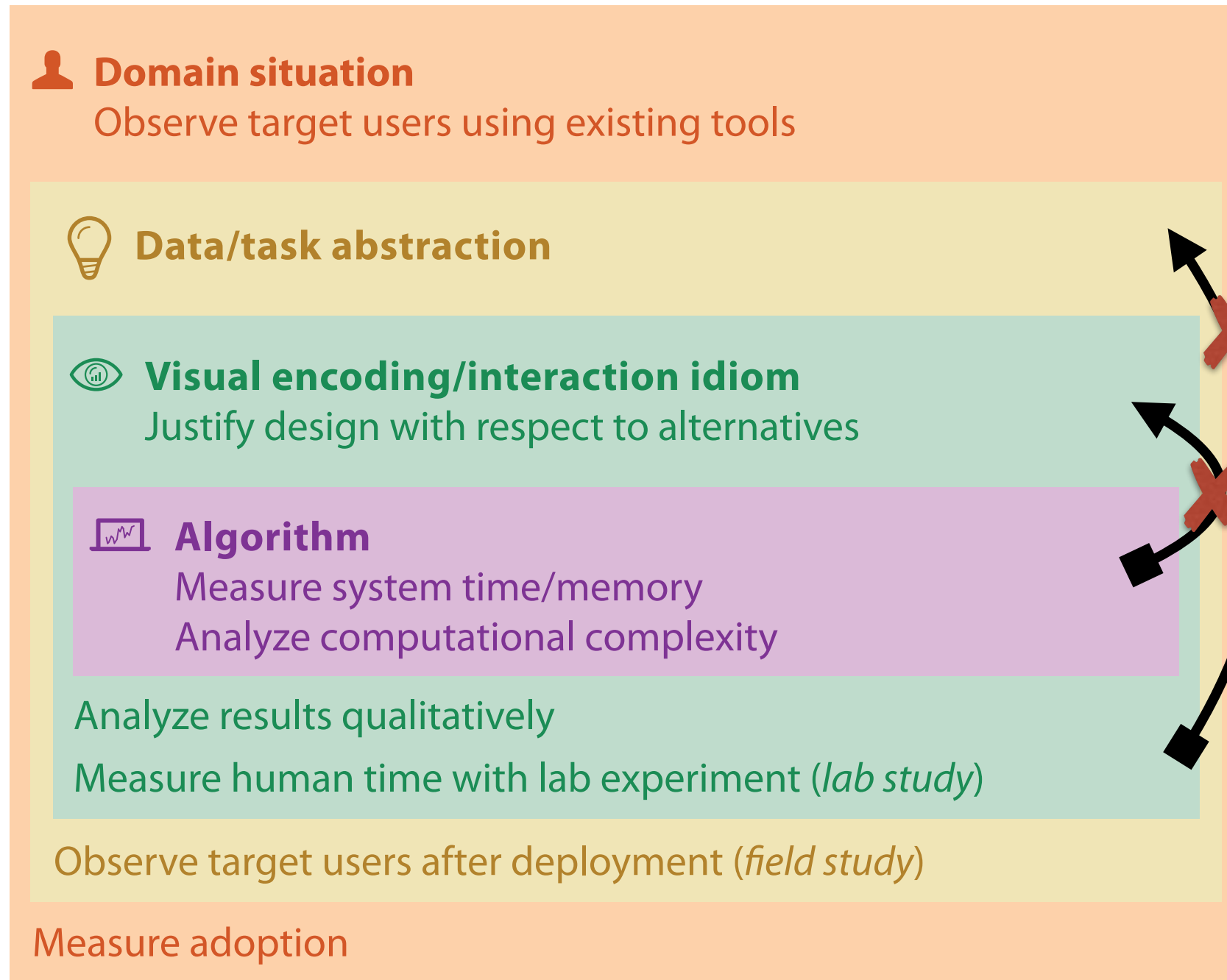


Avoid mismatches



computational benchmarks
do not confirm idiom design

Avoid mismatches



lab studies do not confirm task abstraction

computational benchmarks do not confirm idiom design

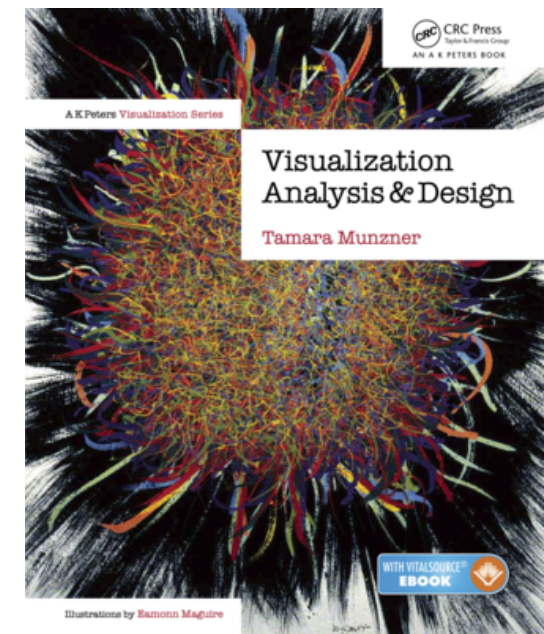
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Analysis: Nested Model (Ch 4) II

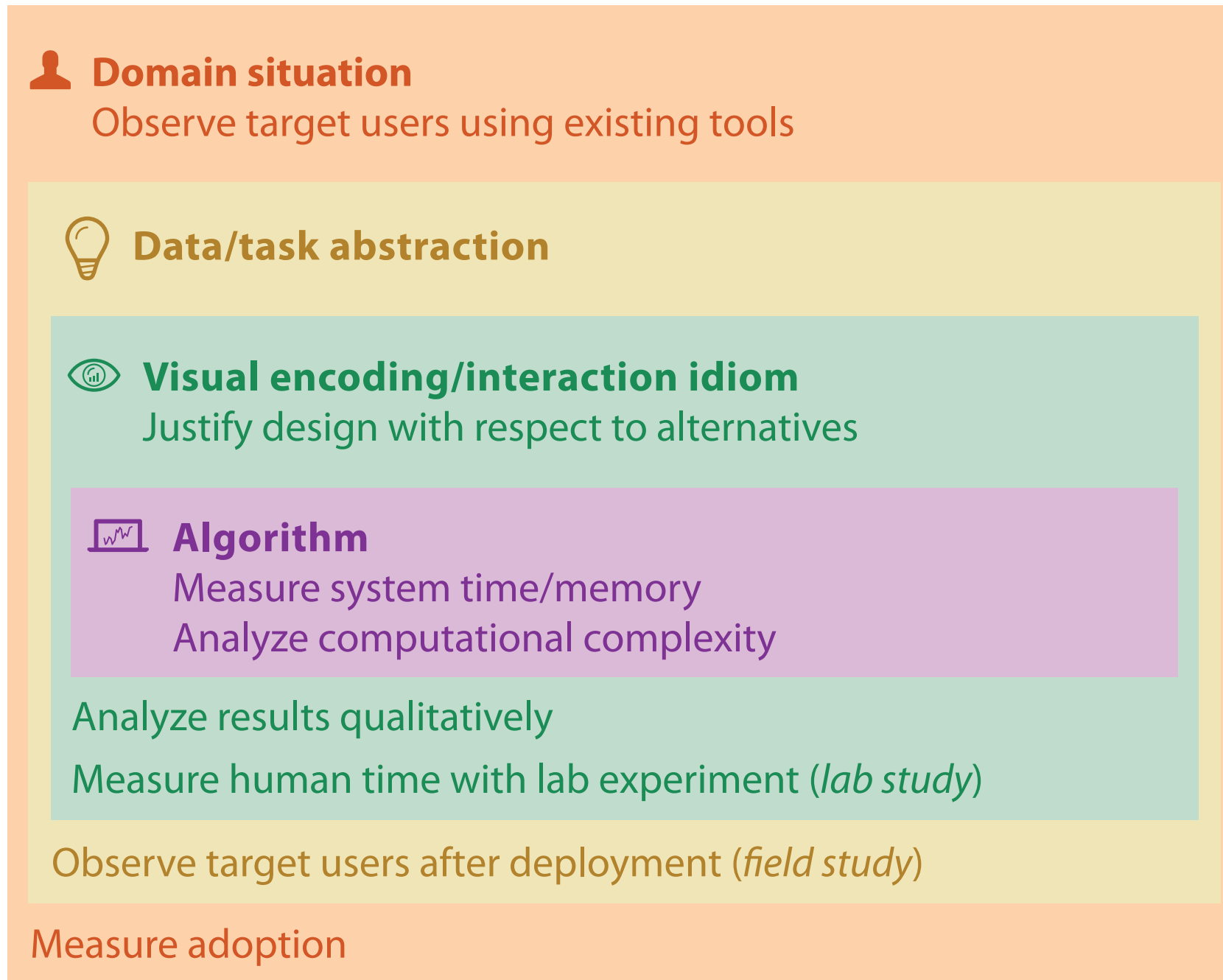
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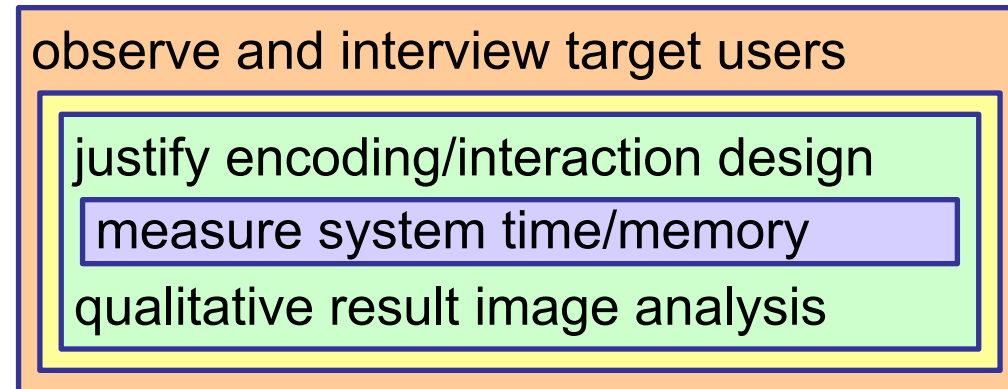


Analysis examples: Single paper includes only subset of methods



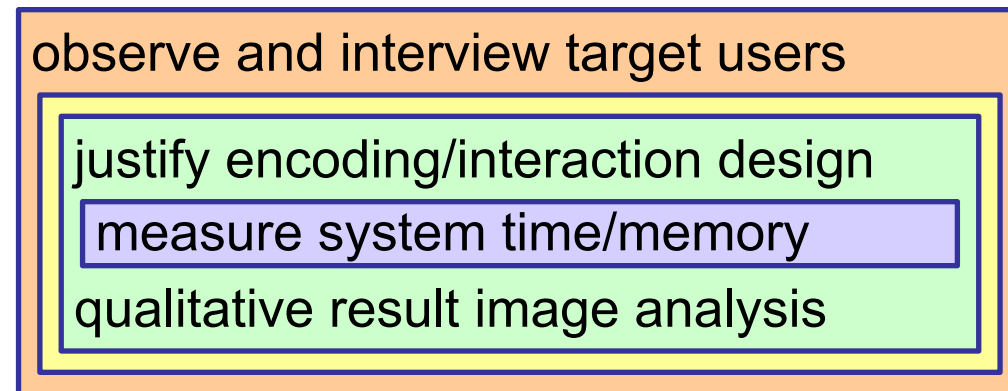
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MatrixExplorer. Henry and Fekete. InfoVis 2006.

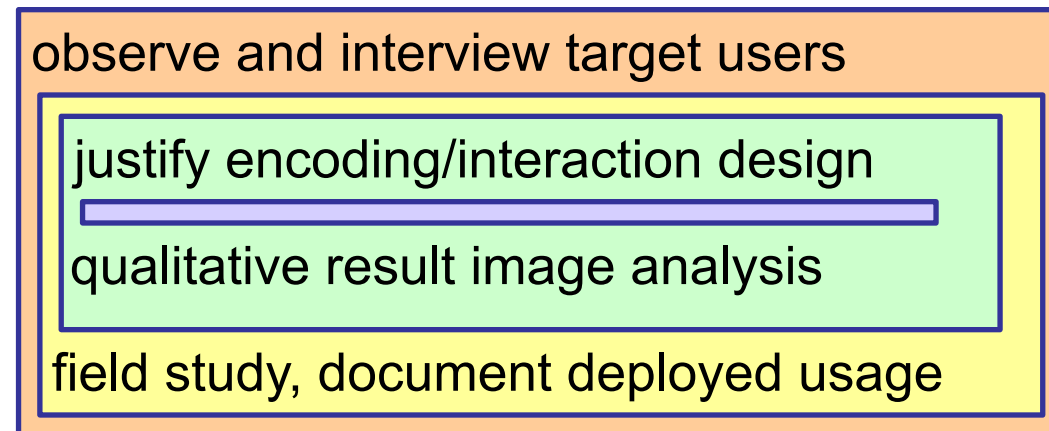


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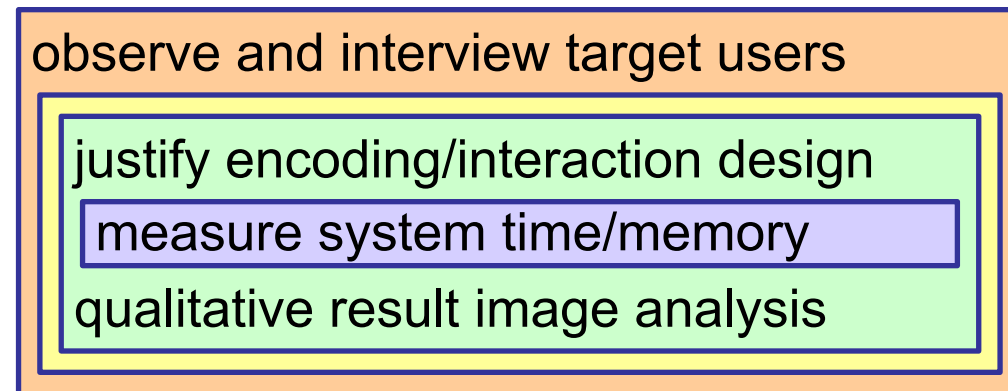


LiveRAC. McLachlan, Munzner, Koutsofios, and North. CHI 2008.

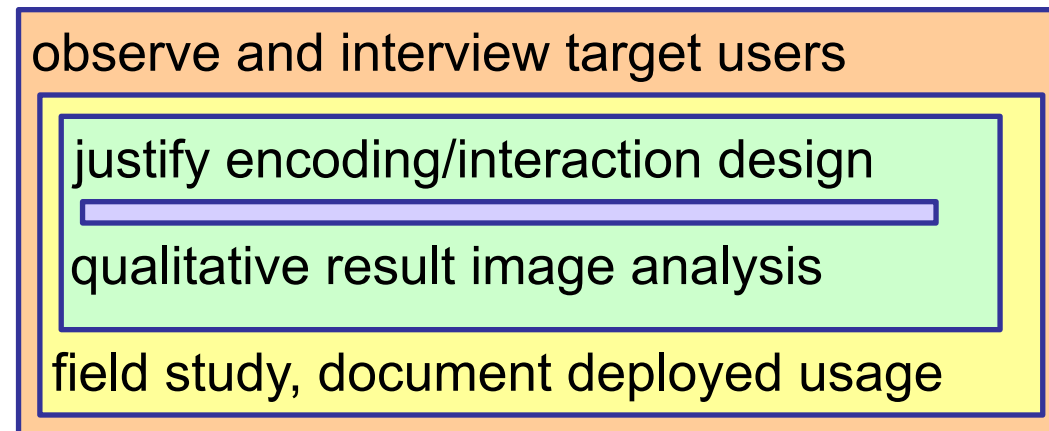


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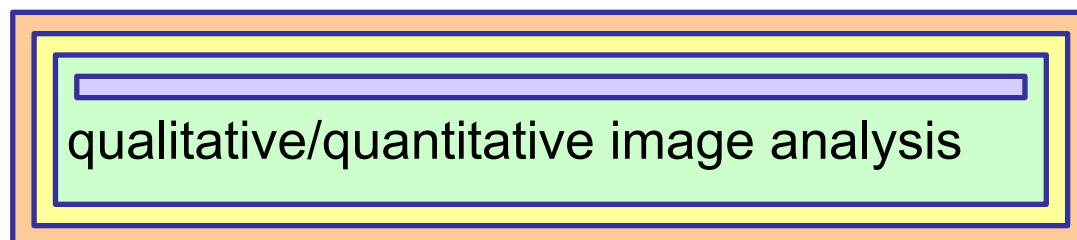
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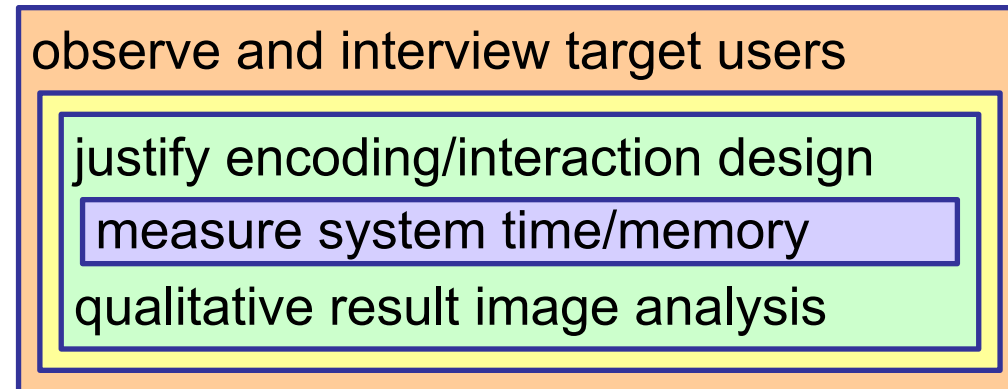


An energy model for visual graph clustering. (LinLog)
Noack. Graph Drawing 2003

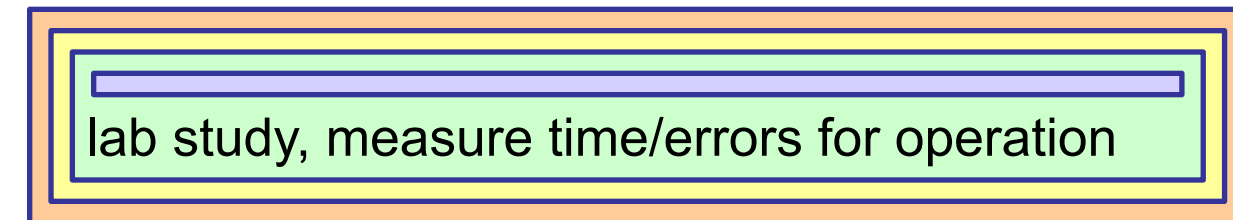


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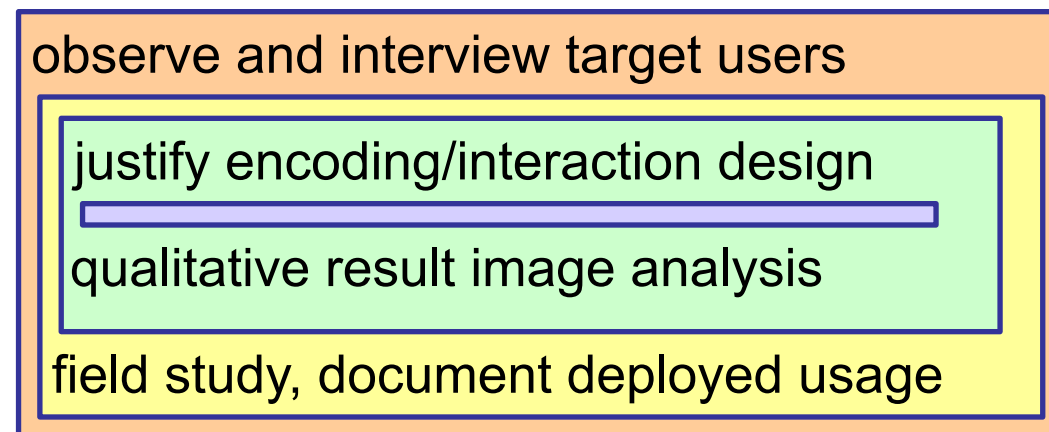
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Effectiveness of animation in trend visualization.
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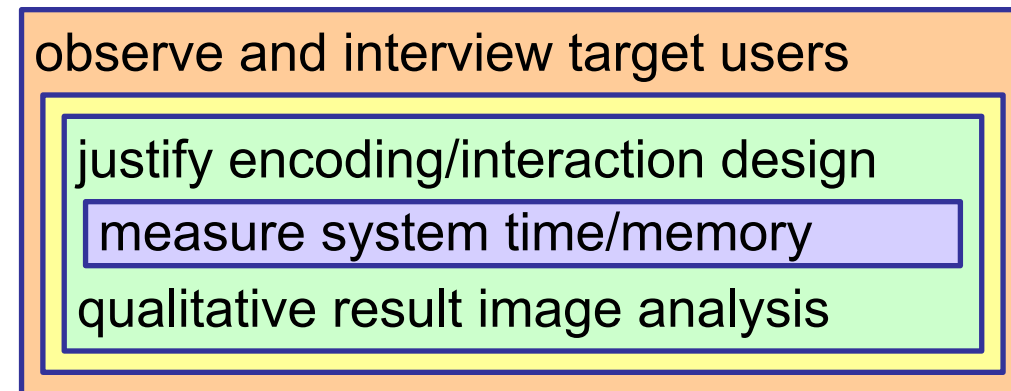


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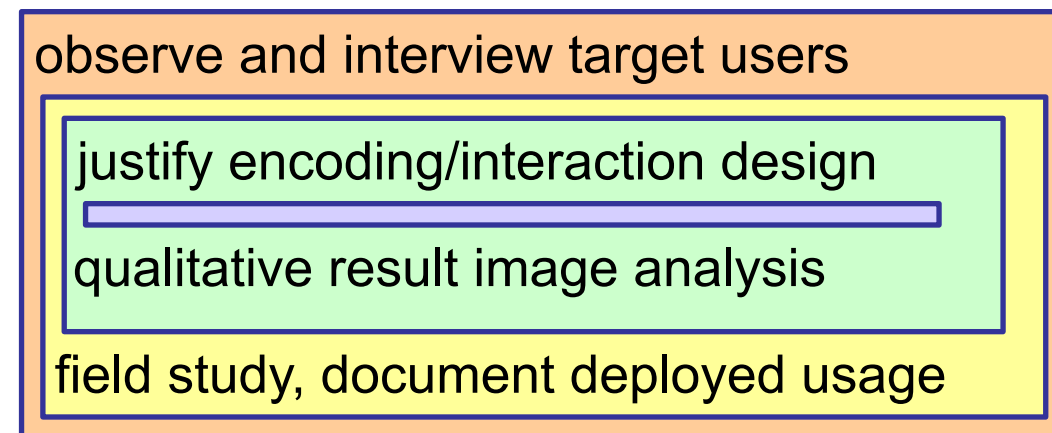


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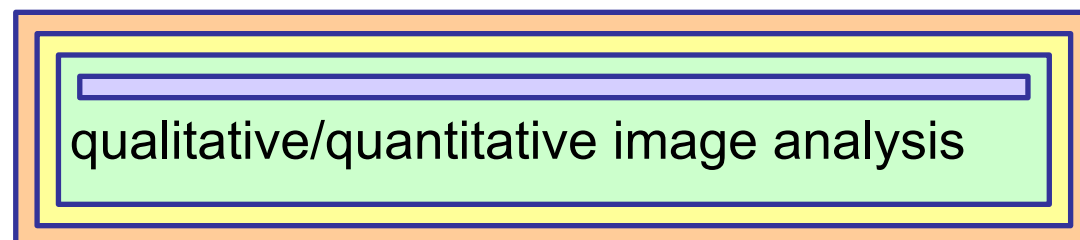
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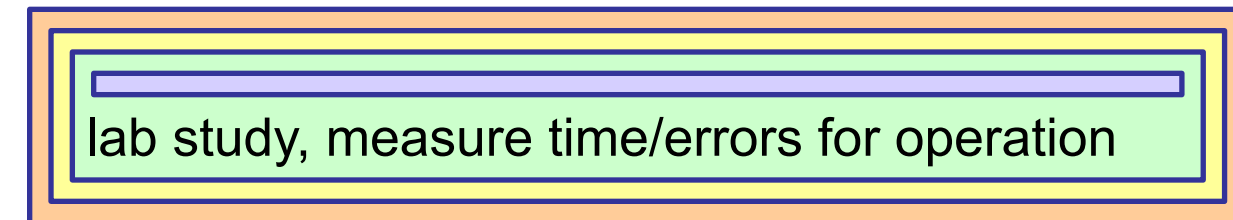
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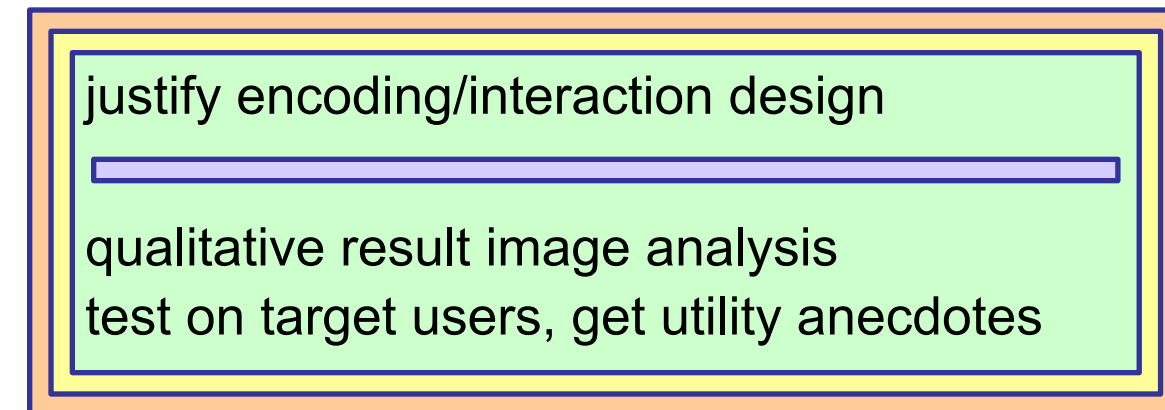
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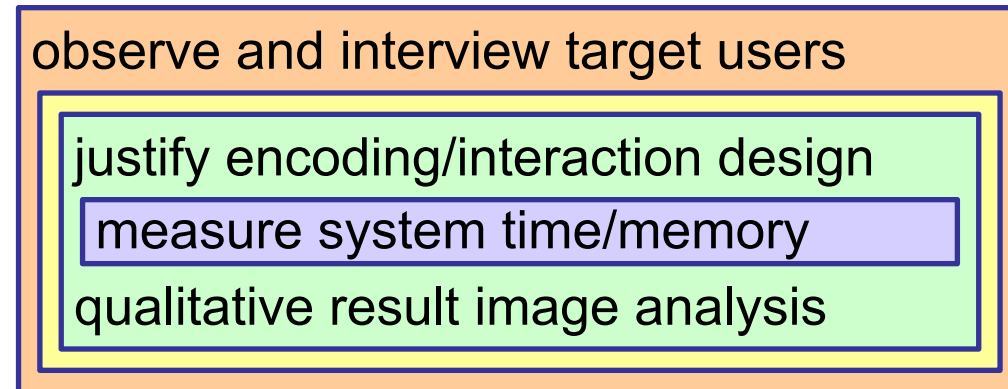


Interactive visualization of genealogical graphs.
McGuffin and Balakrishnan. InfoVis 2005.

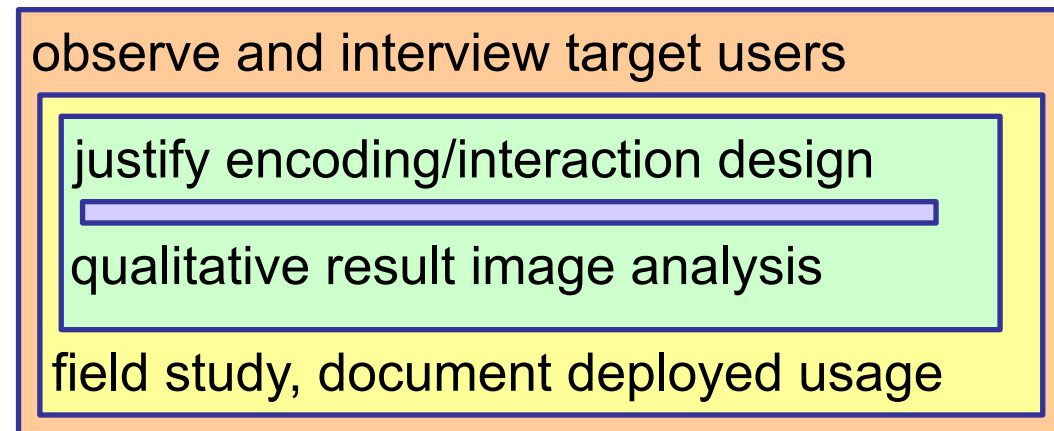


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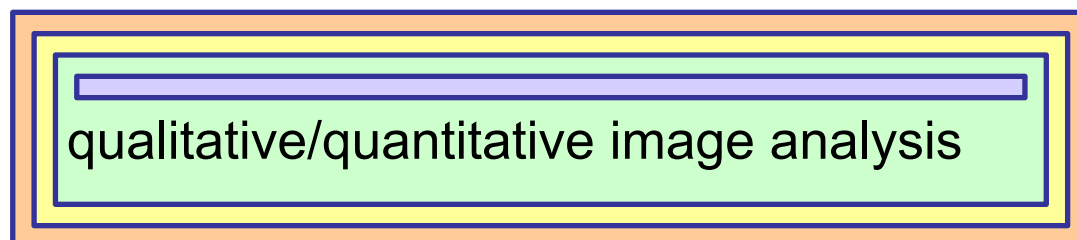
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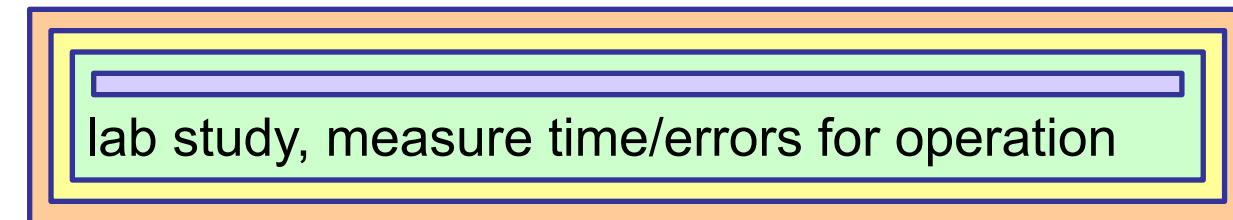
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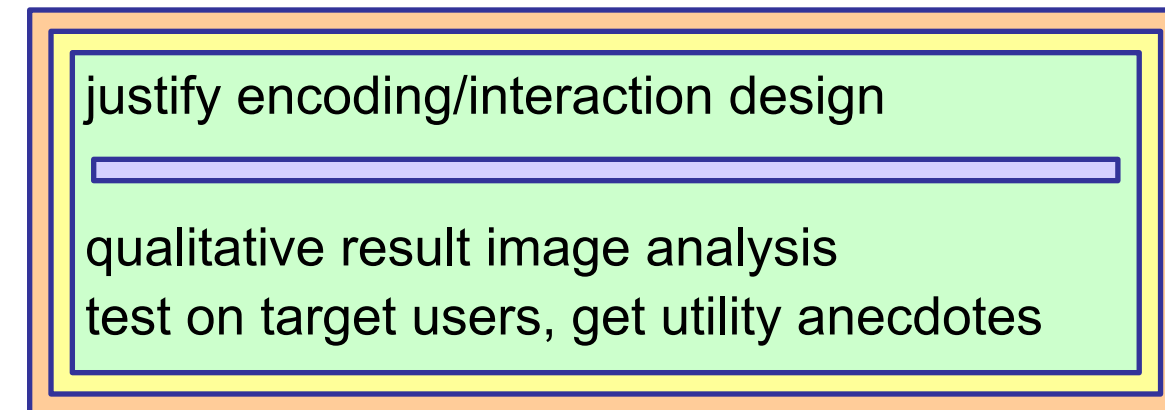
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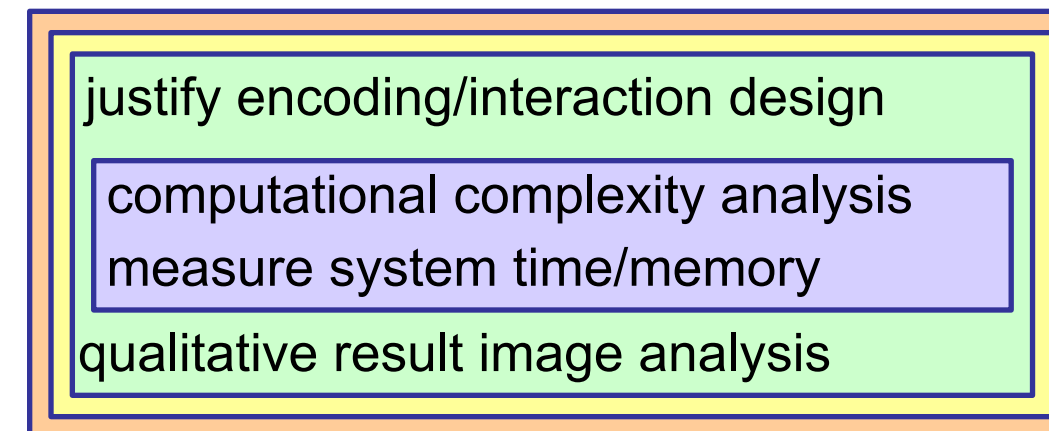
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Interactive visualization of genealogical graphs. McGuffin and Balakrishnan. InfoVis 2005.



Flow map layout. Phan et al. InfoVis 2005.



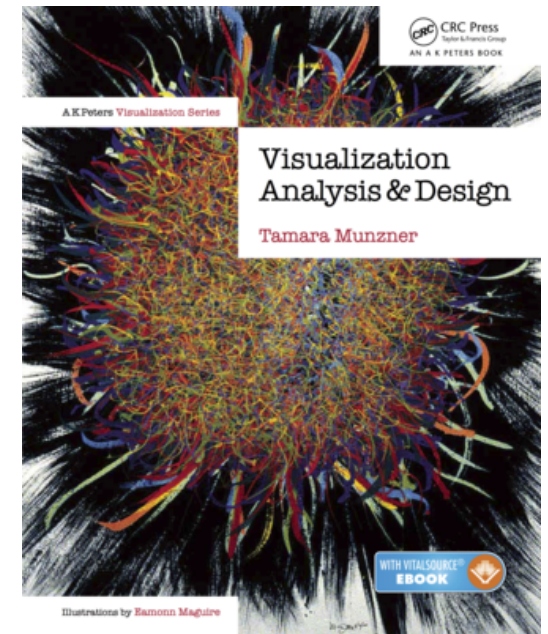
Visualization Analysis & Design

Data Abstraction (Ch 2): In Brief

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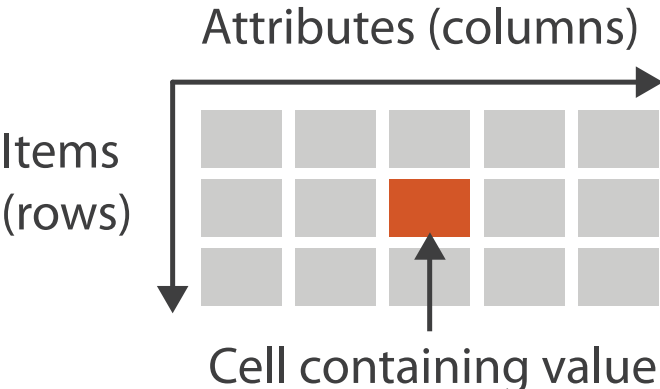


Three major datatypes

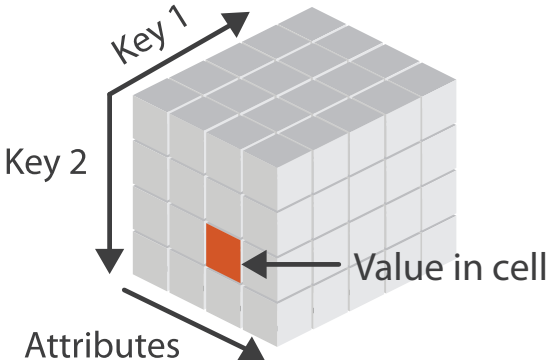
Three major datatypes

→ Dataset Types

→ Tables



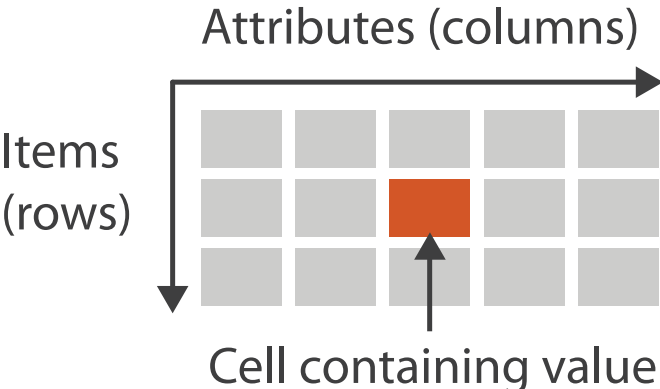
→ *Multidimensional Table*



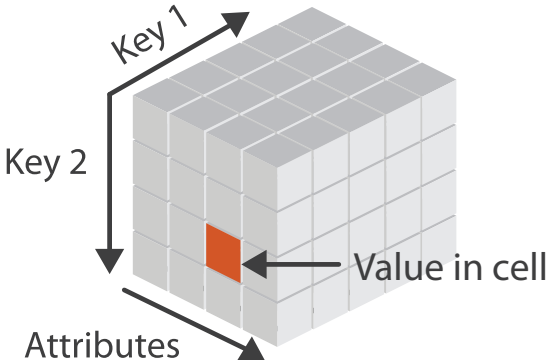
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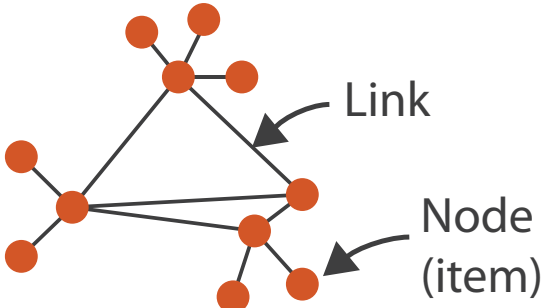
→ Tables



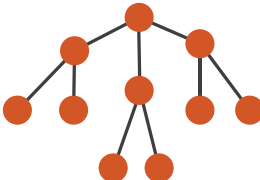
→ *Multidimensional Table*



→ Networks



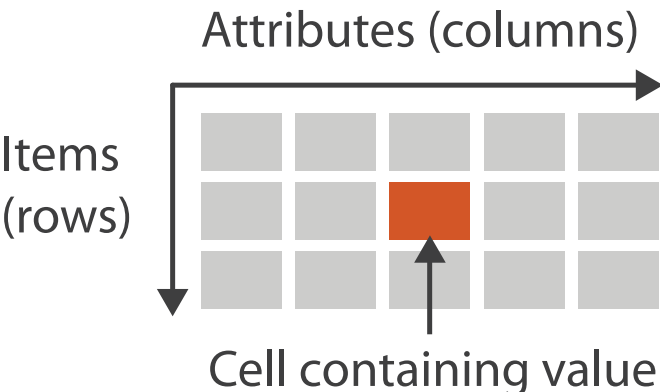
→ *Trees*



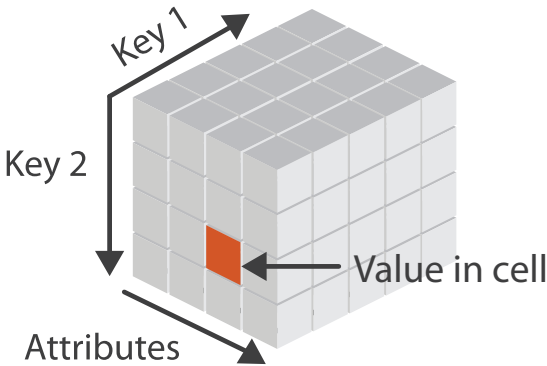
Three major datatypes

→ Dataset Types

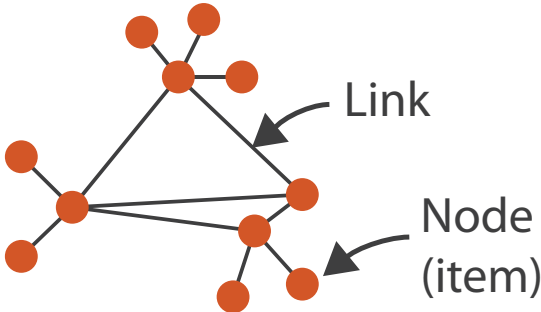
→ Tables



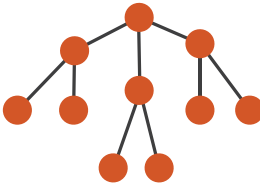
→ Multidimensional Table



→ Networks

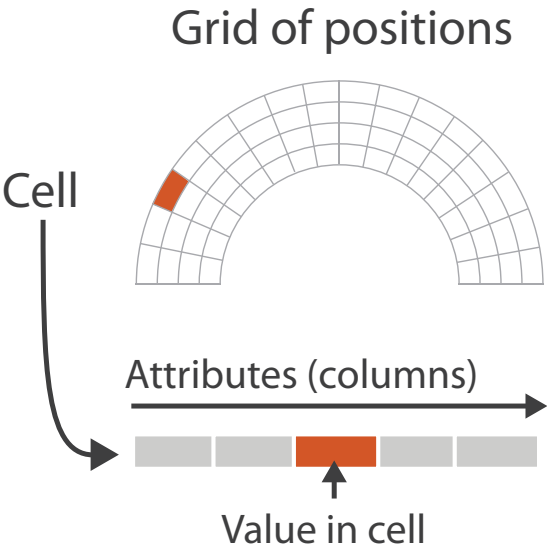


→ Trees

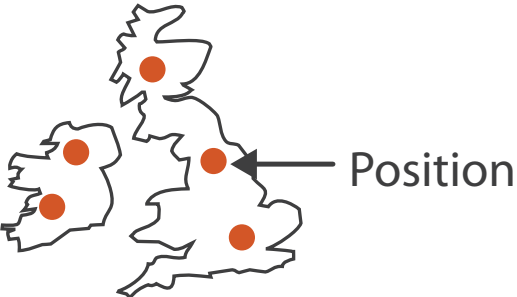


→ Spatial

→ Fields (Continuous)



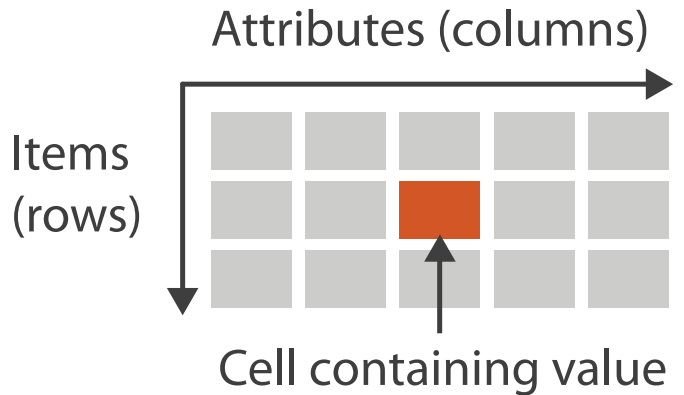
→ Geometry (Spatial)



Three major datatypes

→ Dataset Types

→ Tables

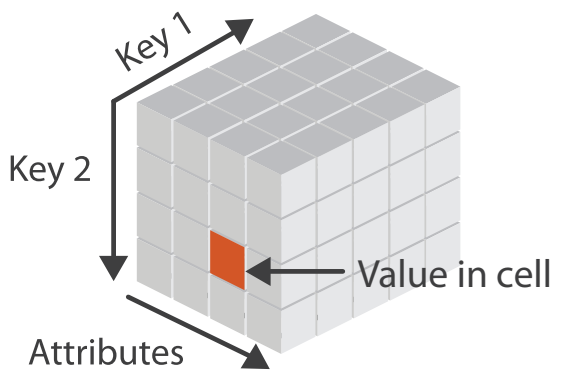


Attributes (columns)

Items (rows)

Cell containing value

→ *Multidimensional Table*



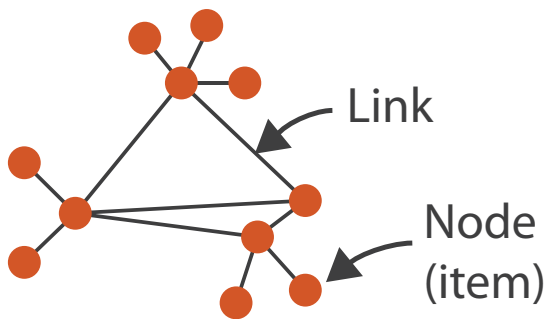
Key 1

Key 2

Attributes

Value in cell

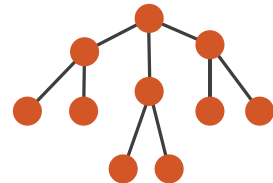
→ Networks



Link

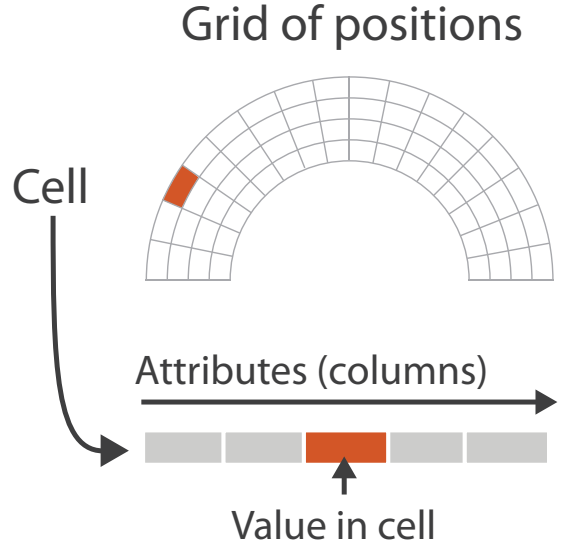
Node (item)

→ Trees



→ Spatial

→ Fields (Continuous)




Grid of positions

Cell

Attributes (columns)

Value in cell

→ Geometry (Spatial)



Position

- visualization vs computer graphics
 - geometry is design decision

Attribute types

➔ Attribute Types

➔ Categorical

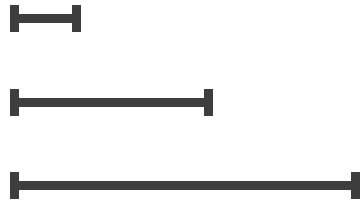


➔ Ordered

➔ *Ordinal*



➔ *Quantitative*



➔ Ordering Direction

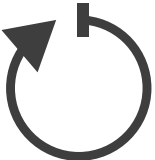
➔ Sequential



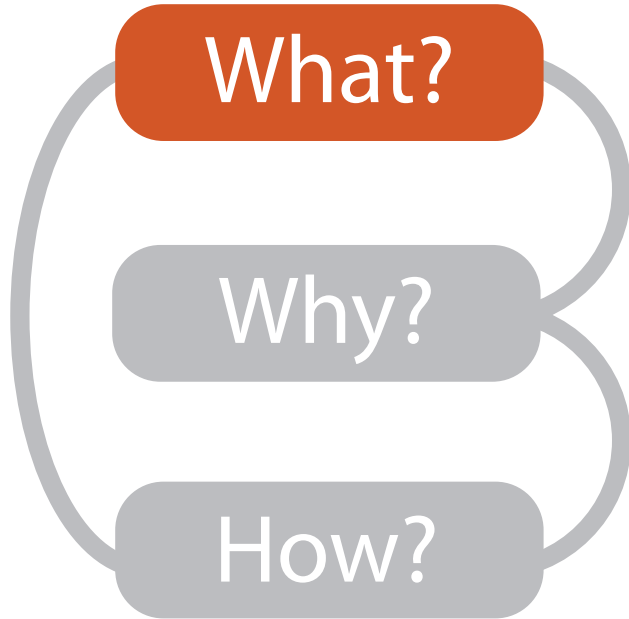
➔ Diverging



➔ Cyclic



What?



Datasets

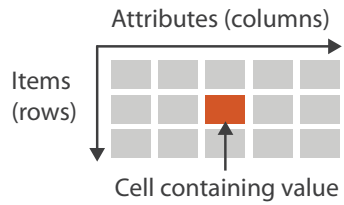
- ➔ Data Types
 - ➔ Items
 - ➔ Attributes
 - ➔ Links
 - ➔ Positions
 - ➔ Grids

➔ Data and Dataset Types

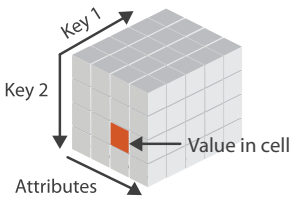
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

➔ Dataset Types

➔ Tables



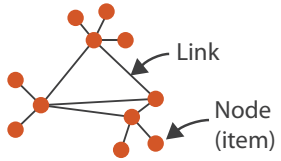
➔ Multidimensional Table



➔ Geometry (Spatial)



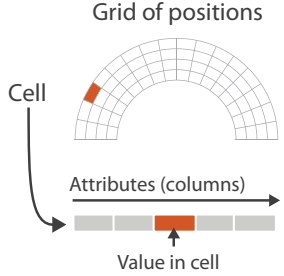
➔ Networks



➔ Trees



➔ Fields (Continuous)



➔ Dataset Availability

➔ Static



➔ Dynamic



Attributes

➔ Attribute Types

➔ Categorical



➔ Ordered

➔ Ordinal



➔ Quantitative



➔ Ordering Direction

➔ Sequential



➔ Diverging



➔ Cyclic



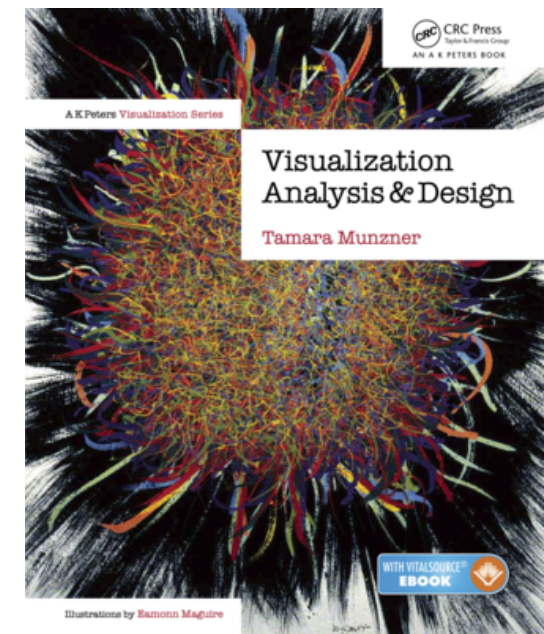
Visualization Analysis & Design

Data Abstraction (Ch 2)

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



What does data mean?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
 - something else??

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
 - something else??

Basil, 7, S, Pear

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
 - something else??

Basil, 7, S, Pear

- What about this data?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
 - something else??

Basil, 7, S, Pear

- What about this data?
 - food shipment of produce (basil & pear) arrived in satisfactory condition on 7th day of month

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
 - something else??

Basil, 7, S, Pear

- What about this data?
 - food shipment of produce (basil & pear) arrived in satisfactory condition on 7th day of month
 - Basil Point neighborhood of city had 7 inches of snow cleared by the Pear Creek Limited snow removal service

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
 - two points far from each other in 3D space?
 - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
 - something else??

Basil, 7, S, Pear

- What about this data?
 - food shipment of produce (basil & pear) arrived in satisfactory condition on 7th day of month
 - Basil Point neighborhood of city had 7 inches of snow cleared by the Pear Creek Limited snow removal service
 - lab rat Basil made 7 attempts to find way through south section of maze, these trials used pear as reward food

Now what?

- semantics: real-world meaning

Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

Now what?

- semantics: real-world meaning

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

Now what?

- semantics: real-world meaning
- data types: structural or mathematical interpretation of data
 - item, link, attribute, position, (grid)
 - different from data types in programming!

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

Items & Attributes

- item: individual entity, discrete
 - eg patient, car, stock, city
 - "independent variable"

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

Items & Attributes

- item: individual entity, discrete
 - eg patient, car, stock, city
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Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

Items & Attributes

- **item**: individual entity, discrete
 - eg patient, car, stock, city
 - "independent variable"
- **attribute**: property that is measured, observed, logged...
 - eg height, blood pressure for patient
 - eg horsepower, make for car
 - "dependent variable"

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

Items & Attributes

- item: individual entity, discrete
 - eg patient, car, stock, city
 - "independent variable"
- attribute: property that is measured, observed, logged...
 - eg height, blood pressure for patient
 - eg horsepower, make for car
 - "dependent variable"

attributes: name, age, shirt size, fave fruit

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

Other data types

- links
 - express relationship between two items
 - eg friendship on facebook, interaction between proteins
- positions
 - spatial data: location in 2D or 3D
 - pixels in photo, voxels in MRI scan, latitude/longitude
- grids
 - sampling strategy for continuous data

Dataset types

Tables

Items

Attributes

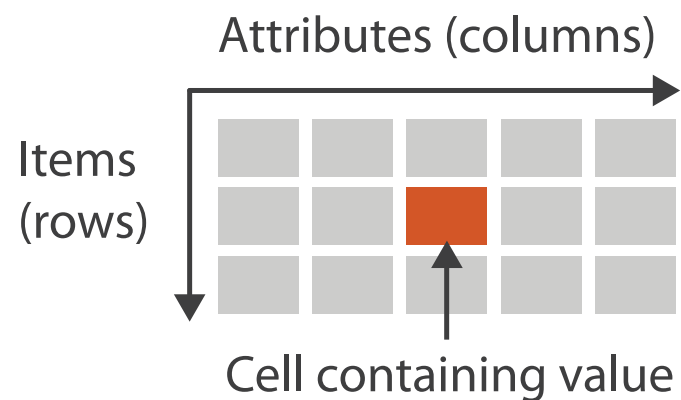
- flat table
 - one item per row
 - each column is attribute
 - cell holds value for item-attribute pair

attributes: name, age, shirt size, fave fruit

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

→ Tables



Dataset types

Tables

Items

Attributes

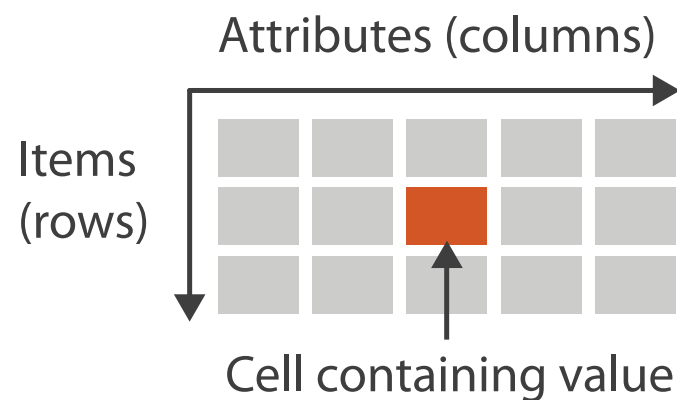
- flat table
 - one item per row
 - each column is attribute
 - cell holds value for item-attribute pair
 - unique key (could be implicit)

attributes: name, age, shirt size, fave fruit

ID	Name	Age	Shirt Size	Favorite Fruit
1	Amy	8	S	Apple
2	Basil	7	S	Pear
3	Clara	9	M	Durian
4	Desmond	13	L	Elderberry
5	Ernest	12	L	Peach
6	Fanny	10	S	Lychee
7	George	9	M	Orange
8	Hector	8	L	Loquat
9	Ida	10	M	Pear
10	Amy	12	M	Orange

item: person

→ Tables



Table

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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	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

Table

item

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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	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

Table

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
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32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	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

item

attribute

Table

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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	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

item

cell

attribute

Dataset types

Tables

Items

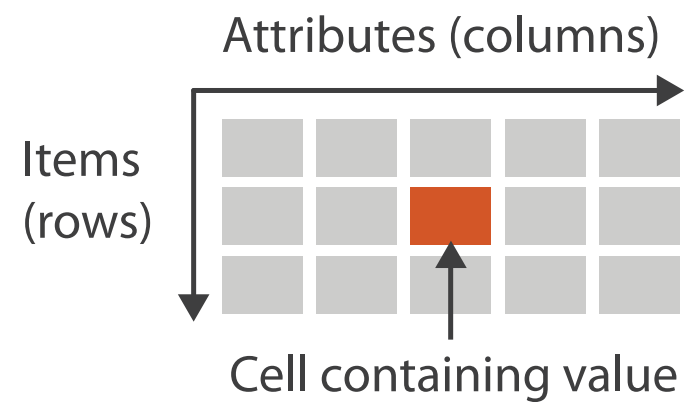
Attributes

- multidimensional tables
 - indexing based on multiple keys
 - eg genes, patients

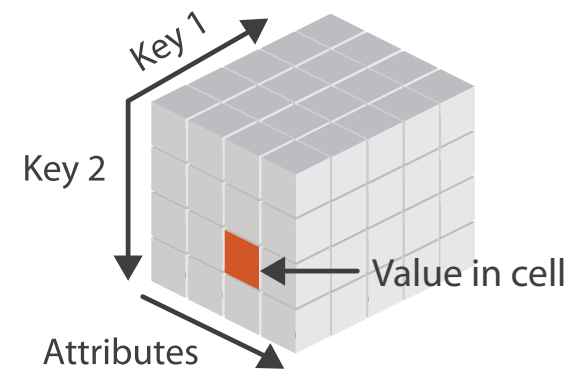
	A	B	C	D	E
1					
2	1	1			
3	2	2			
4	3	3			
5	4	4			
6	5	5			
7	6	6			
8	7	7			
9	8	8			
10	9	9			
11	10	10			
12	11	11			
13	12	12			
14	13	13			
15	14	14			
16	15	15			
17	16	16			
18	17	17			
19	18	18			
20	19	19			
21	20	20			
22	21	21			

	A	B	C	D	E
1					
2	1	1			
3	2	2			
4	3	3			
5	4	4			
6	5	5			
7	6	6			
8	7	7			
9	8	8			
10	9	9			
11	10	10			
12	11	11			
13	12	12			
14	13	13			
15	14	14			
16	15	15			
17	16	16			
18	17	17			
19	18	18			
20	19	19			
21	20	20			
22	21	21			

→ Tables



→ Multidimensional Table



Dataset types

Tables

Items

Attributes

Networks &
Trees

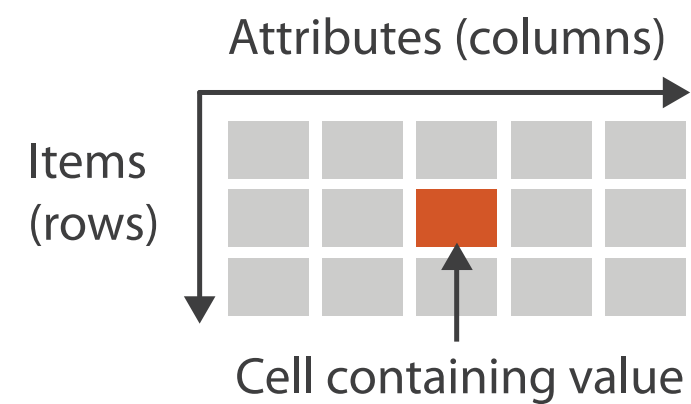
Items (nodes)

Links

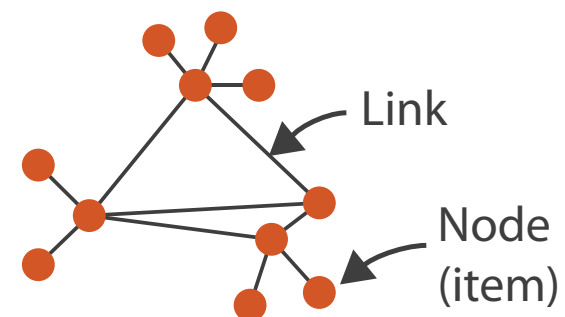
Attributes

- **network/graph**
 - nodes (vertices) connected by links (edges)
 - tree is special case: no cycles
 - often have roots and are directed

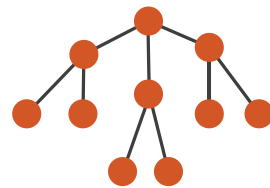
→ Tables



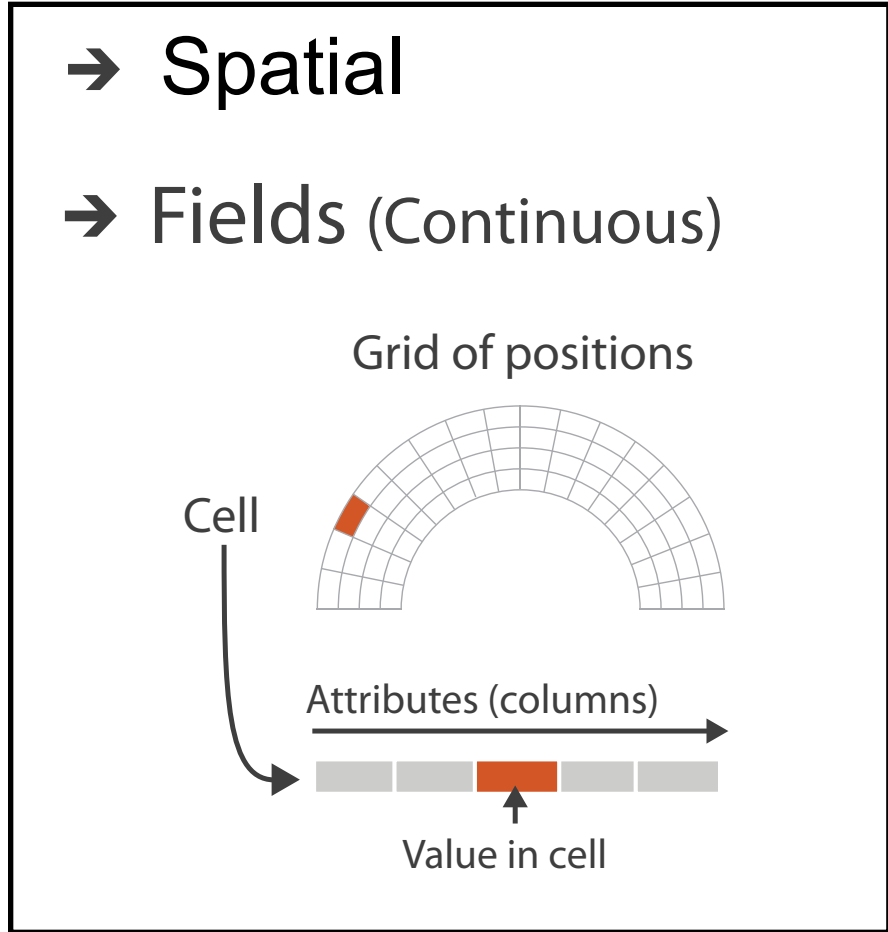
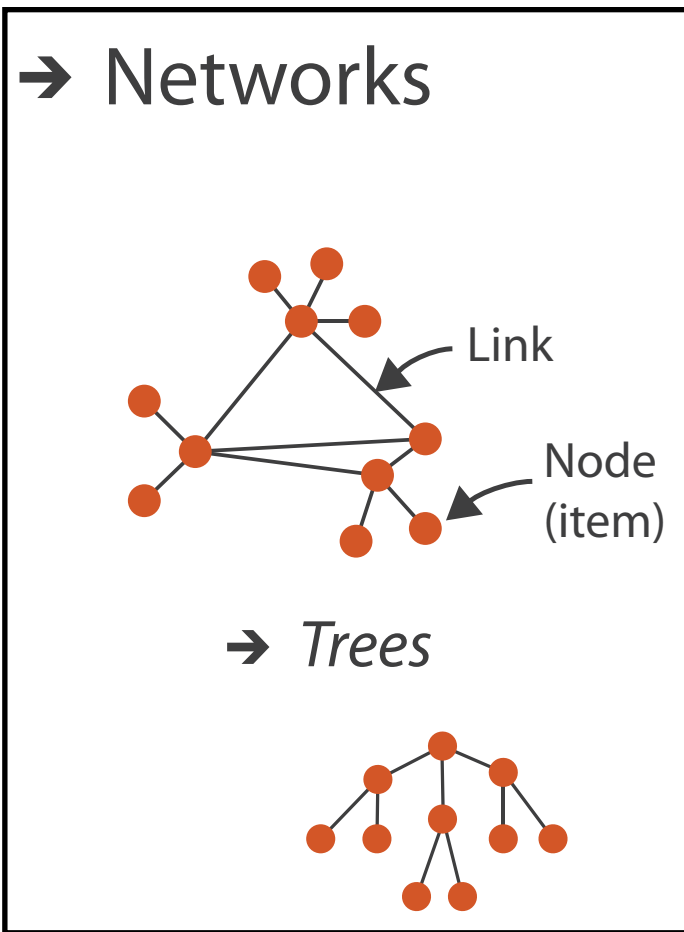
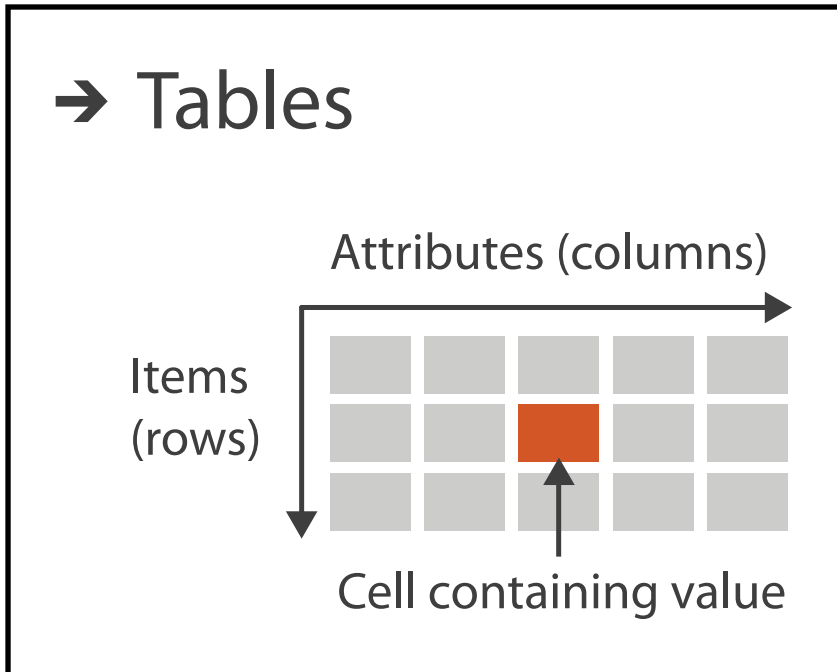
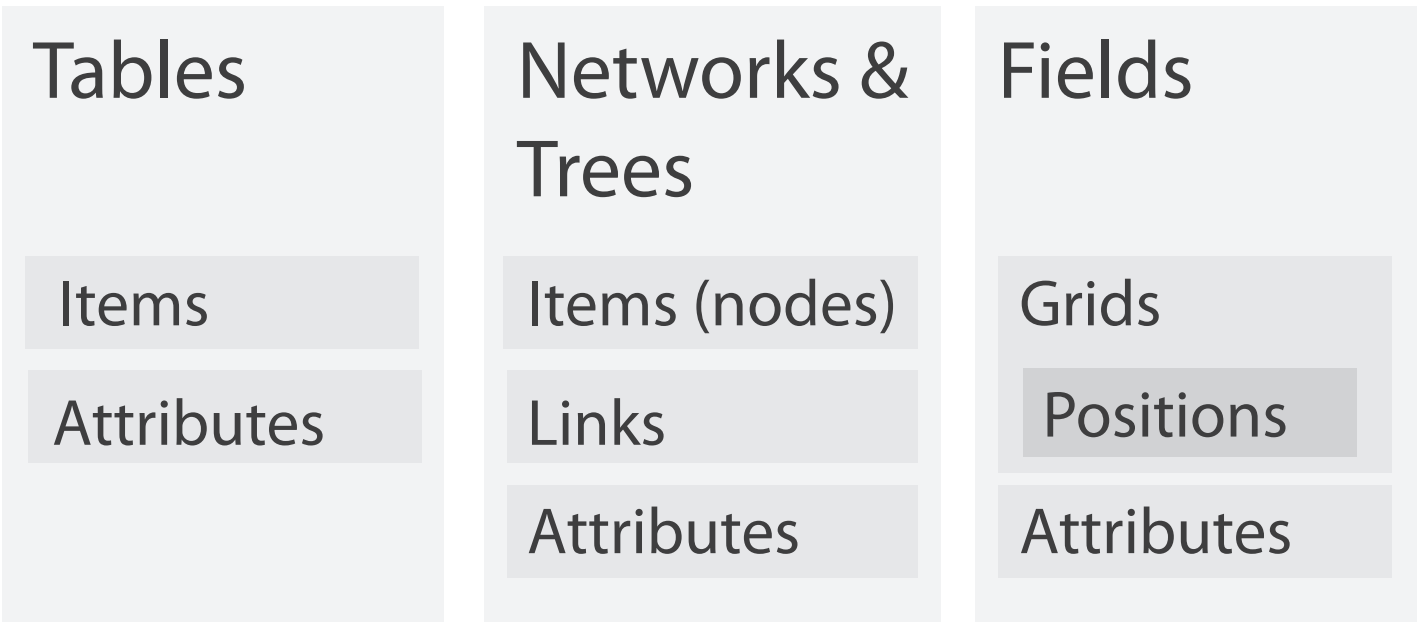
→ Networks



→ Trees



Dataset types

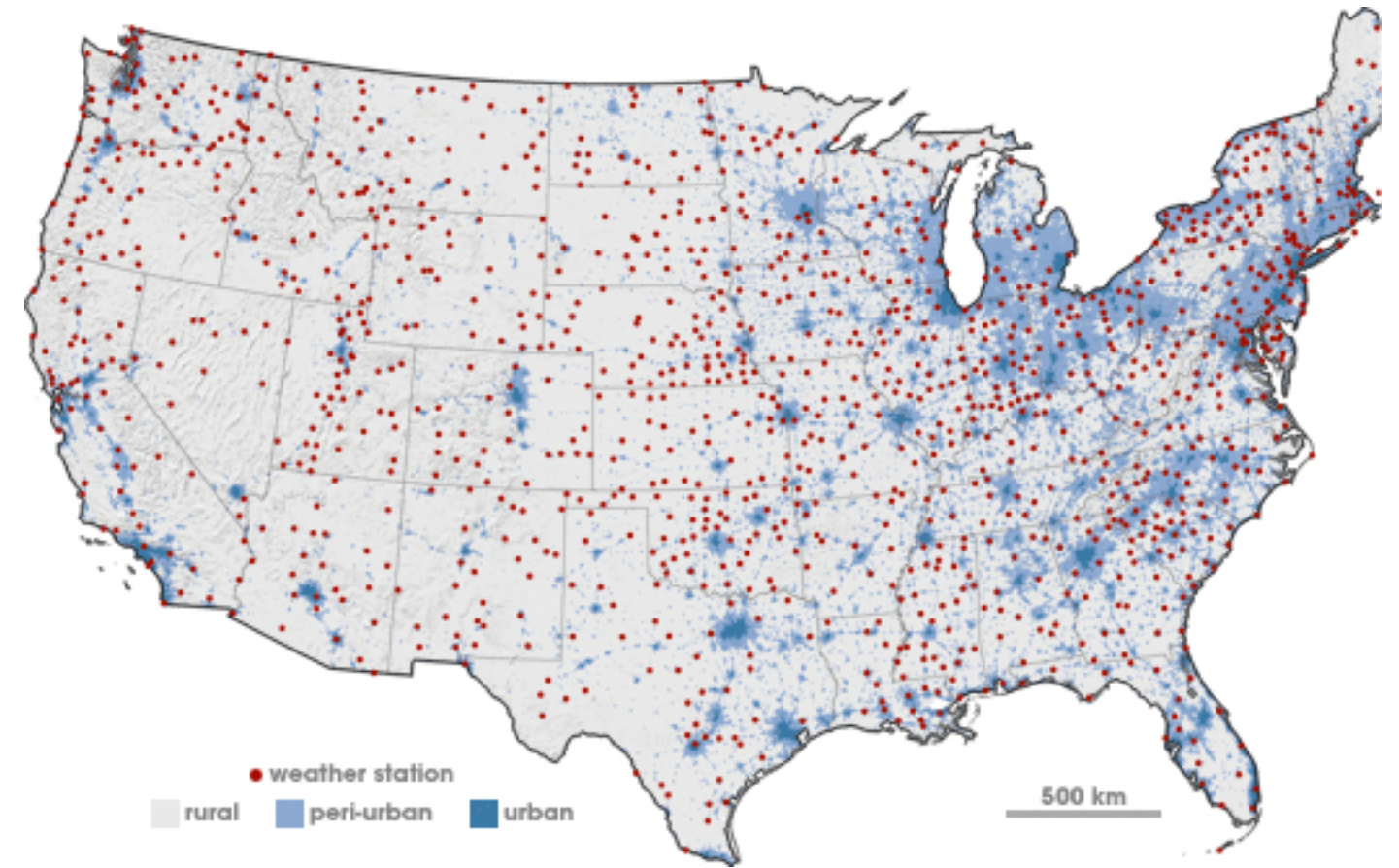
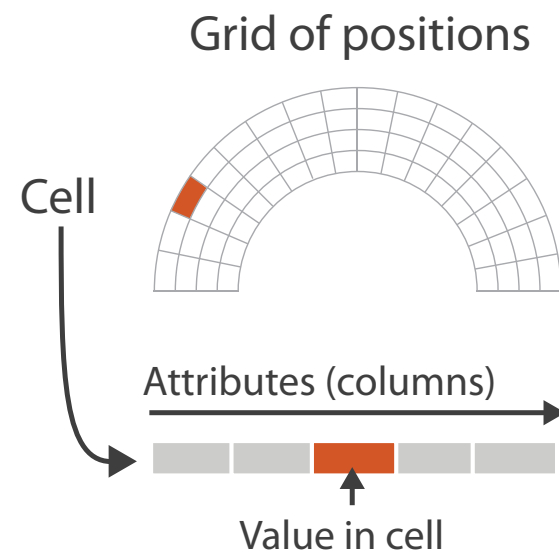


Spatial fields

- attribute values associated w/ cells
- cell contains value from continuous domain
 - eg temperature, pressure, wind velocity
- measured or simulated

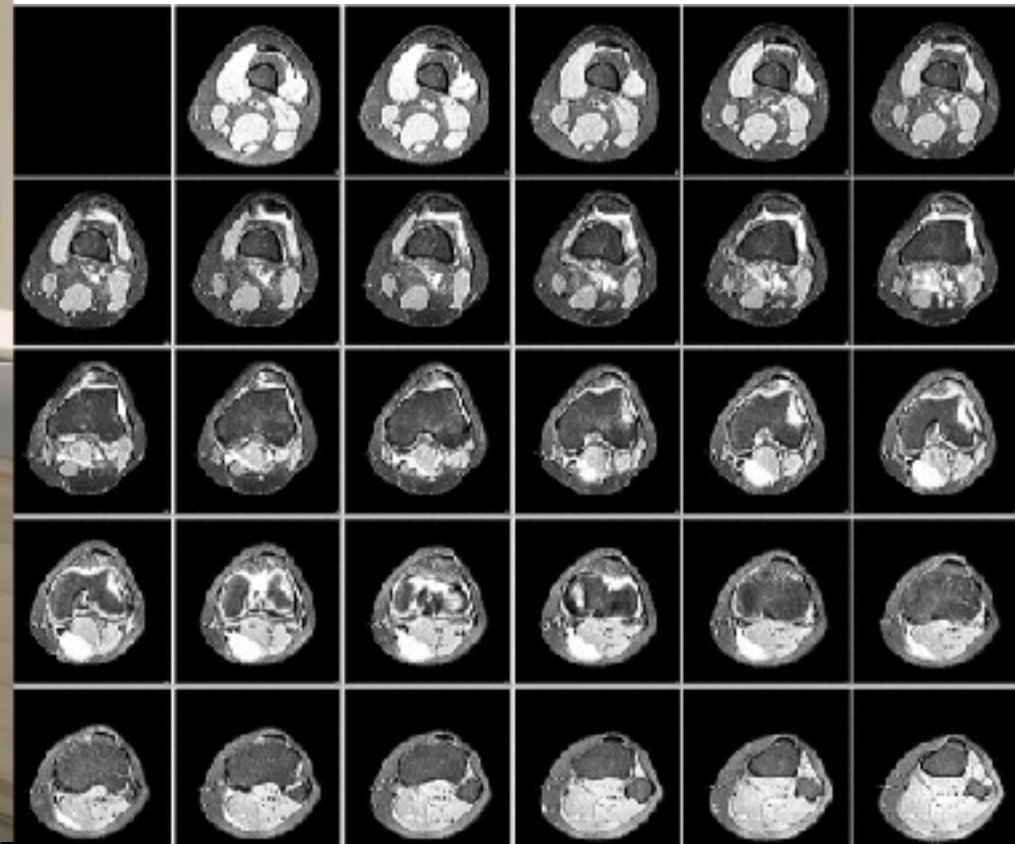
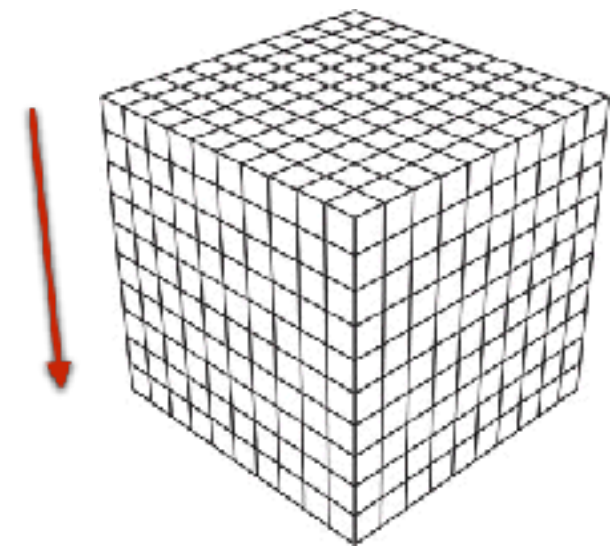
→ Spatial

→ Fields (Continuous)



Spatial fields

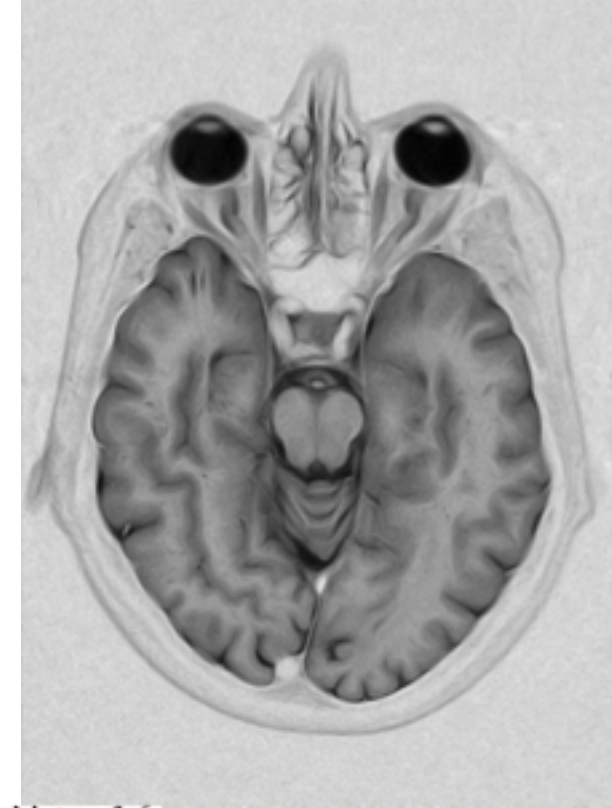
- attribute values associated w/ cells
- cell contains value from continuous domain
 - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
 - sampling:
where attributes are measured
 - interpolation:
how to model attributes elsewhere
 - grid types



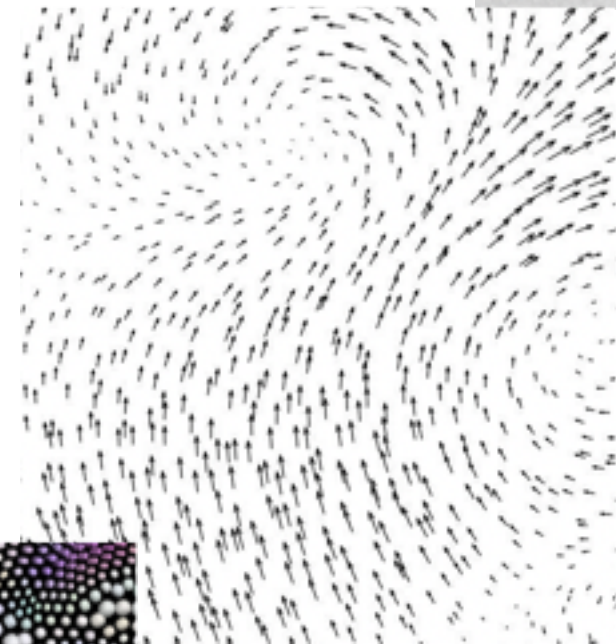
Spatial fields

- attribute values associated w/ cells
- cell contains value from continuous domain
 - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
 - sampling:
where attributes are measured
 - interpolation:
how to model attributes elsewhere
 - grid types
- major divisions
 - attributes per cell:
scalar (1), vector (2), tensor (many)

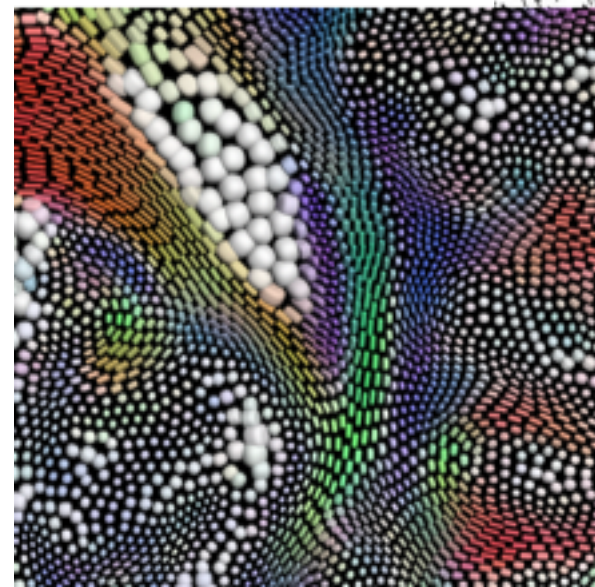
scalar



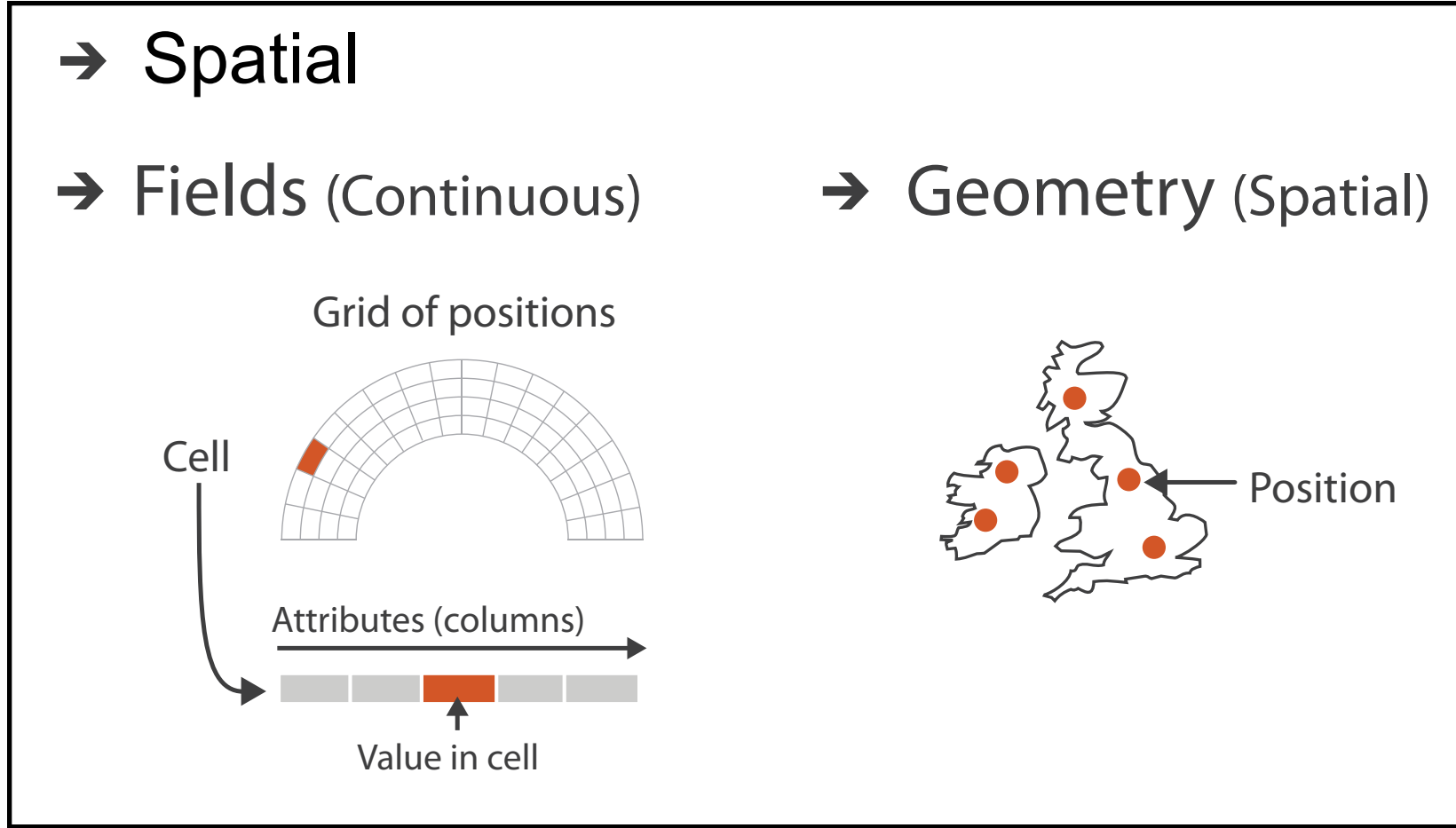
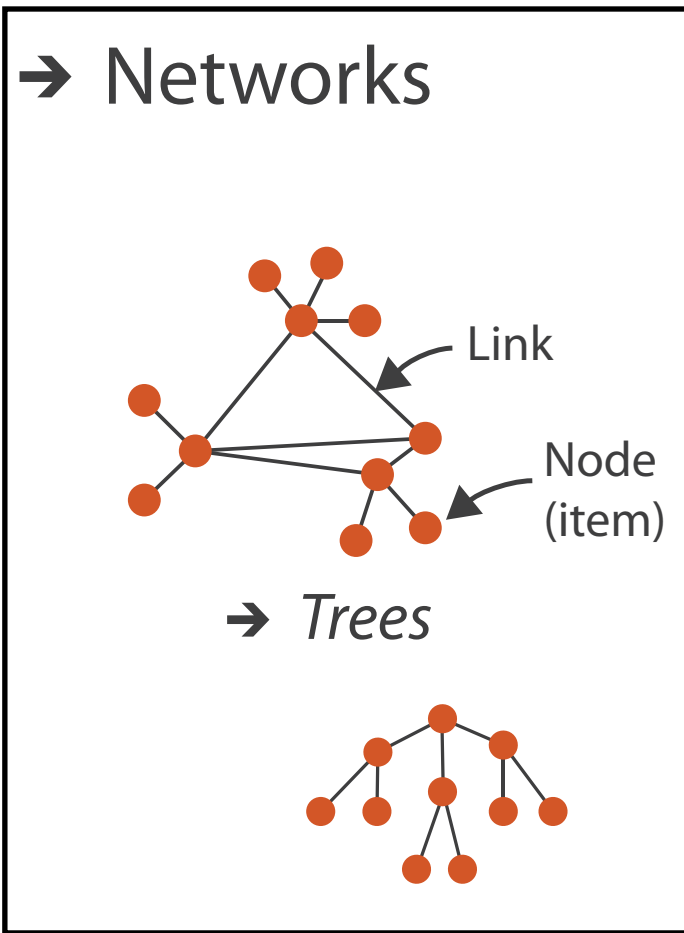
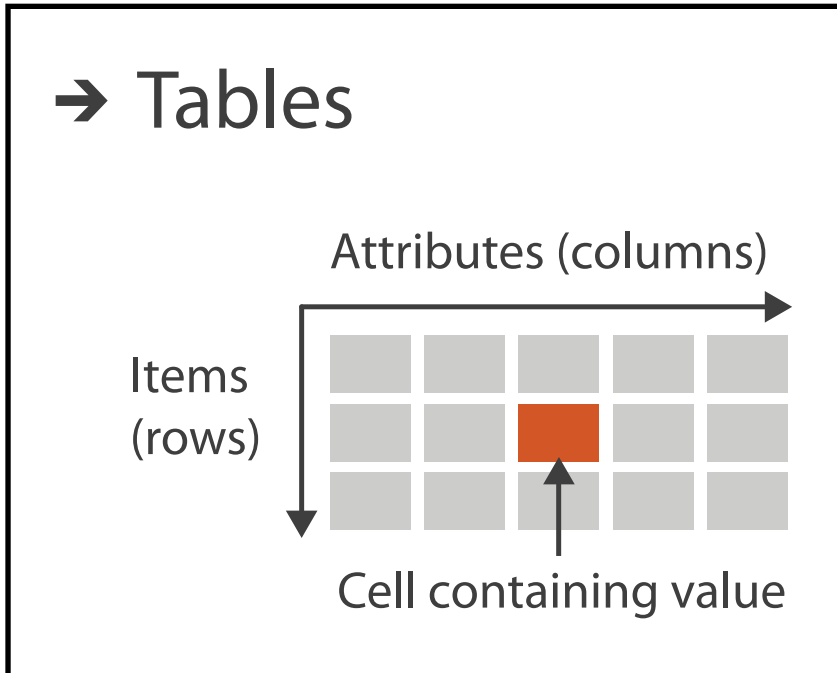
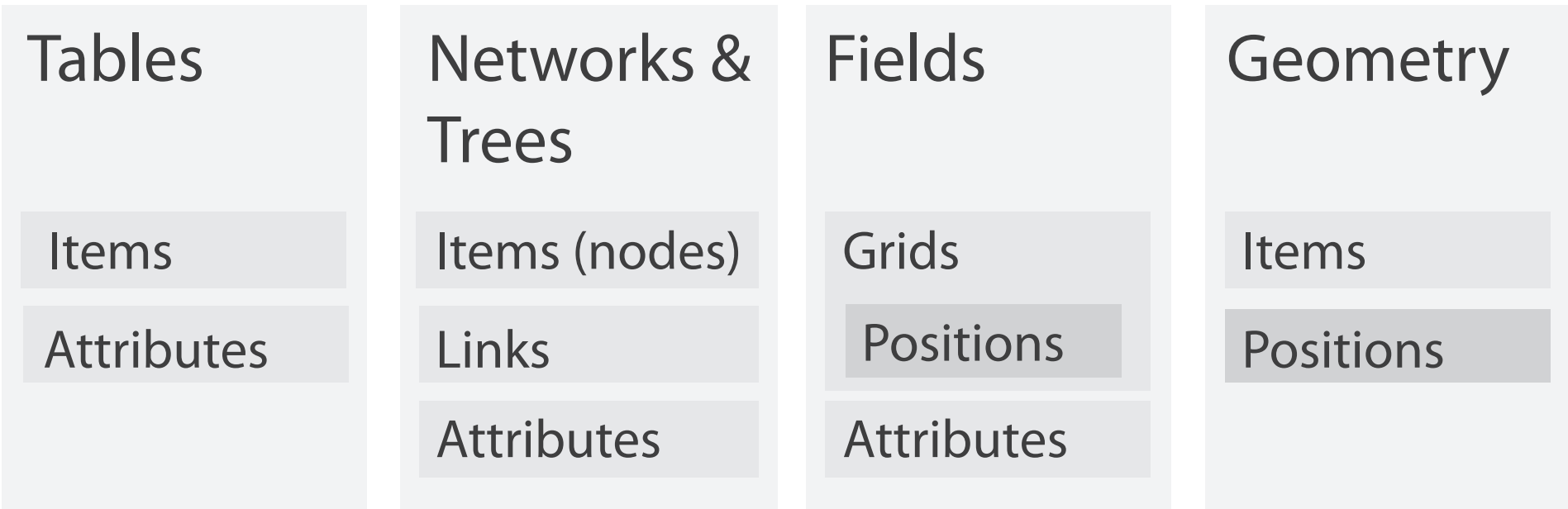
vector



tensor

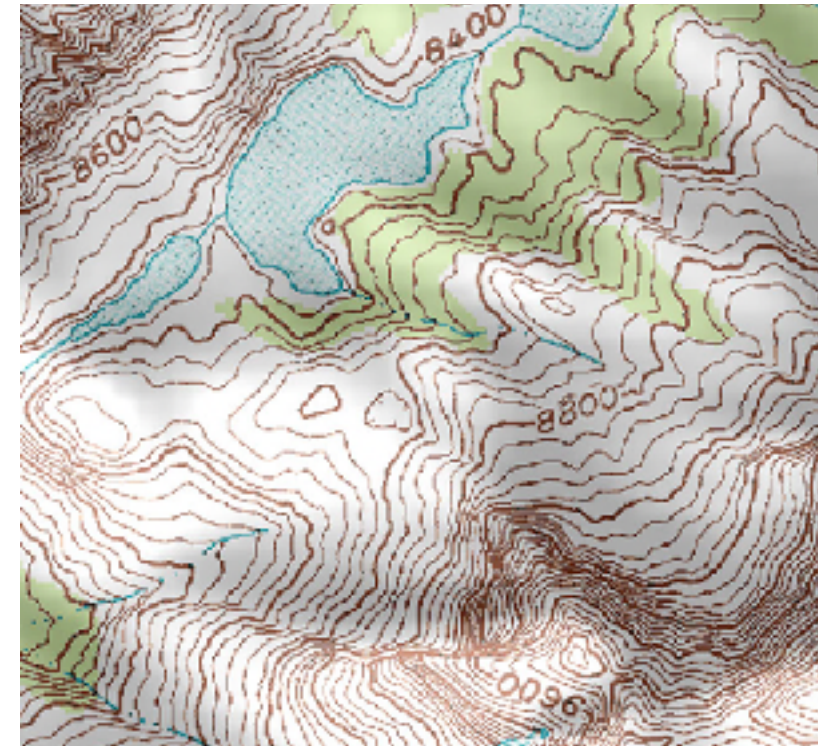


Dataset types



Geometry

- shape of items
- explicit spatial positions / regions
 - points, lines, curves, surfaces, volumes
- boundary between computer graphics and visualization
 - graphics: geometry taken as given
 - vis: geometry is result of a design decision



Dataset types

Tables

Items

Attributes

Networks &
Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

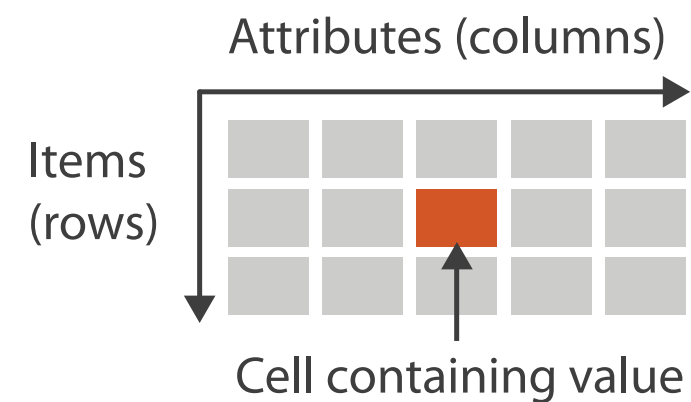
Items

Positions

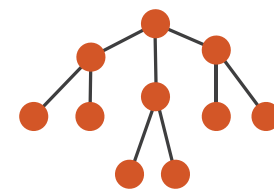
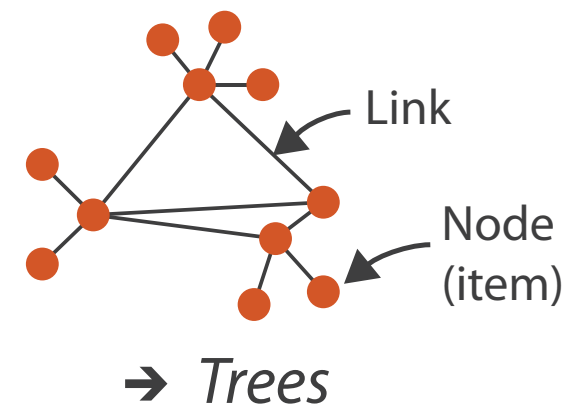
Clusters,
Sets, Lists

Items

→ Tables

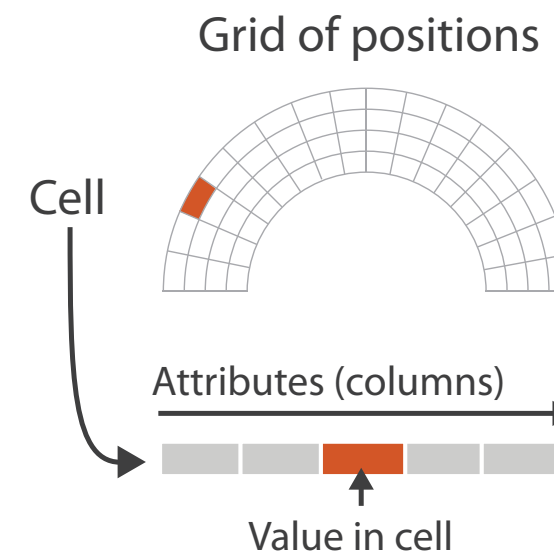


→ Networks



→ Spatial

→ Fields (Continuous)



→ Geometry (Spatial)

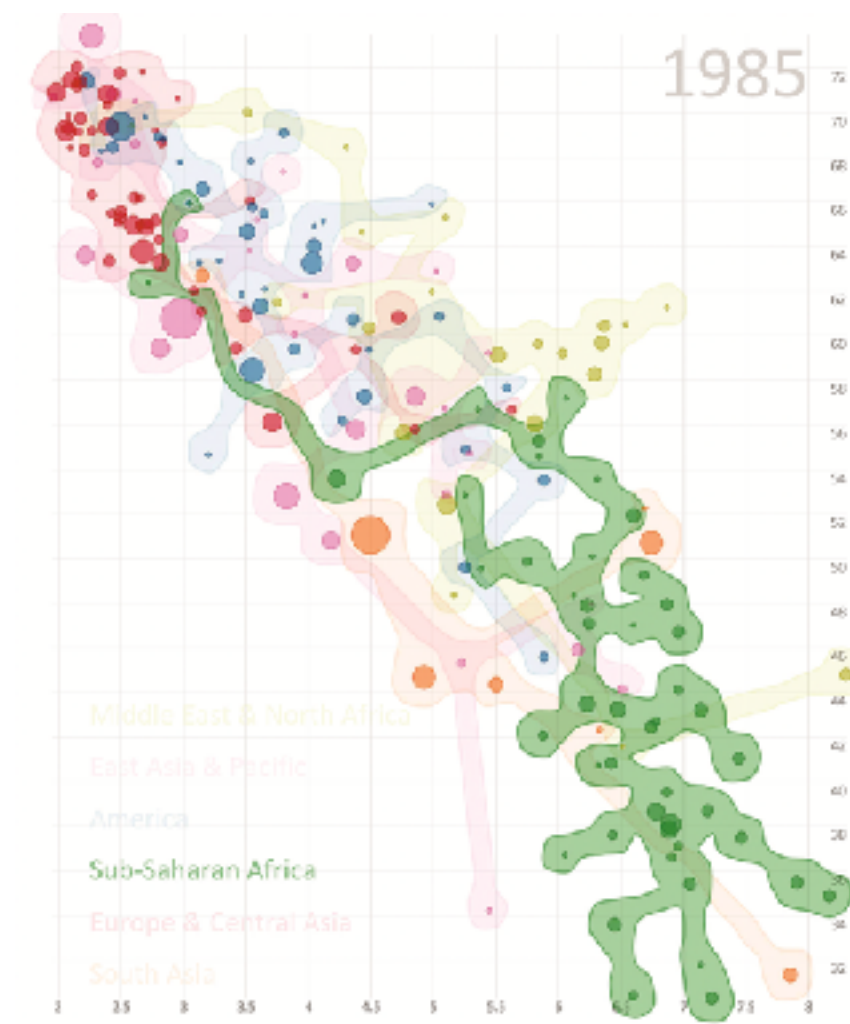


Collections

- how we group items

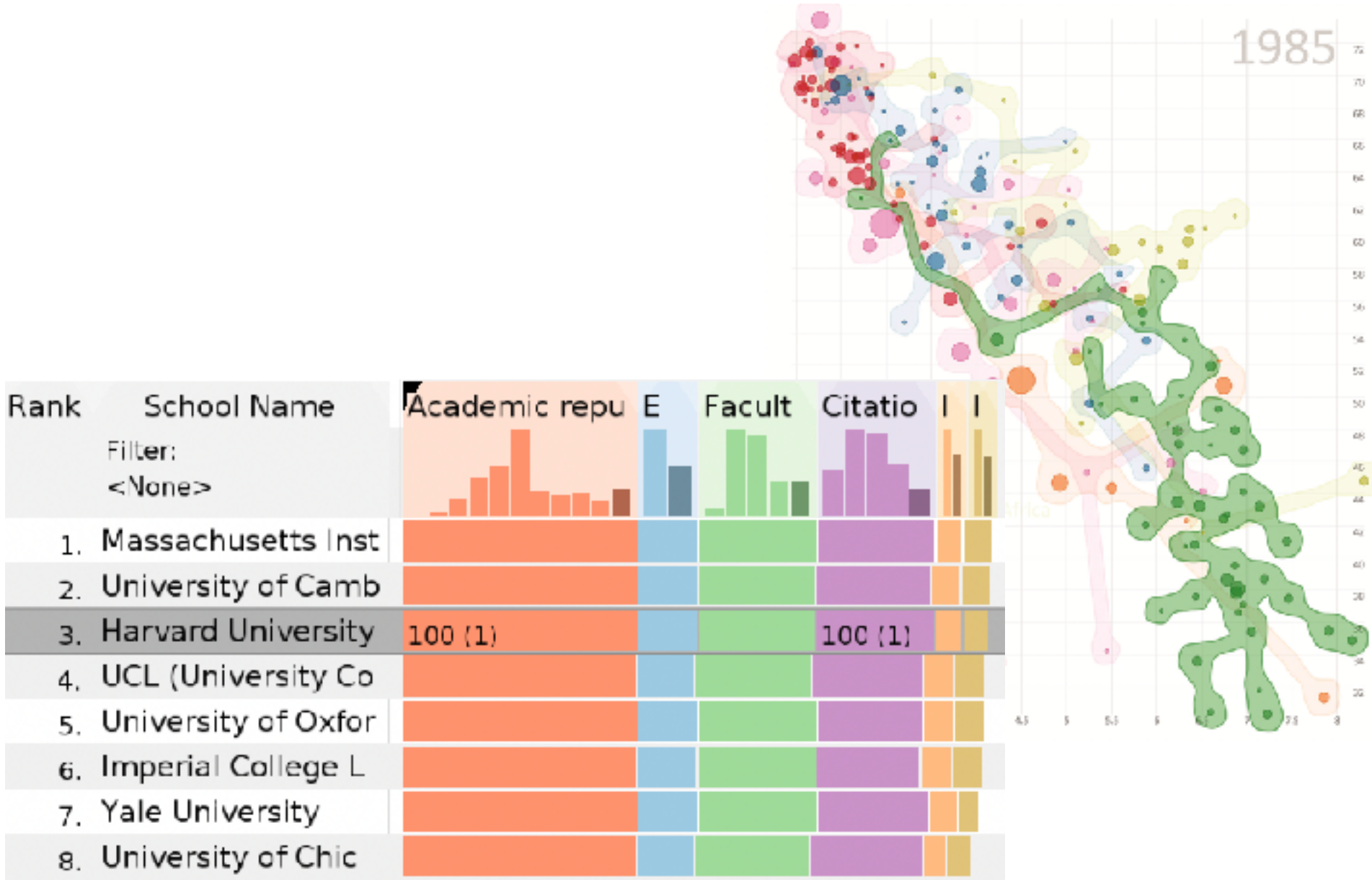
Collections

- how we group items
- sets
 - unique items, unordered



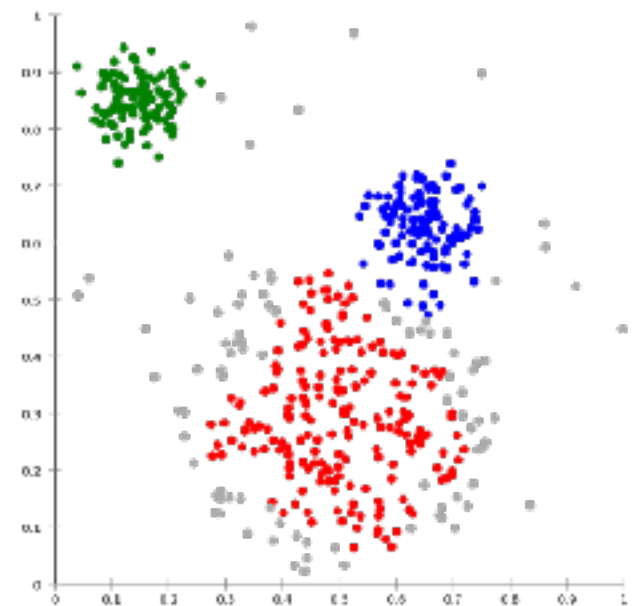
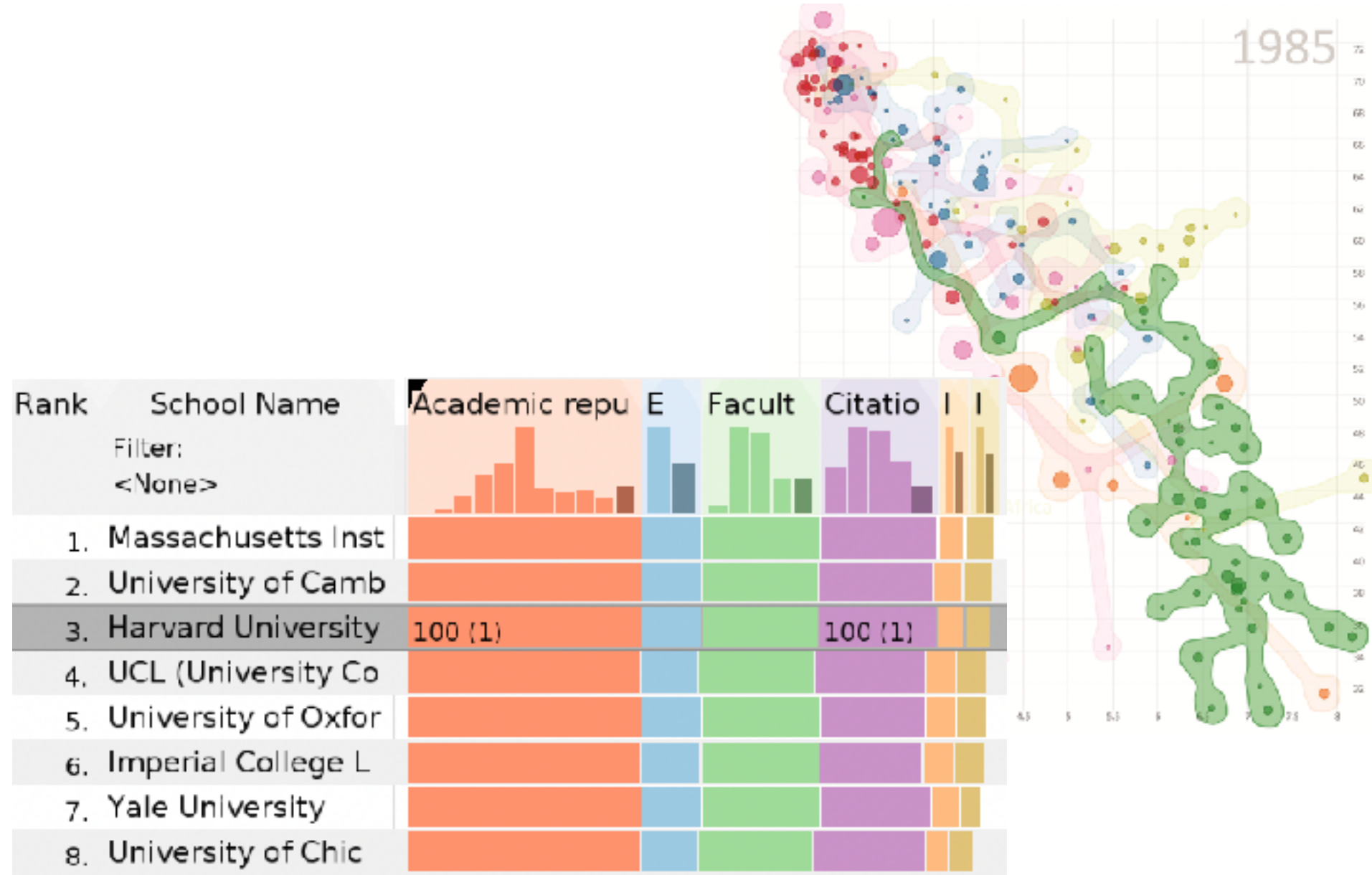
Collections

- how we group items
- sets
 - unique items, unordered
- lists
 - ordered, duplicates possible



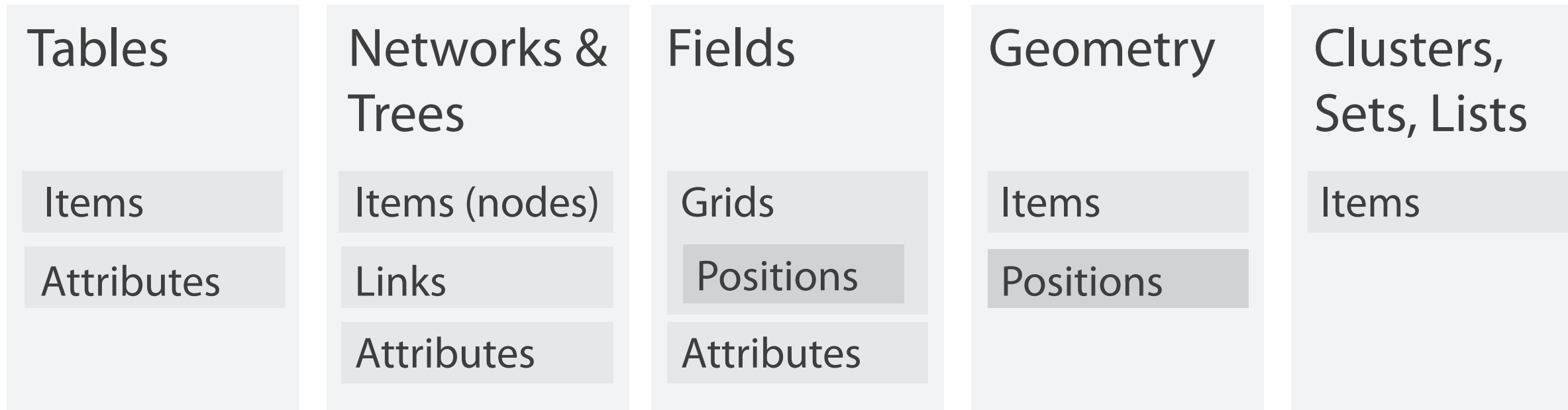
Collections

- how we group items
- sets
 - unique items, unordered
- lists
 - ordered, duplicates possible
- clusters
 - groups of similar items



Dataset and data types

→ Data and Dataset Types



→ Data Types

→ Items → Attributes → Links → Positions → Grids

Attribute types

- which classes of values & measurements?
- categorical (nominal)
 - compare equality
 - no implicit ordering
- ordered
 - ordinal
 - less/greater than defined
 - quantitative
 - meaningful magnitude
 - arithmetic possible

➔ Attribute Types

➔ Categorical

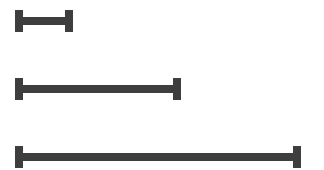


➔ Ordered

➔ *Ordinal*



➔ *Quantitative*



Table

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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	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

categorical
ordinal
quantitative

A	B	C	S	I	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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	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

Other data concerns

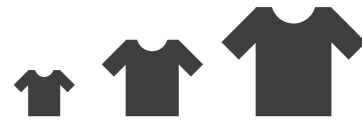
➔ Attribute Types

➔ Categorical

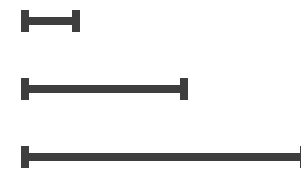


➔ Ordered

➔ Ordinal



➔ Quantitative



➔ Ordering Direction

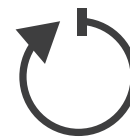
➔ Sequential



➔ Diverging



➔ Cyclic



➔ Dataset Availability

➔ Static



➔ Dynamic



Data abstraction: Three operations

- translate from domain-specific language to generic visualization language
- identify dataset type(s), attribute types
- identify cardinality
 - how many items in the dataset?
 - what is cardinality of each attribute?
 - number of levels for categorical data
 - range for quantitative data
- consider whether to transform data
 - guided by understanding of task

Data vs conceptual models

- data model
 - mathematical abstraction
 - sets with operations, eg floats with $*$ / - +
 - variable data types in programming languages
- conceptual model
 - mental construction (semantics)
 - supports reasoning
 - typically based on understanding of tasks [stay tuned!]
- data abstraction process relies on conceptual model
 - for transforming data if needed

Data vs conceptual model, example

Data vs conceptual model, example

- data model: floats
 - 32.52, 54.06, -14.35, ...

Data vs conceptual model, example

- data model: floats
 - 32.52, 54.06, -14.35, ...
- conceptual model
 - temperature

Data vs conceptual model, example

- data model: floats
 - 32.52, 54.06, -14.35, ...
- conceptual model
 - temperature
- multiple possible data abstractions

Data vs conceptual model, example

- data model: floats
 - 32.52, 54.06, -14.35, ...
- conceptual model
 - temperature
- multiple possible data abstractions
 - continuous to 2 significant figures: quantitative
 - task: forecasting the weather

Data vs conceptual model, example

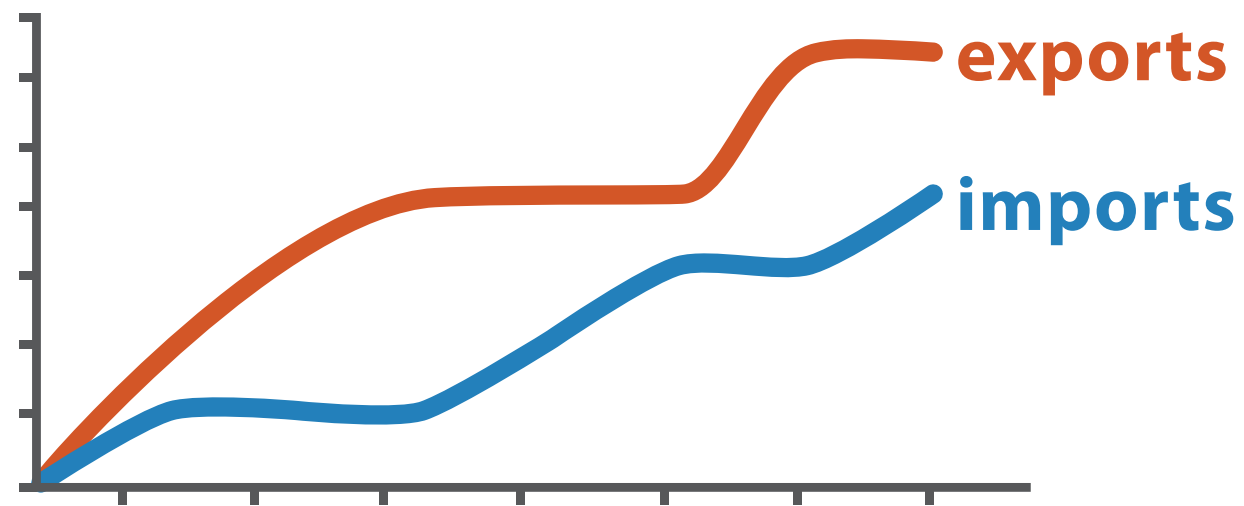
- data model: floats
 - 32.52, 54.06, -14.35, ...
- conceptual model
 - temperature
- multiple possible data abstractions
 - continuous to 2 significant figures: quantitative
 - task: forecasting the weather
 - hot, warm, cold: ordinal
 - task: deciding if bath water is ready

Data vs conceptual model, example

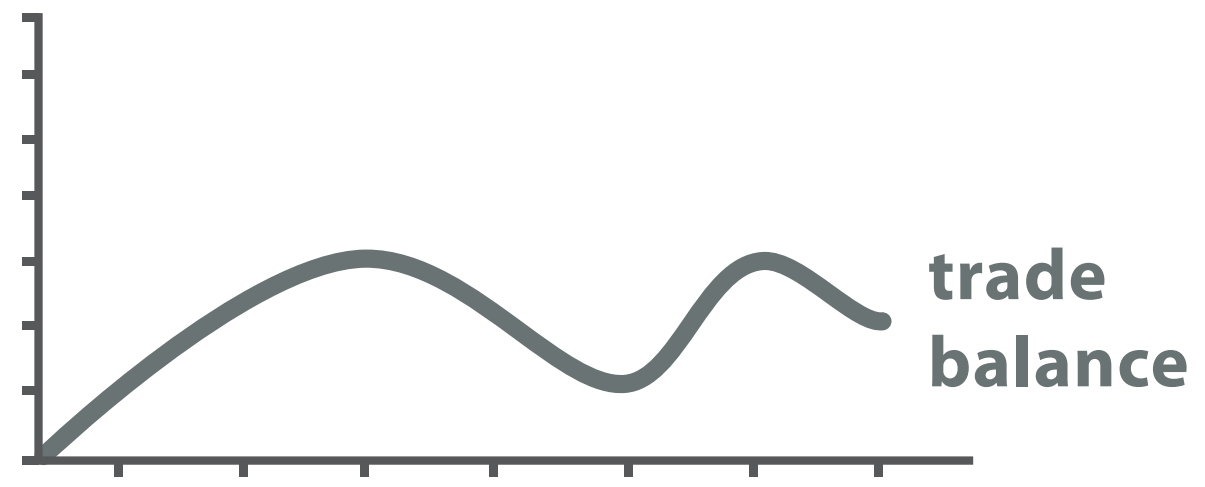
- data model: floats
 - 32.52, 54.06, -14.35, ...
- conceptual model
 - temperature
- multiple possible data abstractions
 - continuous to 2 significant figures: quantitative
 - task: forecasting the weather
 - hot, warm, cold: ordinal
 - task: deciding if bath water is ready
 - above freezing, below freezing: categorical
 - task: decide if I should leave the house today

Derived attributes

- derived attribute: compute from originals
 - simple change of type
 - acquire additional data
 - complex transformation



Original Data



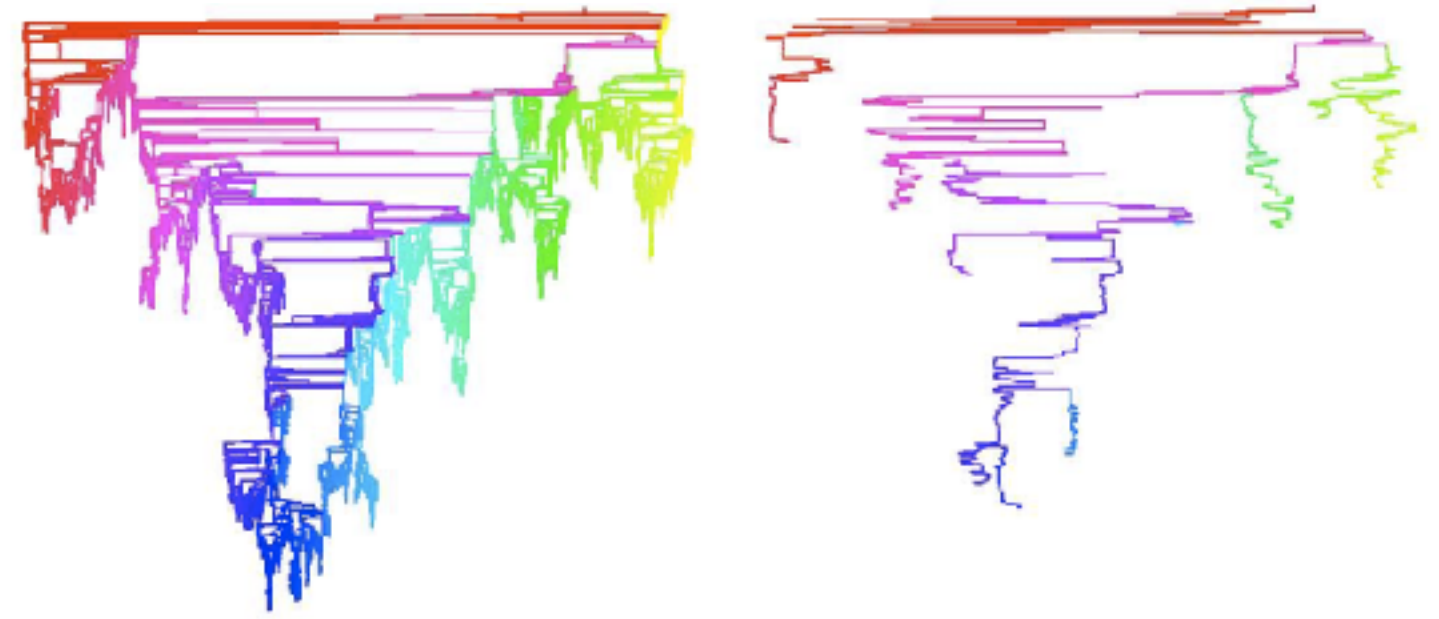
$$\text{trade balance} = \text{exports} - \text{imports}$$

Derived Data

Analysis example: Derive one attribute

- Strahler number
 - centrality metric for trees/networks
 - derived quantitative attribute
 - draw top 5K of 500K for good skeleton

[Using Strahler numbers for real time visual exploration of huge graphs. Auber. Proc. Intl. Conf. Computer Vision and Graphics, pp. 56–69, 2002.]



Task 1

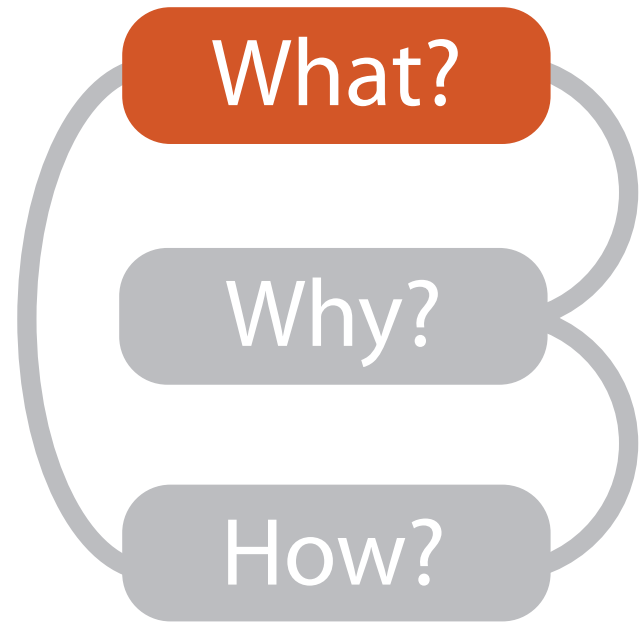
In Tree → **Out** Quantitative attribute on nodes

What?	Why?
→ In Tree	→ Derive
→ Out Quantitative attribute on nodes	

Task 2

In Tree + **In** Quantitative attribute on nodes → **Out** Filtered Tree
Removed unimportant parts

What?	Why?	How?
→ In Tree	→ Summarize	→ Reduce
→ In Quantitative attribute on nodes	→ Topology	→ Filter
→ Out Filtered Tree		



What?

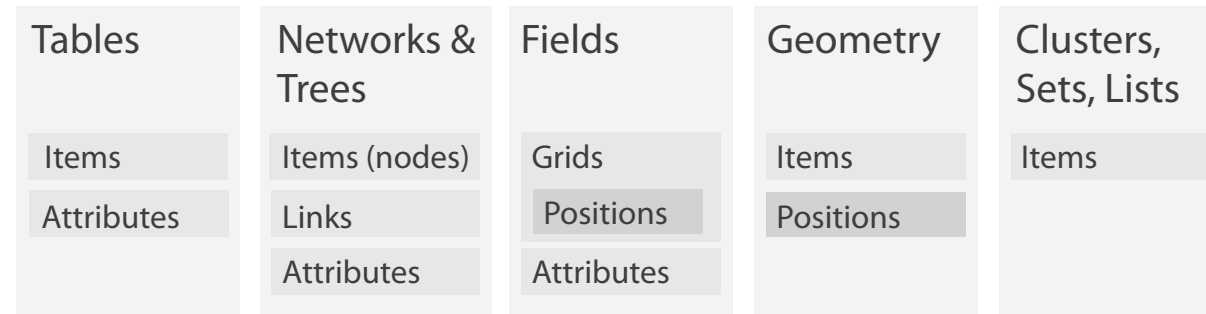
Datasets

Attributes

→ Data Types

- Items
- Attributes
- Links
- Positions
- Grids

→ Data and Dataset Types



→ Attribute Types

- Categorical



- Ordered

- Ordinal

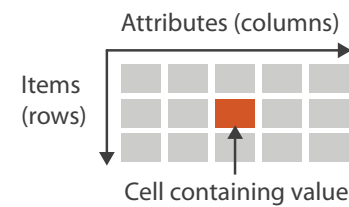


- Quantitative

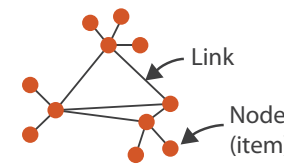


→ Dataset Types

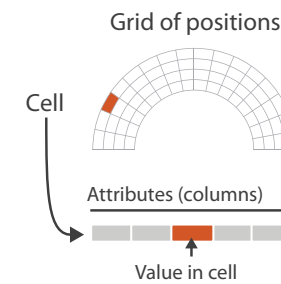
- Tables



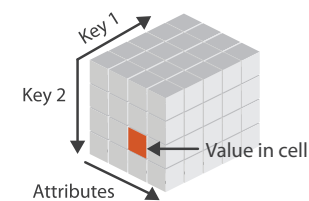
- Networks



- Fields (Continuous)



- Multidimensional Table



- Trees



→ Ordering Direction

- Sequential



- Diverging



- Cyclic



- Geometry (Spatial)



→ Dataset Availability

- Static



- Dynamic



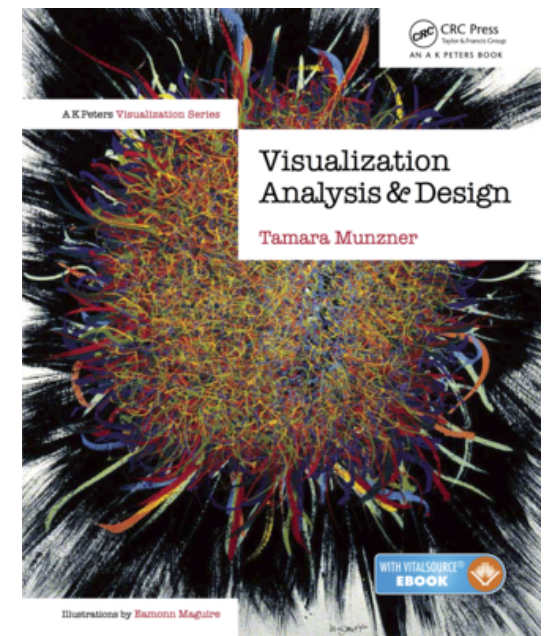
Visualization Analysis & Design

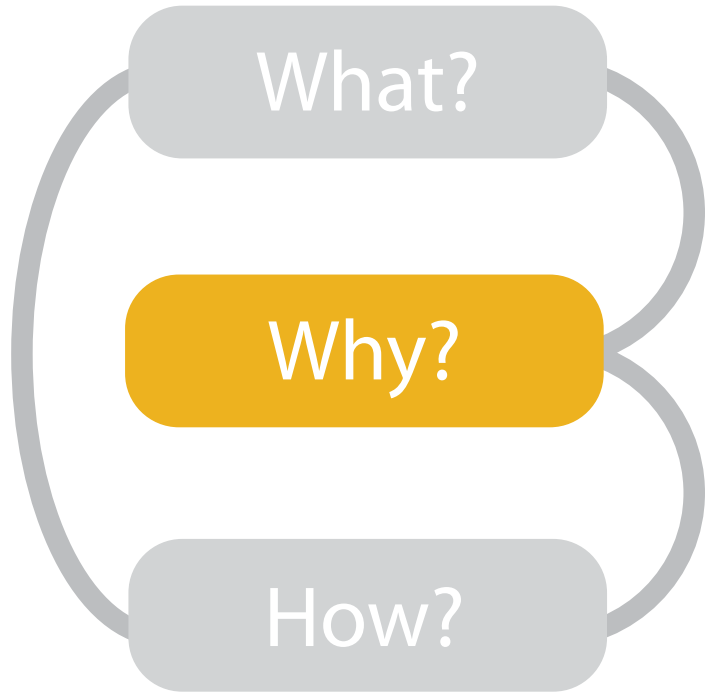
Task Abstraction (Ch 3): In Brief

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)





👉 Actions

🎯 Targets

➔ **Analyze**

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

➔ **Search**

	Target known	Target unknown
Location known	<i>Lookup</i>	<i>Browse</i>
Location unknown	<i>Locate</i>	<i>Explore</i>

➔ **Query**

- ➔ Identify
- ➔ Compare
- ➔ Summarize

➔ **All Data**

- ➔ Trends
- ➔ Outliers
- ➔ Features

➔ **Attributes**

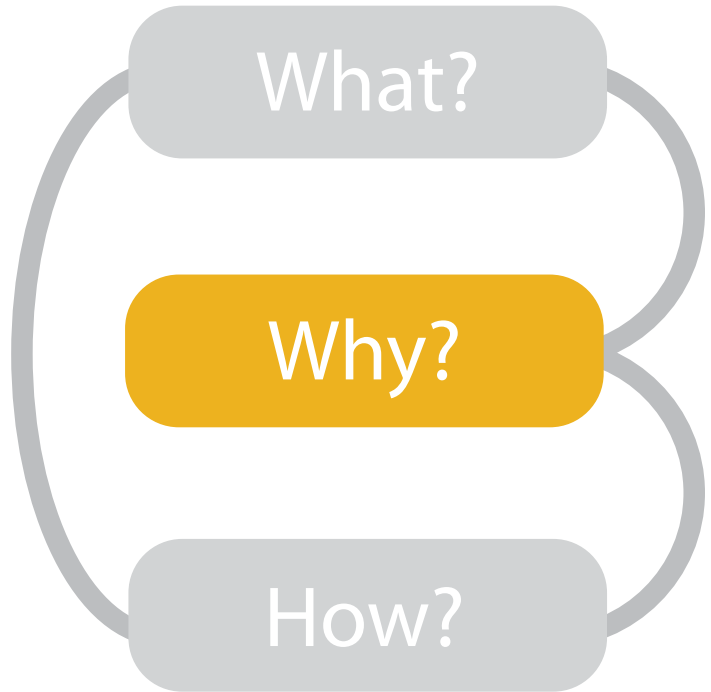
- ➔ One
 - ➔ Distribution
 - ➔ Extremes
- ➔ Many
 - ➔ Dependency
 - ➔ Correlation
 - ➔ Similarity

➔ **Network Data**

- ➔ Topology
- ➔ Paths

➔ **Spatial Data**

- ➔ Shape



👉 Actions

🎯 Targets

➔ **Analyze**

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

➔ **All Data**

- ➔ Trends
- ➔ Outliers
- ➔ Features

➔ **Attributes**

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

➔ **Search**

	Target known	Target unknown
Location known	<i>Lookup</i>	<i>Browse</i>
Location unknown	<i>Locate</i>	<i>Explore</i>

➔ **Query**

- ➔ Identify
- ➔ Compare
- ➔ Summarize

➔ **Network Data**

- ➔ Topology
- ➔ Paths

➔ **Spatial Data**

- ➔ Shape

- {action, target} pairs
 - discover distribution
 - compare trends
 - locate outliers
 - browse topology

Actions: Analyze, Query

- analyze

- consume

- discover vs present

- aka explore vs explain

- enjoy

- aka casual, social

- produce

- annotate, record, derive

- query

- how much data matters?

- one, some, all

- independent choices

- analyze, query, (search)

→ Analyze

- Consume

- Discover



- Present

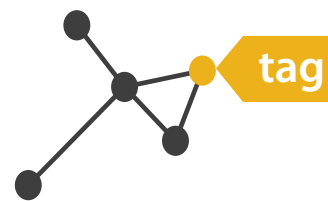


- Enjoy



- Produce

- Annotate



- Record

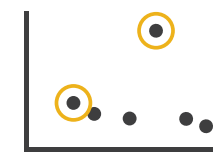


- Derive



→ Query

- Identify



- Compare



- Summarize



Actions: Analyze, Query

- analyze

- consume

- discover vs present

- aka explore vs explain

- enjoy

- aka casual, social

- produce

- annotate, record, derive

- query

- how much data matters?

- one, some, all

- independent choices

- analyze, query, (search)

→ Analyze

- Consume

- Discover



- Present

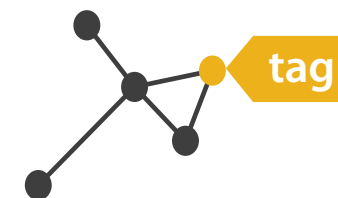


- Enjoy

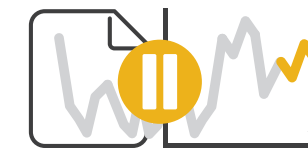


- Produce

- Annotate



- Record

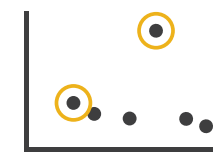


- Derive



→ Query

- Identify



- Compare

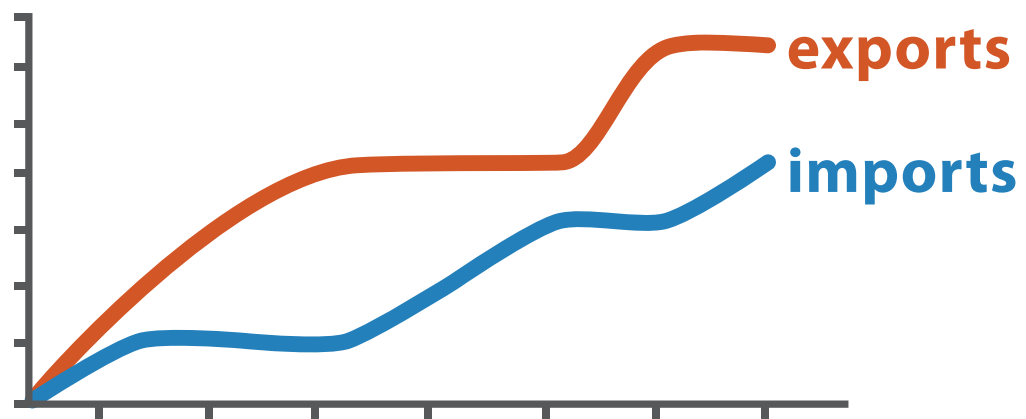


- Summarize

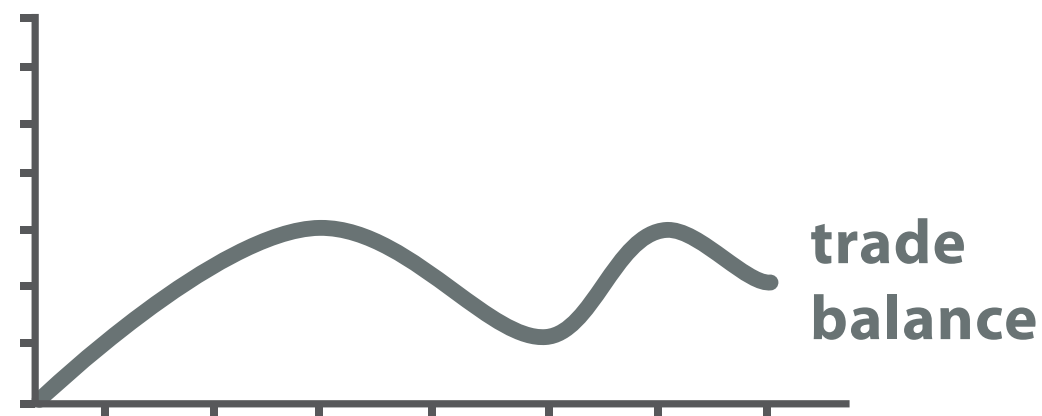


Derive

- don't necessarily just draw what you're given!
 - decide what the right thing to show is
 - create it with a series of transformations from the original dataset
 - draw that
- one of the four major strategies for handling complexity



Original Data



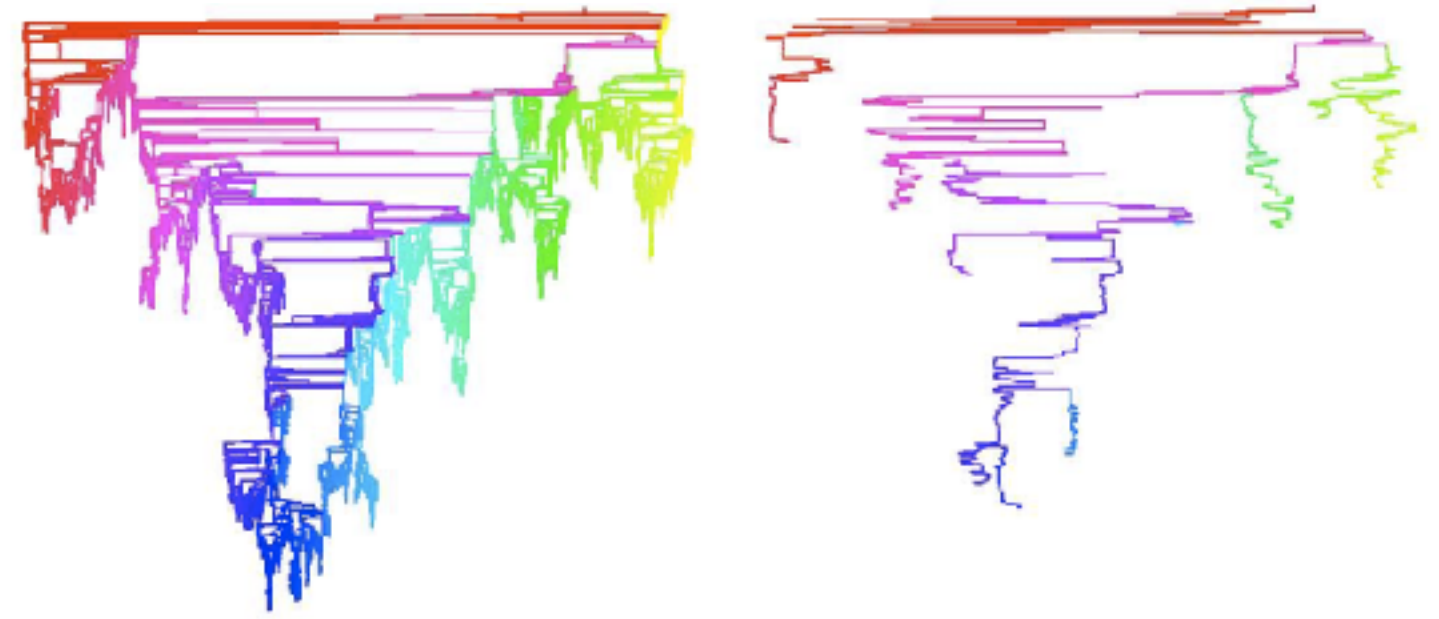
$$\text{trade balance} = \text{exports} - \text{imports}$$

Derived Data

Analysis example: Derive one attribute

- Strahler number
 - centrality metric for trees/networks
 - derived quantitative attribute
 - draw top 5K of 500K for good skeleton

[Using Strahler numbers for real time visual exploration of huge graphs. Auber. Proc. Intl. Conf. Computer Vision and Graphics, pp. 56–69, 2002.]



Task 1

In Tree → **Out** Quantitative attribute on nodes

What?	Why?
→ In Tree	→ Derive
→ Out Quantitative attribute on nodes	

Task 2

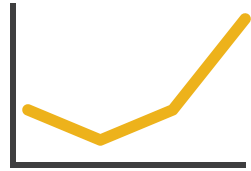
In Tree + **In** Quantitative attribute on nodes → **Out** Filtered Tree
Removed unimportant parts

What?	Why?	How?
→ In Tree	→ Summarize	→ Reduce
→ In Quantitative attribute on nodes	→ Topology	→ Filter
→ Out Filtered Tree		

Why: Targets

→ All Data

→ Trends



→ Outliers



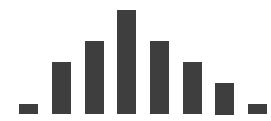
→ Features



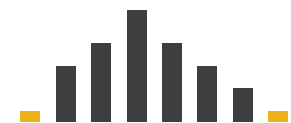
→ Attributes

→ One

→ *Distribution*



→ *Extremes*

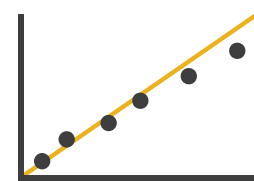


→ Many

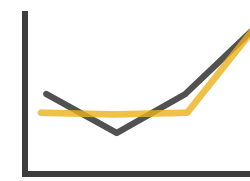
→ *Dependency*



→ *Correlation*

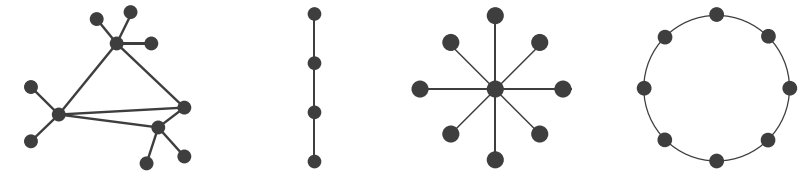


→ *Similarity*



→ Network Data

→ Topology

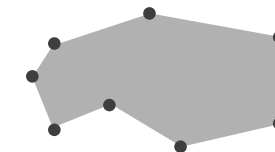


→ *Paths*



→ Spatial Data

→ Shape



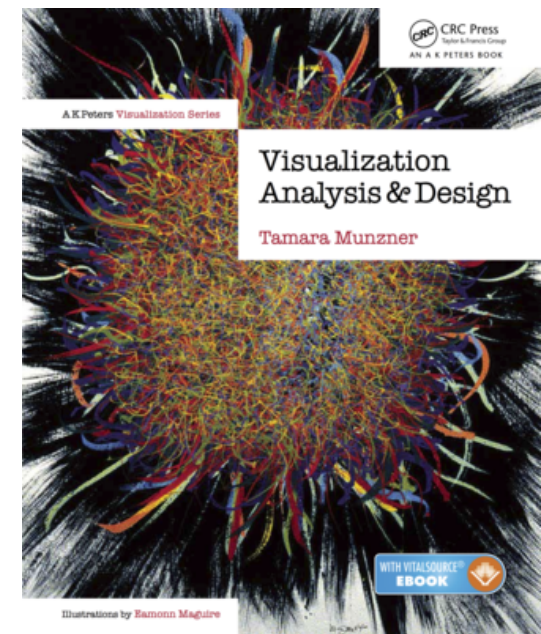
Visualization Analysis & Design

Task Abstraction (Ch 3)

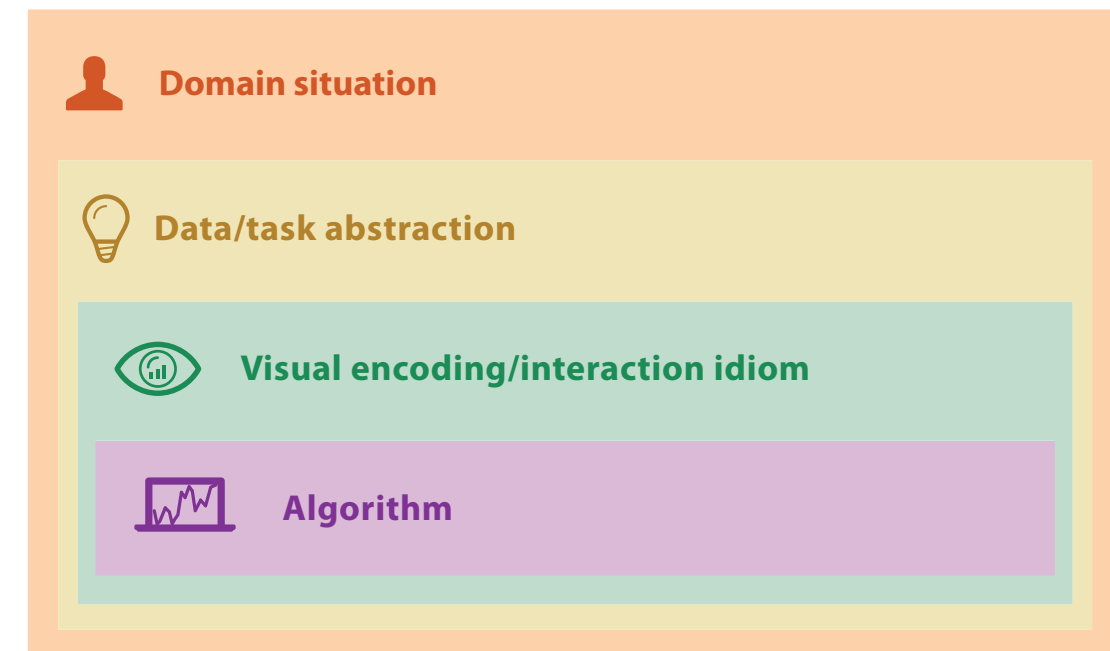
Tamara Munzner

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University of British Columbia

[@tamaramunzner](#)

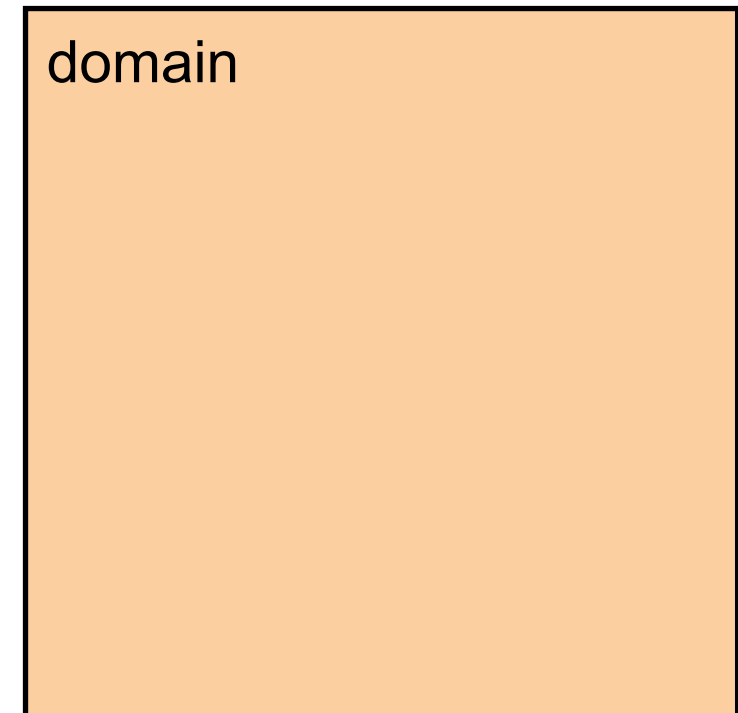
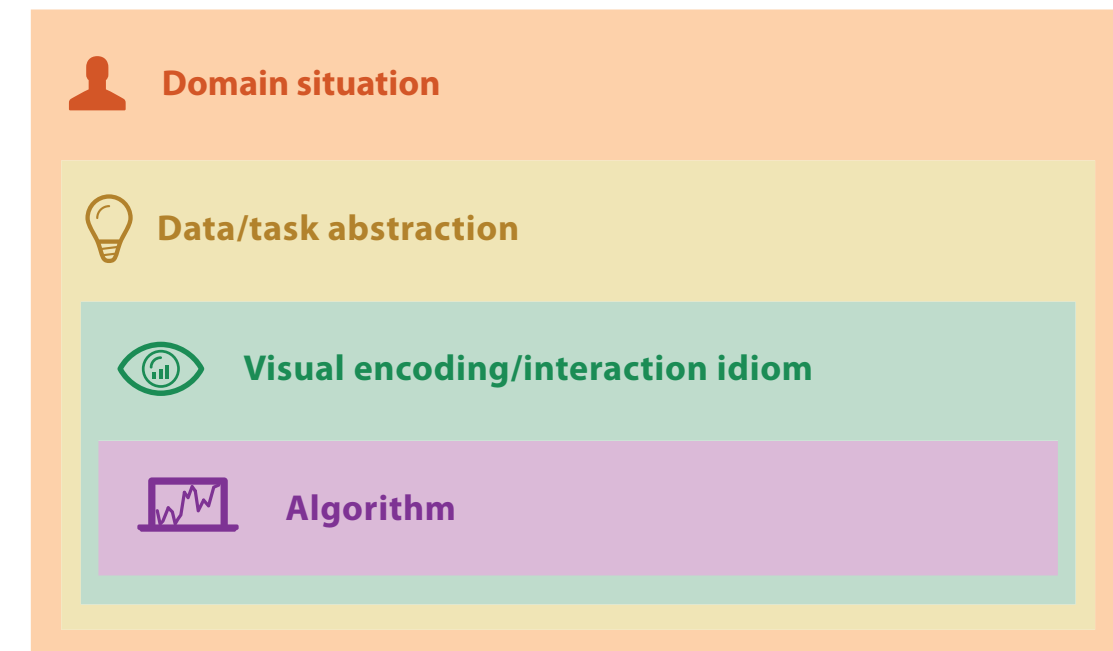


From domain to abstraction



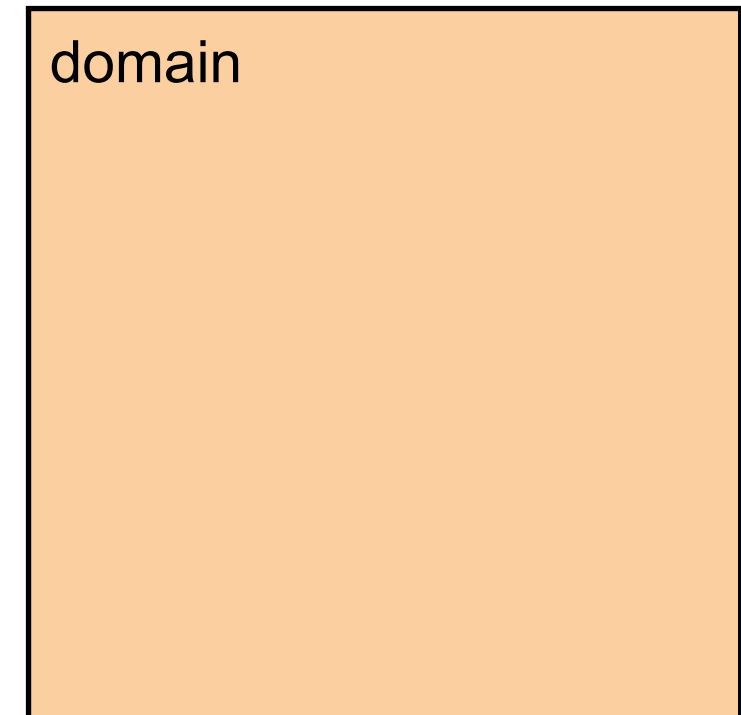
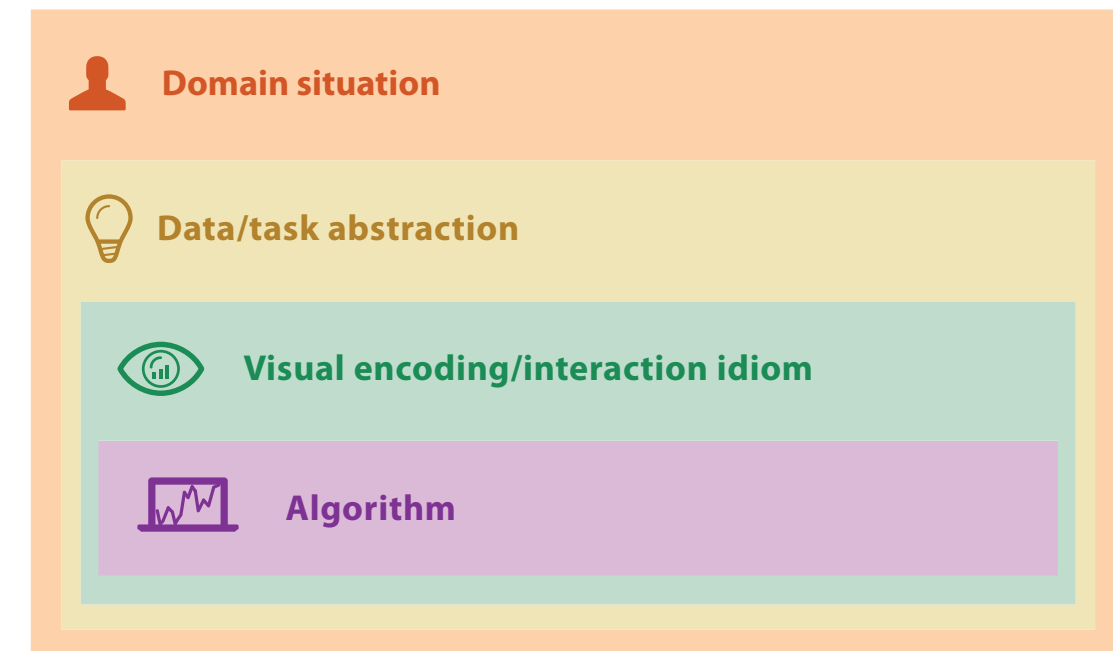
From domain to abstraction

- domain characterization:
details of application domain



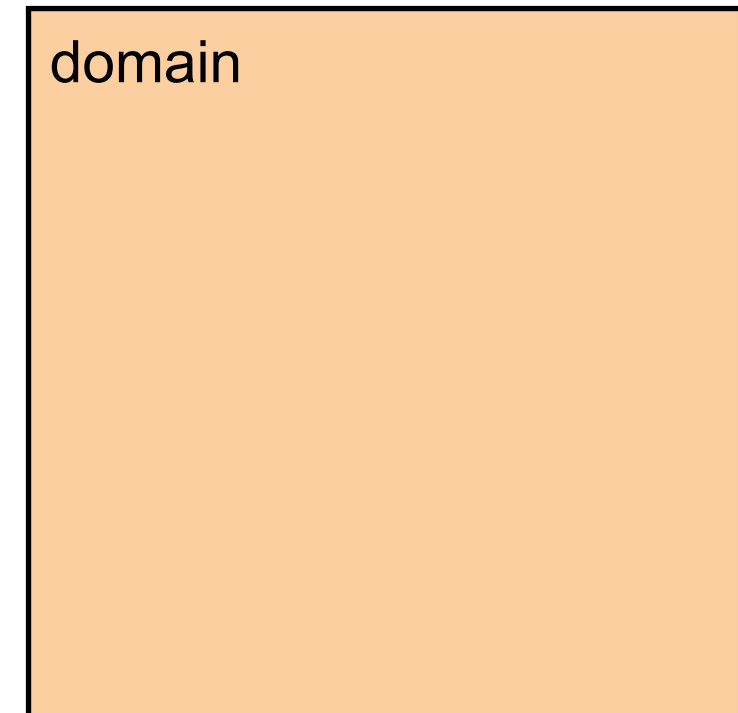
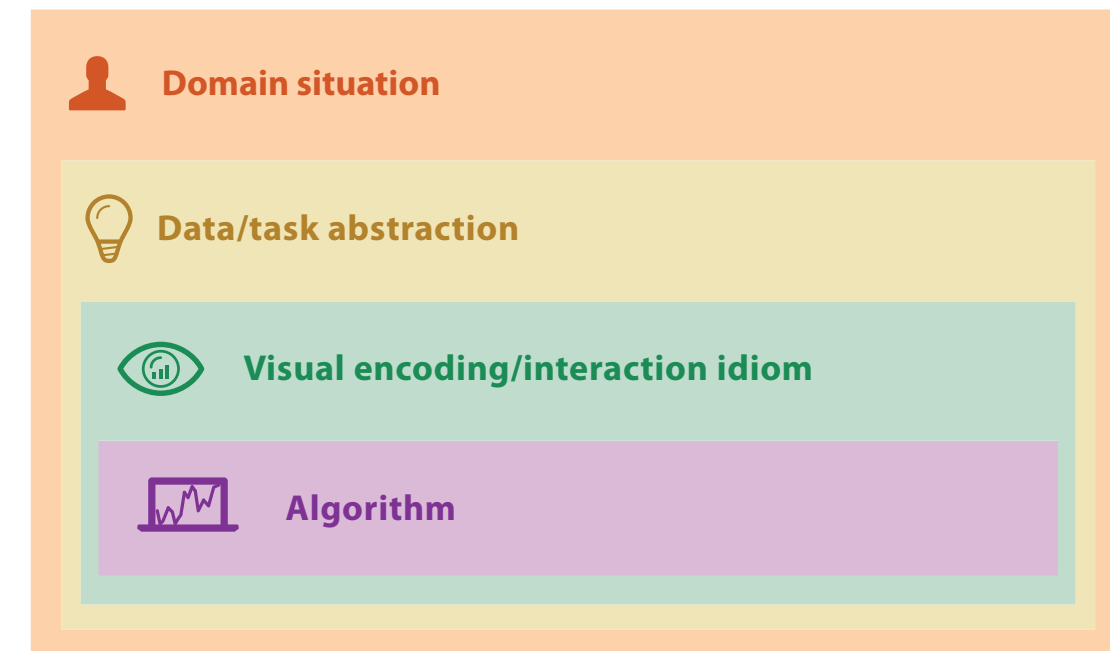
From domain to abstraction

- domain characterization:
details of application domain
 - group of users, target domain, their questions & data
 - varies wildly by domain
 - must be specific enough to get traction



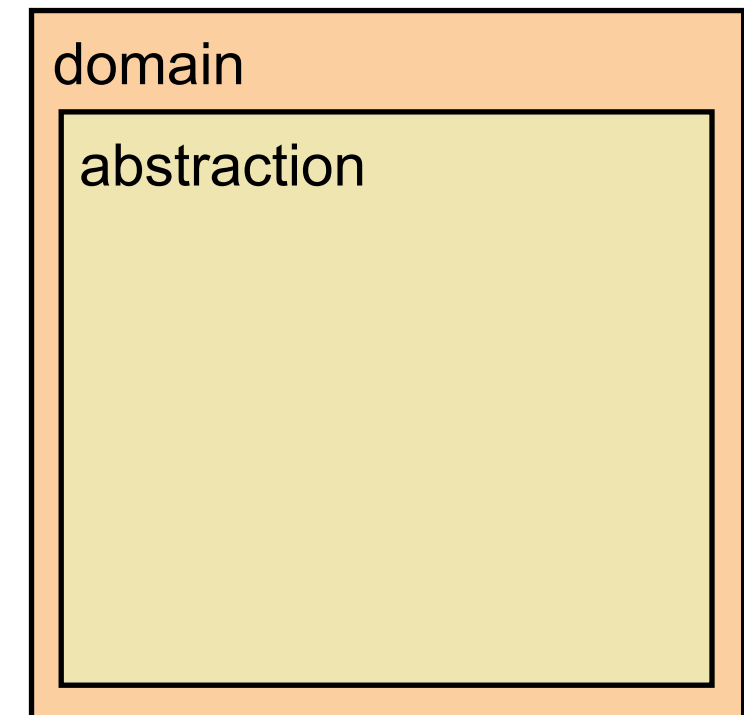
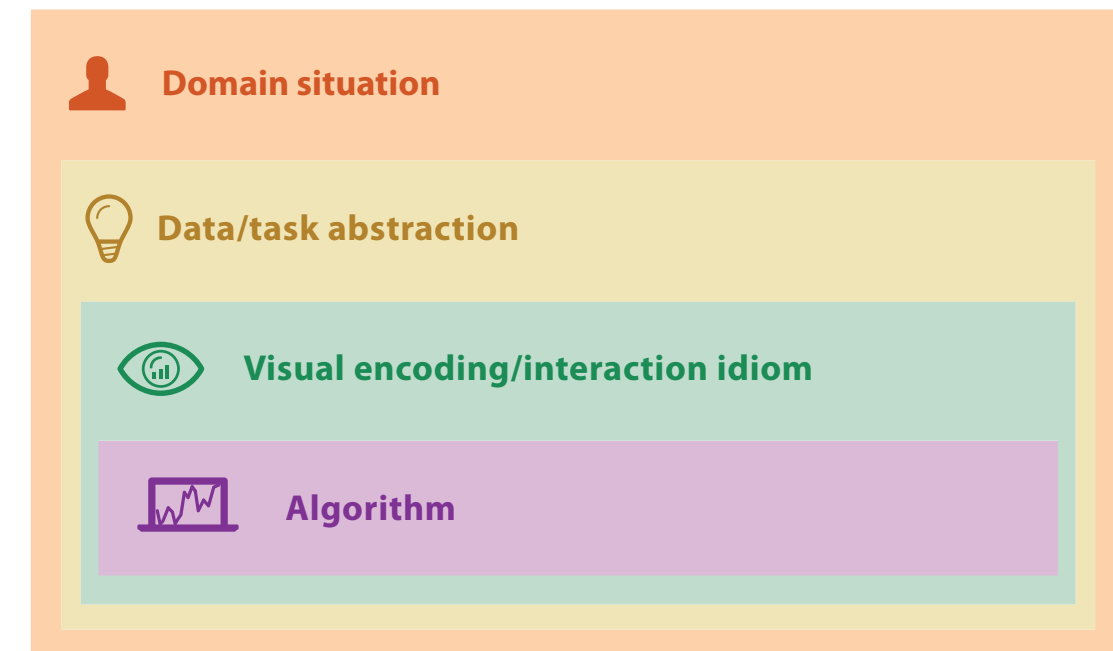
From domain to abstraction

- domain characterization:
details of application domain
 - group of users, target domain, their questions & data
 - varies wildly by domain
 - must be specific enough to get traction
 - domain questions/problems
 - break down into simpler abstract tasks



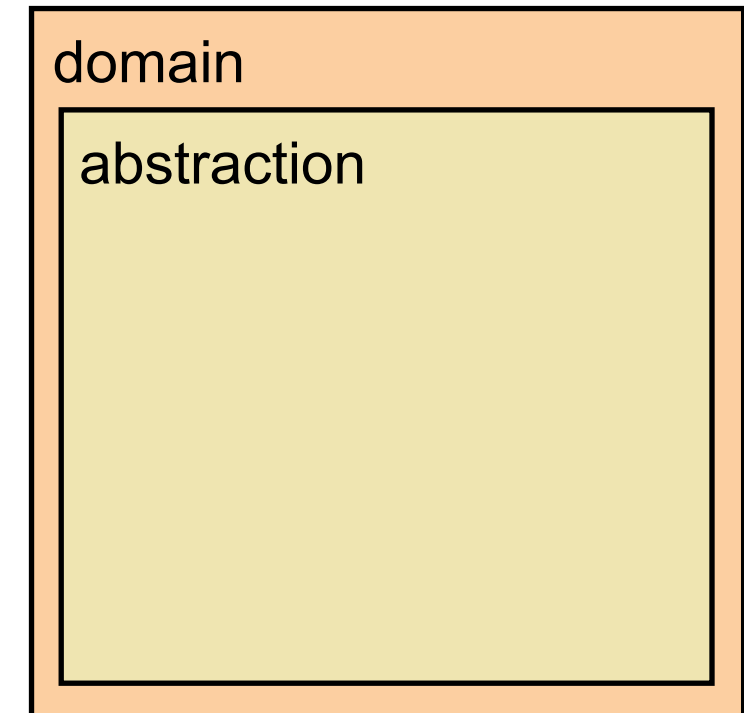
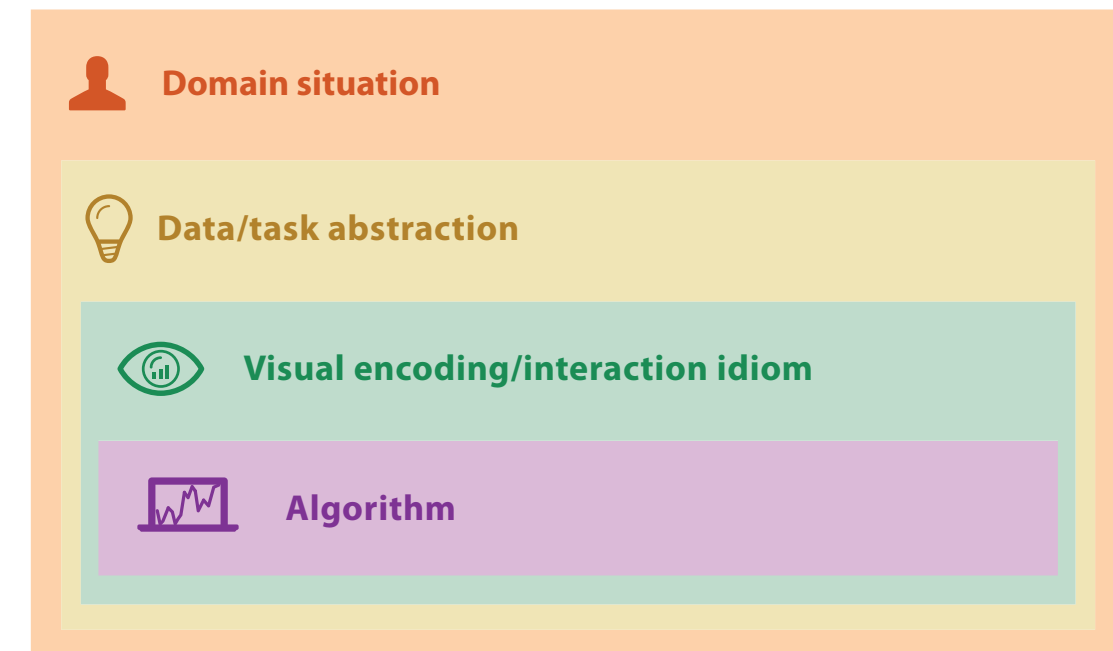
From domain to abstraction

- domain characterization:
details of application domain
 - group of users, target domain, their questions & data
 - varies wildly by domain
 - must be specific enough to get traction
 - domain questions/problems
 - break down into simpler abstract tasks
- abstraction: data & task
 - map *what* and *why* into generalized terms

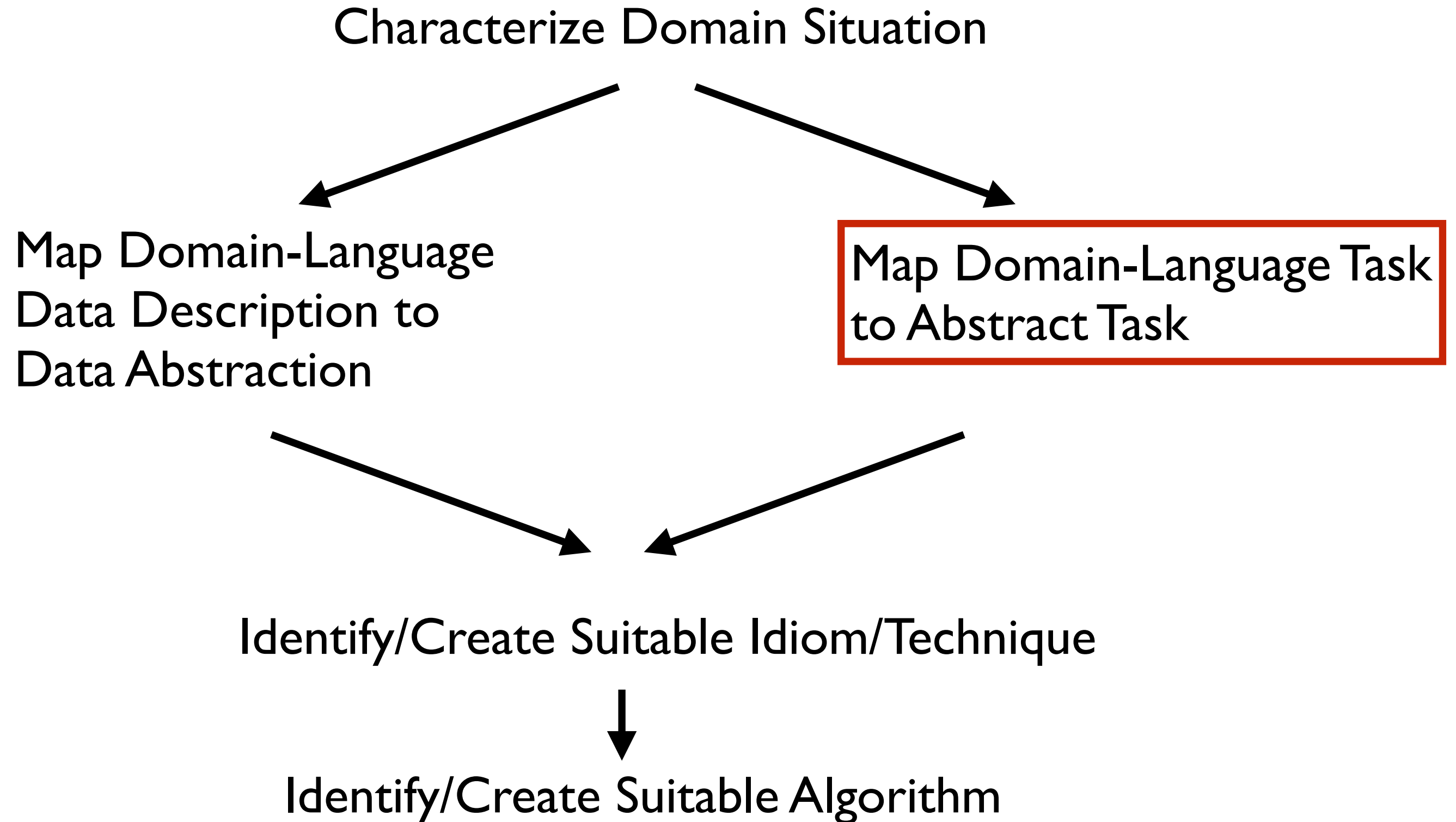


From domain to abstraction

- domain characterization:
details of application domain
 - group of users, target domain, their questions & data
 - varies wildly by domain
 - must be specific enough to get traction
 - domain questions/problems
 - break down into simpler abstract tasks
- abstraction: data & task
 - map *what* and *why* into generalized terms
 - identify tasks that users wish to perform, or already do
 - find data types that will support those tasks
 - possibly transform /derive if need be



Design process



Task abstraction: Actions and targets

- very high-level pattern
- {action, target} pairs
 - *discover distribution*
 - *compare trends*
 - *locate outliers*
 - *browse topology*

Task abstraction: Actions and targets

- very high-level pattern
- actions
 - analyze
 - high-level choices
 - search
 - find a known/unknown item
 - query
 - find out about characteristics of item
- {action, target} pairs
 - *discover distribution*
 - *compare trends*
 - *locate outliers*
 - *browse topology*

Task abstraction: Actions and targets

- very high-level pattern
- actions
 - analyze
 - high-level choices
 - search
 - find a known/unknown item
 - query
 - find out about characteristics of item
- targets
 - what is being acted on
- {action, target} pairs
 - *discover distribution*
 - *compare trends*
 - *locate outliers*
 - *browse topology*

Actions: Analyze

- consume
 - discover vs present
 - classic split
 - aka explore vs explain
 - enjoy
- produce
 - newcomer
 - aka casual, social
- produce
 - annotate, record
 - derive
 - crucial design choice

➔ Analyze

➔ Consume

➔ *Discover*



➔ *Present*

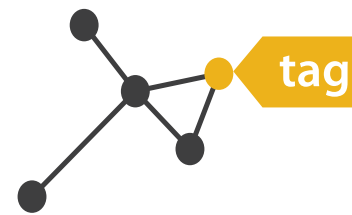


➔ *Enjoy*



➔ Produce

➔ *Annotate*



➔ *Record*



➔ *Derive*







Actions: Search

Actions: Search

- what does user know?
 - target, location





➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>

Actions: Search

- what does user know?
 - target, location
- lookup
 - ex: word in dictionary
 - alphabetical order





➔ Search

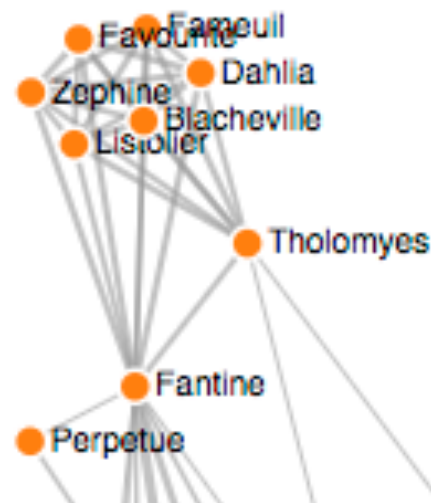
	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>

Actions: Search

- what does user know?
 - target, location
- lookup
 - ex: word in dictionary
 - alphabetical order
- locate
 - ex: keys in your house
 - ex: node in network

➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>







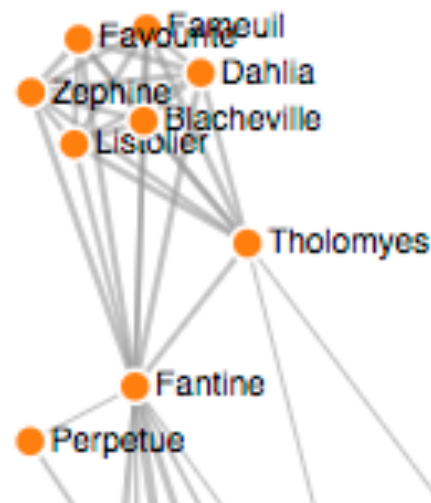
<https://bl.ocks.org/heybignick/3faf257bbbbc7743bb72310d03b86ee8>

Actions: Search

- what does user know?
 - target, location
- lookup
 - ex: word in dictionary
 - alphabetical order
- locate
 - ex: keys in your house
 - ex: node in network
- browse
 - ex: books in bookstore

➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
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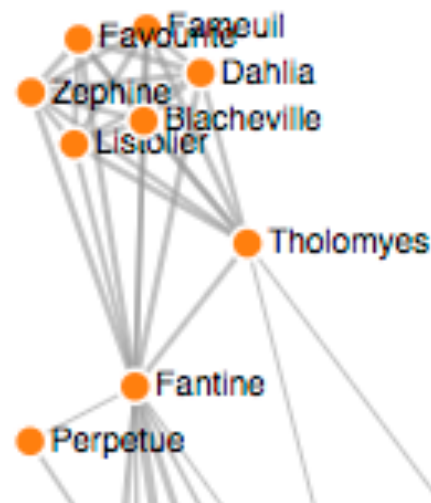
<https://bl.ocks.org/heybignick/3faf257bbbbc7743bb72310d03b86ee8>

Actions: Search

- what does user know?
 - target, location
- lookup
 - ex: word in dictionary
 - alphabetical order
- locate
 - ex: keys in your house
 - ex: node in network
- browse
 - ex: books in bookstore
- explore
 - ex: find cool neighborhood in new city

➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>



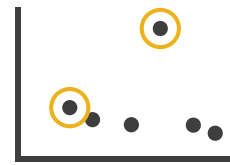
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Actions: Query

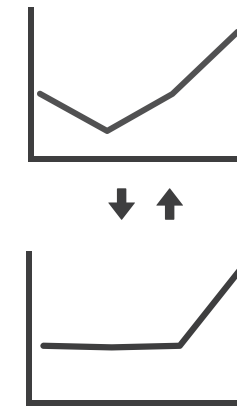
- how much of the data matters?
 - one: identify
 - some: compare
 - all: summarize

→ Query

→ Identify



→ Compare



→ Summarize



Actions

- independent choices for each of these three levels
 - analyze, search, query
 - mix and match

Actions

➔ Analyze

➔ Consume

➔ *Discover*



➔ *Present*



➔ *Enjoy*



➔ Produce

➔ *Annotate*







➔ *Record*



➔ *Derive*

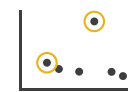


➔ Search

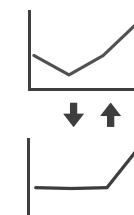
	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>

➔ Query

➔ Identify



➔ Compare



➔ Summarize



Task abstraction: Targets

Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



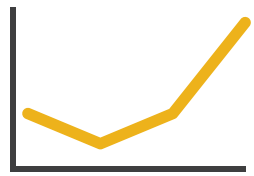
→ Features



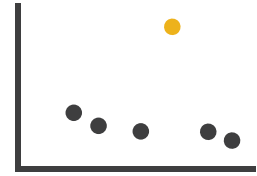
Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



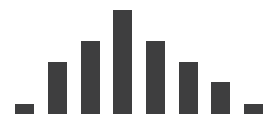
→ Features



→ Attributes

→ One

→ *Distribution*



→ *Extremes*

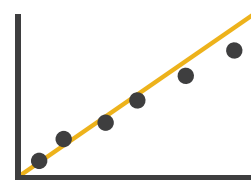


→ Many

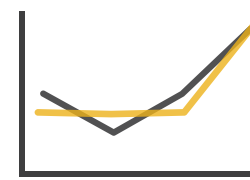
→ *Dependency*



→ *Correlation*



→ *Similarity*



Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



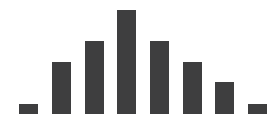
→ Features



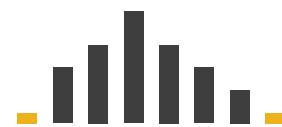
→ Attributes

→ One

→ *Distribution*



→ *Extremes*

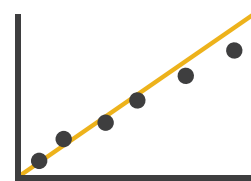


→ Many

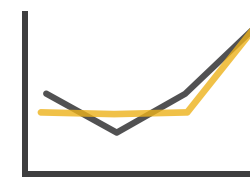
→ *Dependency*



→ *Correlation*

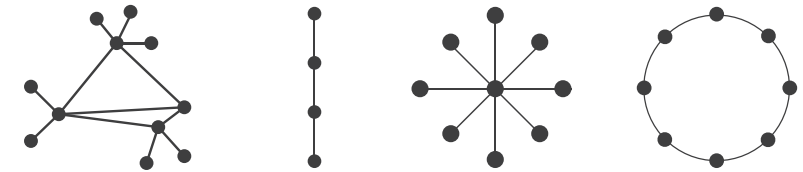


→ *Similarity*



→ Network Data

→ Topology



→ *Paths*



Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



→ Features



→ Attributes

→ One

→ *Distribution*



→ *Extremes*

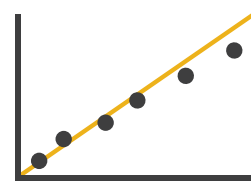


→ Many

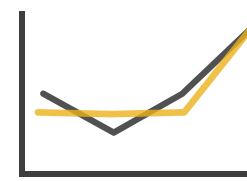
→ *Dependency*



→ *Correlation*

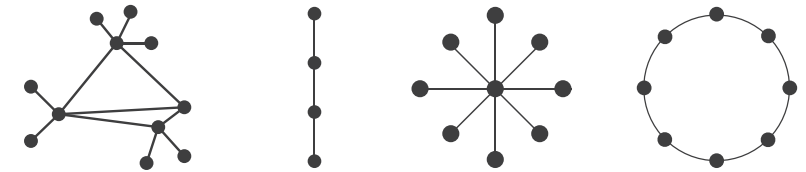


→ *Similarity*



→ Network Data

→ Topology

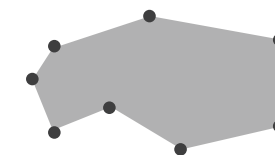


→ *Paths*



→ Spatial Data

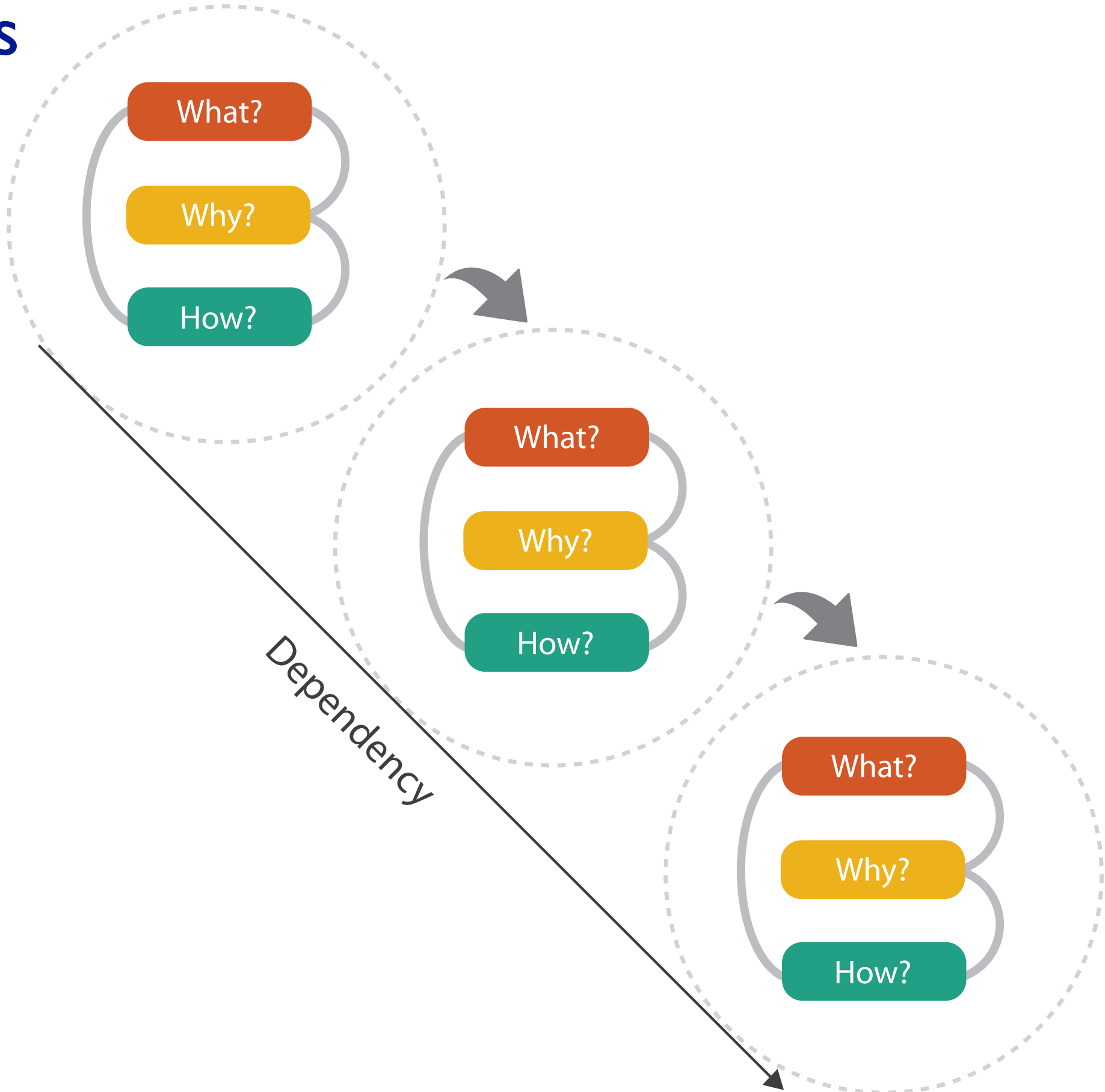
→ Shape

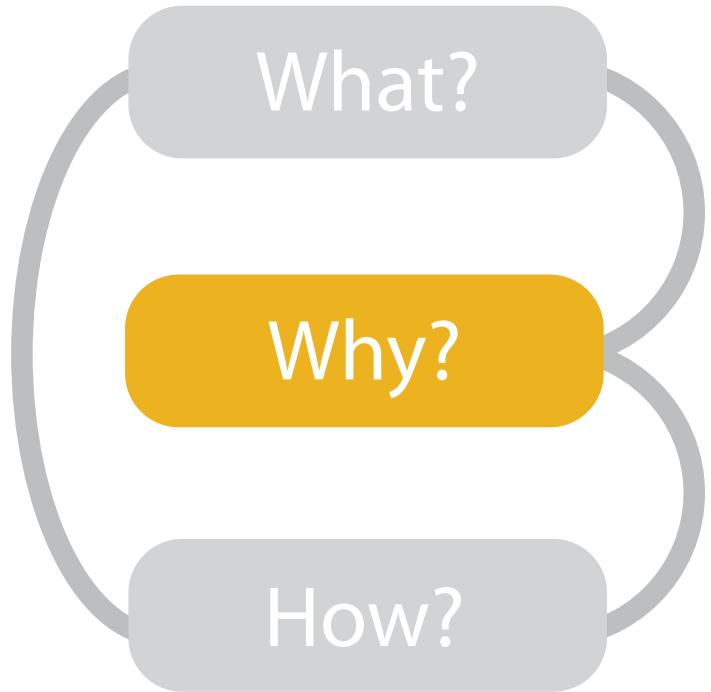


Abstraction

- these {action, target} pairs are good starting point for vocabulary
 - but sometimes you'll need more precision!
- rule of thumb
 - systematically remove all domain jargon
- interplay: task and data abstraction
 - need to use data abstraction within task abstraction
 - to specify your targets!
 - but task abstraction can lead you to transform the data
 - iterate back and forth
 - first pass data, first pass task, second pass data, ...

Means and ends





👉 Actions

🎯 Targets

➔ **Analyze**

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

➔ **Search**

	Target known	Target unknown
Location known	<i>Lookup</i>	<i>Browse</i>
Location unknown	<i>Locate</i>	<i>Explore</i>

➔ **Query**

- ➔ Identify
- ➔ Compare
- ➔ Summarize

➔ **All Data**

- ➔ Trends
- ➔ Outliers
- ➔ Features

➔ **Attributes**

- ➔ One
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- ➔ Shape

- {action, target} pairs
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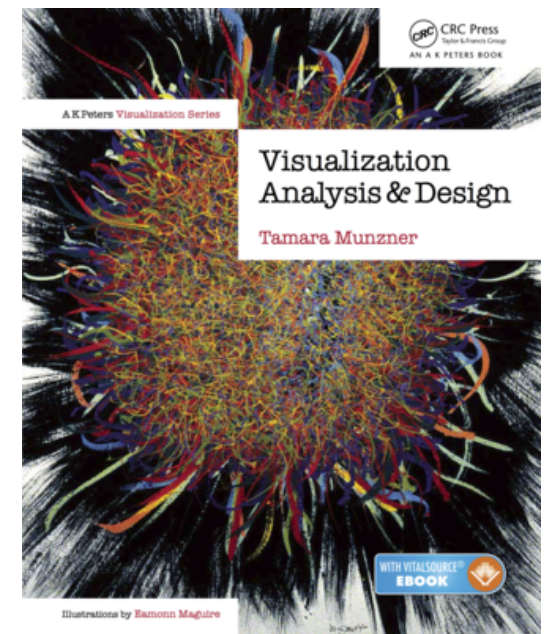
Visualization Analysis & Design

Marks & Channels (Ch 5) I

Tamara Munzner

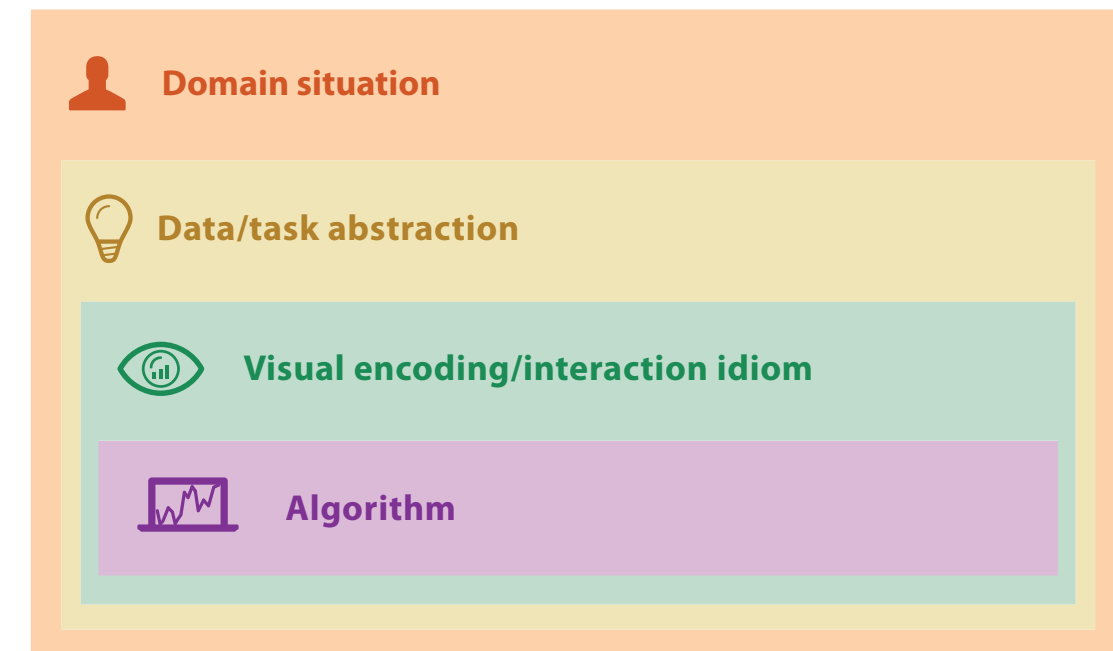
Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



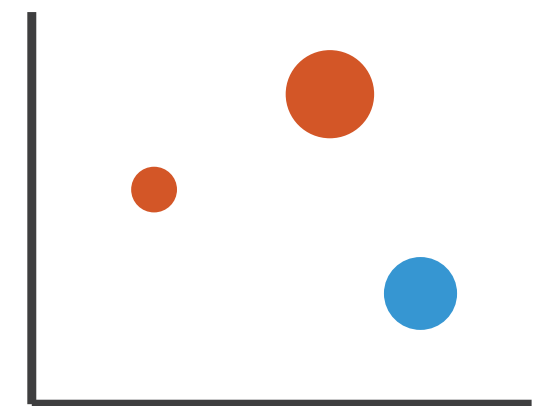
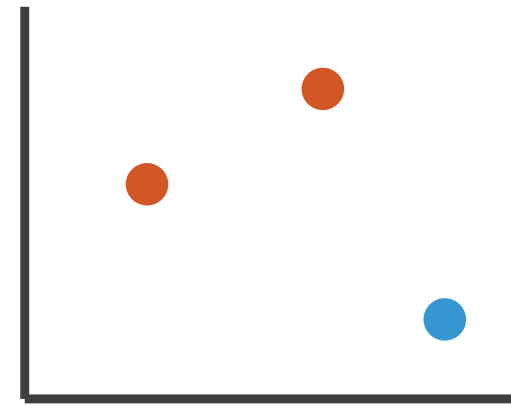
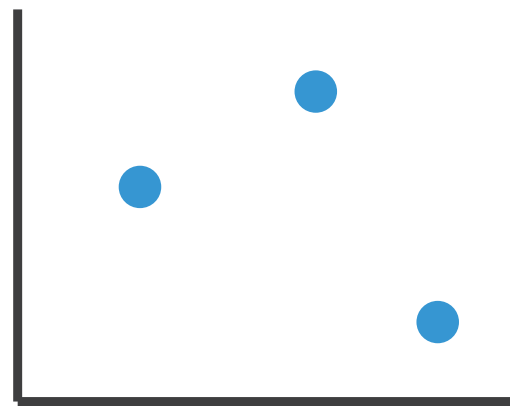
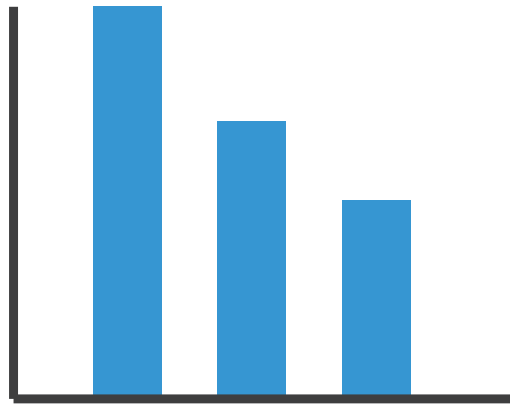
Visual encoding

- how to systematically analyze idiom structure?



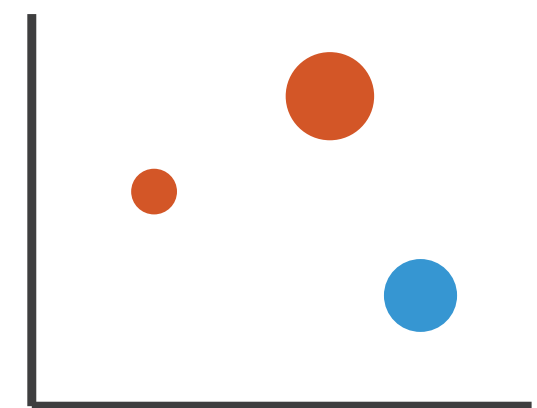
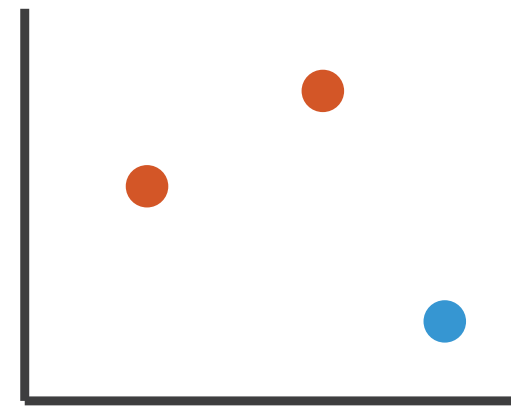
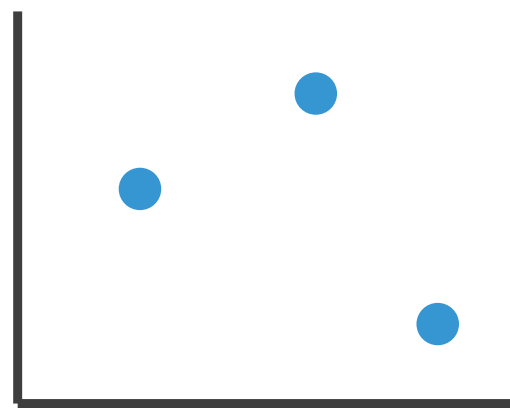
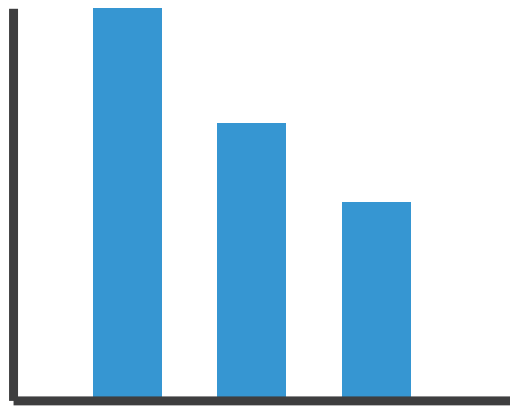
Visual encoding

- how to systematically analyze idiom structure?



Visual encoding

- how to systematically analyze idiom structure?



- marks & channels
 - marks: represent items or links
 - channels: change appearance of marks based on attributes

Marks for items

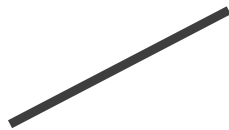
- basic geometric elements

➔ Points



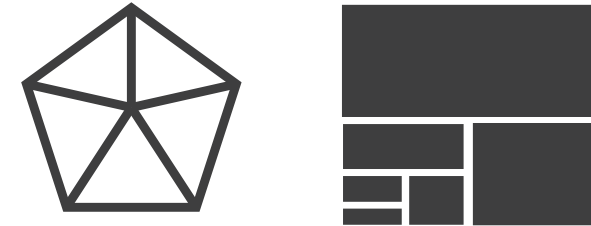
0D

➔ Lines



1D

➔ Interlocking Areas

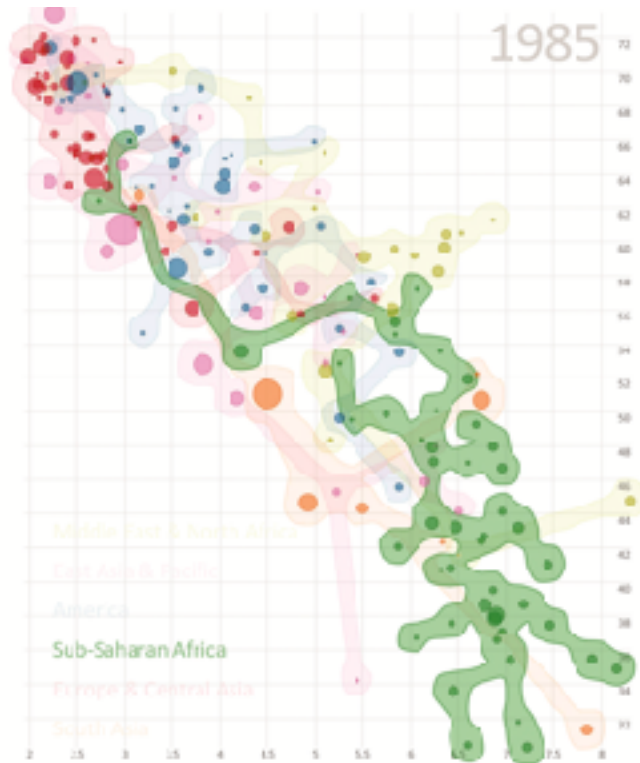
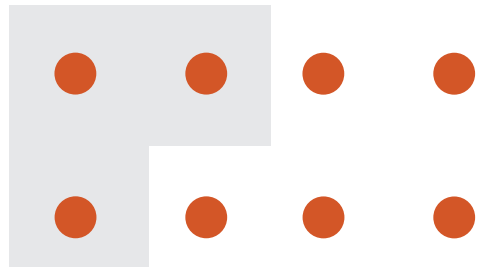


2D

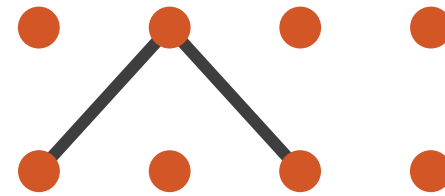
- 3D mark: volume, rarely used

Marks for links

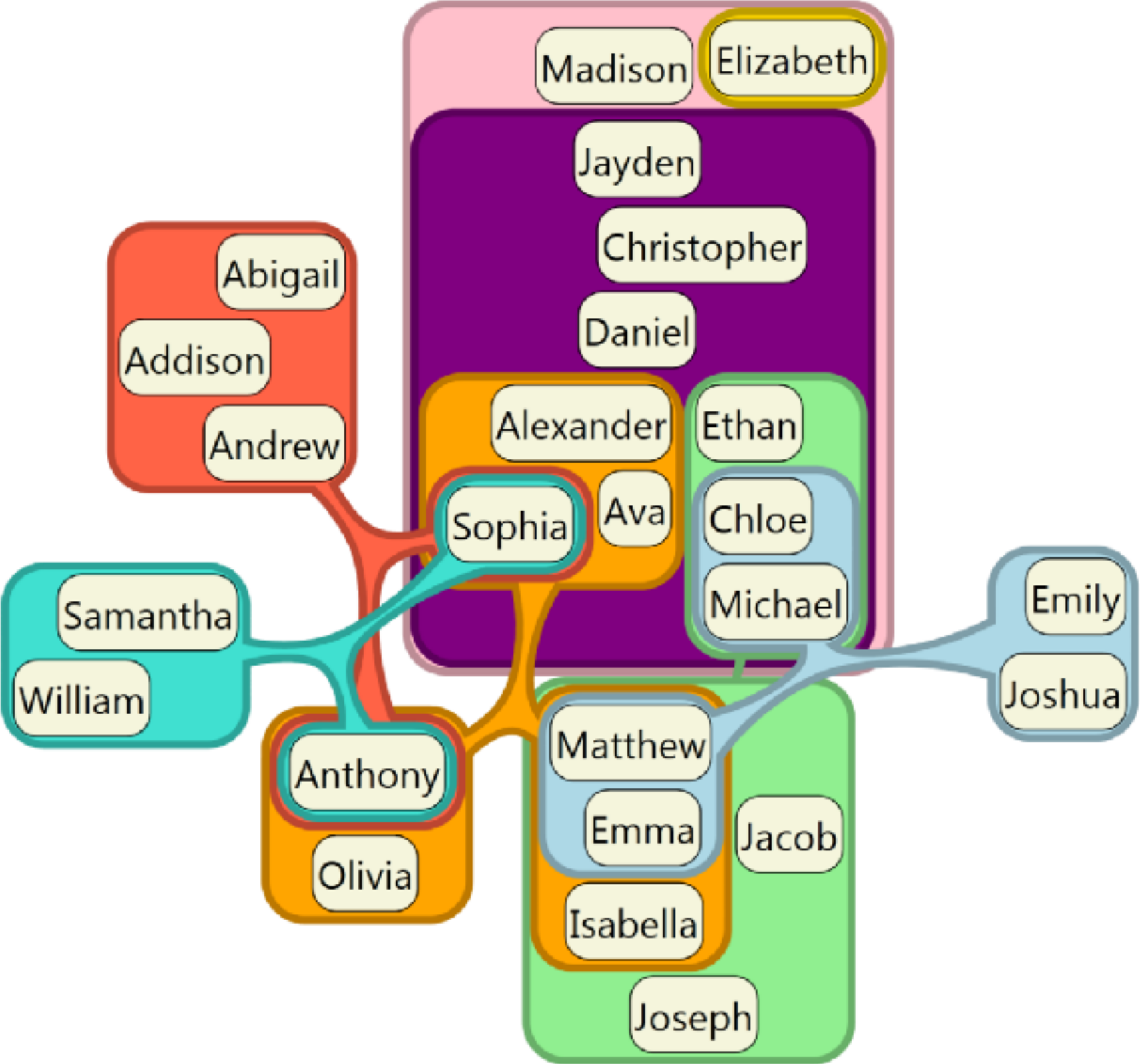
➔ Containment



➔ Connection



Containment can be nested



[[Untangling Euler Diagrams, Riche and Dwyer, 2010](#)]

Channels

- control appearance of marks
 - proportional to or based on attributes
- many names
 - **visual channels**
 - visual variables
 - retinal channels
 - visual dimensions
 - ...

→ Position

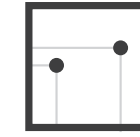
→ Horizontal



→ Vertical



→ Both



→ Shape



→ Size

→ Length



→ Area



→ Color



→ Tilt



→ Volume



Definitions: Marks and channels

- marks
 - geometric primitives

→ Points



→ Lines



→ Areas



Definitions: Marks and channels

- marks
 - geometric primitives
- channels
 - control appearance of marks

→ Points



→ Lines



→ Interlocking Areas



→ Position

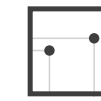
→ Horizontal



→ Vertical



→ Both



→ Color



→ Shape



→ Tilt



→ Size

→ Length



→ Area



→ Volume



Definitions: Marks and channels

- marks
 - geometric primitives
- channels
 - control appearance of marks
- channel properties differ
 - type & amount of information that can be conveyed to human perceptual system

→ Points



→ Lines



→ Interlocking Areas



→ Position

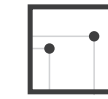
→ Horizontal



→ Vertical



→ Both



→ Color



→ Shape



→ Tilt



→ Size

→ Length



→ Area

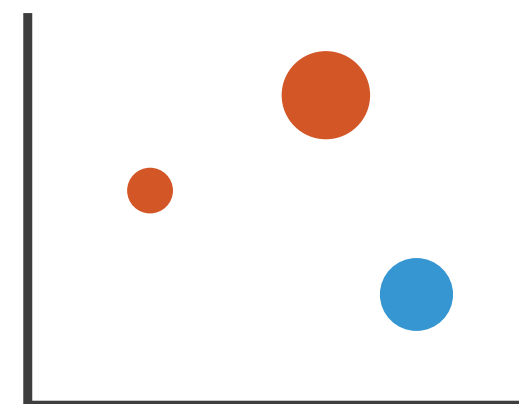
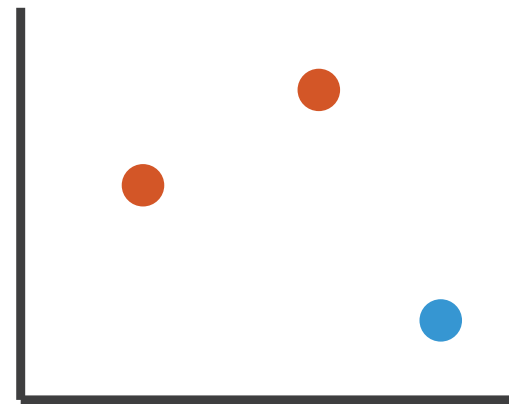
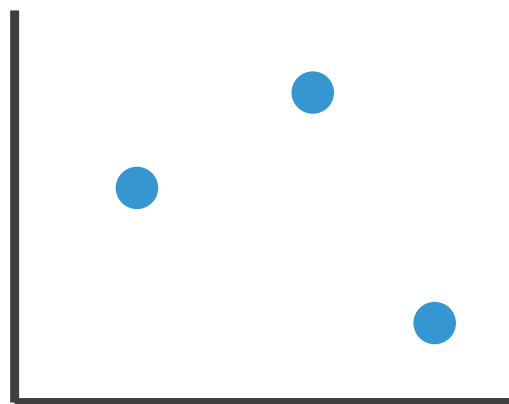
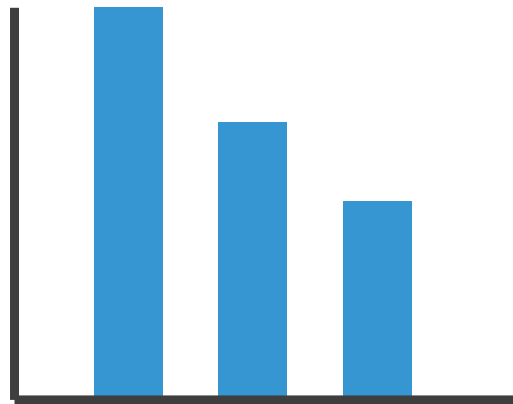


→ Volume



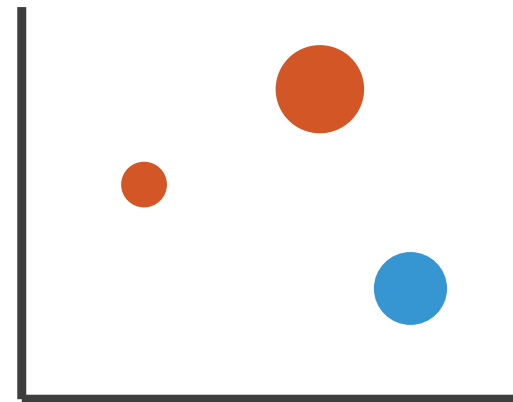
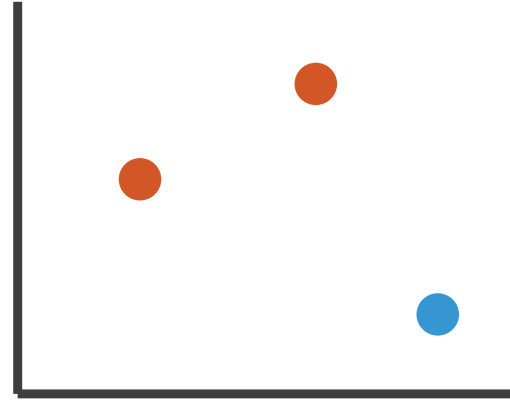
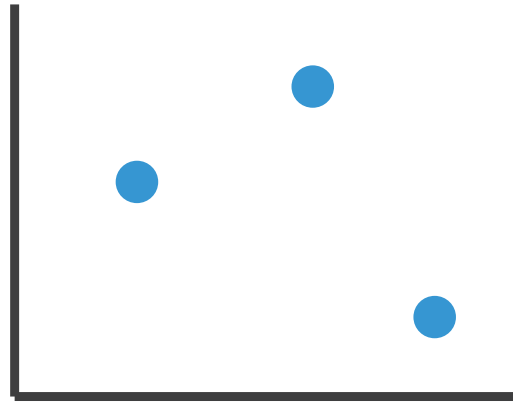
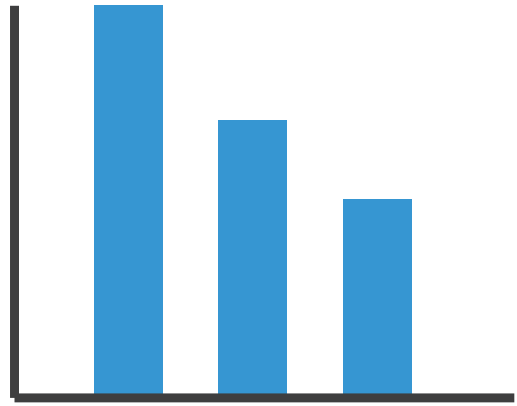
Visual encoding

- analyze idiom structure as combination of marks and channels



Visual encoding

- analyze idiom structure as combination of marks and channels

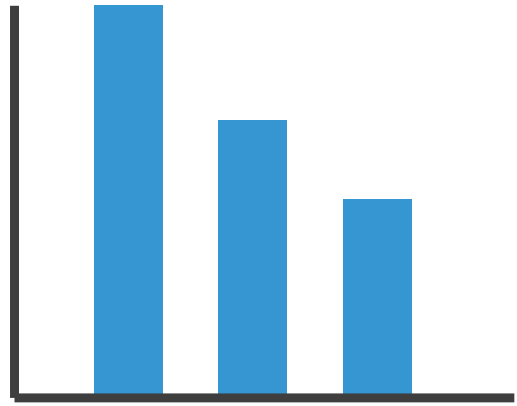


1:
vertical position

mark: line

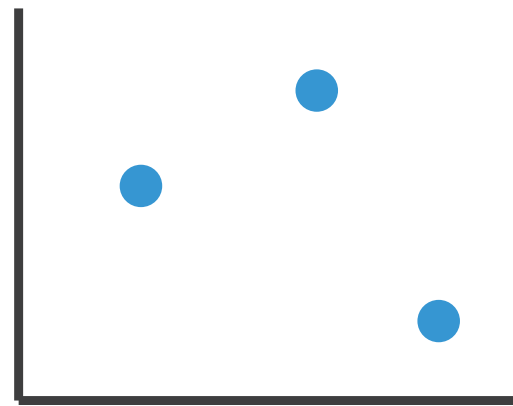
Visual encoding

- analyze idiom structure as combination of marks and channels



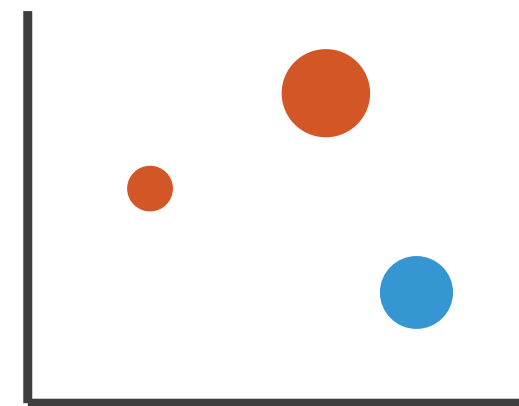
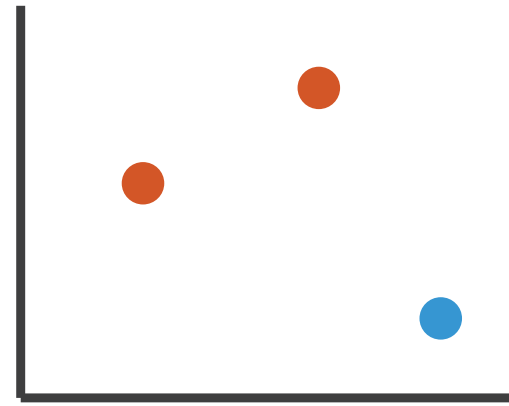
1:
vertical position

mark: line



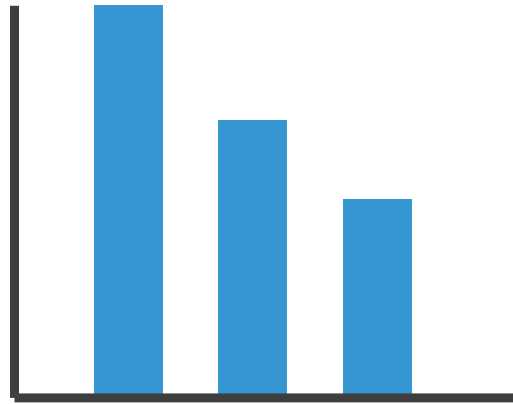
2:
vertical position
horizontal position

mark: point



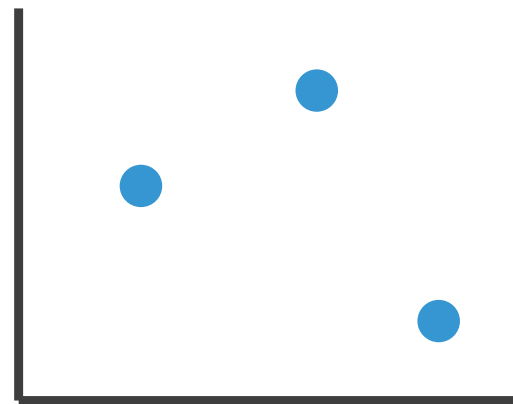
Visual encoding

- analyze idiom structure as combination of marks and channels



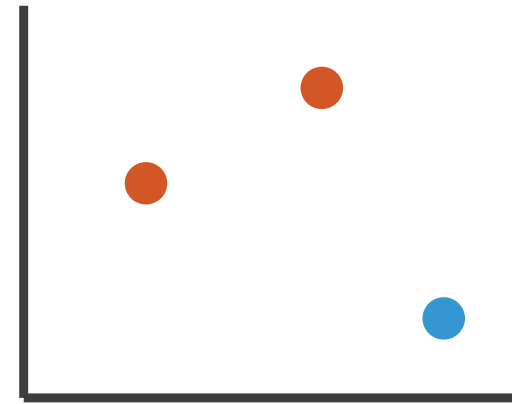
1:
vertical position

mark: line



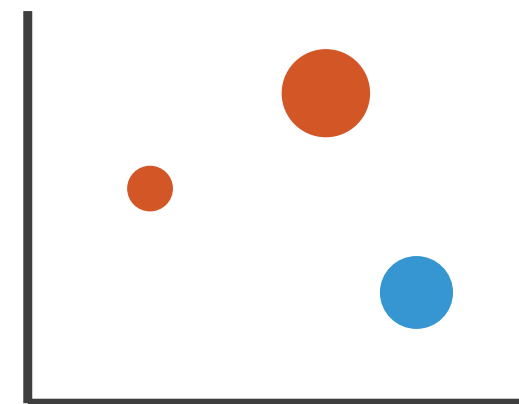
2:
vertical position
horizontal position

mark: point



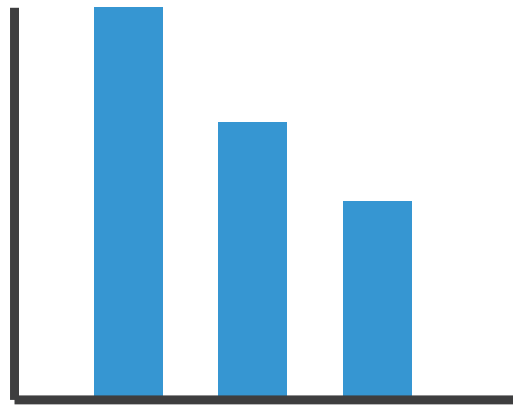
3:
vertical position
horizontal position
color hue

mark: point



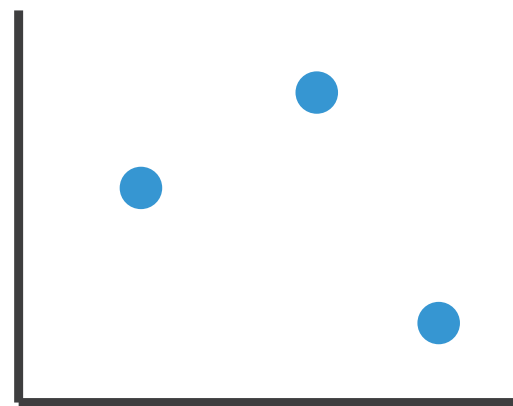
Visual encoding

- analyze idiom structure as combination of marks and channels



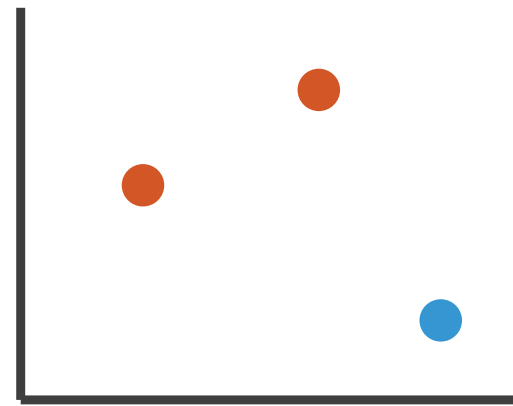
1:
vertical position

mark: line



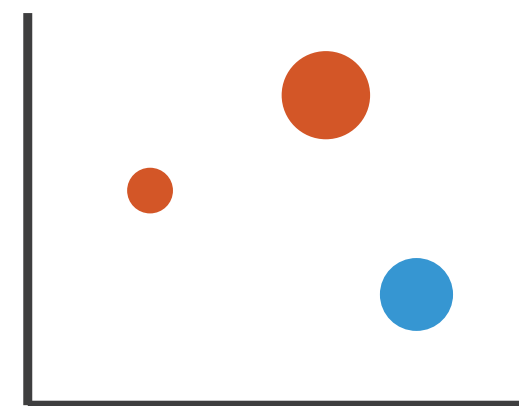
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point

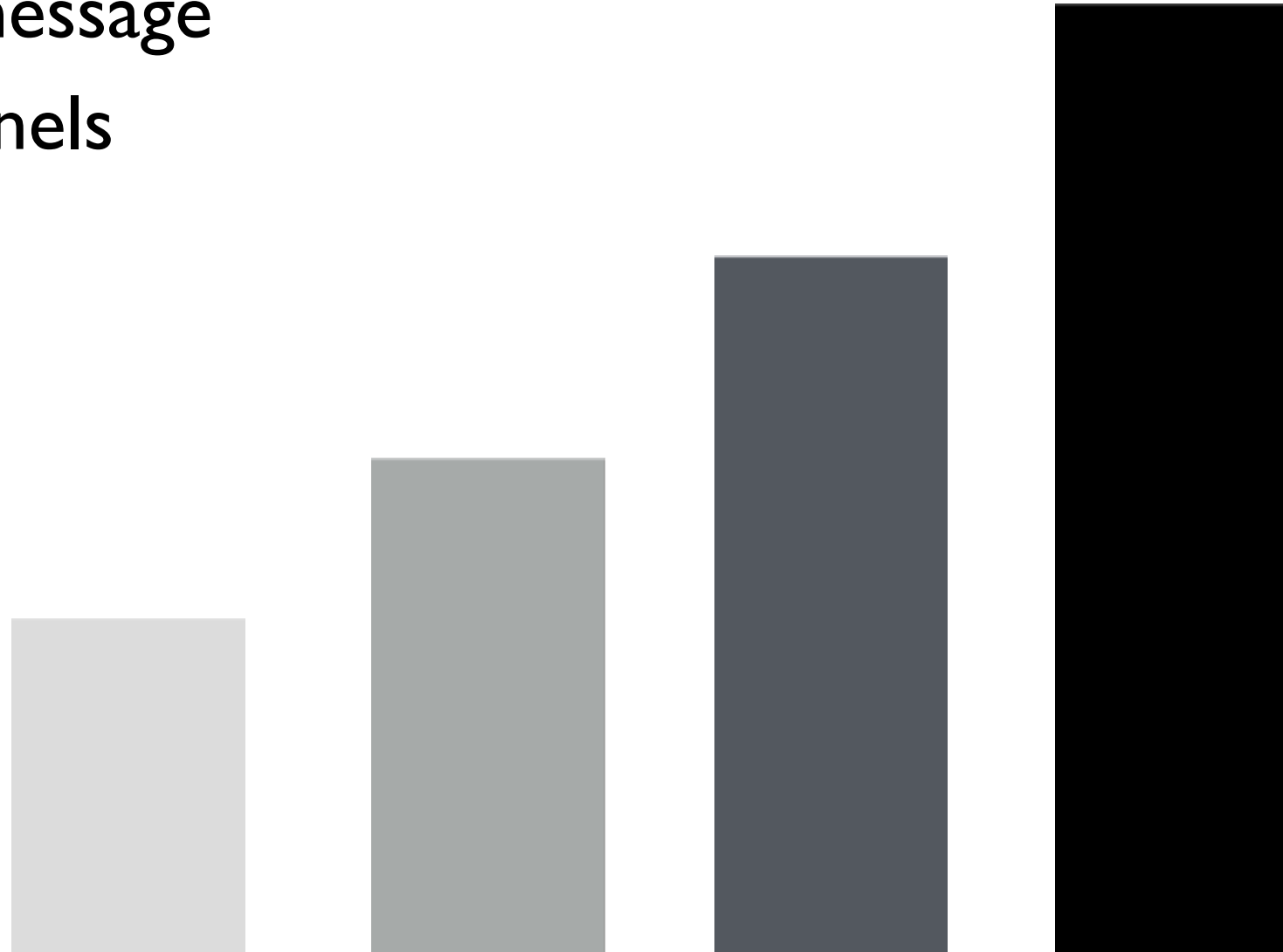


4:
vertical position
horizontal position
color hue
size (area)

mark: point

Redundant encoding

- multiple channels
 - sends stronger message
 - but uses up channels



Length and Luminance

Marks as constraints

- math view: geometric primitives have dimensions

→ Points

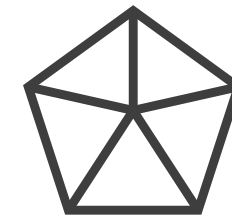
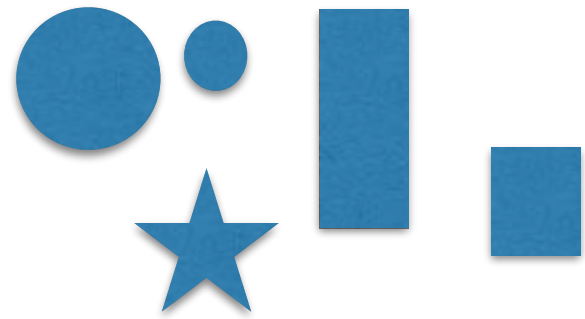
0D

→ Lines

1D

→ Interlocking Areas

2D



Marks as constraints

- math view: geometric primitives have dimensions

→ Points

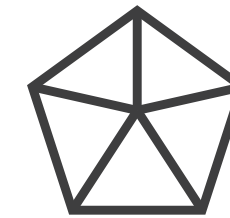
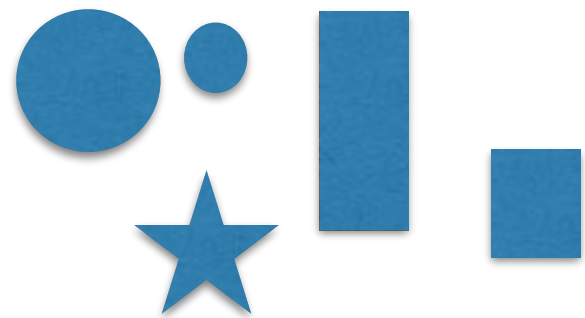
0D

→ Lines

1D

→ Interlocking Areas

2D



- 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
 - interlocking: size, shape, position

Marks as constraints

- math view: geometric primitives have dimensions

→ Points

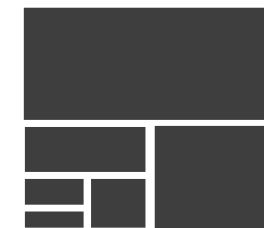
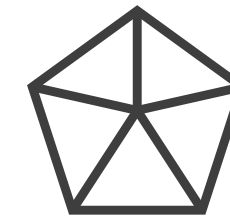
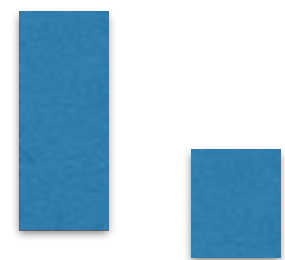
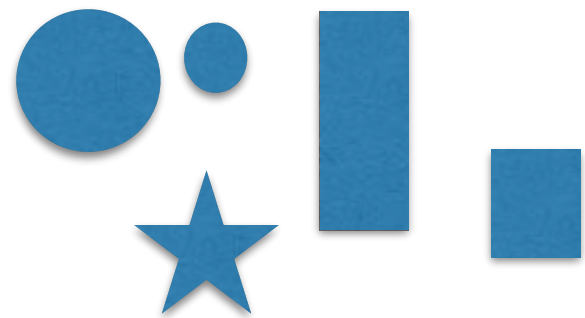
0D

→ Lines

1D

→ Interlocking Areas

2D



- 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
 - interlocking: size, shape, position
- quick check: can you size-code another attribute
 - or is size/shape in use?

Scope of analysis

- simplifying assumptions: one mark per item, single view
- later on
 - multiple views
 - multiple marks in a region (glyph)
 - some items not represented by marks (aggregation and filtering)

When to use which channel?

expressiveness

match channel type to data type

effectiveness

some channels are better than others

Channels: Rankings

Position on common scale



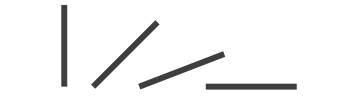
Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



Same

Spatial region



Color hue



Motion



Shape



Channels: Rankings

➔ 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) 

Same

➔ Identity Channels: Categorical Attributes

Spatial region 

Color hue 

Motion 

Shape 

- **expressiveness**
 - match channel and data characteristics

Channels: Rankings

➔ 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) 

Same
Same

➔ Identity Channels: Categorical Attributes

Spatial region 

Color hue 

Motion 

Shape 

➔ Attribute Types

➔ Categorical



➔ Ordered

➔ Ordinal



➔ Quantitative



- **expressiveness**

- match channel and data characteristics

- magnitude for ordered

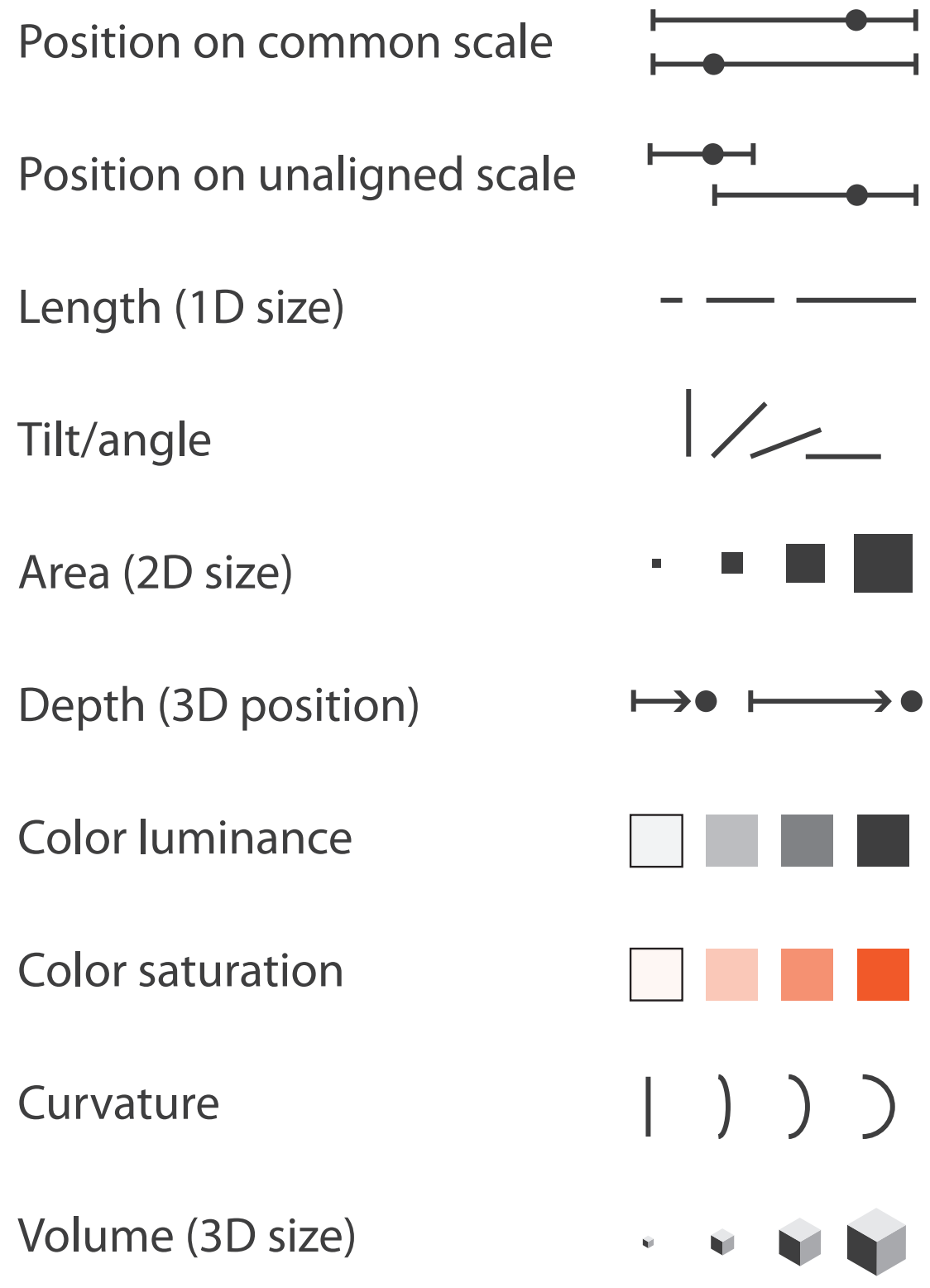
- how much? which rank?

- identity for categorical

- what?

Channels: Rankings

➔ Magnitude Channels: Ordered Attributes



➔ Identity Channels: Categorical Attributes



Best

Effectiveness

Least

Same

Same

- **expressiveness**
 - match channel and data characteristics
- **effectiveness**
 - channels differ in accuracy of perception

Channels: Rankings

➔ Magnitude Channels: Ordered Attributes

Position on common scale



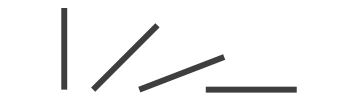
Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



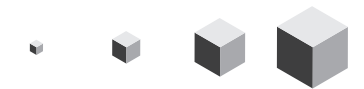
Color saturation



Curvature



Volume (3D size)



Same

Same

➔ Identity Channels: Categorical Attributes

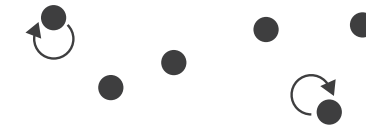
Spatial region



Color hue



Motion



Shape



Best

Effectiveness

Least

- **expressiveness**
 - match channel and data characteristics
- **effectiveness**
 - channels differ in accuracy of perception
 - spatial position ranks high for both

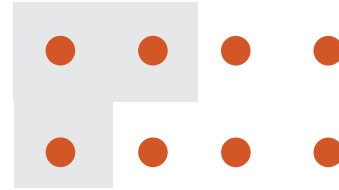
Grouping

- containment
- connection

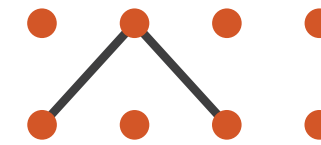
- proximity
 - same spatial region
- similarity
 - same values as other categorical channels

Marks as Links

➔ Containment



➔ Connection



➔ Identity Channels: Categorical Attributes

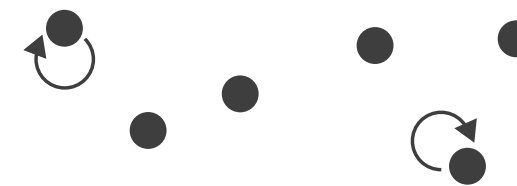
Spatial region



Color hue



Motion



Shape



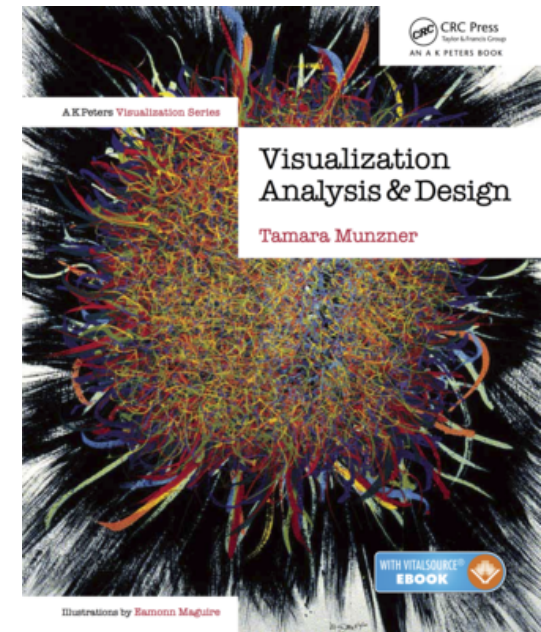
Visualization Analysis & Design

Marks & Channels (Ch 5) II

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



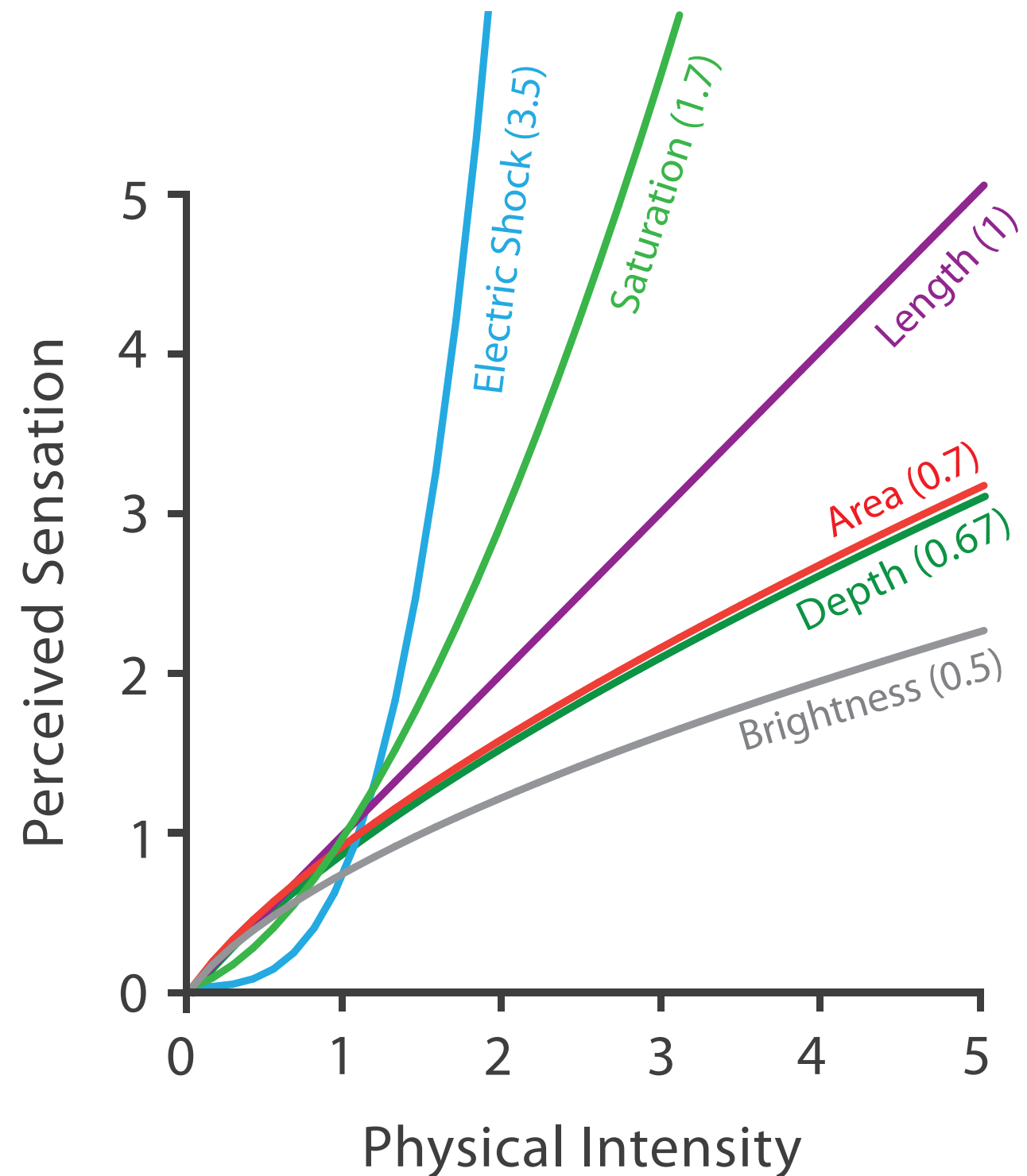
Channel effectiveness

- accuracy: how precisely can we tell the difference between encoded items?
- discriminability: how many unique steps can we perceive?
- separability: is our ability to use this channel affected by another one?
- popout: can things jump out using this channel?

Accuracy: Fundamental theory

- length is accurate: linear
- others magnified or compressed
 - exponent characterizes

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

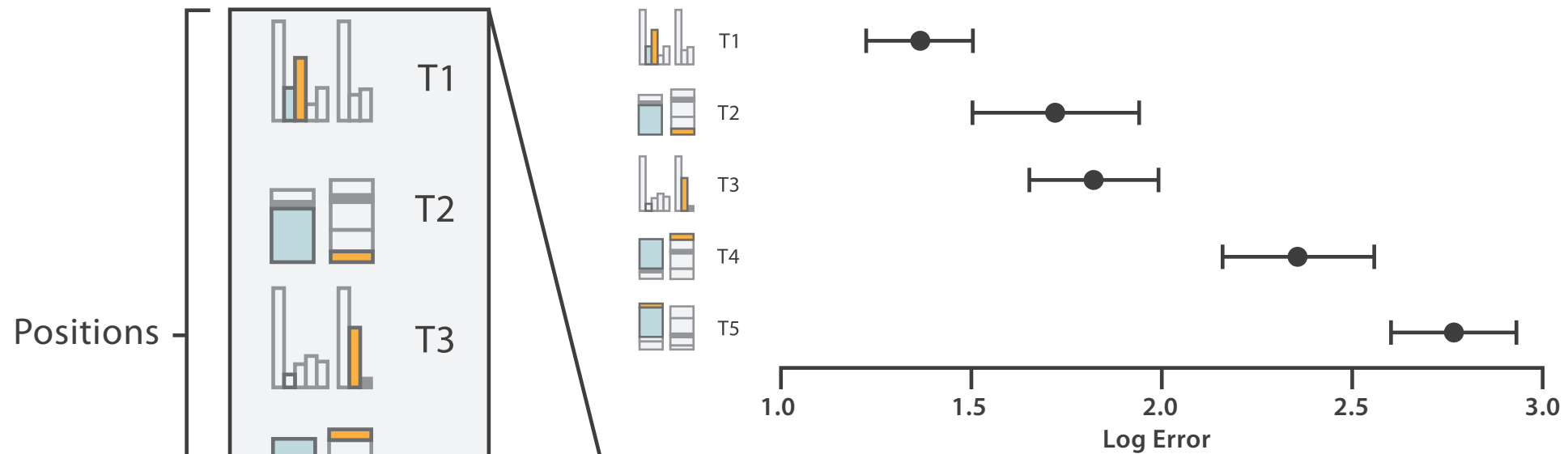


S = sensation

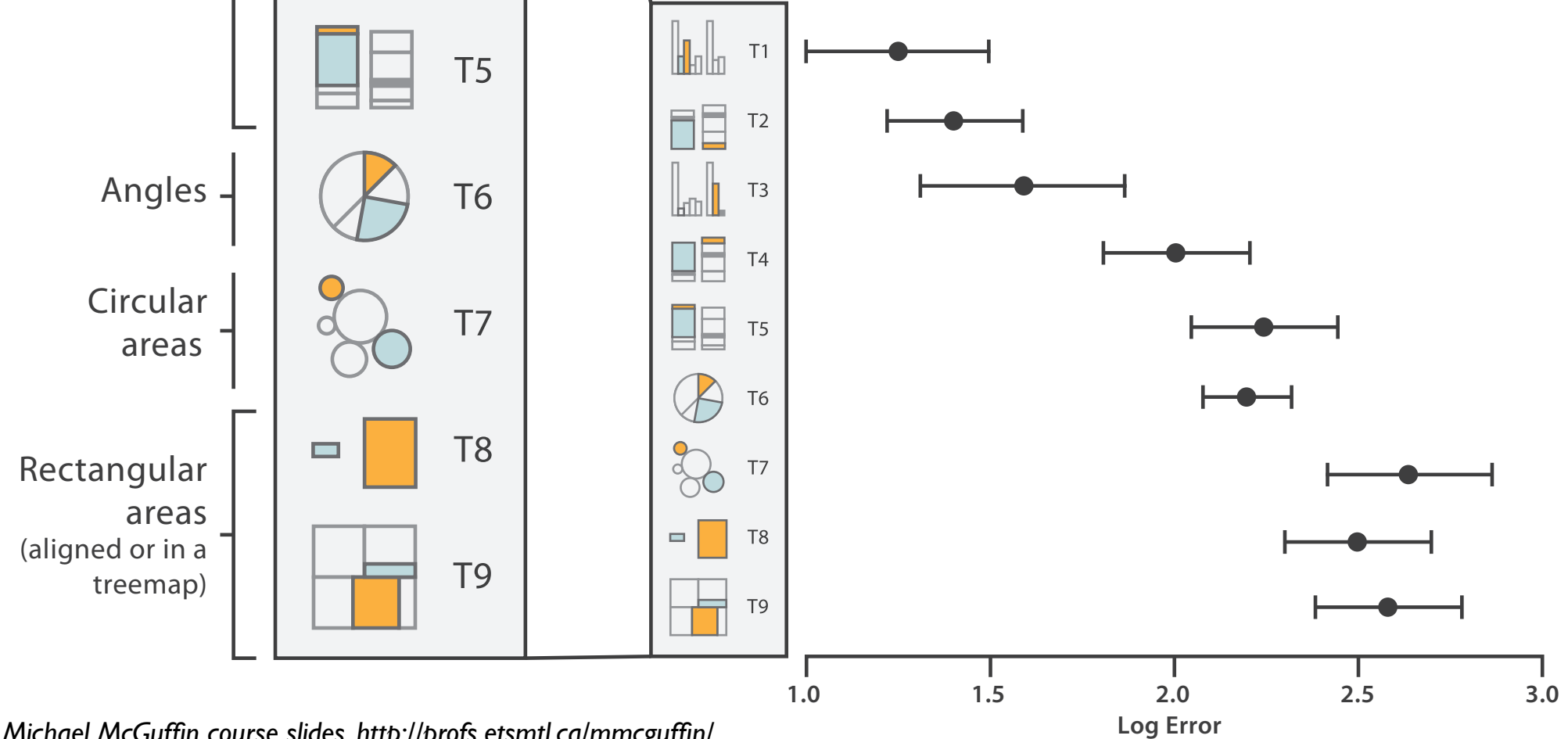
I = intensity

Accuracy: Vis experiments

Cleveland & McGill's Results



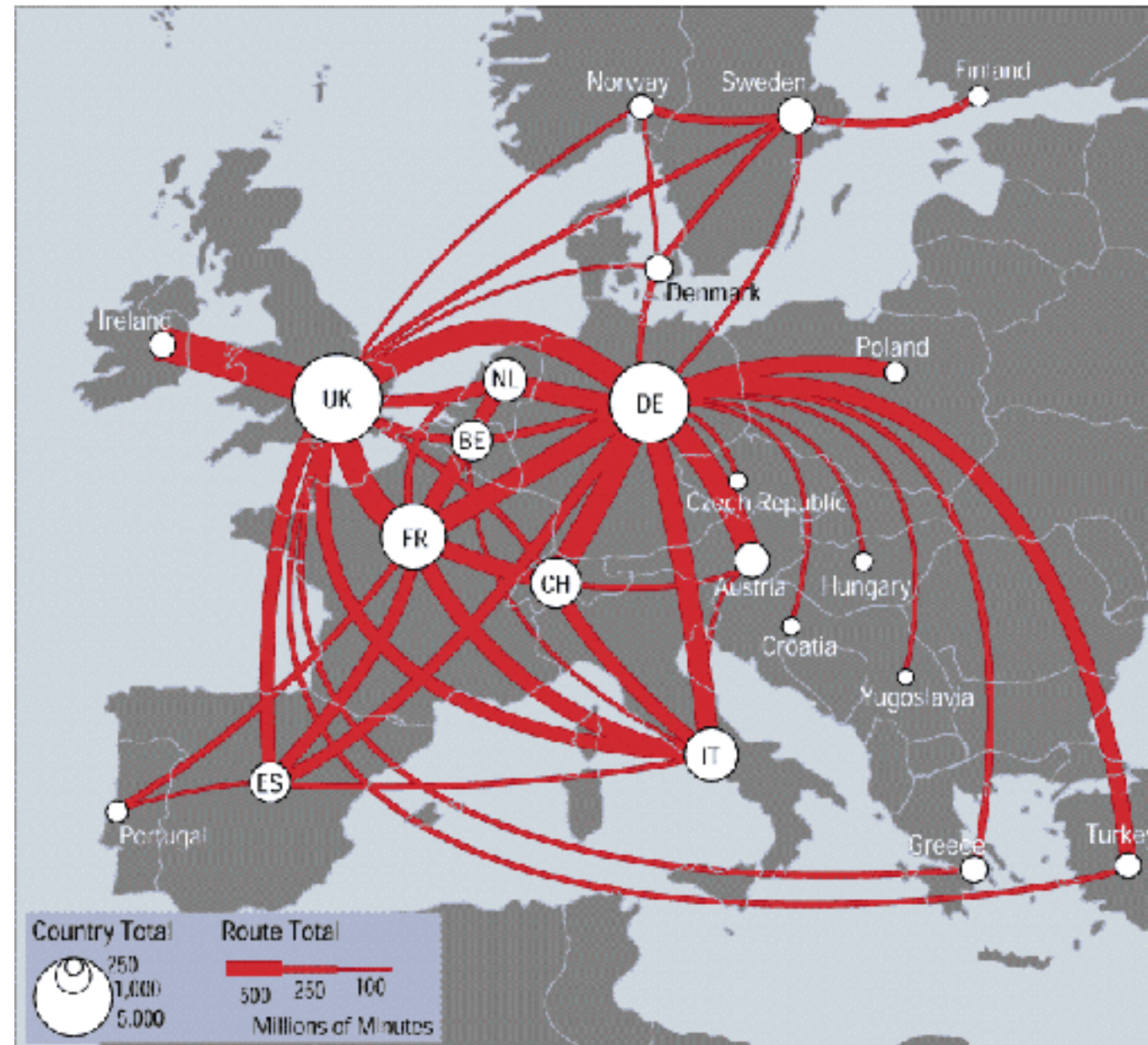
Crowdsourced Results



[Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

Discriminability: How many usable steps?

- must be sufficient for number of attribute levels to show
 - linewidth: few bins

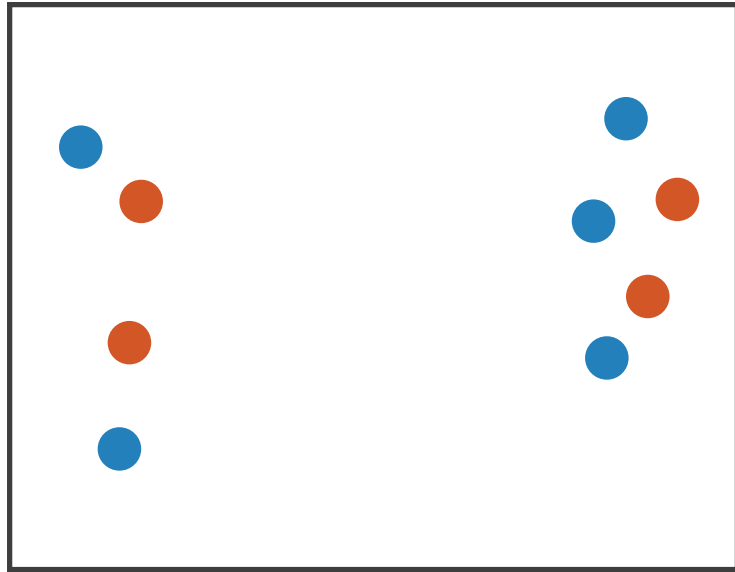


[mappa.mundi.net/maps/maps_014/telegeography.html]

Separability vs. Integrality

Position

+ Hue (Color)

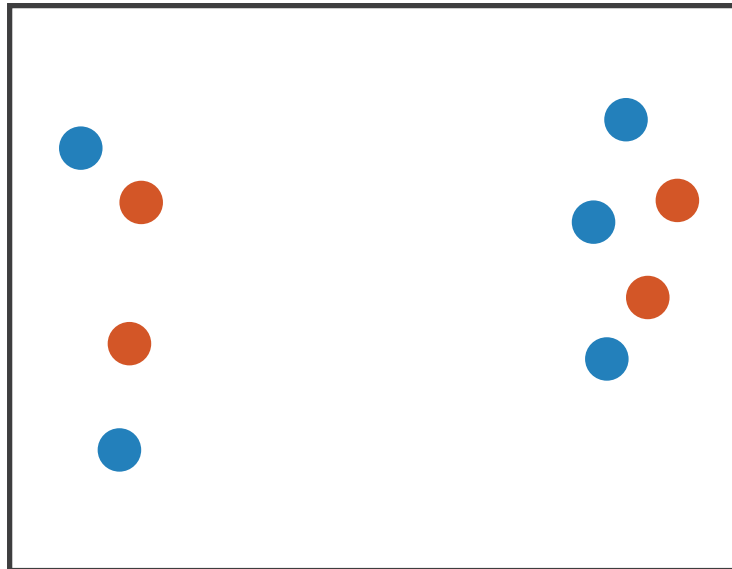


Fully separable

2 groups each

Separability vs. Integrality

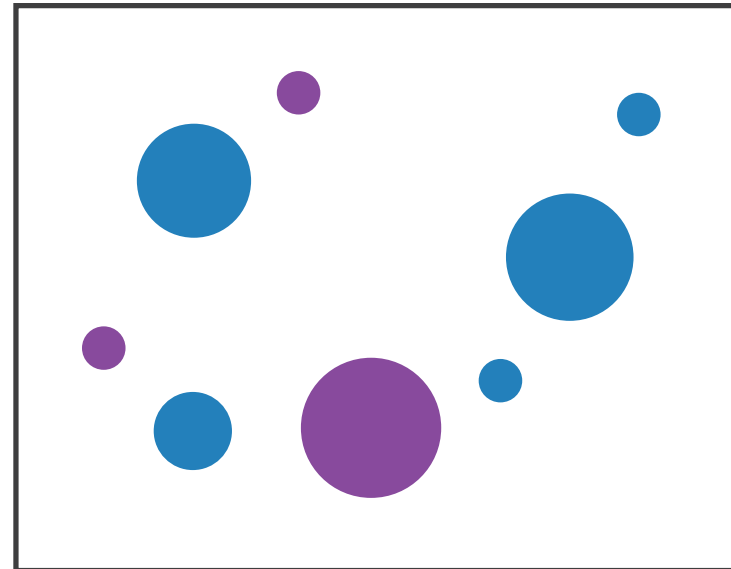
Position
+ Hue (Color)



Fully separable

2 groups each

Size
+ Hue (Color)

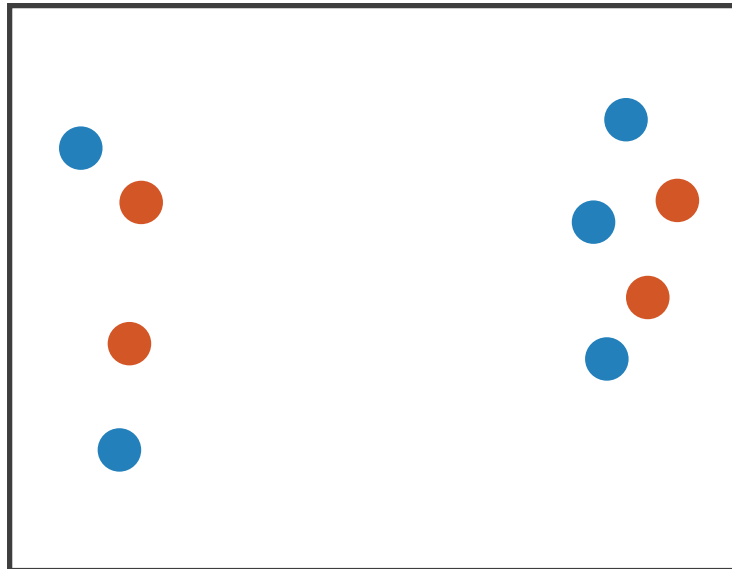


Some interference

2 groups each

Separability vs. Integrality

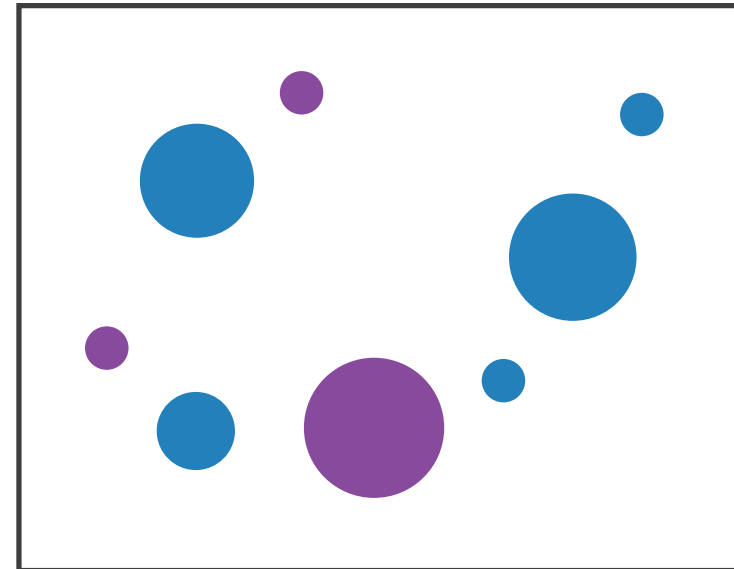
Position
+ Hue (Color)



Fully separable

2 groups each

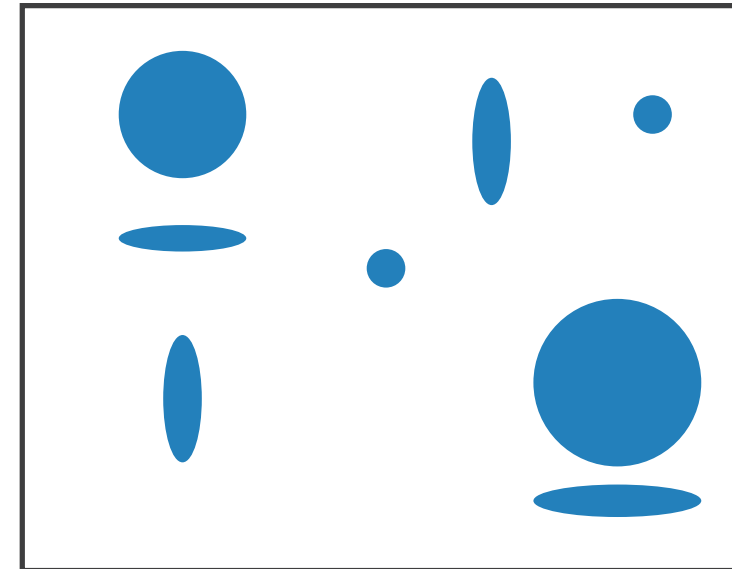
Size
+ Hue (Color)



Some interference

2 groups each

Width
+ Height

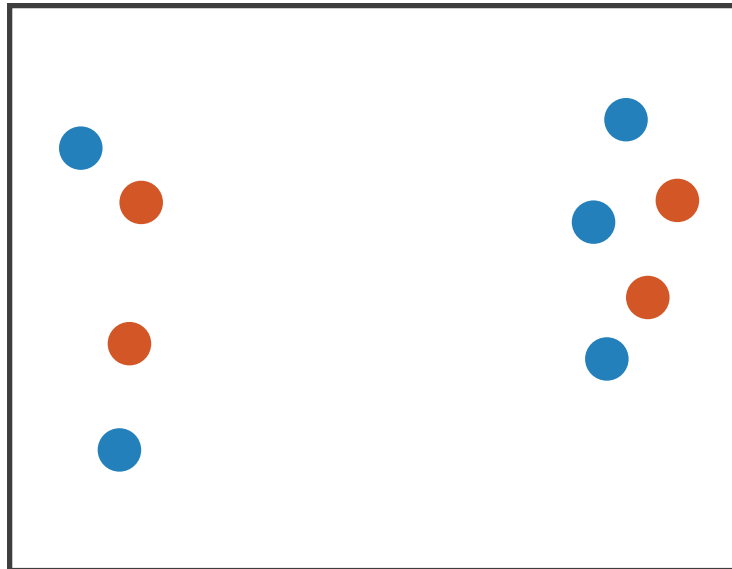


Some/significant
interference

3 groups total:
integral area

Separability vs. Integrality

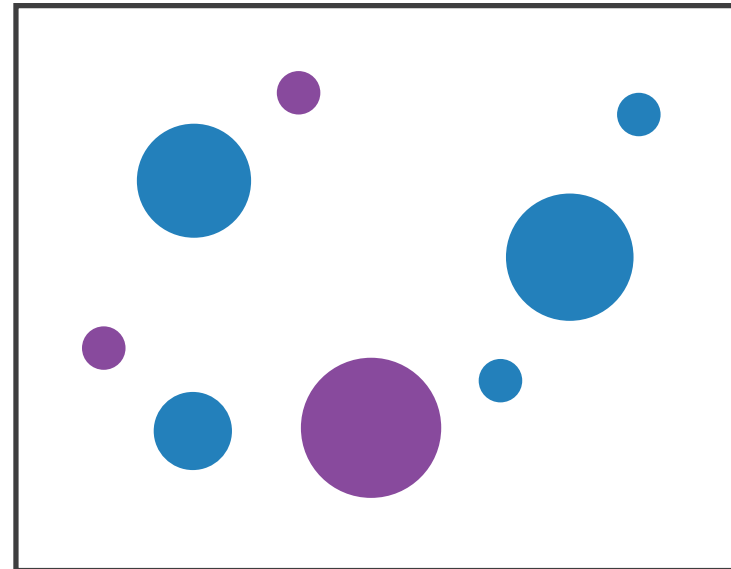
Position
+ Hue (Color)



Fully separable

2 groups each

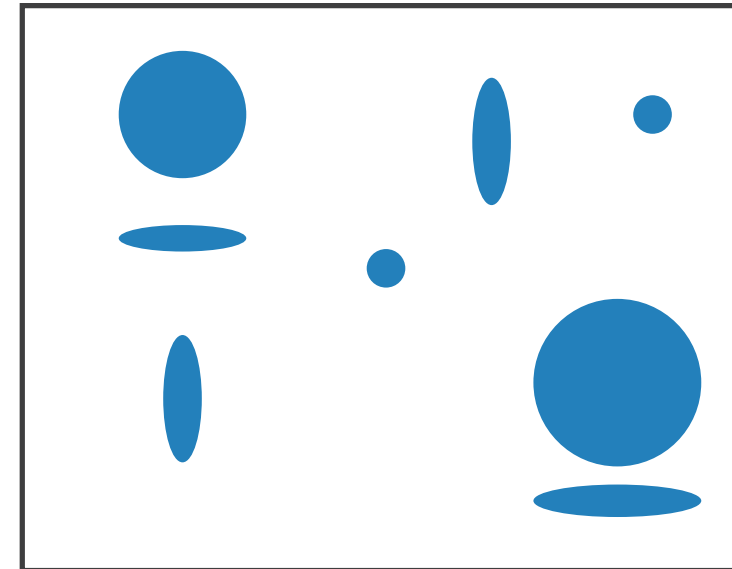
Size
+ Hue (Color)



Some interference

2 groups each

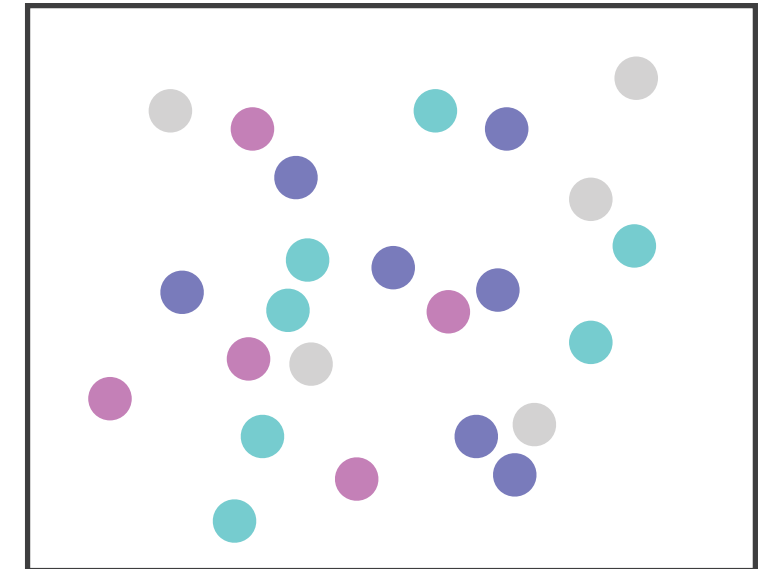
Width
+ Height



Some/significant
interference

3 groups total:
integral area

Red
+ Green



Major interference

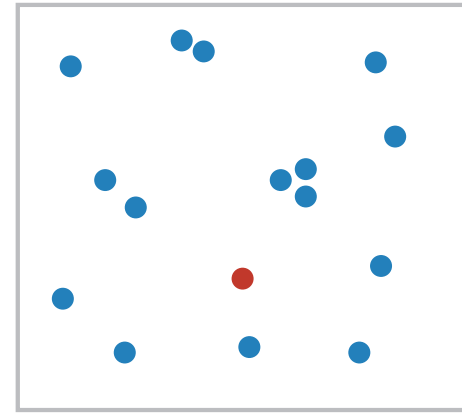
4 groups total:
integral hue

Popout

- find the red dot
 - how long does it take?

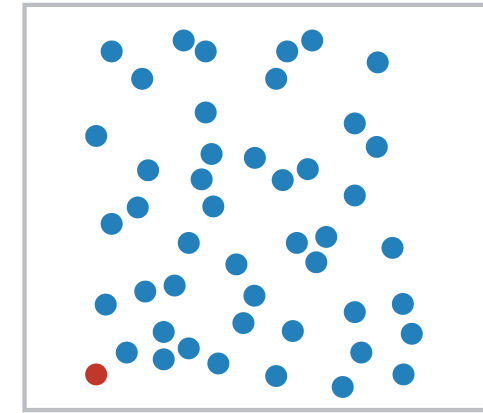
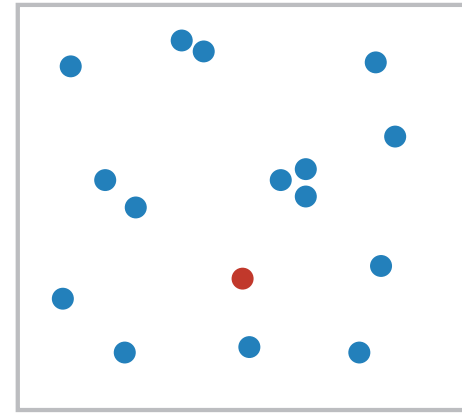
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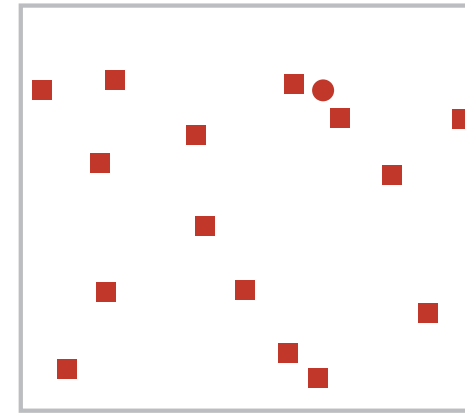
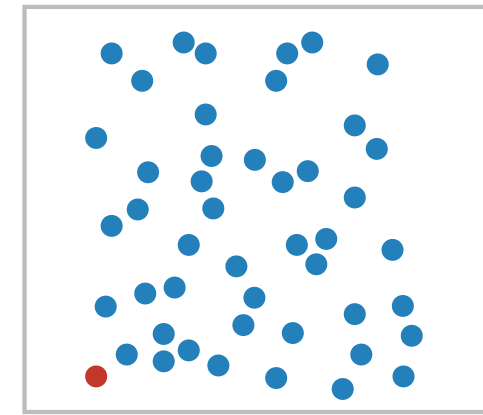
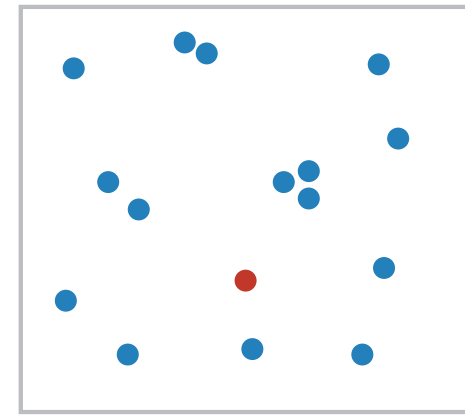
Popout

- find the red dot
 - how long does it take?



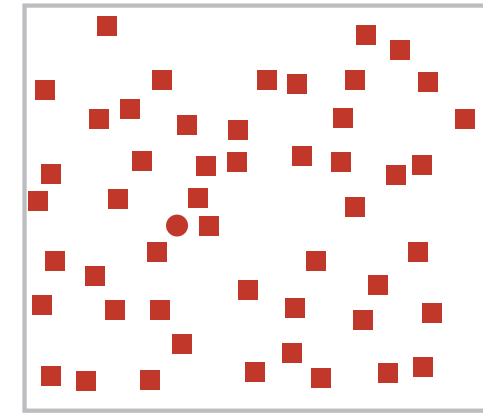
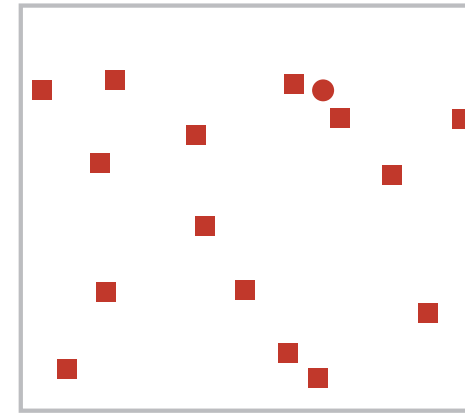
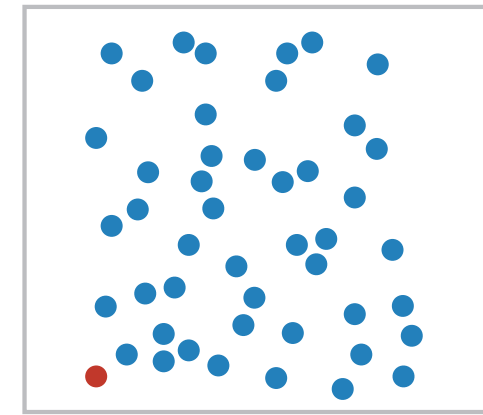
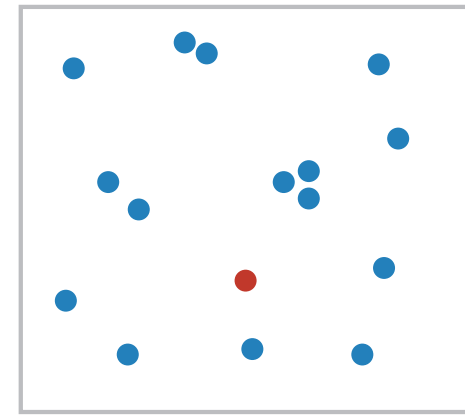
Popout

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 - how long does it take?



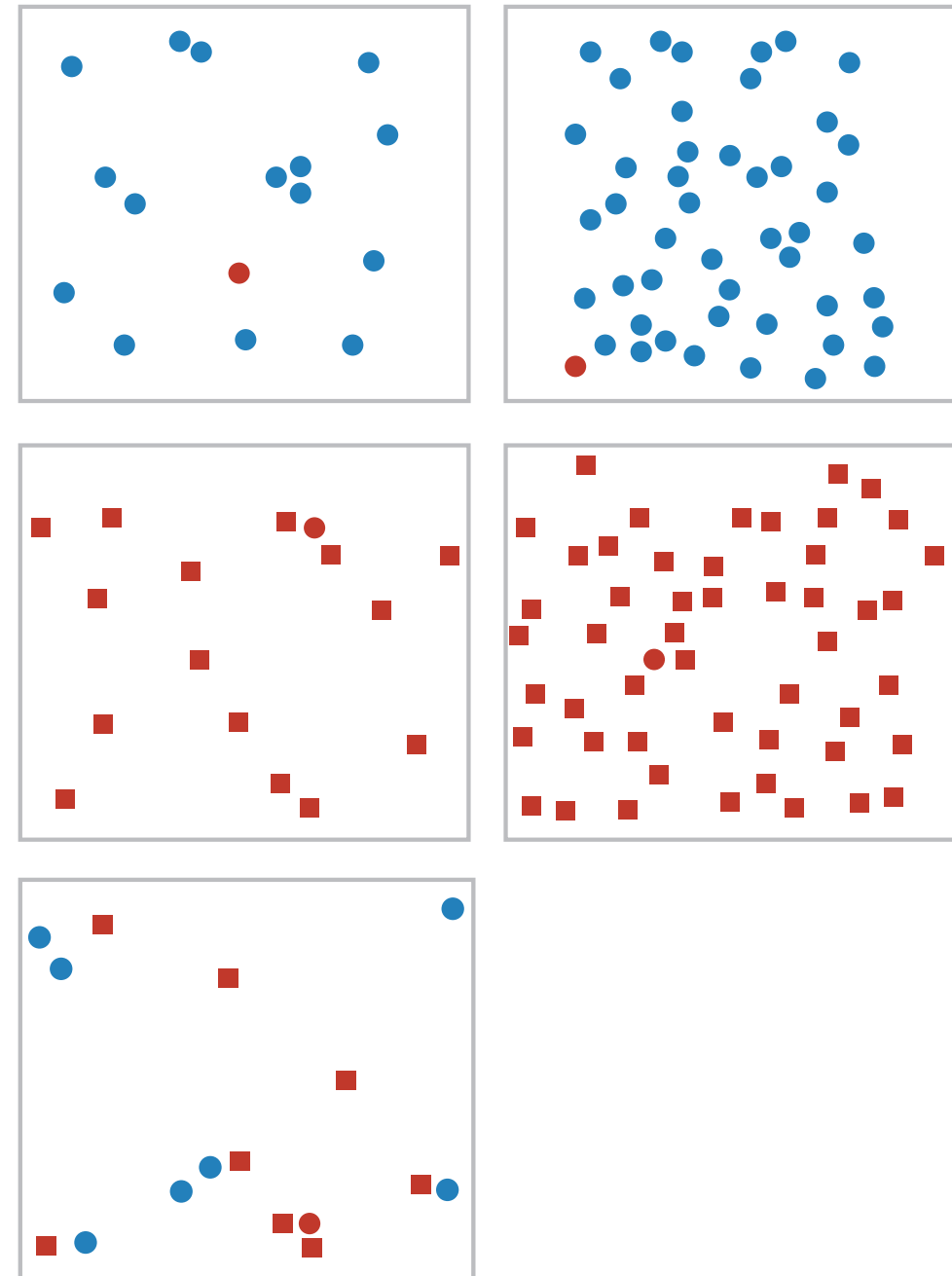
Popout

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 - how long does it take?



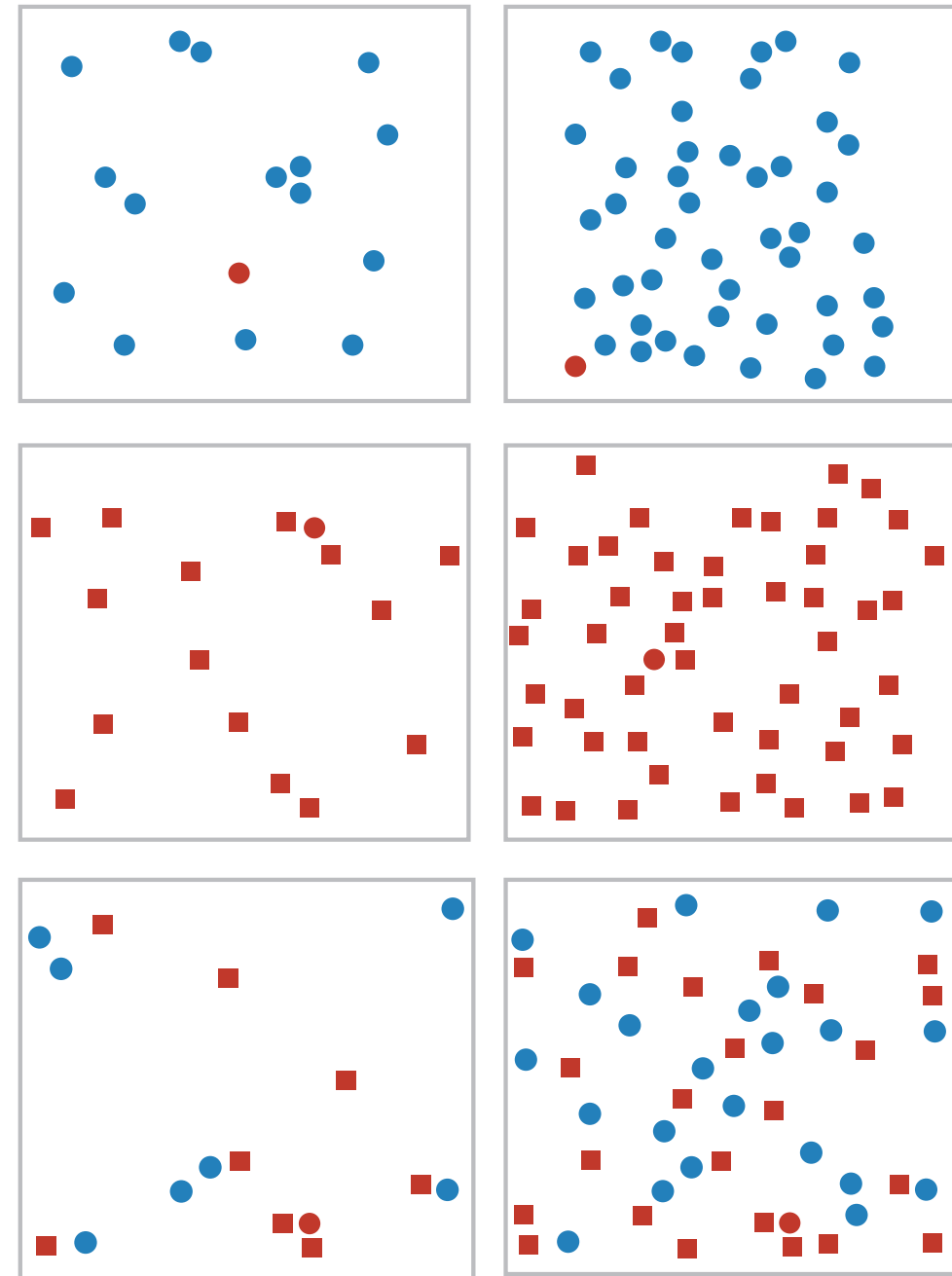
Popout

- find the red dot
 - how long does it take?



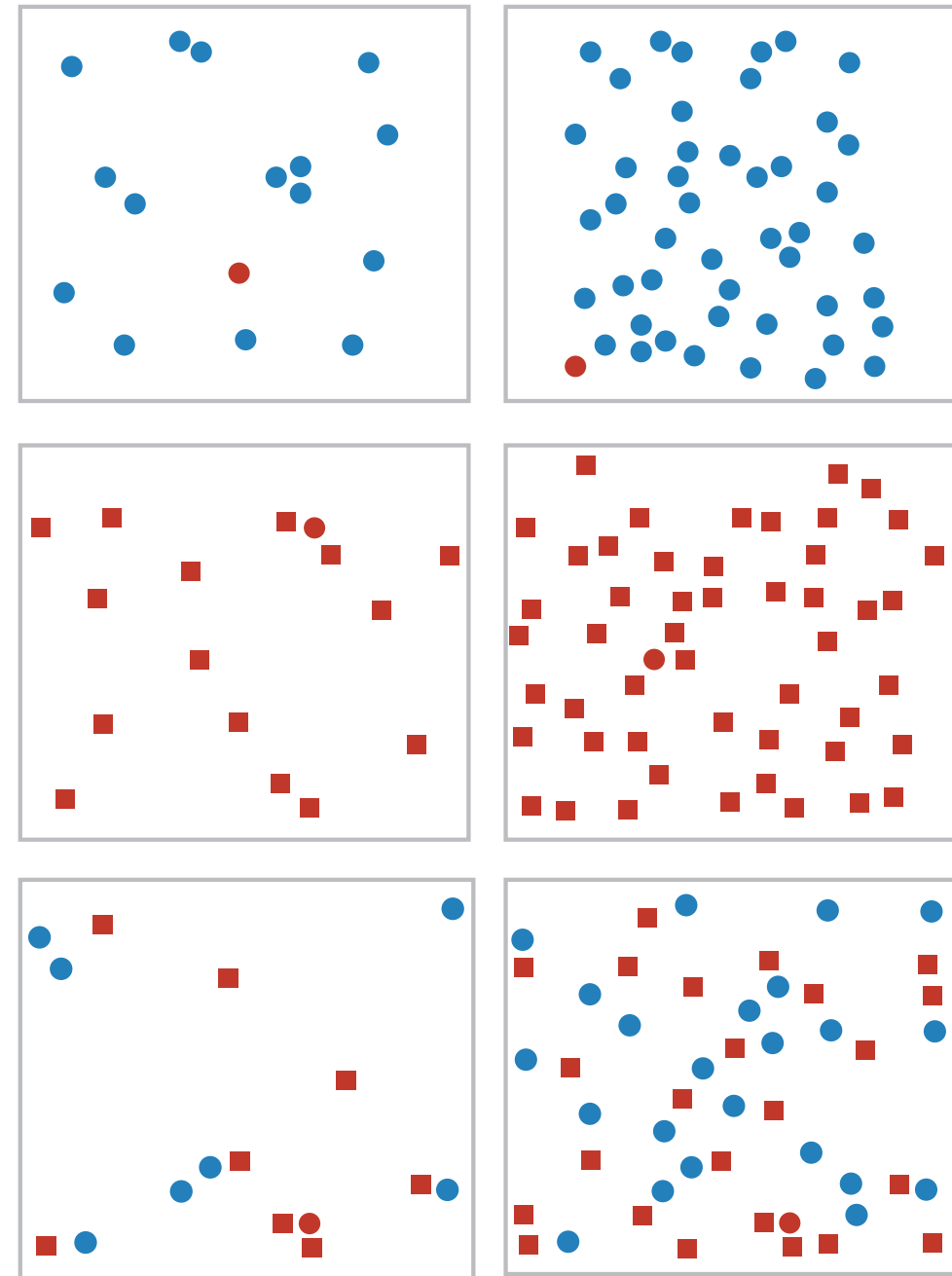
Popout

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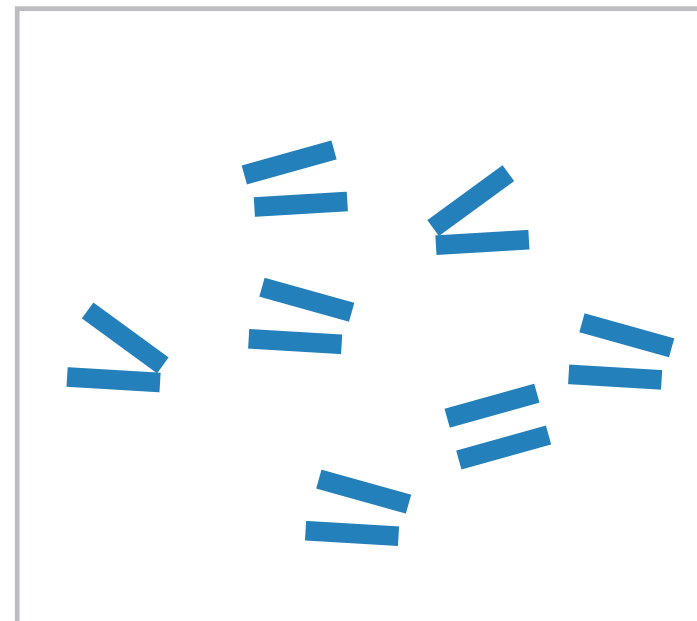
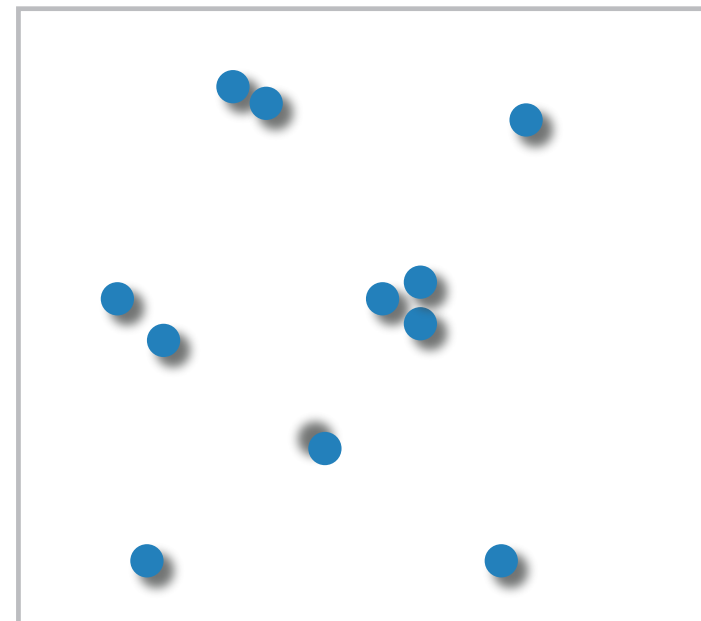
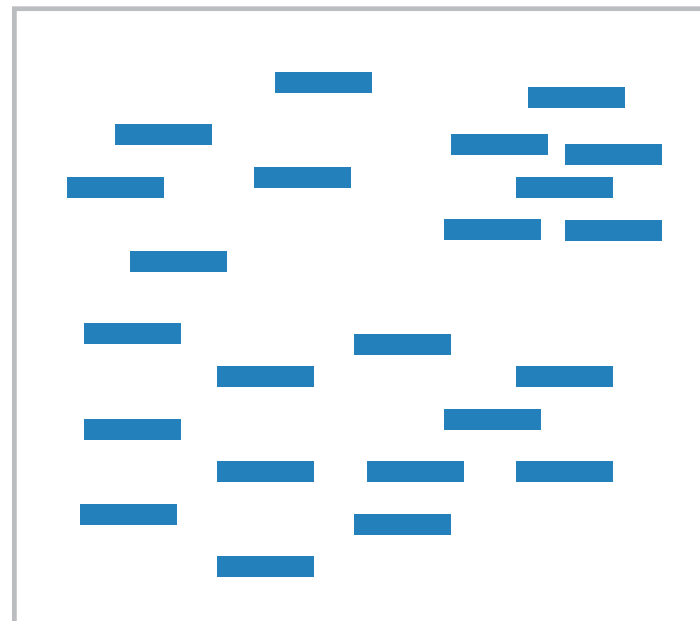
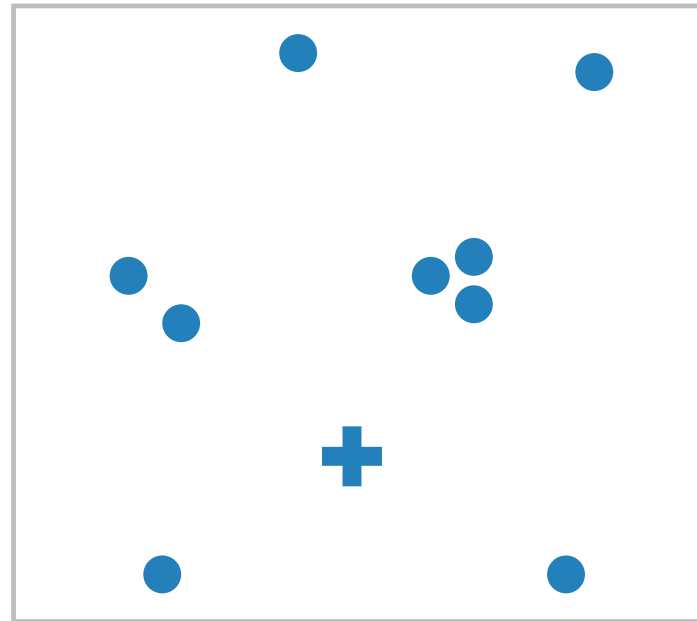
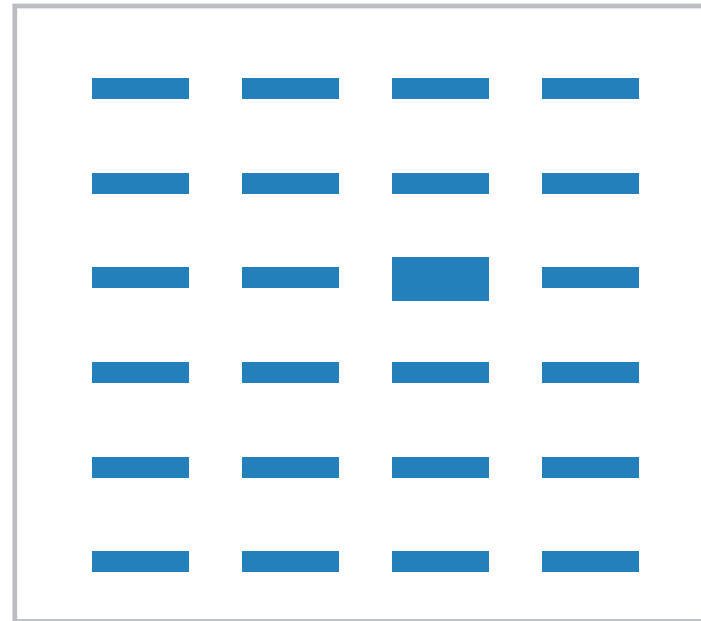
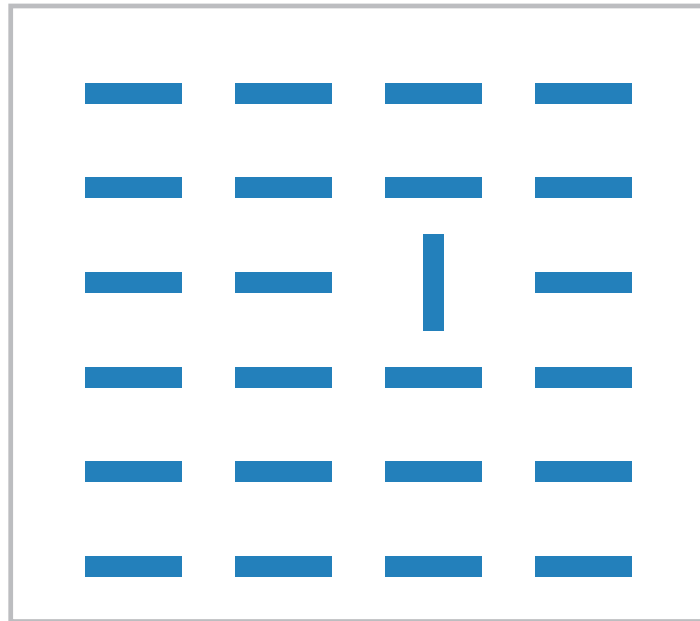


Popout

- find the red dot
 - how long does it take?
- parallel processing on many individual channels
 - speed independent of distractor count
 - speed depends on channel and amount of difference from distractors
- serial search for (almost all) combinations
 - speed depends on number of distractors

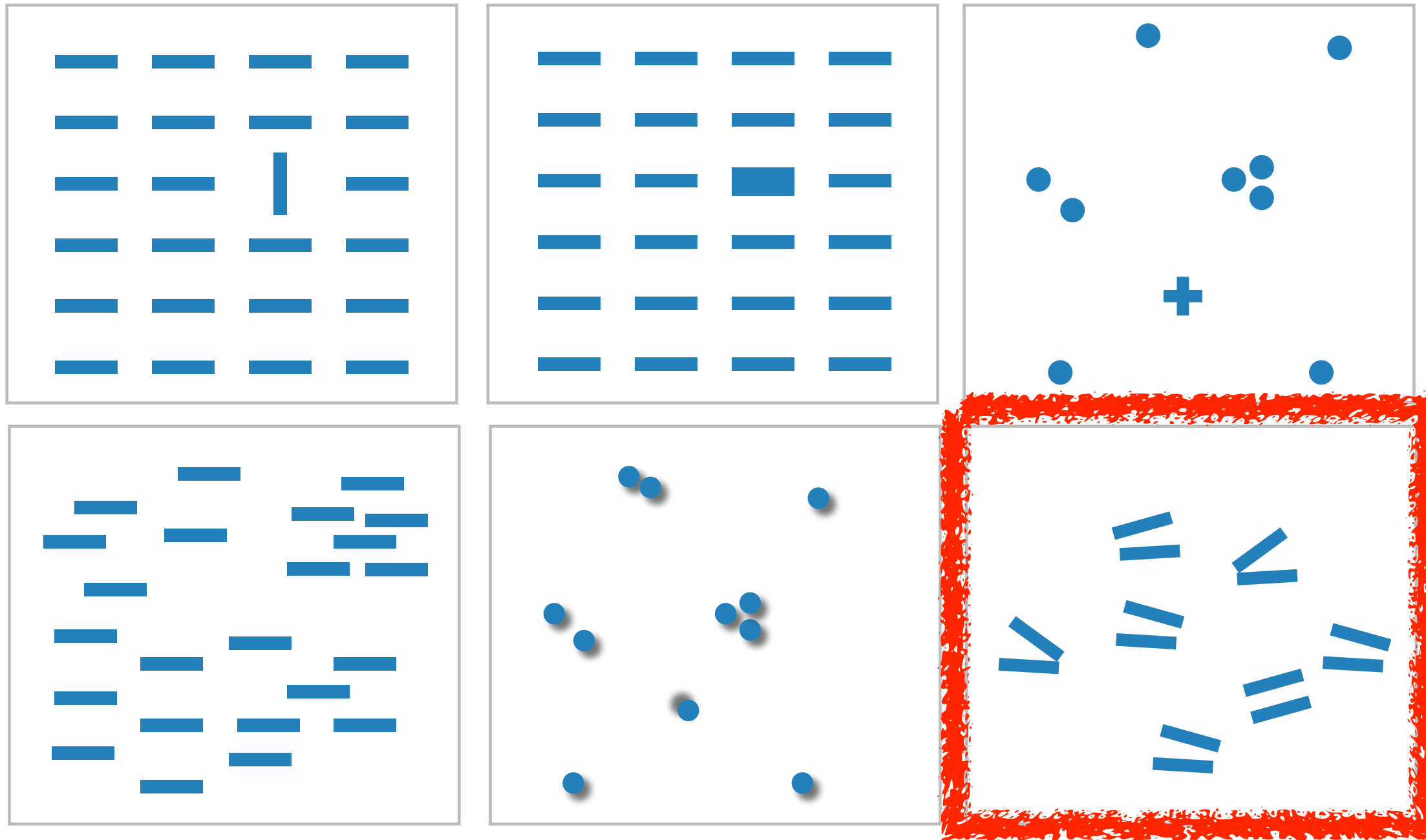


Popout



- many channels
 - tilt, size, shape, proximity, shadow direction, ...

Popout



- many channels
 - tilt, size, shape, proximity, shadow direction, ...
- but not all!
 - parallel line pairs do not pop out from tilted pairs

Factors affecting accuracy

- alignment
- distractors
- distance
- common scale / alignment



Relative vs. absolute judgements

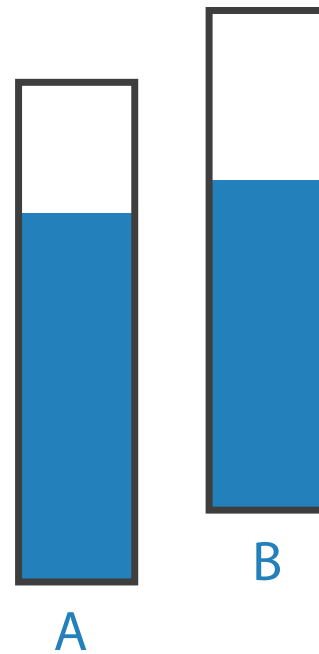
- perceptual system mostly operates with relative judgements, not absolute

Relative vs. absolute judgements

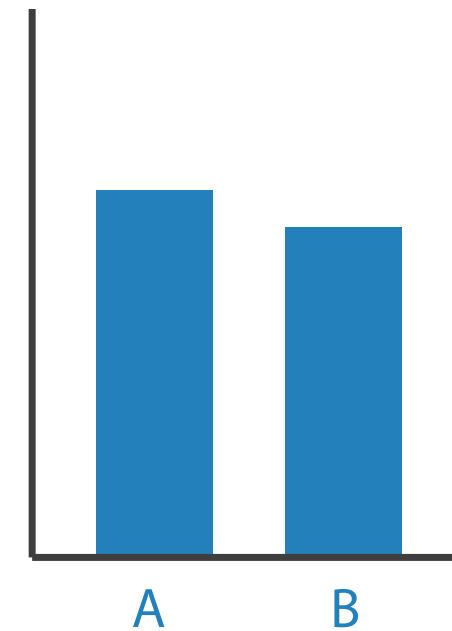
- perceptual system mostly operates with relative judgements, not absolute
 - that's why accuracy increases with common frame/scale and alignment



length



position along
unaligned
common scale



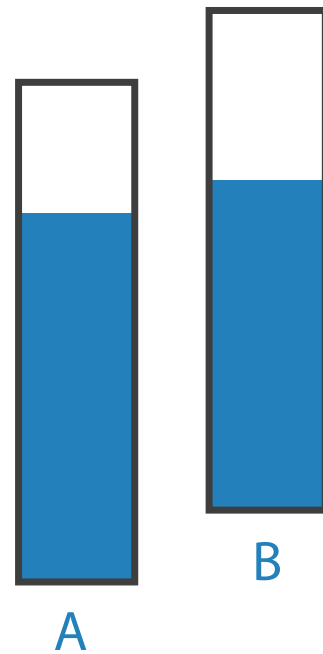
position along
aligned scale

Relative vs. absolute judgements

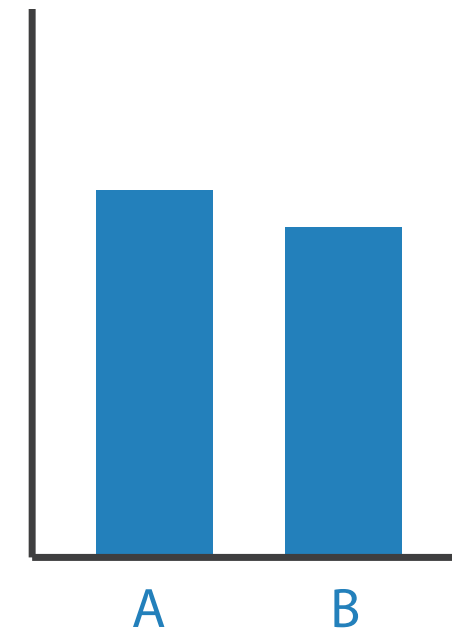
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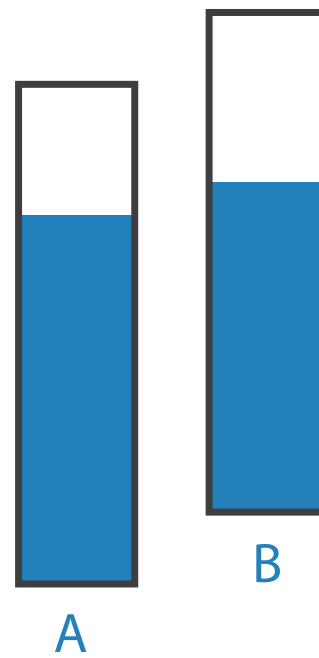
position along
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Relative vs. absolute judgements

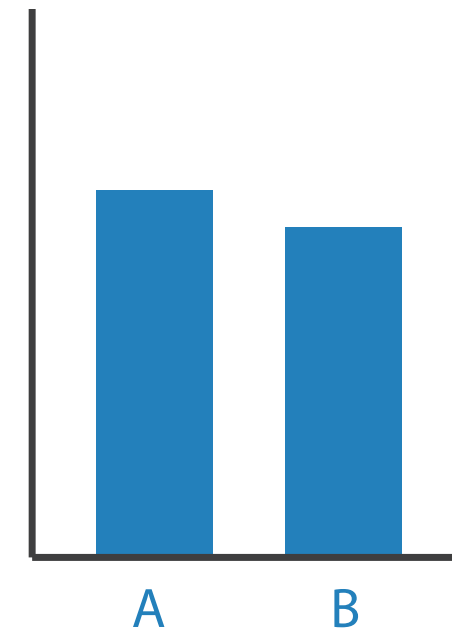
- perceptual system mostly operates with relative judgements, not absolute
 - that's why accuracy increases with common frame/scale and alignment
 - Weber's Law: ratio of increment to background is constant
 - filled rectangles differ in length by 1:9, difficult judgement
 - white rectangles differ in length by 1:2, easy judgement



length



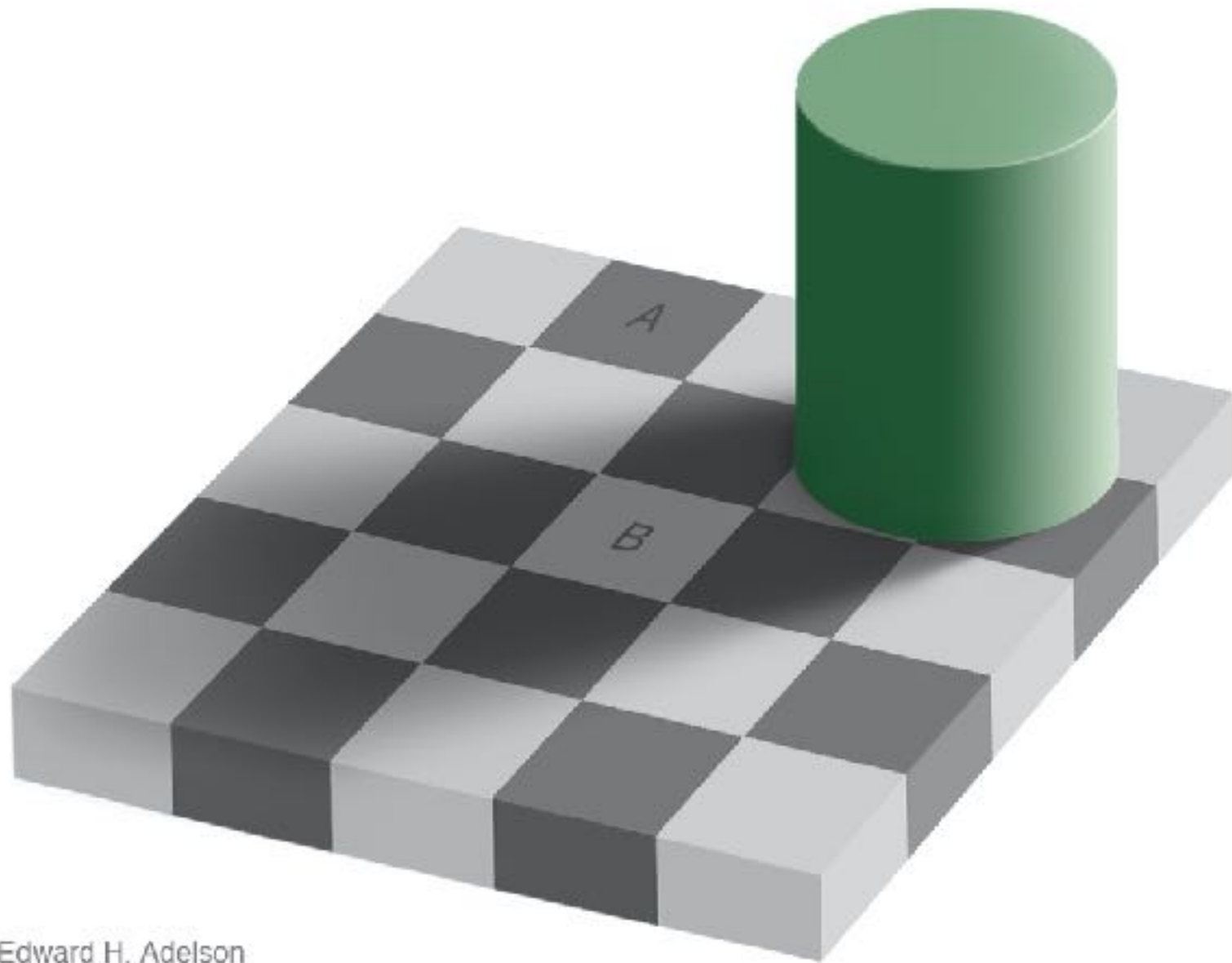
position along
unaligned
common scale



position along
aligned scale

Relative luminance judgements

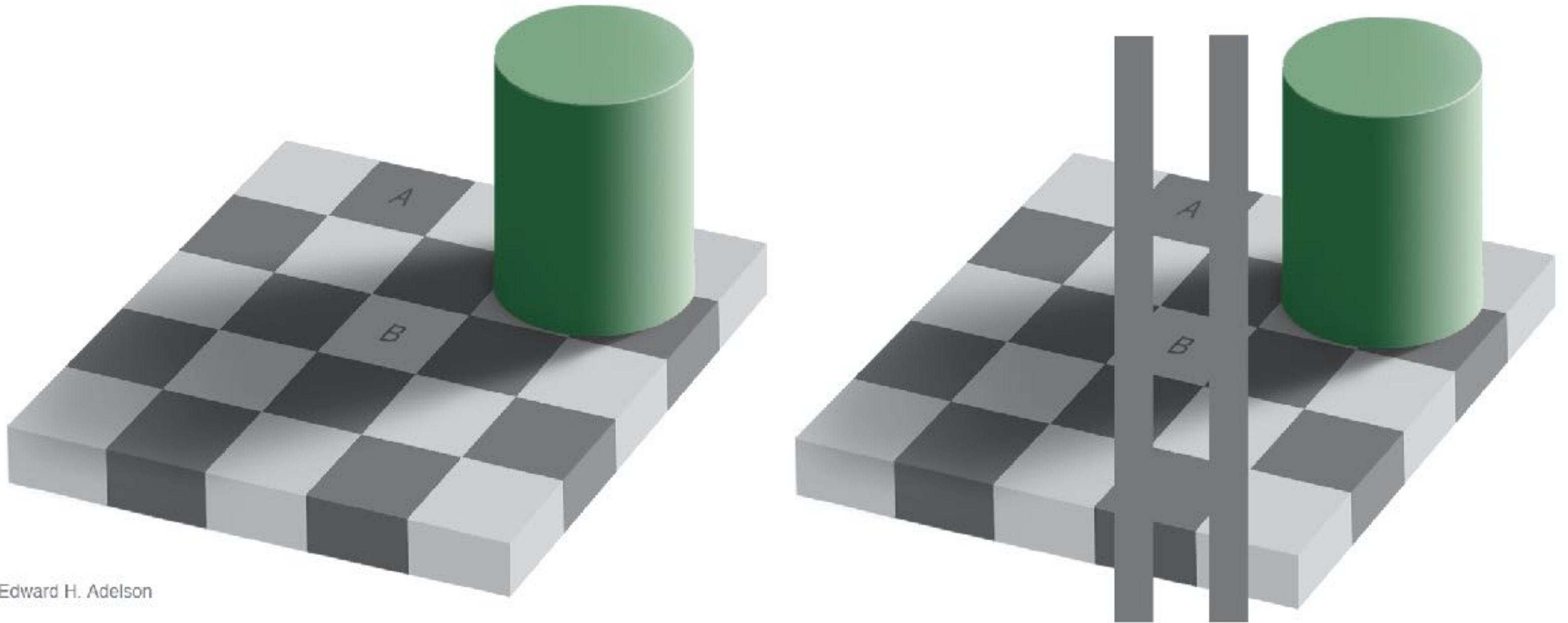
- perception of luminance is contextual based on contrast with surroundings



Edward H. Adelson

Relative luminance judgements

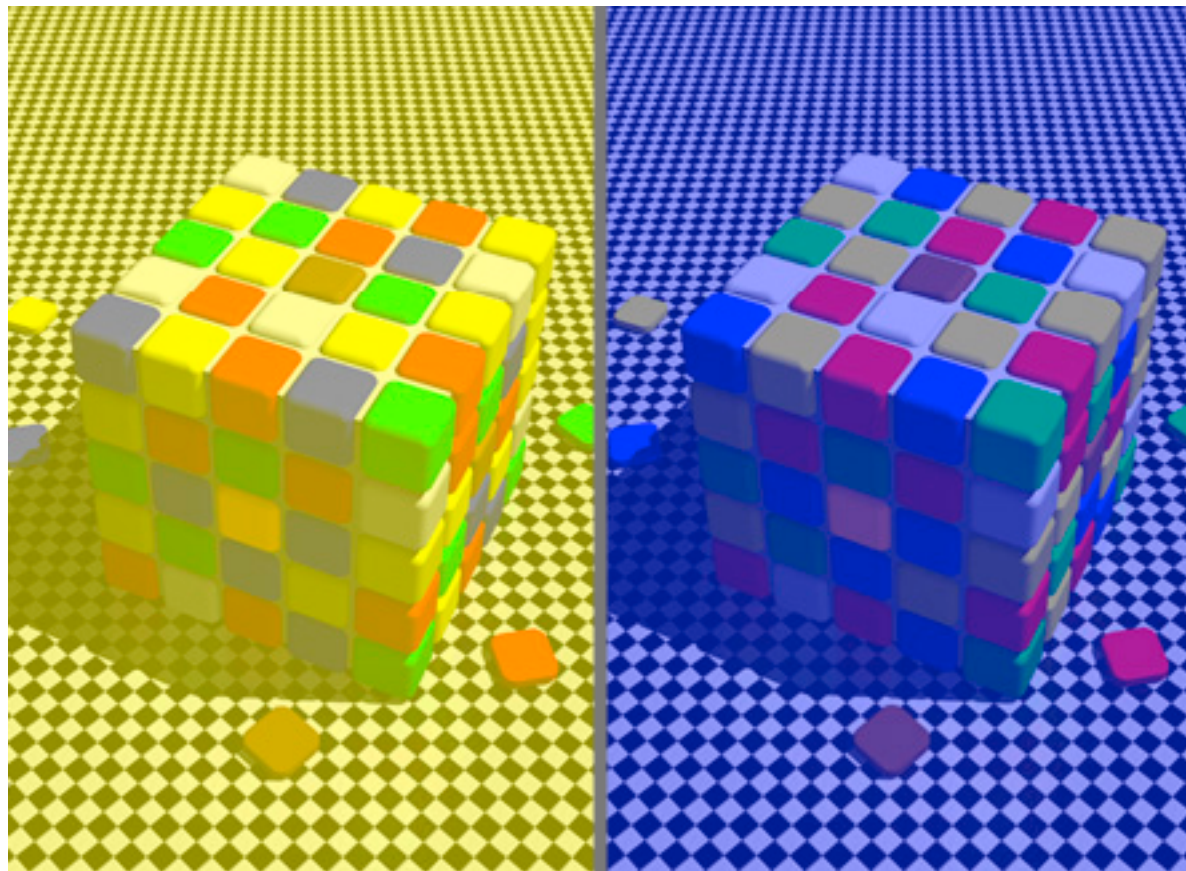
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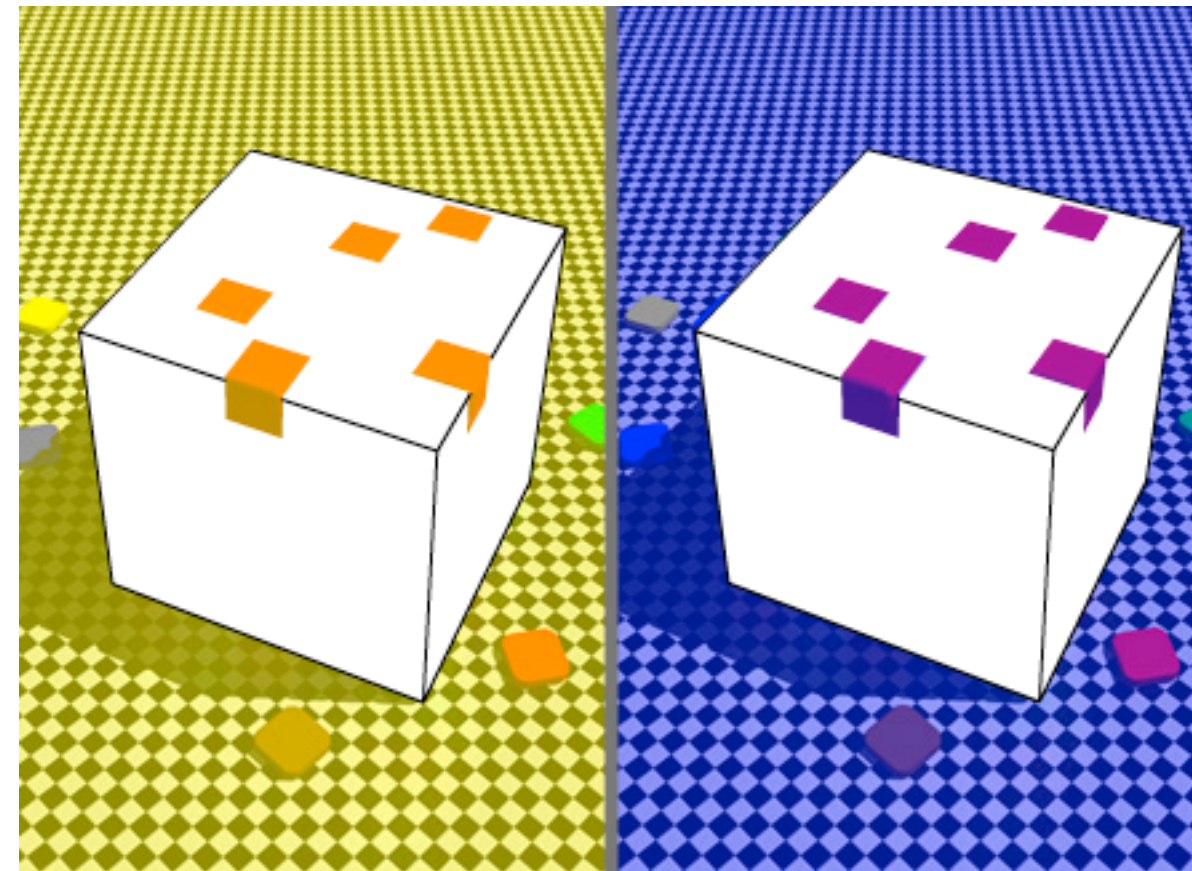
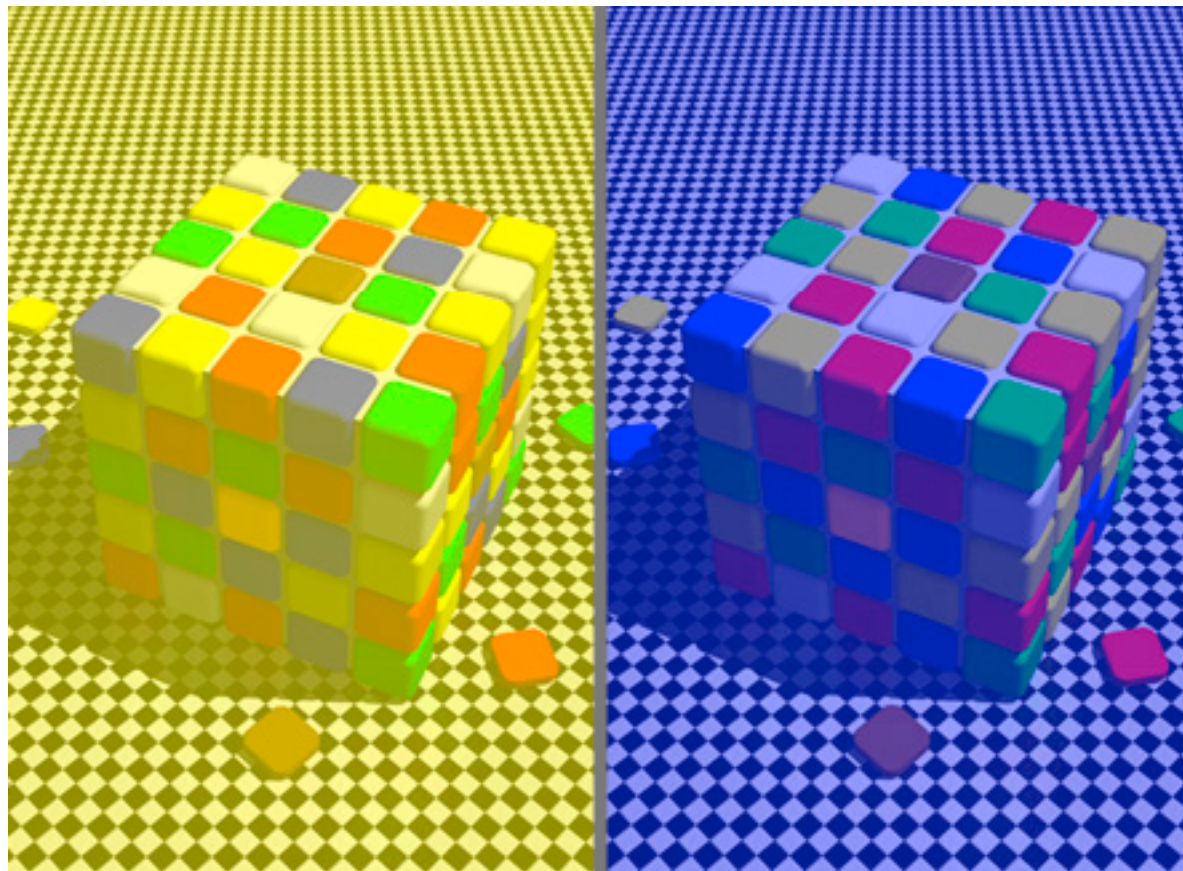
Relative color judgements

- color constancy across broad range of illumination conditions



Relative color judgements

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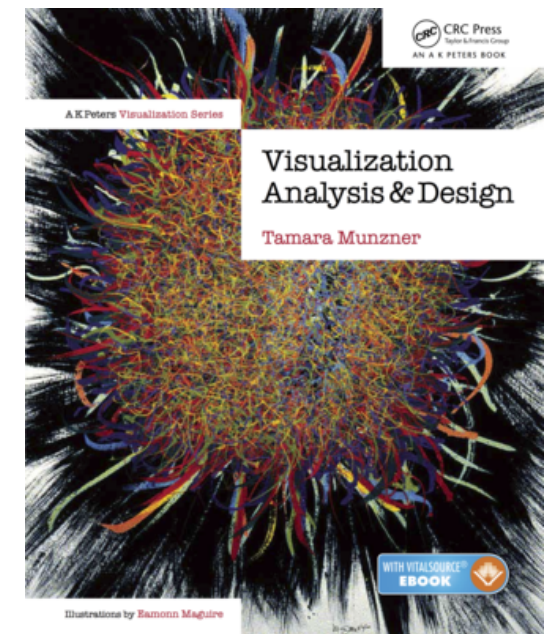
Visualization Analysis & Design

Rules of Thumb (Ch 6)

Tamara Munzner

Department of Computer Science
University of British Columbia

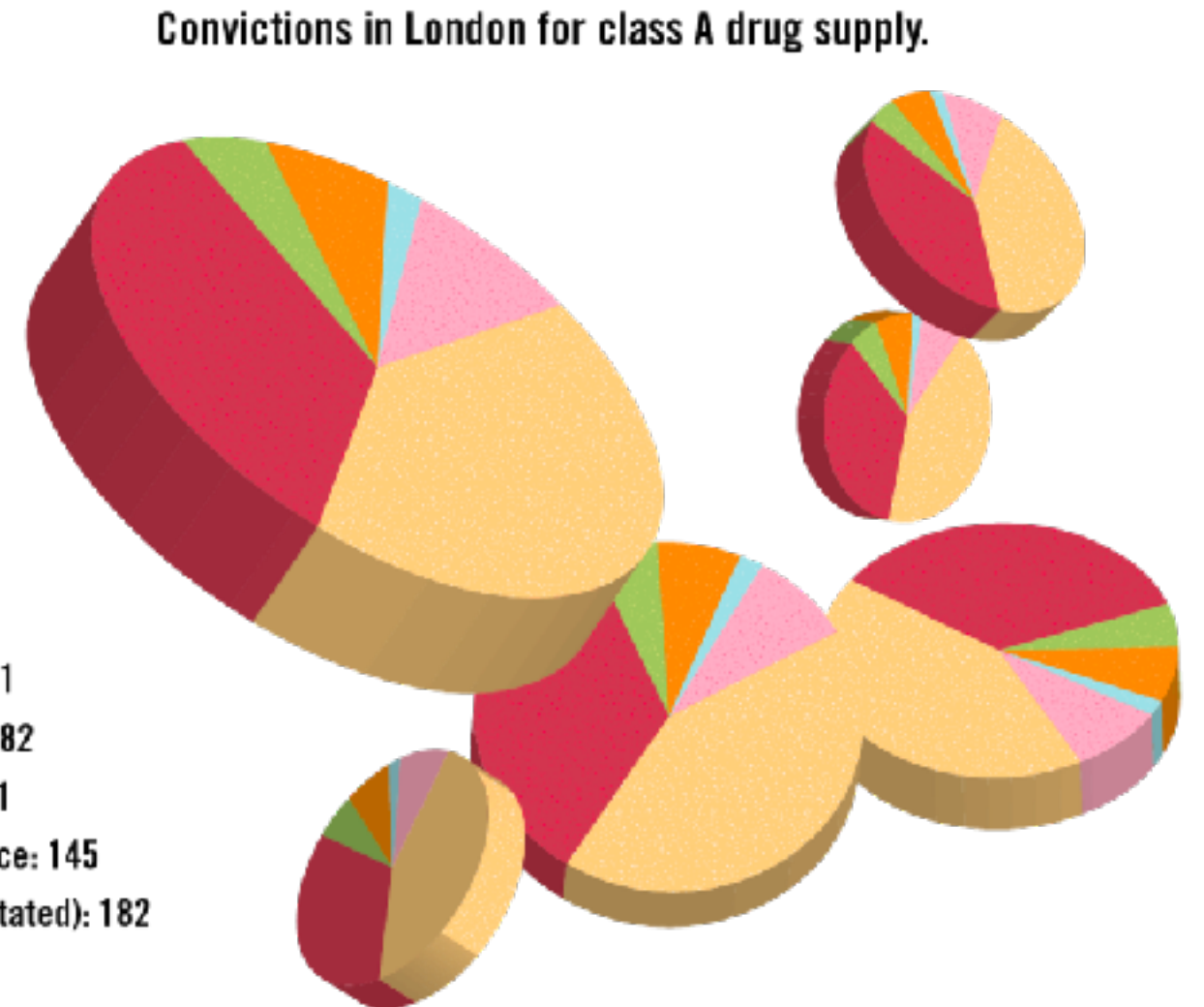
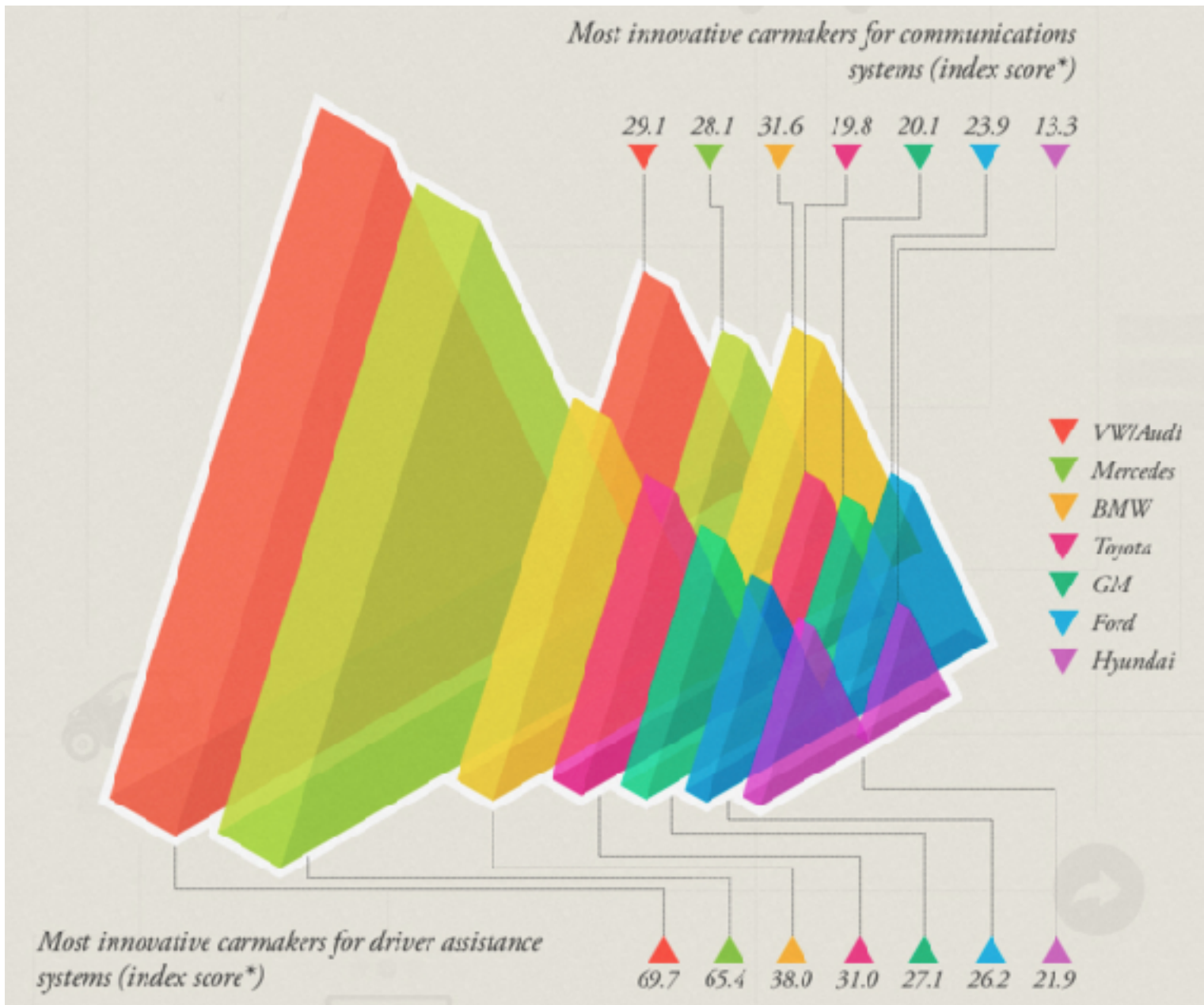
[@tamaramunzner](#)



Rules of Thumb

- Guidelines and considerations, not absolute rules
 - when to use 3D? when to use 2D?
 - when to use eyes instead of memory?
 - when does immersion help?
 - when to use overviews?
 - how long is too long?
 - which comes first, form or function?

Unjustified 3D all too common, in the news and elsewhere



<http://viz.wtf/post/137826497077/eye-popping-3d-triangles>

<http://viz.wtf/post/139002022202/designer-drugs-ht-ducqn>

Depth vs power of the plane

- high-ranked spatial position channels: **planar** spatial position
 - not depth!

→ Magnitude Channels: Ordered Attributes

Position on common scale



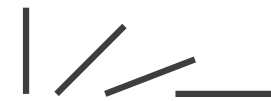
Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



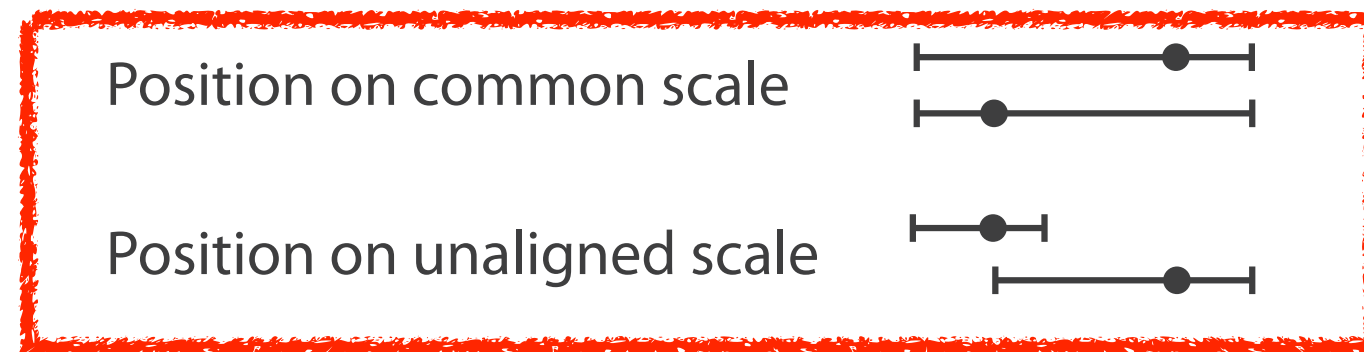
Depth (3D position)



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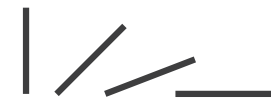
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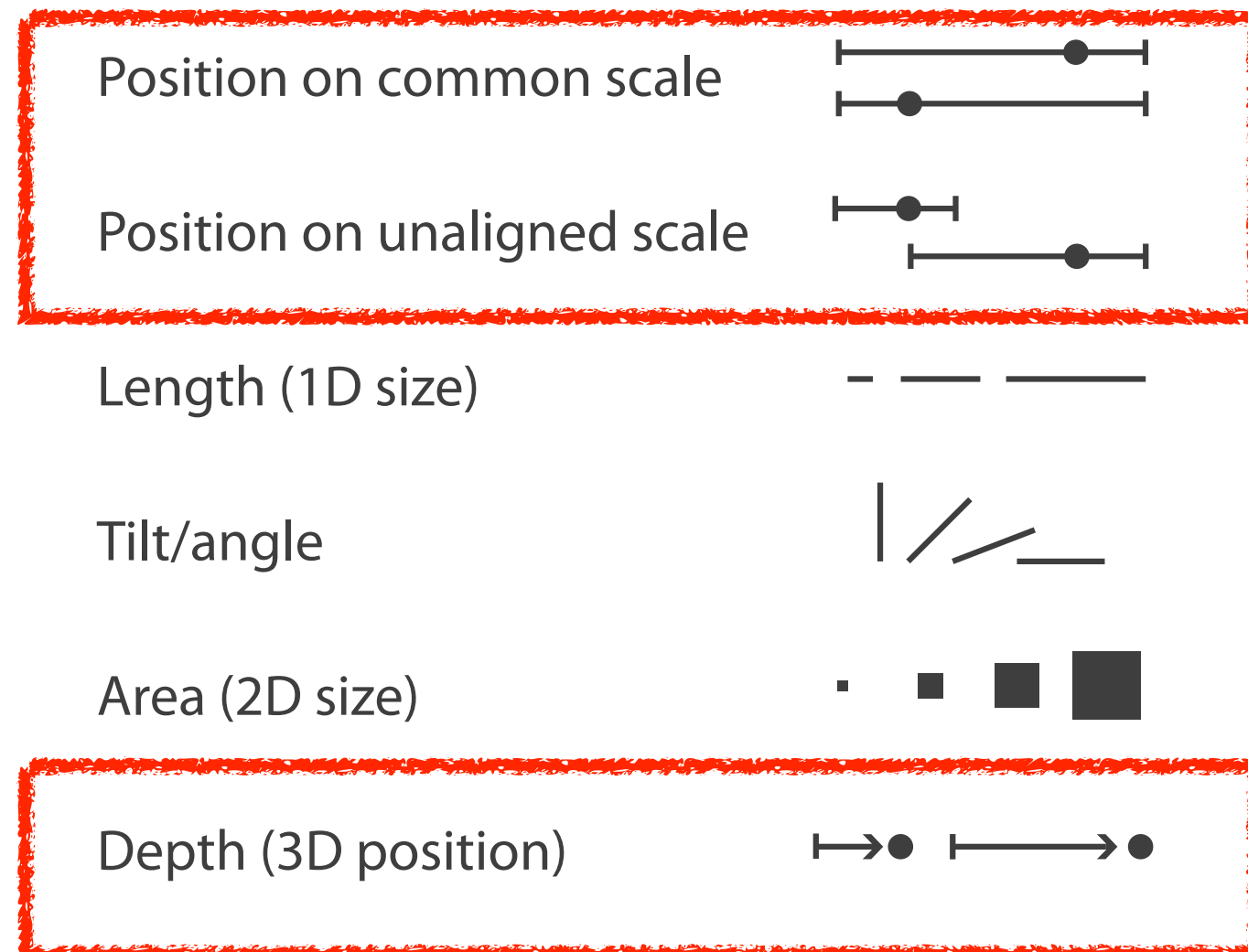
Depth (3D position)



Depth vs power of the plane

- high-ranked spatial position channels: **planar** spatial position
 - not depth!

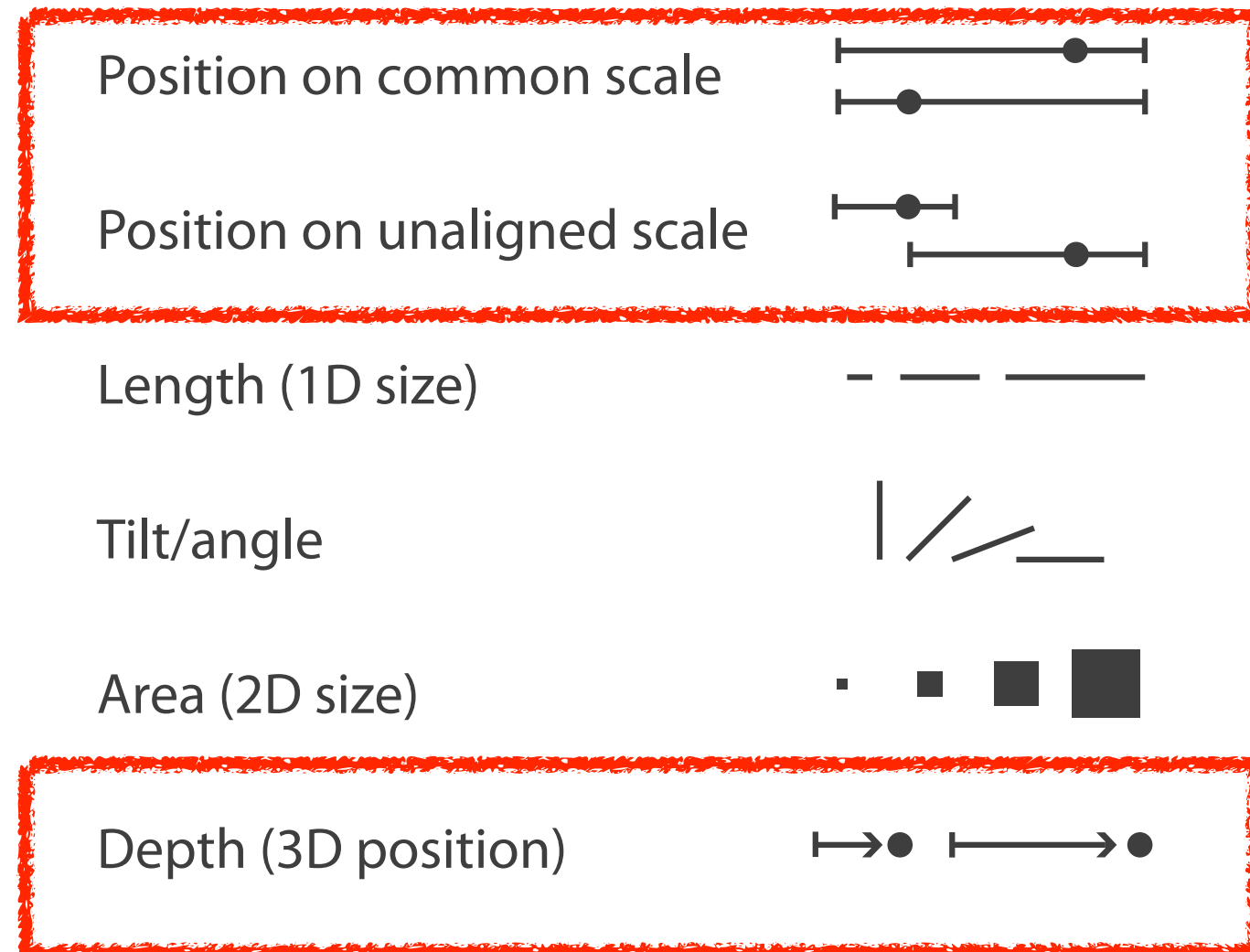
→ Magnitude Channels: Ordered Attributes



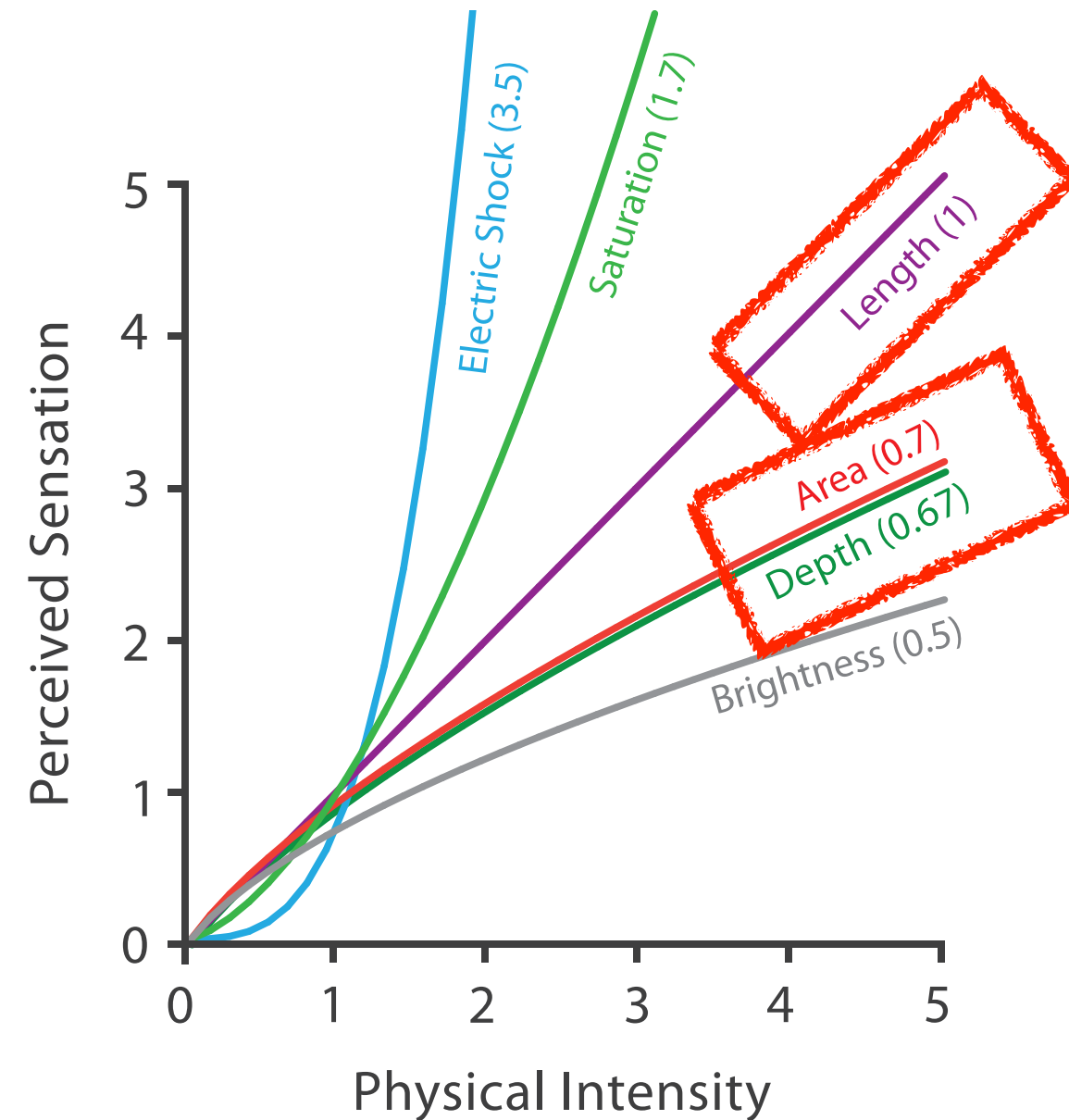
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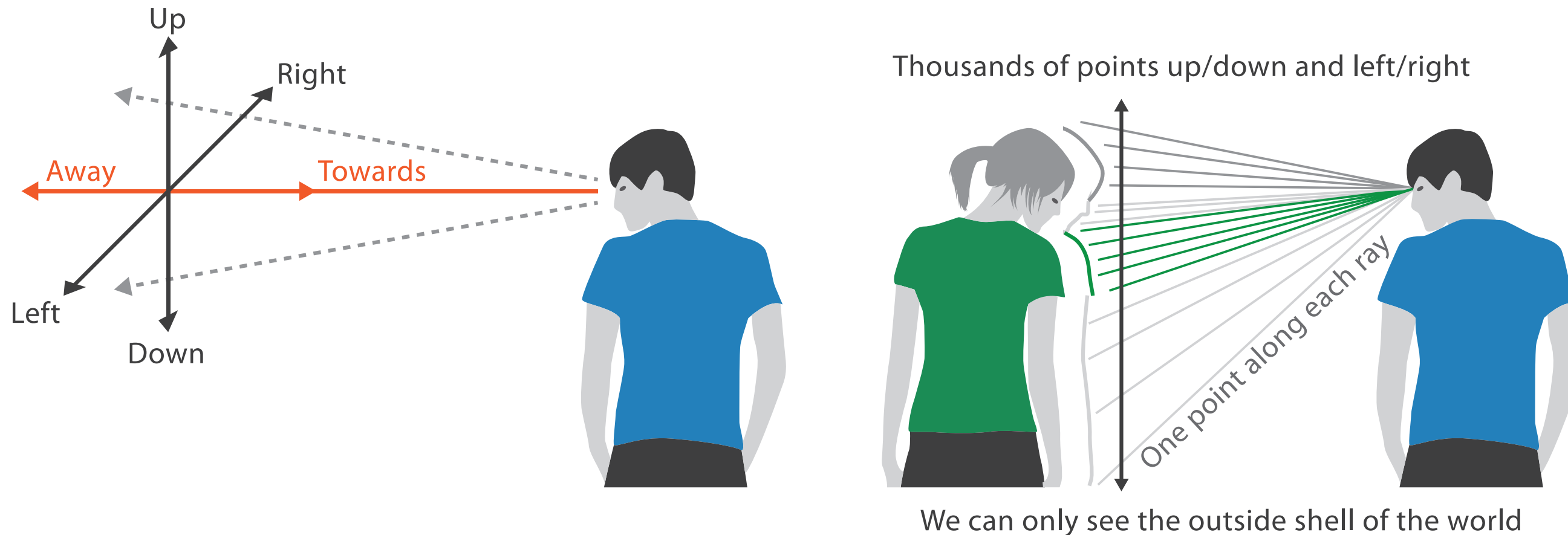


Steven's Psychophysical Power Law: $S = I^N$



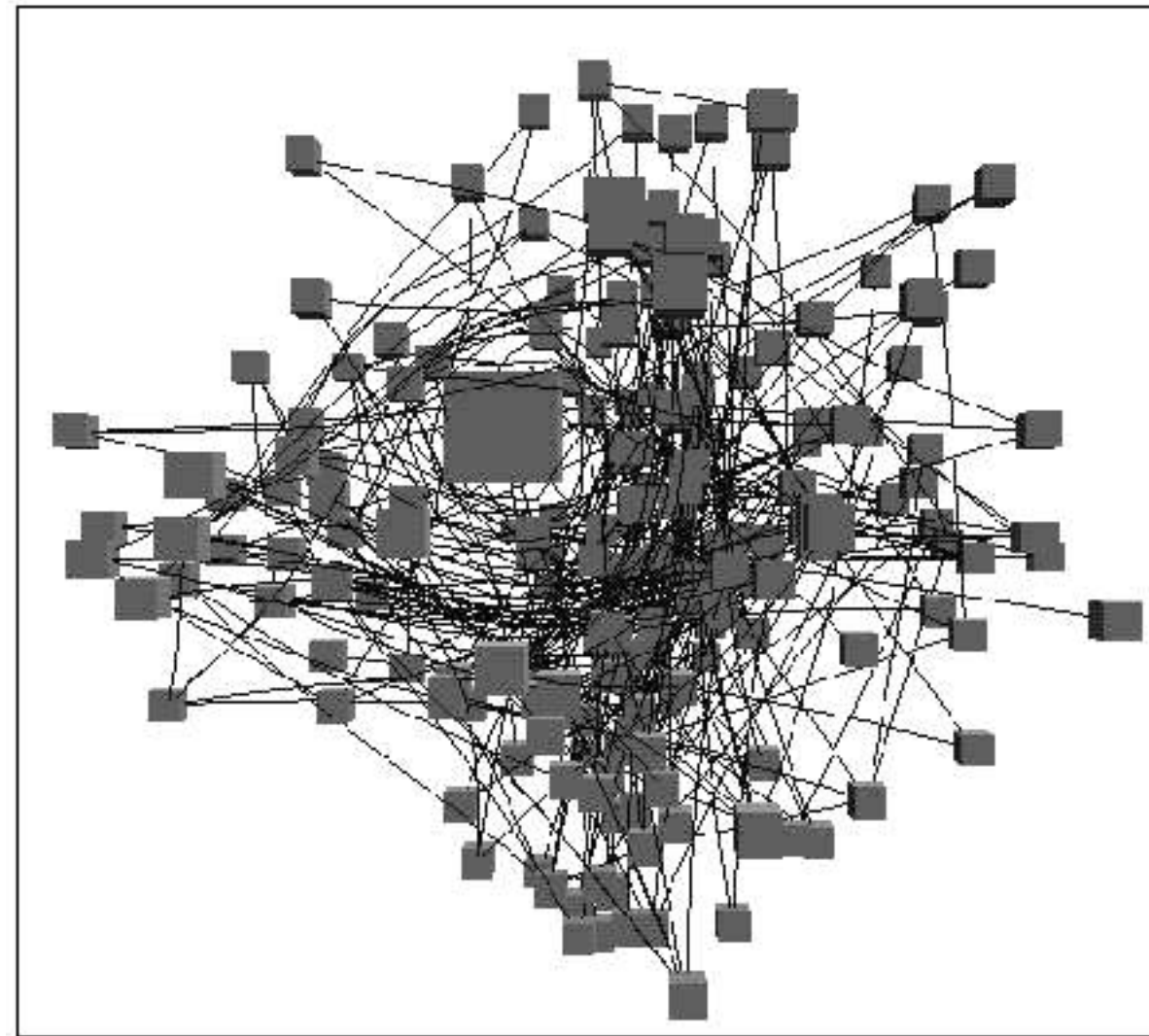
No unjustified 3D: Danger of depth

- we don't really live in 3D: we **see** in 2.05D
 - acquire more info on image plane quickly from eye movements
 - acquire more info for depth slower, from head/body motion



Occlusion hides information

- occlusion
- interaction can resolve, but at cost of time and cognitive load



[Distortion Viewing Techniques for 3D Data. Carpendale et al. InfoVis 1996.]

Perspective distortion loses information

- perspective distortion
 - interferes with all size channel encodings
 - power of the plane is lost!



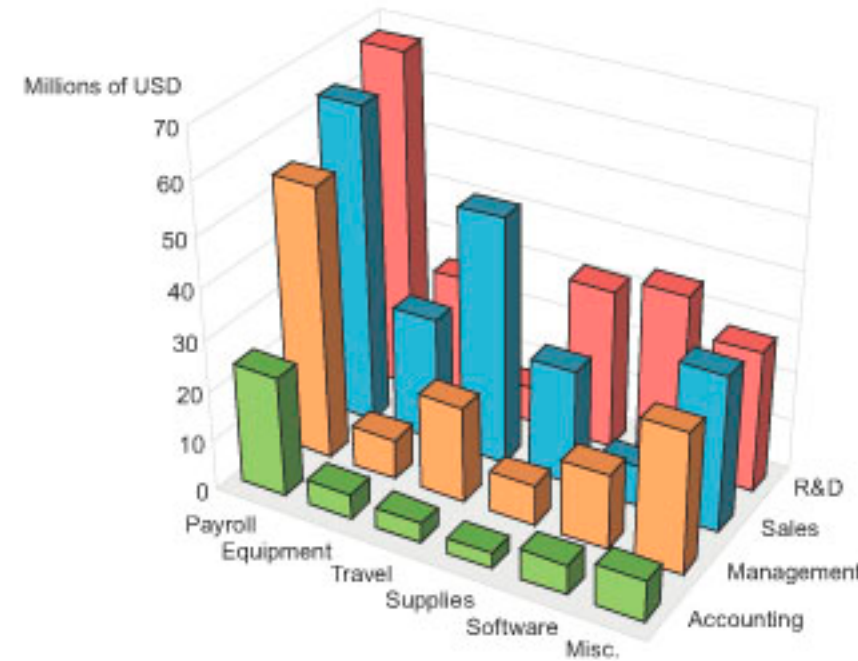
[Visualizing the Results of Multimedia Web Search Engines. Mukherjea, Hirata, and Hara. InfoVis 96]

3D vs 2D bar charts

- 3D bars:
 - very difficult to justify!
 - perspective distortion
 - occlusion
- faceting into 2D almost always better choice

Question 7: Which graph makes it easier to determine R&D's travel expense?

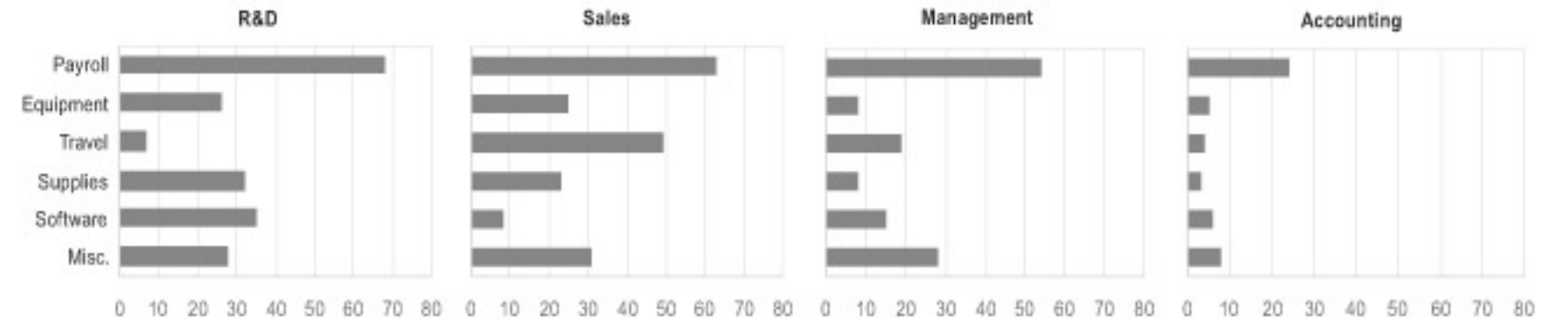
2006 Expenses by Department



3-D Bar Graph (left)

2-D Bar Graphs (below)

2006 Expenses by Department in Millions of USD

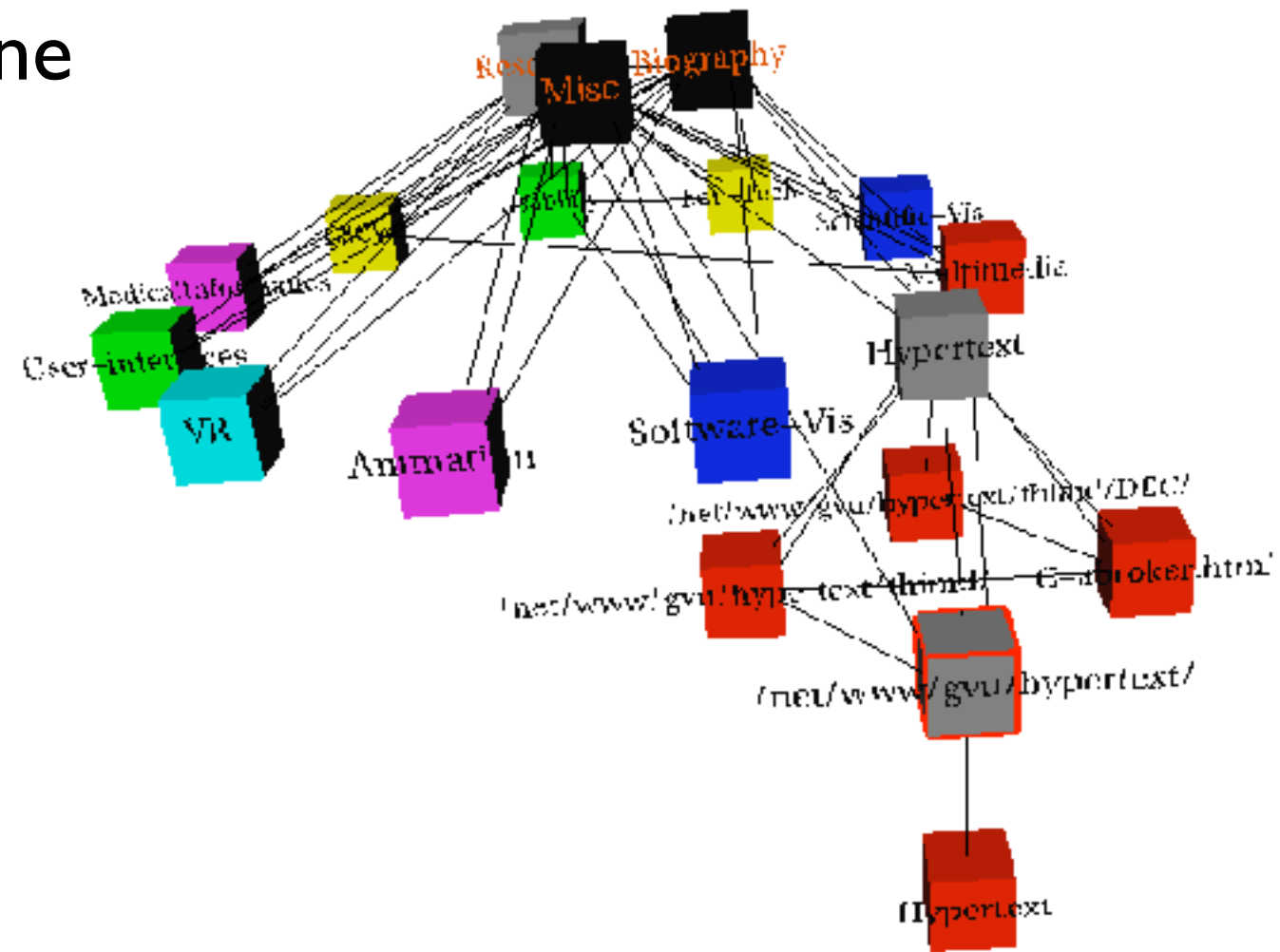


Tilted text isn't legible

- text legibility
 - far worse when tilted from image plane

- further reading

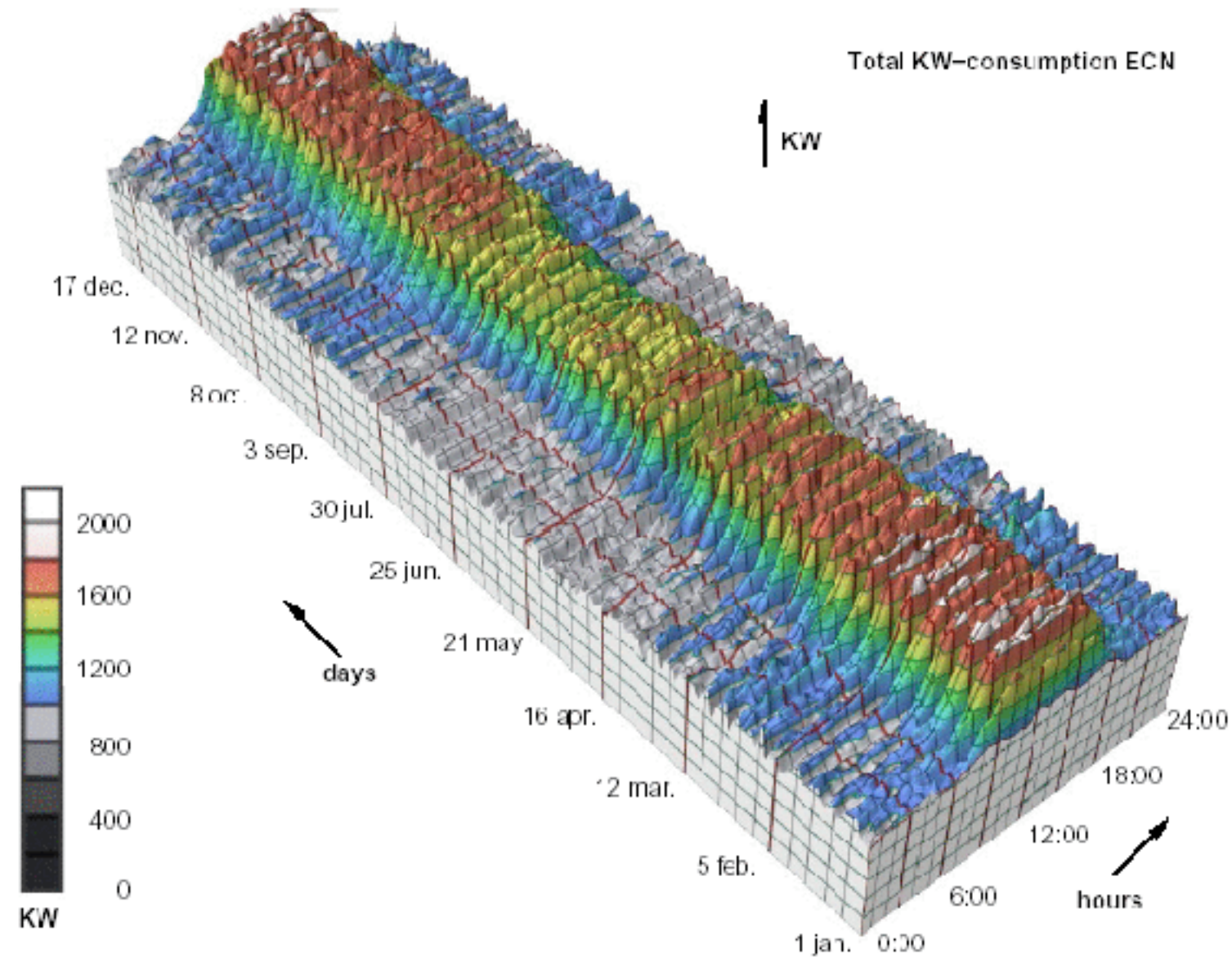
Exploring and Reducing the Effects of Orientation on Text Readability in Volumetric Displays.
Grossman et al. CHI 2007



[Visualizing the World-Wide Web with the Navigational View Builder. Mukherjea and Foley. Computer Networks and ISDN Systems, 1995.]

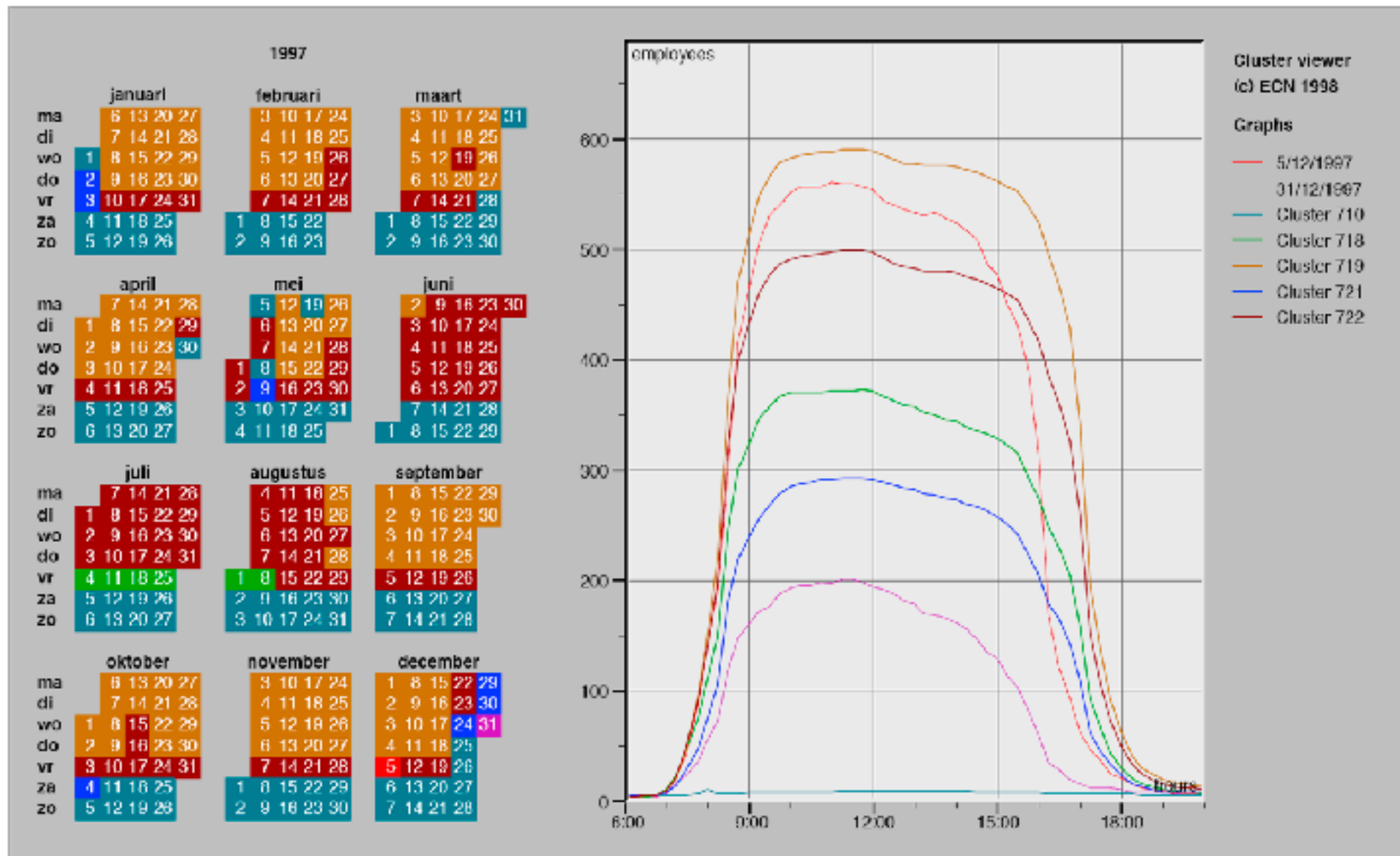
No unjustified 3D example: Time-series data

- extruded curves: detailed comparisons impossible



No unjustified 3D example: Transform for new data abstraction

- derived data: cluster hierarchy
- juxtapose multiple views: calendar, superimposed 2D curves



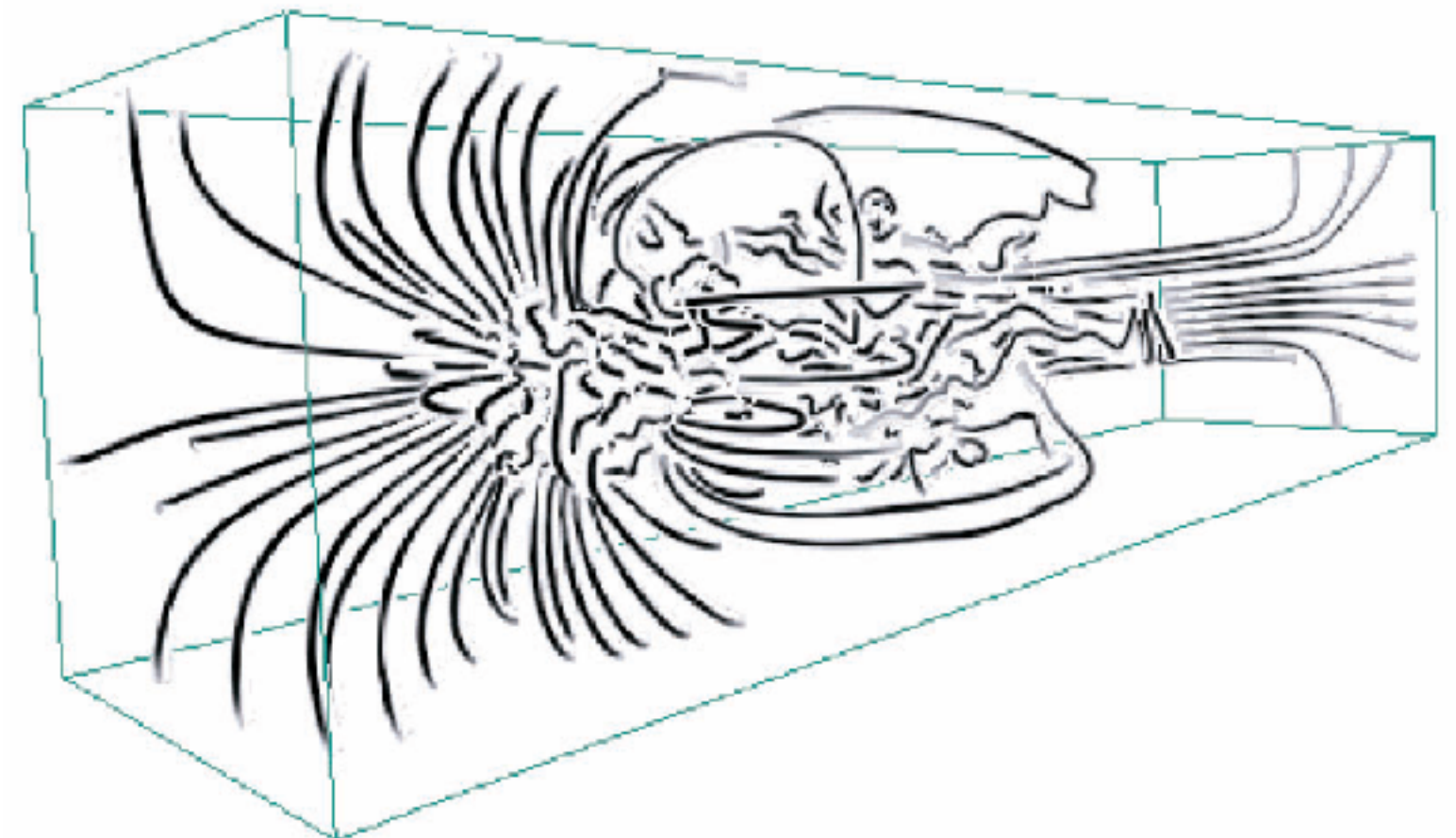
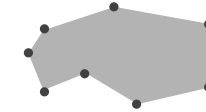
Justified 3D: shape perception

- benefits outweigh costs when task is shape perception for 3D spatial data
 - interactive navigation supports synthesis across many viewpoints

 Targets

 Spatial Data

→ Shape



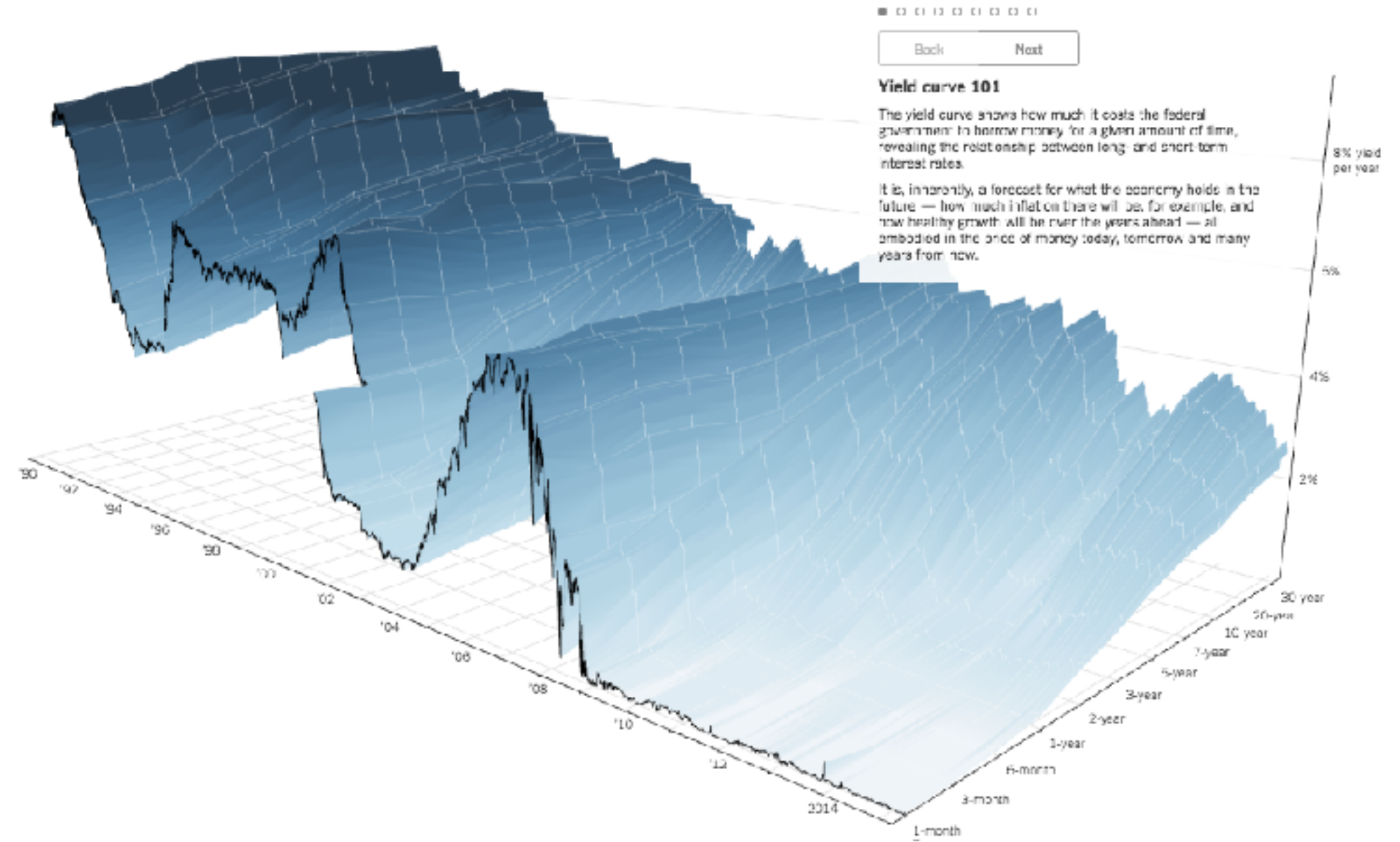
[Image-Based Streamline Generation and Rendering. Li and Shen.
IEEE Trans. Visualization and Computer Graphics (TVCG) 13:3 (2007), 630–640.]

Justified 3D: Economic growth curve

- constrained navigation steps through carefully designed viewpoints

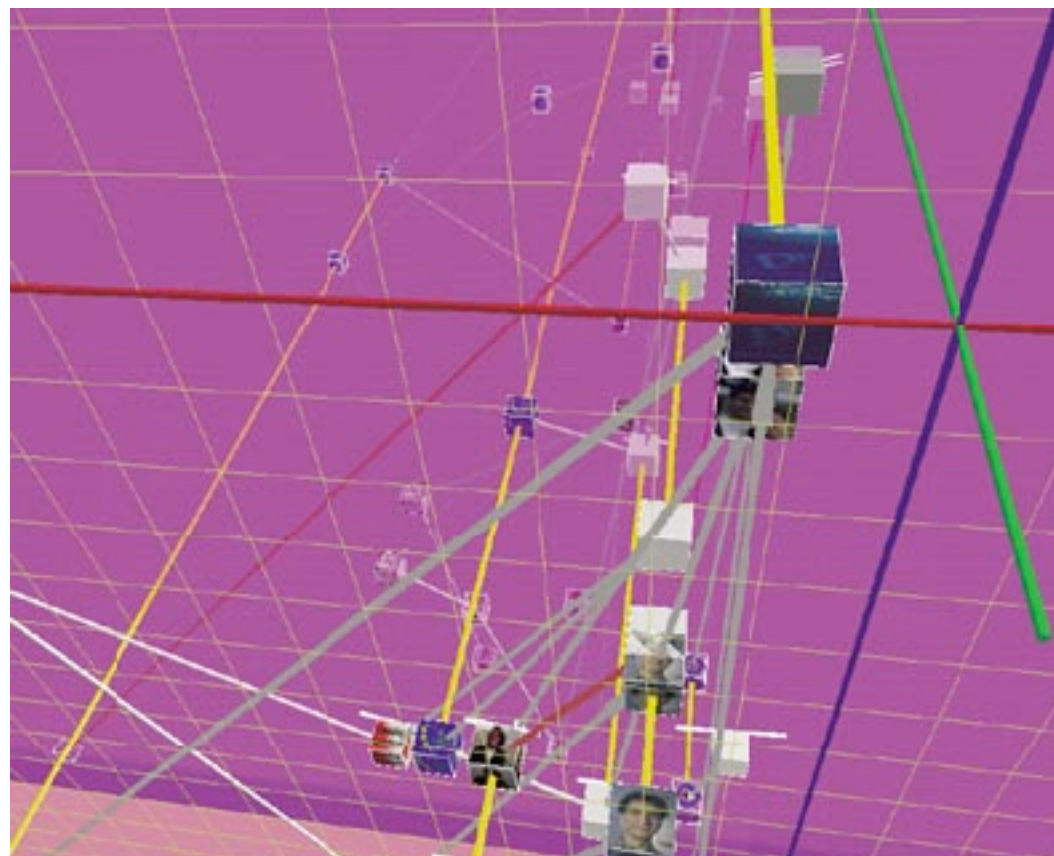
A 3-D View of a Chart That Predicts The Economic Future: The Yield Curve

By GREGOR RUSCH and AMANDA COX MARCH 18, 2015



No unjustified 3D

- 3D legitimate for true 3D spatial data
- 3D needs very careful justification for abstract data
 - enthusiasm in 1990s, but now skepticism
 - be especially careful with 3D for point clouds or networks



[WEBPATH-a three dimensional Web history. Frecon and Smith. Proc. InfoVis 1999]

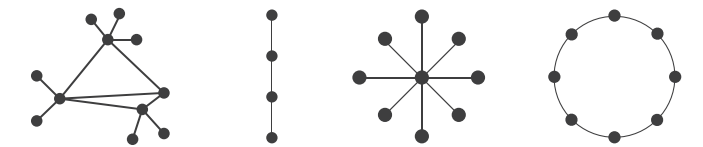
No unjustified 2D

- consider whether network data requires 2D spatial layout
 - especially if reading text is central to task!
 - arranging as network means lower information density and harder label lookup compared to text lists
- benefits outweigh costs when topological structure/context important for task
 - be especially careful for search results, document collections, ontologies



→ Network Data

→ Topology



→ Paths



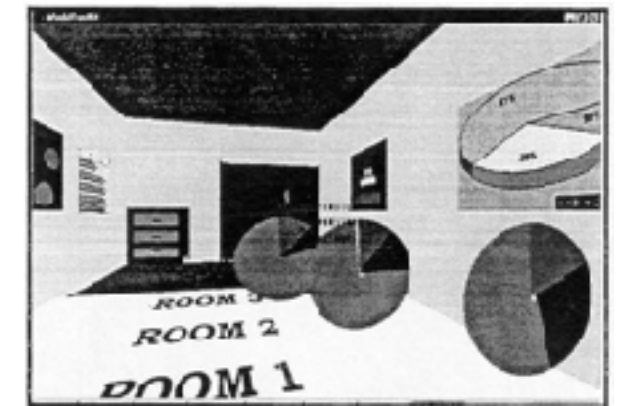
Eyes beat memory

- principle: external cognition vs. internal memory
 - easy to compare by moving eyes between side-by-side views
 - harder to compare visible item to memory of what you saw
- implications for animation
 - great for choreographed storytelling
 - great for transitions between two states
 - poor for many states with changes everywhere
 - consider small multiples instead

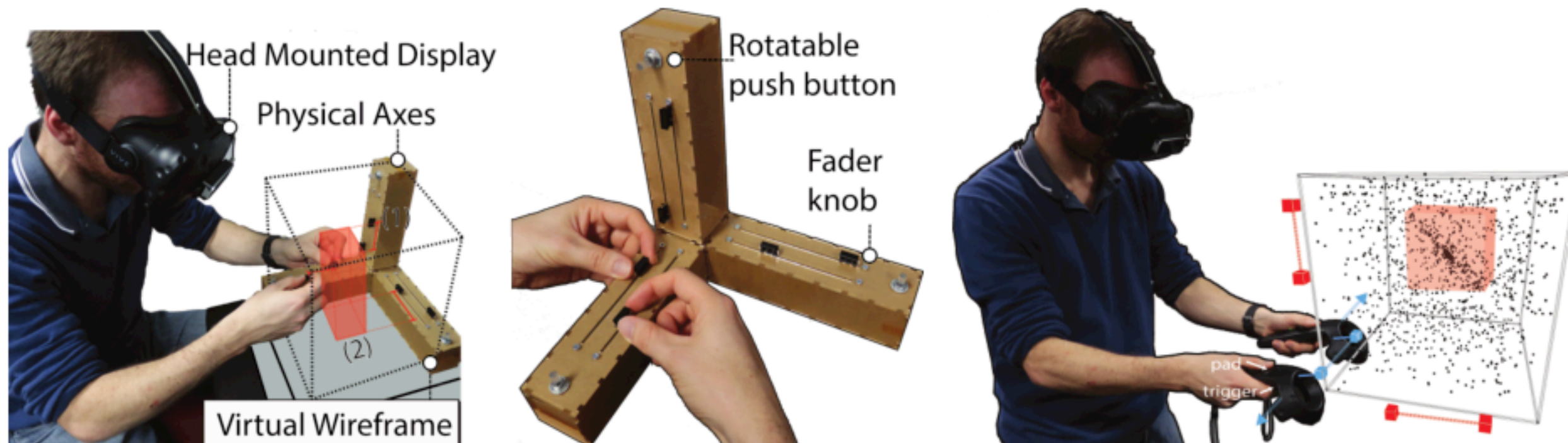


Resolution beats immersion

- immersion typically not helpful for abstract data
 - do not need sense of presence or stereoscopic 3D
 - desktop also better for workflow integration
- resolution much more important: pixels are the scarcest resource
- first wave: virtual reality for abstract data difficult to justify
- second wave: AR/MR (augmented/mixed reality) has more promise



[Development of an information visualization tool using virtual reality. Kirner and Martins. Proc. Symp. Applied Computing 2000]



[A Design Space for Spatio-Data Coordination: Tangible Interaction Devices for Immersive Information Visualisation. Cordeil, Bach, Li, Elliott, and Dwyer. Proc. PacificVis 2017 Notes.]

Overview first, zoom and filter, details on demand

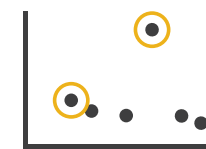
- influential mantra from Shneiderman

[The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. Shneiderman. Proc. IEEE Visual Languages, pp. 336–343, 1996.]

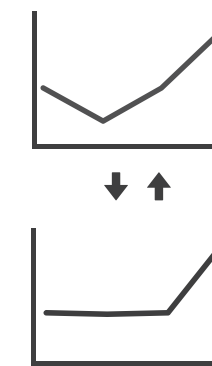
- **overview = summary**
 - microcosm of full vis design problem

→ Query

→ Identify



→ Compare



→ Summarise



Rule of thumb: **Responsiveness is required**

- *visual feedback: three rough categories*

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 - show progress bar for long operations (process in background thread)

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 - bounded response after dialog box - mental model of heavyweight operation (file load)
- **scalability considerations**
 - highlight selection without complete redraw of view (graphics frontbuffer)
 - show hourglass for multi-second operations (check for cancel/undo)
 - show progress bar for long operations (process in background thread)
 - rendering speed when item count is large (guaranteed frame rate)

Function first, form next

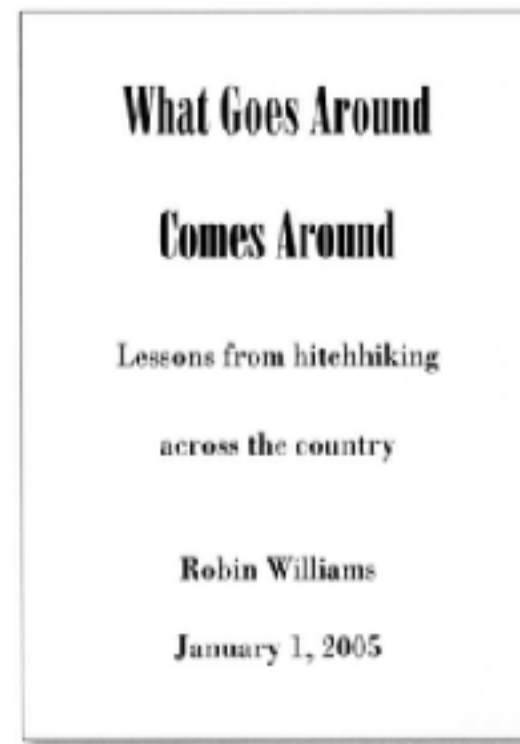
- dangerous to start with aesthetics
 - usually impossible to add function retroactively

Function first, form next

- dangerous to start with aesthetics
 - usually impossible to add function retroactively
- start with focus on functionality
 - possible to improve aesthetics later on, as refinement
 - if no expertise in-house, find good graphic designer to work with
 - aesthetics do matter! another level of function
 - visual hierarchy, alignment, flow
 - Gestalt principles in action

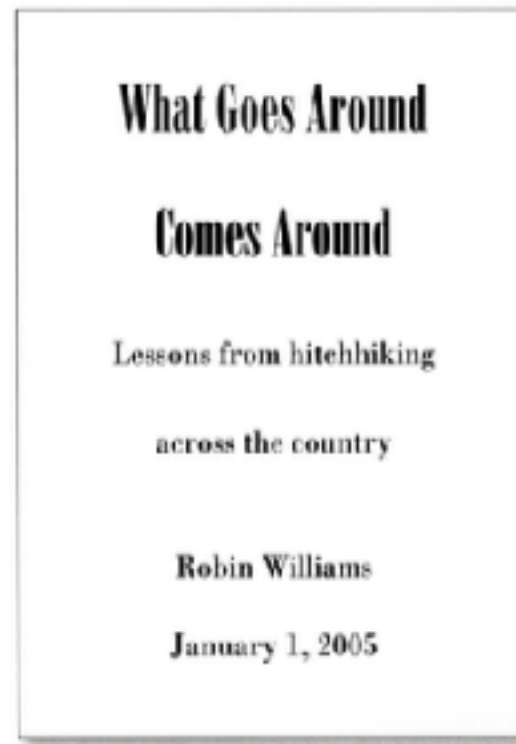
Form: Basic graphic design ideas

Form: Basic graphic design ideas



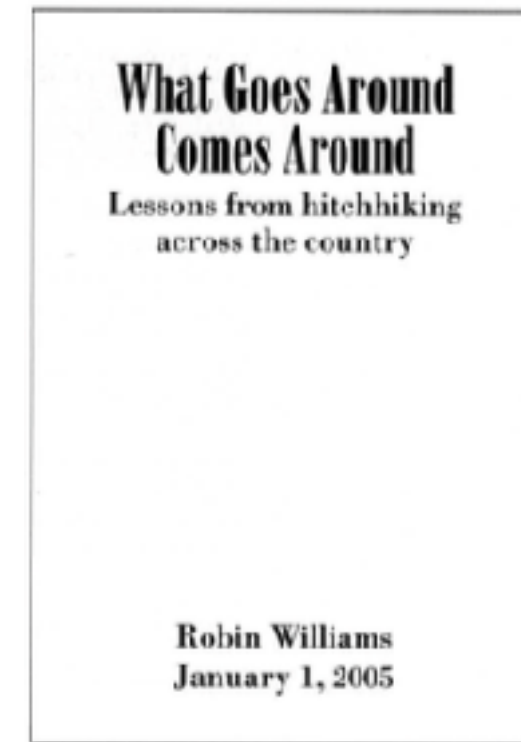
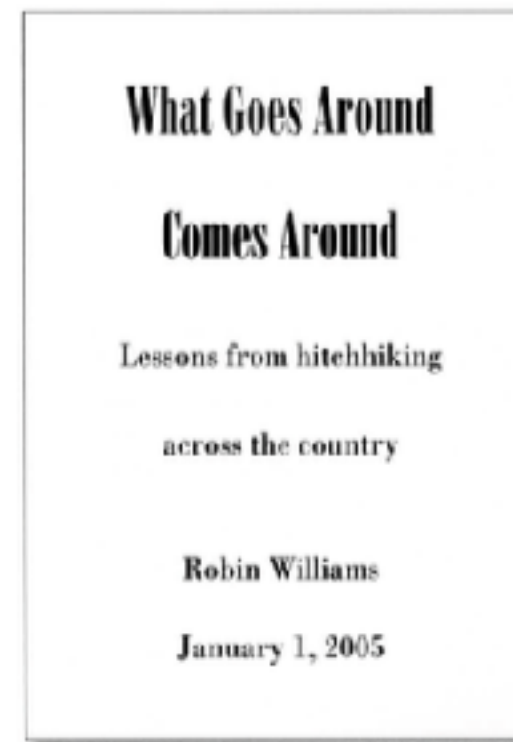
Form: Basic graphic design ideas

- proximity
 - do group related items together
 - avoid equal whitespace between unrelated



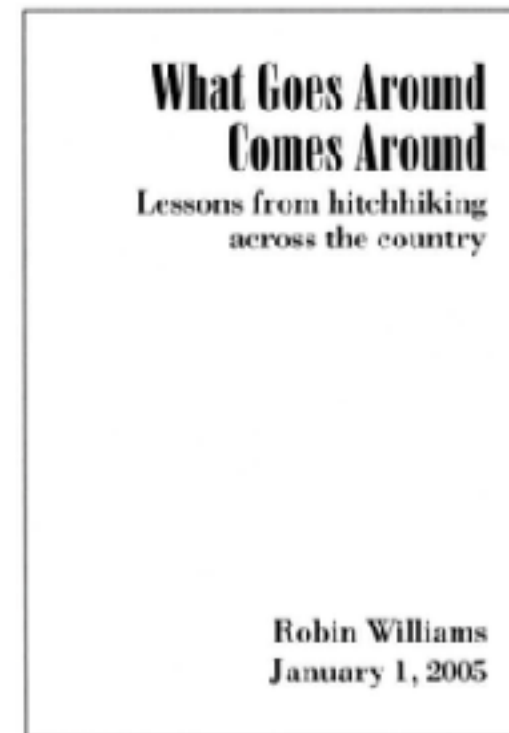
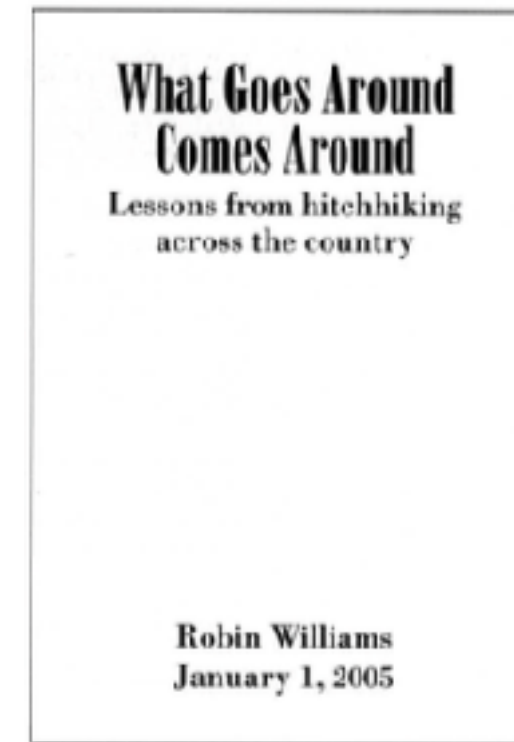
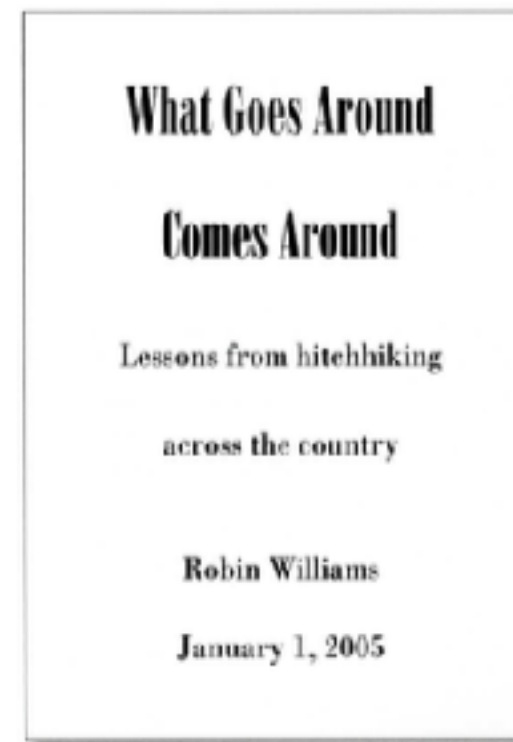
Form: Basic graphic design ideas

- proximity
 - do group related items together
 - avoid equal whitespace between unrelated
- alignment
 - do find/make strong line, stick to it
 - avoid automatic centering



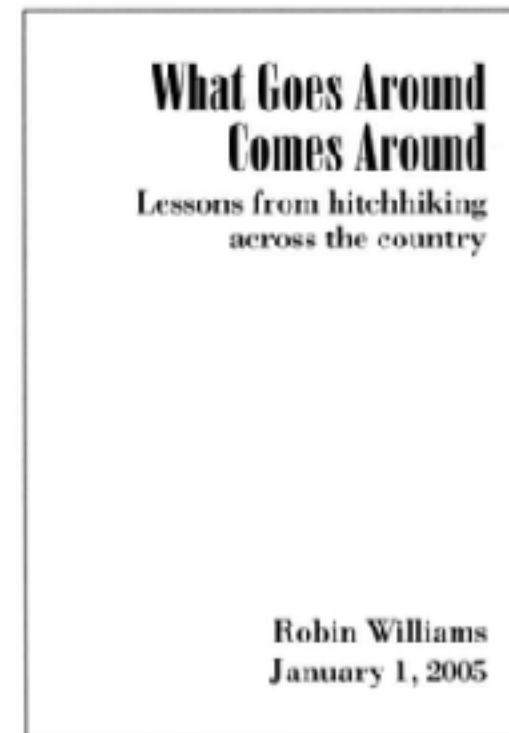
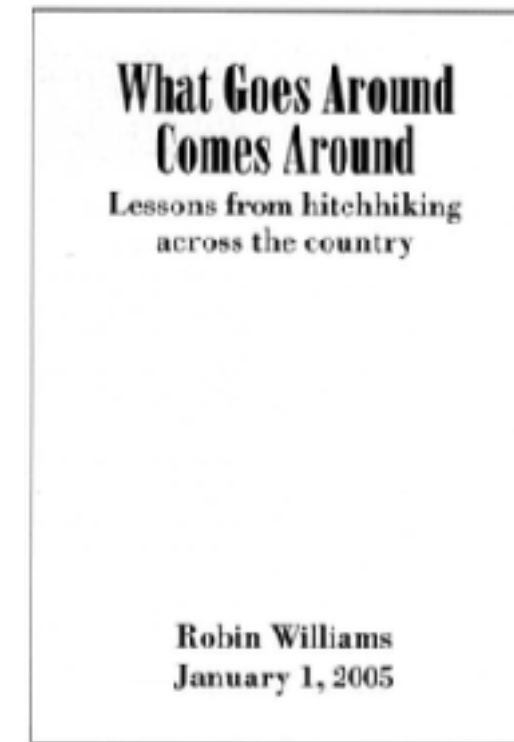
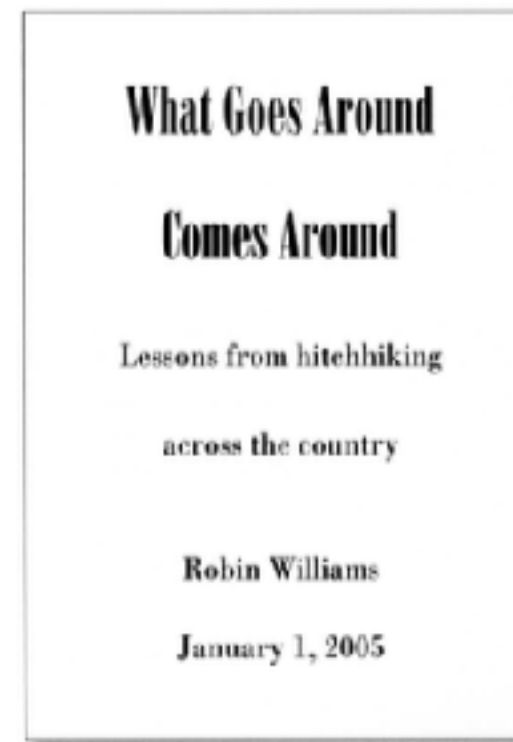
Form: Basic graphic design ideas

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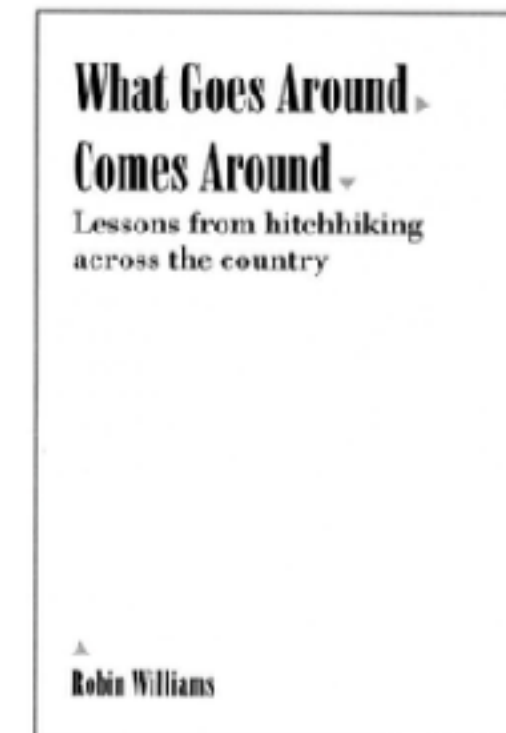
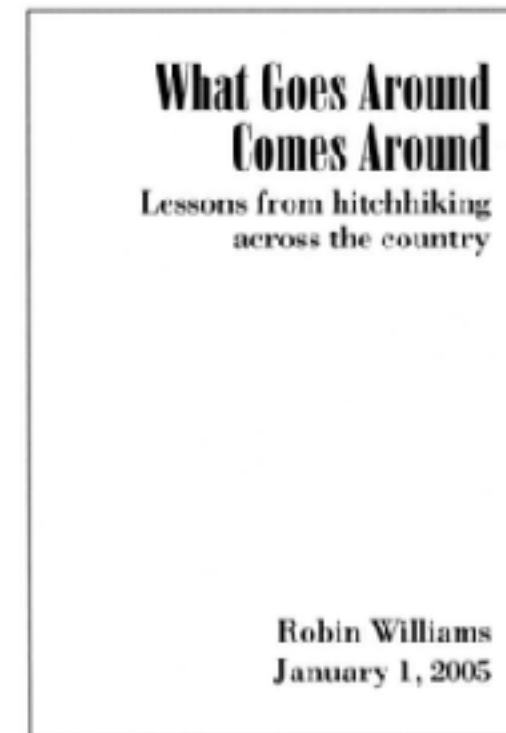
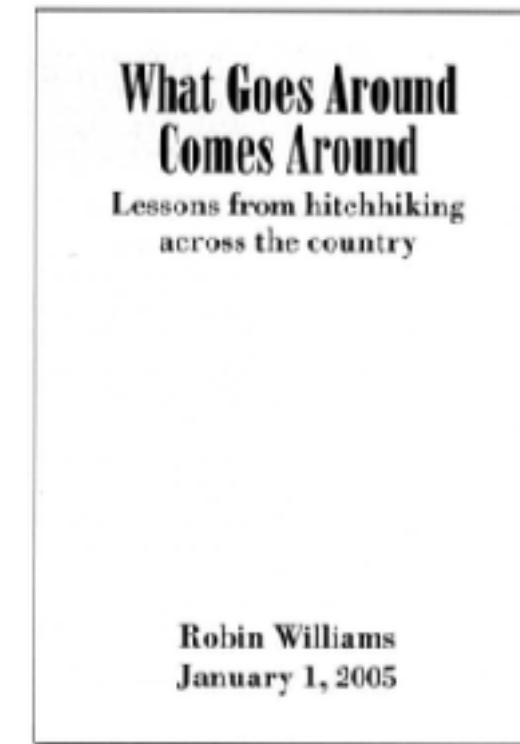
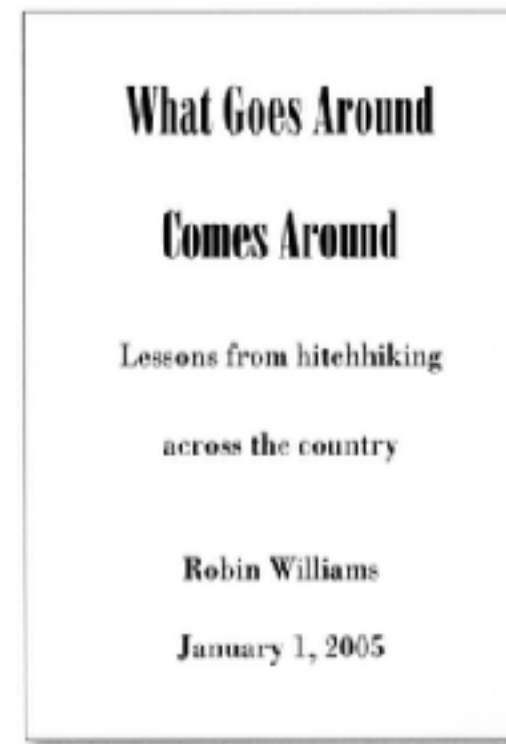
Form: Basic graphic design ideas

- proximity
 - do group related items together
 - avoid equal whitespace between unrelated
- alignment
 - do find/make strong line, stick to it
 - avoid automatic centering
- repetition
 - do unify by pushing existing consistencies



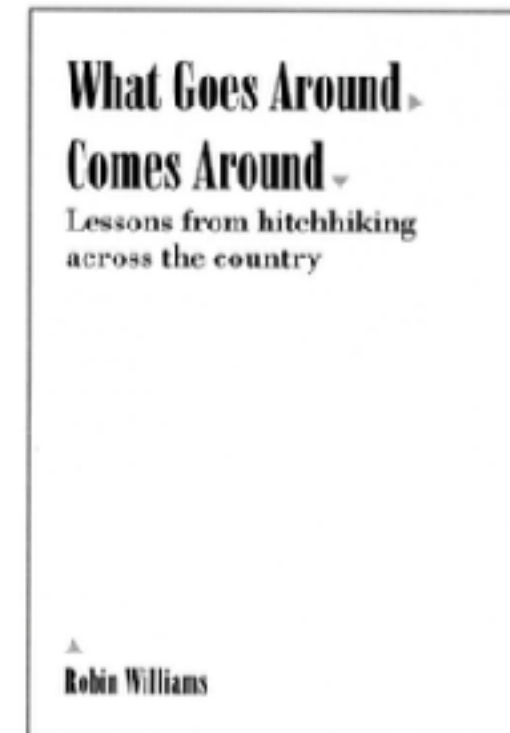
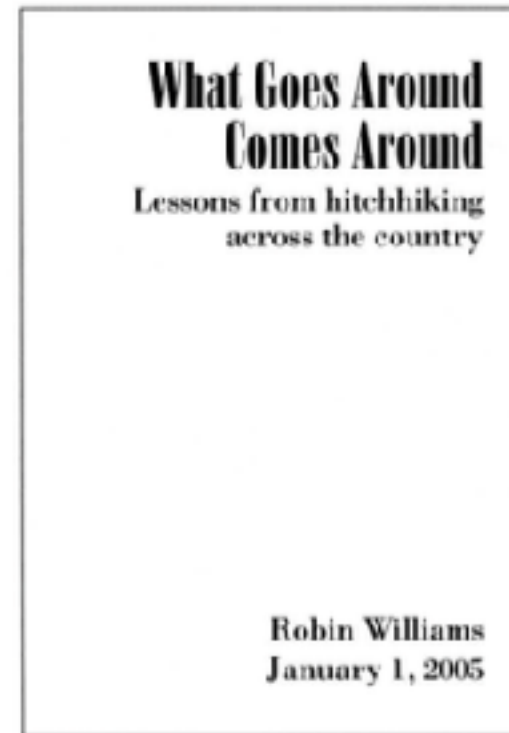
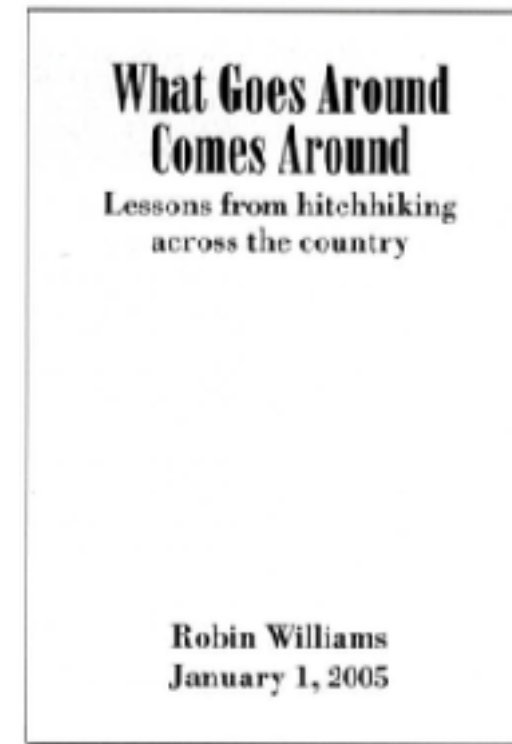
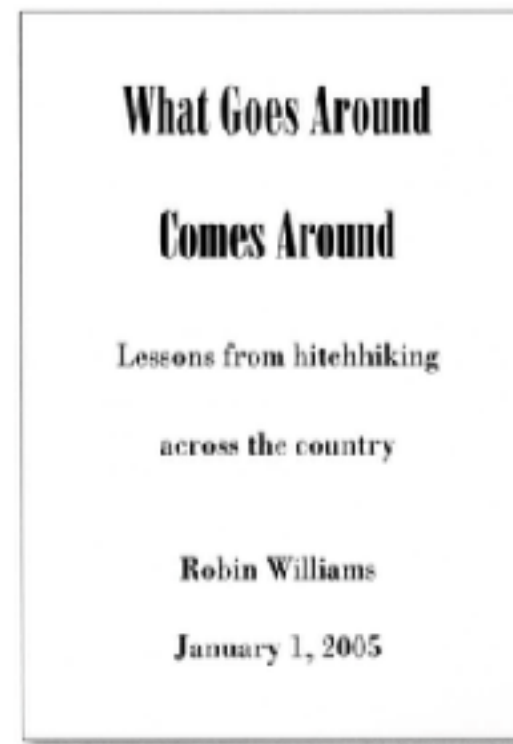
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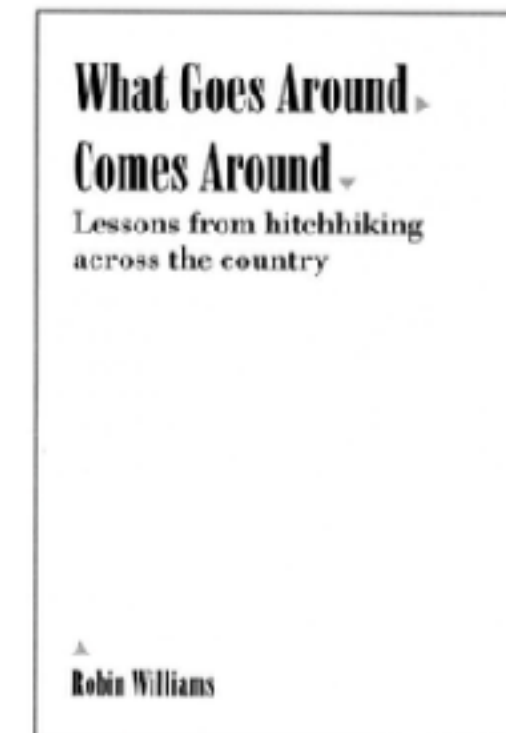
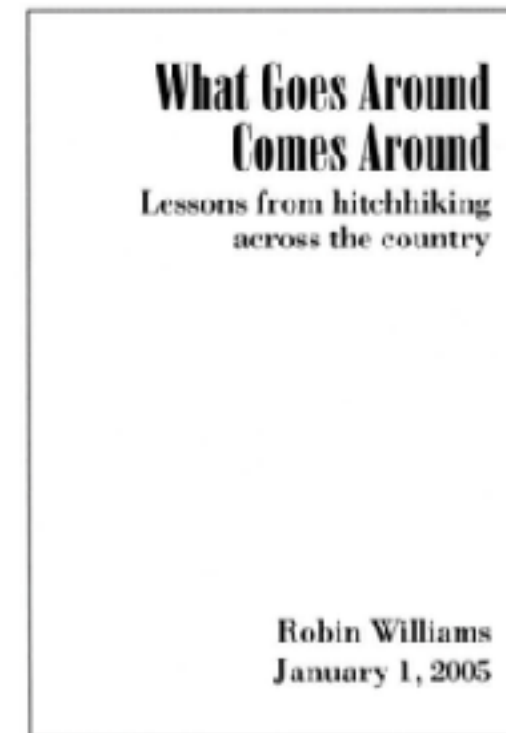
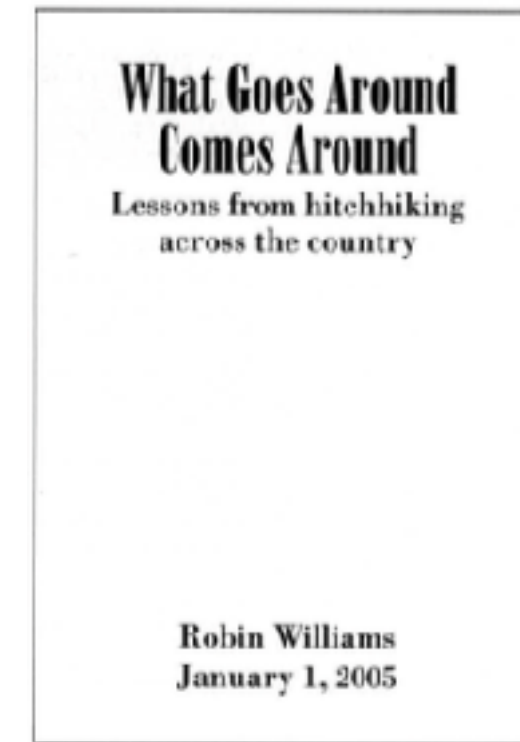
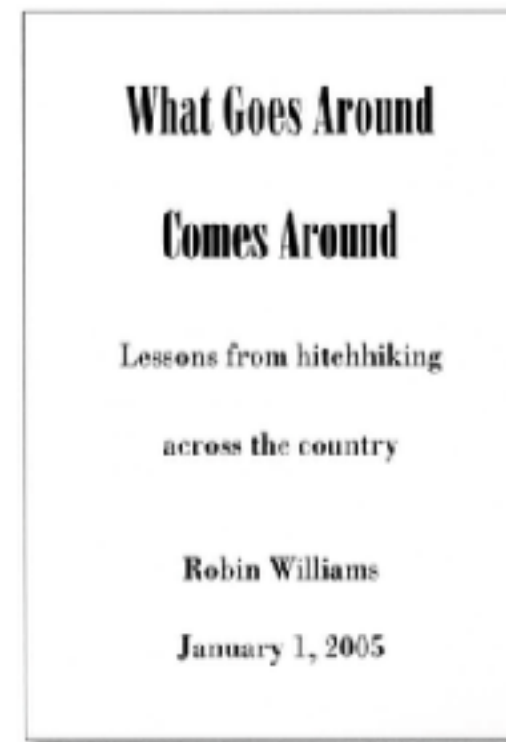
Form: Basic graphic design ideas

- proximity
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 - avoid equal whitespace between unrelated
- alignment
 - do find/make strong line, stick to it
 - avoid automatic centering
- repetition
 - do unify by pushing existing consistencies
- contrast
 - if not identical, then very different
 - avoid not quite the same



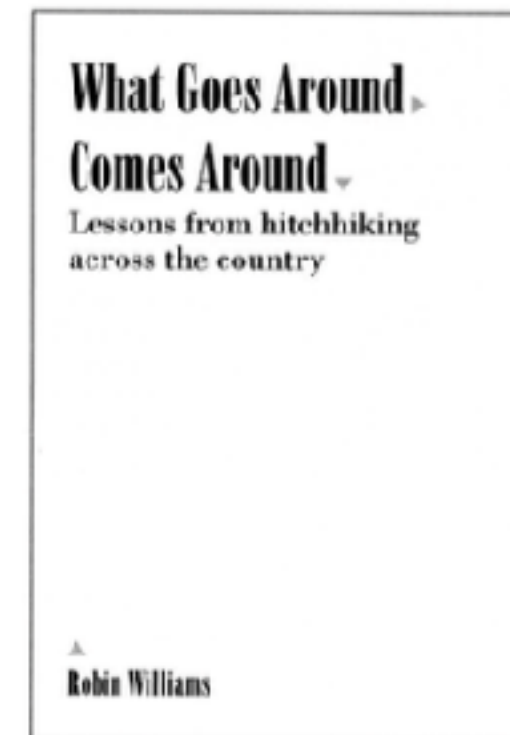
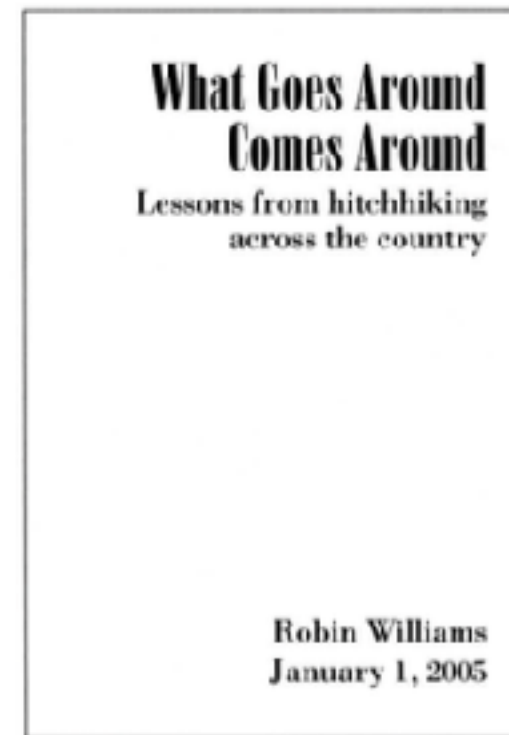
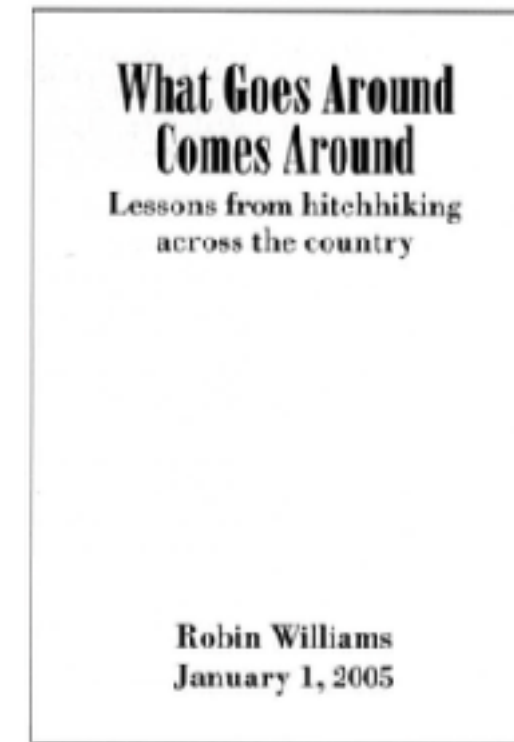
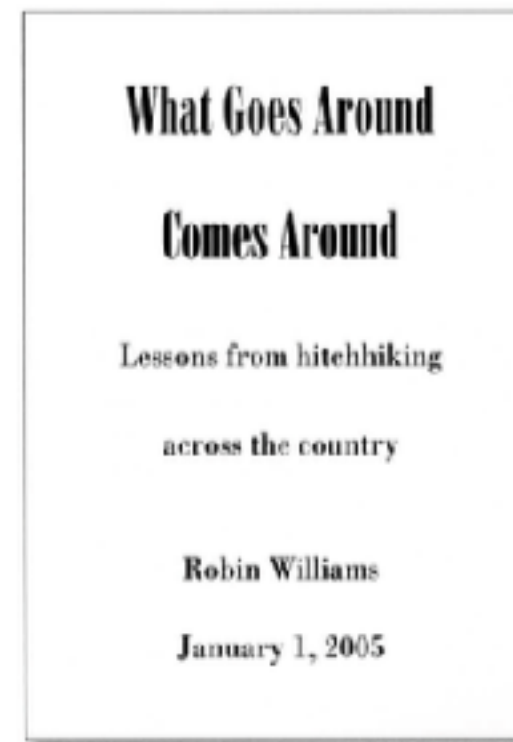
Form: Basic graphic design ideas

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Form: Basic graphic design ideas

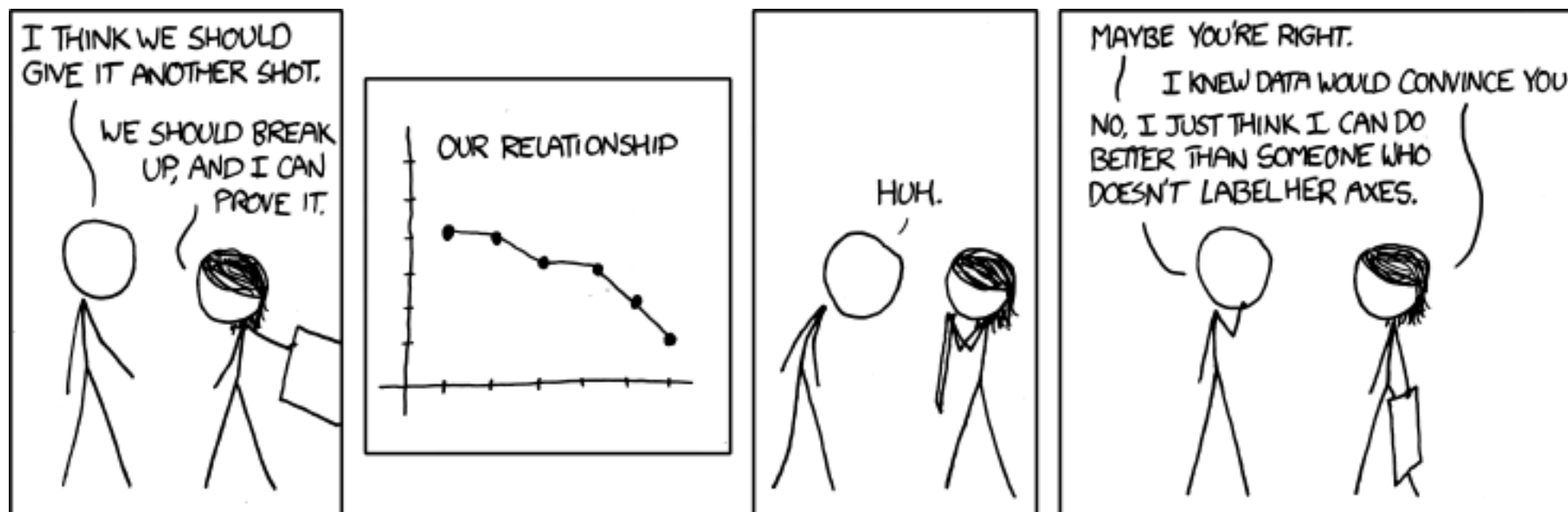
- proximity
 - do group related items together
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 - do find/make strong line, stick to it
 - avoid automatic centering
- repetition
 - do unify by pushing existing consistencies
- contrast
 - if not identical, then very different
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- *The Non-Designer's Design Book, 4th ed. Robin Williams, Peachpit Press, 2015.*
 - fast read, very practical to work through whole thing

Best practices: Labelling

- make visualizations as self-documenting as possible
 - meaningful & useful title, labels, legends
 - axes and panes/subwindows should have labels
 - and axes should have good mix/max boundary tick marks
 - everything that's plotted should have a legend
 - and own header/labels if not redundant with main title
 - use reasonable numerical format
 - avoid scientific notation in most cases



Rules of Thumb Summary

- **No unjustified 3D**
 - Power of the plane
 - Disparity of depth
 - Occlusion hides information
 - Perspective distortion dangers
 - Tilted text isn't legible
- **No unjustified 2D**
- **Eyes beat memory**
- **Resolution over immersion**
- **Overview first, zoom and filter, details on demand**
- **Responsiveness is required**
- **Function first, form next**

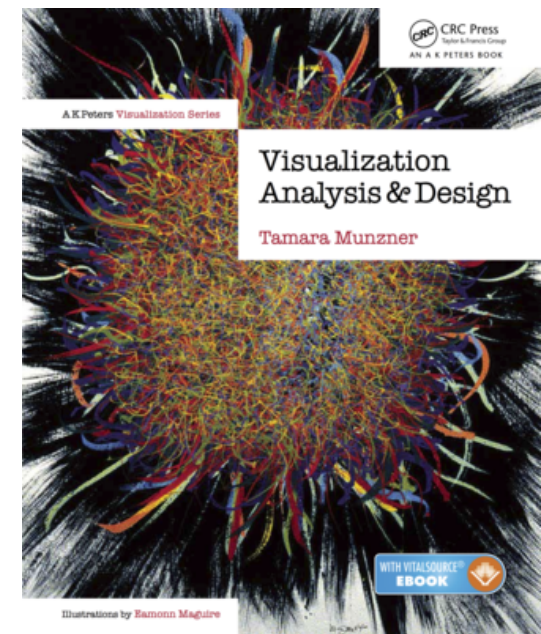
Visualization Analysis & Design

Arrange Tables (Ch 7) I

Tamara Munzner

Department of Computer Science
University of British Columbia

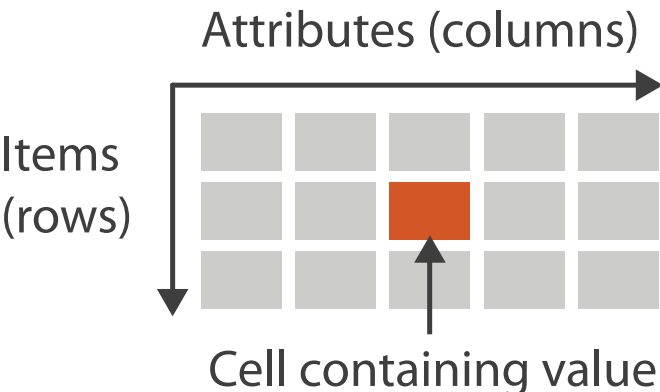
[@tamaramunzner](#)



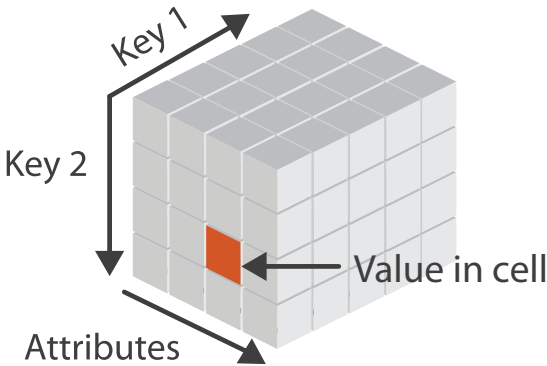
Focus on Tables

→ Dataset Types

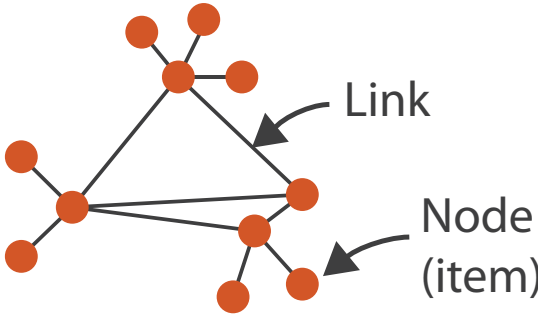
→ Tables



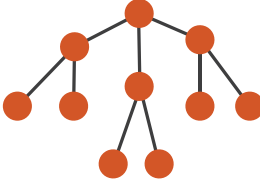
→ Multidimensional Table



→ Networks

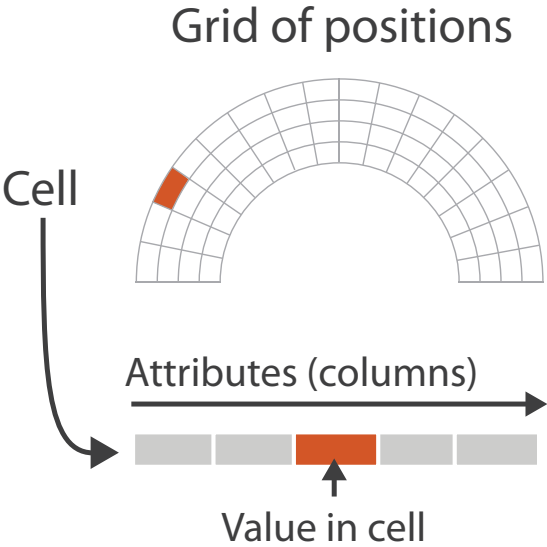


→ Trees



→ Spatial

→ Fields (Continuous)



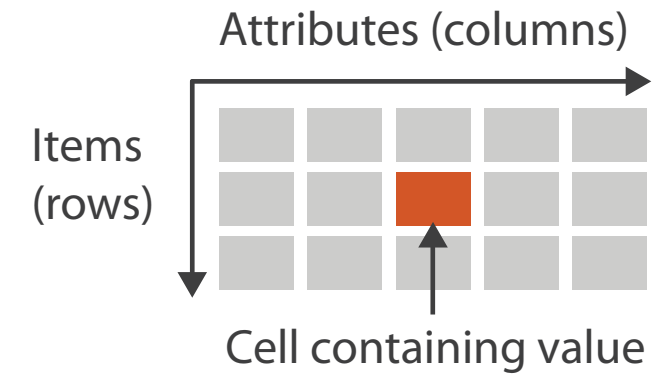
→ Geometry (Spatial)



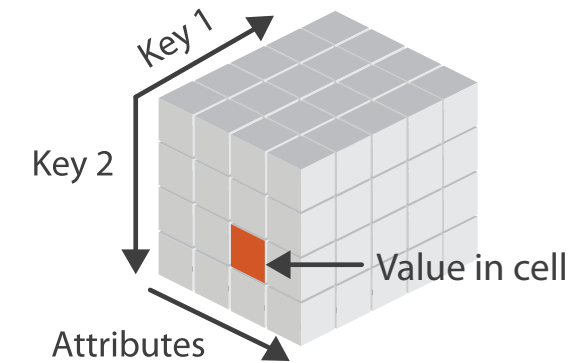
Keys and values

- **key**
 - independent attribute
 - used as unique index to look up items
 - simple tables: 1 key
 - multidimensional tables: multiple keys
- **value**
 - dependent attribute, value of cell

→ Tables



→ *Multidimensional Table*



Keys and values

- **key**
 - independent attribute
 - used as unique index to look up items
 - simple tables: 1 key
 - multidimensional tables: multiple keys
- **value**
 - dependent attribute, value of cell
- **classify arrangements by keys used**
 - 0, 1, 2, ...

→ 0 Keys

⊕ Express Values



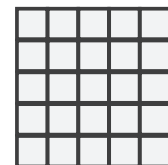
→ 1 Key

List

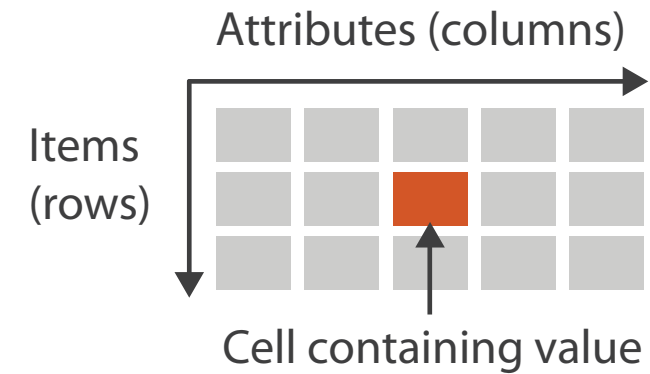


→ 2 Keys

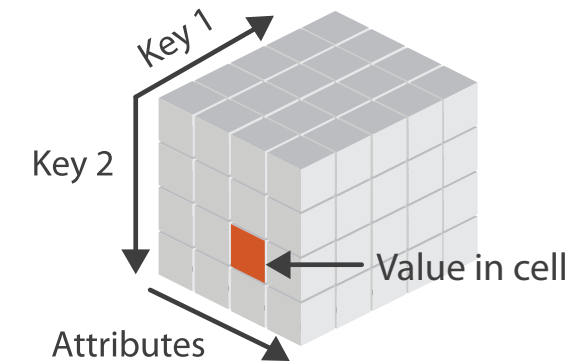
Matrix



→ Tables



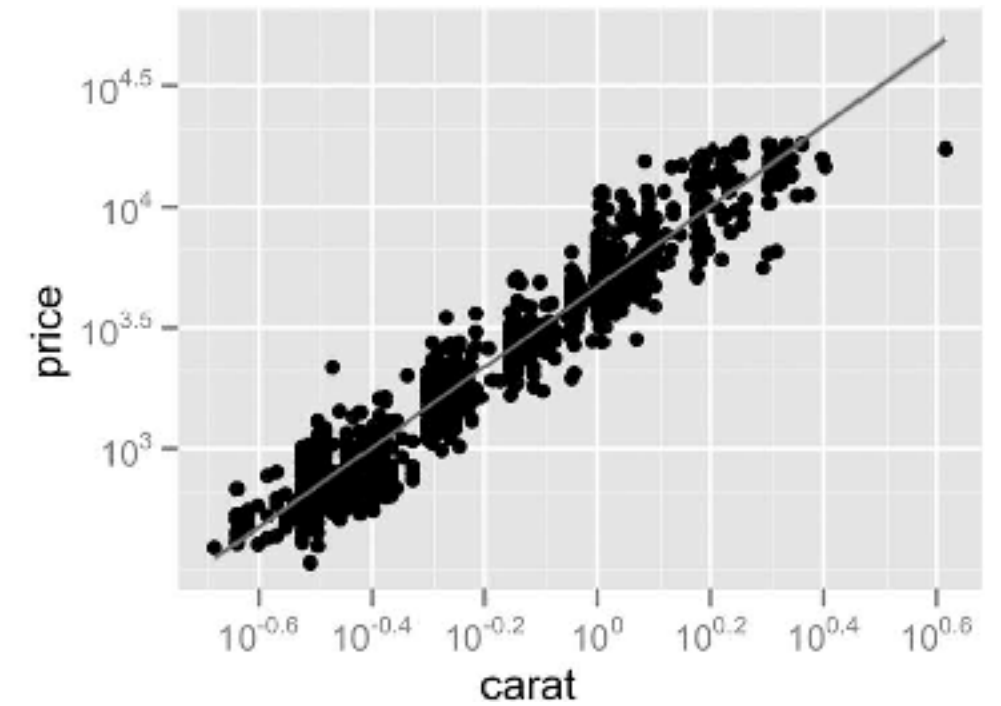
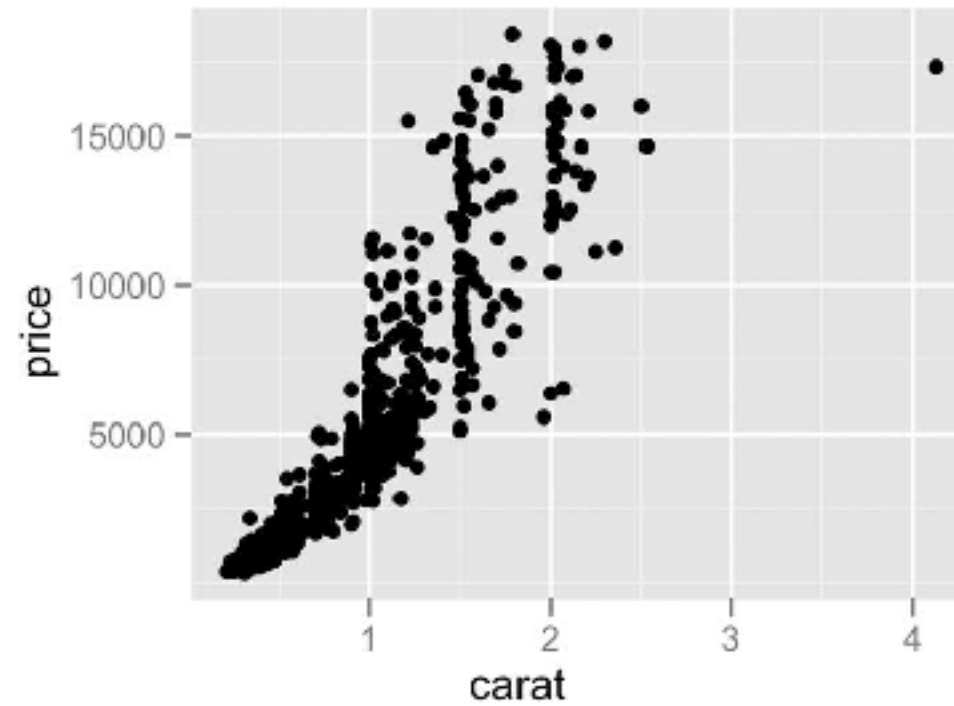
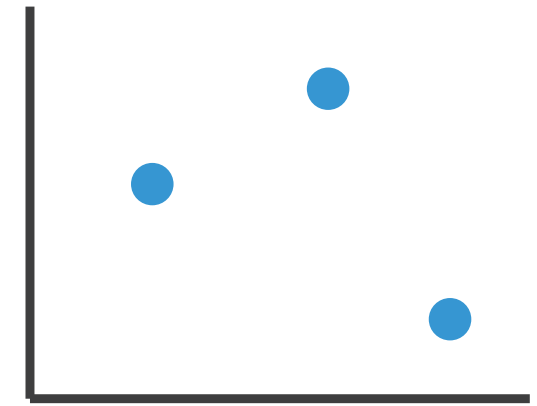
→ *Multidimensional Table*



Idiom: scatterplot

- **express** values (magnitudes)
 - quantitative attributes
- no keys, only values

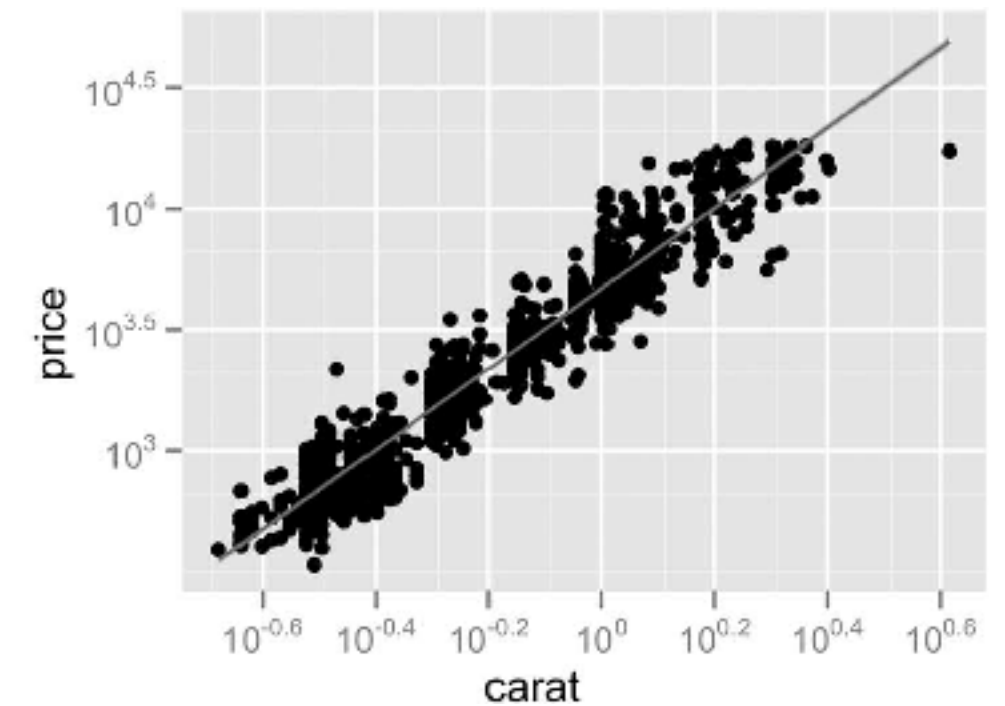
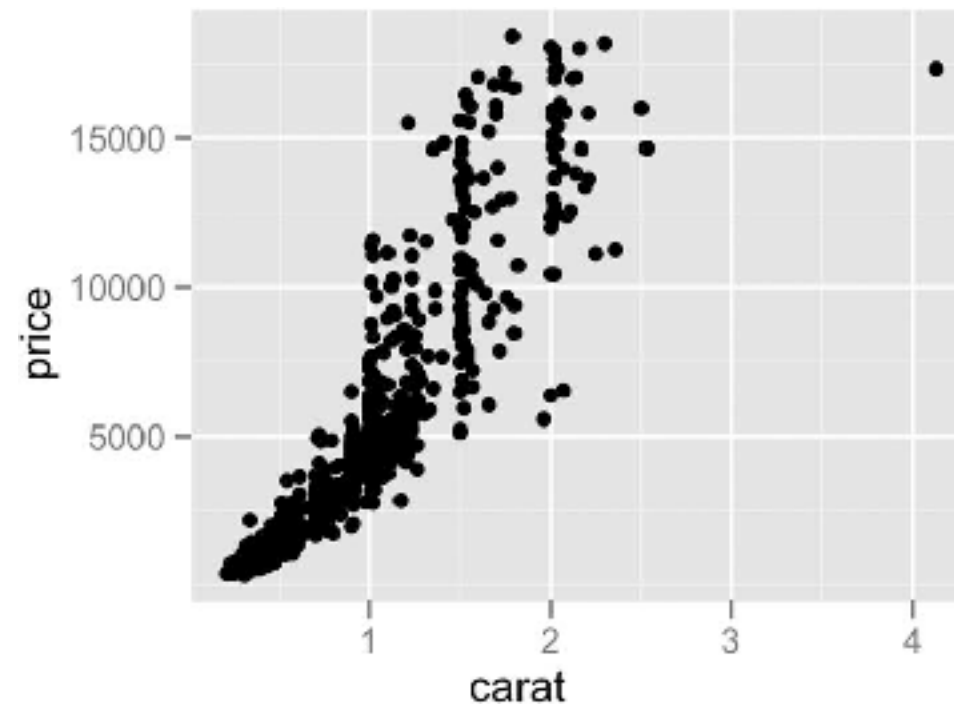
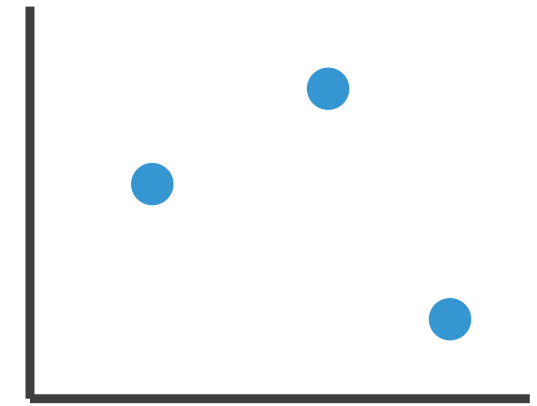
⊞ Express Values



Idiom: scatterplot

- **express** values (magnitudes)
 - quantitative attributes
- no keys, only values
 - data
 - 2 quant attribs
 - mark: points
 - channels
 - horiz + vert position

⊙ → Express Values



Idiom: scatterplot

- **express** values (magnitudes)

- quantitative attributes

- no keys, only values

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- 2 quant attribs

- mark: points

- channels

- horiz + vert position

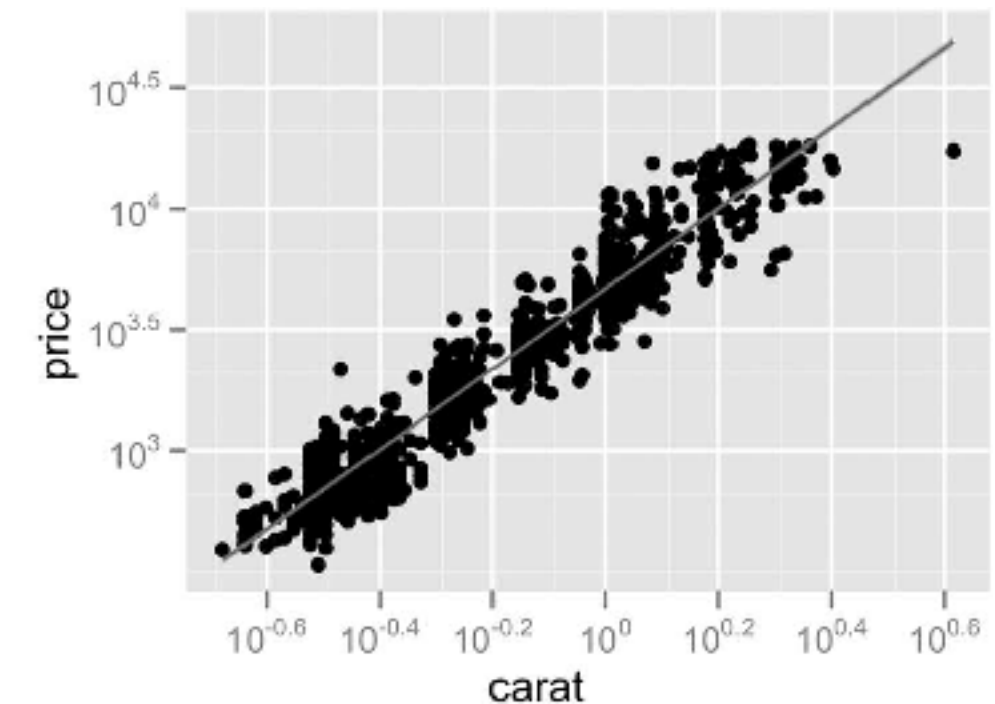
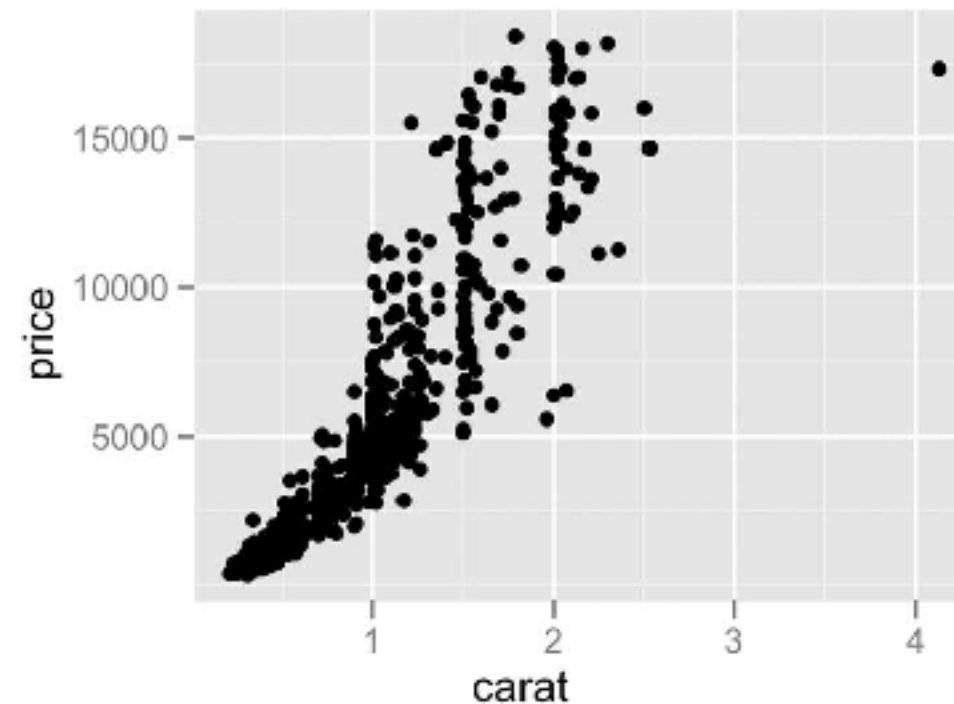
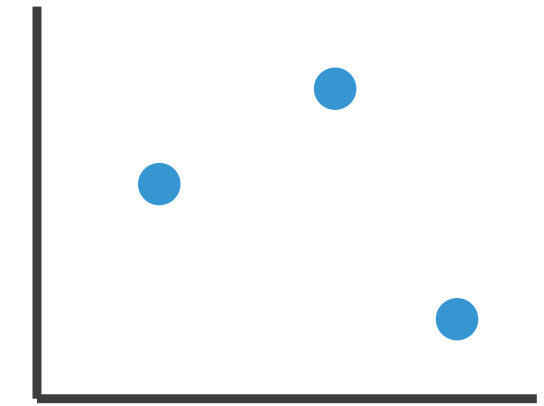
- tasks

- find trends, outliers, distribution, correlation, clusters

- scalability

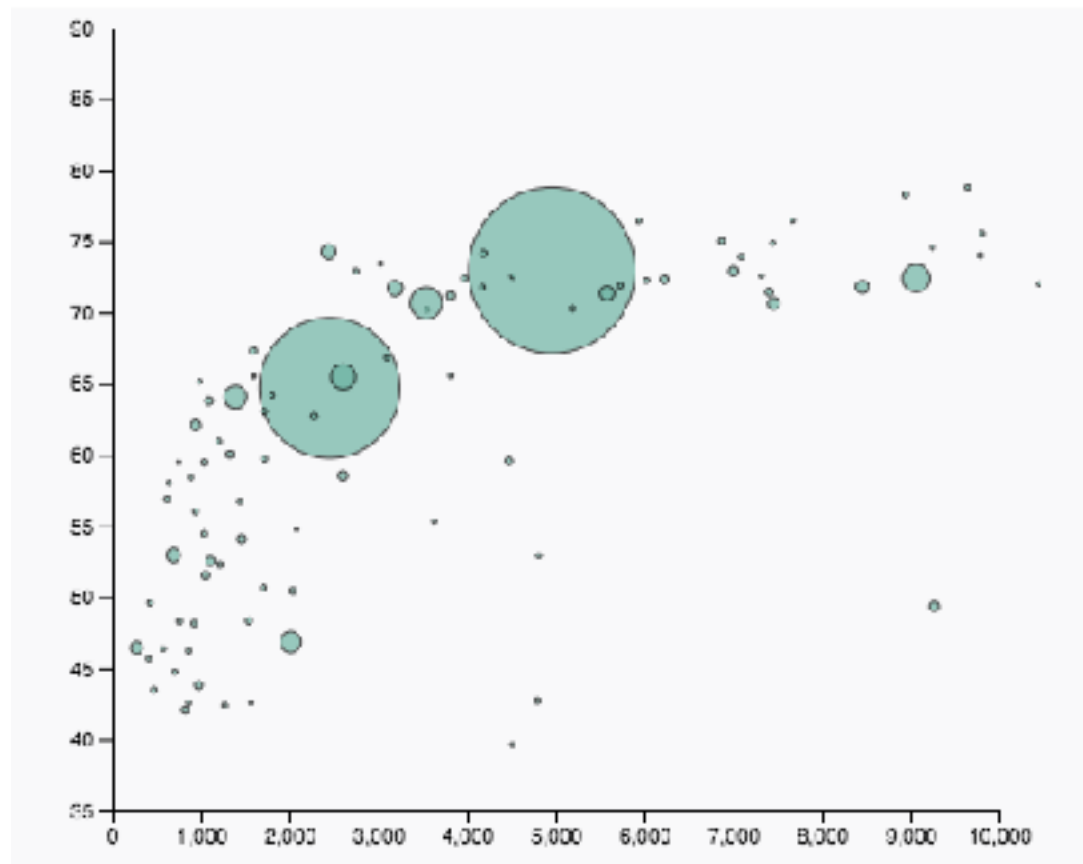
- hundreds of items

⊙ → Express Values

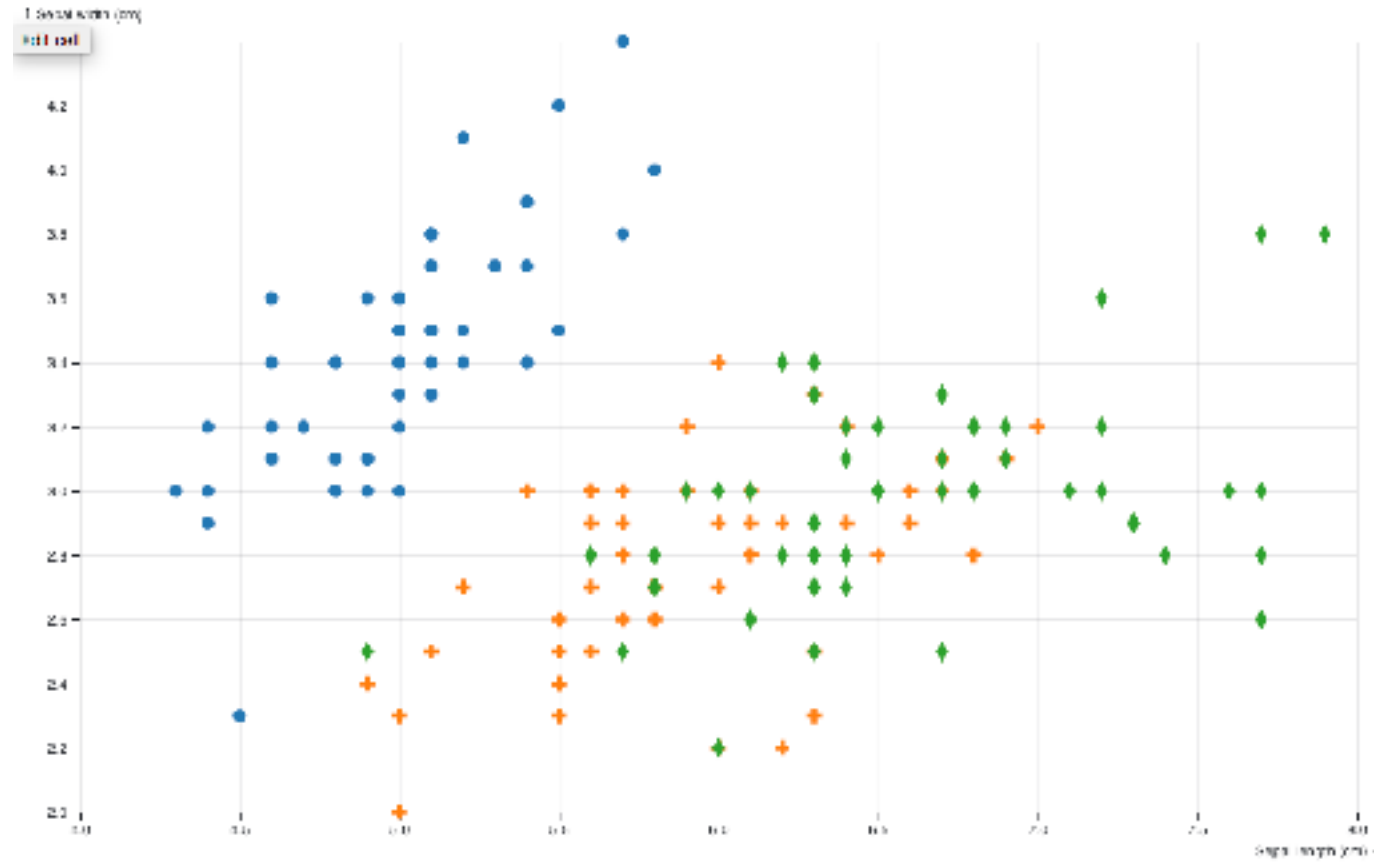


Scatterplots: Encoding more channels

- additional channels viable since using point marks
 - color
 - size (1 quant attribute, used to control 2D area)
 - note radius would mislead, take square root since area grows quadratically
 - shape



https://www.d3-graph-gallery.com/graph/bubble_basic.html

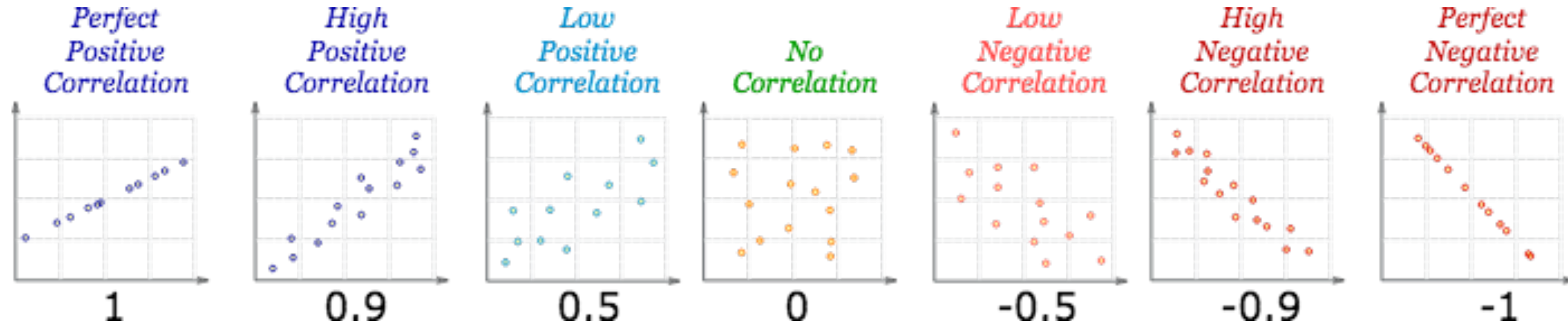


<https://observablehq.com/@d3/scatterplot-with-shapes>

Scatterplot tasks

Scatterplot tasks

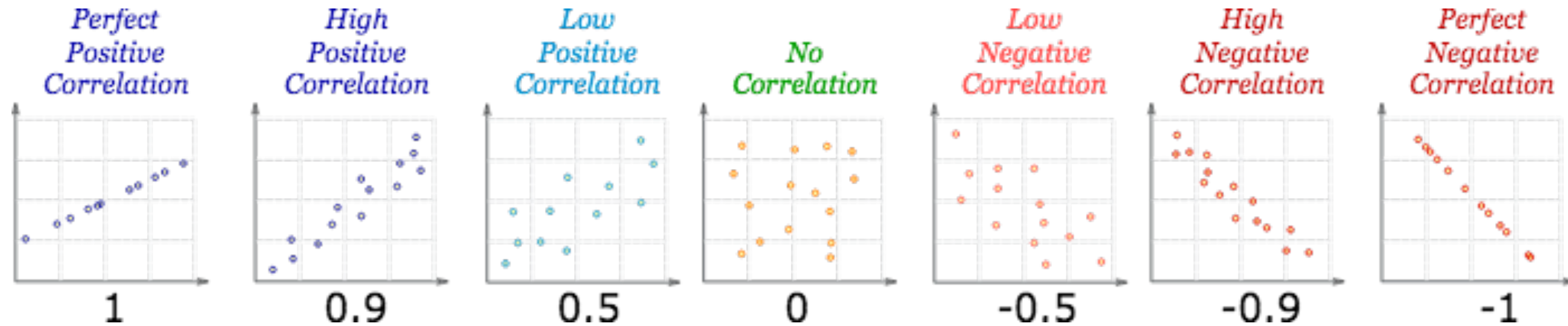
- correlation



<https://www.mathsisfun.com/data/scatter-xy-plots.html>

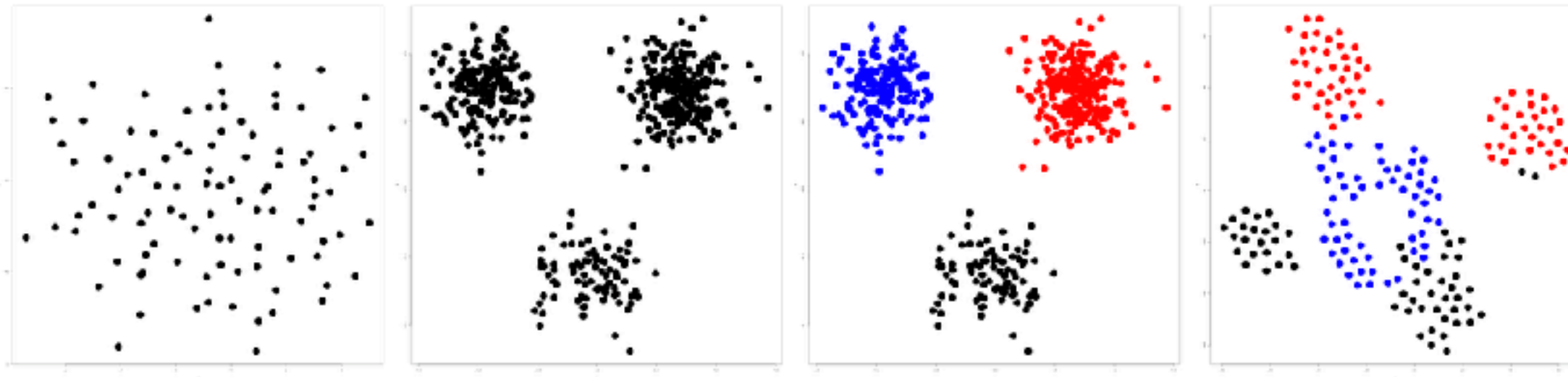
Scatterplot tasks

- correlation



<https://www.mathsisfun.com/data/scatter-xy-plots.html>

- clusters/groups, and clusters vs classes

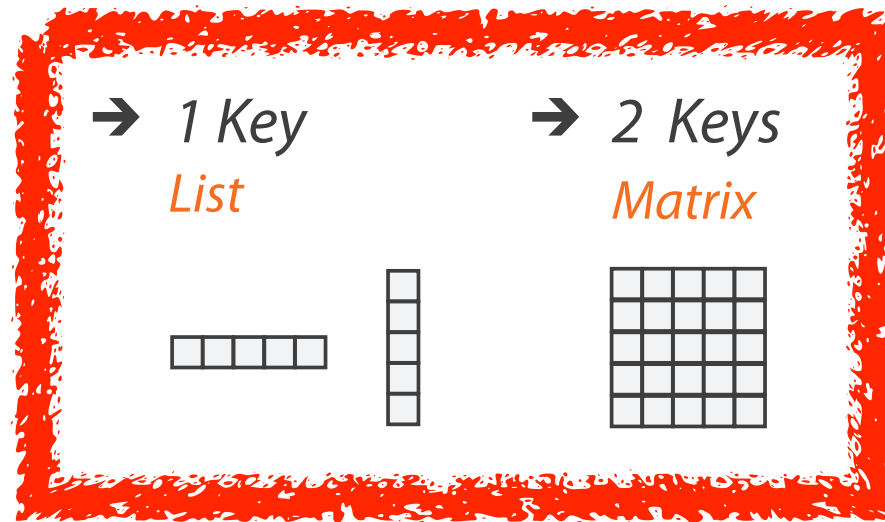


<https://www.cs.ubc.ca/labs/imager/tr/2014/DRVisTasks/>

Some keys

→ 0 Keys

⊙ Express Values

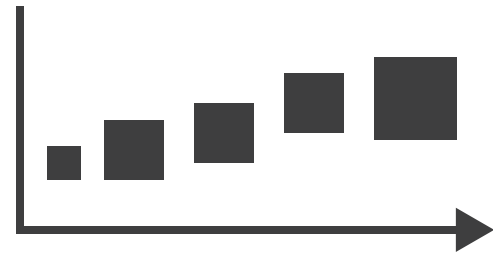


Some keys: Categorical regions

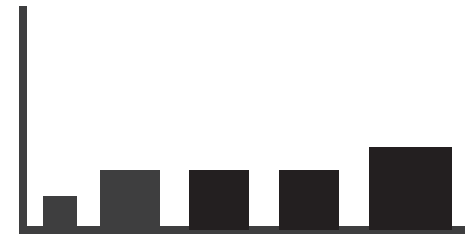
→ Separate



→ Order



→ Align

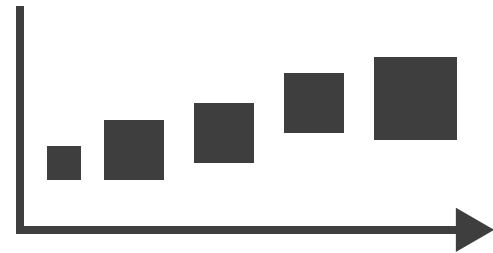


Regions: Separate, order, align

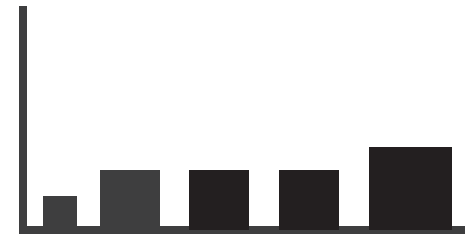
→ Separate



→ Order

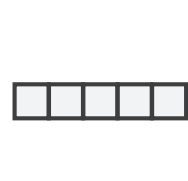


→ Align

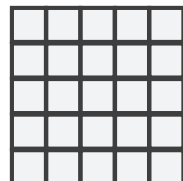


- regions: contiguous bounded areas distinct from each other
 - separate into spatial regions: one mark per region (for now)
- use categorical or ordered attribute to separate into regions
 - no conflict with expressiveness principle for categorical attributes
- use ordered attribute to order and align regions

→ 1 Key
List

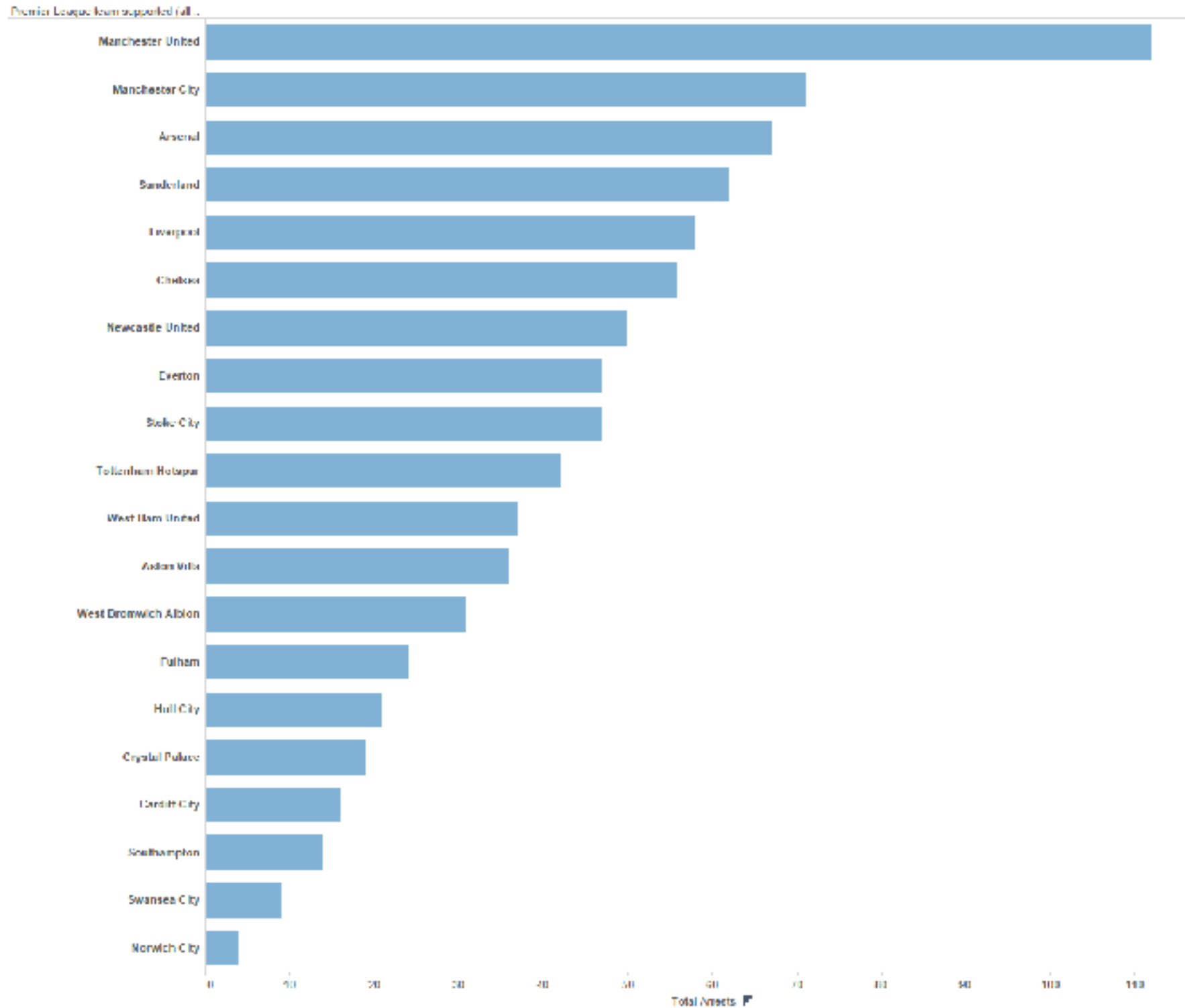


→ 2 Keys
Matrix



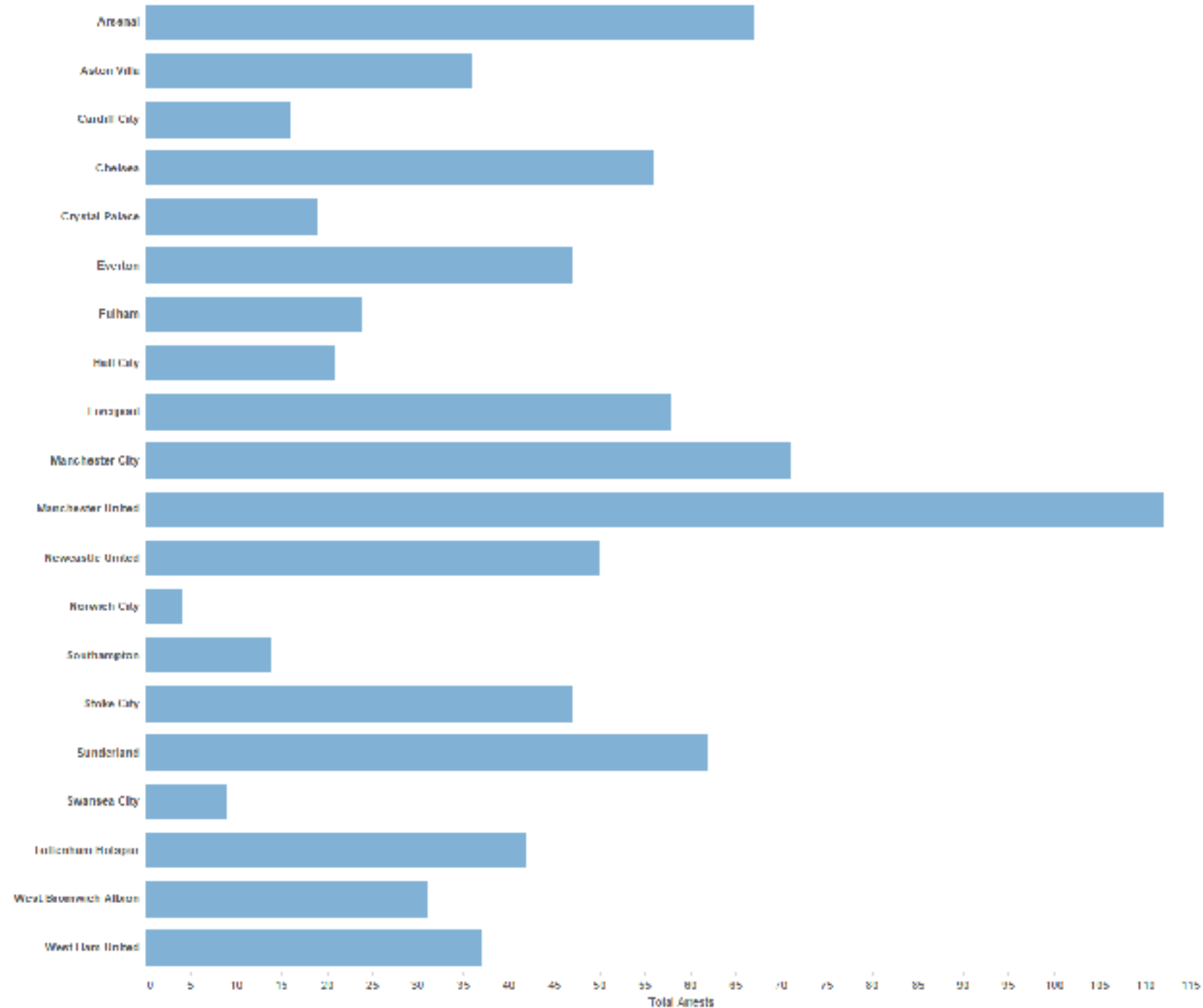
Separated and aligned and ordered

- best case



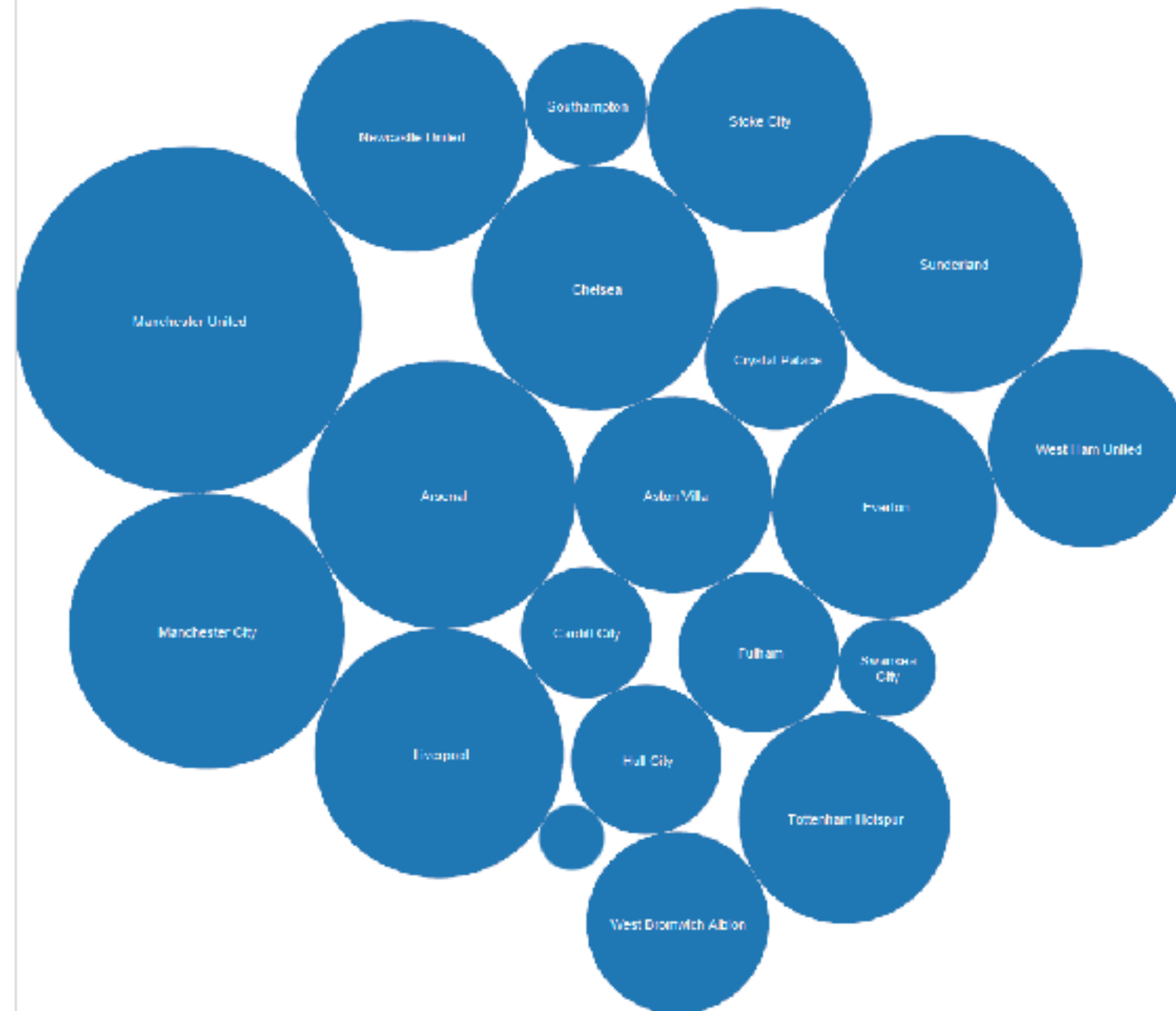
Separated and aligned but not ordered

- limitation: hard to know rank. what's 4th? what's 7th?



Separated but not aligned or ordered

- limitation: hard to make comparisons with size (vs aligned position)



Idiom: bar chart

- one key, one value

- data

- 1 categ attrib, 1 quant attrib

- mark: lines

- channels

- length to express quant value

- spatial regions: one per mark

- separated horizontally, aligned vertically

- ordered by quant attrib

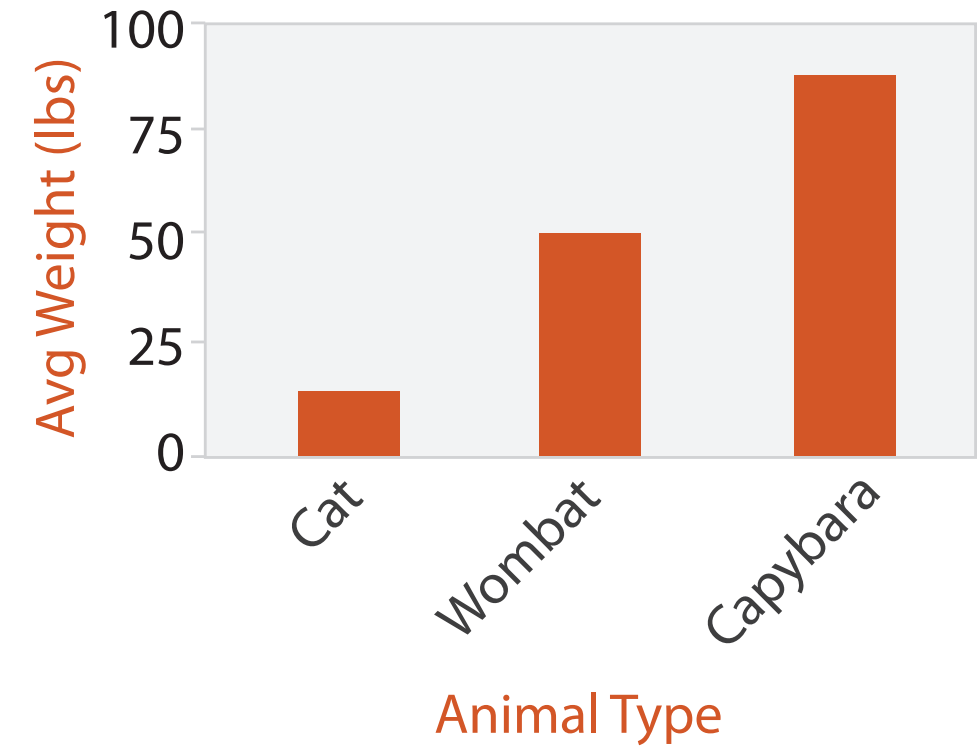
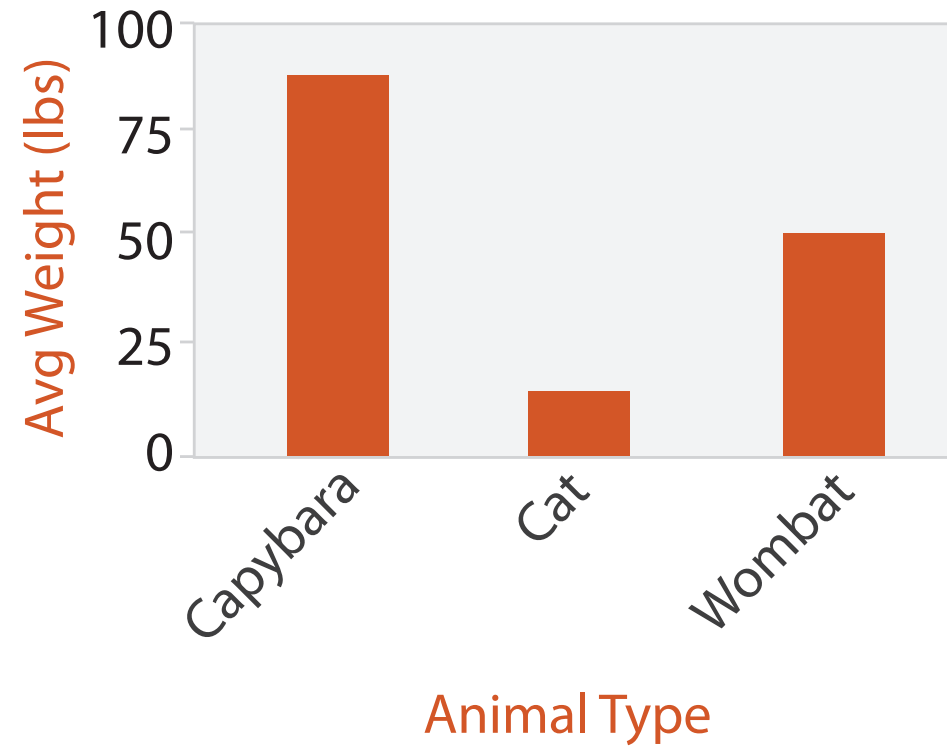
- » by label (alphabetical), by length attrib (data-driven)

- task

- compare, lookup values

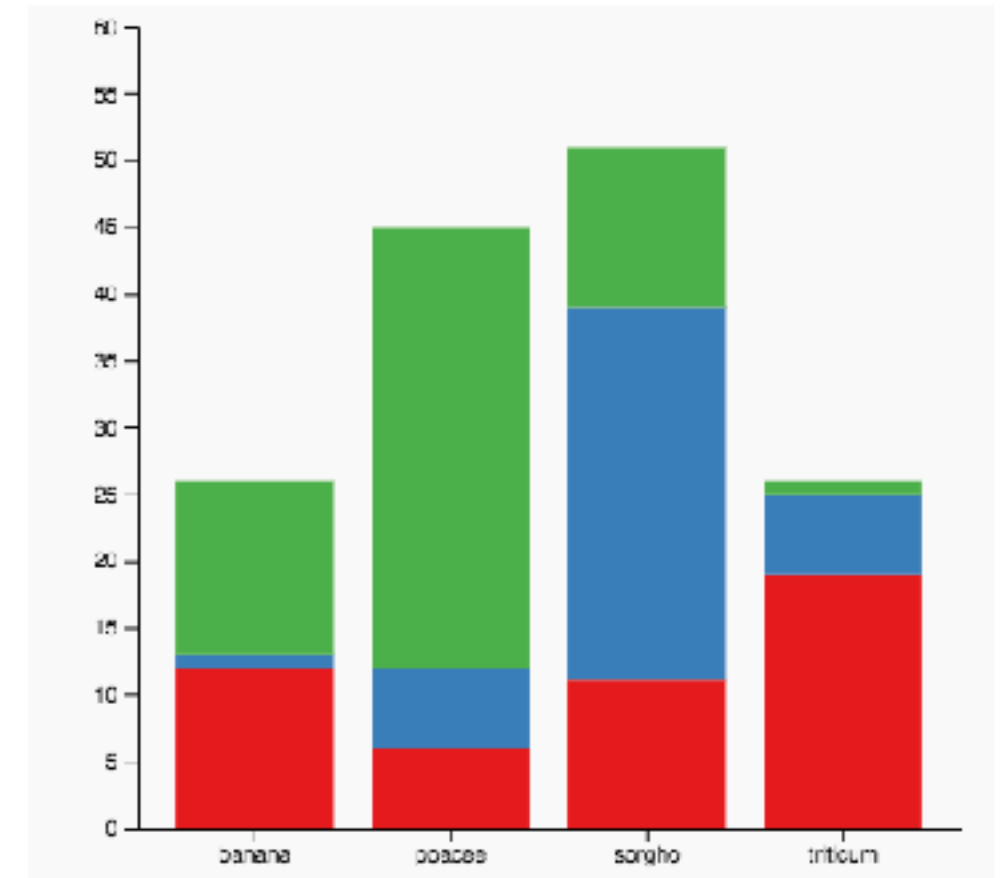
- scalability

- dozens to hundreds of levels for key attrib [bars], hundreds for values



Idiom: stacked bar chart

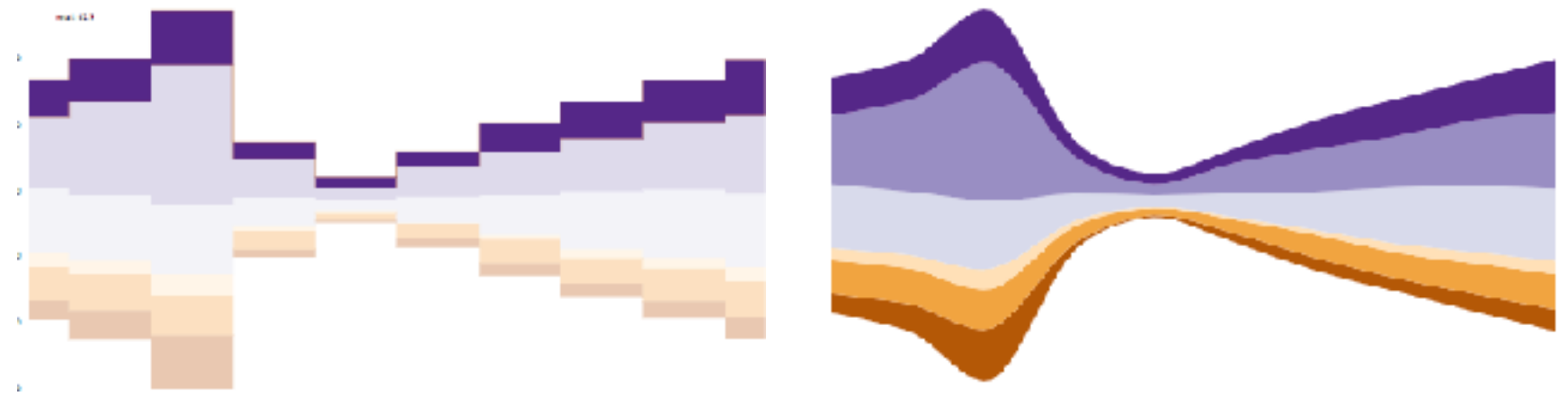
- one more key
 - data
 - 2 categ attrib, 1 quant attrib
 - mark: vertical stack of line marks
 - **glyph**: composite object, internal structure from multiple marks
 - channels
 - length and color hue
 - spatial regions: one per glyph
 - aligned: full glyph, lowest bar component
 - unaligned: other bar components
 - task
 - part-to-whole relationship
 - scalability: asymmetric
 - for *stacked* key attrib, 10-12 levels [segments]
 - for *main* key attrib, dozens to hundreds of levels [bars]



https://www.d3-graph-gallery.com/graph/barplot_stacked_basicWide.html

Idiom: streamgraph

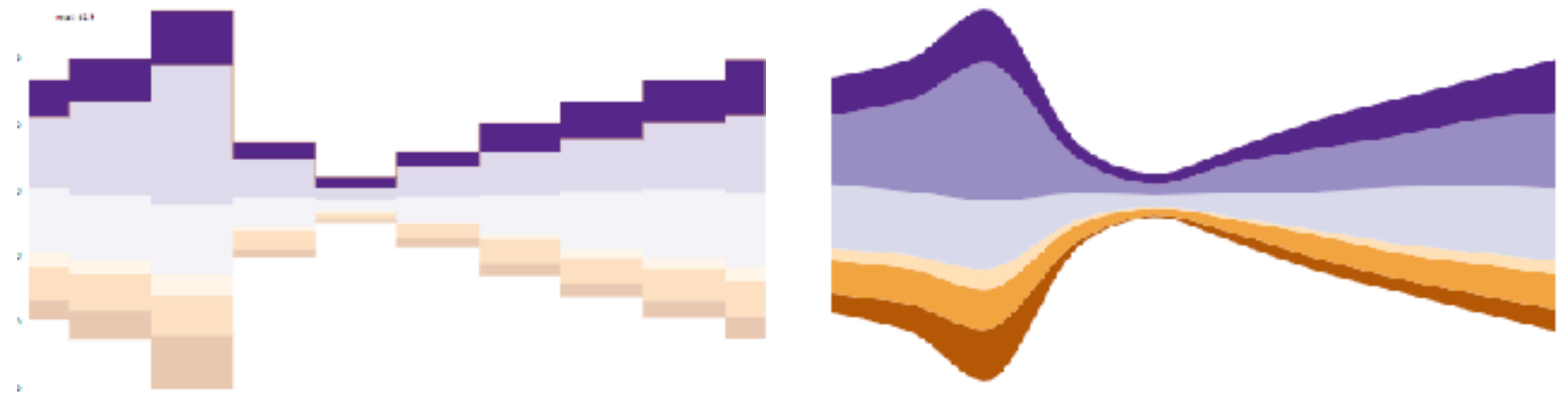
- generalized stacked graph
 - emphasizing horizontal continuity
 - vs vertical items
 - data
 - 1 categ key attrib (movies)
 - 1 ordered key attrib (time)
 - 1 quant value attrib (counts)
 - derived data
 - geometry: layers, where height encodes counts
 - 1 quant attrib (layer ordering)



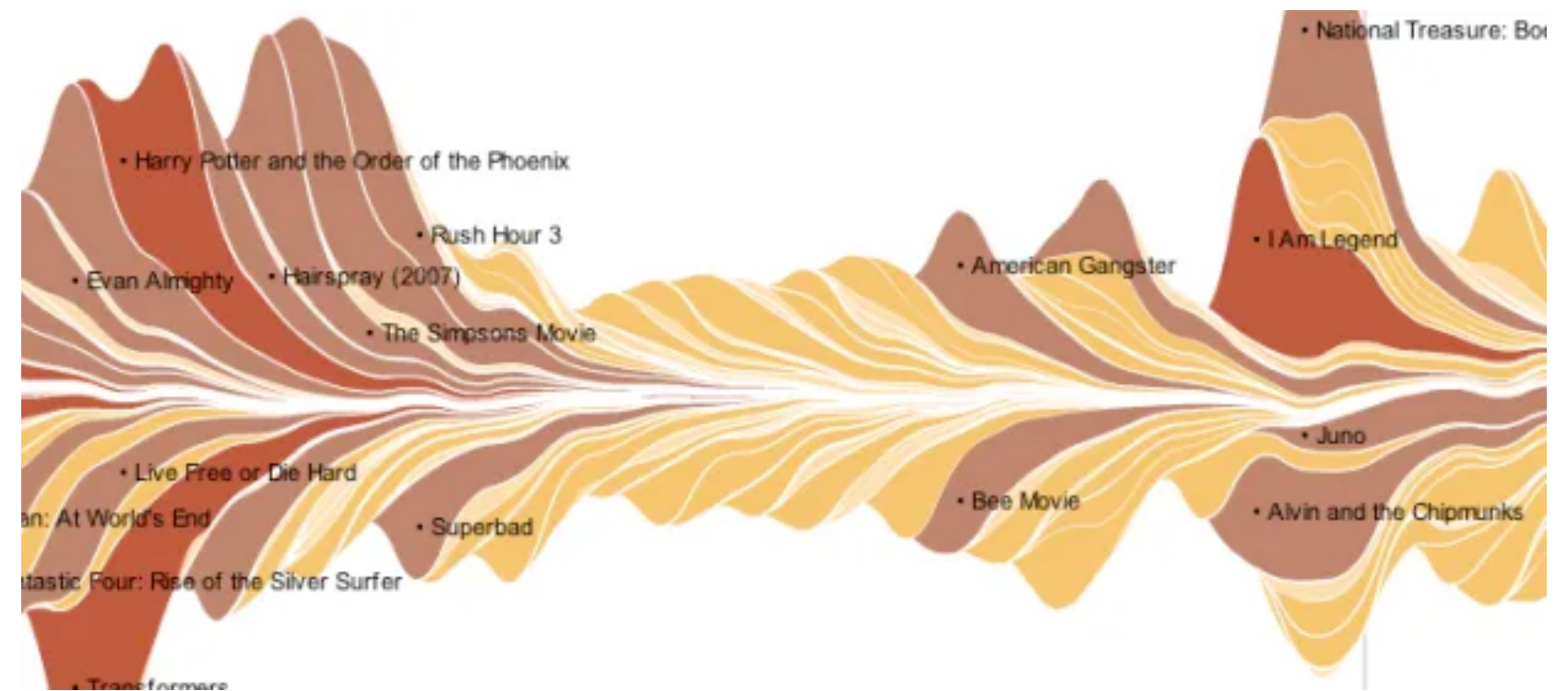
[Stacked Graphs Geometry & Aesthetics. Byron and Wattenberg. *IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008)* 14(6): 1245–1252, (2008).]

Idiom: streamgraph

- generalized stacked graph
 - emphasizing horizontal continuity
 - vs vertical items
 - data
 - 1 categ key attrib (movies)
 - 1 ordered key attrib (time)
 - 1 quant value attrib (counts)
 - derived data
 - geometry: layers, where height encodes counts
 - 1 quant attrib (layer ordering)
 - scalability
 - hundreds of time keys
 - dozens to hundreds of movies keys
 - more than stacked bars: most layers don't extend across whole chart



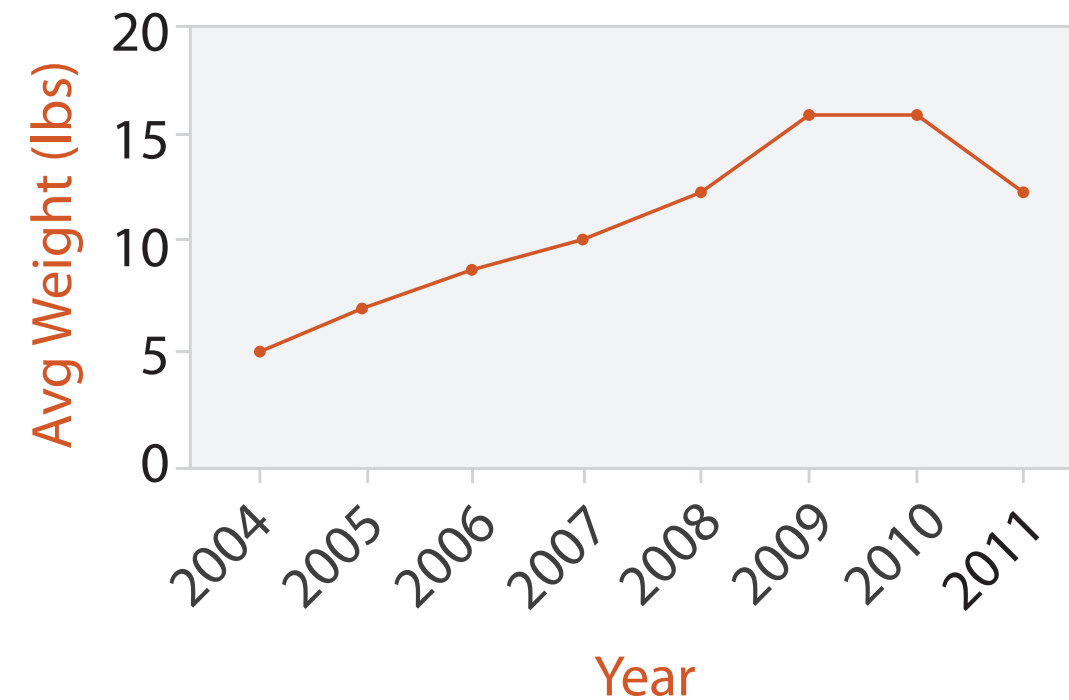
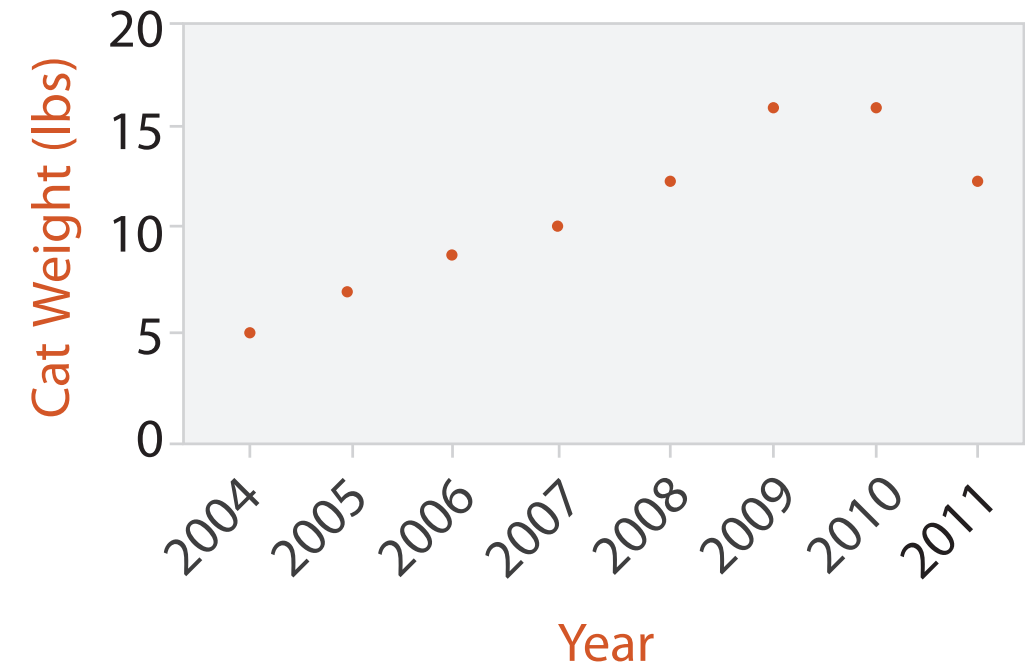
[Stacked Graphs Geometry & Aesthetics. Byron and Wattenberg. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14(6): 1245–1252, (2008).]



<https://flowingdata.com/2008/02/25/ebb-and-flow-of-box-office-receipts-over-past-20-years/>

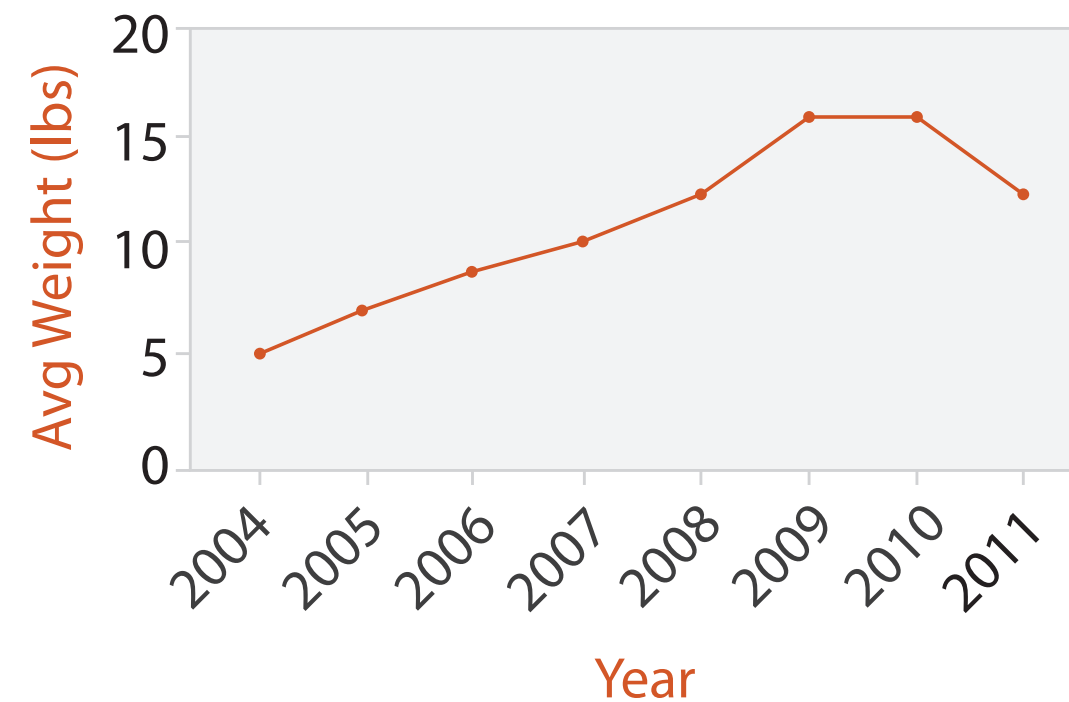
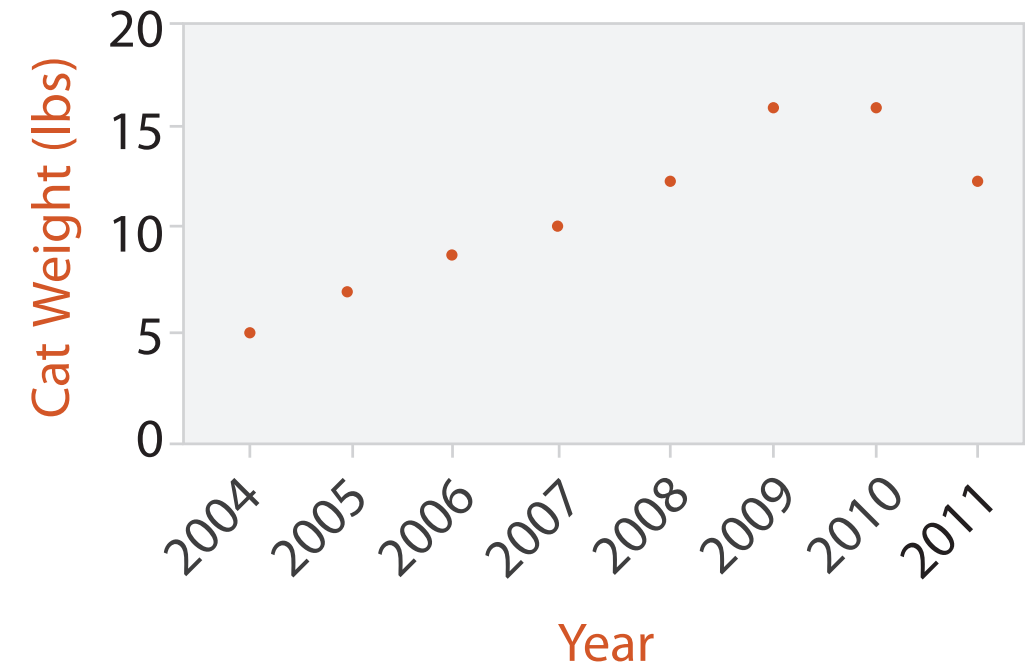
Idiom: dot / line chart

- one key, one value
 - data
 - 2 quant attribs
 - mark: points
 - AND line connection marks between them
 - channels
 - aligned lengths to express quant value
 - separated and ordered by key attrib into horizontal regions



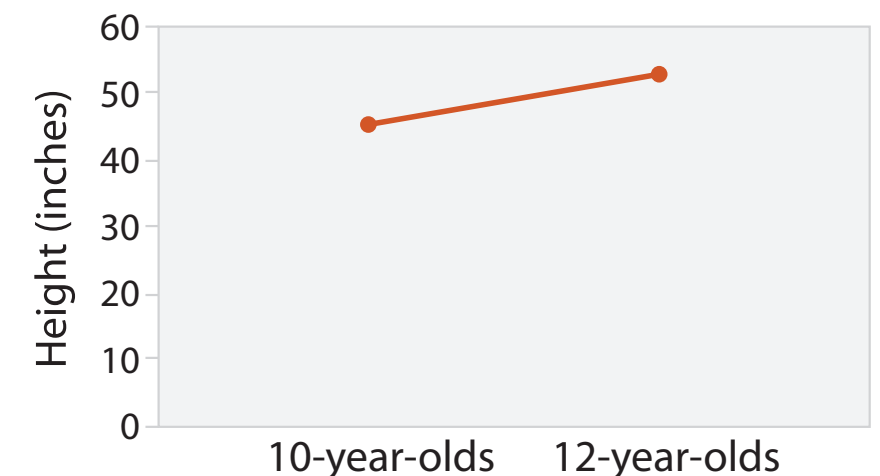
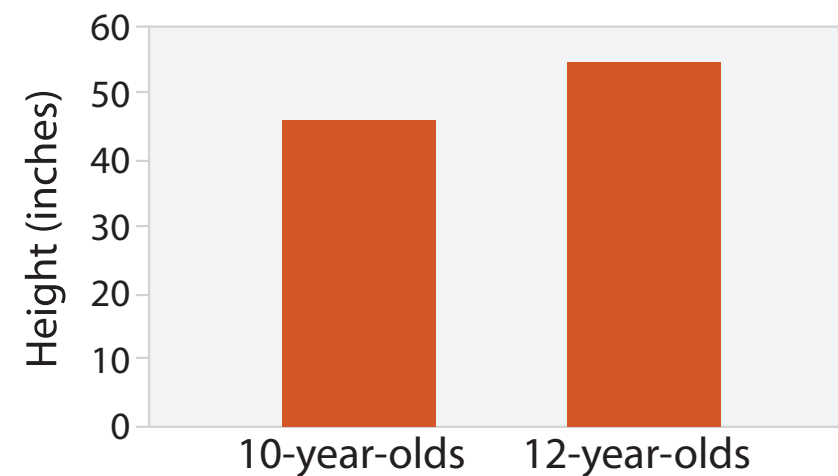
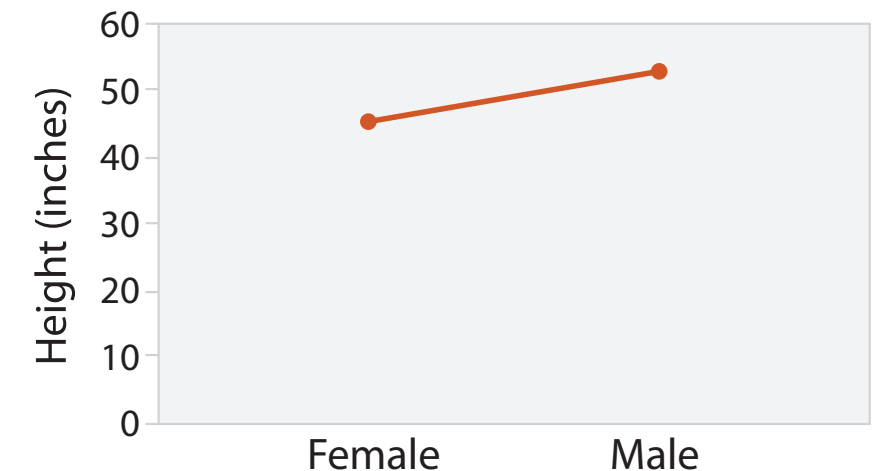
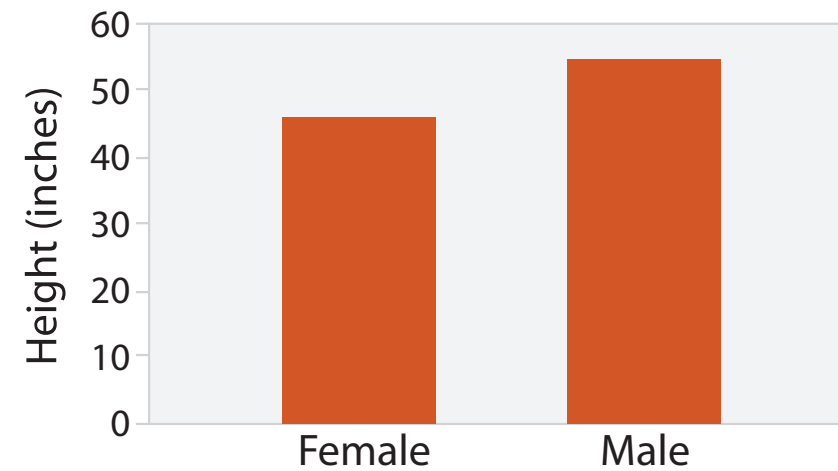
Idiom: dot / line chart

- one key, one value
 - data
 - 2 quant attribs
 - mark: points
 - AND line connection marks between them
 - channels
 - aligned lengths to express quant value
 - separated and ordered by key attrib into horizontal regions
 - task
 - find trend
 - connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next
 - scalability
 - hundreds of key levels, hundreds of value levels



Choosing bar vs line charts

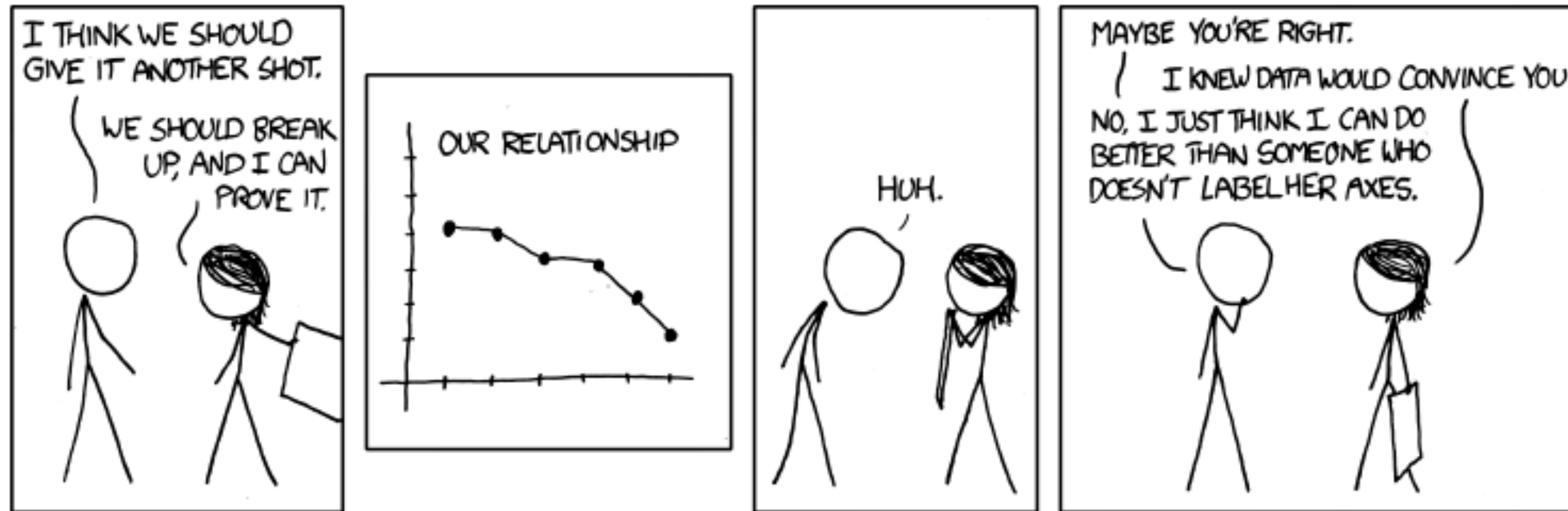
- depends on type of key attrib
 - bar charts if categorical
 - line charts if ordered
- do not use line charts for categorical key attribs
 - violates expressiveness principle
 - implication of trend so strong that it overrides semantics!
 - “The more male a person is, the taller he/she is”



after [Bars and Lines: A Study of Graphic Communication. Zacks and Tversky. *Memory and Cognition* 27:6 (1999), 1073–1079.]

Chart axes: label them!

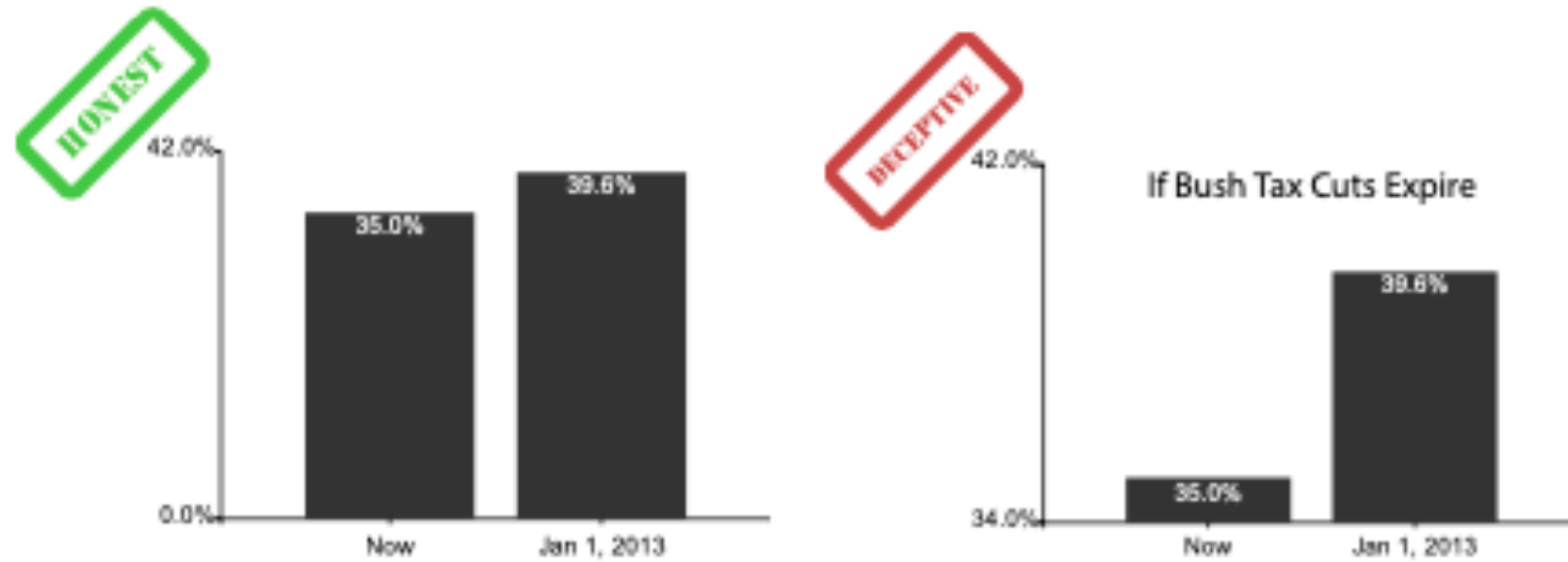
- best practice to label
 - few exceptions: individual small multiple views could share axis label



<https://xkcd.com/833/>

Chart axes: avoid cropping y axis

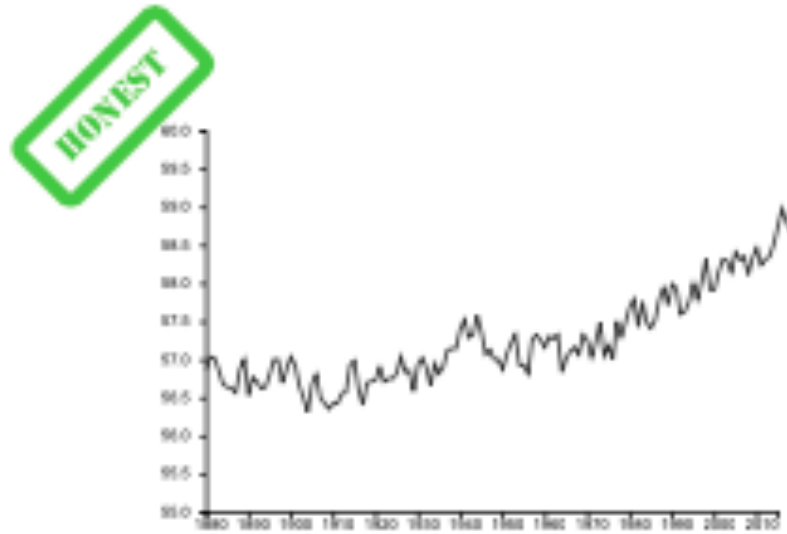
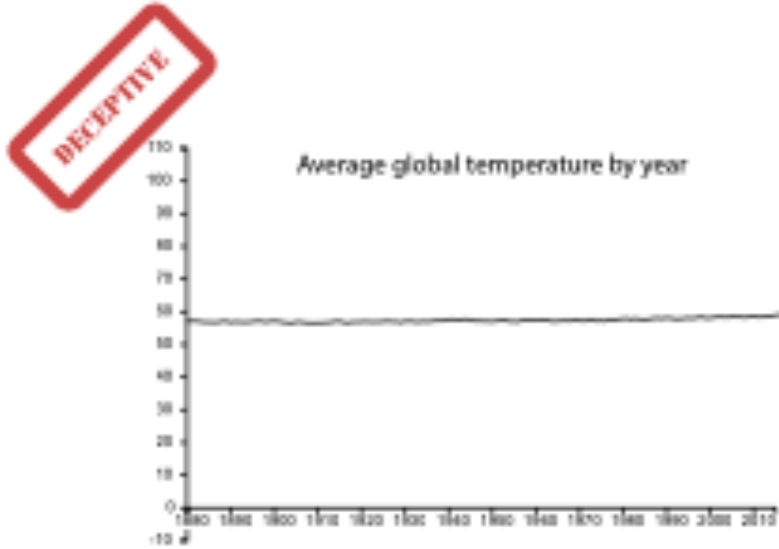
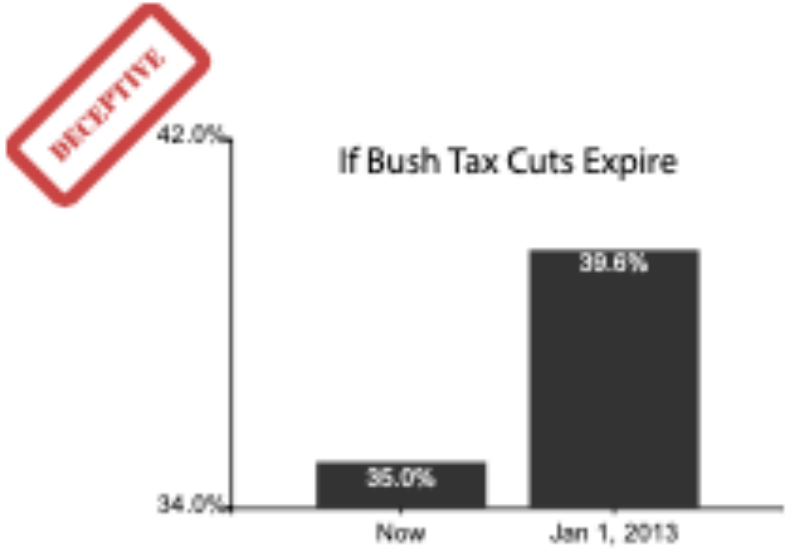
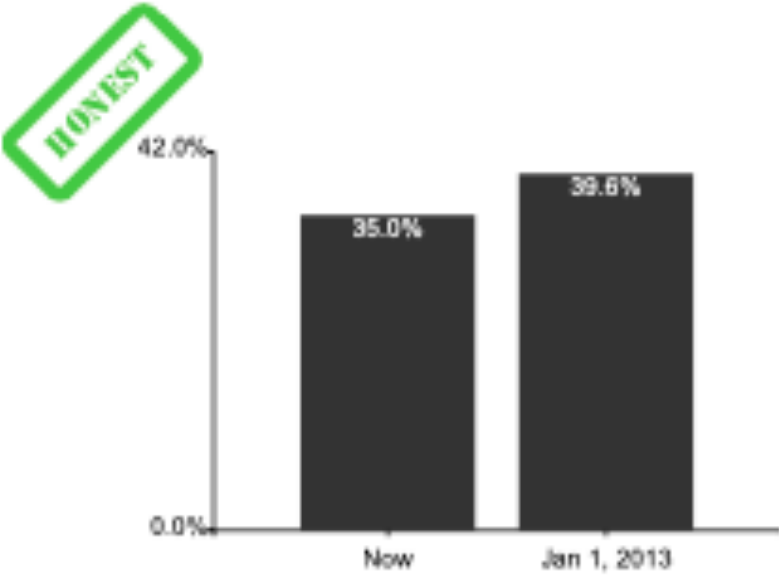
- include 0 at bottom left or slope misleads



*[Truncating the Y-Axis: Threat or Menace?
Correll, Bertini, & Franconeri, CHI 2020.]*

Chart axes: avoid cropping y axis

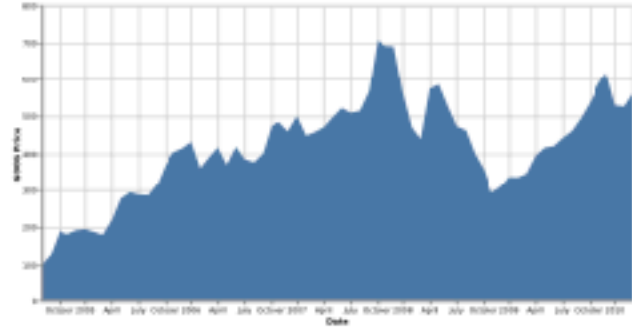
- include 0 at bottom left or slope misleads
 - some exceptions (arbitrary 0, small change matters)



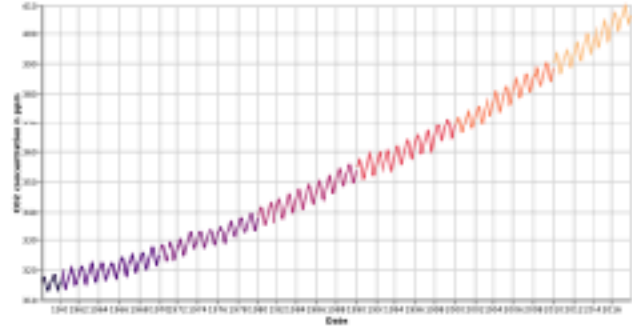
(a) Statistical process charts rely on comparison to an expected value, and so deviations from that value, not from zero, are important



(b) Index charts compare to an indexed value rather than zero.



(c) Stock charts must show small differences in stock value, as these can translate to enormous monetary gains or losses.

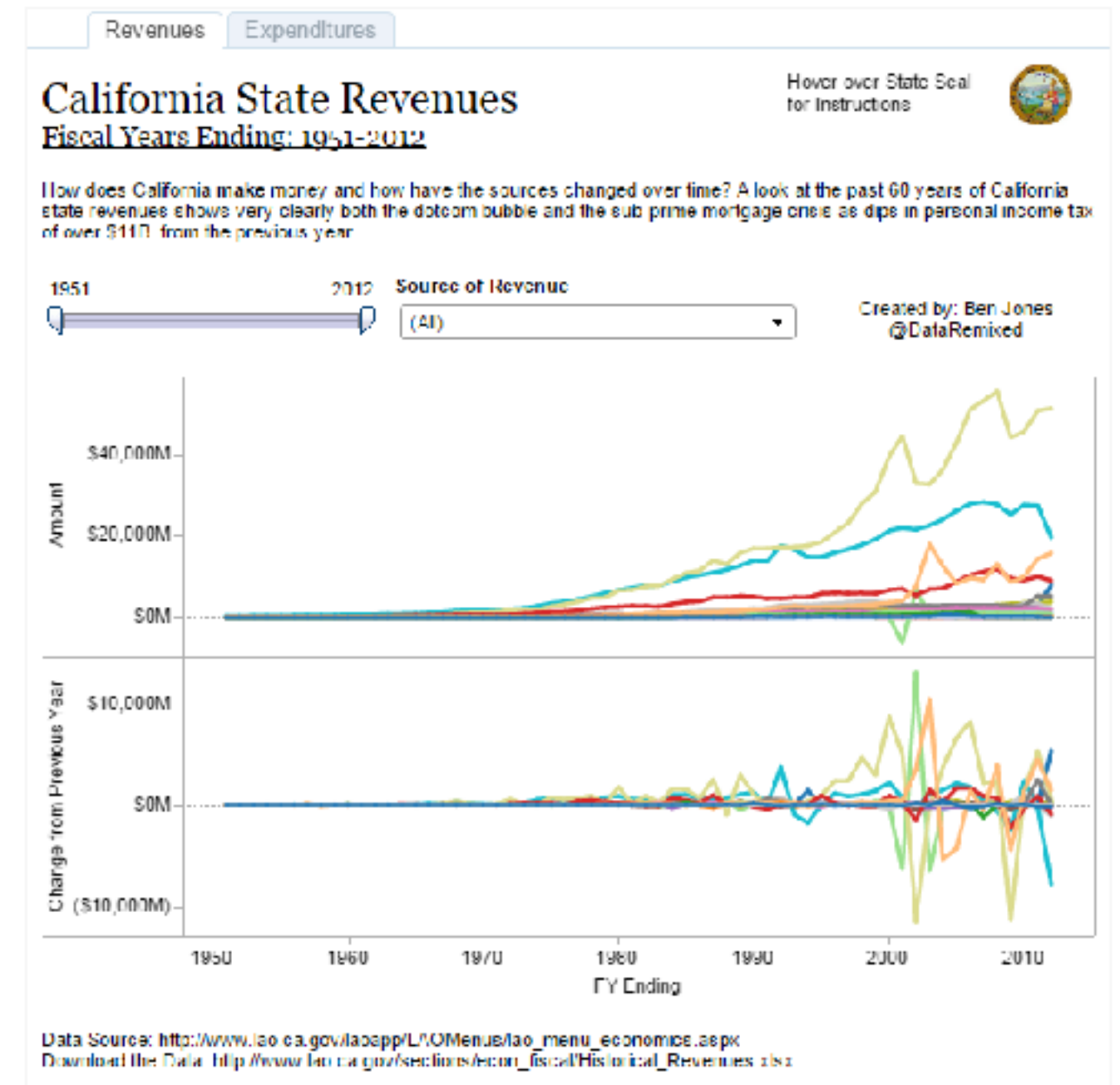


(d) Climate Anomaly charts rely on both highlighting deviation from a non-zero expected value but also emphasize the potentially disastrous impact of even minute changes in climate.

[Truncating the Y-Axis: Threat or Menace? Correll, Bertini, & Franconeri, CHI 2020.]

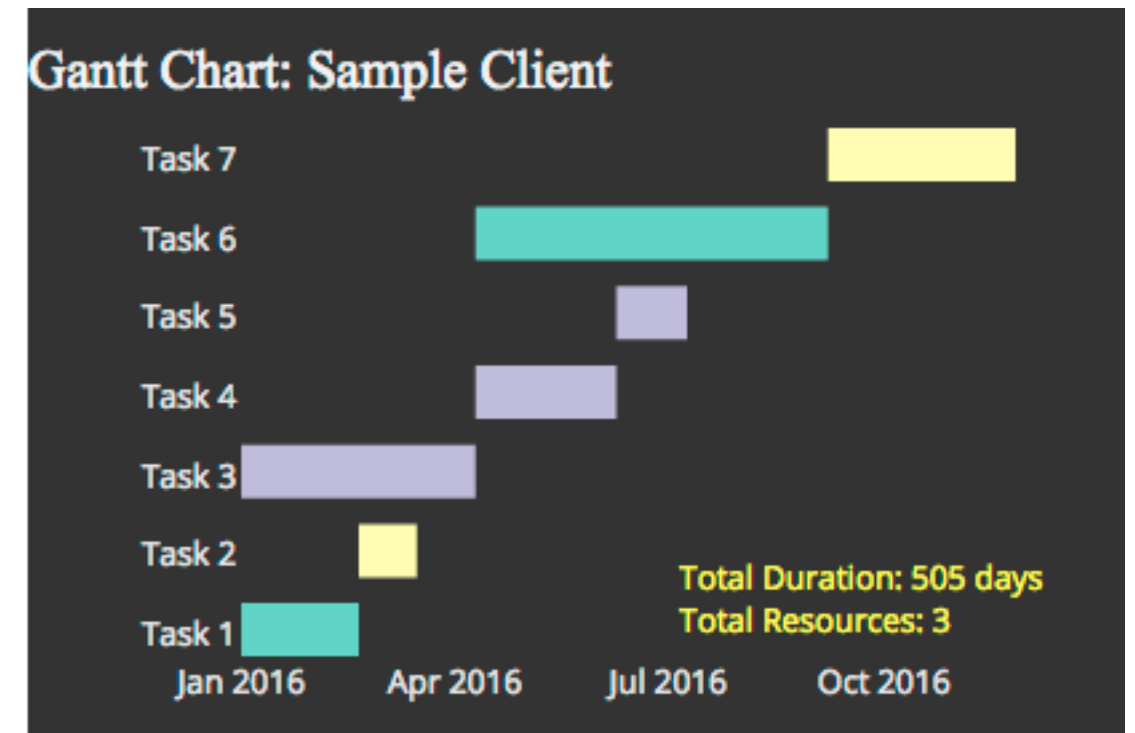
Idiom: Indexed line charts

- data: 2 quant attribs
 - 1 key + 1 value
- derived data: new quant value attrib
 - index
 - plot instead of original value
- task: show change over time
 - principle: normalized, not absolute
- scalability
 - same as standard line chart



Idiom: Gantt charts

- one key, two (related) values
 - data
 - 1 categ attrib, 2 quant attribs
 - mark: line
 - length: duration
 - channels
 - horiz position: start time
(+end from duration)
 - task
 - emphasize temporal overlaps & start/end dependencies between items
 - scalability
 - dozens of key levels [bars]
 - hundreds of value levels [durations]

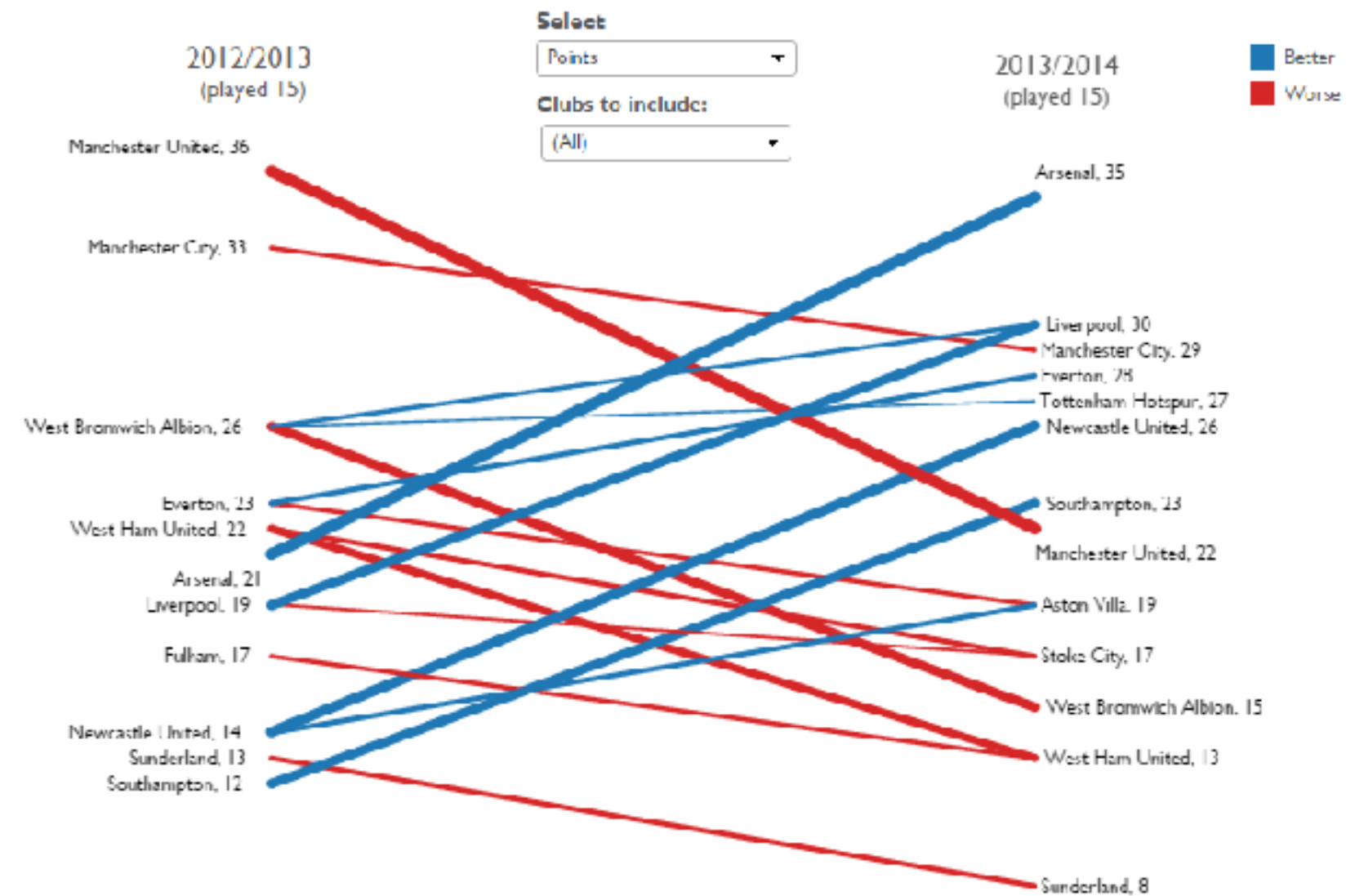


<https://www.r-bloggers.com/gantt-charts-in-r-using-plotly/>

Idiom: Slopegraphs

- two values
 - data
 - 2 quant value attribs
 - (1 derived attrib: change magnitude)
 - mark: point + line
 - line connecting mark between pts
 - channels
 - 2 vertical pos: express attrib value
 - (linewidth/size, color)
 - task
 - emphasize changes in rank/value
 - scalability
 - hundreds of value levels
 - dozens of items

Barclay's Premier League Tables: Comparing 2012/2013 Starts to 2013/2014 Starts



<https://public.tableau.com/profile/ben.jones#!/vizhome/Slopegraphs/Slopegraphs>

2 Keys

→ 0 Keys

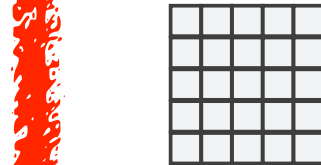
→ Express Values



→ 1 Key
List



→ 2 Keys
Matrix

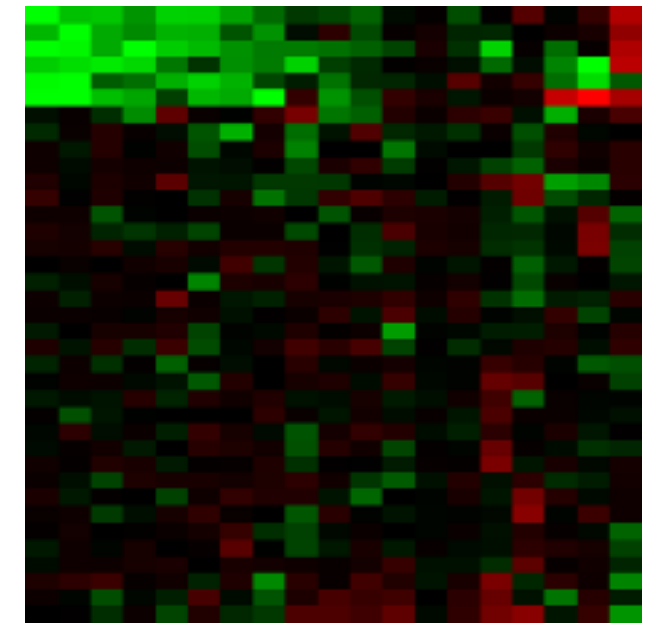
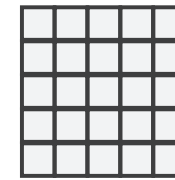


Idiom: heatmap

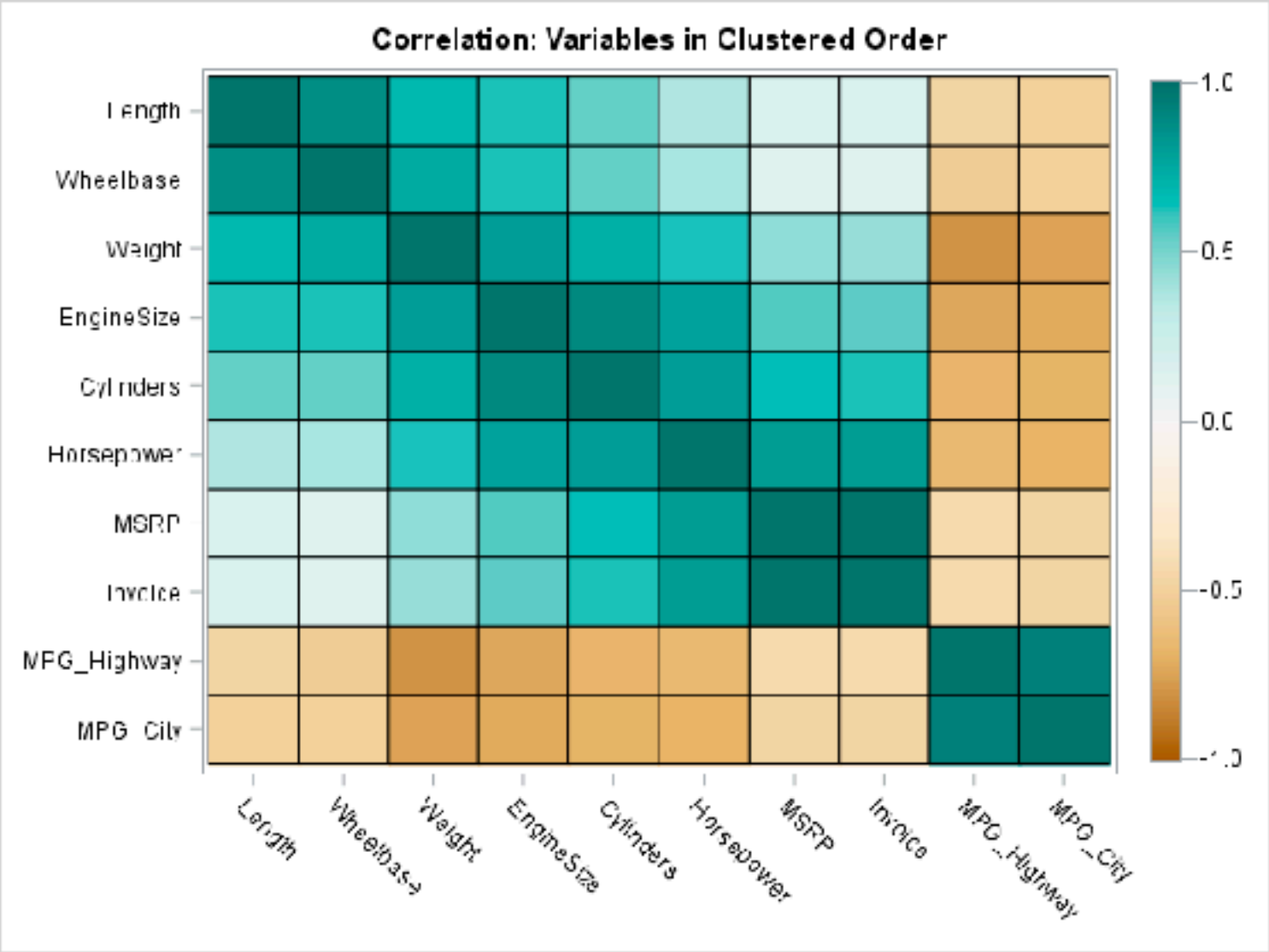
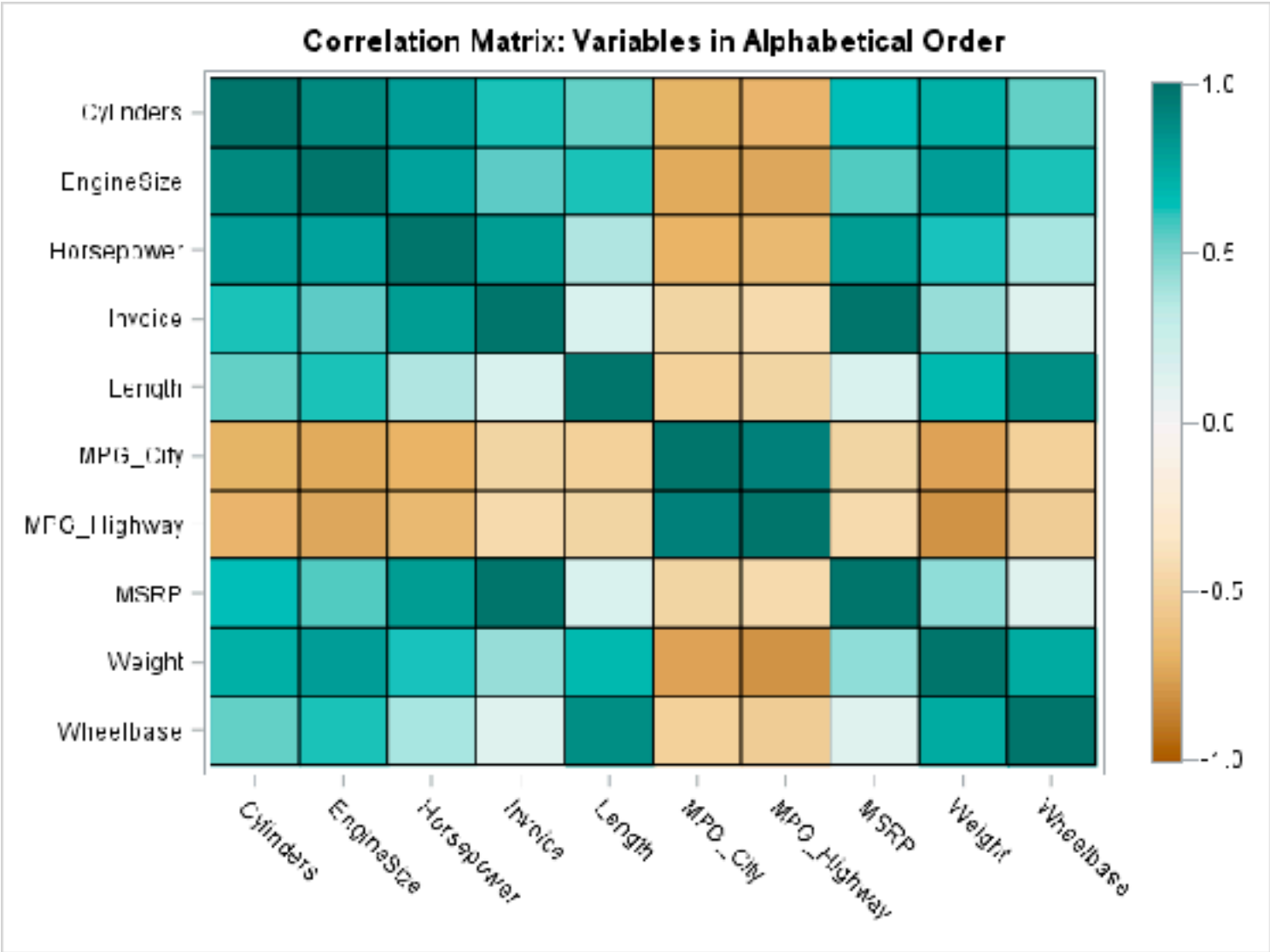
- two keys, one value
 - data
 - 2 categ attribs (gene, experimental condition)
 - 1 quant attrib (expression levels)
 - marks: point
 - separate and align in 2D matrix
 - indexed by 2 categorical attributes
 - channels
 - color by quant attrib
 - (ordered diverging colormap)
 - task
 - find clusters, outliers
 - scalability
 - 1M items, 100s of categ levels, ~10 quant attrib levels

→ 2 Keys

Matrix

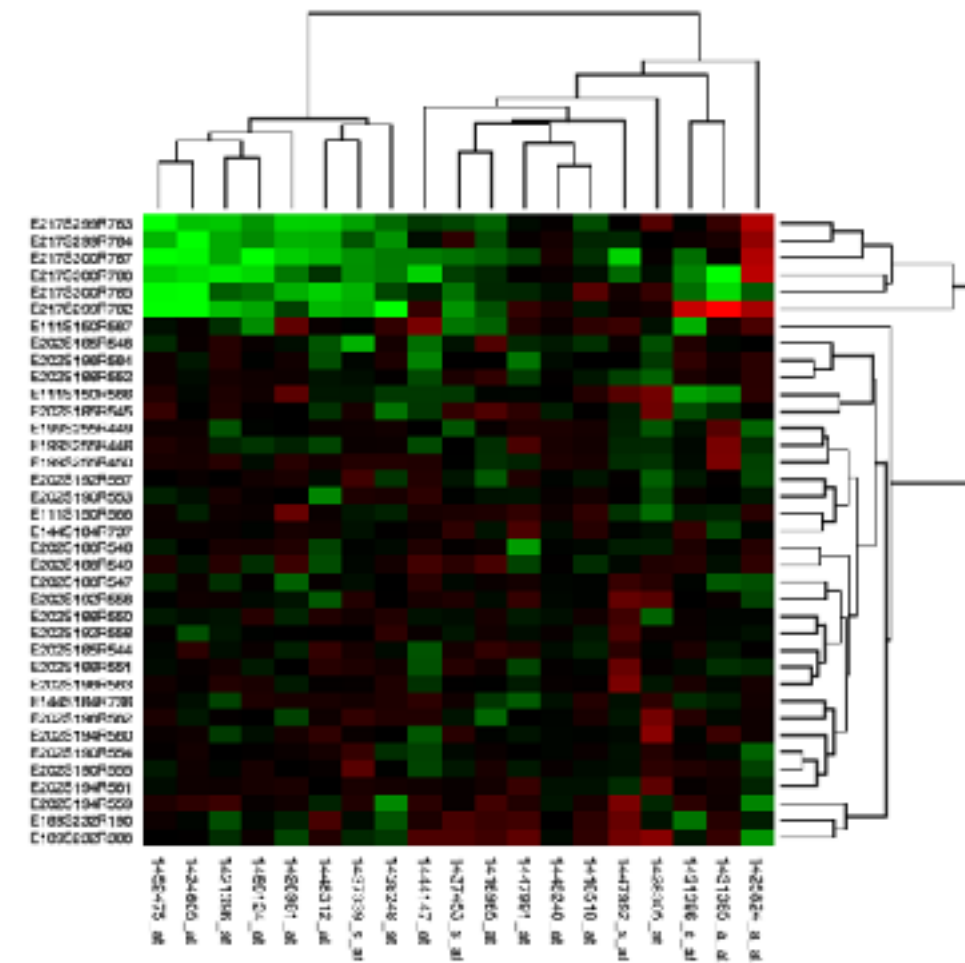


Heatmap reordering



Idiom: cluster heatmap

- in addition
 - derived data
 - 2 cluster hierarchies
 - dendrogram
 - parent-child relationships in tree with connection line marks
 - leaves aligned so interior branch heights easy to compare
 - heatmap
 - marks (re-)ordered by cluster hierarchy traversal
 - task: assess quality of clusters found by automatic methods



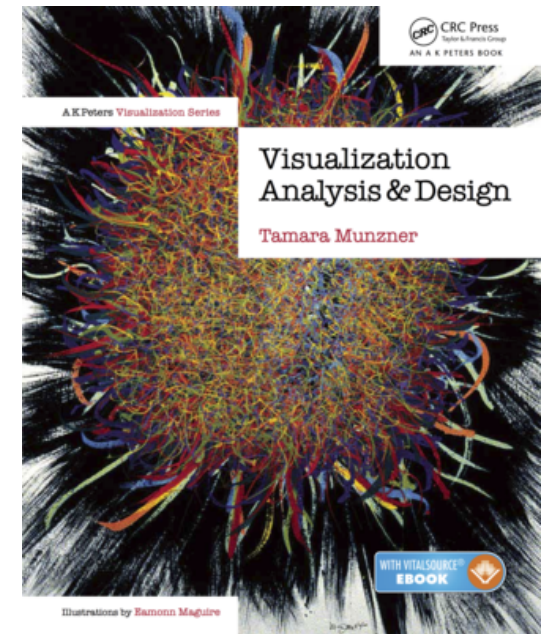
Visualization Analysis & Design

Tables (Ch 7) II

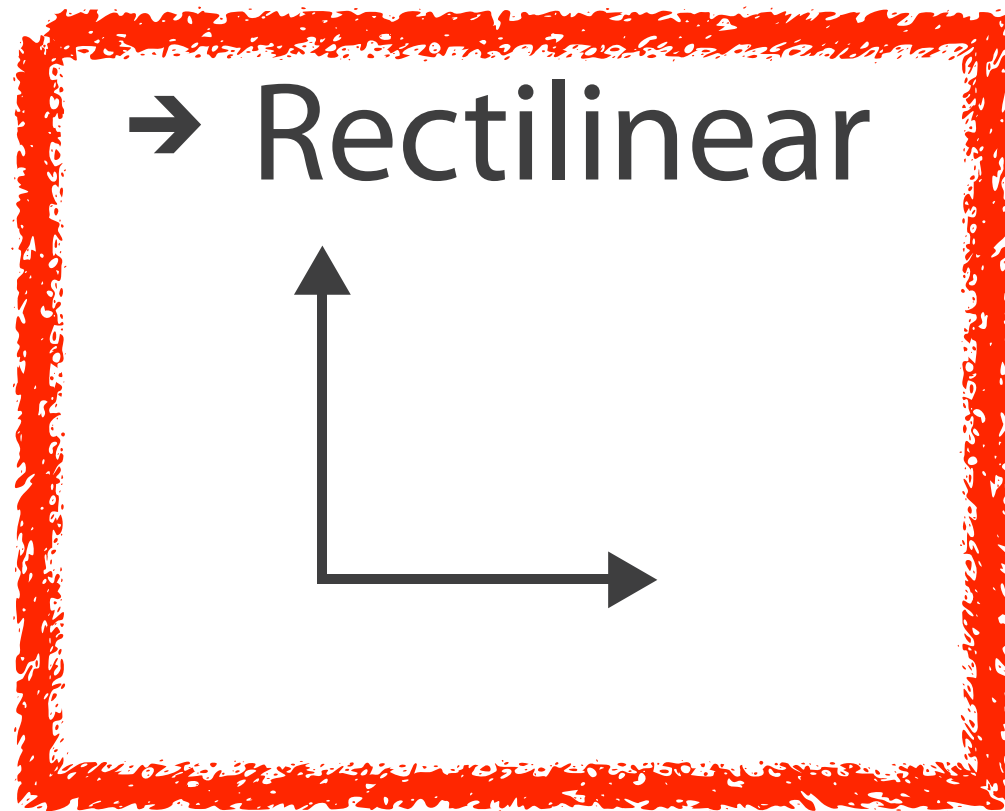
Tamara Munzner

Department of Computer Science
University of British Columbia

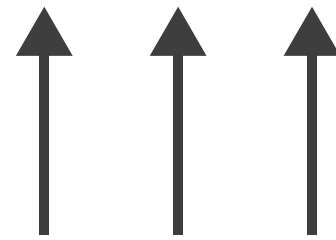
[@tamaramunzner](#)



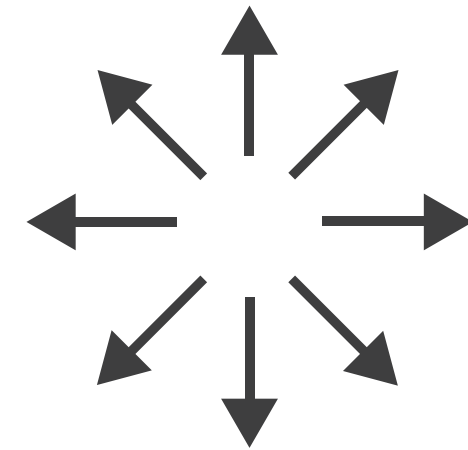
→ Axis Orientation



→ Parallel

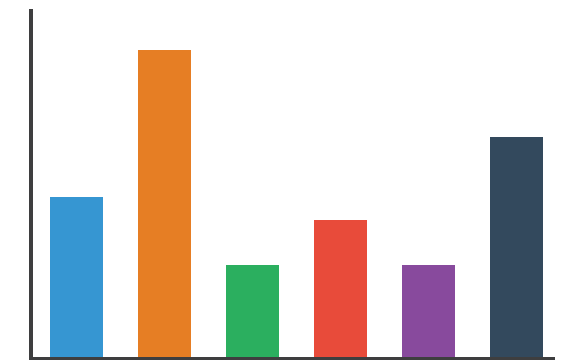
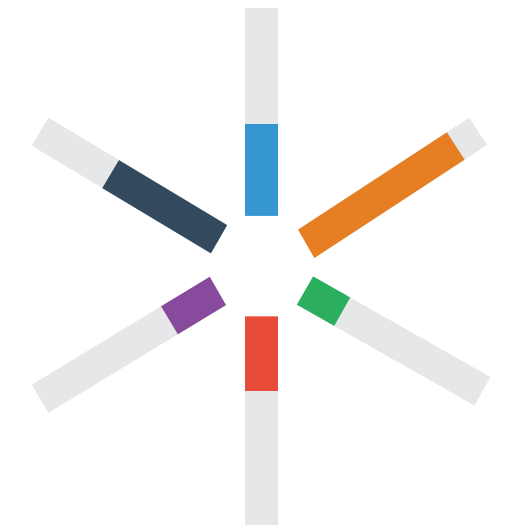


→ Radial



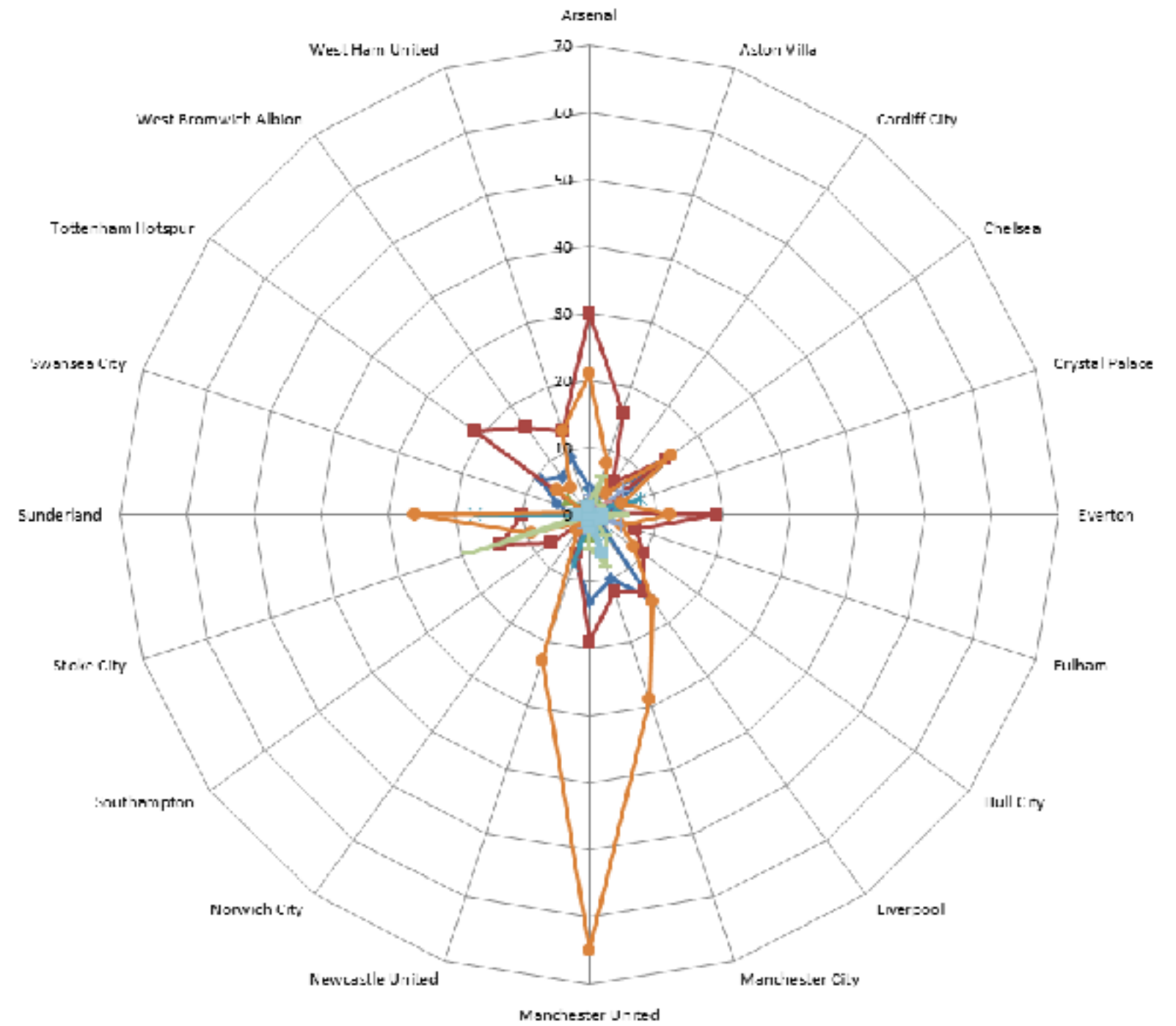
Idioms: radial bar chart, star plot

- star plot
 - line mark, radial axes meet at central point
- radial bar chart
 - line mark, radial axes meet at central ring
 - channels: length, angle/orientation
- bar chart
 - rectilinear axes, aligned vertically
- accuracy
 - length not aligned with radial layouts
 - less accurately perceived than rectilinear aligned



Idiom: radar plot

- radial line chart
 - point marks, radial layout
 - connecting line marks
- avoid unless data is cyclic



“Radar graphs: Avoid them (99.9% of the time)”



Os sinais da bússola eleitoral

Disputa de 2010 foi parecida com a de 2006

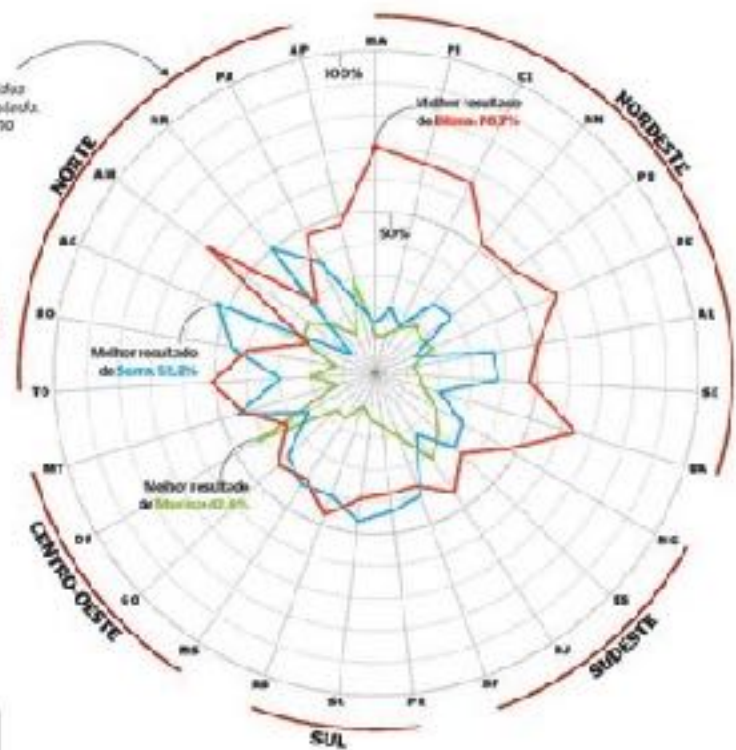
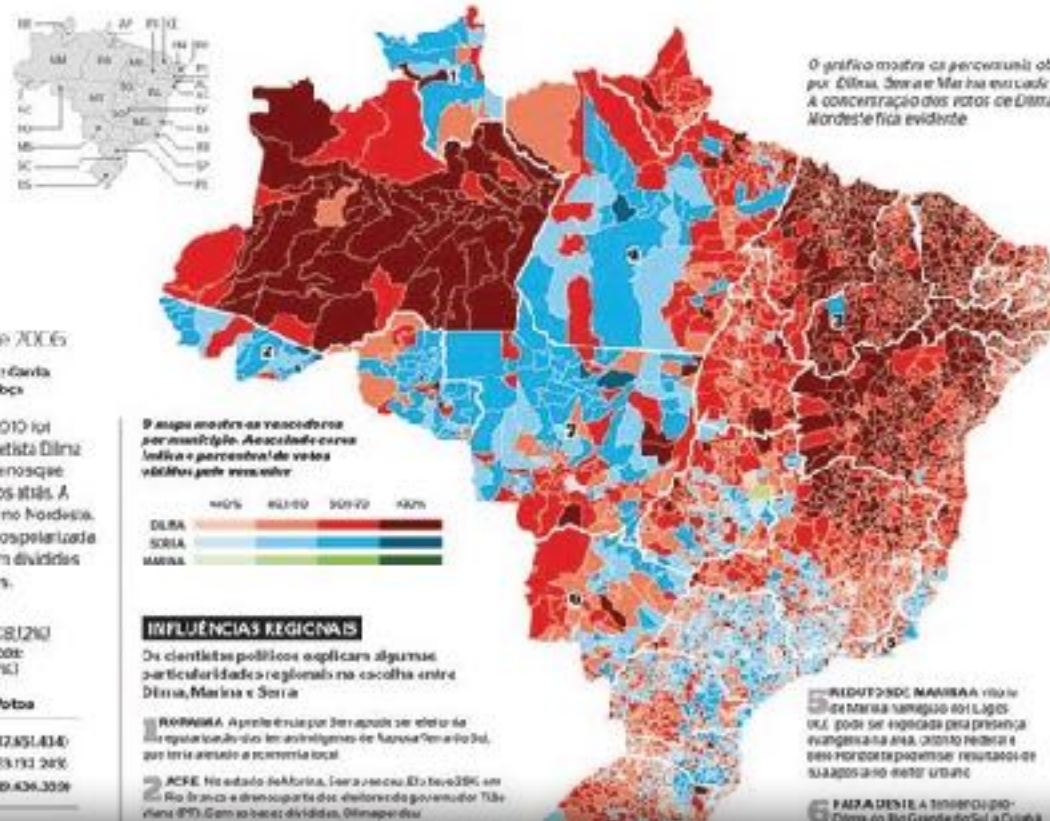
Alberto Campos, Alexandre Moraes, Carlos Eduardo Cruz, Carlos Elias, Daniel Junior, Marco Vergetti e Ricardo Mendes

O **PRIMEIRO** turno da eleição presidencial de 2010 foi muito parecido com o da disputa de 2006. Apesar de Dilma Rousseff ter apenas 17 pontos percentuais menos que o índice obtido pelo presidente Lula quatro anos atrás, a concentração maior de seus votos também foi no Nordeste. Dessa vez, porém, a disputa foi um pouco menos polarizada. Os votos que se dividiram segundo turno foram divididos entre o tucano José Serra e a verde Marina Silva.

Votos: 135.904.433, **abstenção:** 24.610.296 (18,12%)
votos válidos: 101.590.157 (91,36%), **votos brancos:** 3.479.340 (3,39%) e **votos nulos:** 6.510.754 (6,39%)

Candidato	votos	Porcentagem
Dilma Rousseff (PT)	47.851.434	46,9%
José Serra (PSDB)	33.732.289	33,0%
Marina Silva (PV)	19.826.309	19,3%

Outros candidatos
 Nilcéia Freixo (PSC)
 José Maria Cyrus (PSC)
 Sá Maria (PSC)
 Ney Nóbis (PSC)
 Ivan Pinheiro (PSC)
 Rui Costa Pinheiro (PSC)

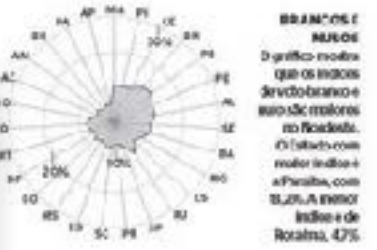
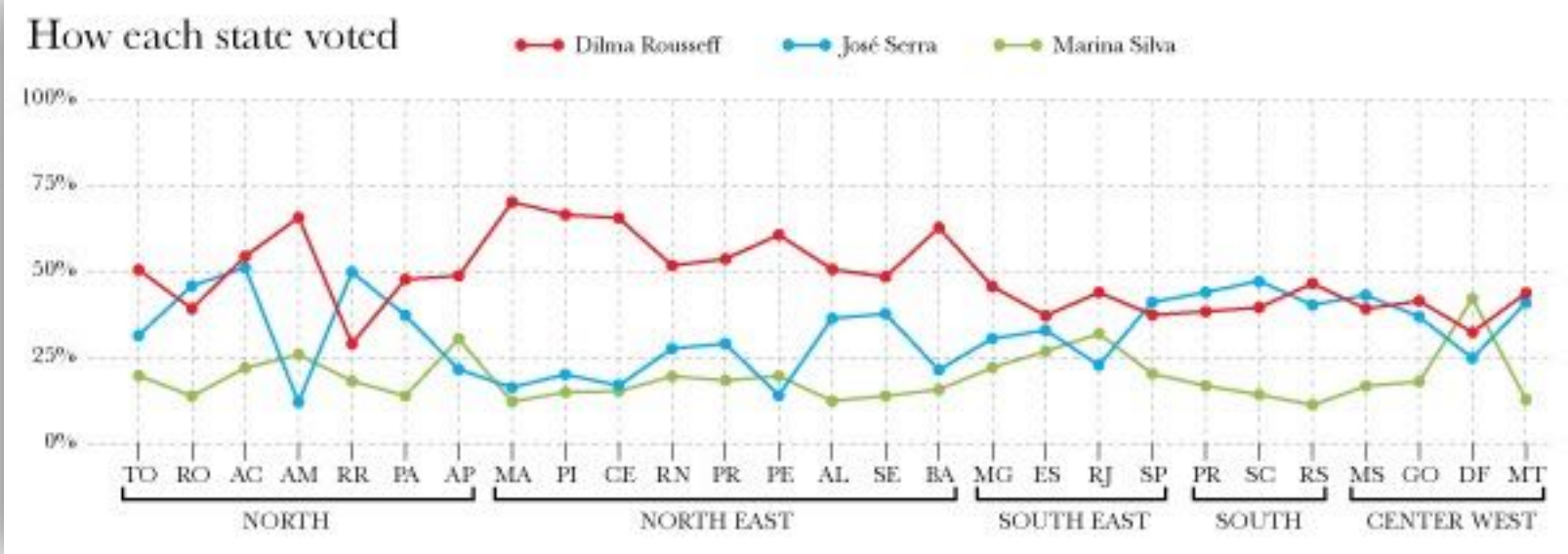


INFLUÊNCIAS REGIONAIS

Os cientistas políticos explicam algumas particularidades regionais na caçolha entre Dilma, Marina e Serra

- PARANÁ:** A preferência por Serra após se eleger o governador foi influenciada pelo apoio de Fernando Collor, por ter a atuação a ser vista local.
- ACRE:** Heraldo de Moura, Serra venceu. Ele teve 29% em Rio Branco e drenou parte dos eleitores do governador Tilden Fritsch. Com o seu apoio, Dilma perdeu.
- PARANÁ:** A preferência por Marina após o primeiro turno pode ser explicada pela presença evangélica na área. O voto recediu e Serra derrotou a paqueta. Resultados de 2010: Serra 40%, Dilma 30%.
- PARANÁ:** Dilma do Rio Grande do Sul e Curitiba.

original
difficult to interpret



redesign for
rectilinear

Idioms: pie chart, coxcomb chart

- pie chart

- **interlocking area** marks with angle channel: **2D area varies**

- separated & ordered radially, uniform height

- accuracy: area less accurate than rectilinear aligned line length

- **task: part-to-whole judgements**

- coxcomb chart

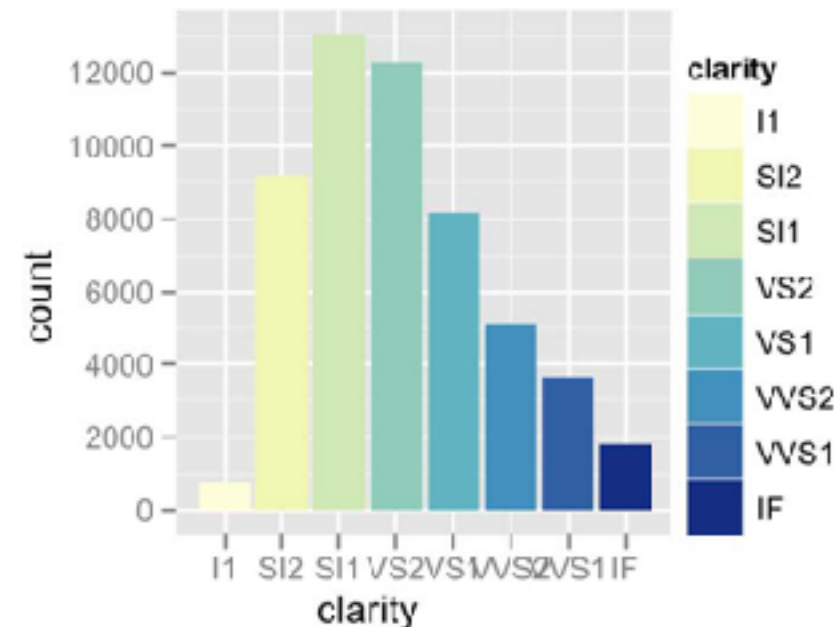
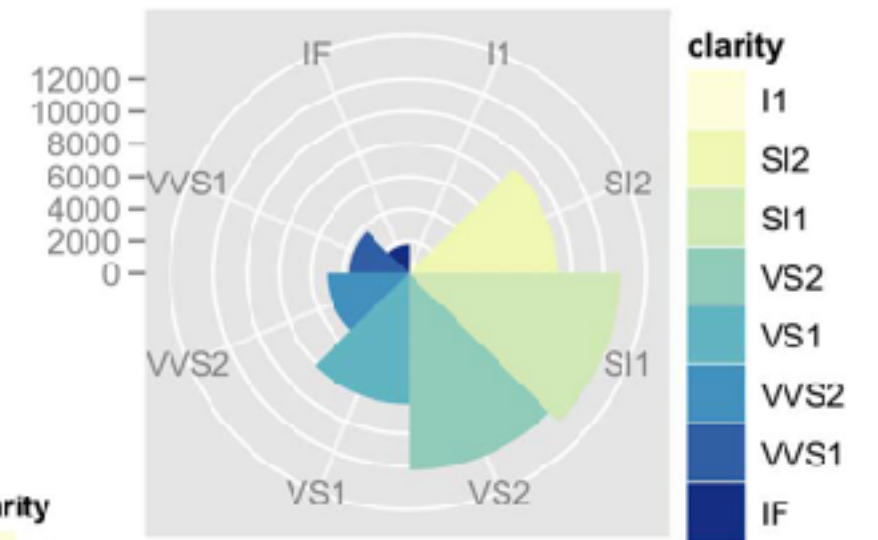
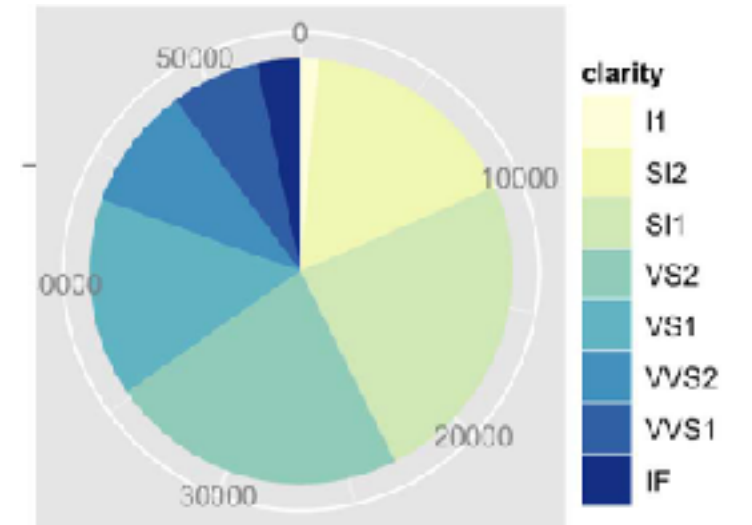
- line marks with length channel: **ID length varies**

- separated & ordered radially, uniform width

- direct analog to radial bar charts

- data

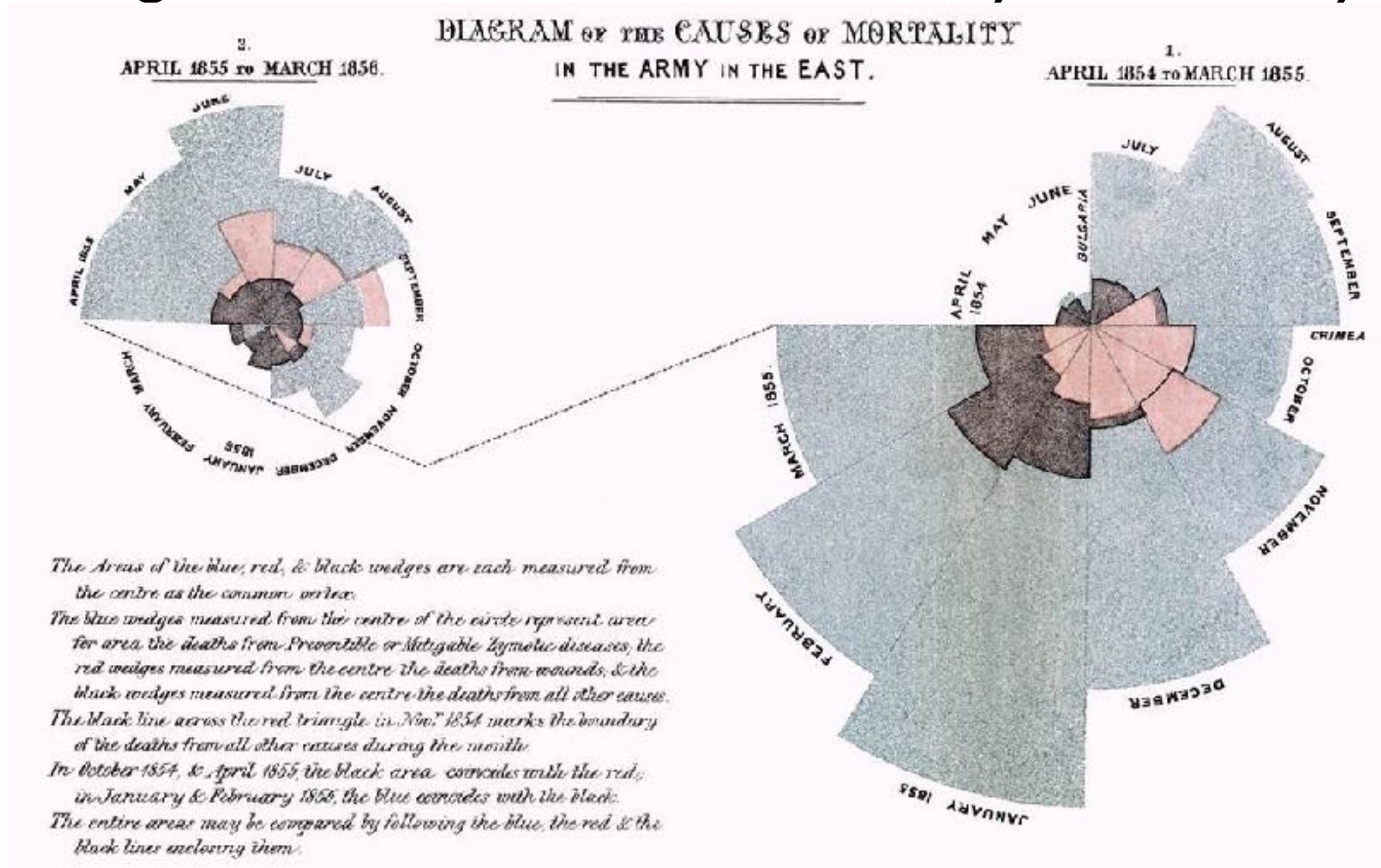
- I categ key attrib, I quant value attrib



[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

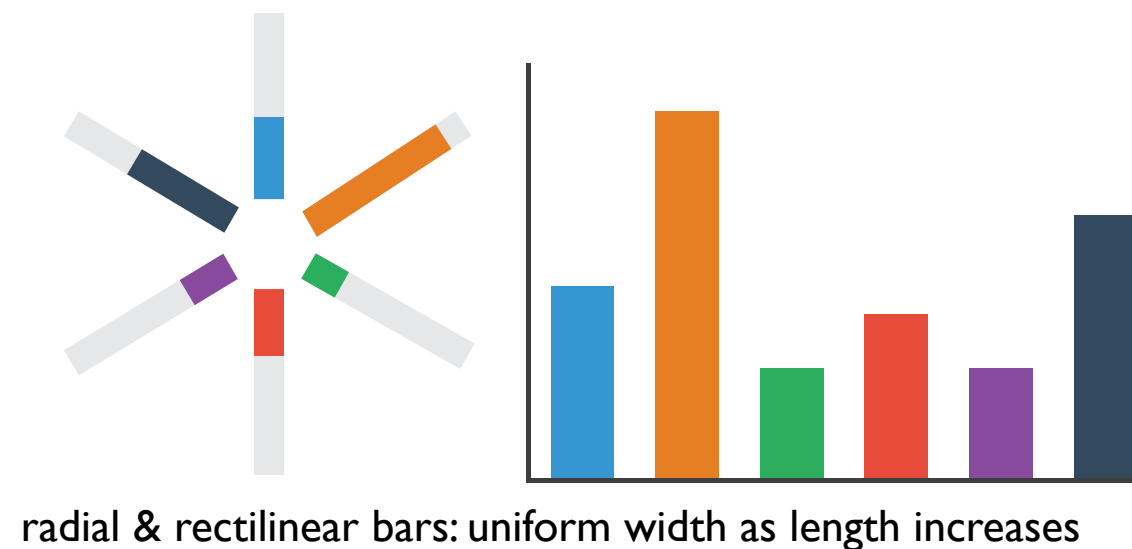
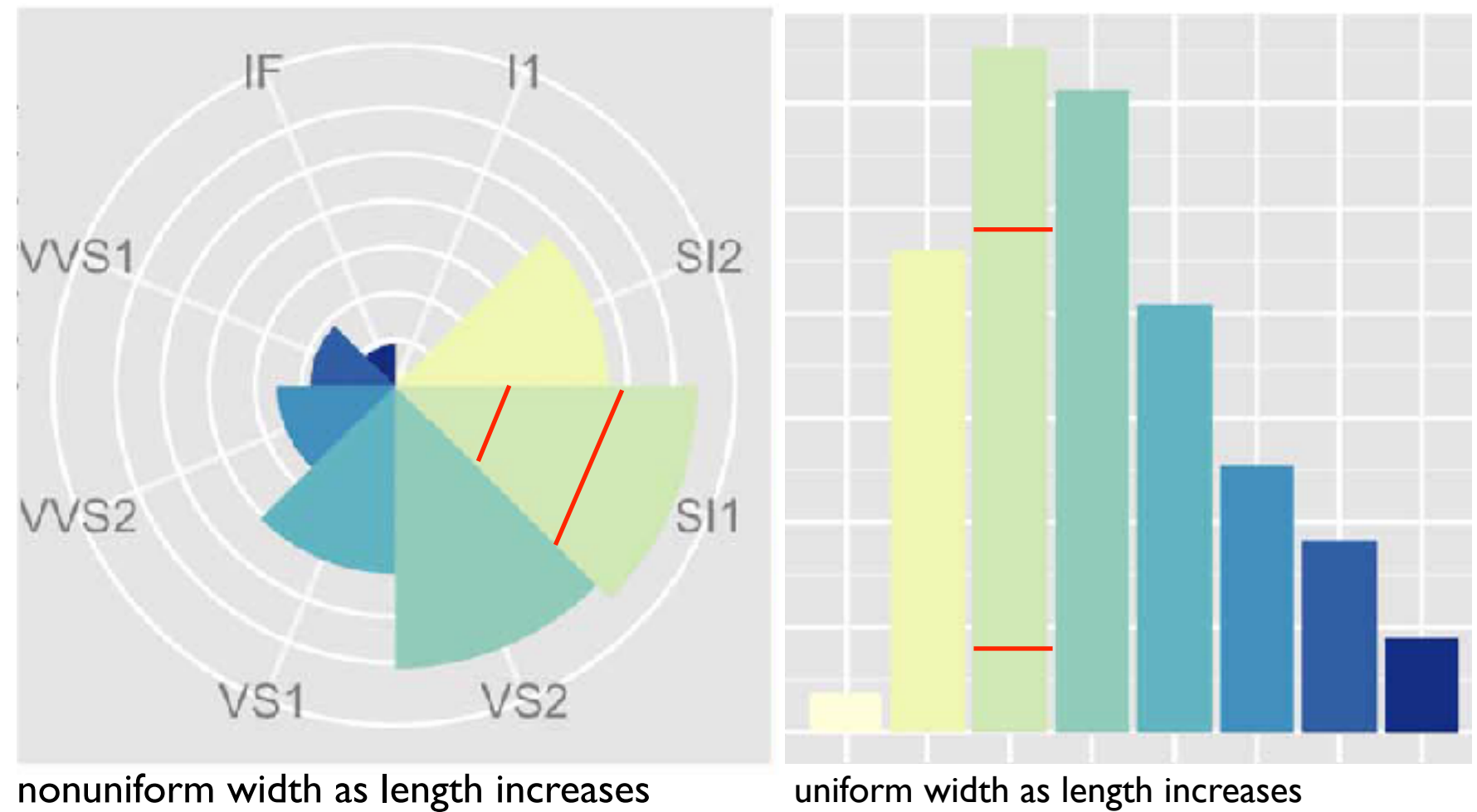
Coxcomb / nightingale rose / polar area chart

- invented by Florence Nightingale:
Diagram of the Causes of Mortality in the Army in the East



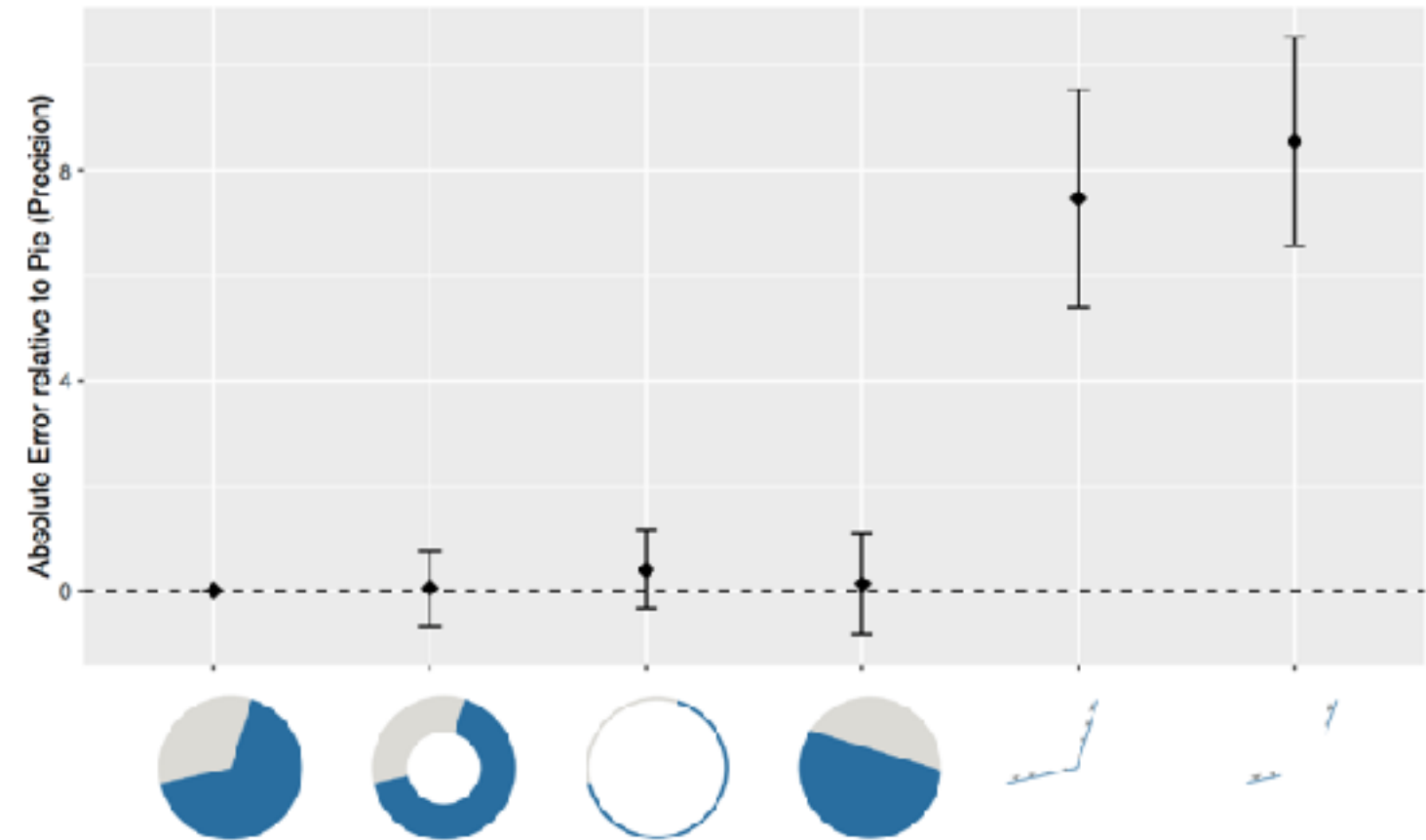
Coxcomb: perception

- encode: **ID length**
- decode/perceive: **2D area**
- nonuniform line/sector width as length increases
 - so area variation is nonlinear wrt line mark length!
- bar chart safer: uniform width, so area is linear with line mark length
 - **both radial & rectilinear cases**



Pie charts: perception

- some empirical evidence that people respond to arc length
 - decode/perceive: not angles
 - maybe also areas?...
- donut charts no worse than pie charts



[Arcs, Angles, or Areas: Individual Data Encodings in Pie and Donut Charts. Skau and Kosara. Proc. EuroVis 2016.]

<https://eagereyes.org/blog/2016/an-illustrated-tour-of-the-pie-chart-study-results>

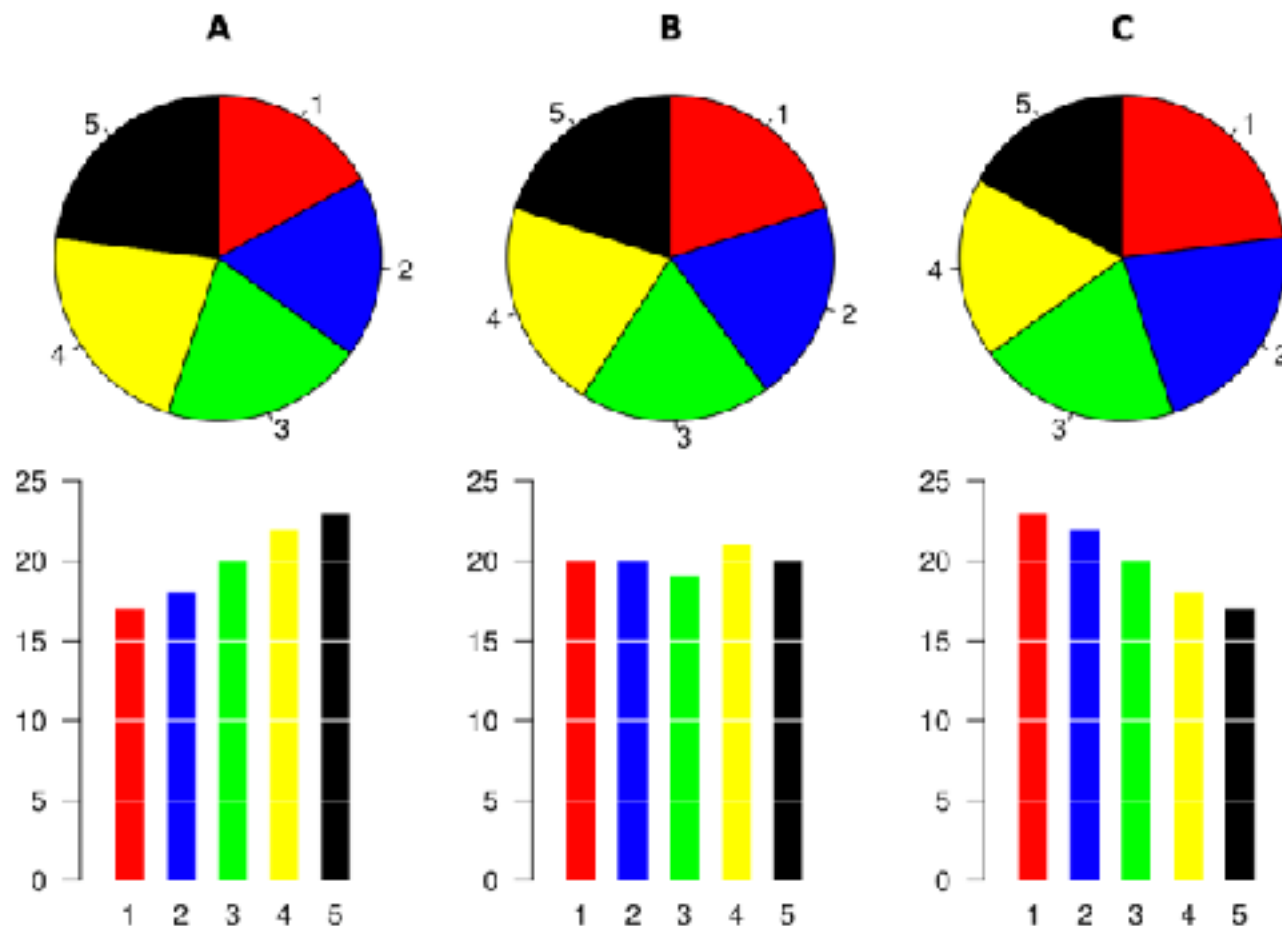
Pie charts: best practices

- not so bad for two (or few) levels, for part-to-whole task



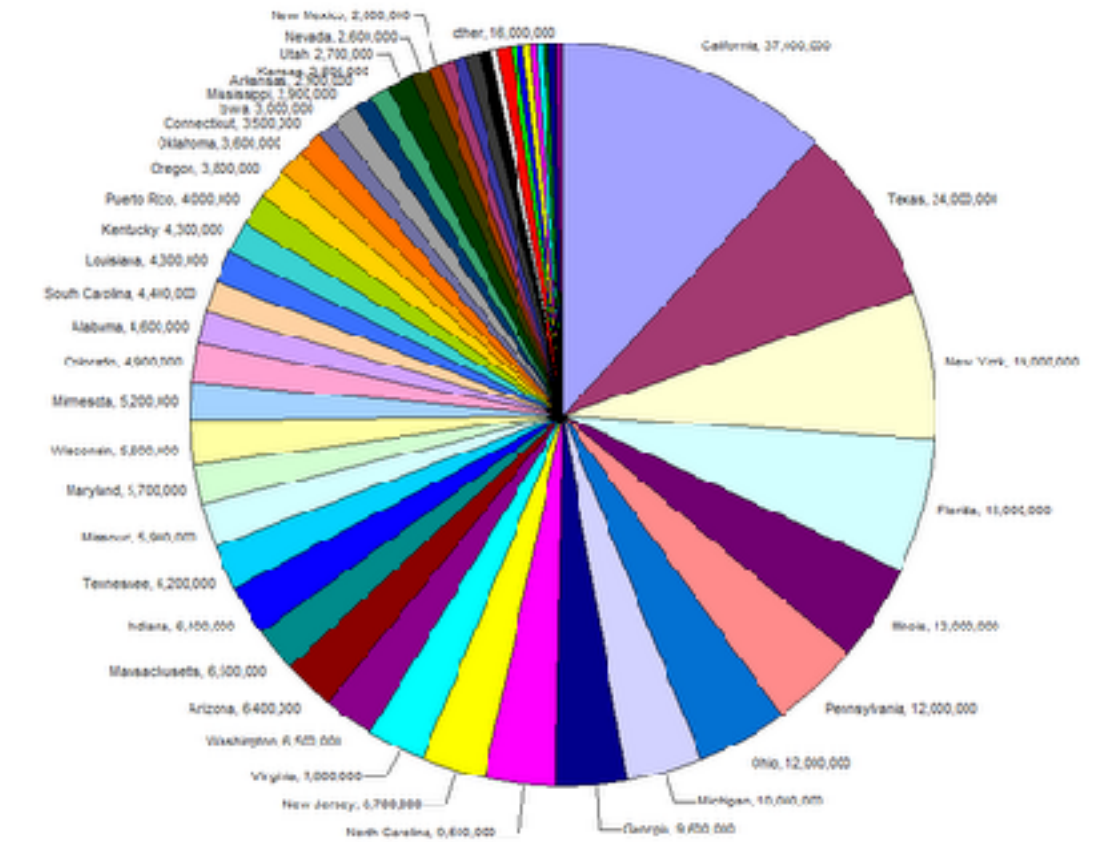
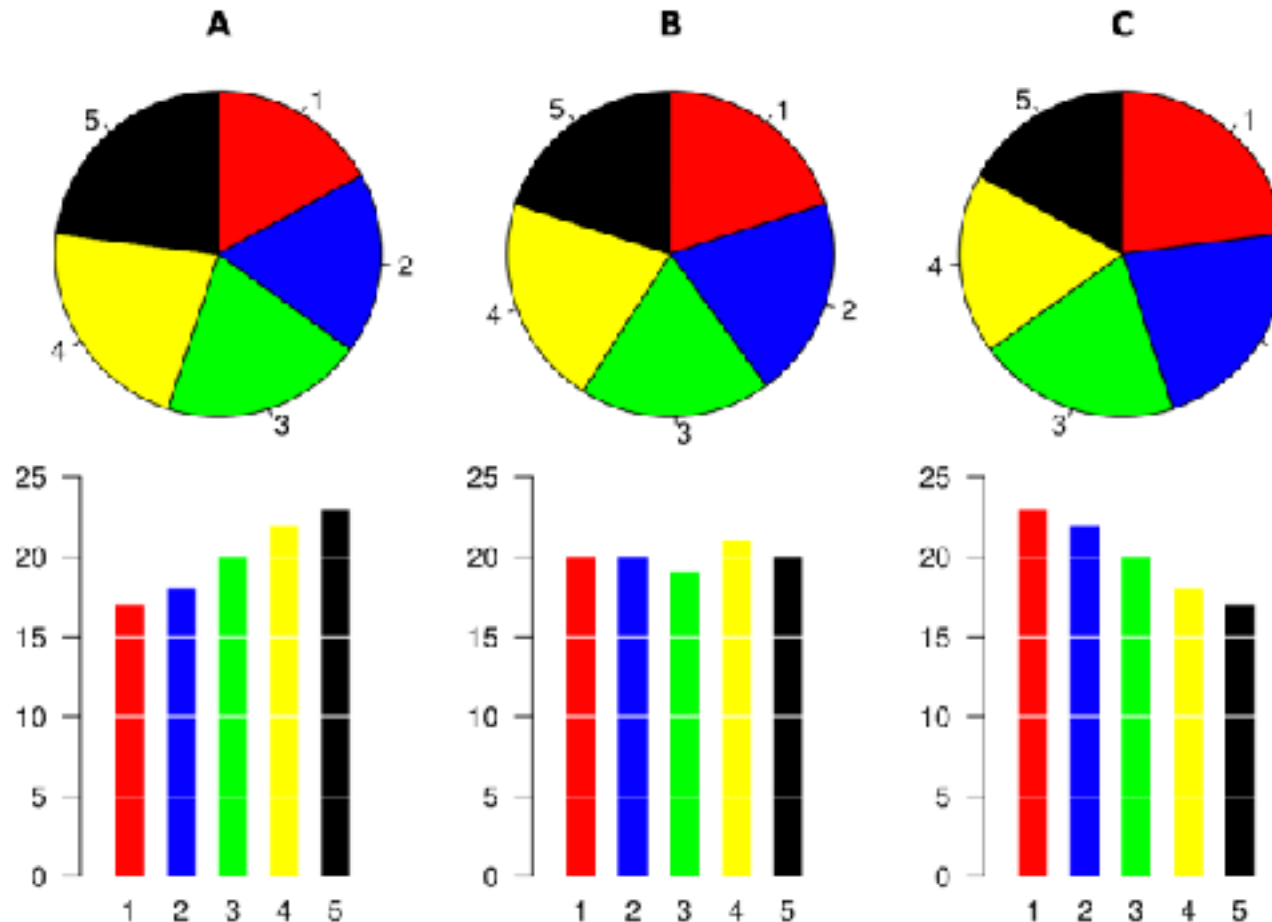
Pie charts: best practices

- not so bad for two (or few) levels, for part-to-whole task
- dubious for several levels if details matter



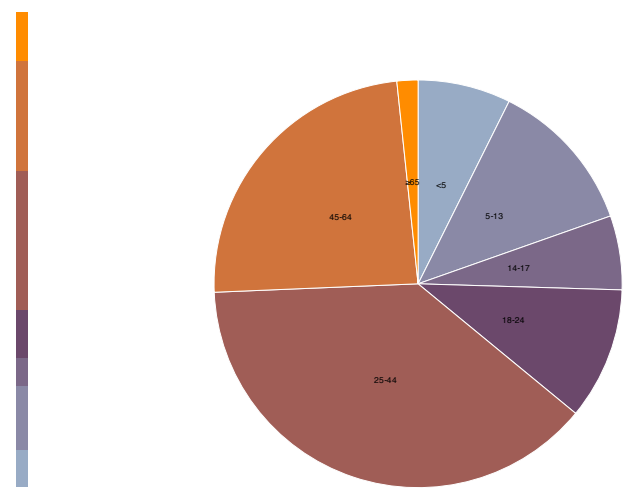
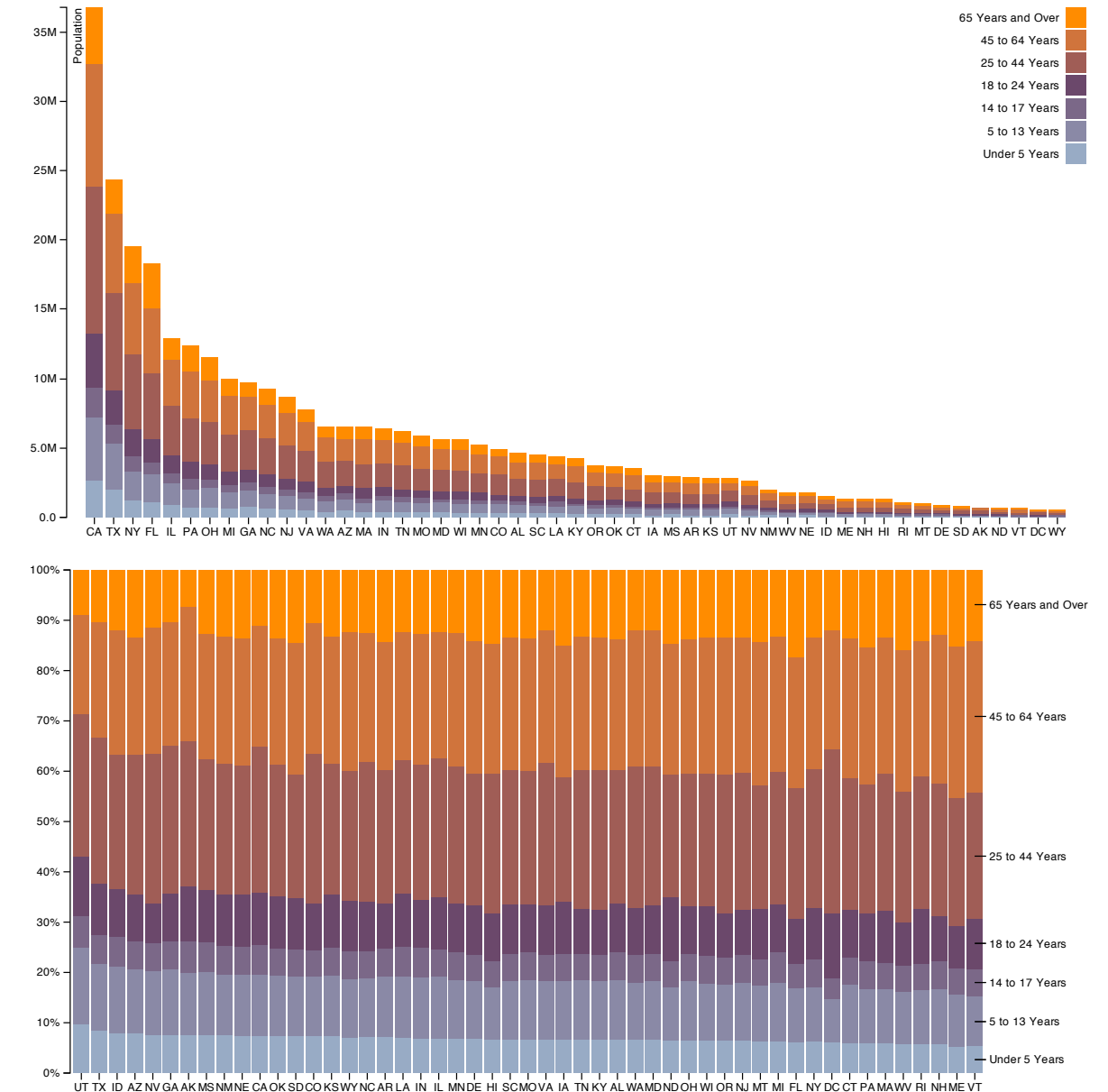
Pie charts: best practices

- not so bad for two (or few) levels, for part-to-whole task
- dubious for several levels if details matter
- terrible for many levels



Idioms: **normalized stacked bar chart**

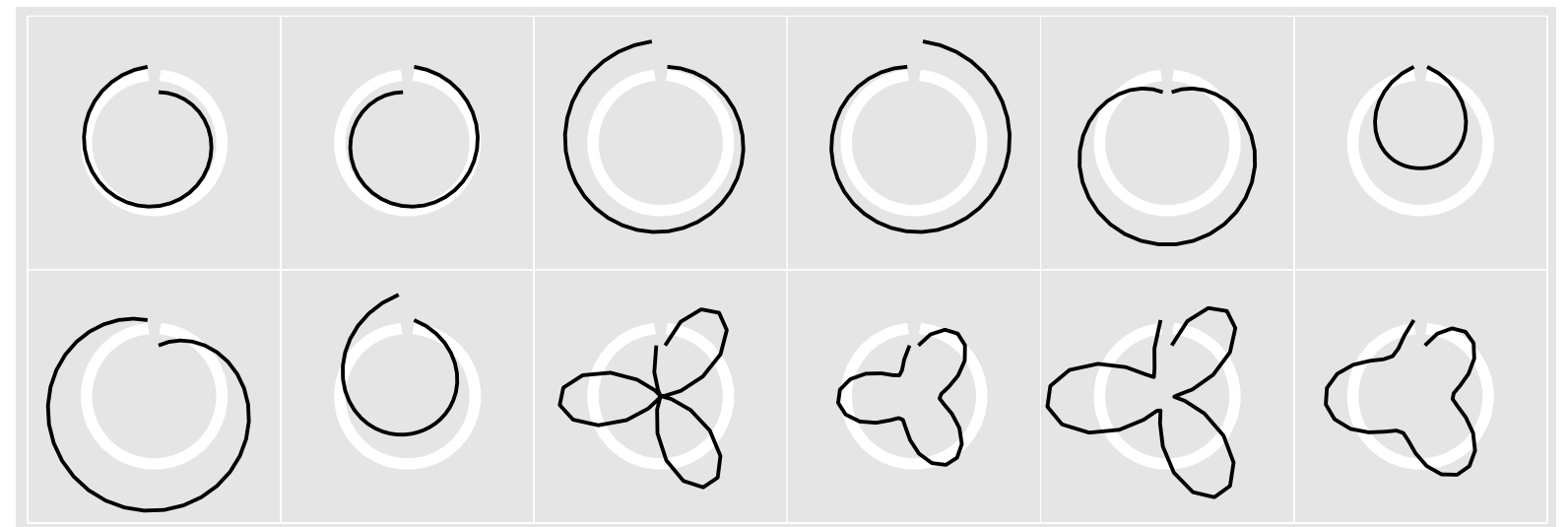
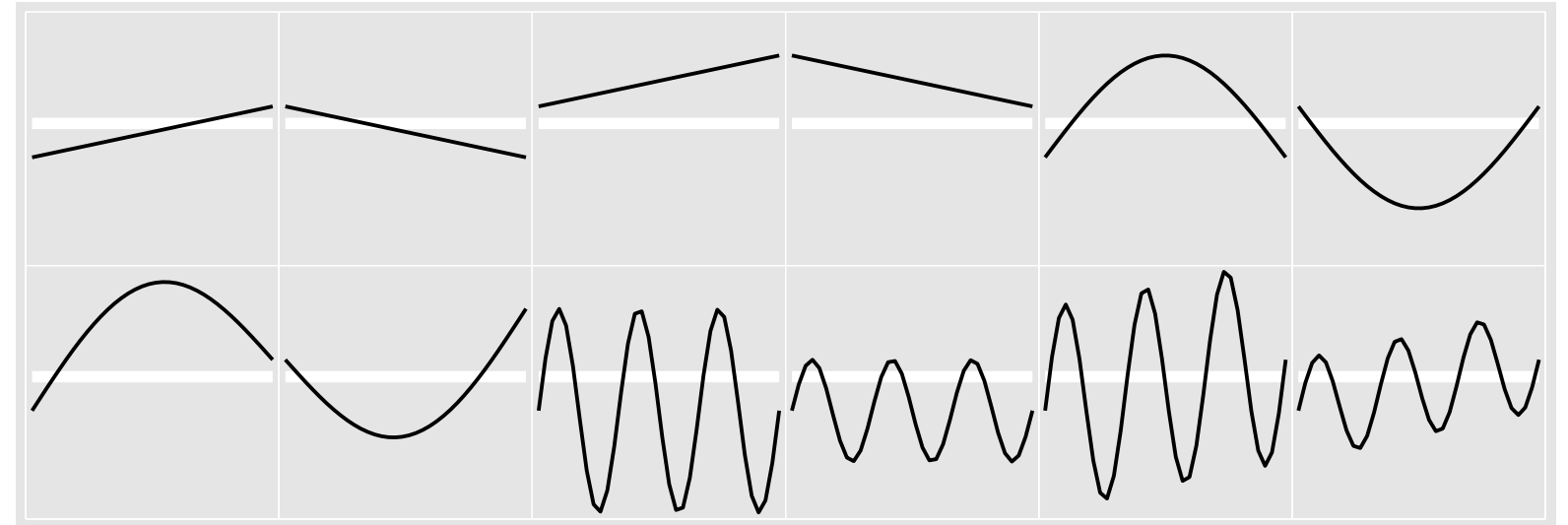
- task
 - part-to-whole judgements
- **normalized stacked bar chart**
 - stacked bar chart, normalized to full vert height
 - single stacked bar equivalent to full pie
 - high information density: requires narrow rectangle
- **pie chart**
 - information density: requires large circle



<http://bl.ocks.org/mbostock/3886208>,
<http://bl.ocks.org/mbostock/3887235>,
<http://bl.ocks.org/mbostock/3886394>.

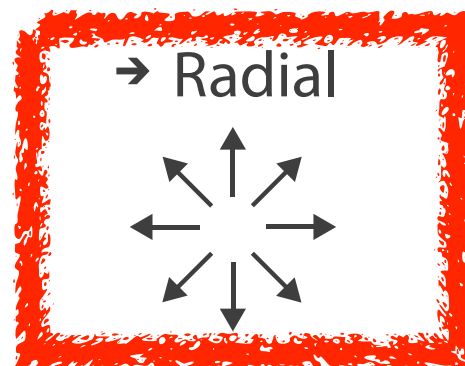
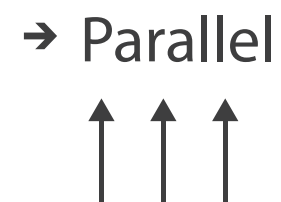
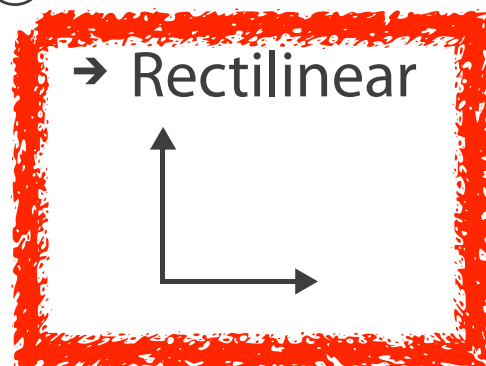
Idiom: **glyphmaps**

- rectilinear good for linear vs nonlinear trends
- radial good for cyclic patterns
 - evaluating periodicity



[Glyph-maps for Visually Exploring Temporal Patterns in Climate Data and Models. Wickham, Hofmann, Wickham, and Cook. *Environmetrics* 23:5 (2012), 382–393.]

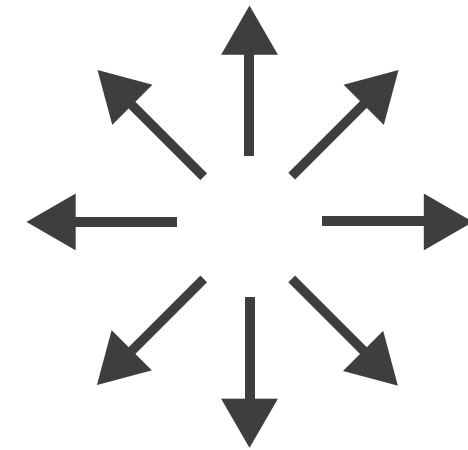
➔ Axis Orientation



→ Axis Orientation

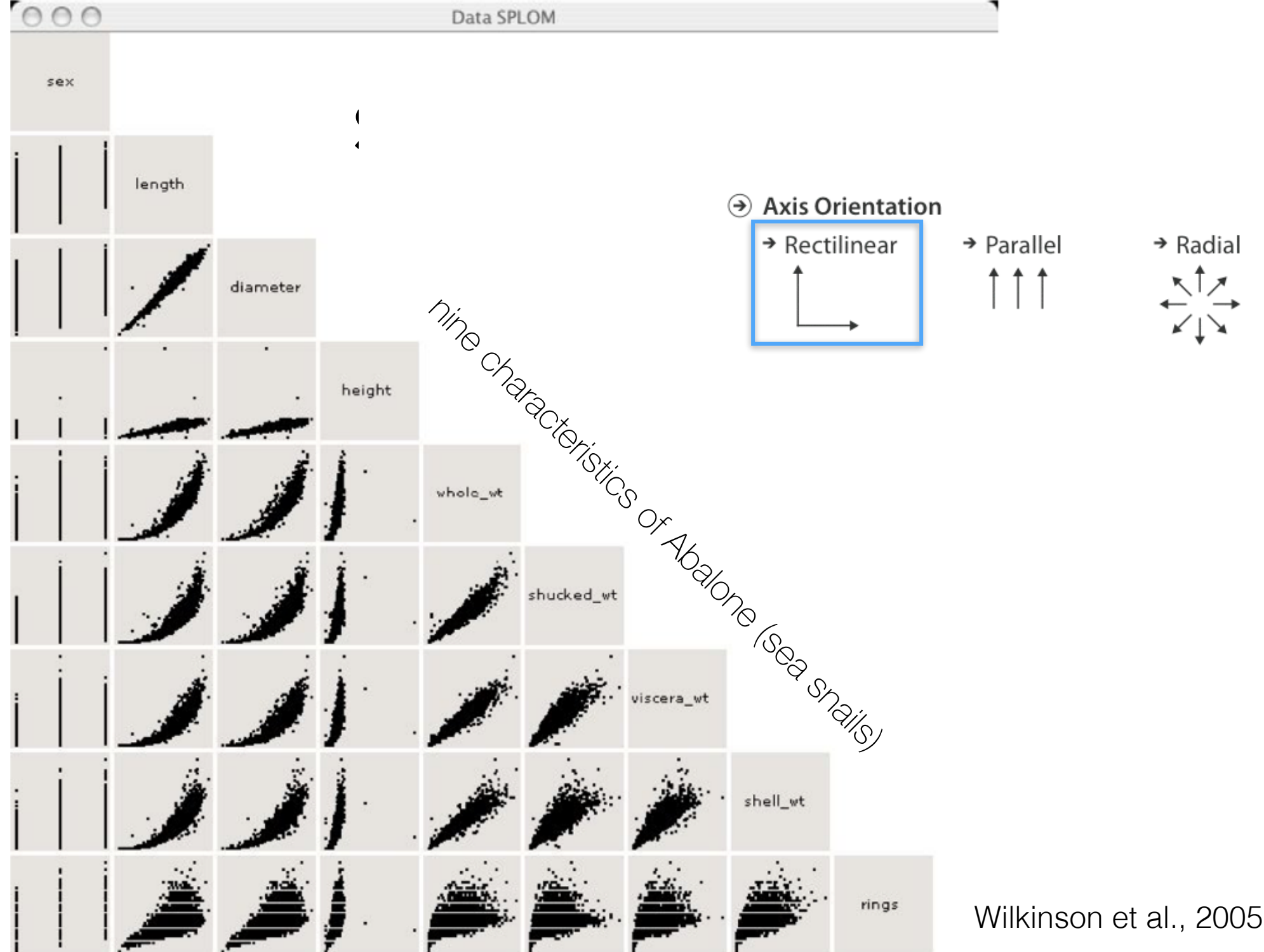


→ Radial



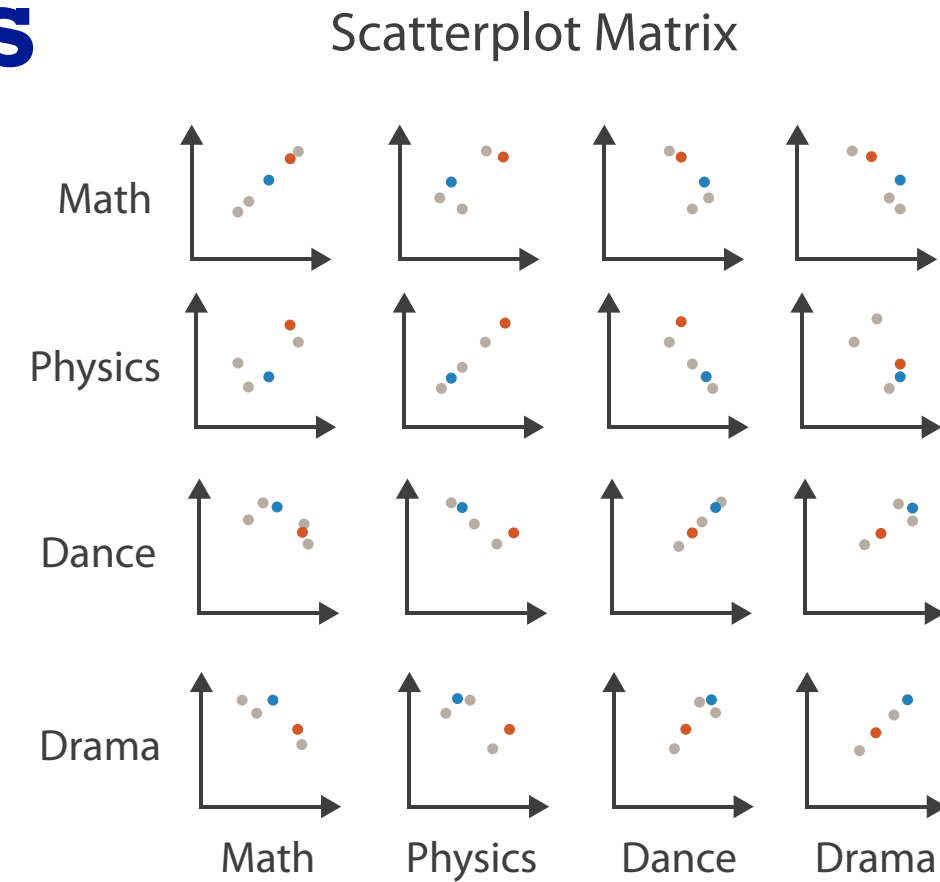
Idiom: **SPL**OM

- scatterplot matrix (SPL**OM**)
 - rectilinear axes, point mark
 - all possible pairs of axes
 - scalability
 - one dozen attribs
 - dozens to hundreds of items



Idioms: parallel coordinates

- scatterplot limitation
 - visual representation with orthogonal axes
 - can show only two attributes with spatial position channel



Table

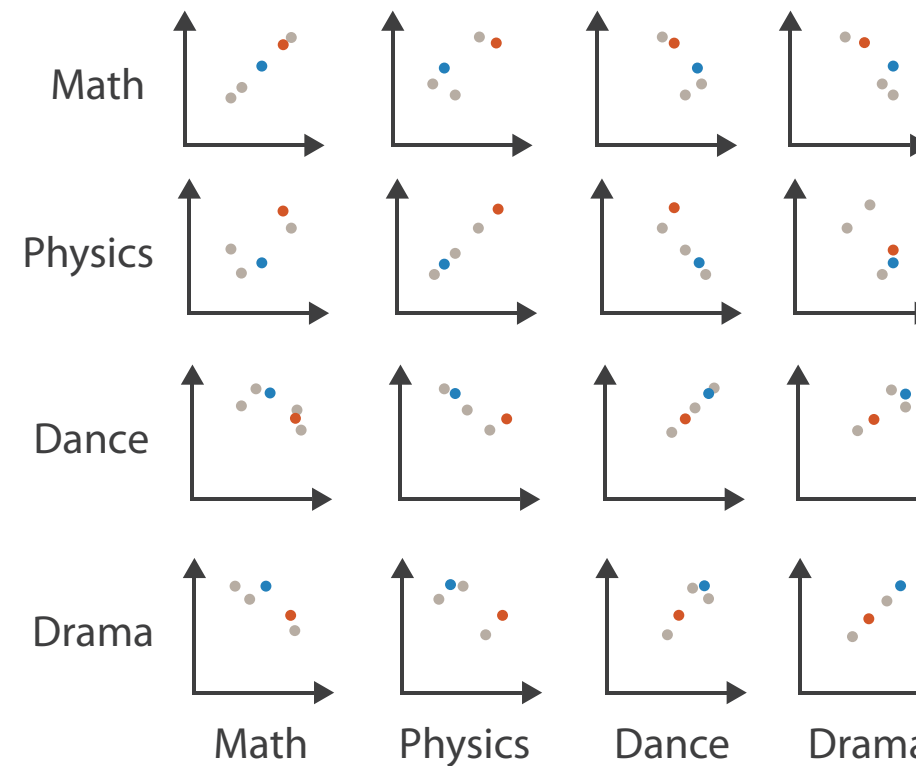
Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

after [Visualization Course Figures. McGuffin, 2014.
<http://www.michaelmcguffin.com/courses/vis/>]

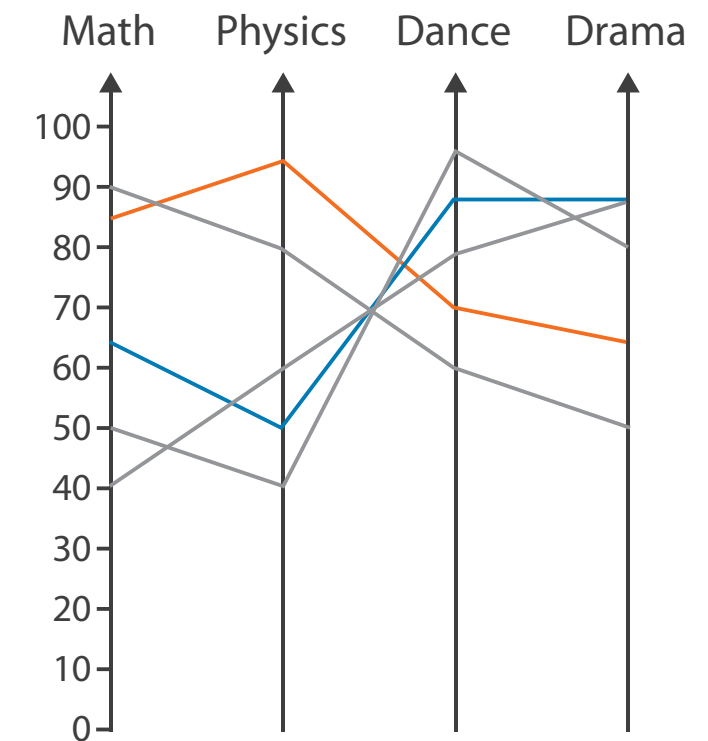
Idioms: parallel coordinates

- scatterplot limitation
 - visual representation with orthogonal axes
 - can show only two attributes with spatial position channel
- alternative: line up axes in parallel to show many attributes with position
 - item encoded with a line with n segments
 - n is the number of attributes shown
- parallel coordinates
 - parallel axes, jagged line for item
 - rectilinear axes, item as point
 - axis ordering is major challenge
 - scalability
 - dozens of attribs
 - hundreds of items

Scatterplot Matrix



Parallel Coordinates



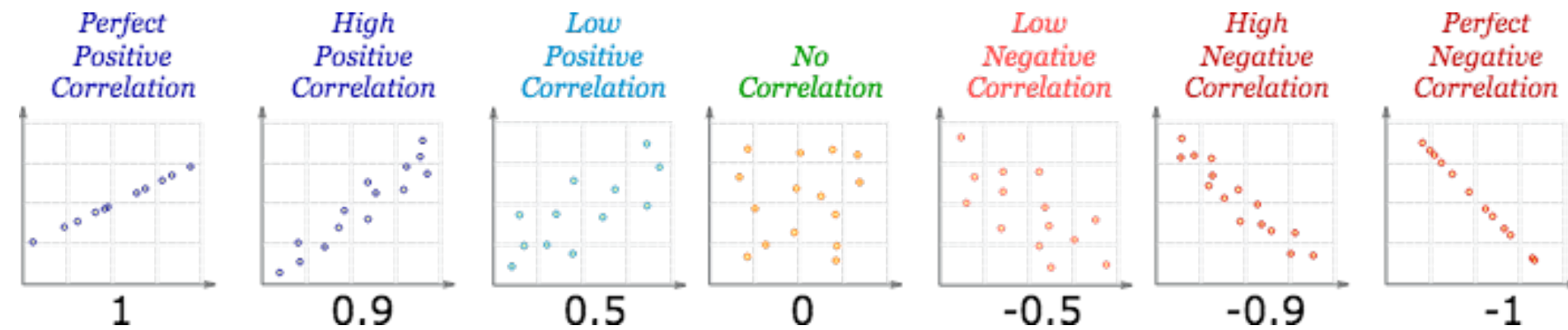
Table

Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

after [Visualization Course Figures. McGuffin, 2014.
<http://www.michaelmcguffin.com/courses/vis/>]

Task: Correlation

- scatterplot matrix
 - positive correlation
 - diagonal low-to-high
 - negative correlation
 - diagonal high-to-low
 - uncorrelated: spread out
- parallel coordinates
 - positive correlation
 - parallel line segments
 - negative correlation
 - all segments cross at halfway point
 - uncorrelated
 - scattered crossings



<https://www.mathsisfun.com/data/scatter-xy-plots.html>

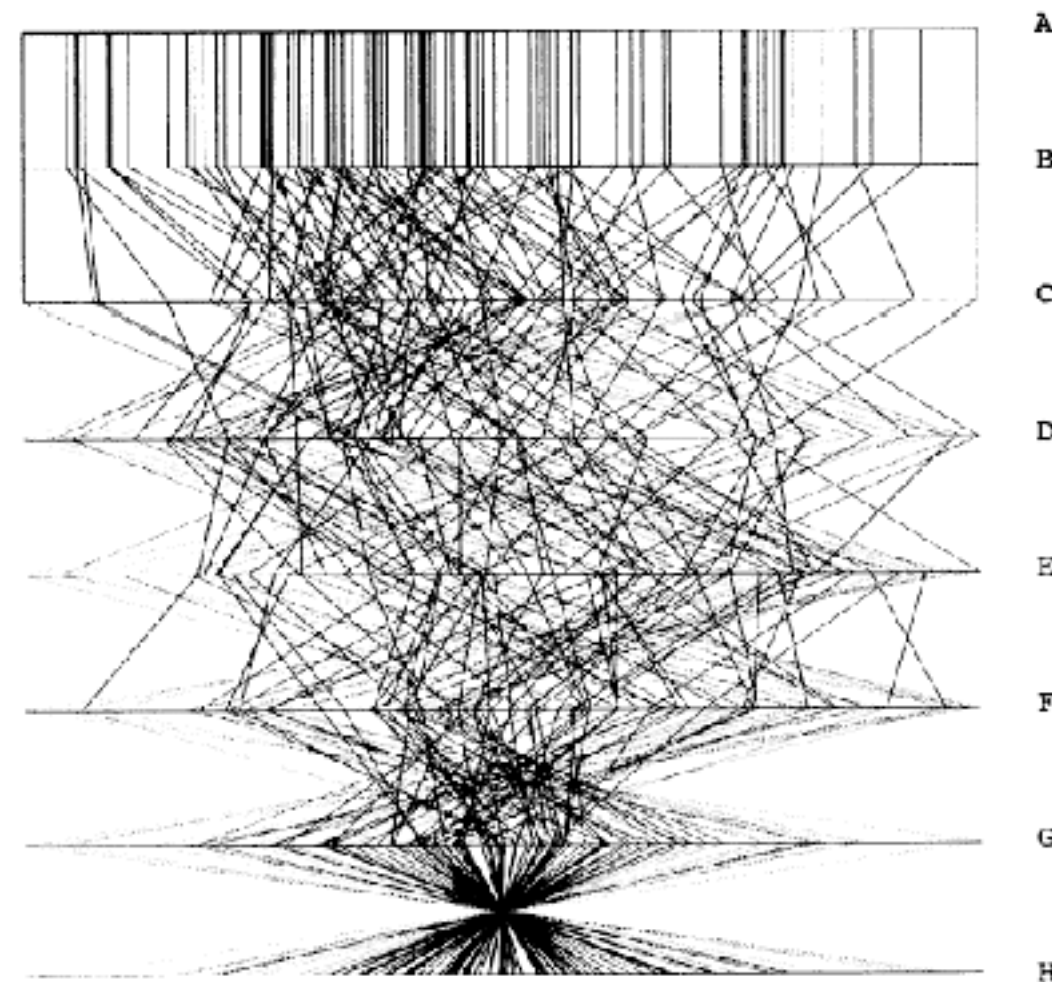
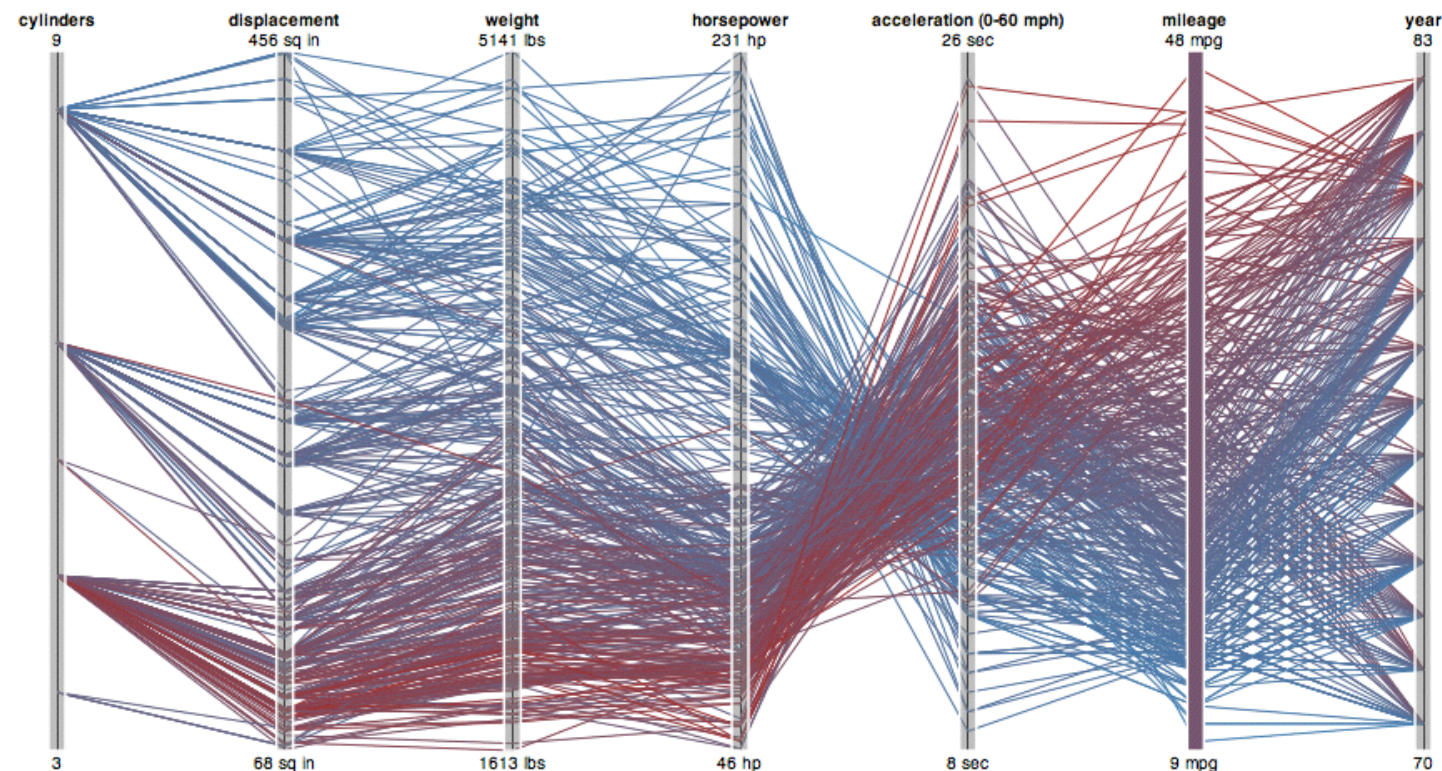


Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of $\rho = 1, .8, .2, 0, -.2, -.8, \text{ and } -1$.

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. *Journ. American Statistical Association* 85:411 (1990), 664–675.]

Parallel coordinates, limitations

- visible patterns only between neighboring axis pairs
- how to pick axis order?
 - usual solution: reorderable axes, interactive exploration
 - same weakness as many other techniques
 - downside of interaction: human-powered search
 - some algorithms proposed, none fully solve

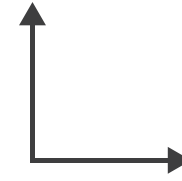


Orientation limitations

- rectilinear: scalability wrt #axes
 - 2 axes best, 3 problematic, 4+ impossible

⊗ Axis Orientation

→ Rectilinear

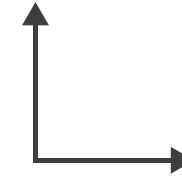


Orientation limitations

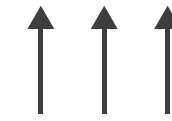
- **rectilinear: scalability wrt #axes**
 - 2 axes best, 3 problematic, 4+ impossible
- **parallel: unfamiliarity, training time**

⊕ Axis Orientation

→ Rectilinear



→ Parallel

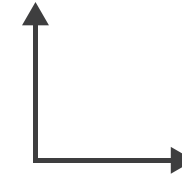


Orientation limitations

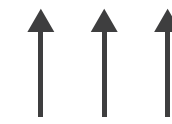
- **rectilinear: scalability wrt #axes**
 - 2 axes best, 3 problematic, 4+ impossible
- **parallel: unfamiliarity, training time**
- **radial: perceptual limits**
 - polar coordinate asymmetry
 - angles lower precision than length
 - nonuniform sector width/size depending on radial distance
 - frequently problematic
 - but sometimes can be deliberately exploited!
 - for 2 attribs of very unequal importance

➔ Axis Orientation

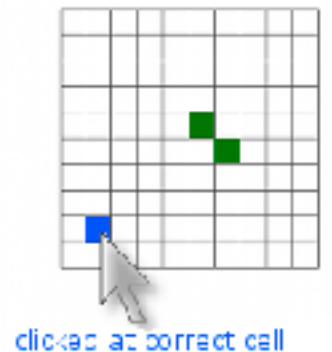
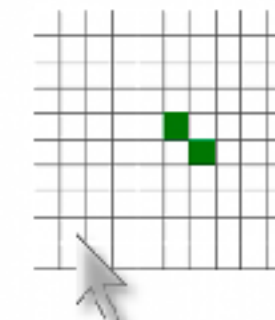
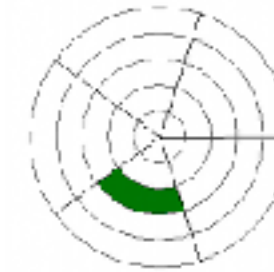
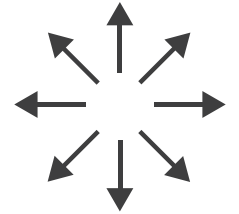
➔ Rectilinear



➔ Parallel



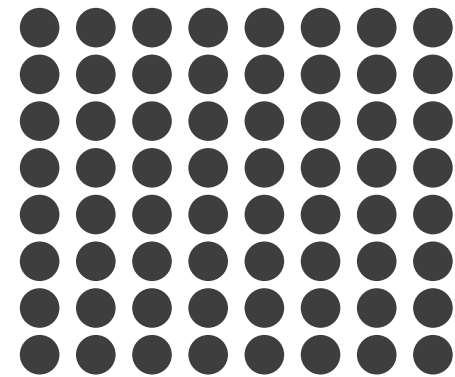
➔ Radial



Layout density

① Layout Density

→ Dense



→ Space-Filling

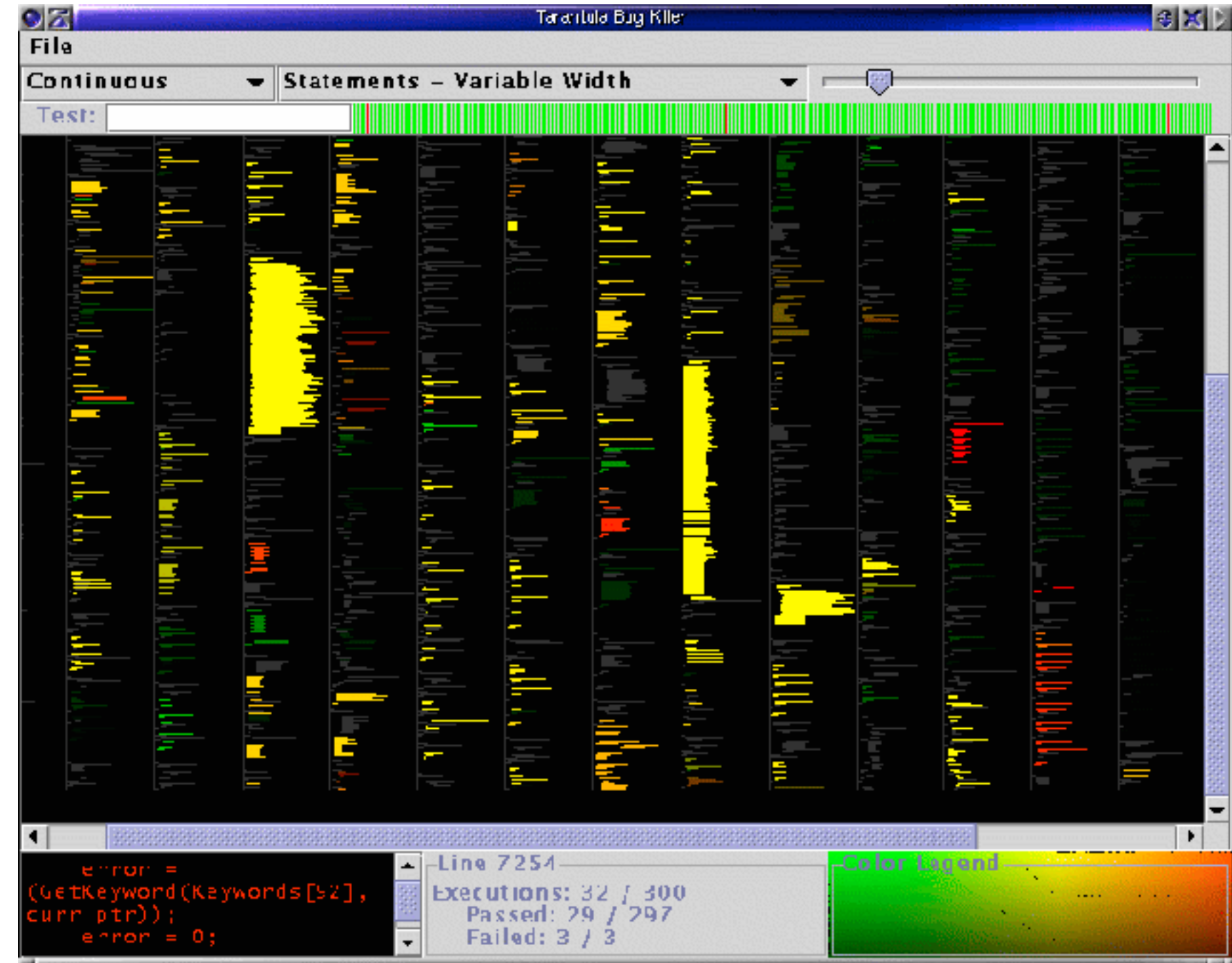
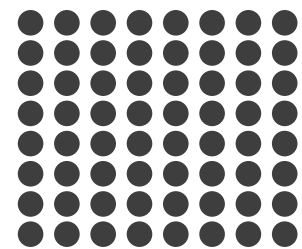


Idiom: Dense software overviews

- data: text
 - text + 1 quant attrib per line
- derived data:
 - one pixel high line
 - length according to original
- color line by attrib
- scalability
 - 10K+ lines

➔ Layout Density

➔ Dense



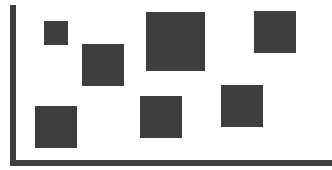
Arrange tables

① Express Values

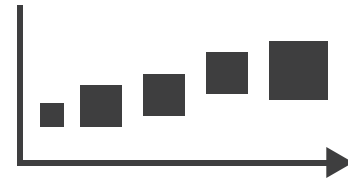


② Separate, Order, Align Regions

→ Separate



→ Order



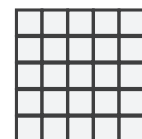
→ Align



→ 1 Key
List

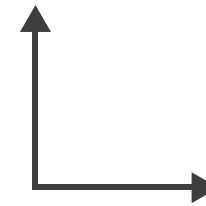


→ 2 Keys
Matrix

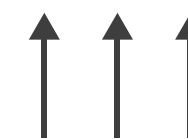


③ Axis Orientation

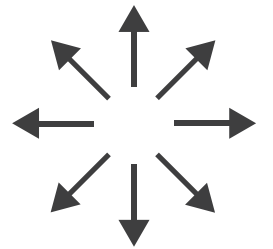
→ Rectilinear



→ Parallel

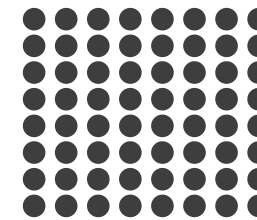


→ Radial



④ Layout Density

→ Dense



How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



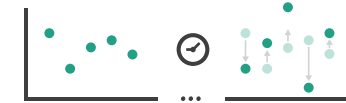
→ Motion

Direction, Rate, Frequency, ...

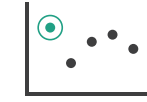


Manipulate

→ Change



→ Select



→ Navigate

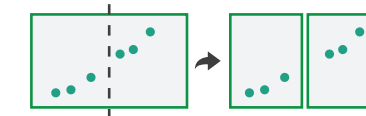


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

→ Filter



→ Aggregate



→ Embed



What?

Why?

How?

How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



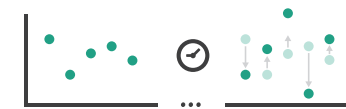
→ Motion

Direction, Rate, Frequency, ...

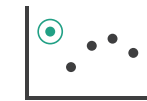


Manipulate

→ Change



→ Select



→ Navigate

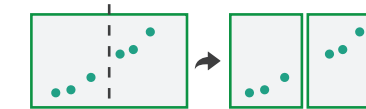


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

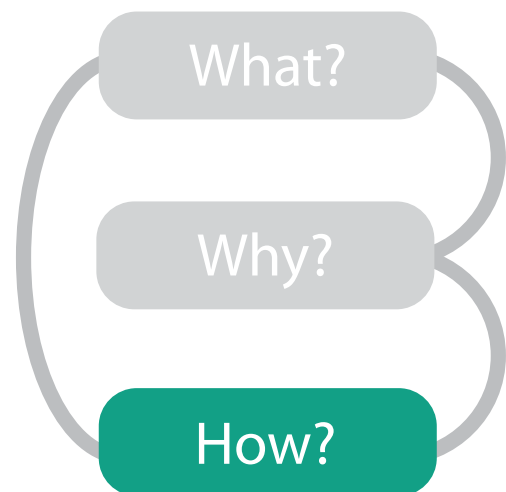
→ Filter



→ Aggregate



→ Embed



Visualization Analysis & Design

Tables (Ch 7) III

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)

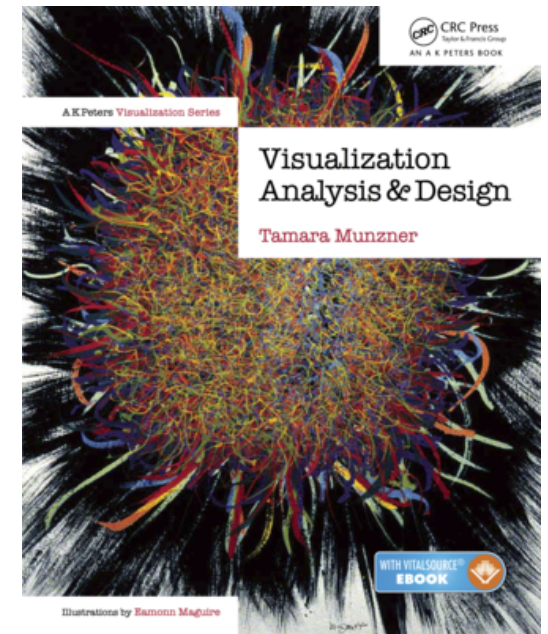
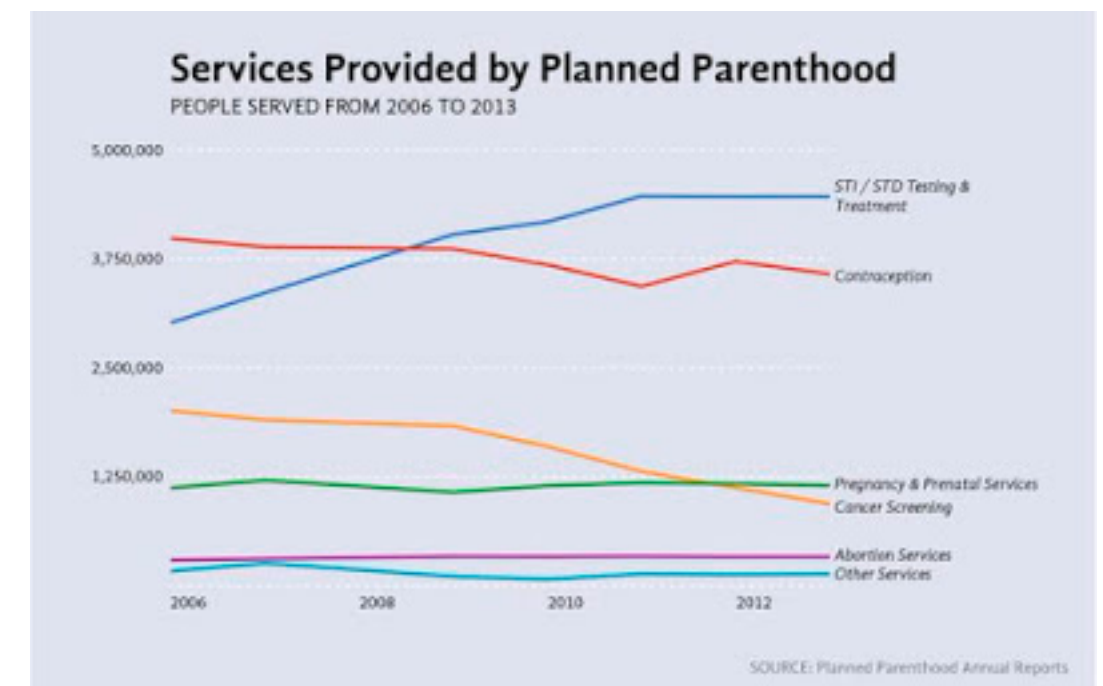
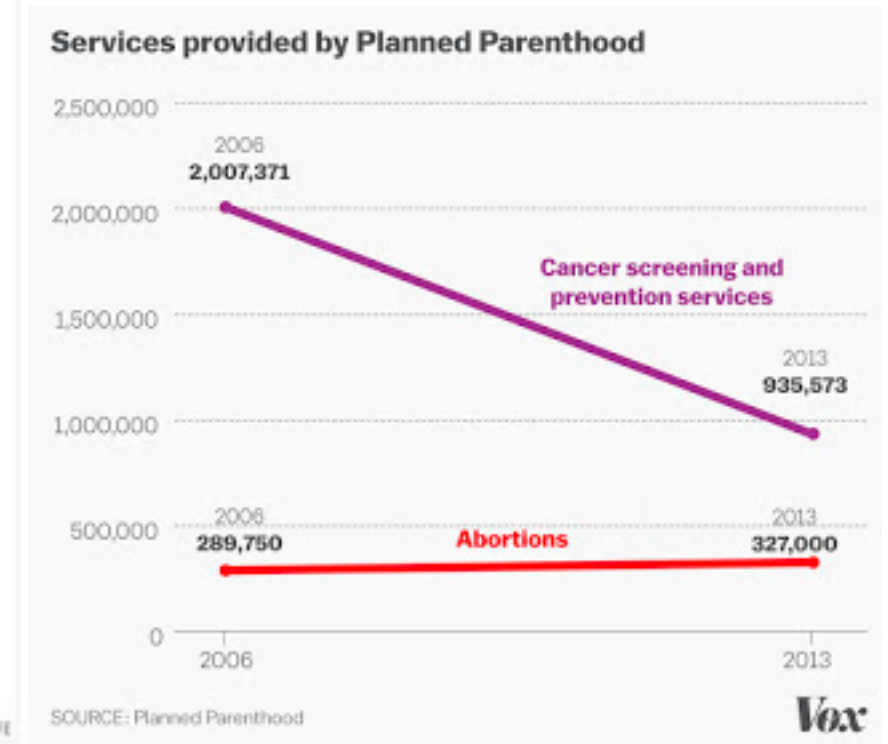
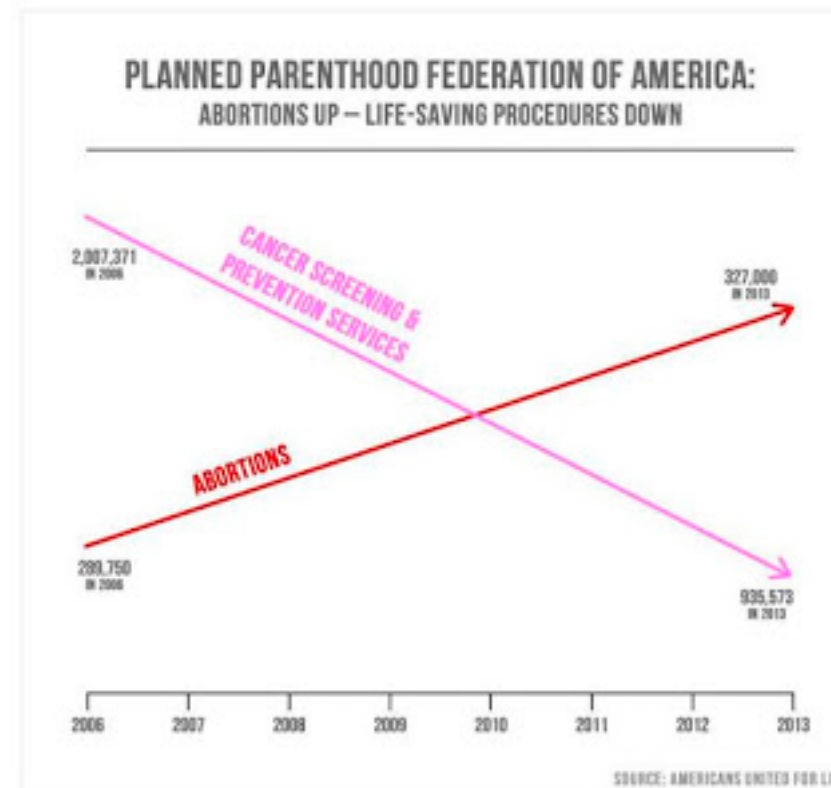


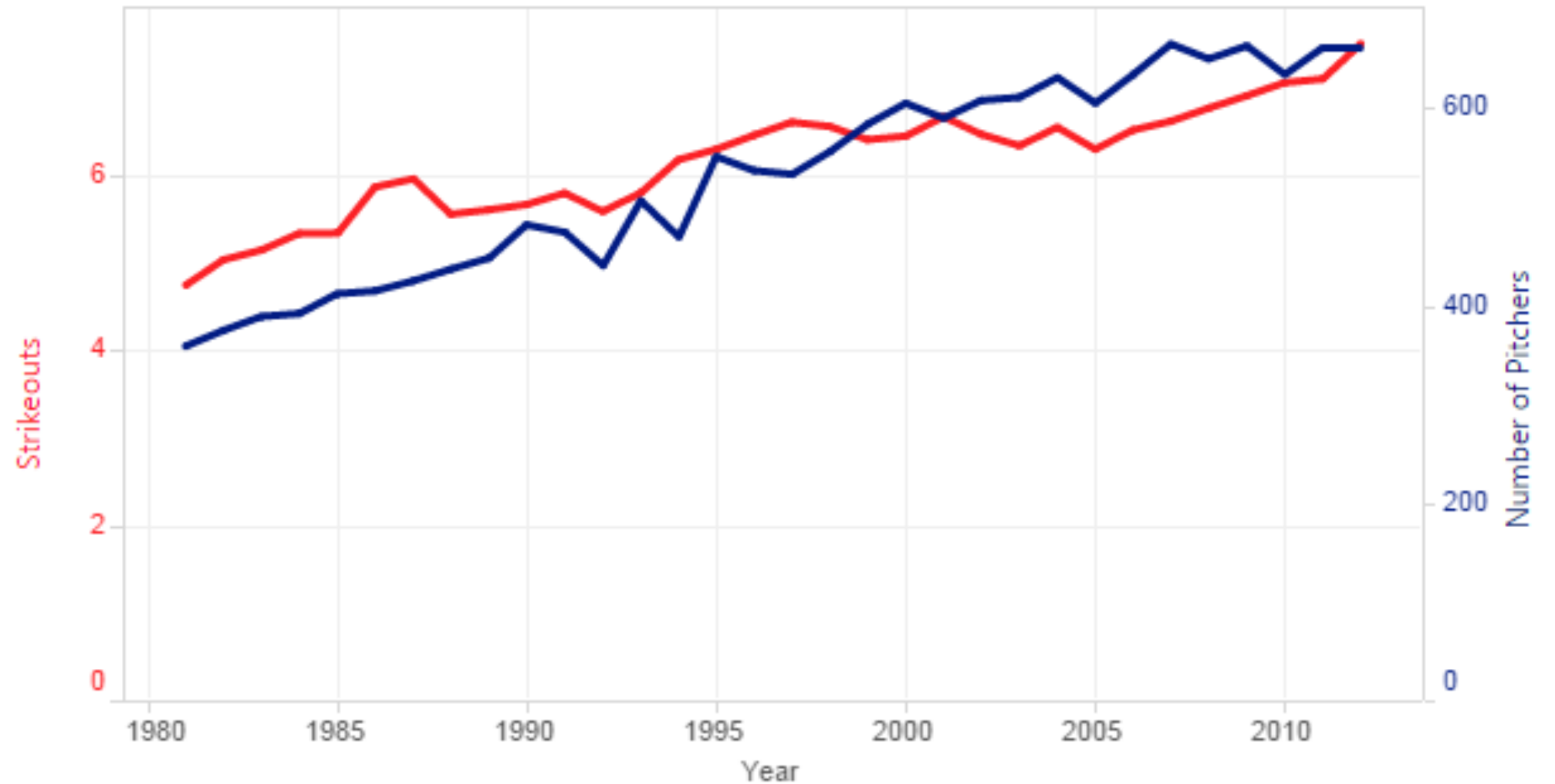
Chart axes

- labelled axis is critical
- avoid cropping y-axis
 - include 0 at bottom left
 - or slope misleads



Idiom: dual-axis line charts

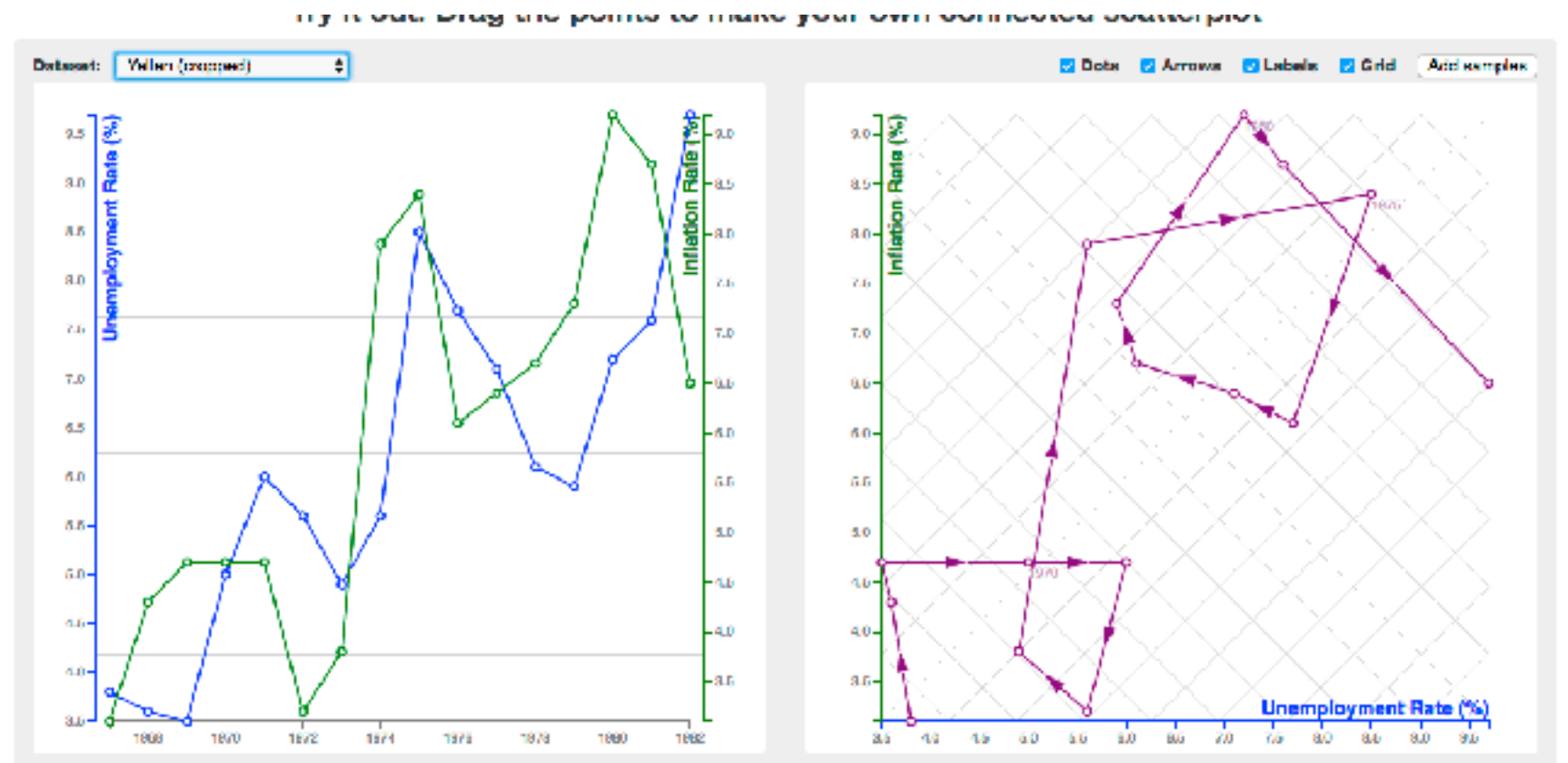
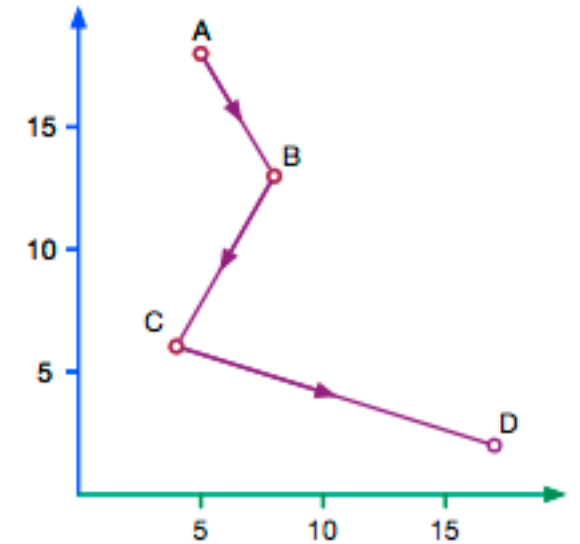
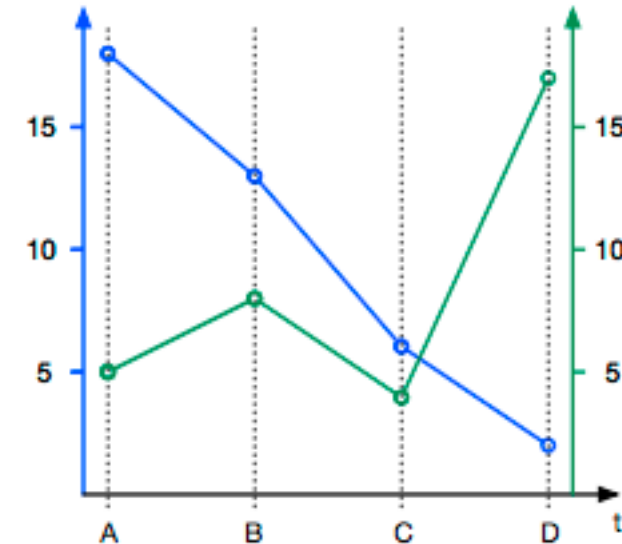
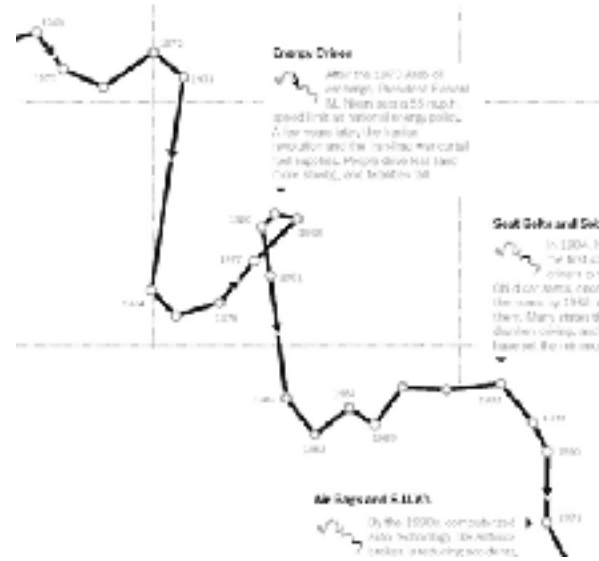
- controversial
 - acceptable if commensurate
 - beware, very easy to mislead!



Source | <http://www.baseball-reference.com/leagues/MLB/pitch.shtml> Ben Jones (@DataRemixed) | 5/4/2013

Idiom: **connected scatterplots**

- scatterplot with line connection marks
 - popular in journalism
 - horiz + vert axes: value attribs
 - line connection marks: temporal order
 - alternative to dual-axis charts
 - horiz: time
 - vert: two value attribs
- empirical study
 - engaging, but correlation unclear



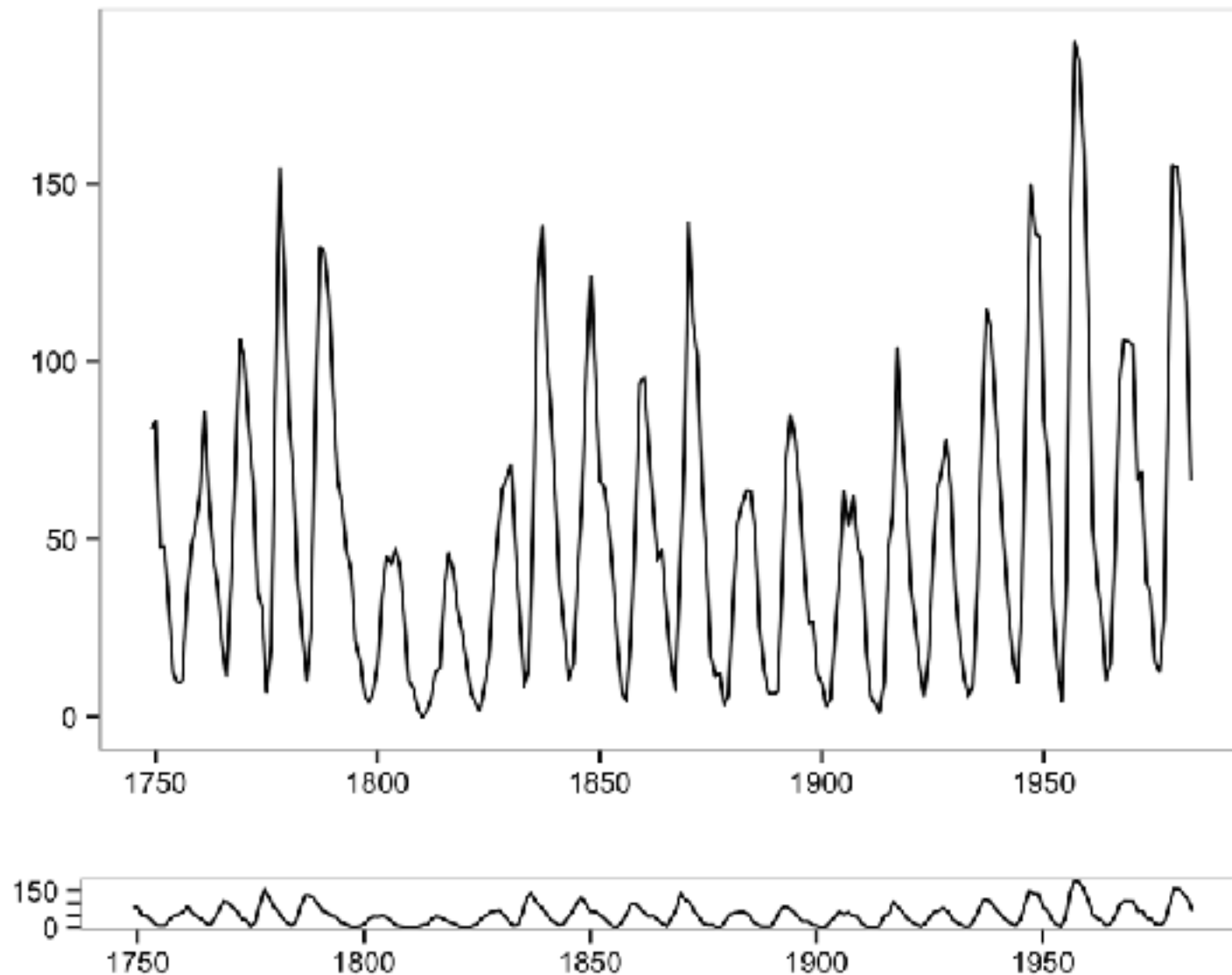
[The Connected Scatterplot for Presenting Paired Time Series. Haroz, Kosara and Franconeri. IEEE TVCG 22(9):2174-86, 2016.]

http://steveharoz.com/research/connected_scatterplot/

Choosing line chart aspect ratios

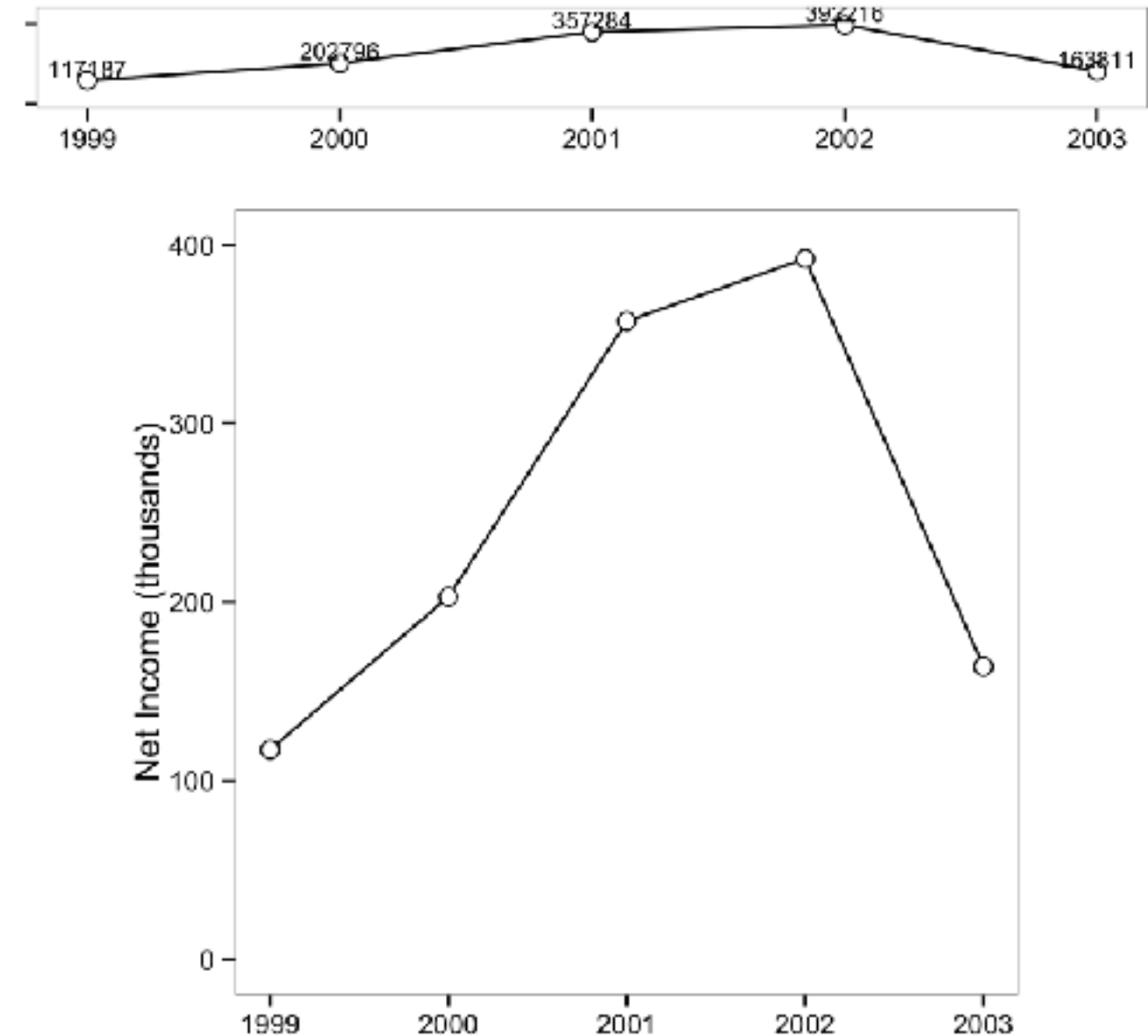
- I: banking to 45 (1980s)
 - Cleveland perceptual argument: most accurate angle judgement at 45

Fig 7.1 Sunspot Data: Aspect Ratio 1



https://github.com/jennybc/r-graph-catalog/tree/master/figures/fig07-01_sunspot-data-aspect-ratio-1

Fig 7.2 Annual Report: Aspect Ratio 2



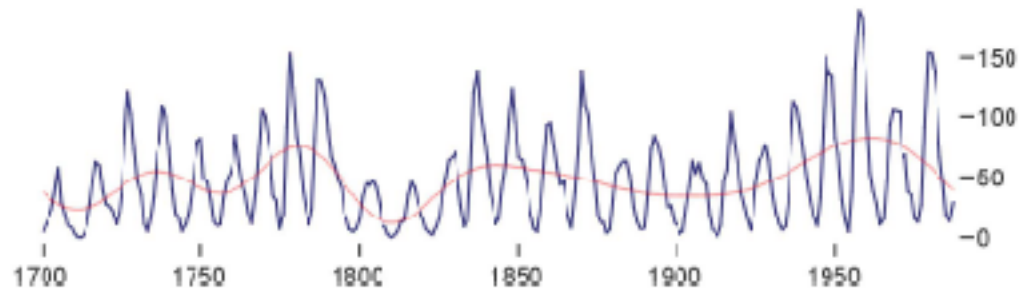
https://github.com/jennybc/r-graph-catalog/tree/master/figures/fig07-02_annual-report-aspect-ratio-2

Choosing line chart aspect ratios

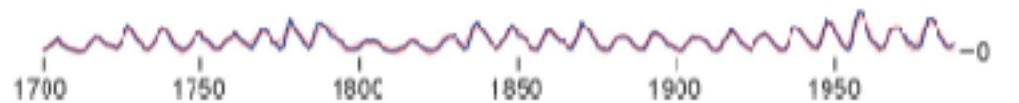
- 2: multi scale banking to 45 (2006)
 - frequency domain analysis to find ratios
 - FFT the data, convolve with Gaussian to smooth
 - find interesting spikes/ranges in power spectrum
 - cull nearby regions if similar, ensure overview
 - create trend curves (red) for each aspect ratio

Sunspot Cycles

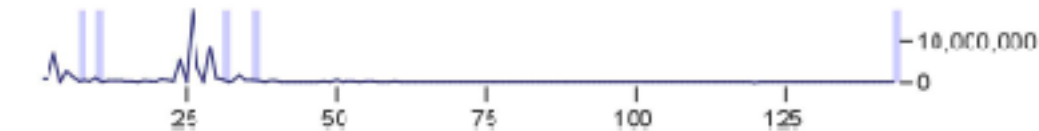
Aspect Ratio = 3.96



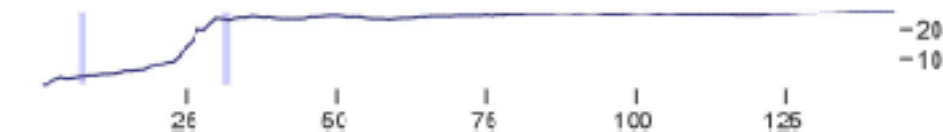
Aspect Ratio = 22.35



Power Spectrum



Aspect Ratios

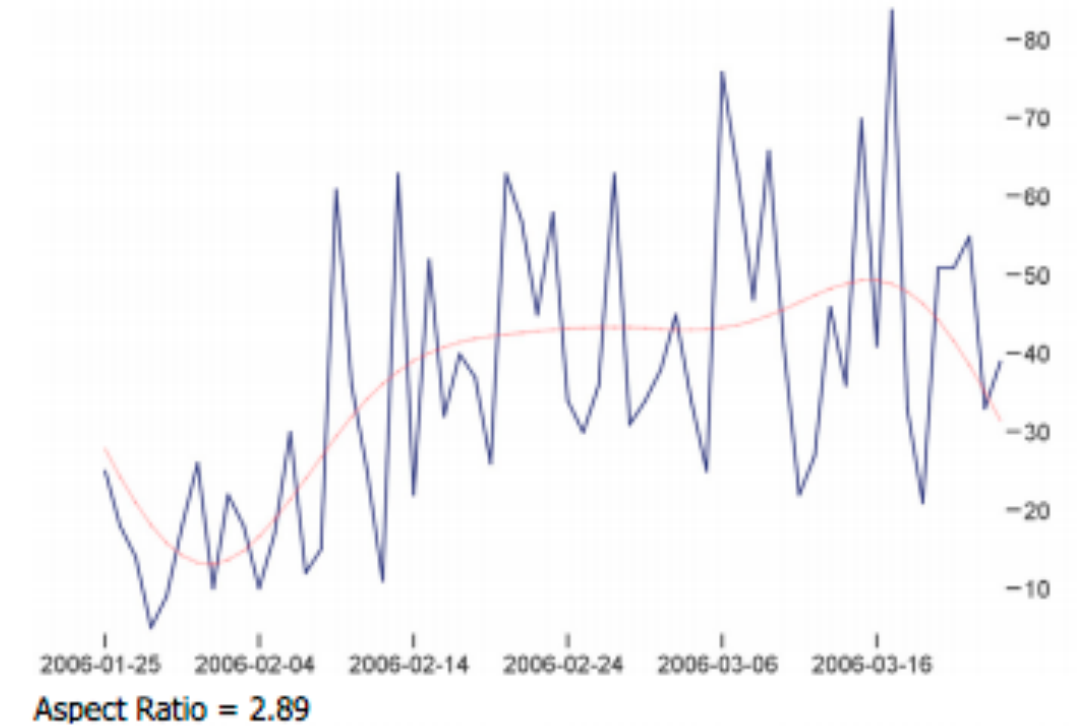


[Multi-Scale Banking to 45 Degrees.
Heer and Agrawala, Proc InfoVis 2006]

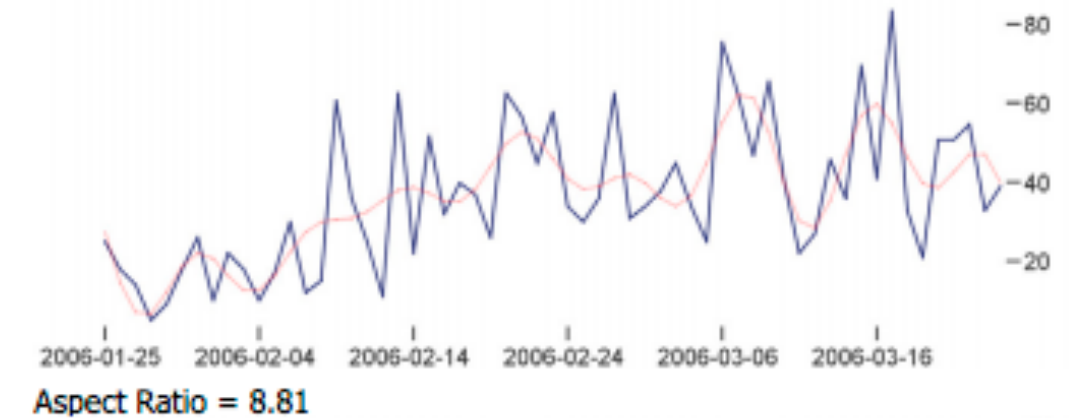
Downloads of the prefuse toolkit

Aspect Ratio = 1.44

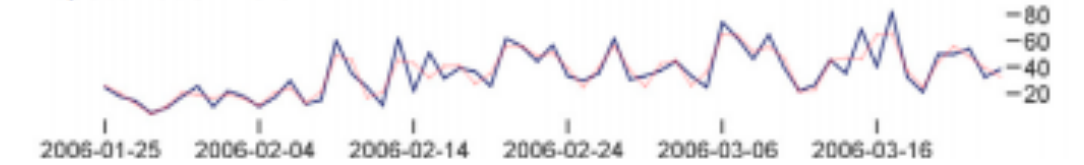
overall



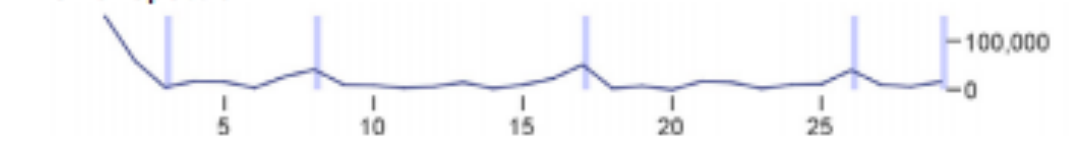
weekly



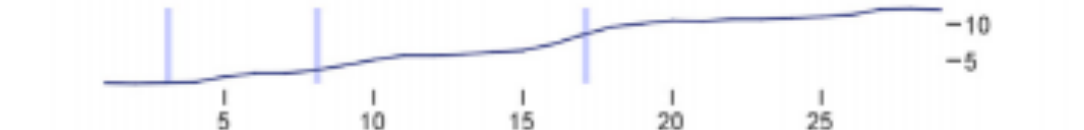
daily



Power Spectrum

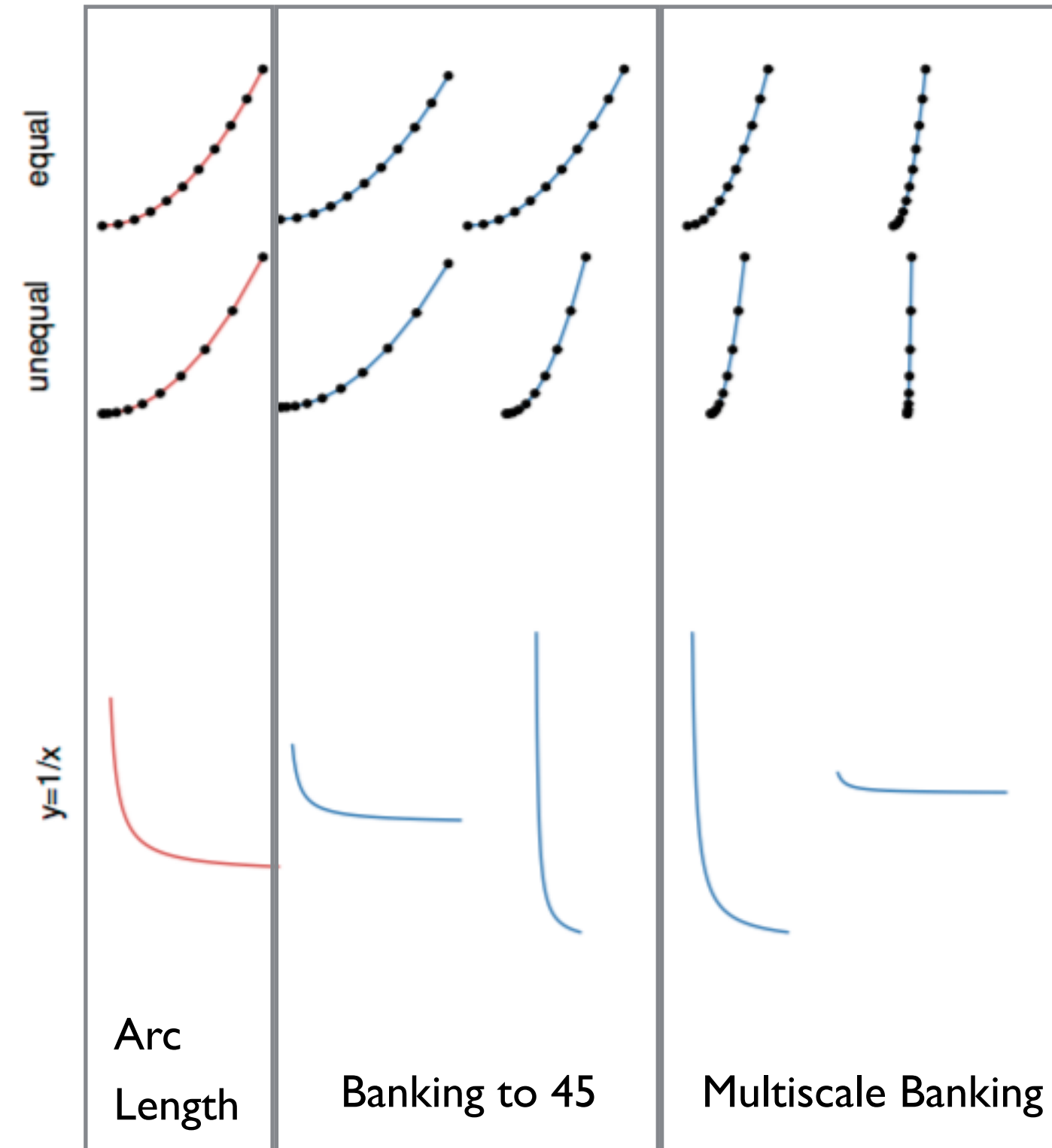


Aspect Ratios



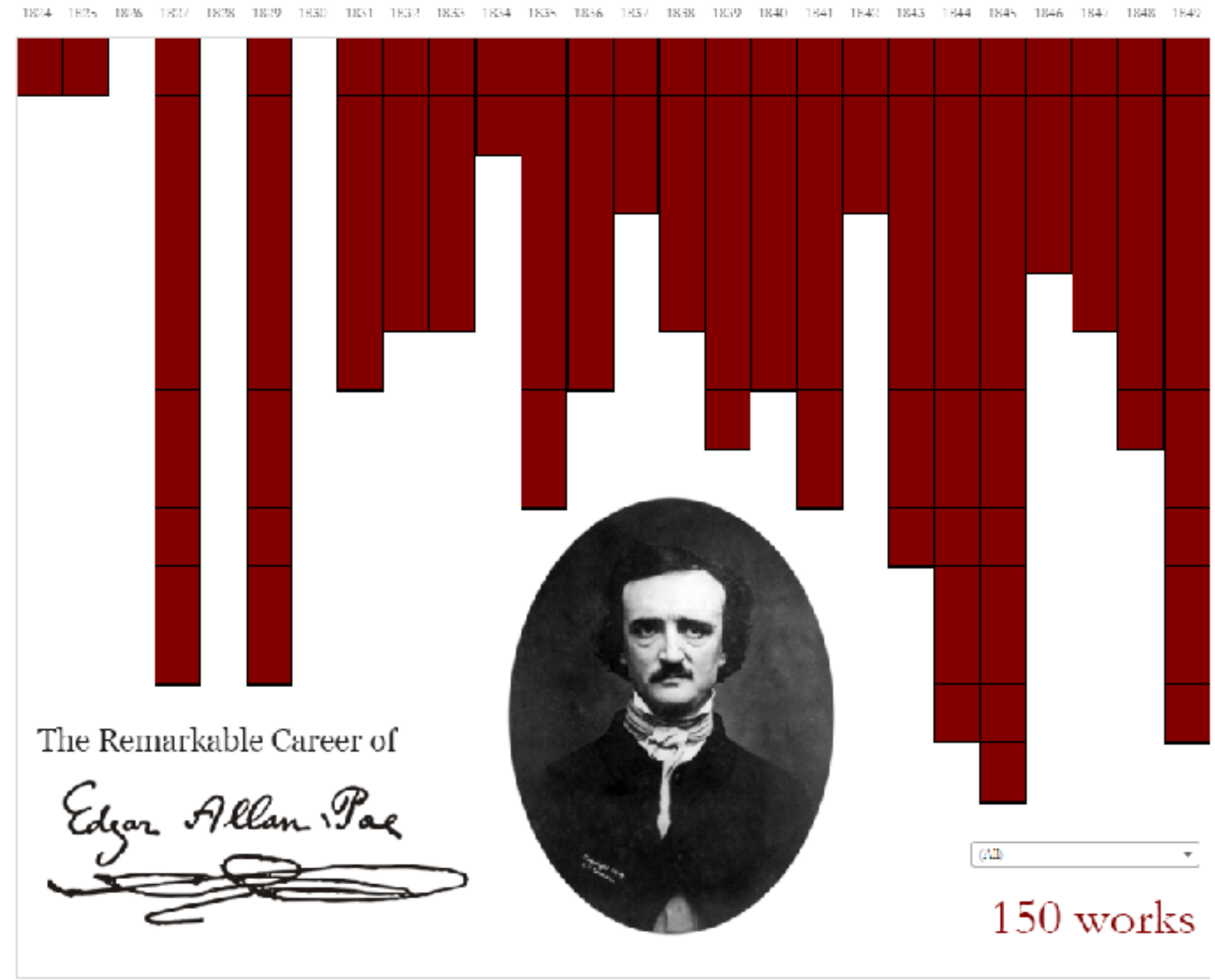
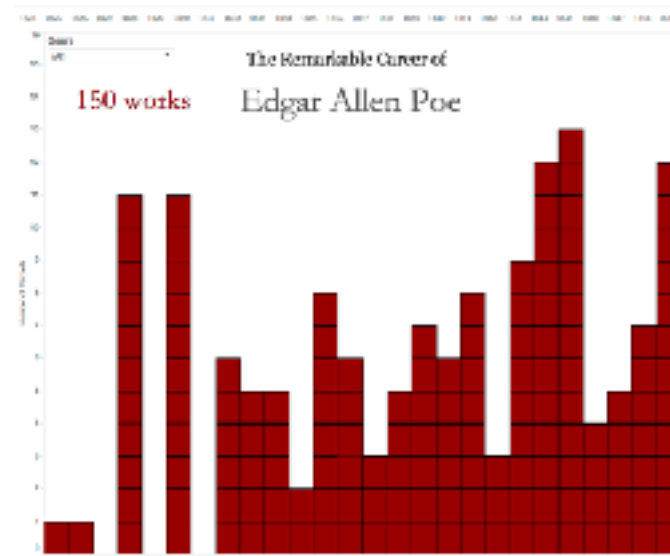
Choosing line chart aspect ratios

- 3: arc length based aspect ratio (2011)
 - minimize the arc length of curve while keeping the area of the plot constant
 - parametrization and scale invariant
 - symmetry preserving
 - robust & fast to compute
- meta-points from this progression
 - young field; prescriptive advice changes rapidly
 - reasonable defaults required deep dive into perception meets math



Breaking conventions

- presentation vs exploration
 - engaging/evocative
 - inverted y axis
 - blood drips down on Poe



Source: https://en.wikipedia.org/wiki/Edgar_Allan_Poe_bibliography

Ben Jones, 7 October 2015

<https://public.tableau.com/profile/ben.jones#!/vizhome/EdgarAllanPoeBoring/EdgarAllenPoeBoring>

<https://public.tableau.com/profile/ben.jones#!/vizhome/EdgarAllanPoeViz/EdgarAllanPoeViz>

[Slide inspired by Ben Jones]

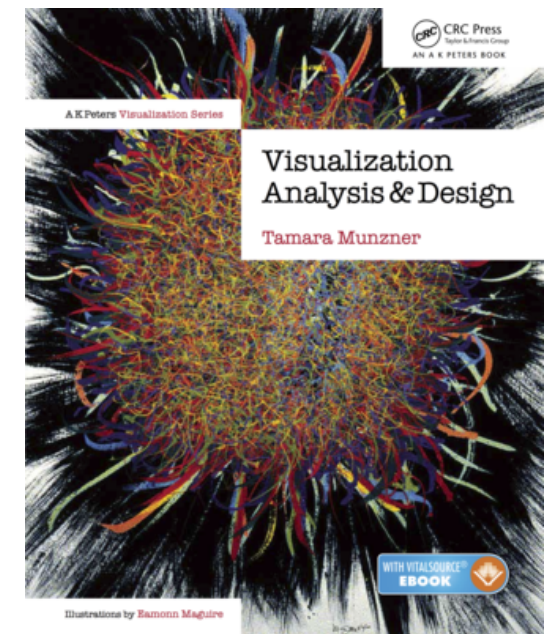
Visualization Analysis & Design

Network Data (Ch 9)

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Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



Network data

- networks

- model relationships between things

- aka graphs

- two kinds of items, both can have attributes

- nodes

- links

- tree

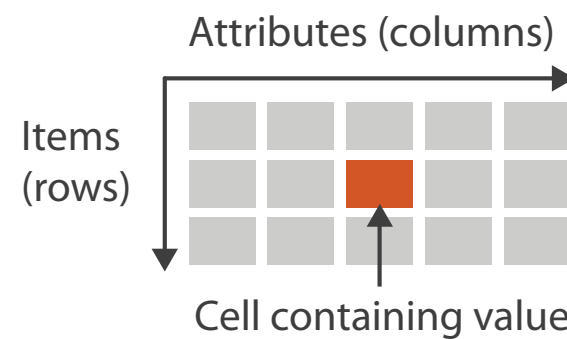
- special case

- no cycles

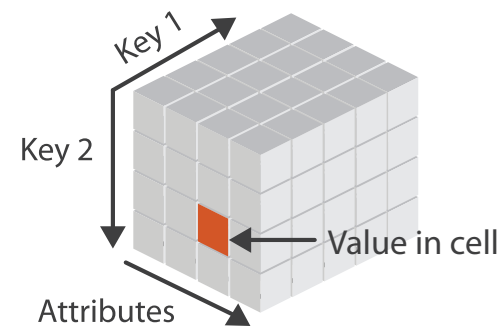
- one parent per node

Dataset Types

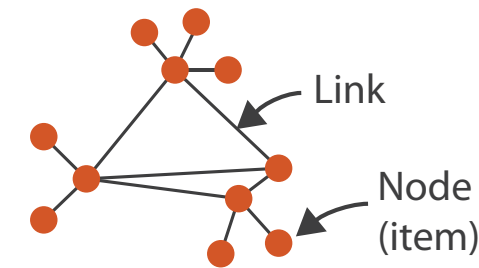
→ Tables



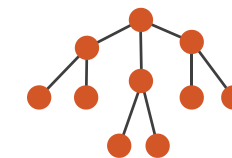
→ *Multidimensional Table*



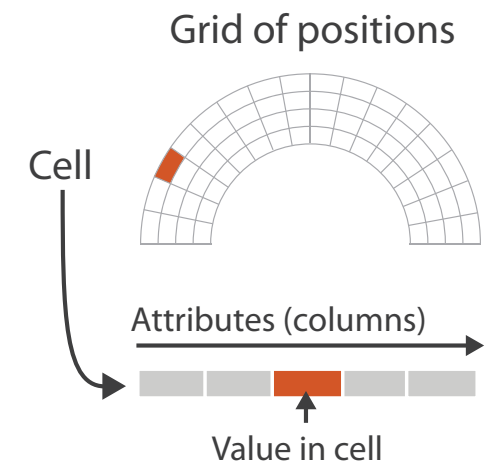
→ Networks



→ Trees

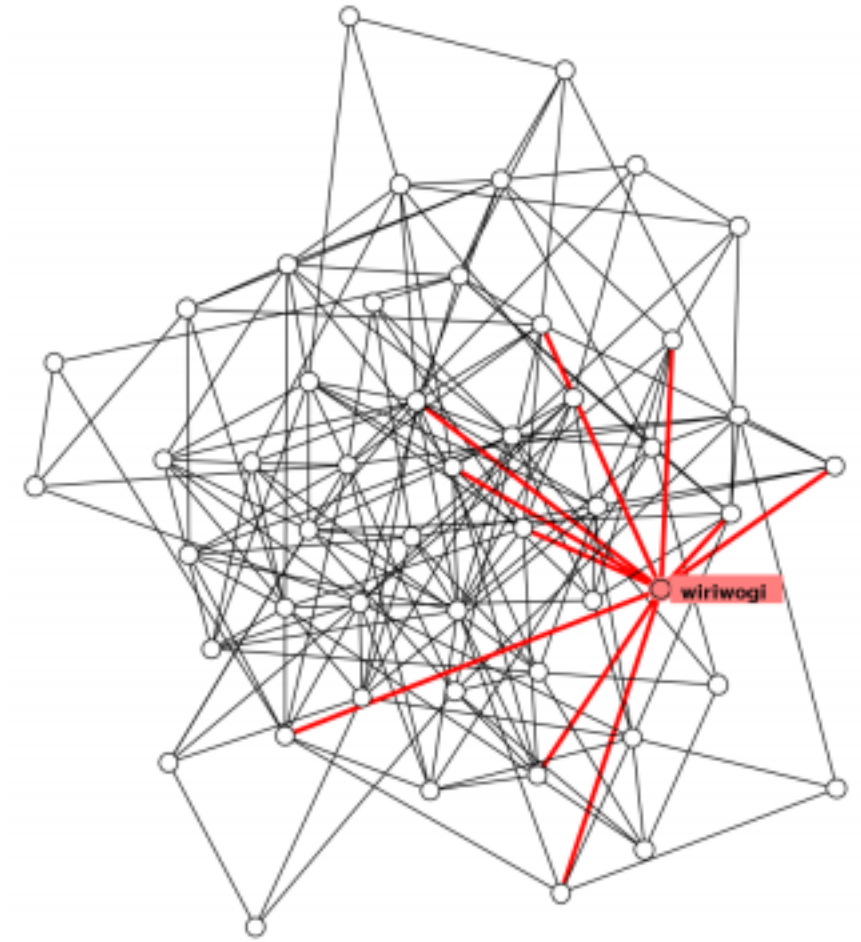


→ Spatial
→ Fields (Continuous)



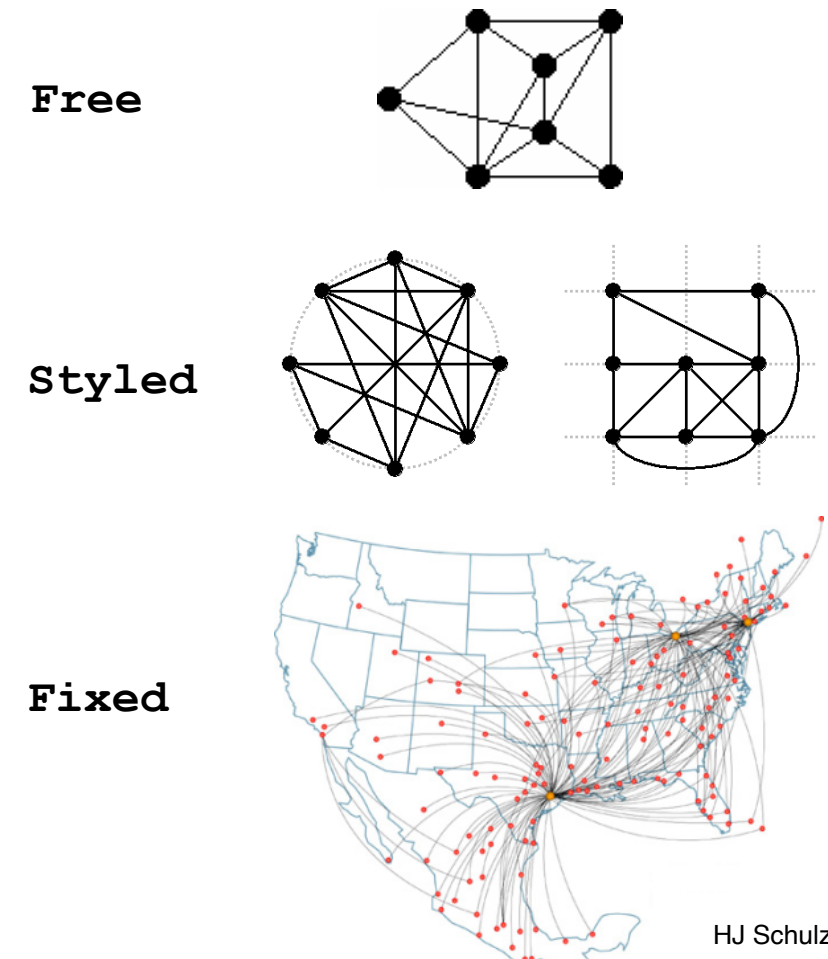
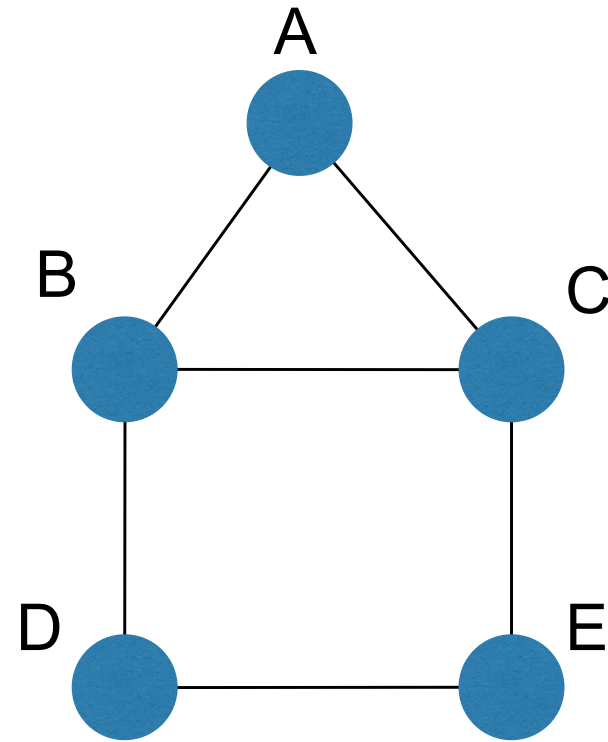
Network tasks: topology-based and attribute-based

- topology based tasks
 - find paths
 - find (topological) neighbors
 - compare centrality/importance measures
 - identify clusters / communities
- attribute based tasks (similar to table data)
 - find distributions, ...
- combination tasks, incorporating both
 - example: find friends-of-friends who like cats
 - topology: find all adjacent nodes of given node
 - attributes: check if has-pet (node attribute) == cat



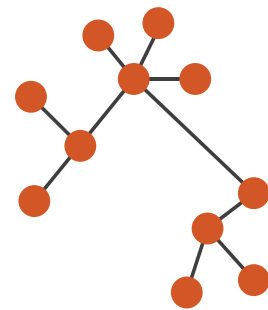
Node-link diagrams

- nodes: point marks
- links: line marks
 - straight lines or arcs
 - connections between nodes
- intuitive & familiar
 - most common
 - many, many variants



➔ Node-Link Diagrams Connection Marks

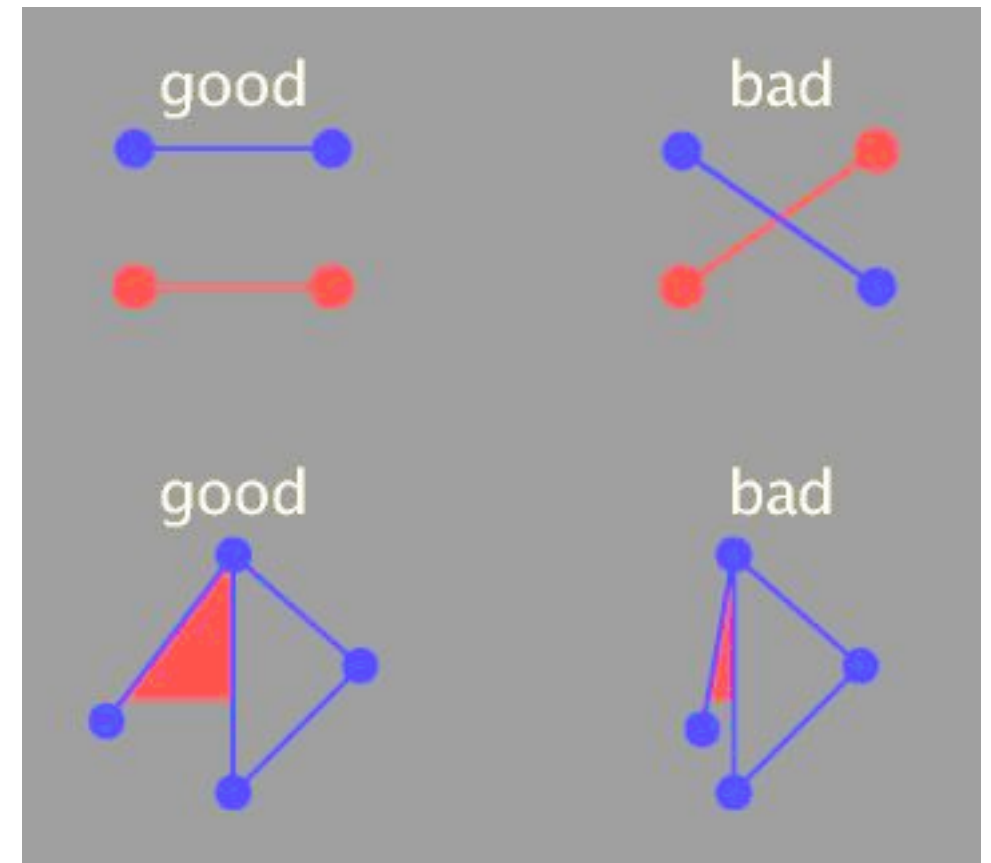
- ✓ NETWORKS
- ✓ TREES



HJ Schulz 2006

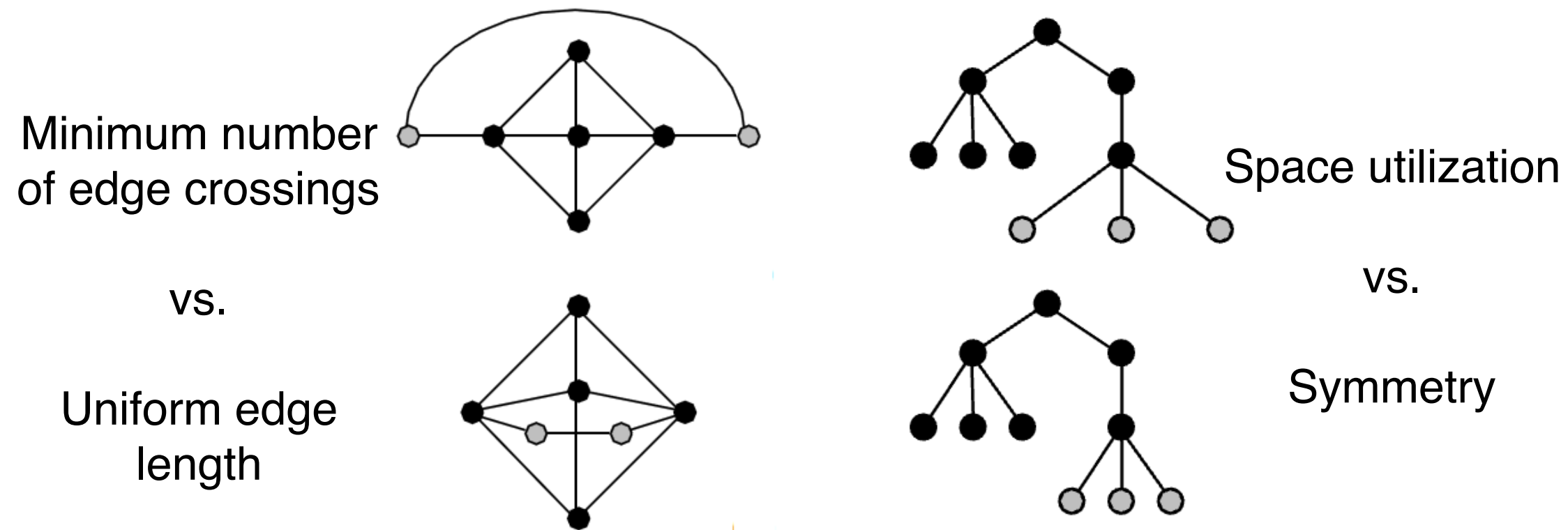
Criteria for good node-link layouts

- minimize
 - edge crossings, node overlaps
 - distances between topological neighbor nodes
 - total drawing area
 - edge bends
- maximize
 - angular distance between different edges
 - aspect ratio disparities
- emphasize symmetry
 - similar graph structures should look similar in layout



Criteria conflict

- most criteria NP-hard individually
- many criteria directly conflict with each other



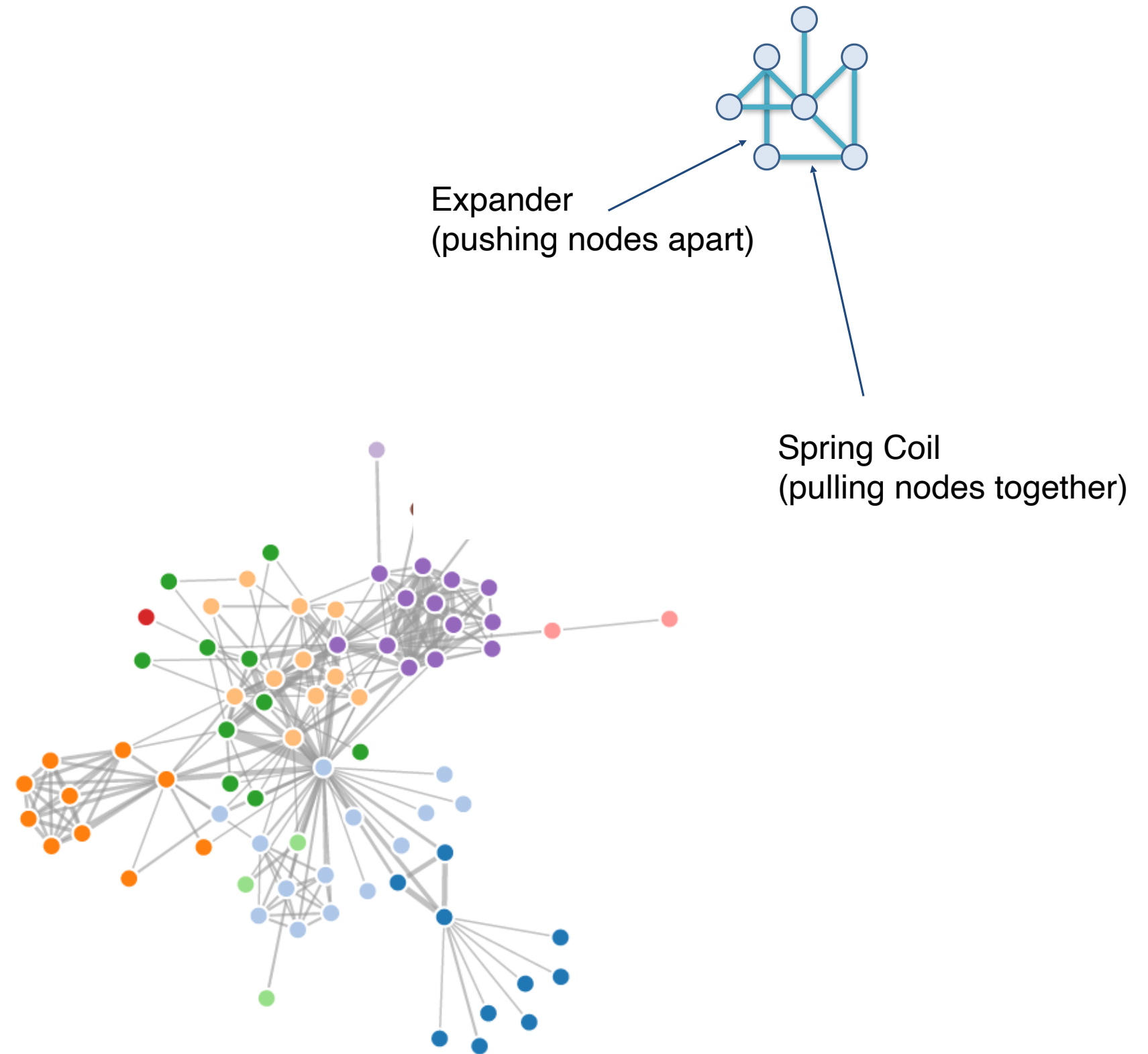
Schulz 2004

Optimization-based layouts

- formulate layout problem as optimization problem
- convert criteria into weighted cost function
 - $F(\text{layout}) = a * [\text{crossing counts}] + b * [\text{drawing space used}] + \dots$
- use known optimization techniques to find layout at minimal cost
 - energy-based physics models
 - force-directed placement
 - spring embedders

Force-directed placement

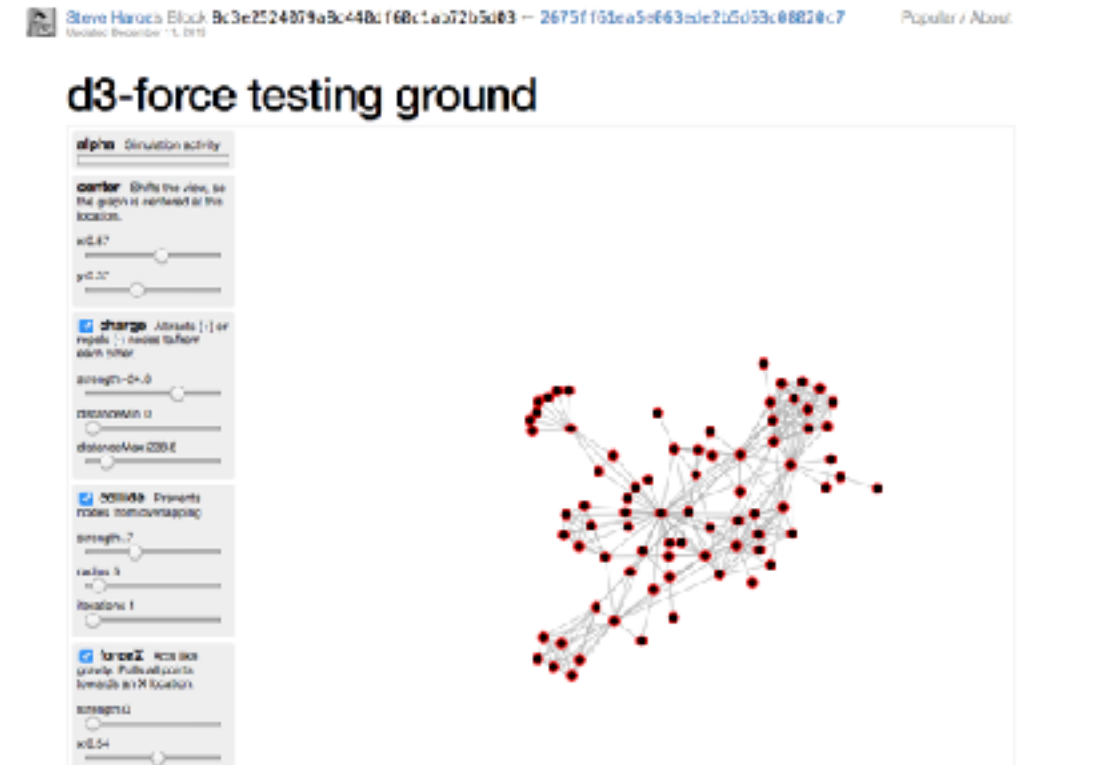
- physics model
 - links = springs pull together
 - nodes = magnets repulse apart
- algorithm
 - place vertices in random locations
 - while not equilibrium
 - calculate force on vertex
 - sum of
 - » pairwise repulsion of all nodes
 - » attraction between connected nodes
 - move vertex by $c * \text{vertex_force}$



<http://mbostock.github.com/d3/ex/force.html>

Force-directed placement properties

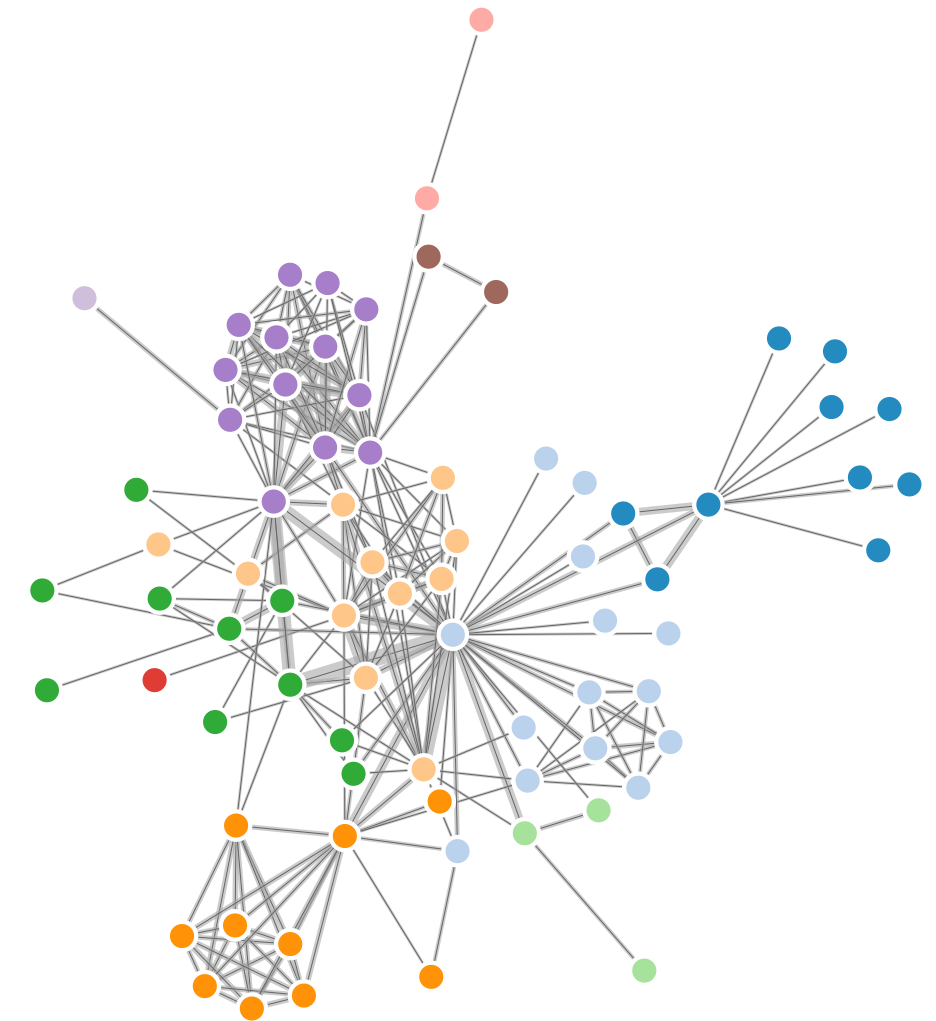
- strengths
 - reasonable layout for small, sparse graphs
 - clusters typically visible
 - edge length uniformity
- weaknesses
 - nondeterministic
 - computationally expensive: $O(n^3)$ for n nodes
 - each step is n^2 , takes $\sim n$ cycles to reach equilibrium
 - naive FD doesn't scale well beyond 1K nodes
 - iterative progress: engaging but distracting



<https://bl.ocks.org/steveharoz/8c3e2524079a8c440df60c1ab72b5d03>

Idiom: **force-directed placement**

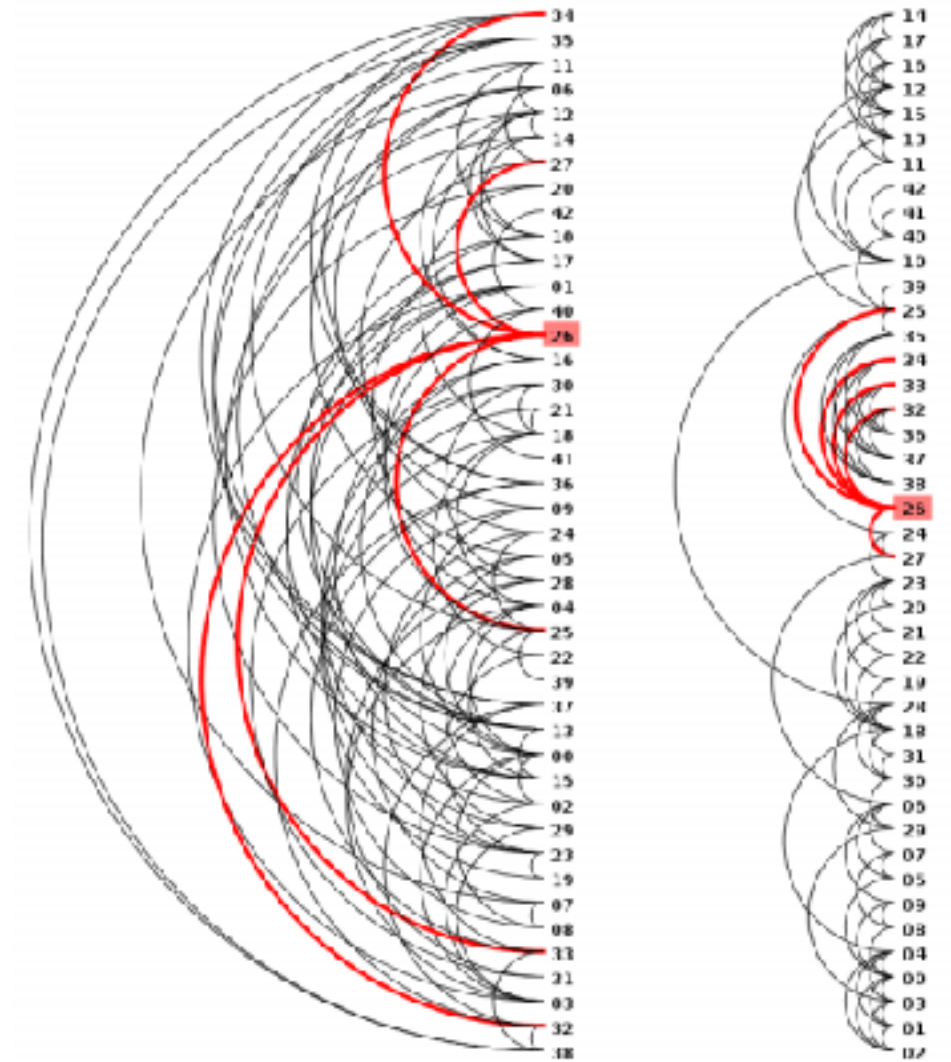
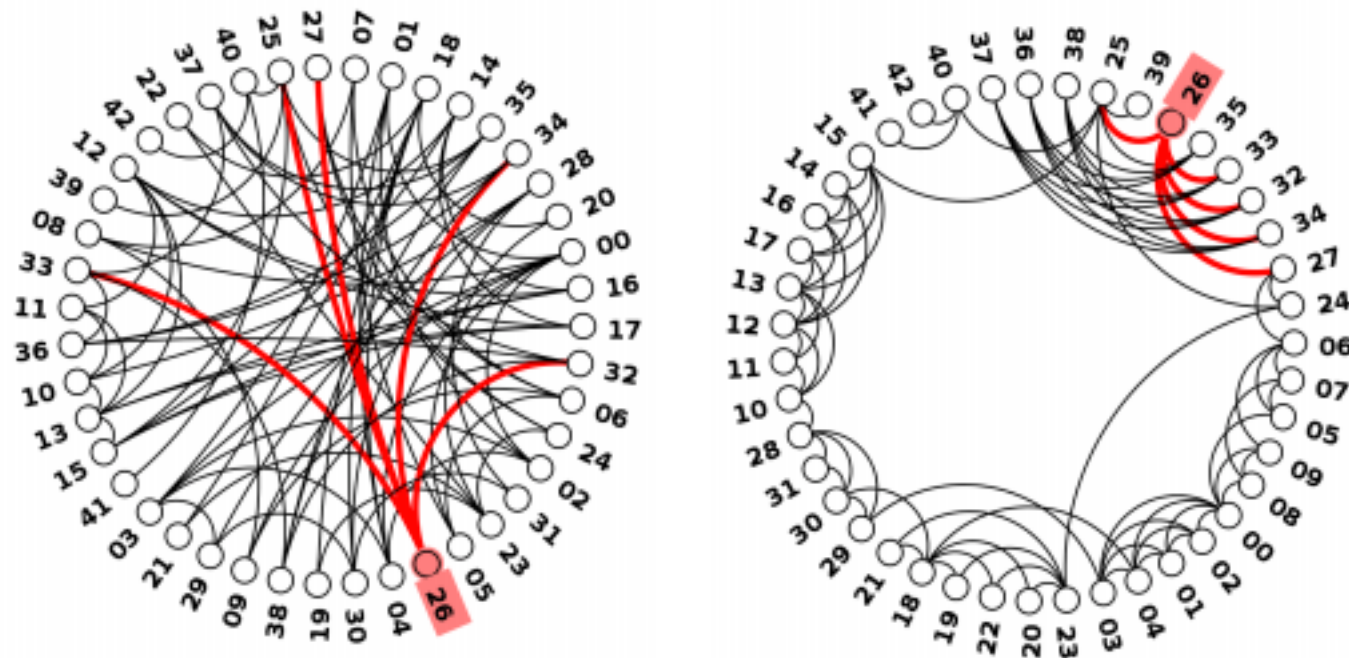
- visual encoding
 - link connection marks, node point marks
- considerations
 - spatial position: no meaning directly encoded
 - left free to minimize crossings
 - proximity semantics?
 - sometimes meaningful
 - sometimes arbitrary, artifact of layout algorithm
 - tension with length
 - long edges more visually salient than short
- tasks
 - explore topology; locate paths, clusters
- scalability
 - node/edge density $E < 4N$



<http://mbostock.github.com/d3/ex/force.html>

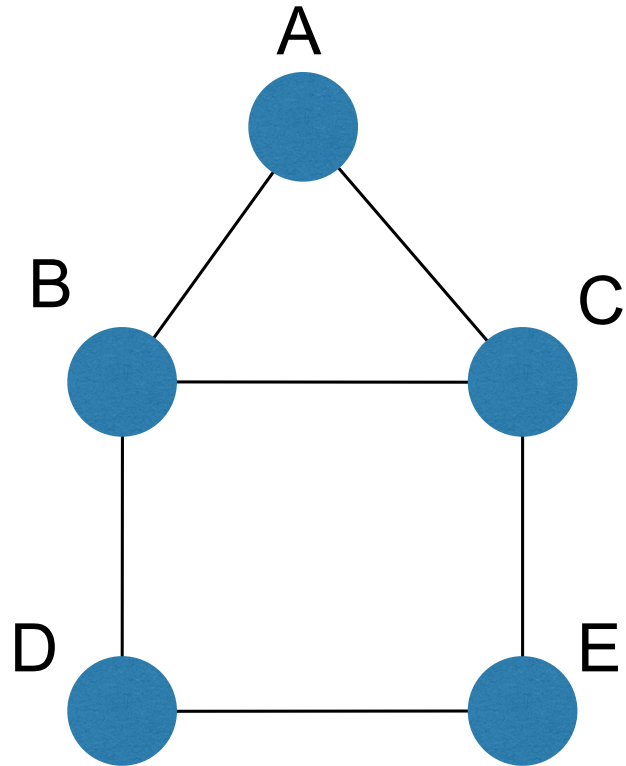
Idiom: circular layouts / arc diagrams (node-link)

- restricted node-link layouts: lay out nodes around circle or along line
- data
 - original: network
 - derived: node ordering attribute (global computation)
- considerations: node ordering crucial to avoid excessive clutter from edge crossings
 - examples: before & after barycentric ordering



Adjacency matrix representations

- derive adjacency matrix from network



	A	B	C	D	E
A		■	■		
B	■		■	■	
C	■	■			■
D		■			■
E			■	■	

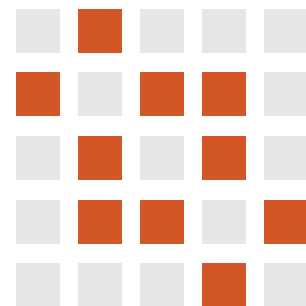


Adjacency Matrix

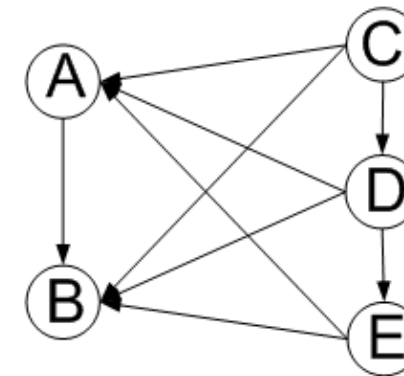
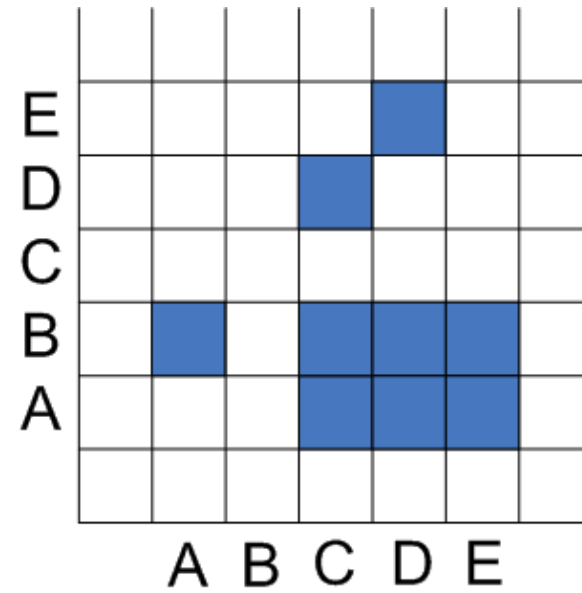
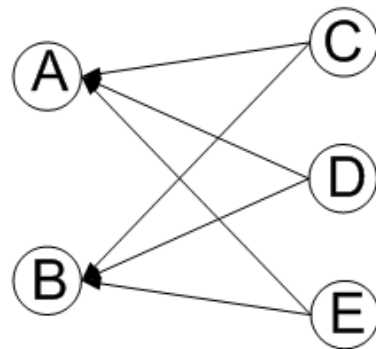
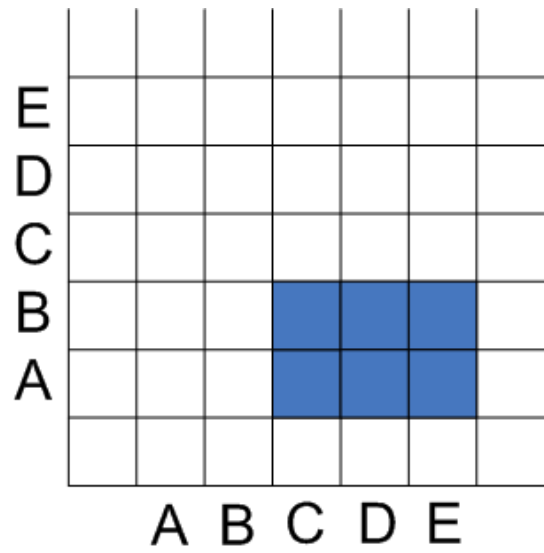
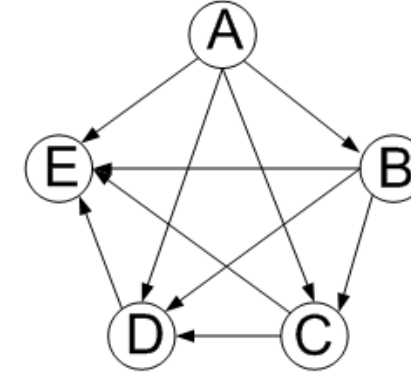
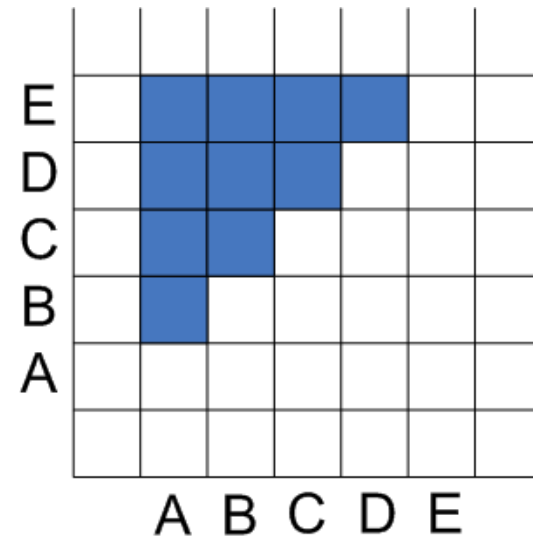
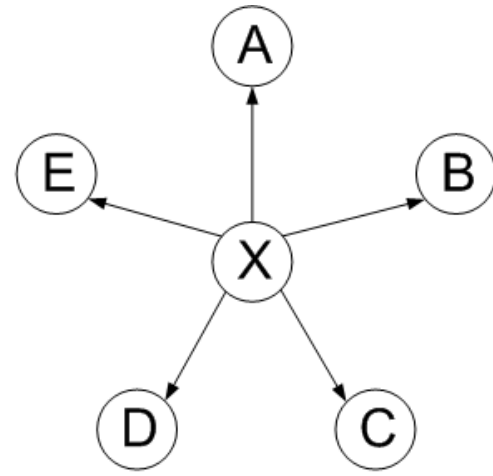
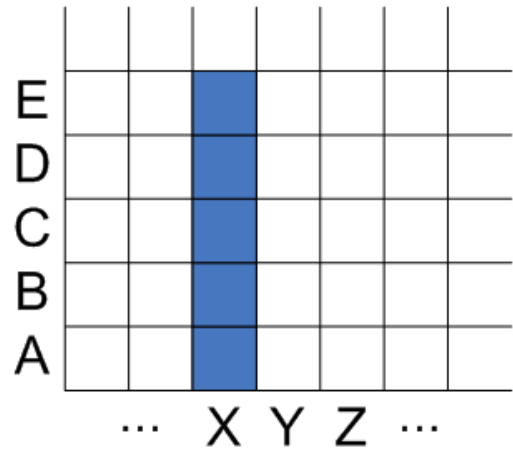
Derived Table

✓ NETWORKS

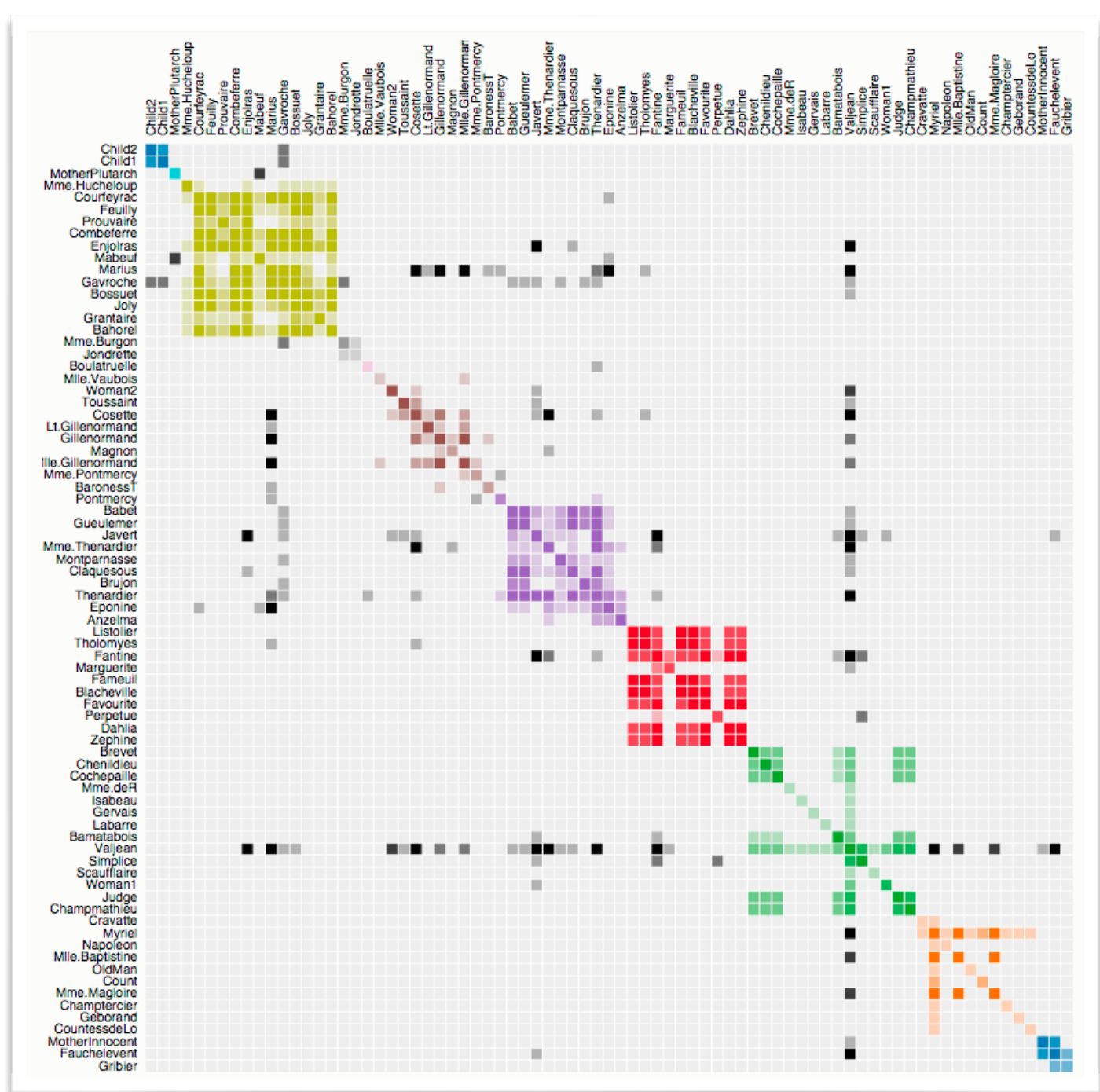
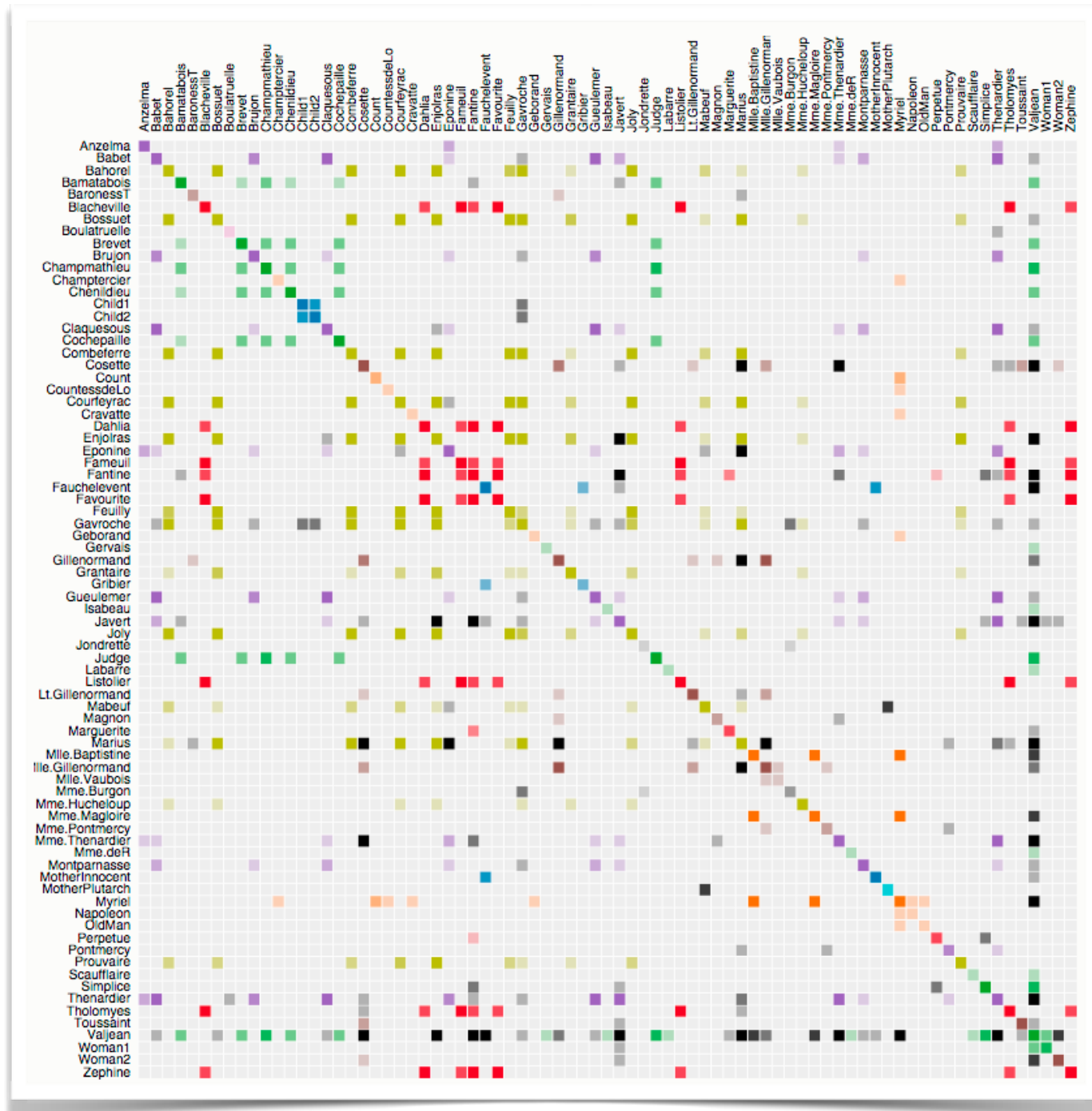
✓ TREES



Adjacency matrix examples



Node order is crucial: Reordering

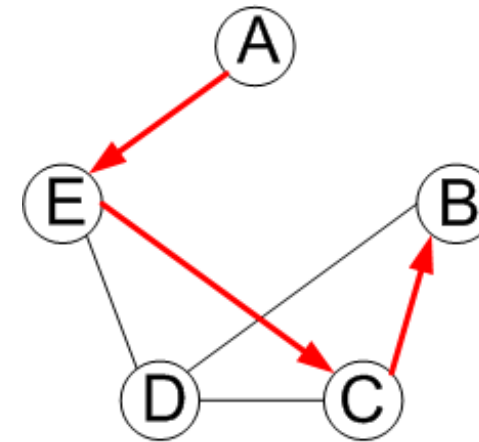


<https://bost.ocks.org/mike/miserables/>

Adjacency matrix

		TO							
		A	B	C	D	E	F	G	H
FROM	A		■	■					
	B	■		■	■				
	C		■				■		
	D								■
	E				■		■	■	
	F					■		■	
	G						■		■
	H					■		■	

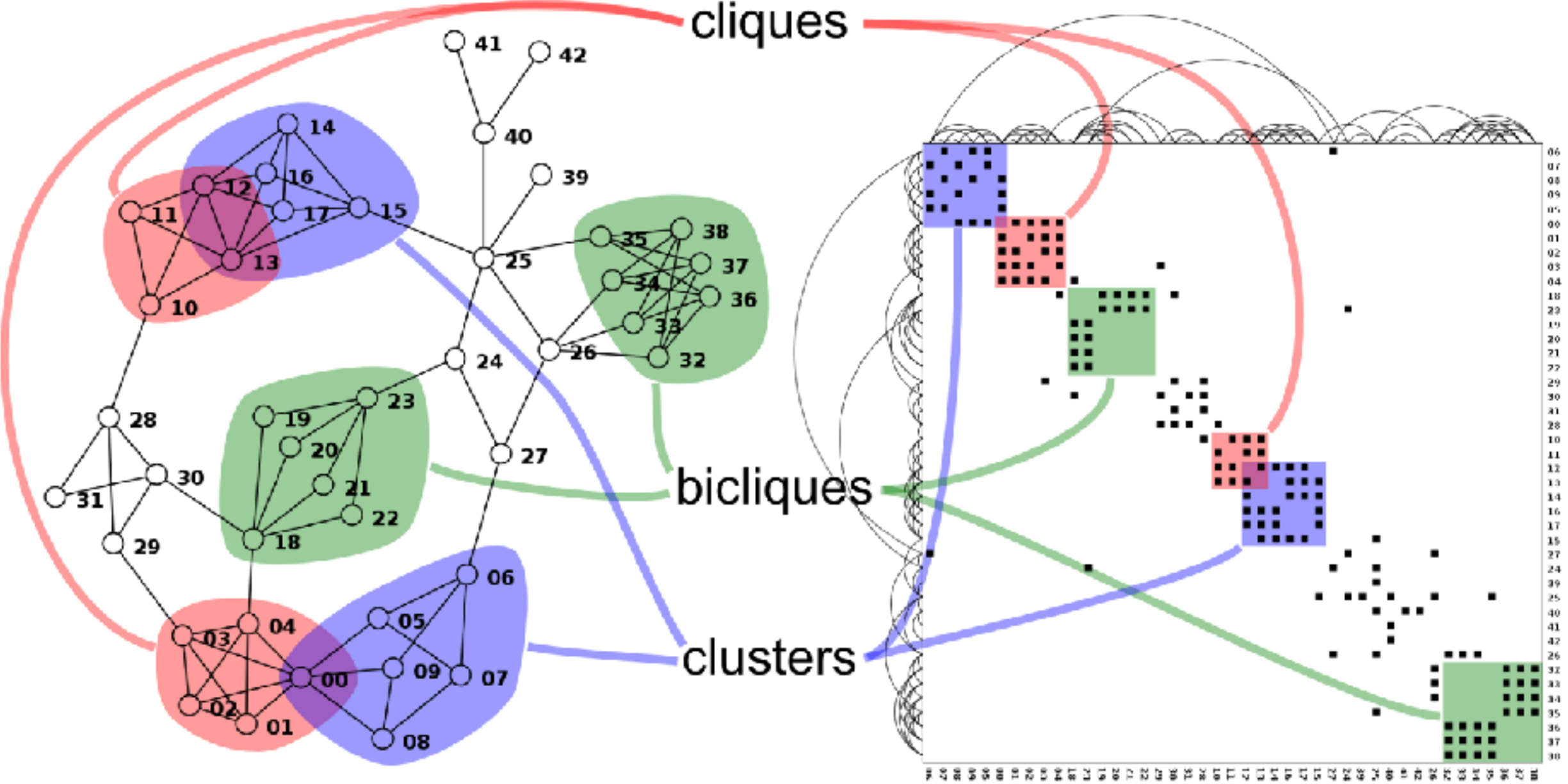
good for topology tasks
related to neighborhoods
(node 1-hop neighbors)



E		■	■	■	
D		■	■		■
C		■		■	■
B			■	■	
A					■
	A	B	C	D	E

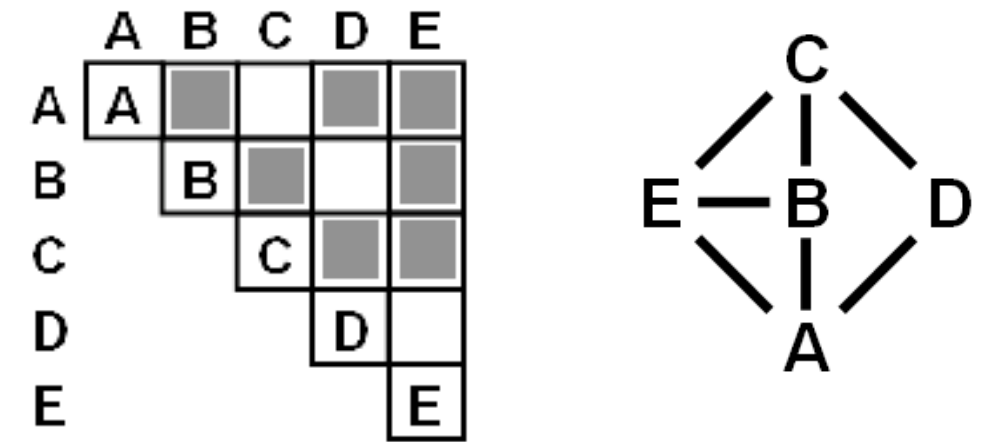
bad for topology tasks
related to paths

Structures visible in both

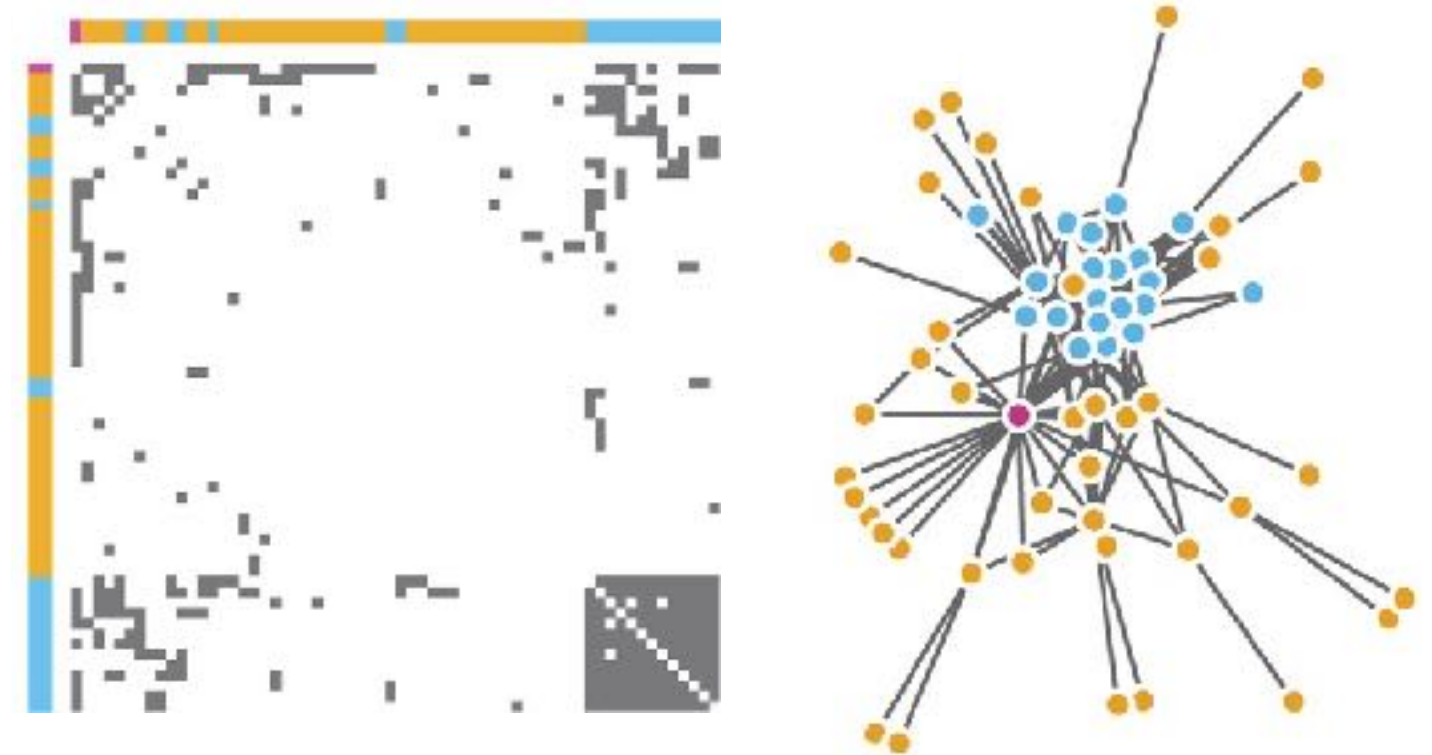


Idiom: adjacency matrix view

- data: network
 - transform into same data/encoding as heatmap
- derived data: table from network
 - 1 quant attrib
 - weighted edge between nodes
 - 2 categ attribs: node list x 2
- visual encoding
 - cell shows presence/absence of edge
- scalability
 - 1K nodes, 1M edges



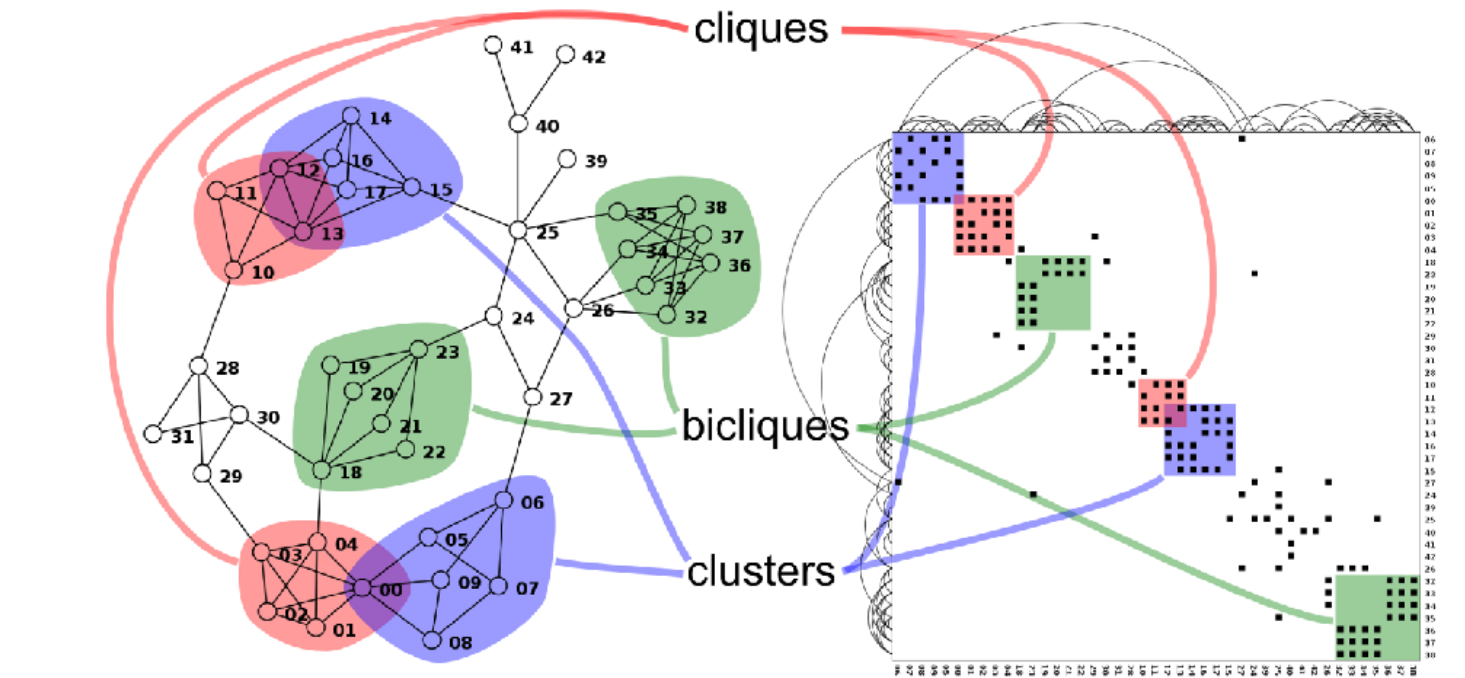
[NodeTrix: a Hybrid Visualization of Social Networks. Henry, Fekete, and McGuffin. IEEE TVCG (Proc. InfoVis) 13(6):1302-1309, 2007.]



[Points of view: Networks. Gehlenborg and Wong. Nature Methods 9:115.]

Node-link vs. matrix comparison

- node-link diagram strengths
 - topology understanding, path tracing
 - intuitive, flexible, no training needed
- adjacency matrix strengths
 - focus on edges rather than nodes
 - layout straightforward (reordering needed)
 - predictability, scalability
 - some topology tasks trainable
- empirical study
 - node-link best for small networks
 - matrix best for large networks
 - if tasks don't involve path tracing!

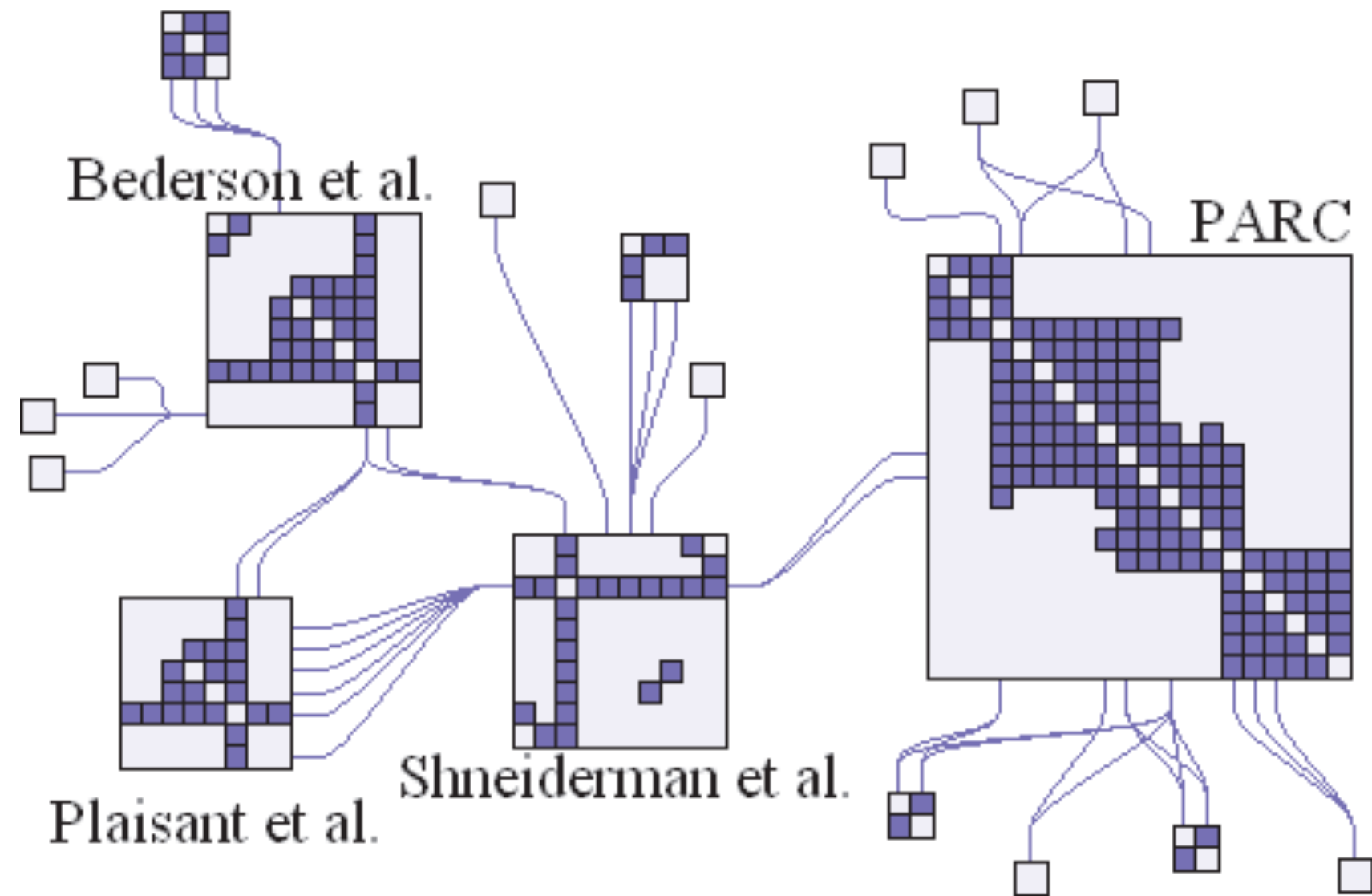


<http://www.michaelmcguffin.com/courses/vis/patternsInAdjacencyMatrix.png>

[On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis. Ghoniem, Fekete, and Castagliola. Information Visualization 4:2 (2005), 114–135.]

Idiom: NodeTrix

- hybrid nodelink/matrix
- capture strengths of both



[NodeTrix: a Hybrid Visualization of Social Networks.
Henry, Fekete, and McGuffin. IEEE TVCG (Proc. InfoVis)
13(6):1302-1309, 2007.]

Trees

Node-link trees

- Reingold-Tilford

- tidy drawings of trees

- exploit parent/child structure

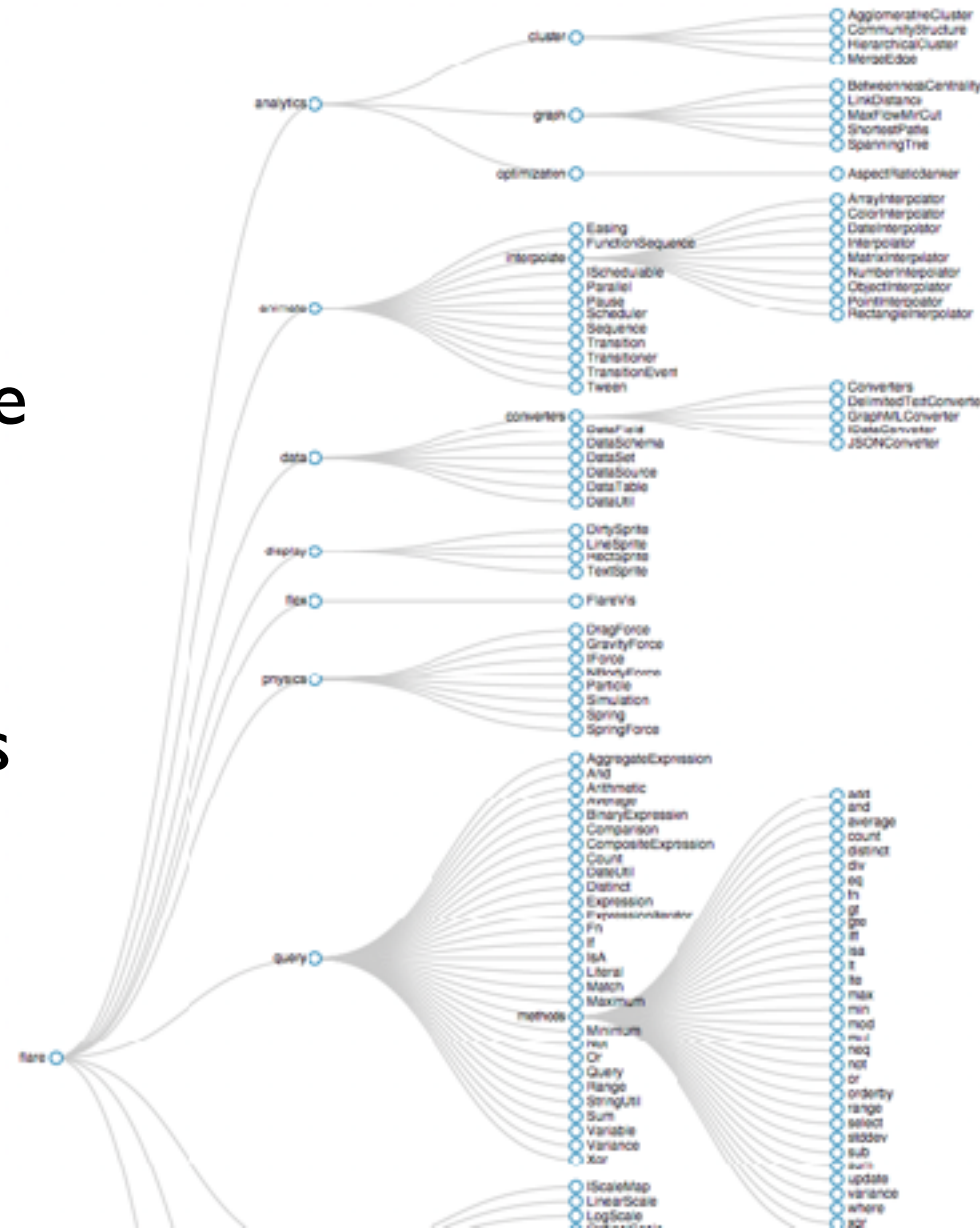
- allocate space: compact but without overlap

- rectilinear and radial variants

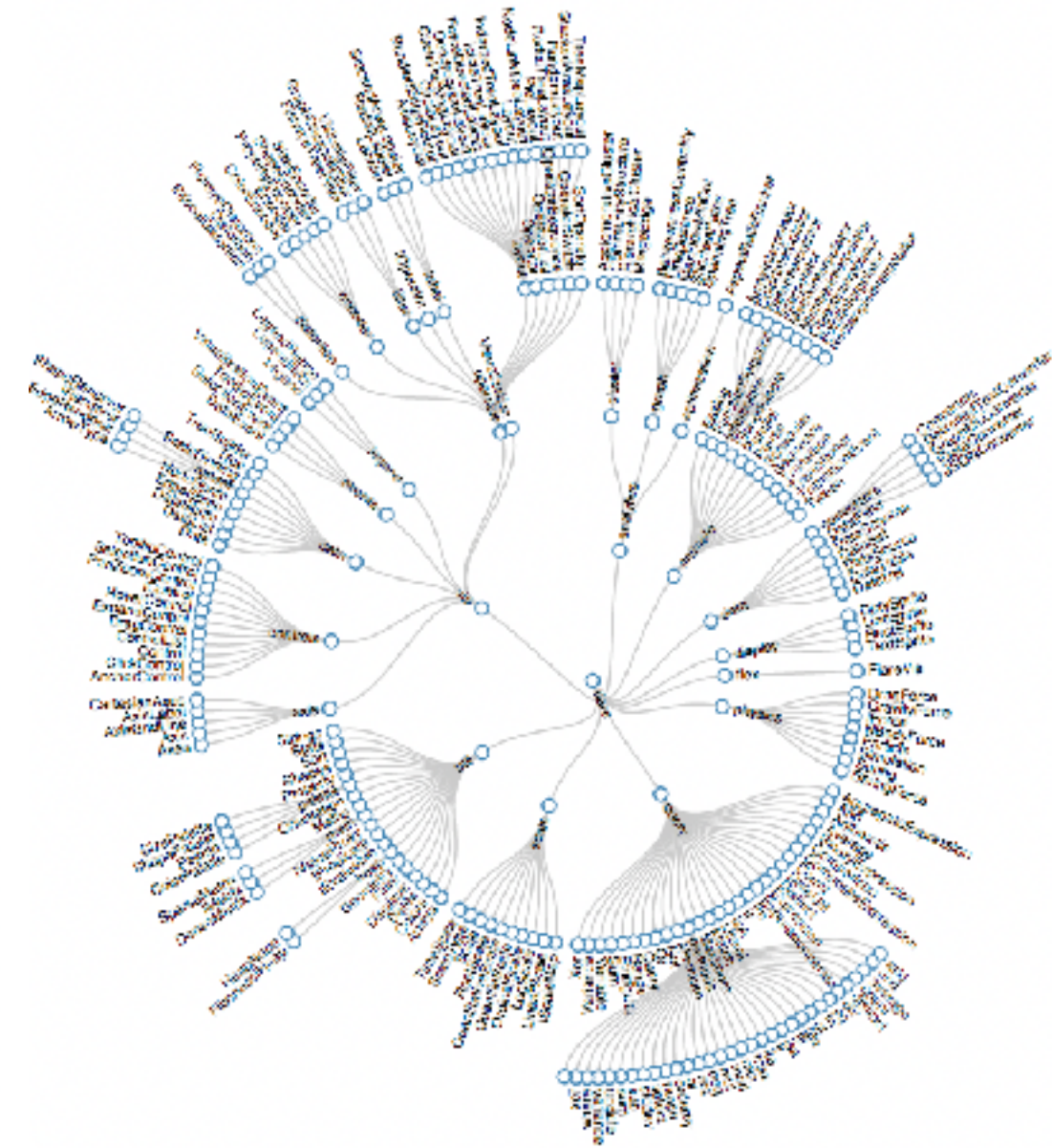
[Tidier drawing of trees. Reingold and Tilford. IEEE Trans. Software Eng., SE-7(2):223–228, 1981.]

- nice algorithm writeup

<http://billmill.org/pymag-trees/>



<http://bl.ocks.org/mbostock/4339184>

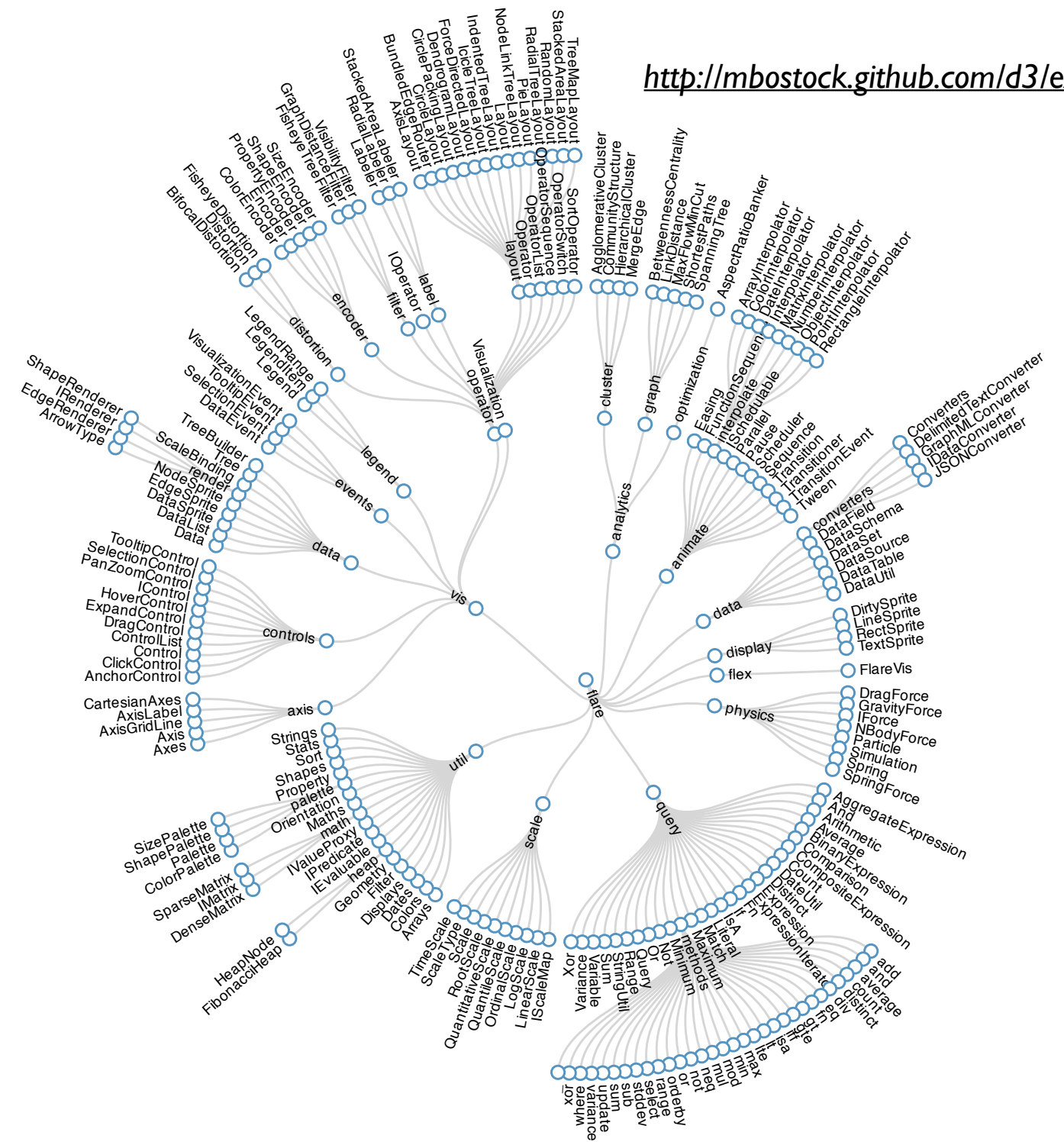


<http://bl.ocks.org/mbostock/4063550>

Idiom: radial node-link tree

<http://mbostock.github.com/d3/ex/tree.html>

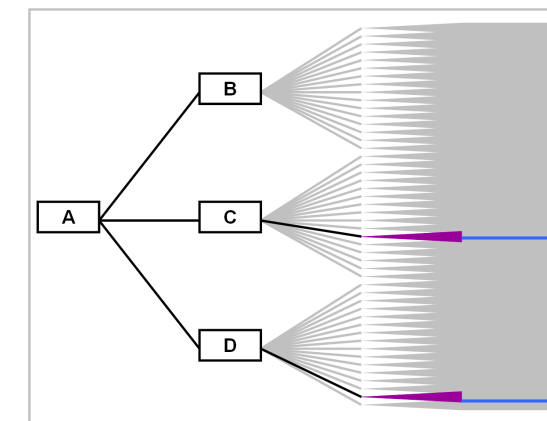
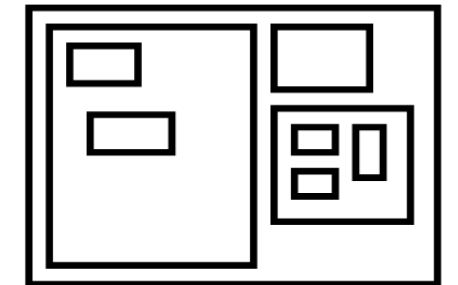
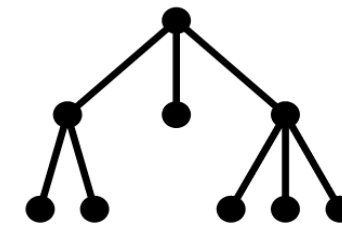
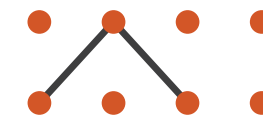
- data
 - tree
- encoding
 - link connection marks
 - point node marks
 - radial axis orientation
 - angular proximity: siblings
 - distance from center: depth in tree
- tasks
 - understanding topology, following paths
- scalability
 - 1K - 10K nodes (with/without labels)



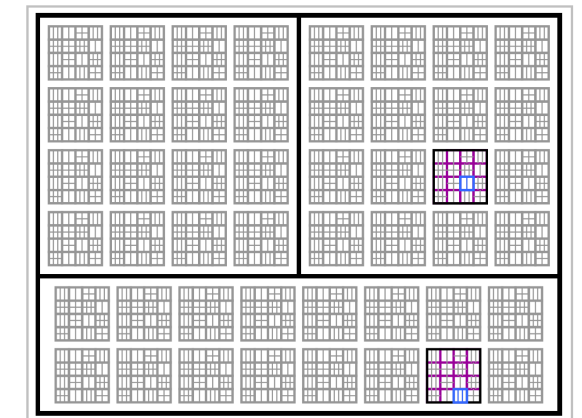
Link marks: Connection and containment

- marks as links (vs. nodes)
 - common case in network drawing
 - 1D case: connection
 - ex: all node-link diagrams
 - emphasizes topology, path tracing
 - networks and trees
 - 2D case: containment
 - ex: all treemap variants
 - emphasizes attribute values at leaves (size coding)
 - only trees

→ Connection → Containment



Node-Link Diagram



Treemap

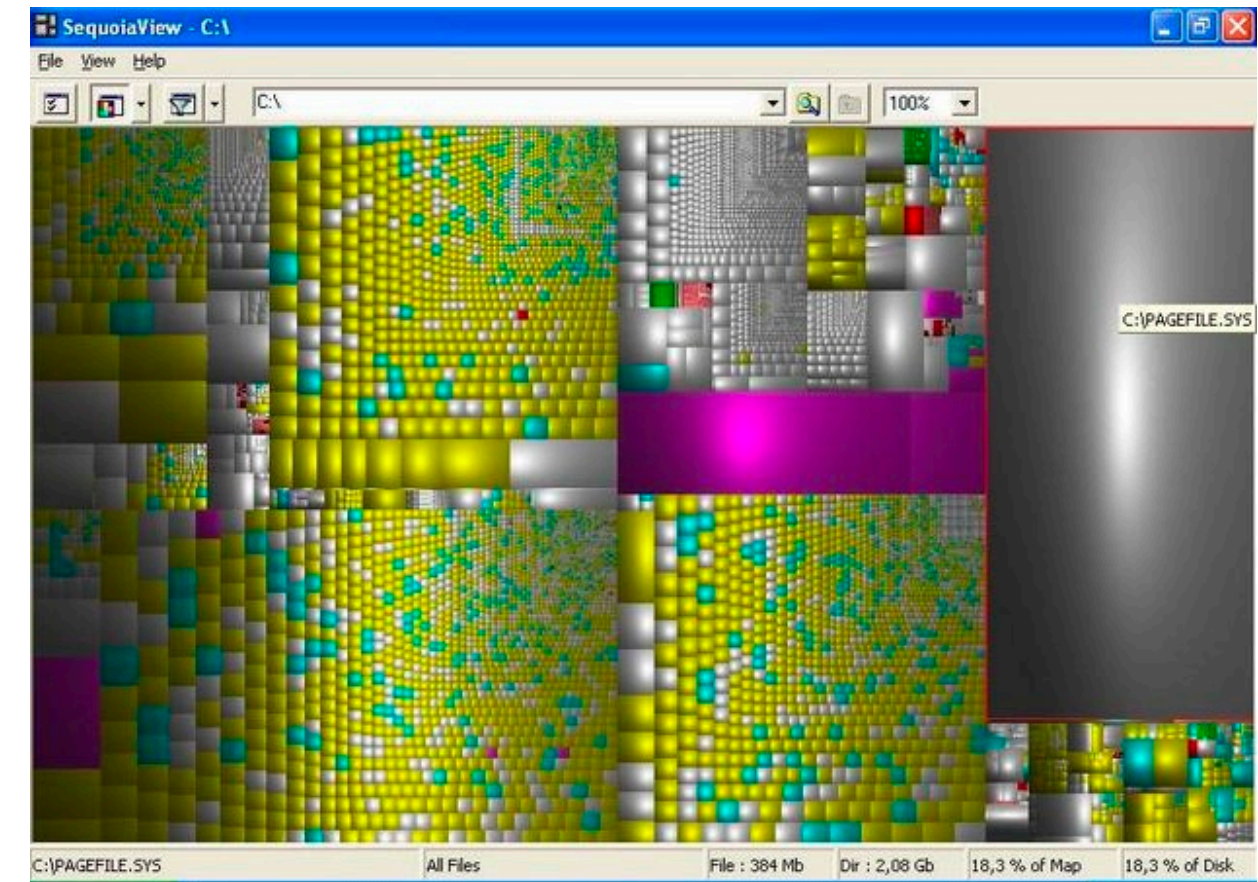
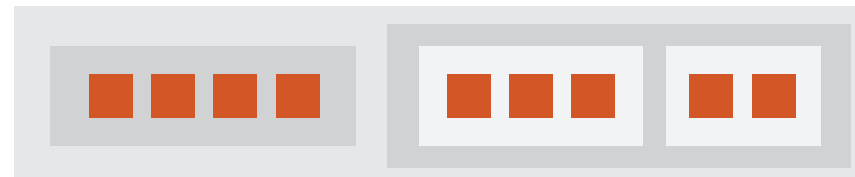
[Elastic Hierarchies: Combining Treemaps and Node-Link Diagrams.
Dong, McGuffin, and Chignell. Proc. InfoVis 2005, p. 57-64.]

Idiom: treemap

- data
 - tree
 - 1 quant attrib at leaf nodes
- encoding
 - area containment marks for hierarchical structure
 - rectilinear orientation
 - size encodes quant attrib
- tasks
 - query attribute at leaf nodes
 - ex: disk space usage within filesystem
- scalability
 - IM leaf nodes

➔ **Enclosure**
Containment Marks

NETWORKS TREES



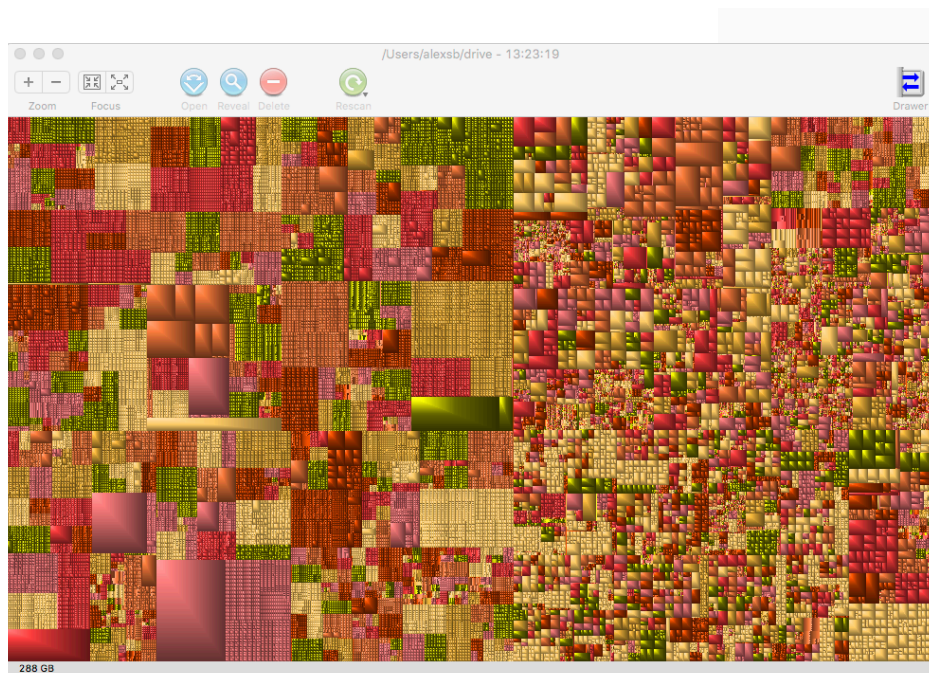
<https://www.win.tue.nl/sequoiaview/>

[Cushion Treemaps. van Wijk and van de Wetering.
Proc. Symp. InfoVis 1999, 73-78.]

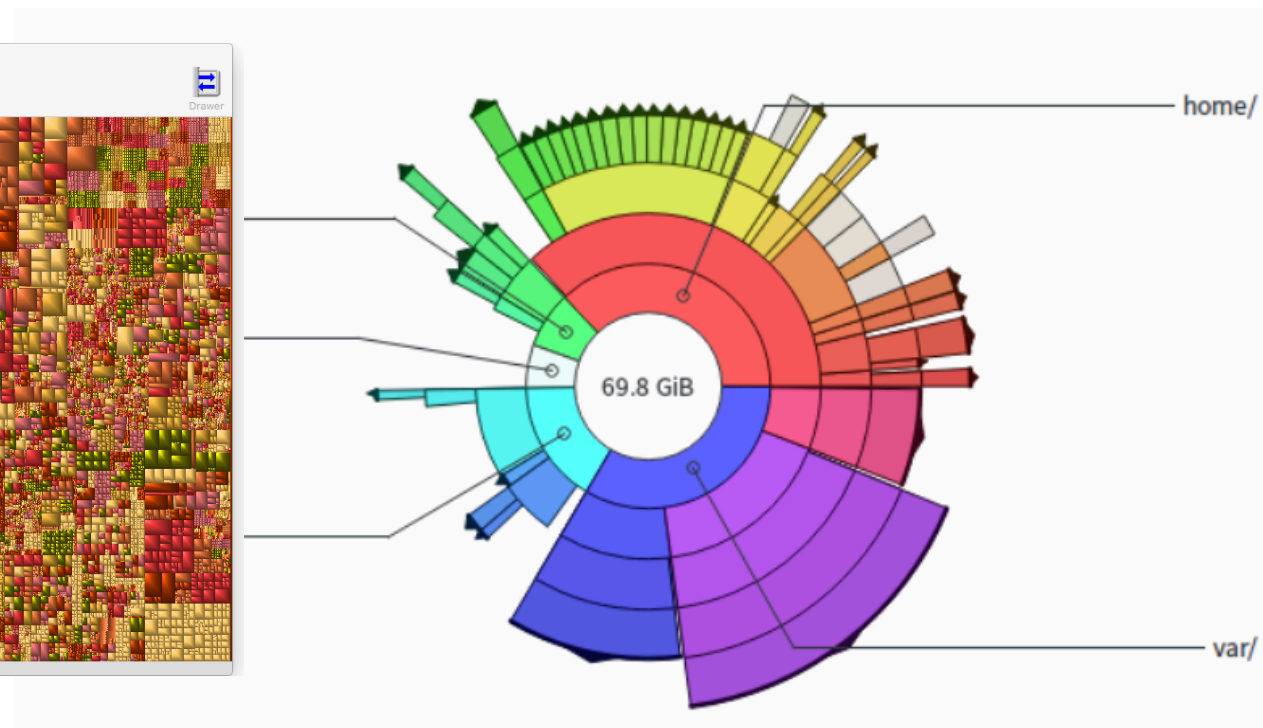
Idiom: implicit tree layouts (sunburst, icicle plot)

- alternative to connection and containment: position
 - show parent-child relationships only through relative positions

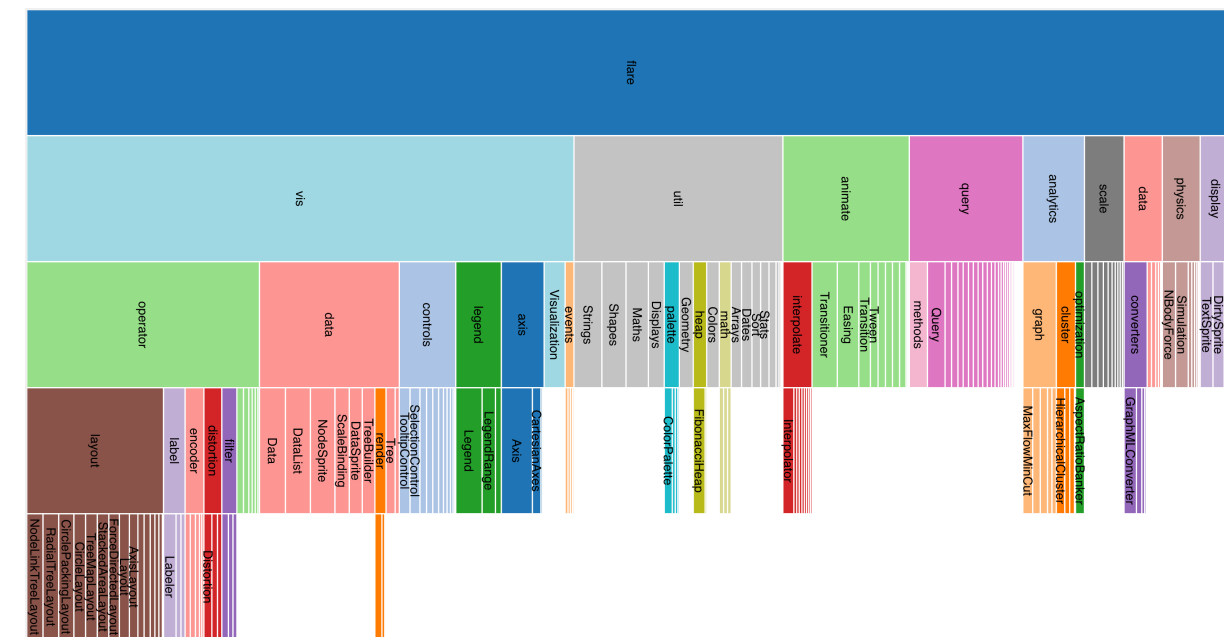
Treemap
containment



Sunburst
position (radial)



Icicle Plot
position (rectilinear)

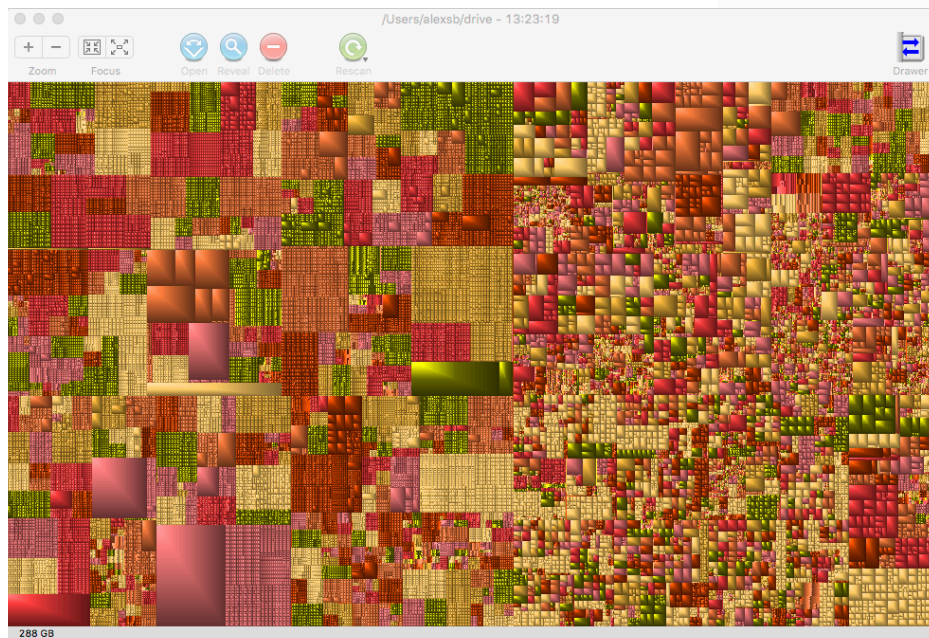


Idiom: implicit tree layouts (sunburst, icicle plot)

- alternative to connection and containment: position
 - show parent-child relationships only through relative positions

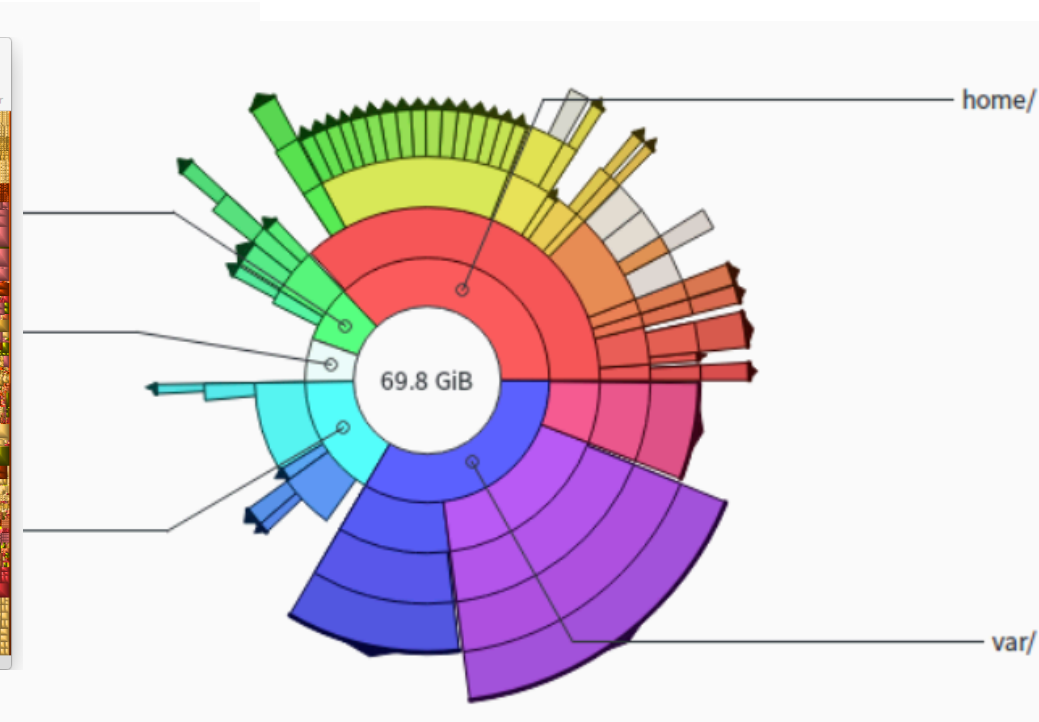
Treemap

containment
only leaves visible



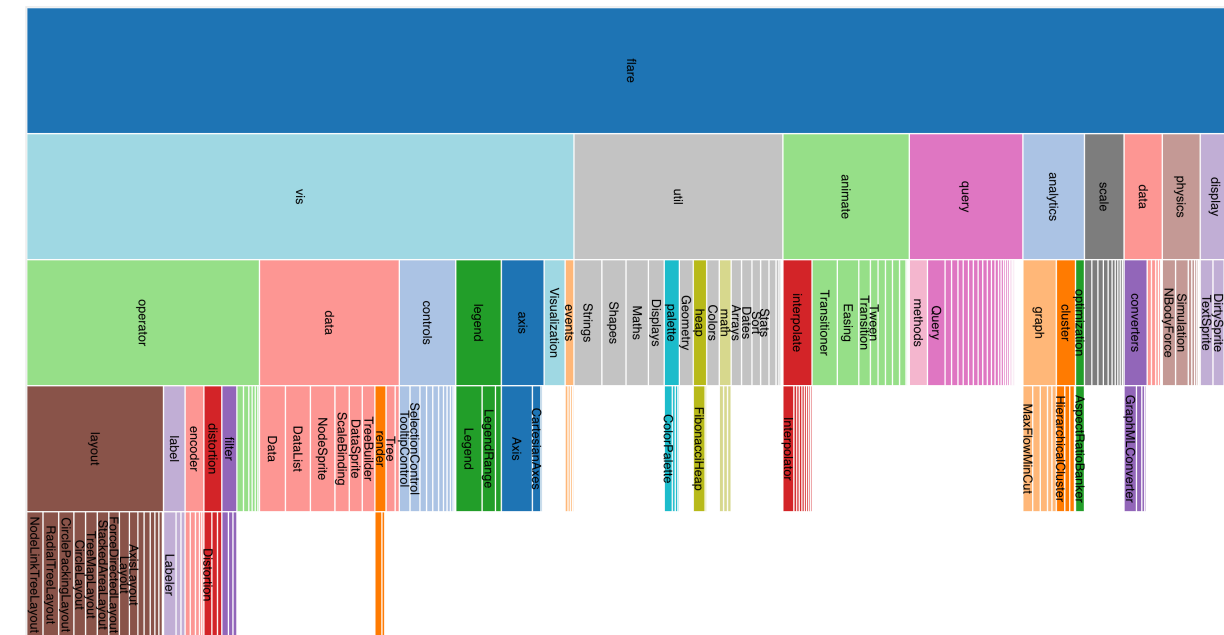
Sunburst

position (radial)
inner nodes & leaves visible



Icicle Plot

position (rectilinear)
inner nodes & leaves visible



Idiom: implicit tree layouts (sunburst, icicle plot)

- alternative to connection and containment: position
 - show parent-child relationships only through relative positions

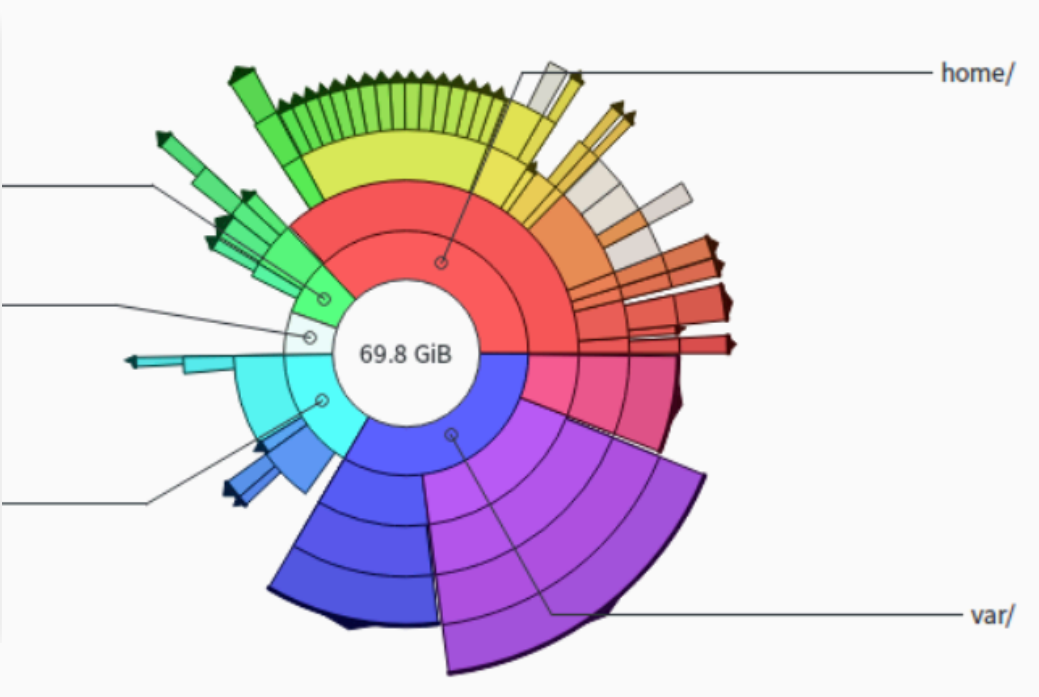
Treemap

containment
only leaves visible



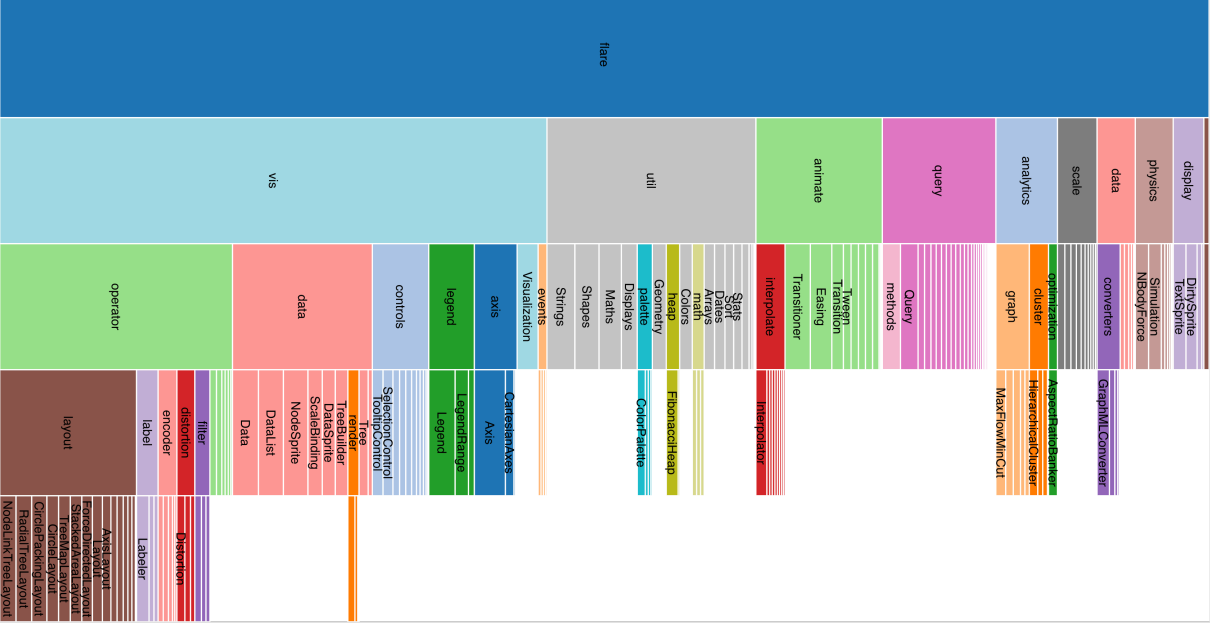
Sunburst

position (radial)
inner nodes & leaves visible



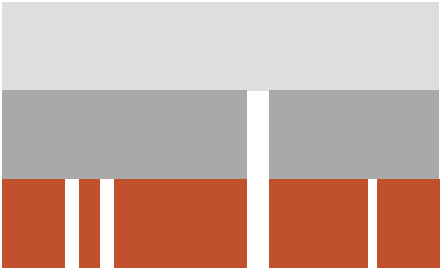
Icicle Plot

position (rectilinear)
inner nodes & leaves visible

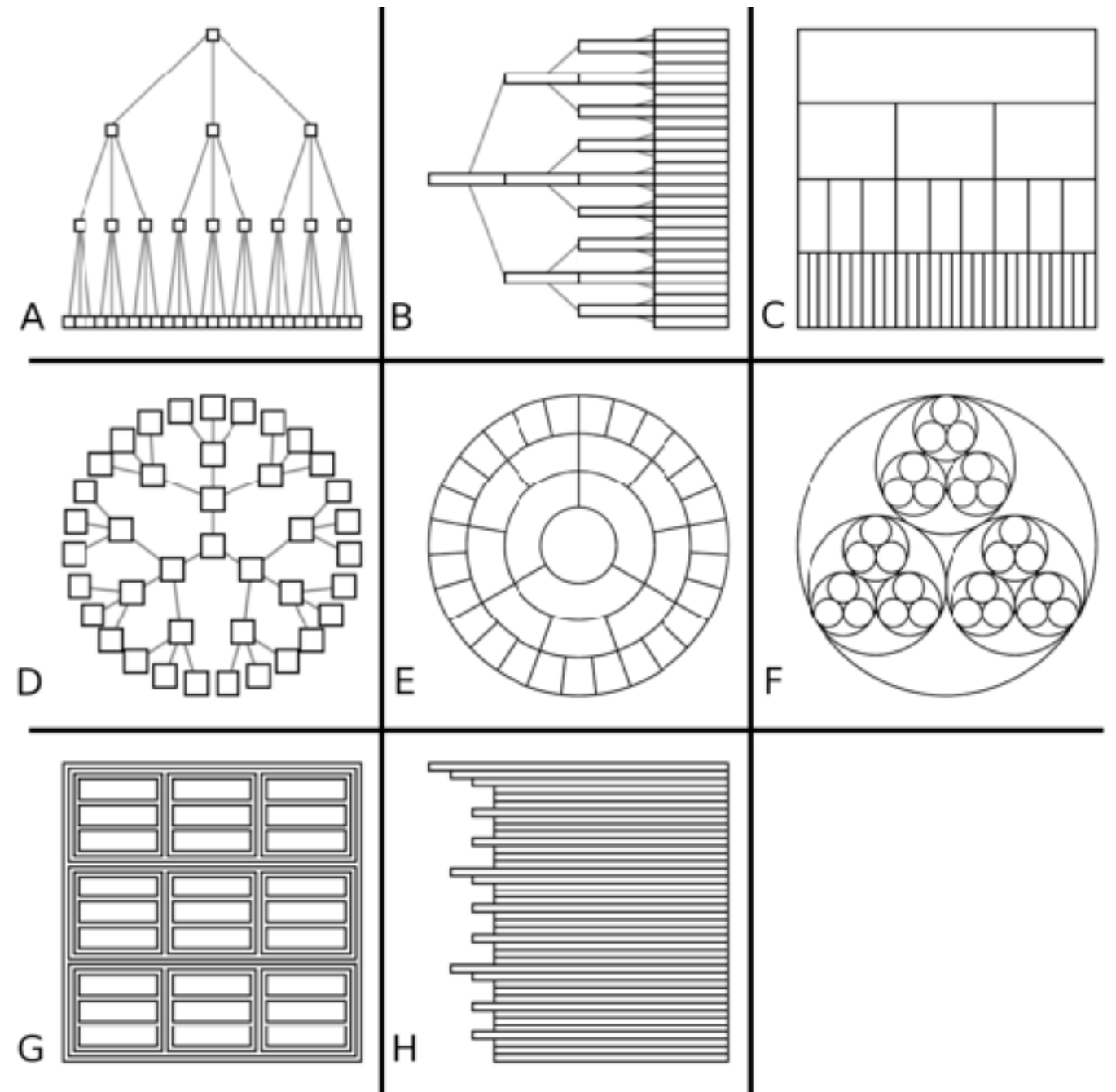


➔ **Implicit**
Spatial Position

✗ NETWORKS ✓ TREES

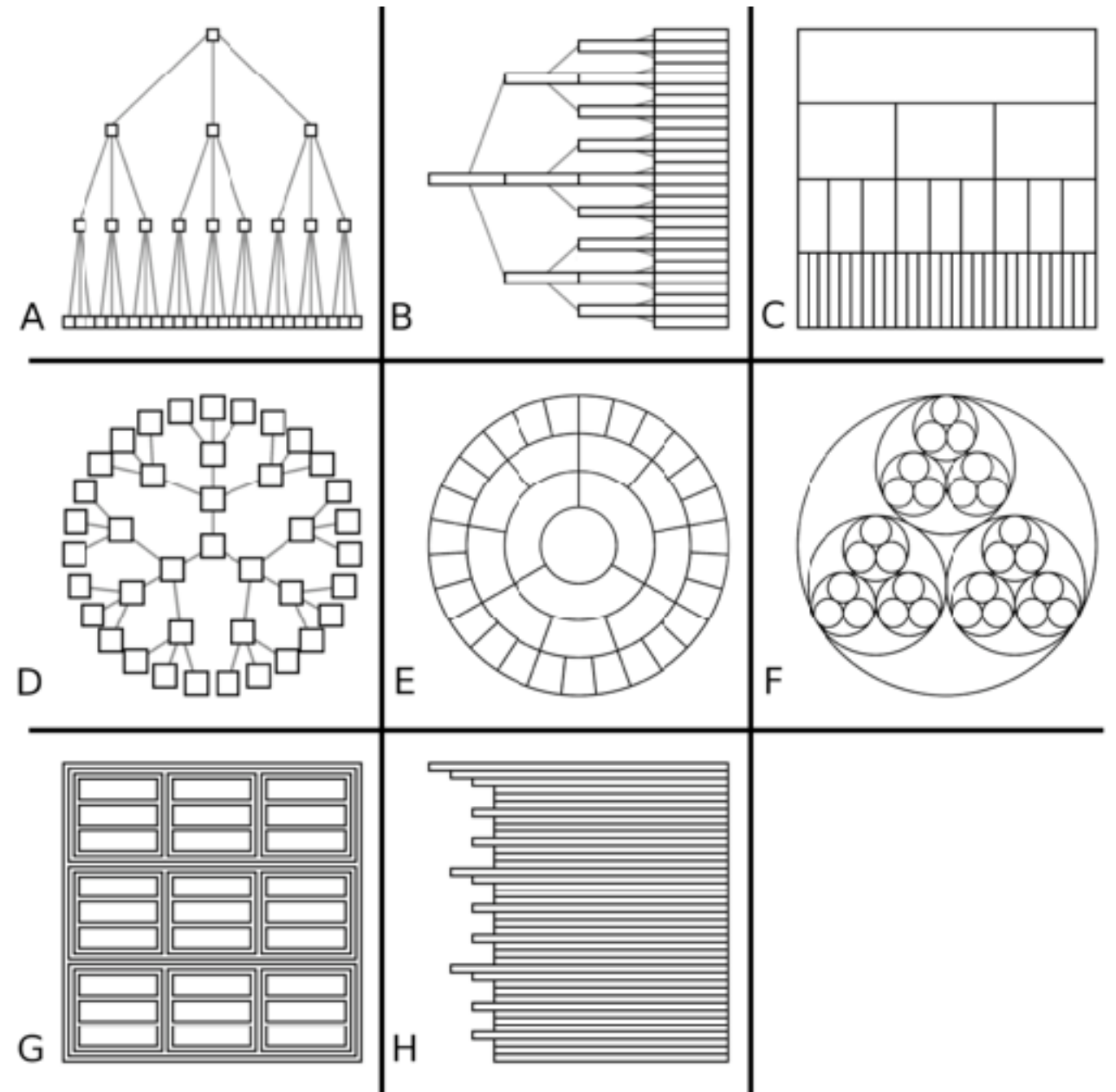


Tree drawing idioms comparison



Comparison: tree drawing idioms

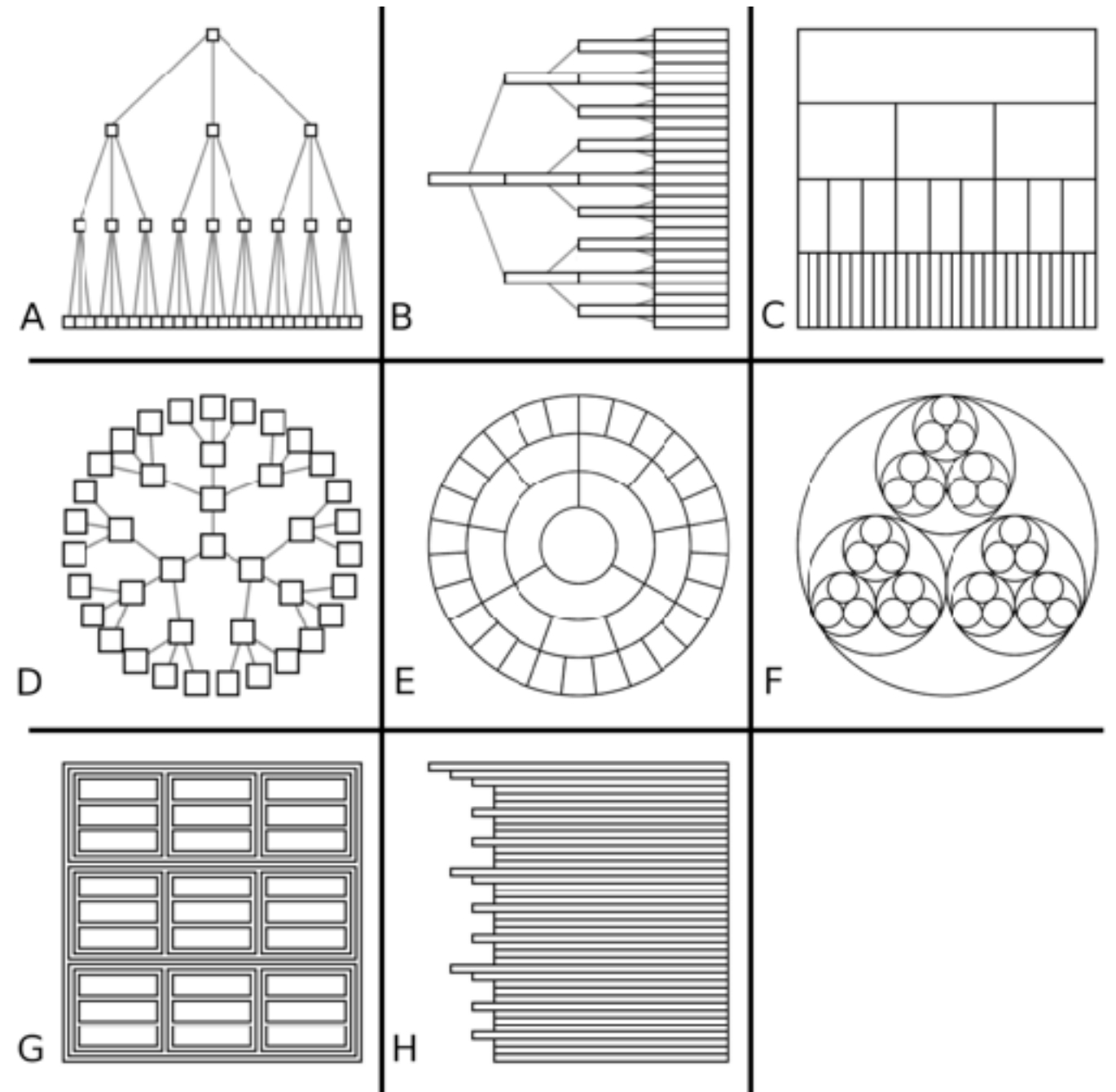
- data shown
 - link relationships
 - tree depth
 - sibling order



[Quantifying the Space-Efficiency of 2D Graphical Representations of Trees.
McGuffin and Robert. *Information Visualization* 9:2 (2010), 115–140.]

Comparison: tree drawing idioms

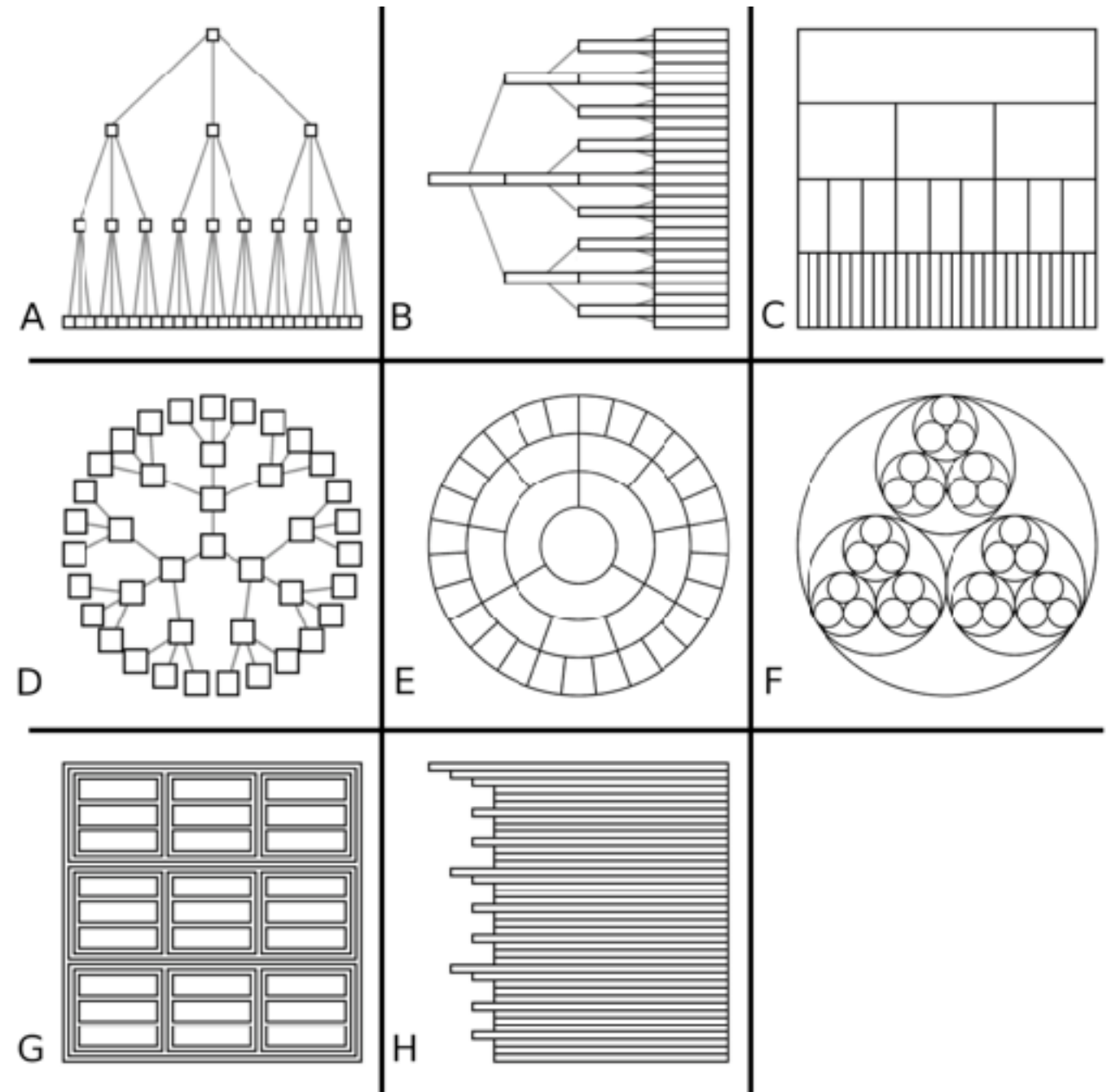
- data shown
 - link relationships
 - tree depth
 - sibling order
- design choices
 - connection vs containment link marks
 - rectilinear vs radial layout
 - spatial position channels



[Quantifying the Space-Efficiency of 2D Graphical Representations of Trees.
McGuffin and Robert. *Information Visualization* 9:2 (2010), 115–140.]

Comparison: tree drawing idioms

- data shown
 - link relationships
 - tree depth
 - sibling order
- design choices
 - connection vs containment link marks
 - rectilinear vs radial layout
 - spatial position channels
- considerations
 - redundant? arbitrary?
 - information density?
 - avoid wasting space
 - consider where to fit labels!



[Quantifying the Space-Efficiency of 2D Graphical Representations of Trees.
McGuffin and Robert. *Information Visualization* 9:2 (2010), 115–140.]

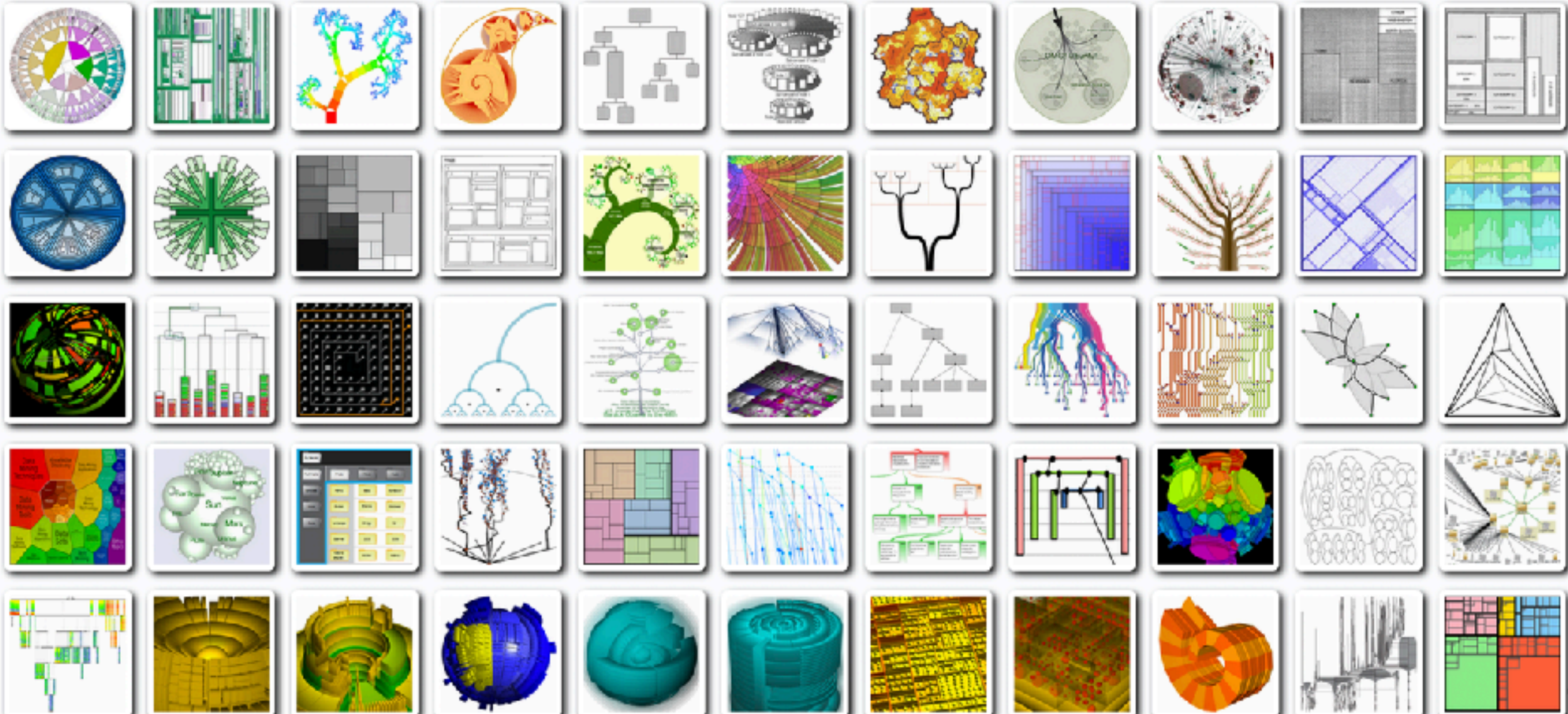
treevis.net: Many, many options!

How to cite this site?

Check out other surveys!

treevis.net - A Visual Bibliography of Tree Visualization 2.0 by Hans-Jörg Schulz v.21-OCT-2014

Dimensionality: All Representation: All Alignment: All Fulltext Search: × Techniques Shown: **277**



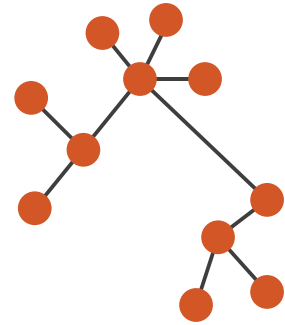
The image displays a grid of 50 thumbnail images, each representing a different tree visualization technique. The thumbnails are arranged in five rows and ten columns. The techniques shown include: circular tree diagrams, hierarchical charts, 3D models, network graphs, and various other visual representations of tree structures. The thumbnails are diverse in style, color, and layout, illustrating the wide range of options available on the website.

<https://treevis.net/>

Arrange networks and trees

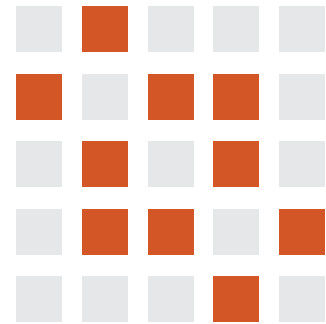
→ Node–Link Diagrams Connection Marks

✓ NETWORKS ✓ TREES



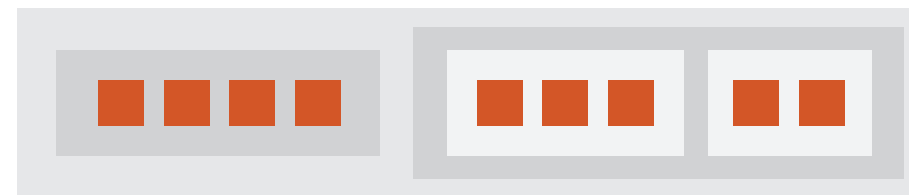
→ Adjacency Matrix Derived Table

✓ NETWORKS ✓ TREES



→ Enclosure Containment Marks

✗ NETWORKS ✓ TREES



→ Implicit Spatial Position

✗ NETWORKS ✓ TREES



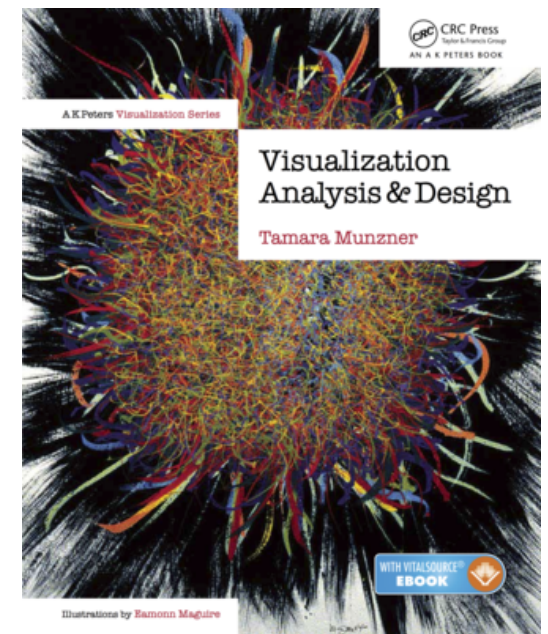
Visualization Analysis & Design

Network Data (Ch 9) II

Tamara Munzner

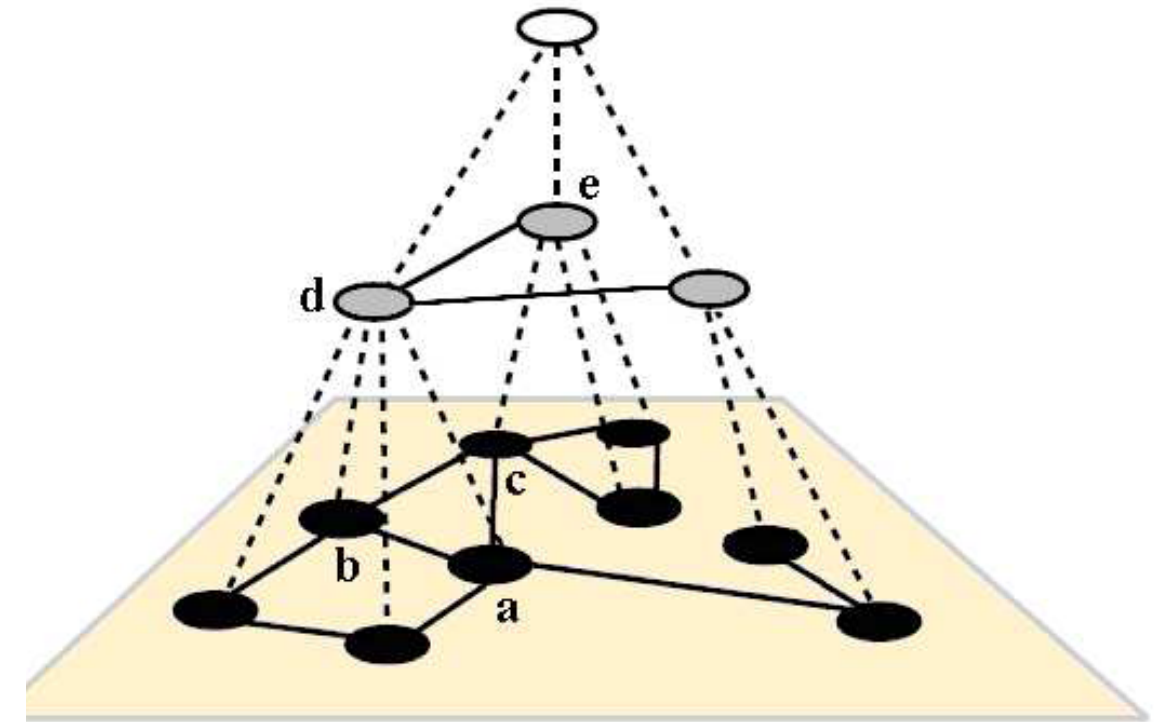
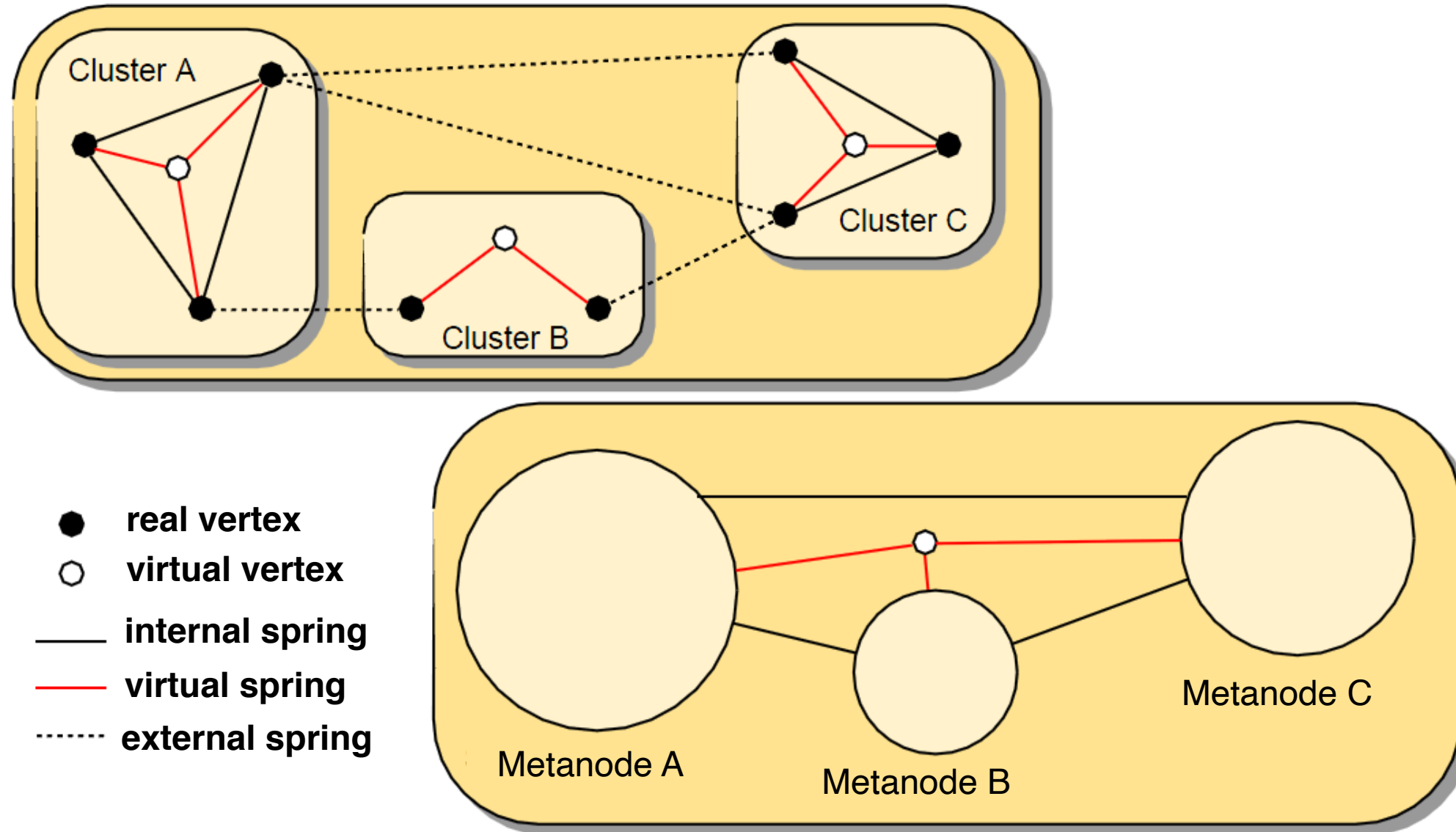
Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



Multilevel networks

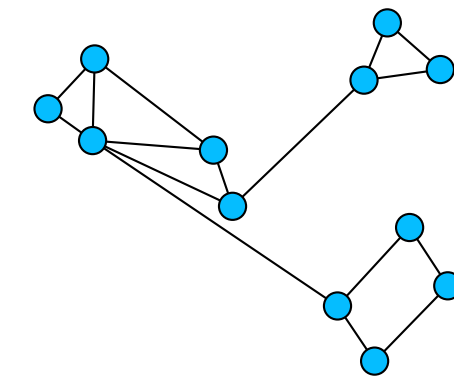
- derive cluster hierarchy of metanodes on top of original graph nodes



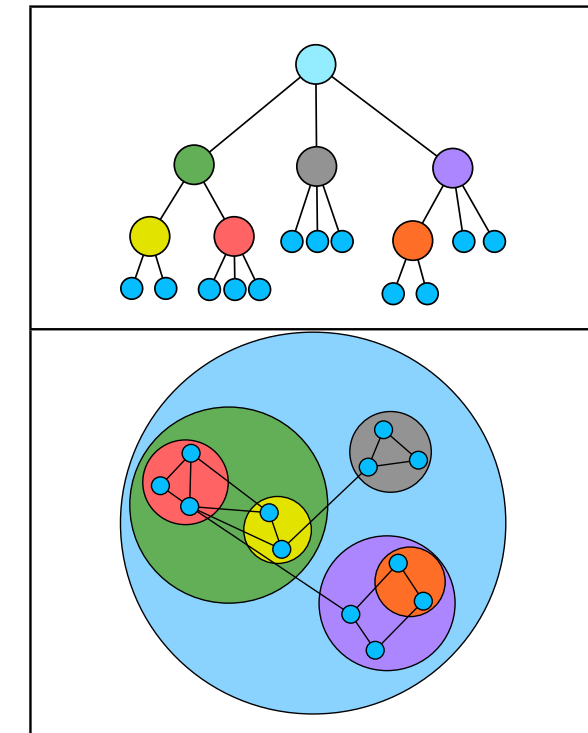
[Schulz 2004]

Idiom: GrouseFlocks

- data: compound network
 - network
 - cluster hierarchy atop it
 - derived or interactively chosen
- visual encoding
 - connection marks for network links
 - containment marks for hierarchy
 - point marks for nodes
- dynamic interaction
 - select individual metanodes in hierarchy to expand/contract



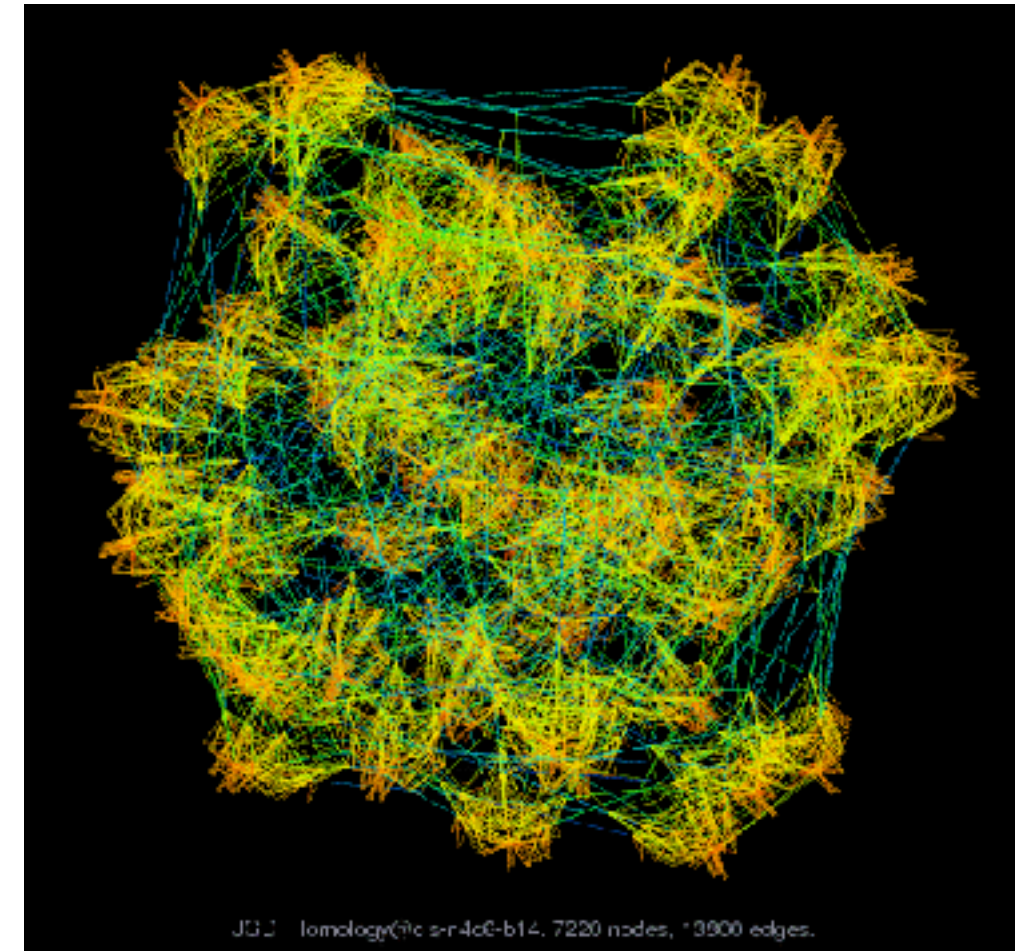
Graph Hierarchy 1



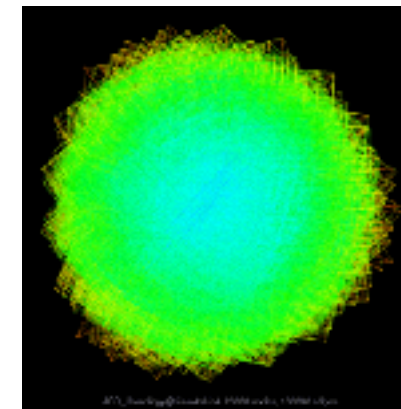
[GrouseFlocks: Steerable Exploration of Graph Hierarchy Space. Archambault, Munzner, and Auber. *IEEE TVCG* 14(4):900-913, 2008.]

Idiom: **sfdp** (multi-level force-directed placement)

- data: compound graph
 - original: network
 - derived: cluster hierarchy atop it
- considerations
 - better algorithm for same encoding technique
 - same: fundamental use of space
 - hierarchy used for algorithm speed/quality but not shown explicitly
- scalability
 - nodes, edges: 1K-10K
 - hairball problem eventually hits

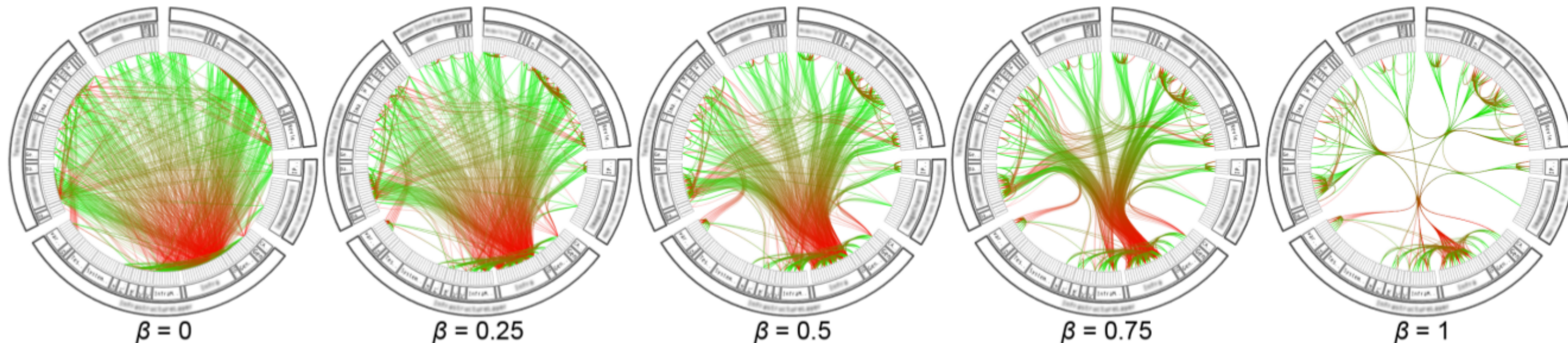


[Efficient and high quality force-directed graph drawing. Hu. The Mathematica Journal 10:37–71, 2005.]



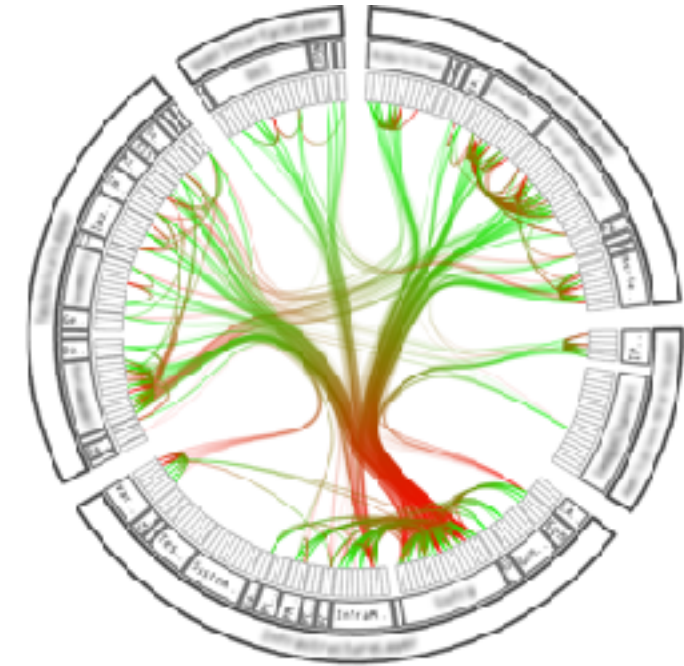
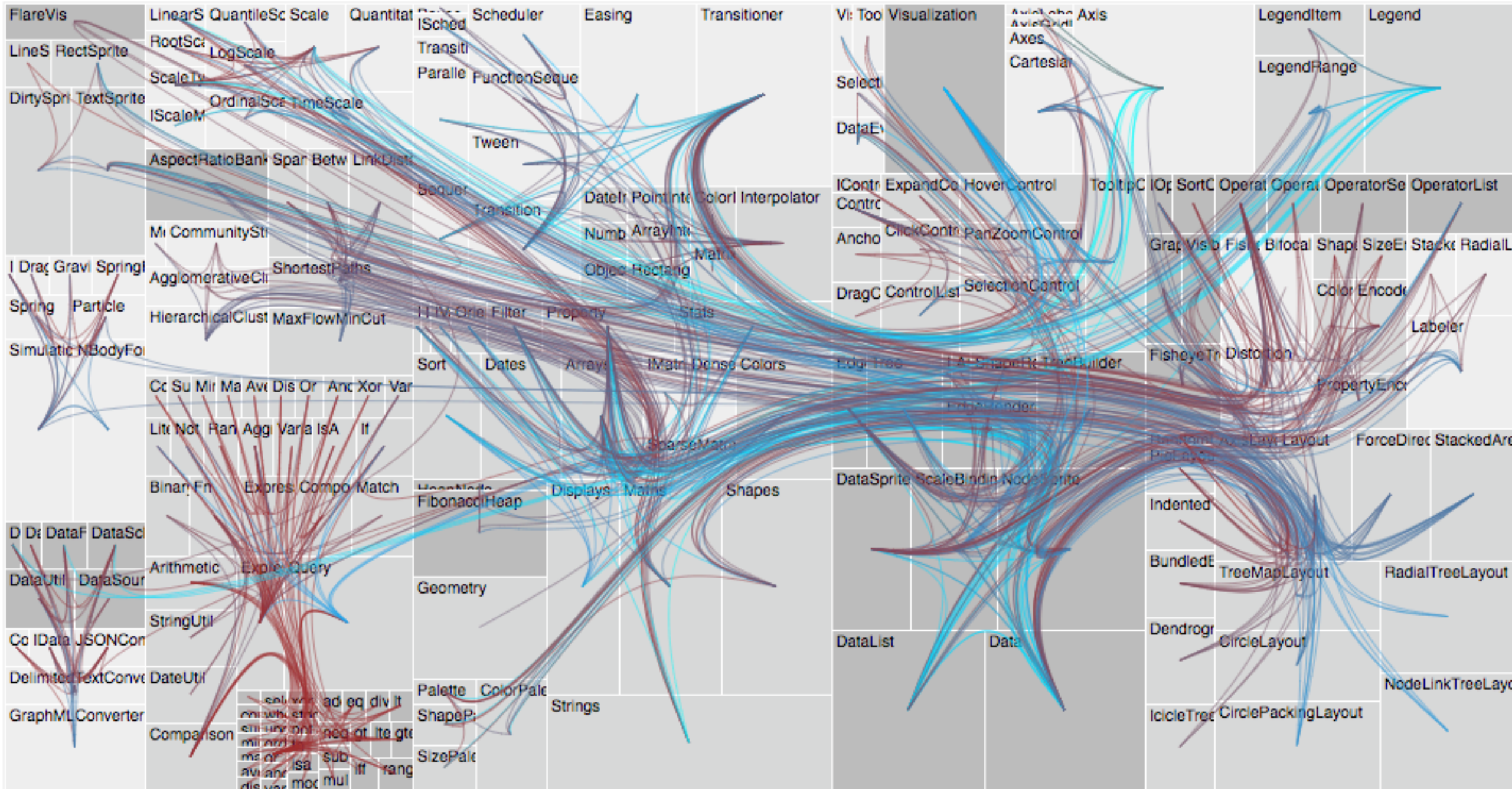
Idiom: hierarchical edge bundling

- data
 - any layout of compound network
 - network: software classes (nodes), import/export between classes (links)
 - cluster hierarchy: class package structure
 - derived: bundles of edges with same source/destination (multi-level)
- idiom: curve edge routes according to bundles
- task: edge clutter reduction



Hierarchical edge bundling

- works for any layout: treemap vs radial



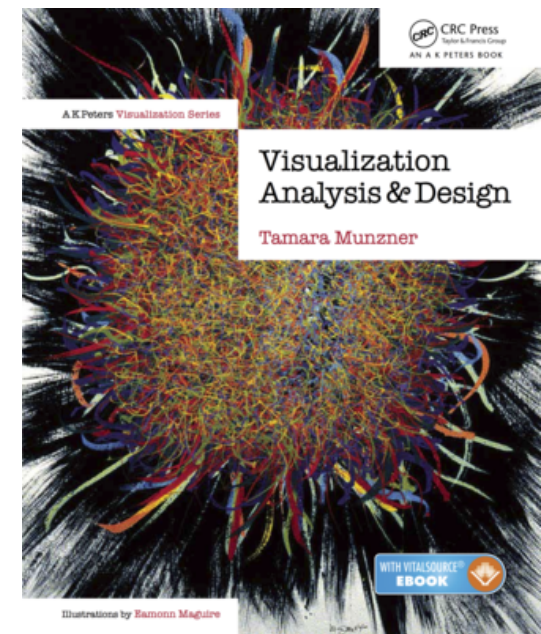
Visualization Analysis & Design

Spatial Data (Ch 9)

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University of British Columbia

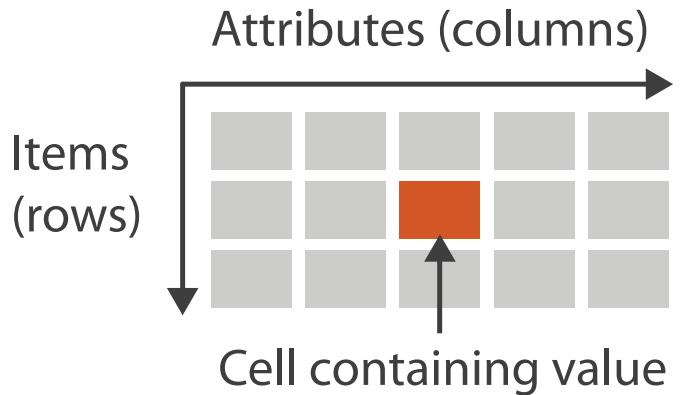
[@tamaramunzner](#)



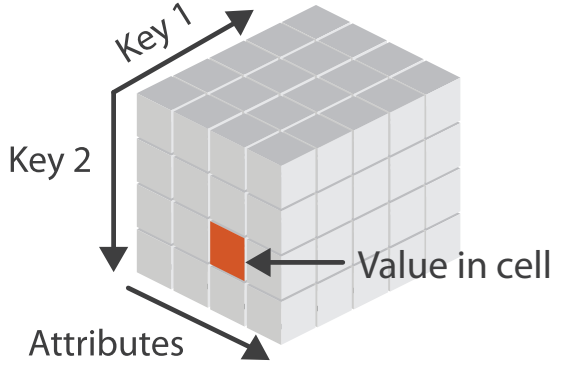
Focus on Spatial

→ Dataset Types

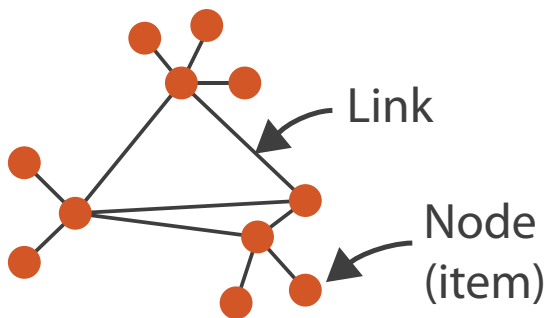
→ Tables



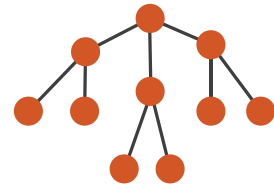
→ Multidimensional Table



→ Networks

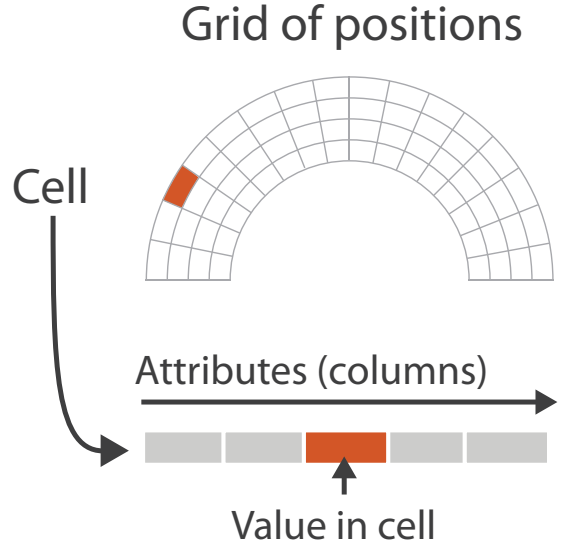


→ Trees



→ Spatial

→ Fields (Continuous)



→ Geometry (Spatial)



How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



What?

Why?

How?

→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



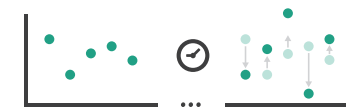
→ Motion

Direction, Rate, Frequency, ...

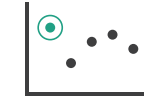


Manipulate

→ Change



→ Select

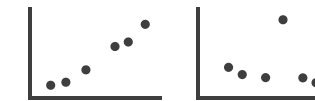


→ Navigate

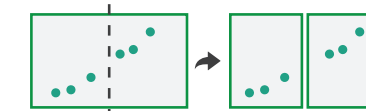


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

→ Filter



→ Aggregate



→ Embed



How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



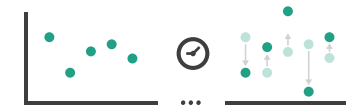
→ Motion

Direction, Rate, Frequency, ...

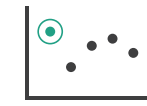


Manipulate

→ Change



→ Select



→ Navigate

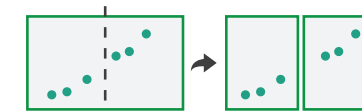


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

→ Filter



→ Aggregate



→ Embed



What?

Why?

How?

Spatial data

- use given spatial position
- when?
 - dataset contains spatial attributes and they have primary importance
 - central tasks revolve around understanding spatial relationships
- examples
 - geographical/cartographic data
 - sensor/simulation data

Geographic Maps

Geographic Map



Interlocking marks

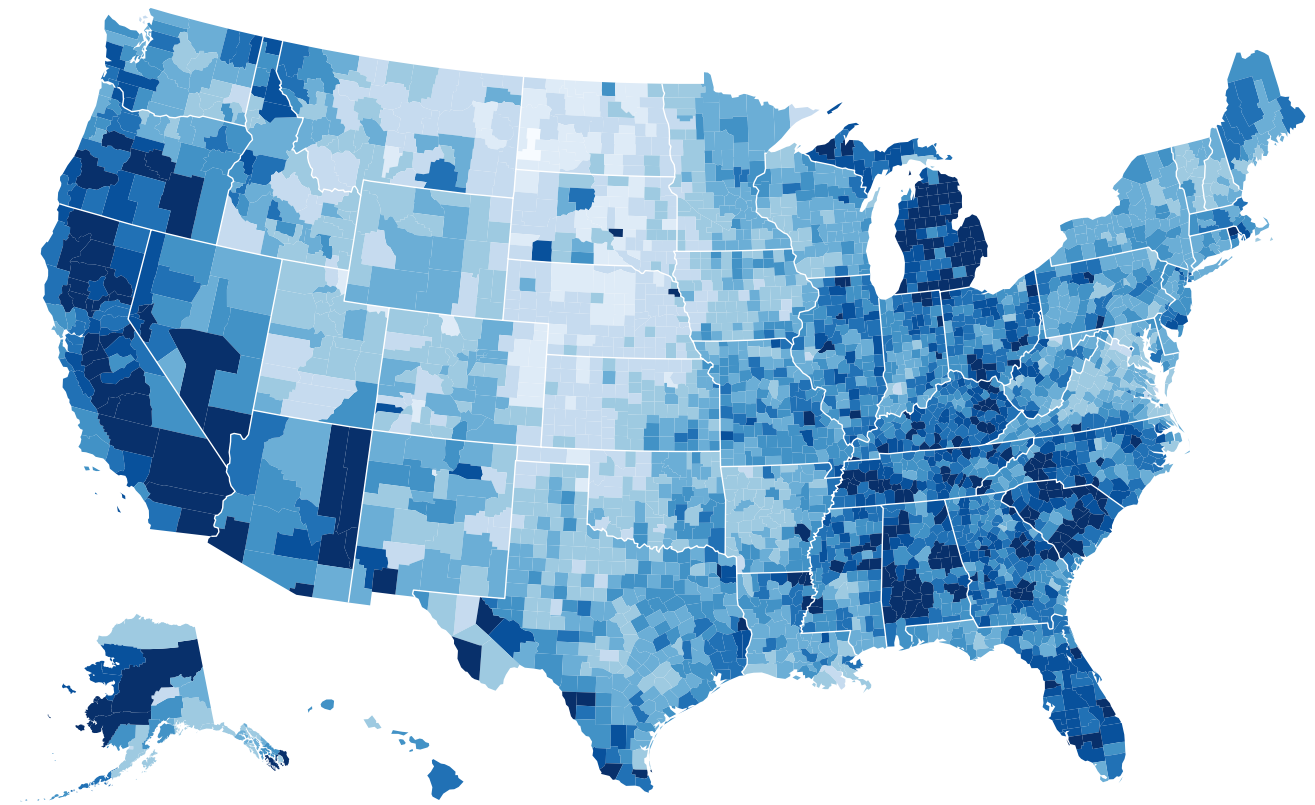
- **shape coded**
 - **area coded**
 - **position coded**
-
- cannot encode another attribute with these channels, they're "taken"

Thematic maps

- show spatial variability of attribute ("theme")
 - combine geographic / reference map with (simple, flat) tabular data
 - join together
 - region: interlocking area marks (provinces, countries with outline shapes)
 - also could have point marks (cities, locations with 2D lat/lon coords)
 - region: categorical key attribute in table
 - use to look up value attributes
- major idioms
 - choropleth
 - symbol maps
 - cartograms
 - dot density maps

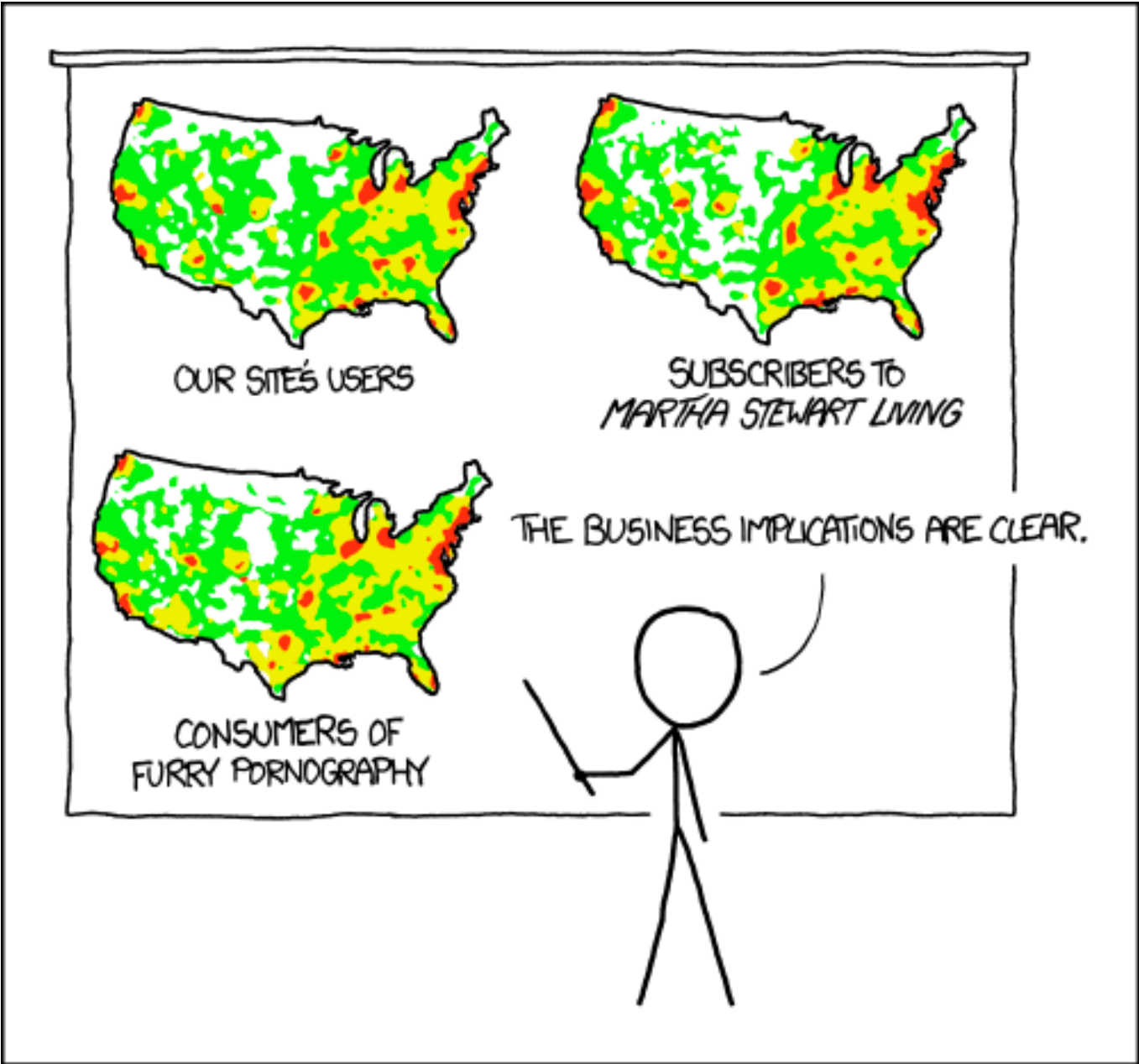
Idiom: **choropleth map**

- use given spatial data
 - when central task is understanding spatial relationships
- data
 - geographic geometry
 - table with 1 quant attribute per region
- encoding
 - position:
 - use given geometry for area mark boundaries
 - color:
 - sequential segmented colormap



<http://bl.ocks.org/mbostock/4060606>

Beware: Population maps trickiness!

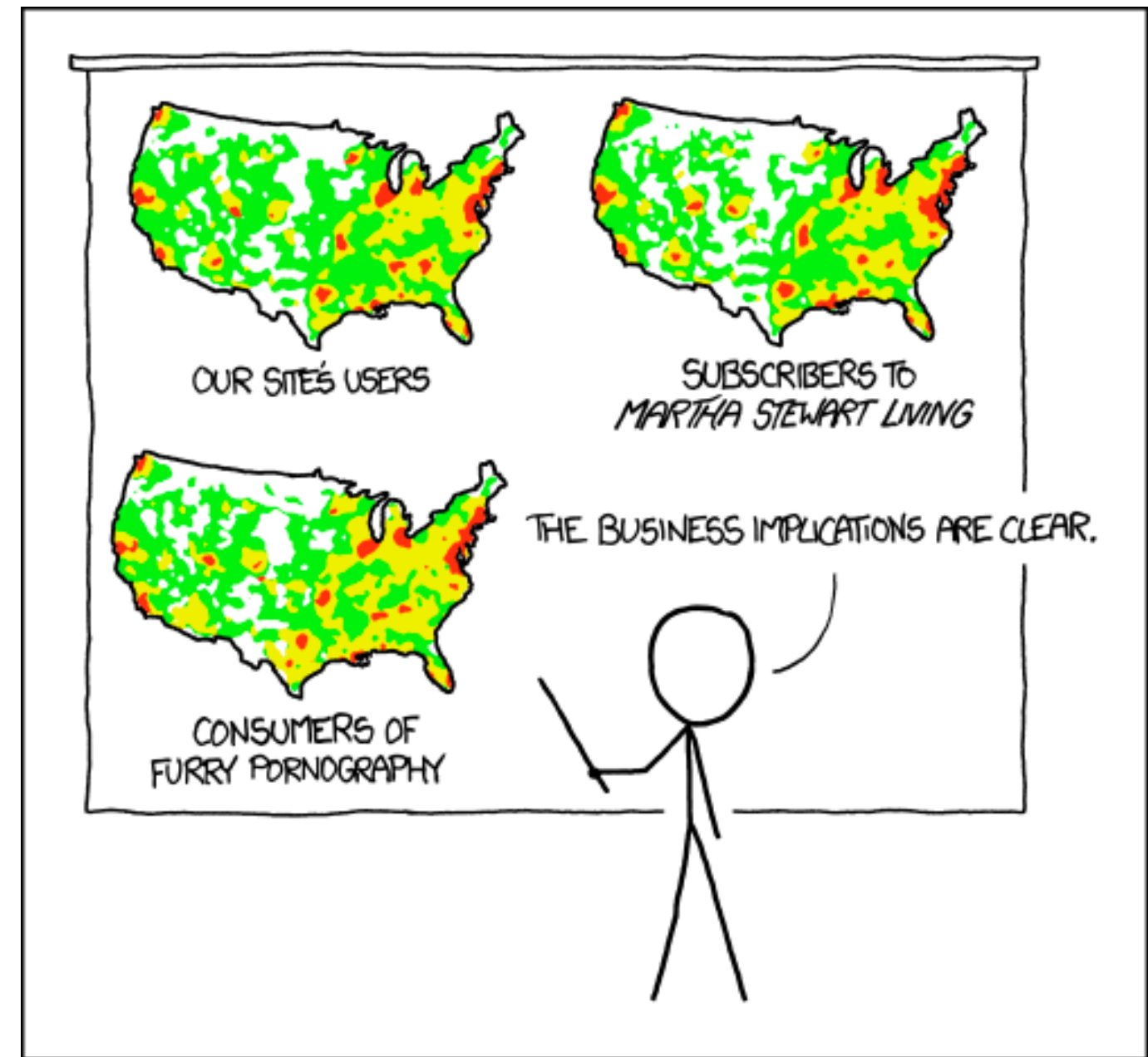


PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE
BASICALLY JUST POPULATION MAPS

[<https://xkcd.com/1138>]

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live

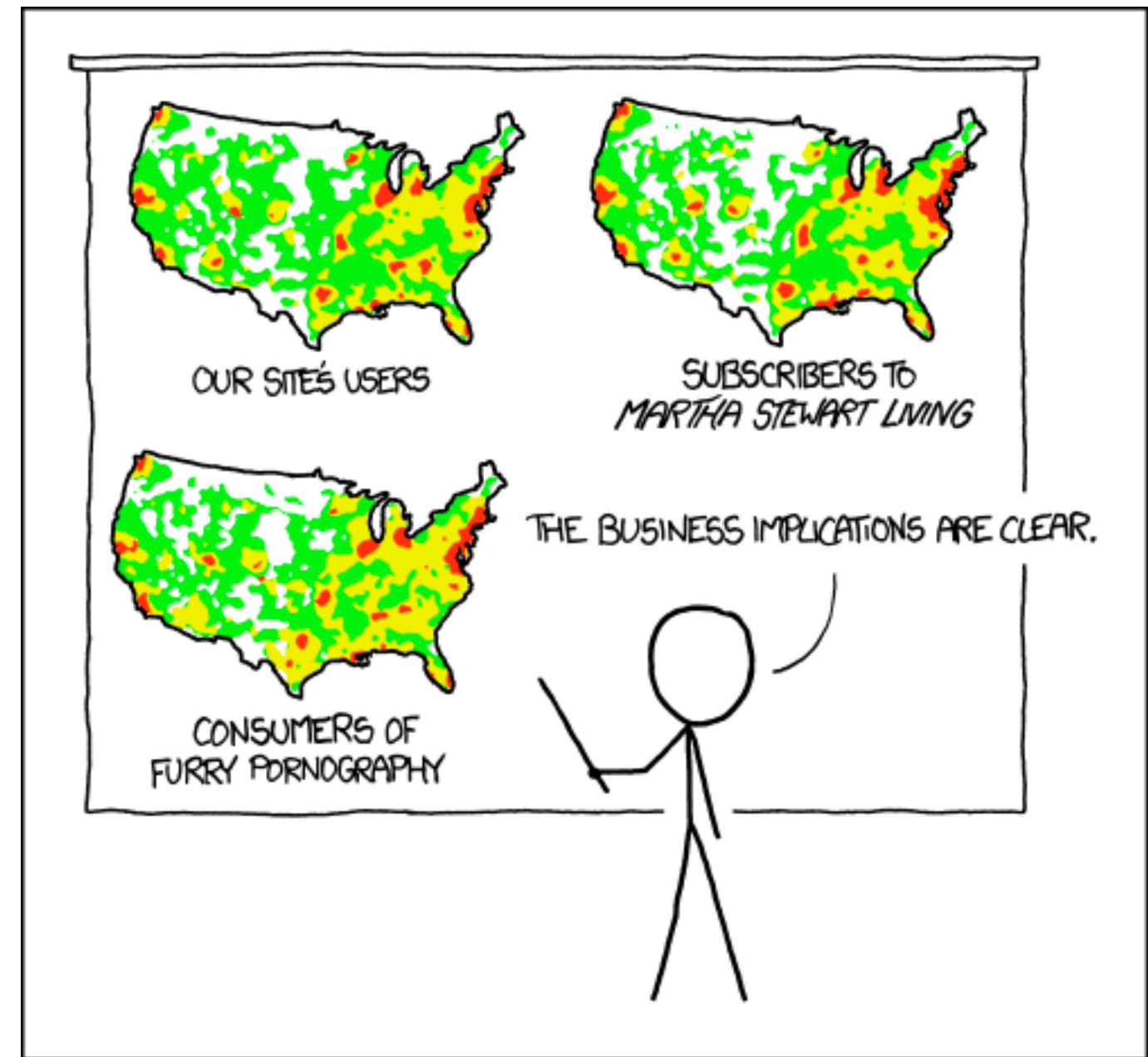


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[<https://xkcd.com/1138>]

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
 - encode raw data values
 - tied to underlying population
 - but should use normalized values
 - unemployed people per 100 citizens, mean family income

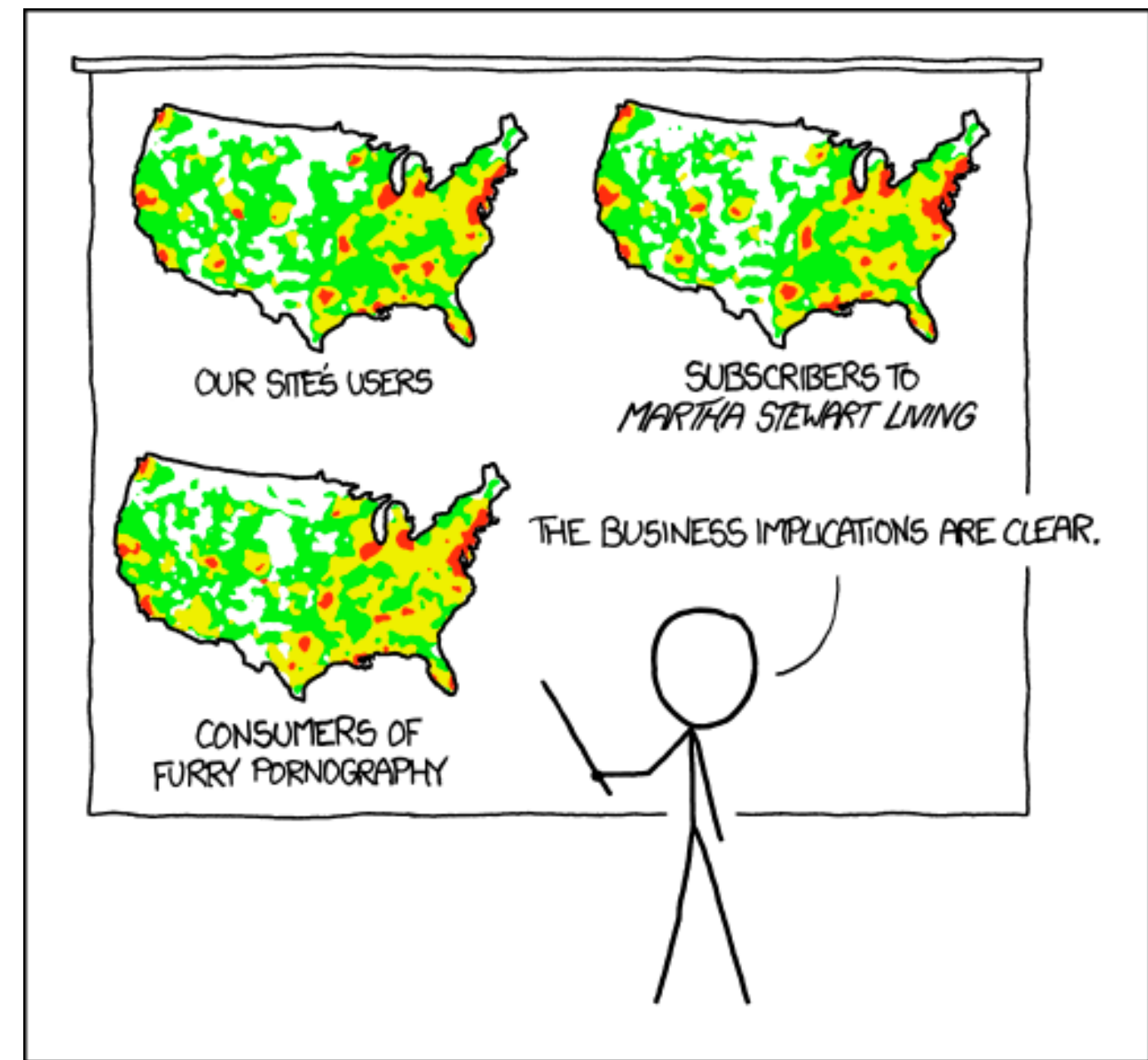


PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE
BASICALLY JUST POPULATION MAPS

[<https://xkcd.com/1138>]

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
 - encode raw data values
 - tied to underlying population
 - but should use normalized values
 - unemployed people per 100 citizens, mean family income
- general issue
 - absolute counts vs relative/normalized data
 - failure to normalize is common error



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE
BASICALLY JUST POPULATION MAPS

[<https://xkcd.com/1138>]

Choropleth maps: Recommendations

- only use when central task is understanding spatial relationships
- show only one variable at a time
- normalize when appropriate
- be careful when choosing colors & bins
- best case: regions are roughly equal sized

Choropleth map: Pros & cons

- pros

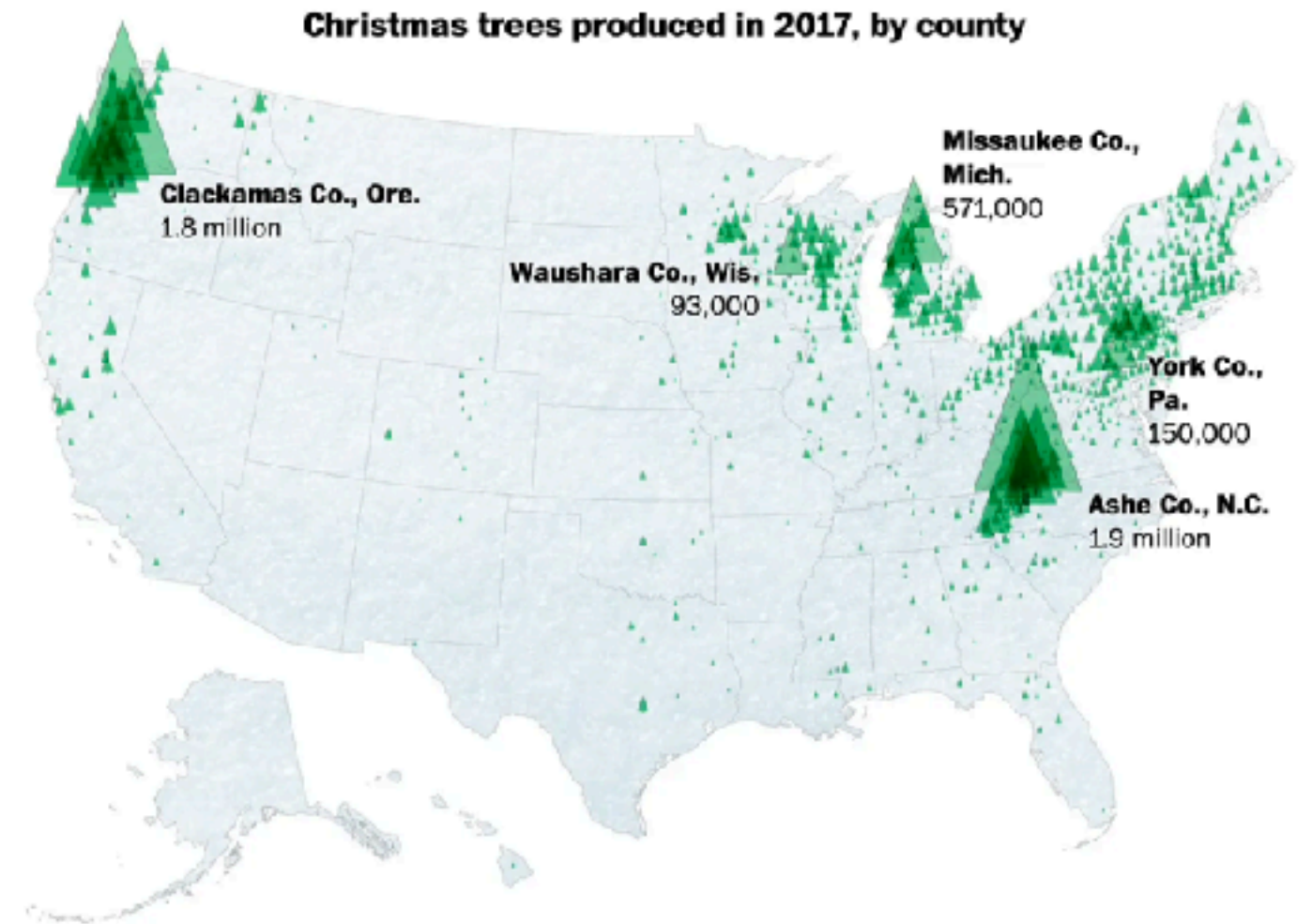
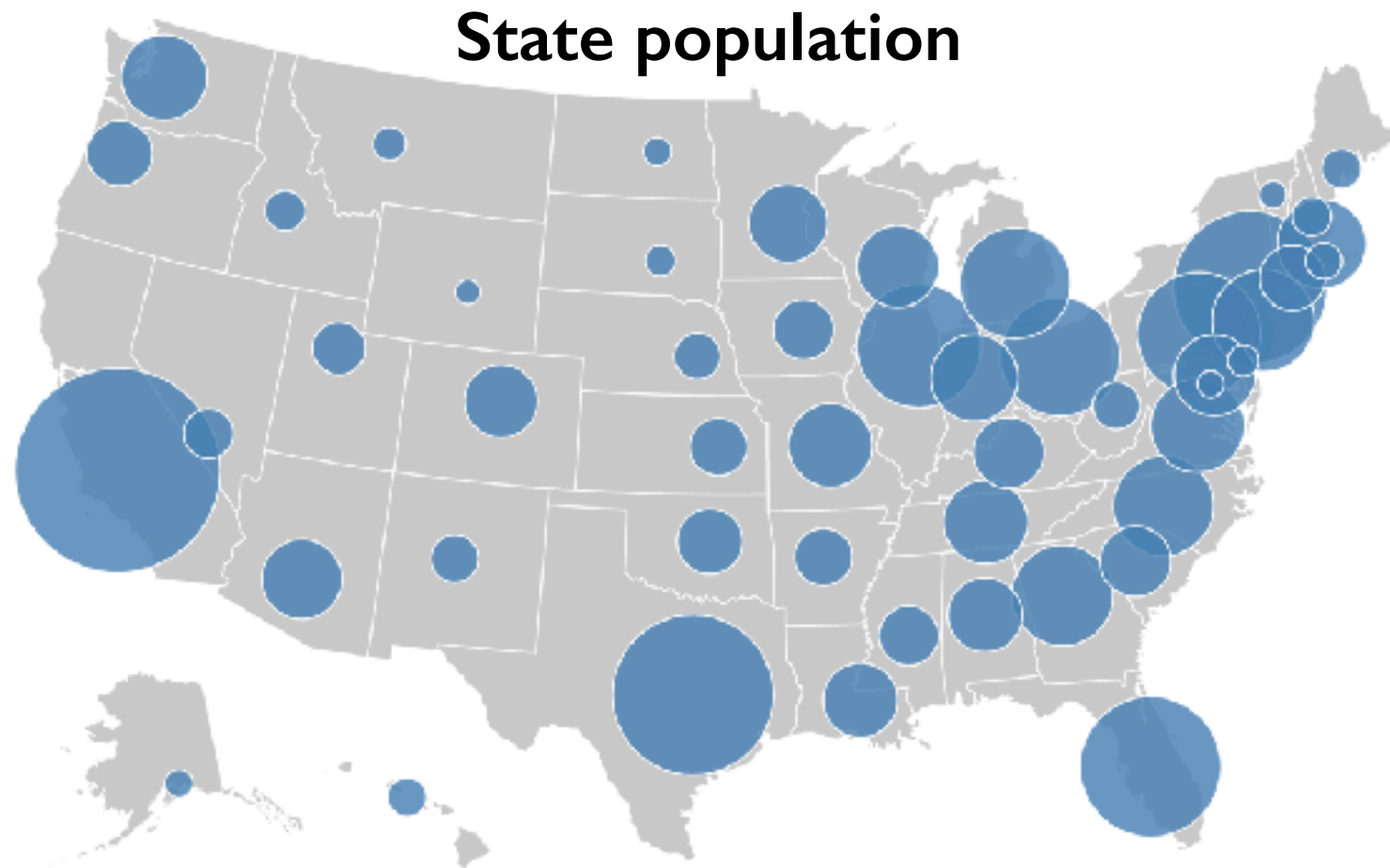
- easy to read and understand
- well established visualization (no learning curve)
- data is often collected and aggregated by geographical regions

- cons

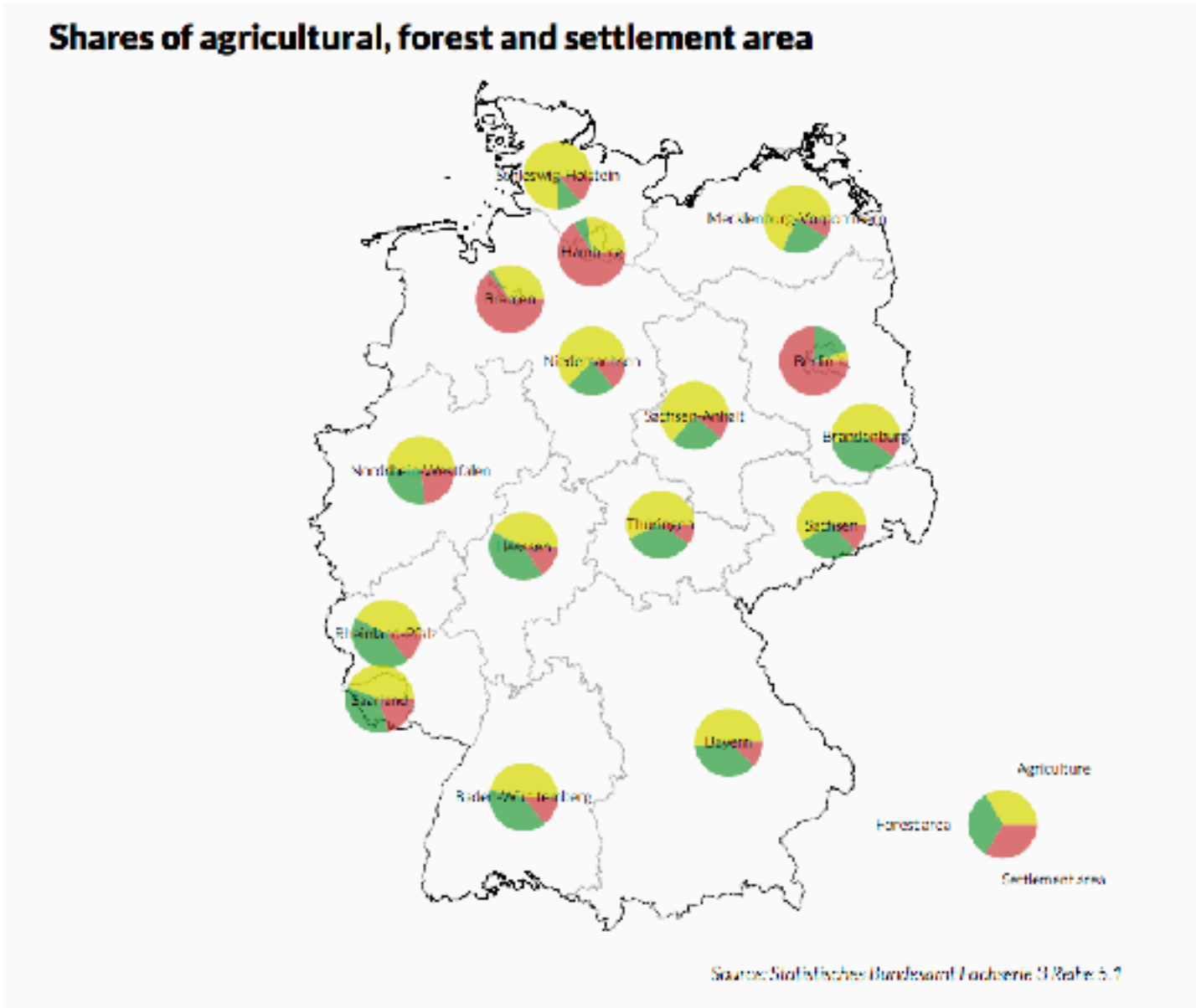
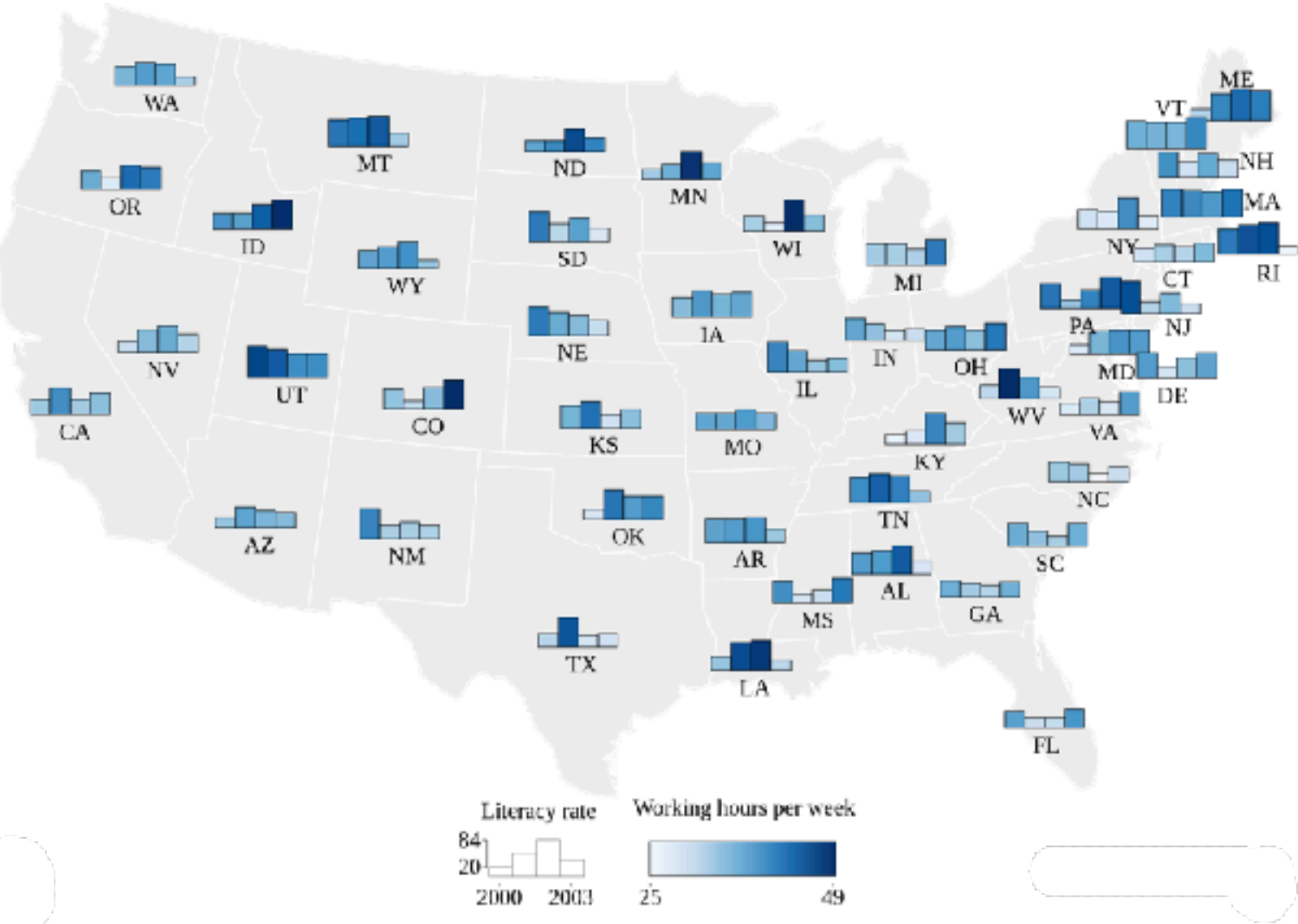
- most effective visual variable used for geographic location
- visual salience depends on region size, not true importance wrt attribute value
 - large regions appear more important than small ones
- color palette choice has a huge influence on the result

Idiom: **Symbol maps**

- symbol is used to represent aggregated data (mark or glyph)
 - allows use of size and shape and color channels
 - aka proportional symbol maps, graduated symbol maps
- keep original spatial geometry in the background
- often a good alternative to choropleth maps



Symbol maps with glyphs



Symbol map: Pros & cons

- pros

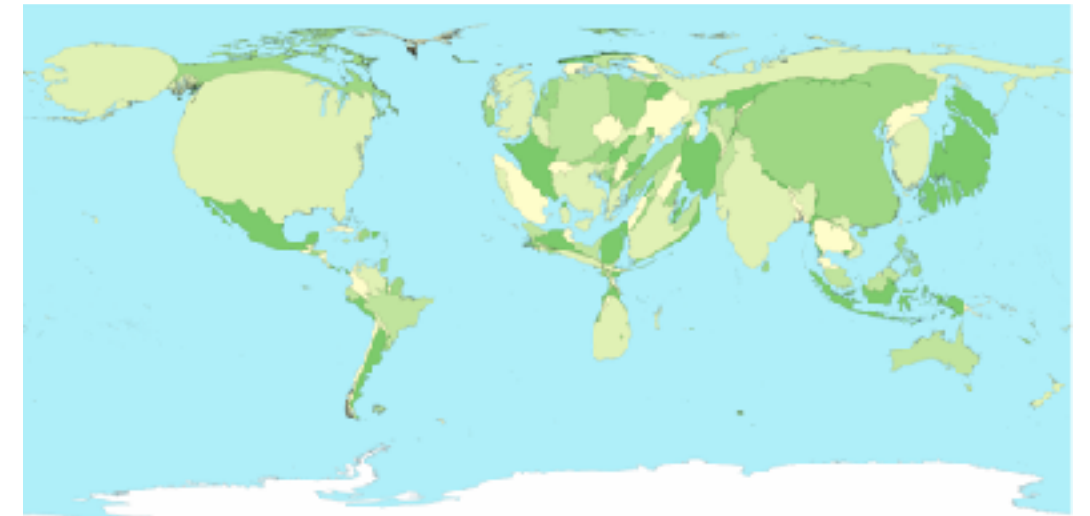
- somewhat intuitive to read and understand
- mitigate problems with region size vs data salience
 - marks: symbol size follows attribute value
 - glyphs: symbol size can be uniform

- cons

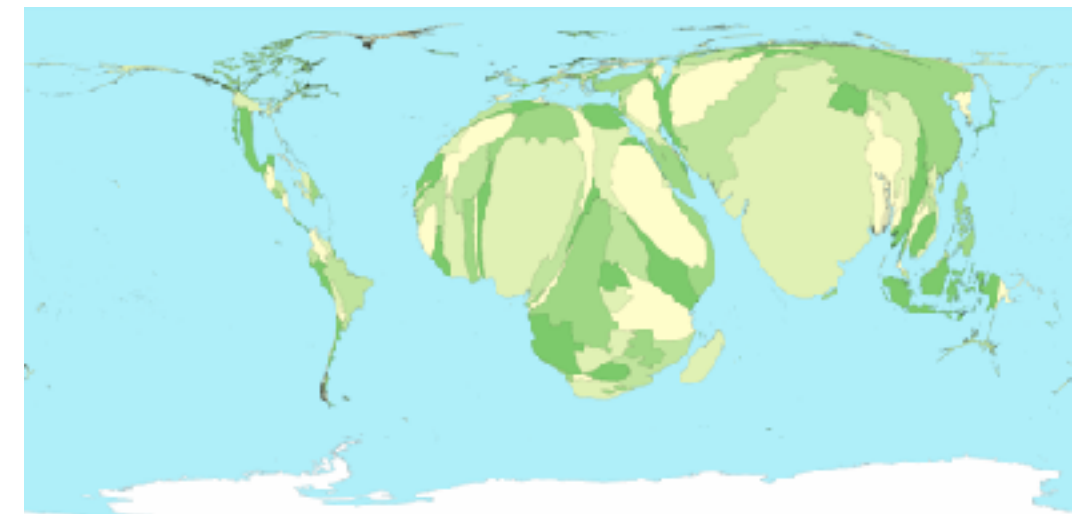
- possible occlusion / overlap
 - symbols could overlap each other
 - symbols could occlude region boundaries
- complex glyphs may require explanation / training

Idiom: **Contiguous cartogram**

- interlocking marks:
shape, area, and position coded
- derive new interlocking marks
 - based on combination of original interlocking marks and new quantitative attribute
- algorithm to create new marks
 - input: target size
 - goal: shape as close to the original as possible
 - requirement: maintain constraints
 - relative position
 - contiguous boundaries with their neighbours

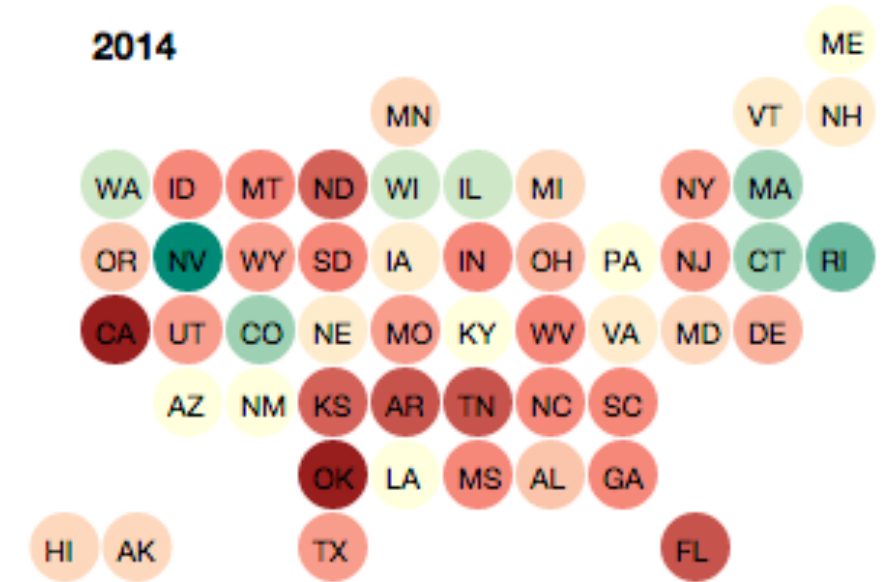
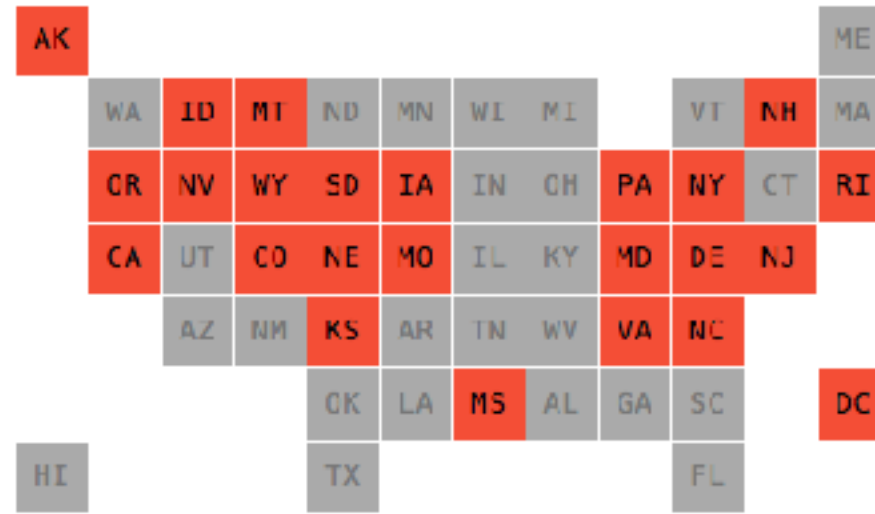
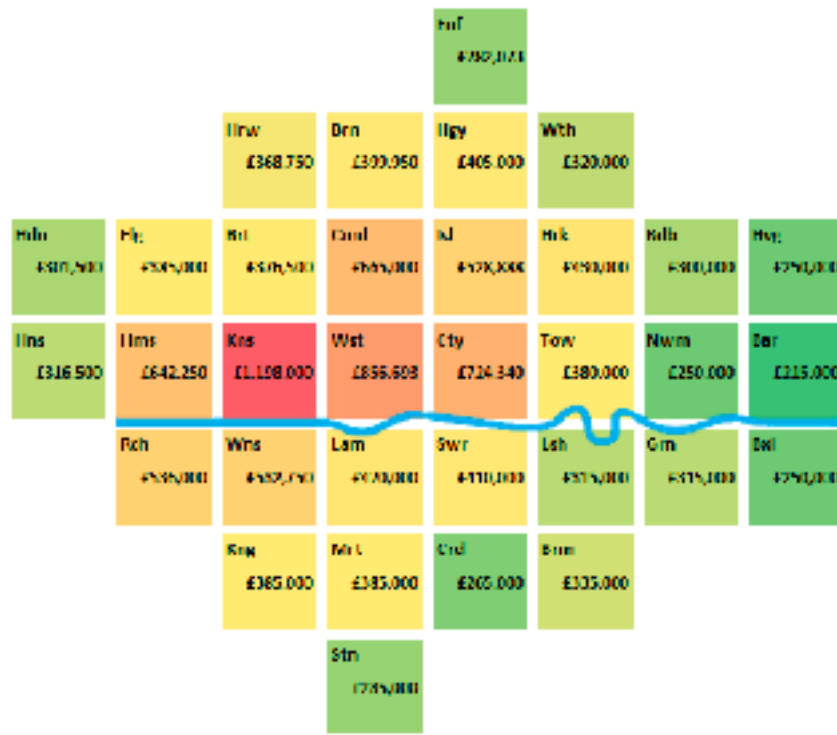


Greenhouse Emissions



Child Mortality

Idiom: Grid Cartogram



- uniform-sized shapes arranged in rectilinear grid
- maintain approximate spatial position and arrangement

Cartogram: Pros & cons

- pros

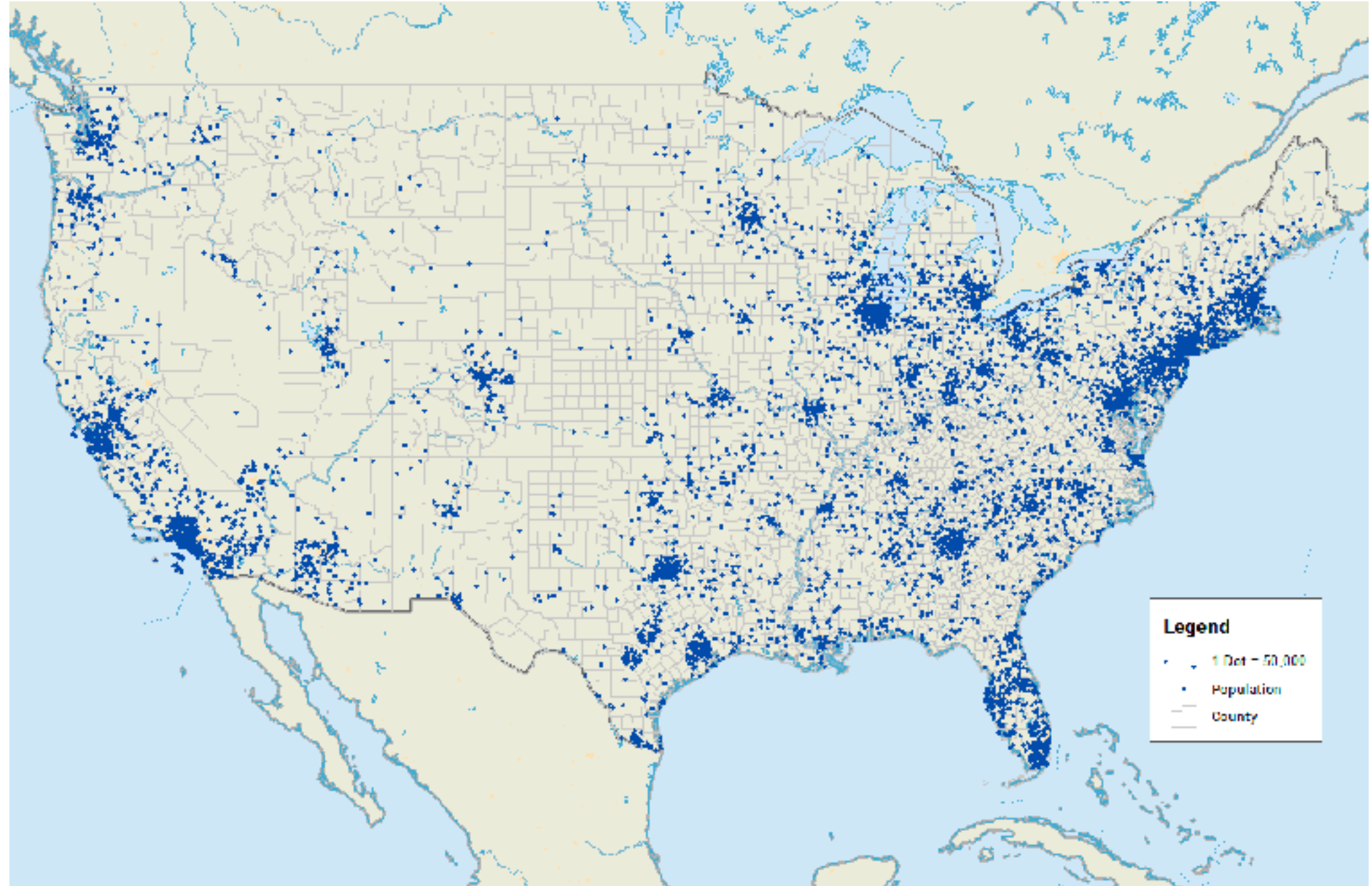
- can be intriguing and engaging
- best case: strong and surprising size disparities
- non-contiguous cartograms often easier to understand

- cons

- require substantial familiarity with original dataset & use of memory
 - compare distorted marks to memory of original marks
 - mitigation strategies: transitions or side by side views
- major distortion is problematic
 - may be aesthetically displeasing
 - may result in unrecognizable marks
- difficult to extract exact quantities

Idiom: **Dot density maps**

- visualize distribution of a phenomenon by placing dots
- one symbol represents a constant number of items
 - dots have uniform size & shape
 - allows use of color channel
- task:
show spatial patterns, clusters



Dot density maps: Pros and cons

- pros

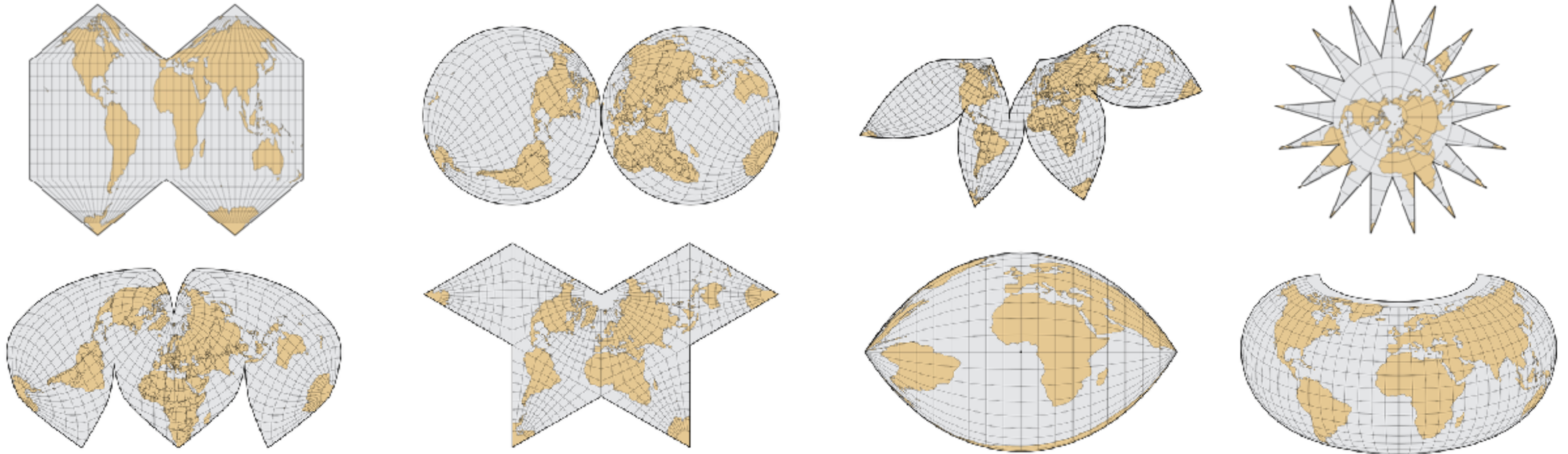
- straightforward to understand
- avoids choropleth non-uniform region size problems

- cons

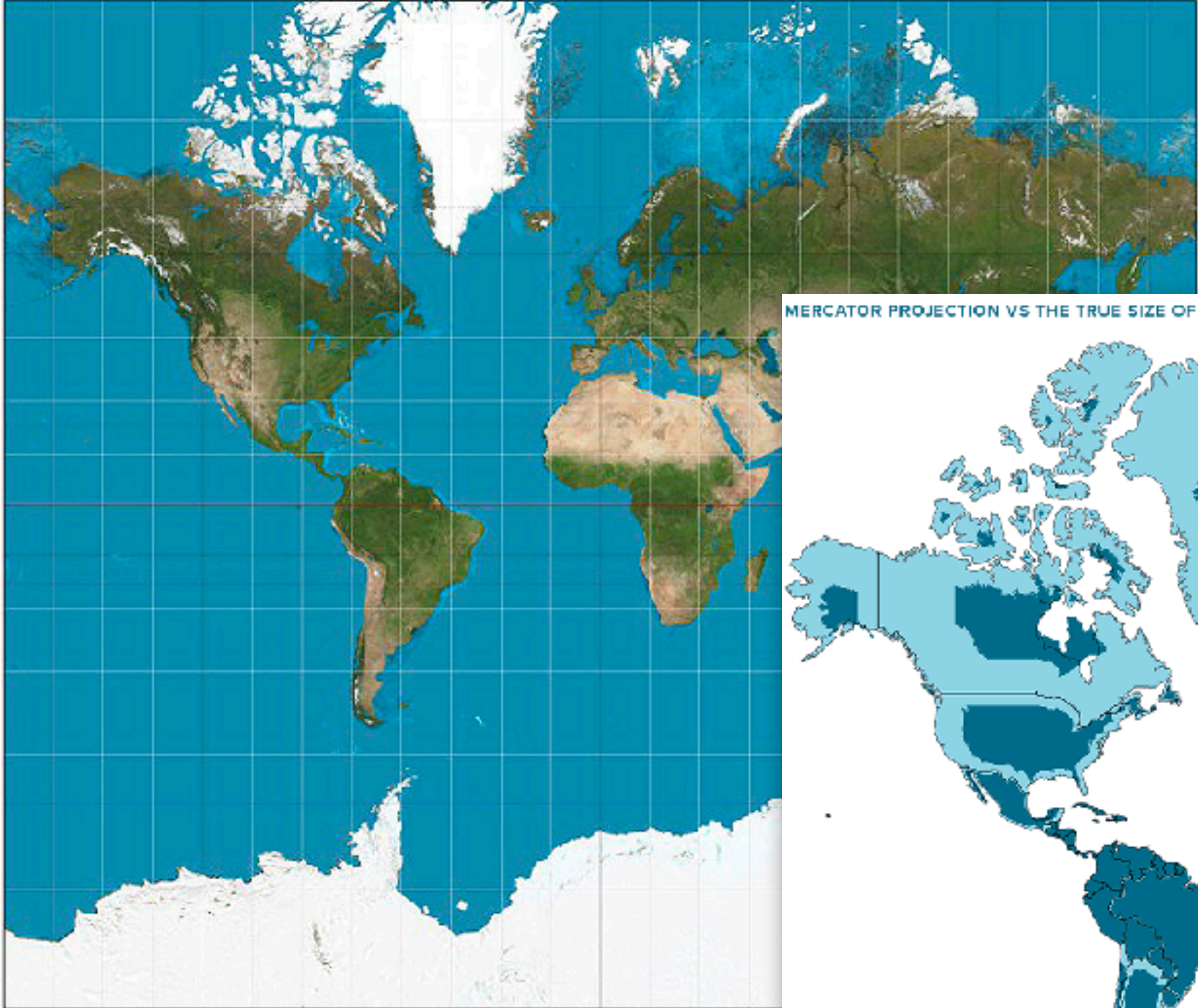
- challenge: normalization, just like choropleths
 - show population density (correlated with attribute), not effect of interest
- perceptual disadvantage:
difficult to extract quantities
- performance disadvantage:
rendering many dots can be slow

Map Projections

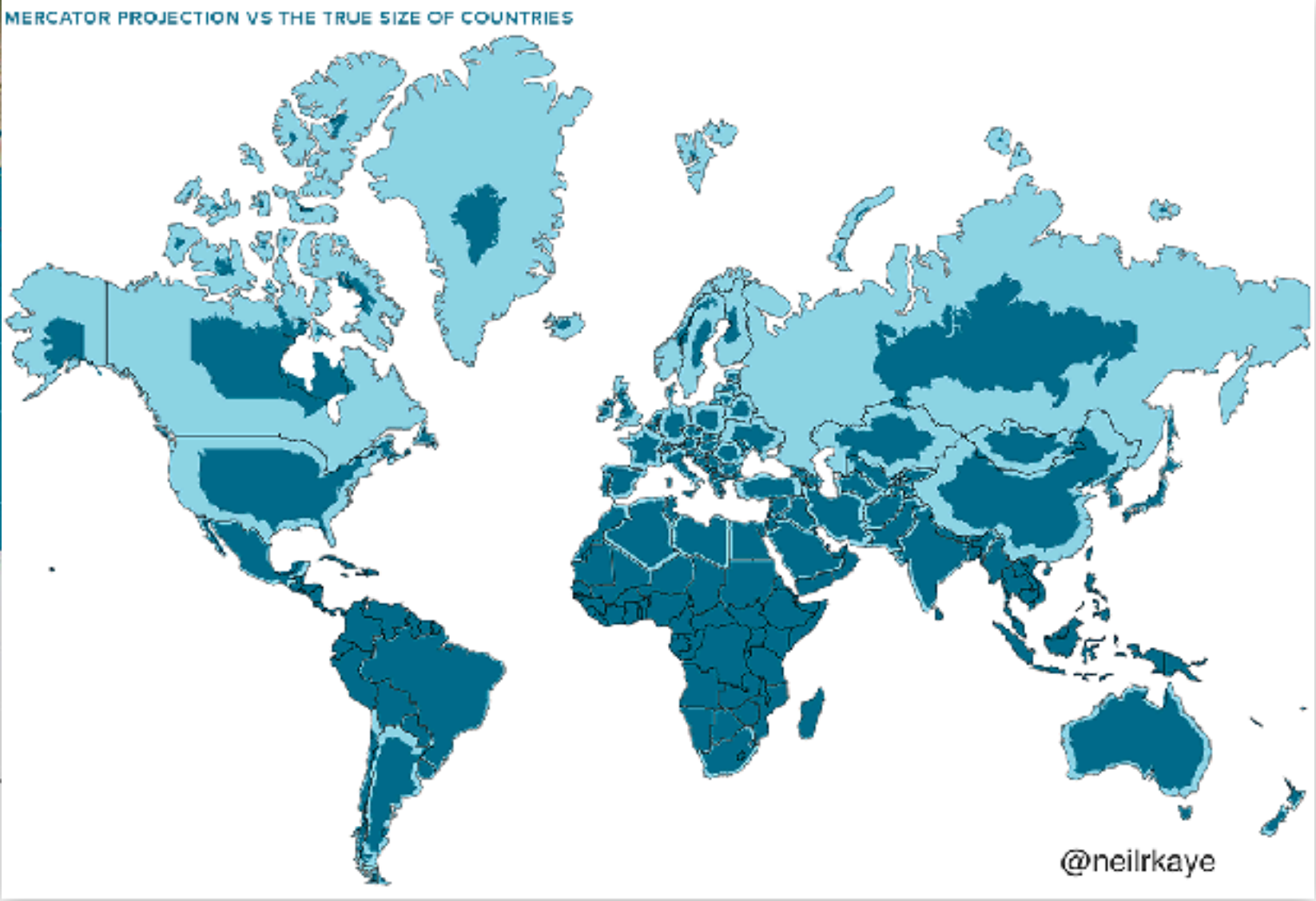
- mathematical functions that map 3D surface geometry of the Earth to 2D maps
- all projections of sphere on plane necessarily distort surface in some way
- **interactive:** philogb.github.io/page/myriahedral/ and jasondavies.com/maps/



Mercator Projection



» Heavily distorts country sizes; particularly close to the poles.



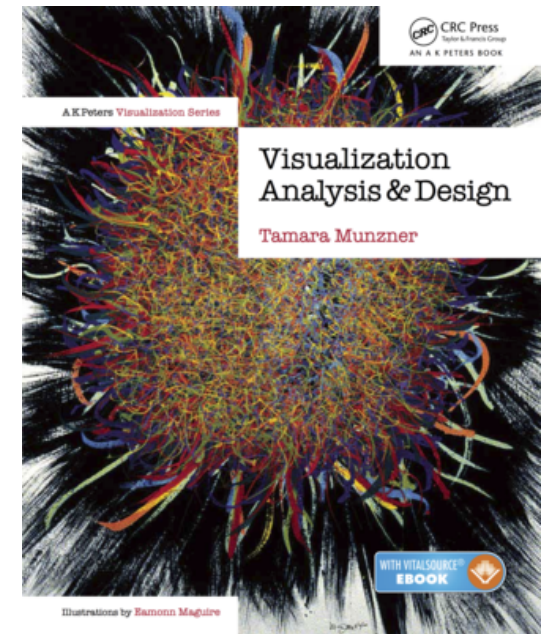
Visualization Analysis & Design

Spatial Data (Ch 9) II

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Department of Computer Science
University of British Columbia

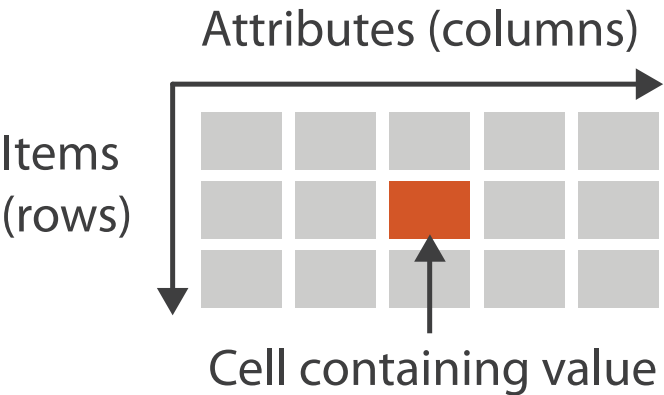
[@tamaramunzner](#)



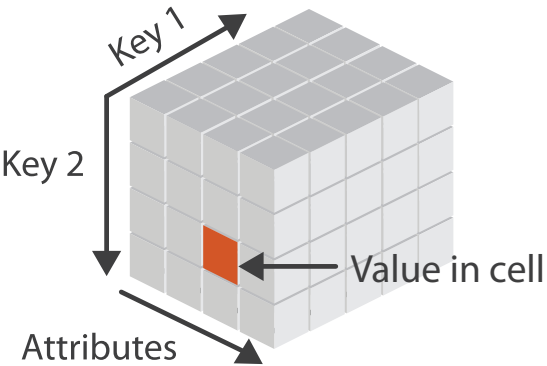
Focus on Spatial

→ Dataset Types

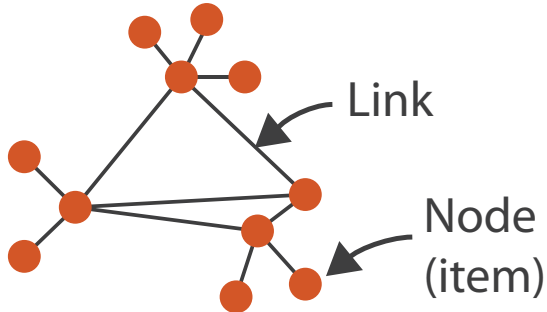
→ Tables



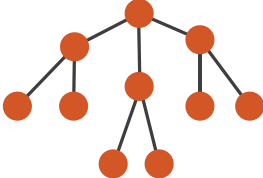
→ Multidimensional Table



→ Networks

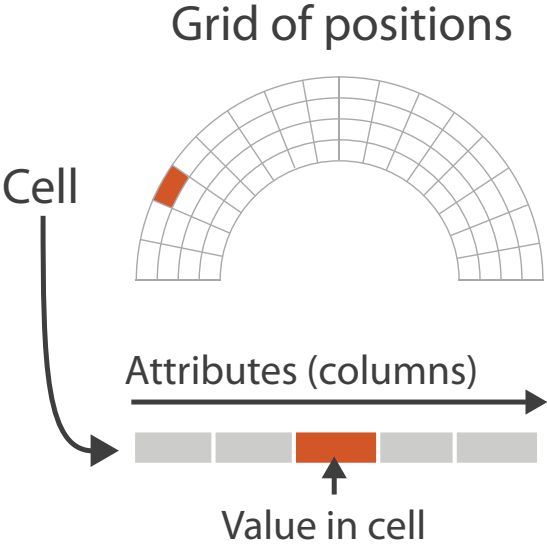


→ Trees

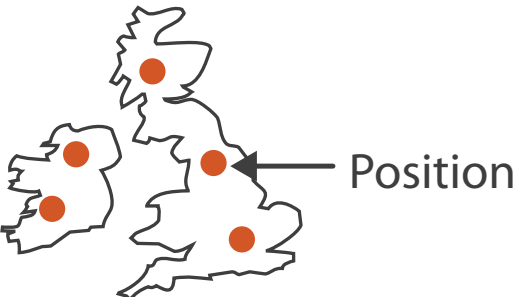


→ Spatial

→ Fields (Continuous)



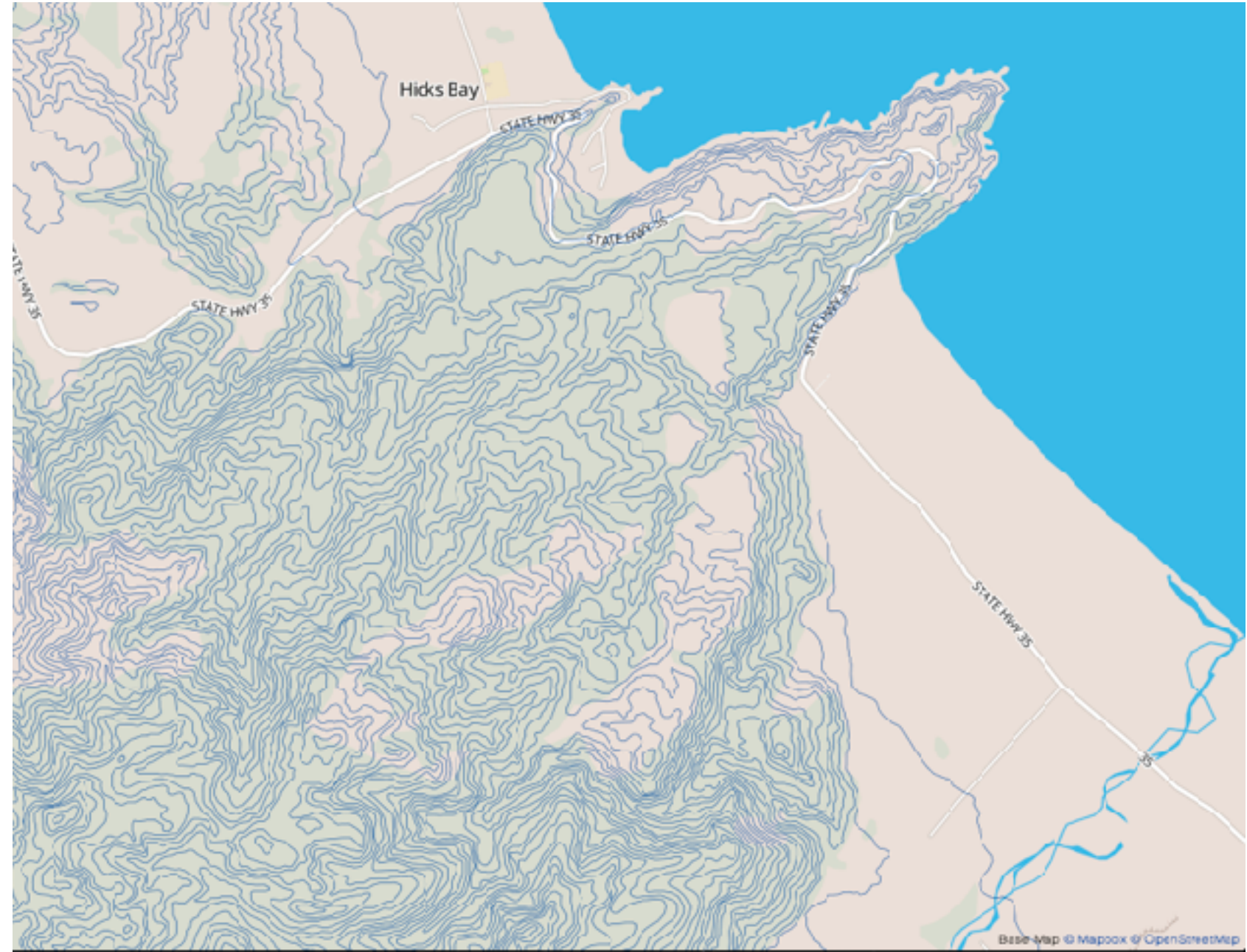
→ Geometry (Spatial)



Spatial Fields

Idiom: **topographic map**

- data
 - geographic geometry
 - scalar spatial field
 - 1 quant attribute per grid cell
- derived data
 - isoline geometry
 - isocontours computed for specific levels of scalar values
- task
 - understanding terrain shape
 - densely lined regions = steep
- pros
 - use only 2D position, avoid 3D challenges
 - color channel available for other attributes
- cons
 - significant clutter from additional lines



Land Information New Zealand Data Service

Idioms: **isosurfaces**, **direct volume rendering**

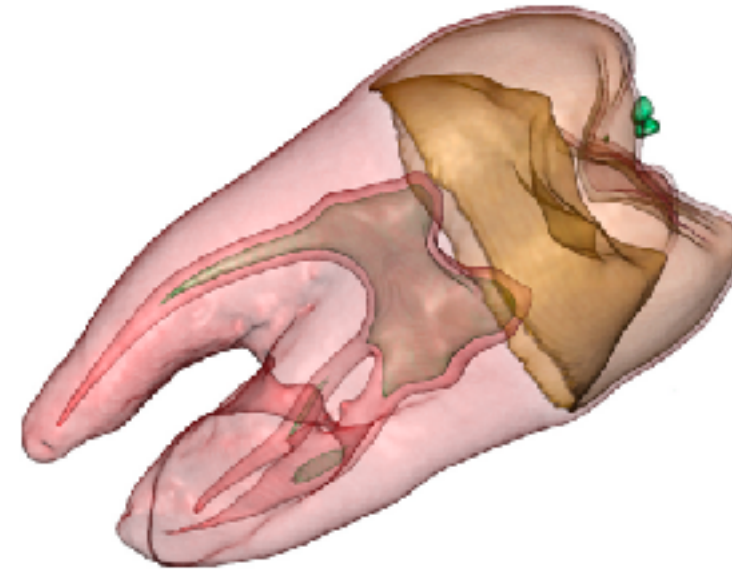
- **data**
 - scalar spatial field (3D volume)
 - 1 quant attribute per grid cell
- **task**
 - shape understanding, spatial relationships

[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]

[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Idioms: **isosurfaces**, **direct volume rendering**

- **data**
 - scalar spatial field (3D volume)
 - 1 quant attribute per grid cell
- **task**
 - shape understanding, spatial relationships
- **isosurface**
 - derived data: isocontours computed for specific levels of scalar values

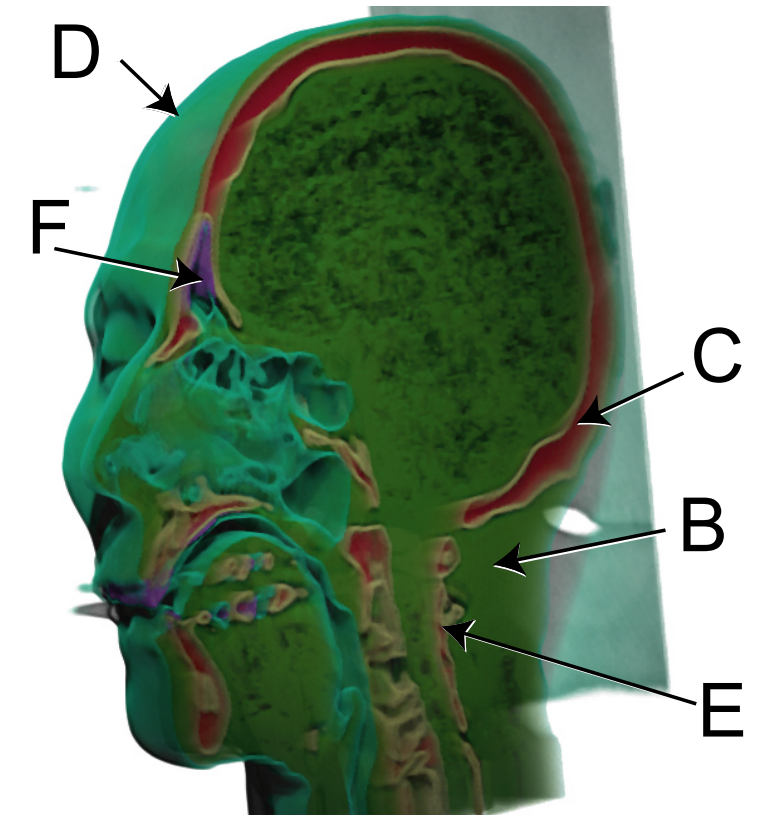
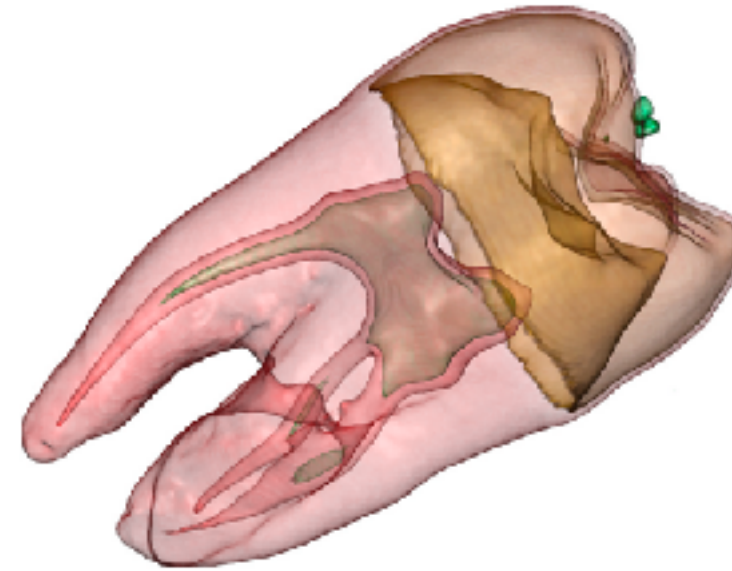


[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]

[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Idioms: **isosurfaces**, **direct volume rendering**

- **data**
 - scalar spatial field (3D volume)
 - 1 quant attribute per grid cell
- **task**
 - shape understanding, spatial relationships
- **isosurface**
 - derived data: isocontours computed for specific levels of scalar values
- **direct volume rendering**
 - transfer function maps scalar values to color, opacity
 - no derived geometry

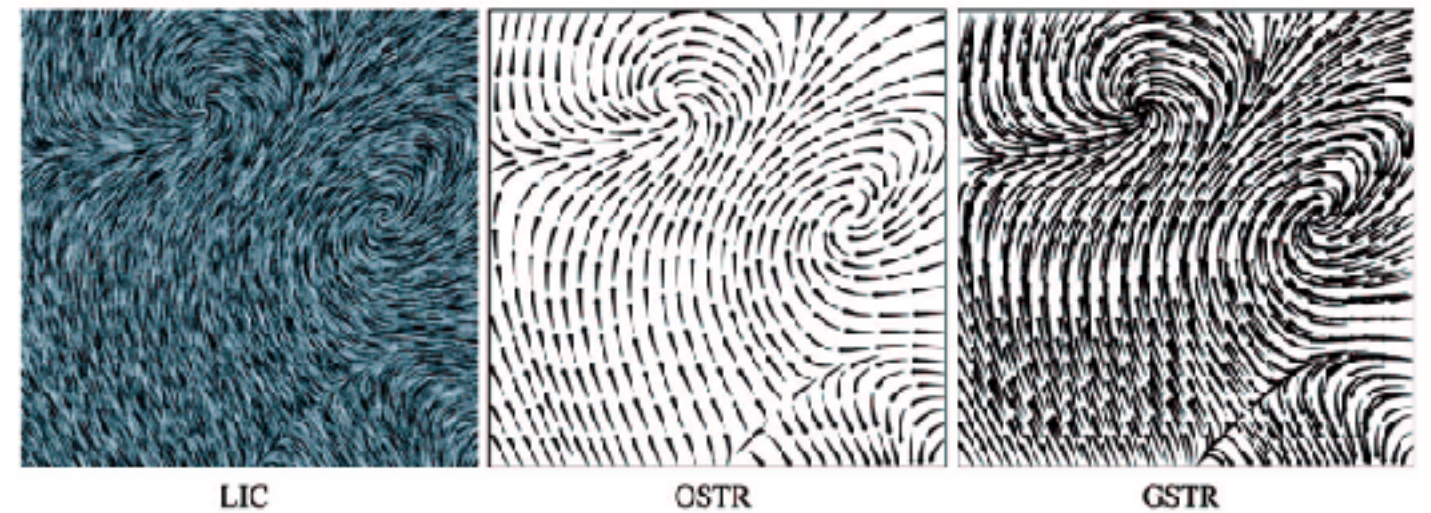
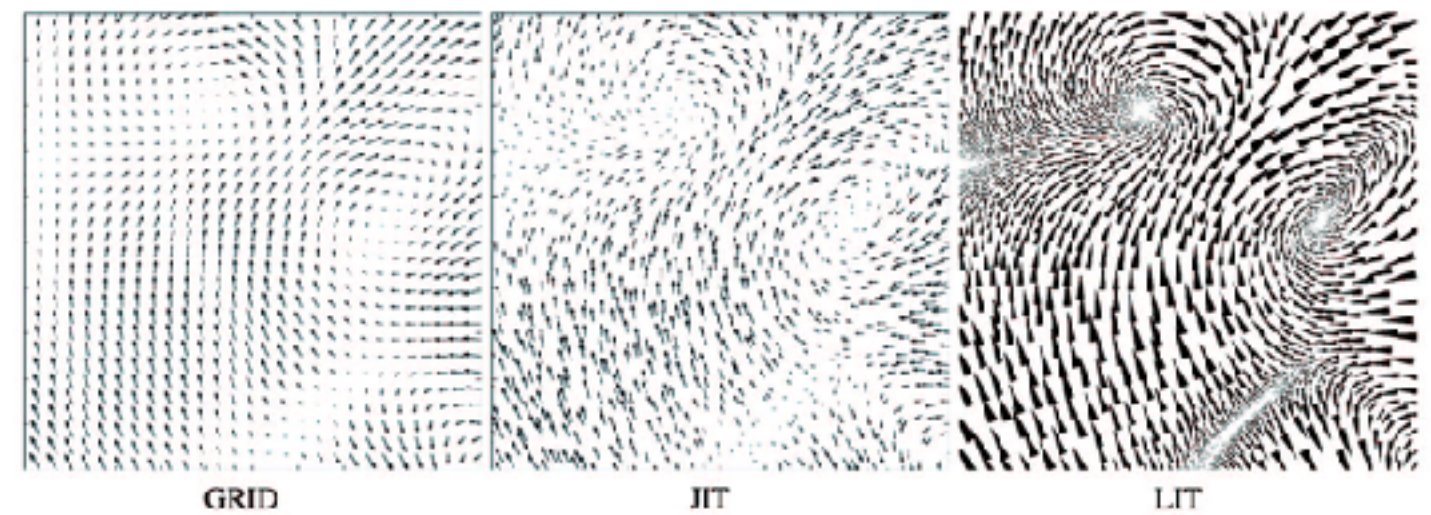


[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]

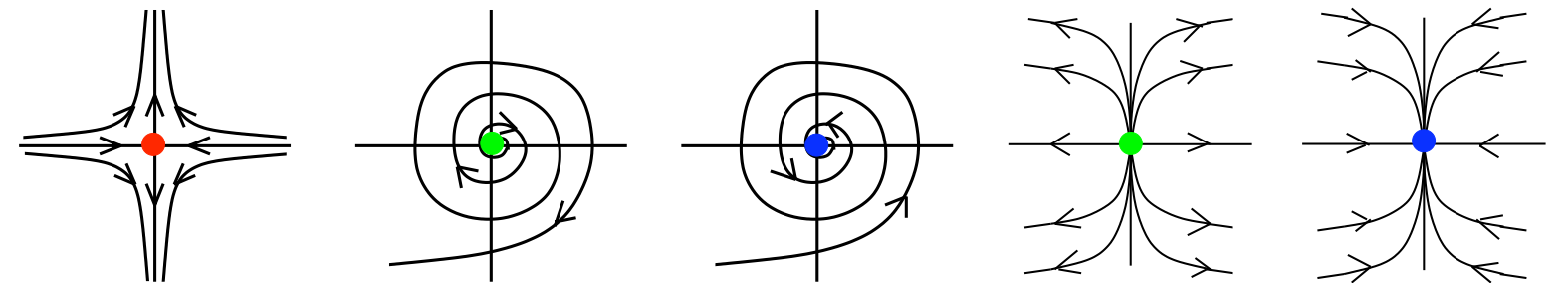
[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Vector and tensor fields

- data
 - multiple attribs per cell (vector: 2)
- idiom families
 - flow *glyphs*
 - purely local
 - *geometric flow*
 - derived data from tracing particle trajectories
 - sparse set of seed points
 - *texture flow*
 - derived data, dense seeds
 - *feature flow*
 - global computation to detect features



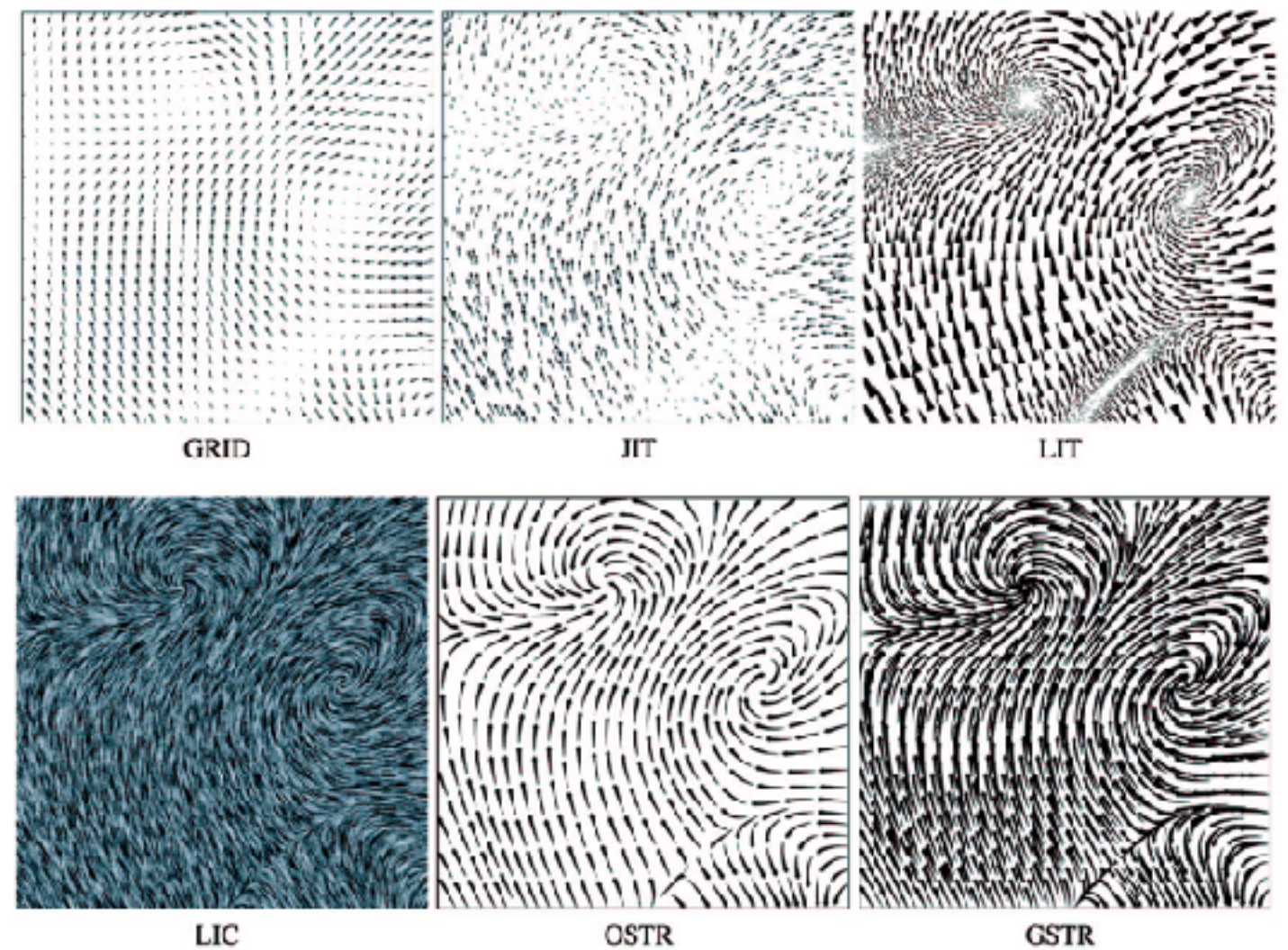
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



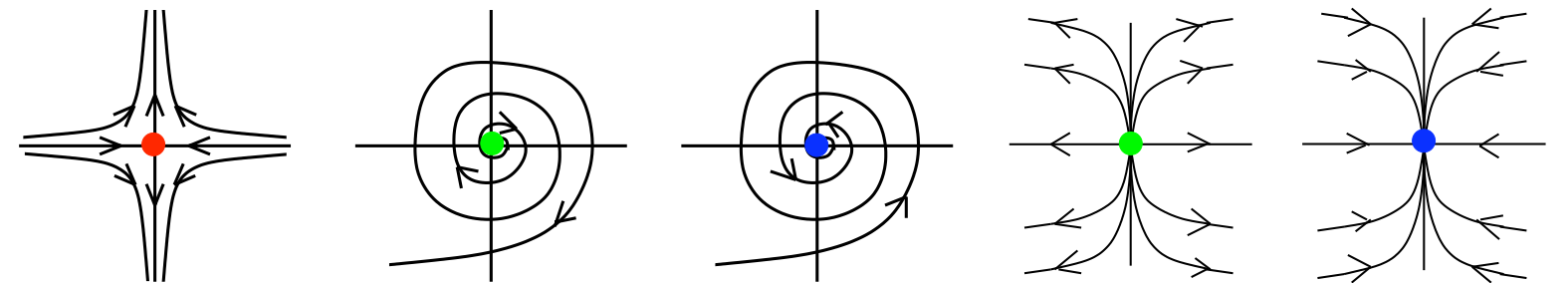
[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

Vector fields

- empirical study tasks
 - finding critical points, identifying their types
 - identifying what type of critical point is at a specific location
 - predicting where a particle starting at a specified point will end up (advection)



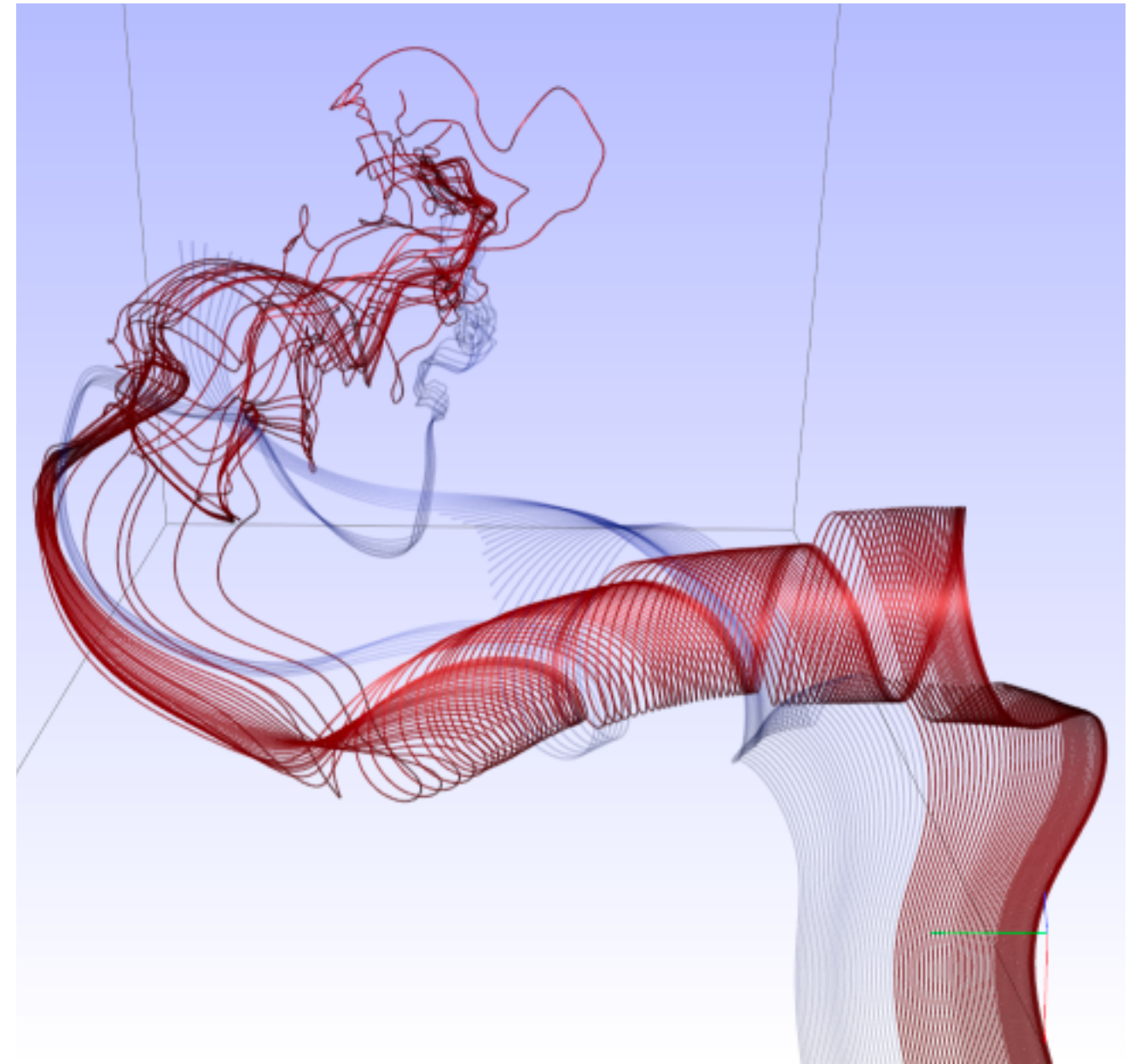
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. *IEEE Trans. Visualization and Computer Graphics (TVCG)* 11:1 (2005), 59–70.]



[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. *Computers & Graphics* 26:2 (2002), 249–257.]

Idiom: **similarity-clustered streamlines**

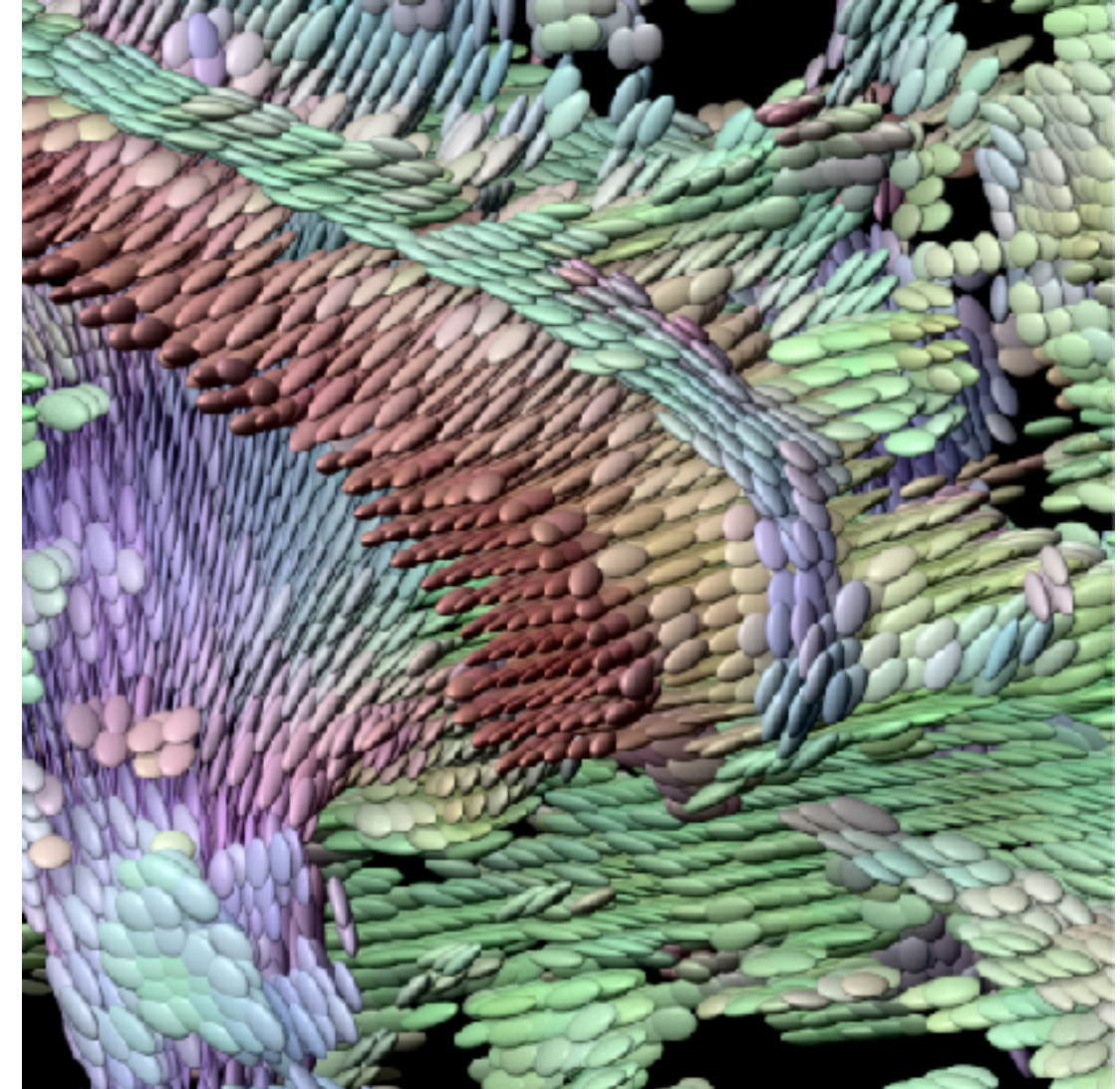
- data
 - 3D vector field
- derived data (from field)
 - streamlines: trajectory particle will follow
- derived data (per streamline)
 - curvature, torsion, tortuosity
 - signature: complex weighted combination
 - compute cluster hierarchy across all signatures
 - encode: color and opacity by cluster
- tasks
 - find features, query shape
- scalability
 - millions of samples, hundreds of streamlines



[Similarity Measures for Enhancing Interactive Streamline Seeding. McLoughlin, Jones, Laramee, Malki, Masters, and Hansen. IEEE Trans. Visualization and Computer Graphics 19:8 (2013), 1342–1353.]

Idiom: Ellipsoid Tensor Glyphs

- data
 - tensor field: multiple attributes at each cell (entire matrix)
 - stress, conductivity, curvature, diffusivity...
 - derived data:
 - shape (eigenvalues)
 - orientation (eigenvectors)
- visual encoding
 - glyph: 3D ellipsoid



Arrange spatial data

→ Use Given

→ Geometry

→ *Geographic*

→ Spatial Fields

→ *Scalar Fields (one value per cell)*

→ *Isocontours*

→ *Direct Volume Rendering*

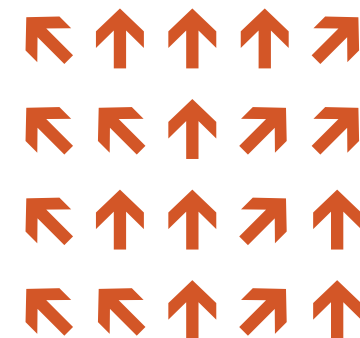
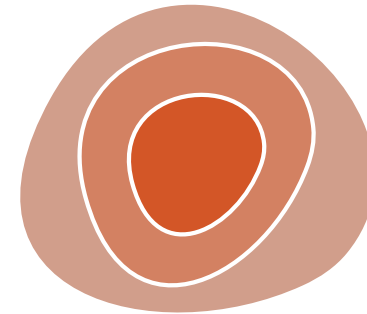
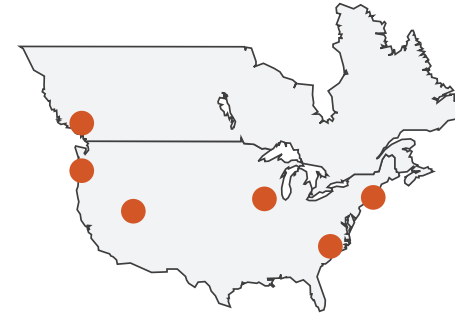
→ *Vector and Tensor Fields (many values per cell)*

→ *Flow Glyphs (local)*

→ *Geometric (sparse seeds)*

→ *Textures (dense seeds)*

→ *Features (globally derived)*



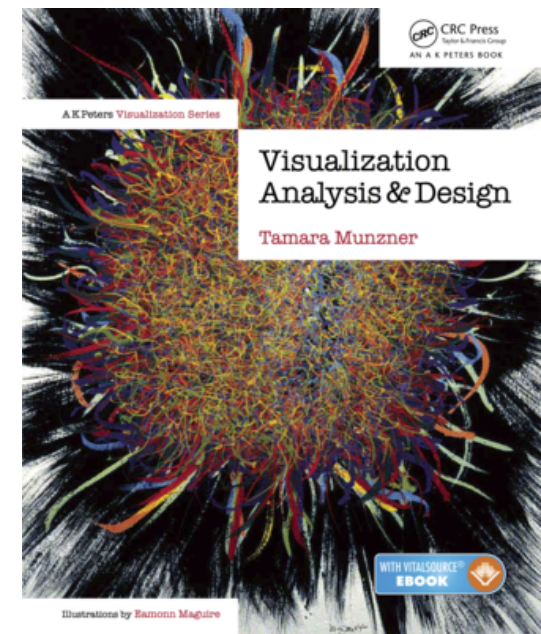
Visualization Analysis & Design

Color (Ch 10)

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



Idiom design choices: Visual encoding

Encode

➔ Arrange

➔ Express



➔ Separate



➔ Order



➔ Align



➔ Use



➔ Map

from **categorical** and **ordered** attributes

➔ Color

➔ Hue



➔ Saturation



➔ Luminance



➔ Size, Angle, Curvature, ...

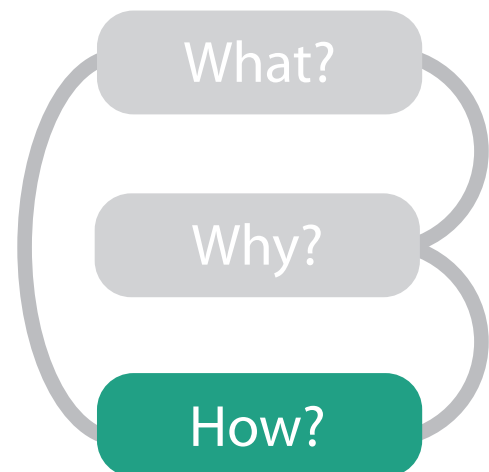


➔ Shape



➔ Motion

Direction, Rate, Frequency, ...



Idiom design choices: Beyond spatial arrangement

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



What?

Why?

How?

→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



→ Motion

Direction, Rate, Frequency, ...



Channels: What's up with color?

➔ 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) 

Same Same

➔ Identity Channels: Categorical Attributes

Spatial region 

Color hue 

Motion 

Shape 

Best
Effectiveness
Least

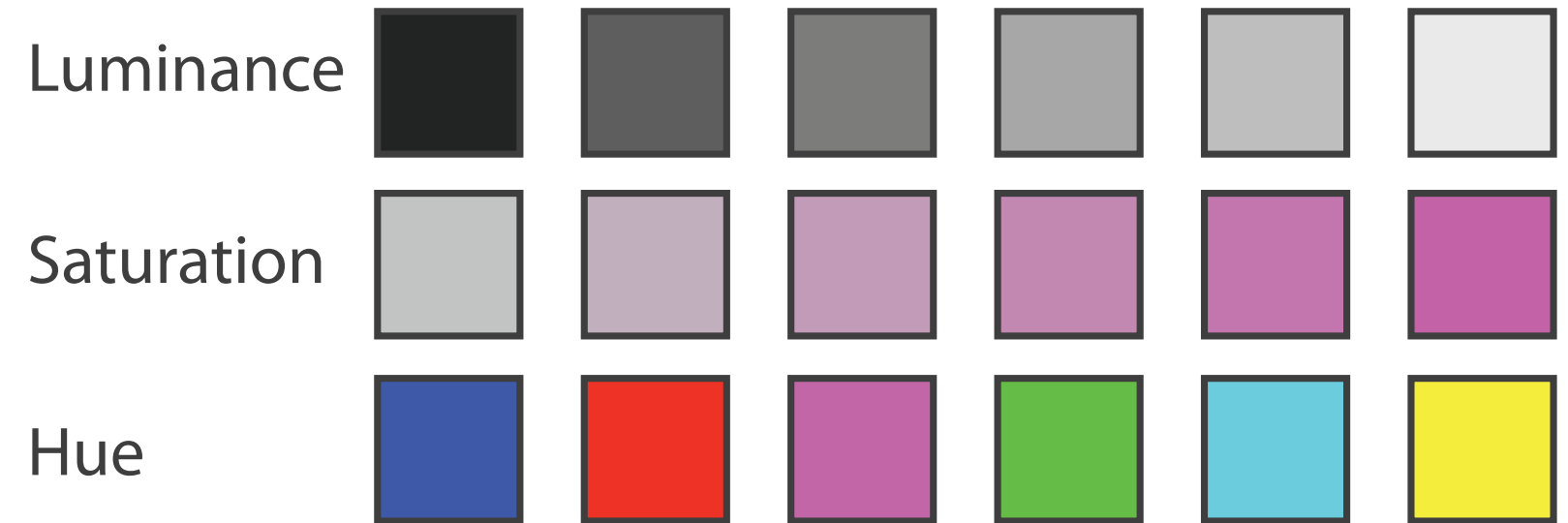
Decomposing color

Decomposing color

- first rule of color: do not (just) talk about color!
 - color is confusing if treated as monolithic

Decomposing color

- first rule of color: do not (just) talk about color!
 - color is confusing if treated as monolithic
- decompose into three channels
 - ordered can show magnitude
 - **luminance**: how bright (B/W)
 - **saturation**: how colourful
 - categorical can show identity
 - **hue**: what color



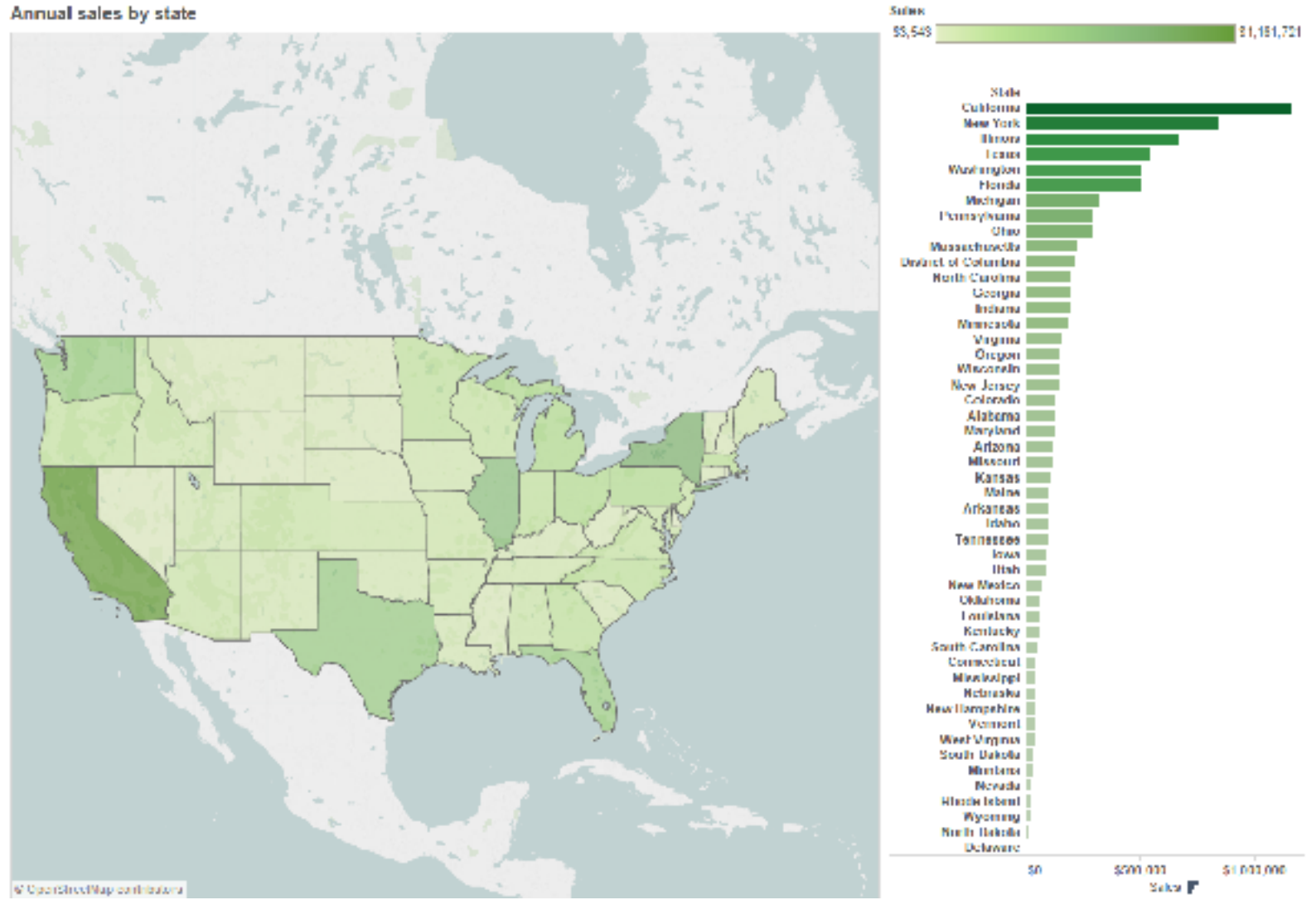
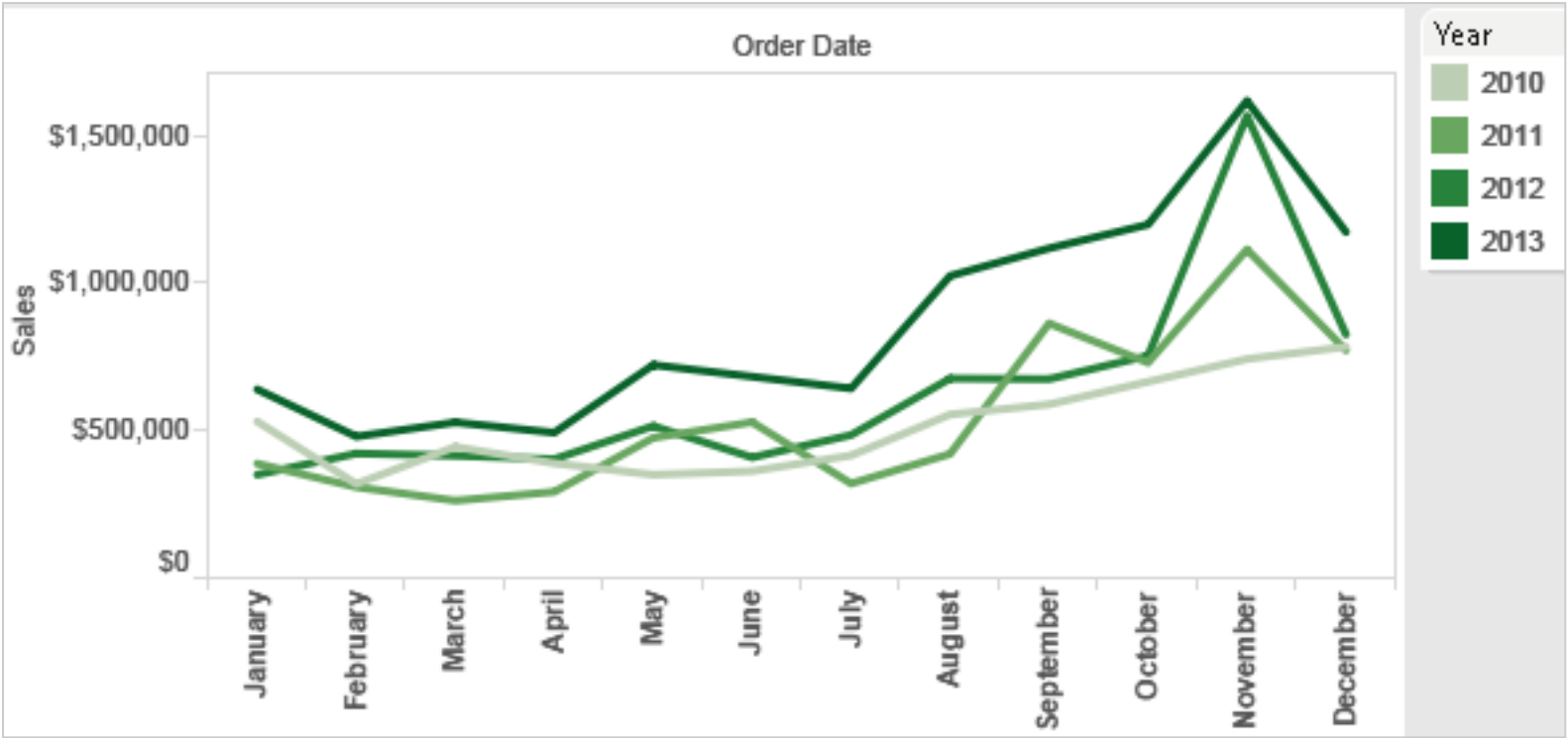
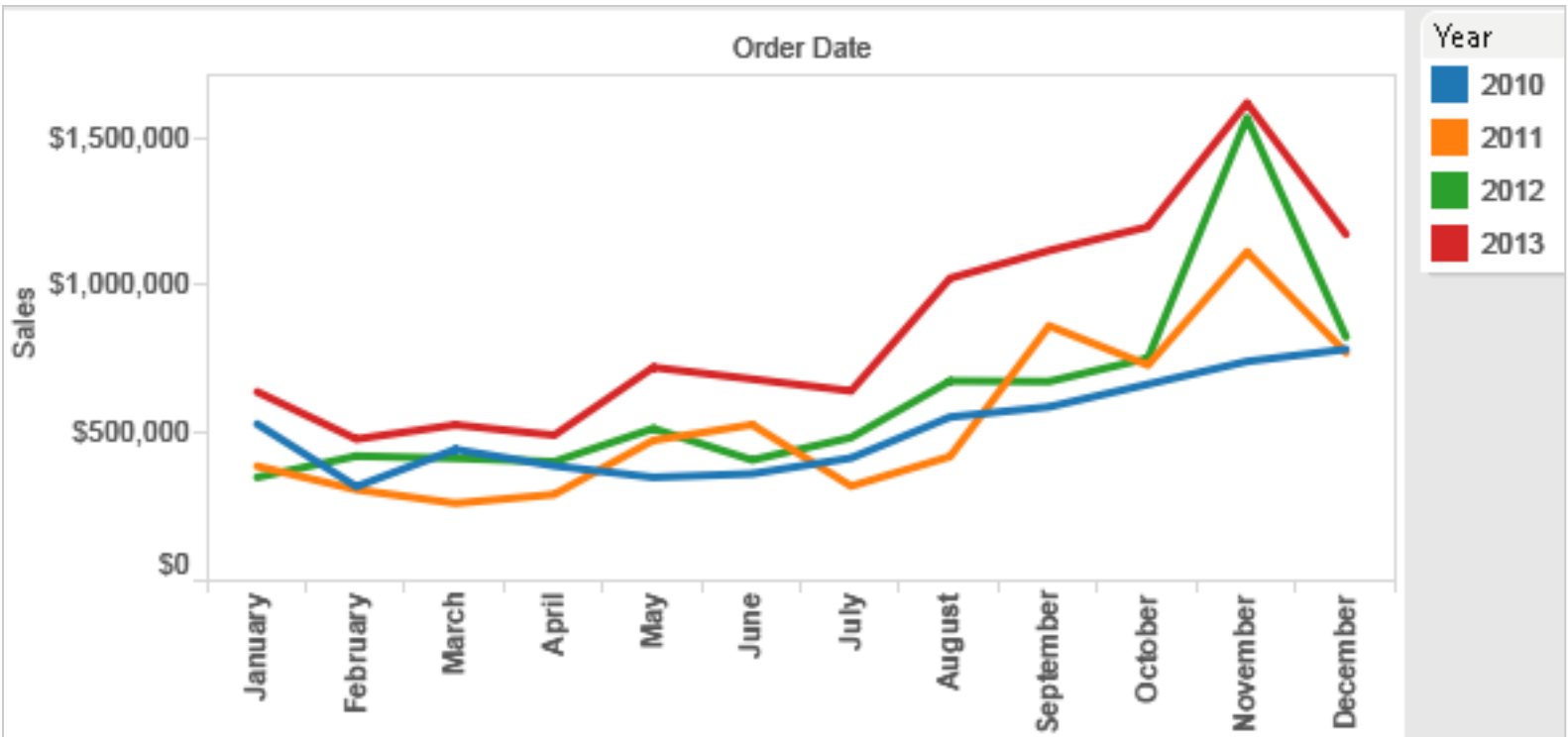
Decomposing color

- first rule of color: do not (just) talk about color!
 - color is confusing if treated as monolithic
- decompose into three channels
 - ordered can show magnitude
 - **luminance**: how bright (B/W)
 - **saturation**: how colourful
 - categorical can show identity
 - **hue**: what color
- channels have different properties
 - what they convey directly to perceptual system
 - how much they can convey
 - how many discriminable bins can we use?



Color Channels in Visualization

Categorical vs ordered color



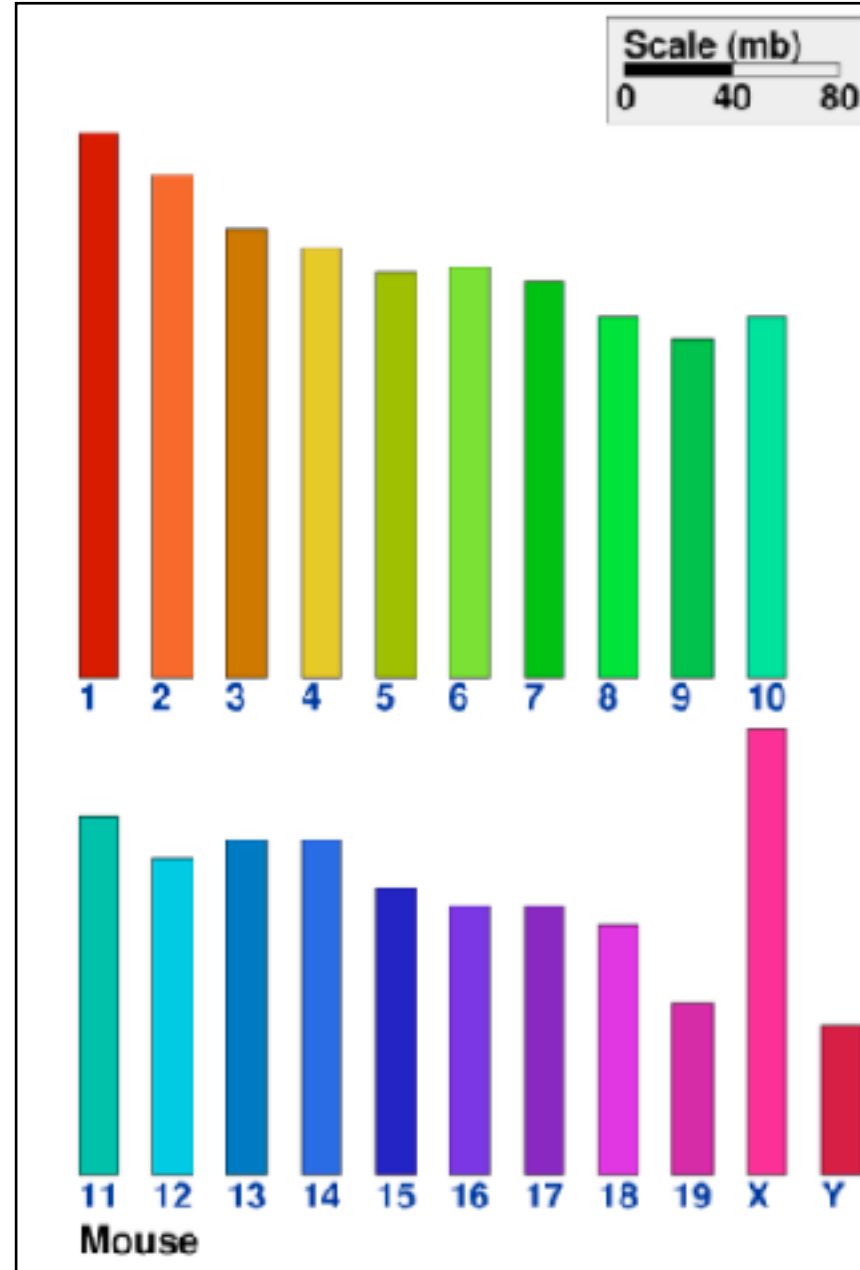
[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Categorical color: limited number of discriminable bins

- human perception built on relative comparisons

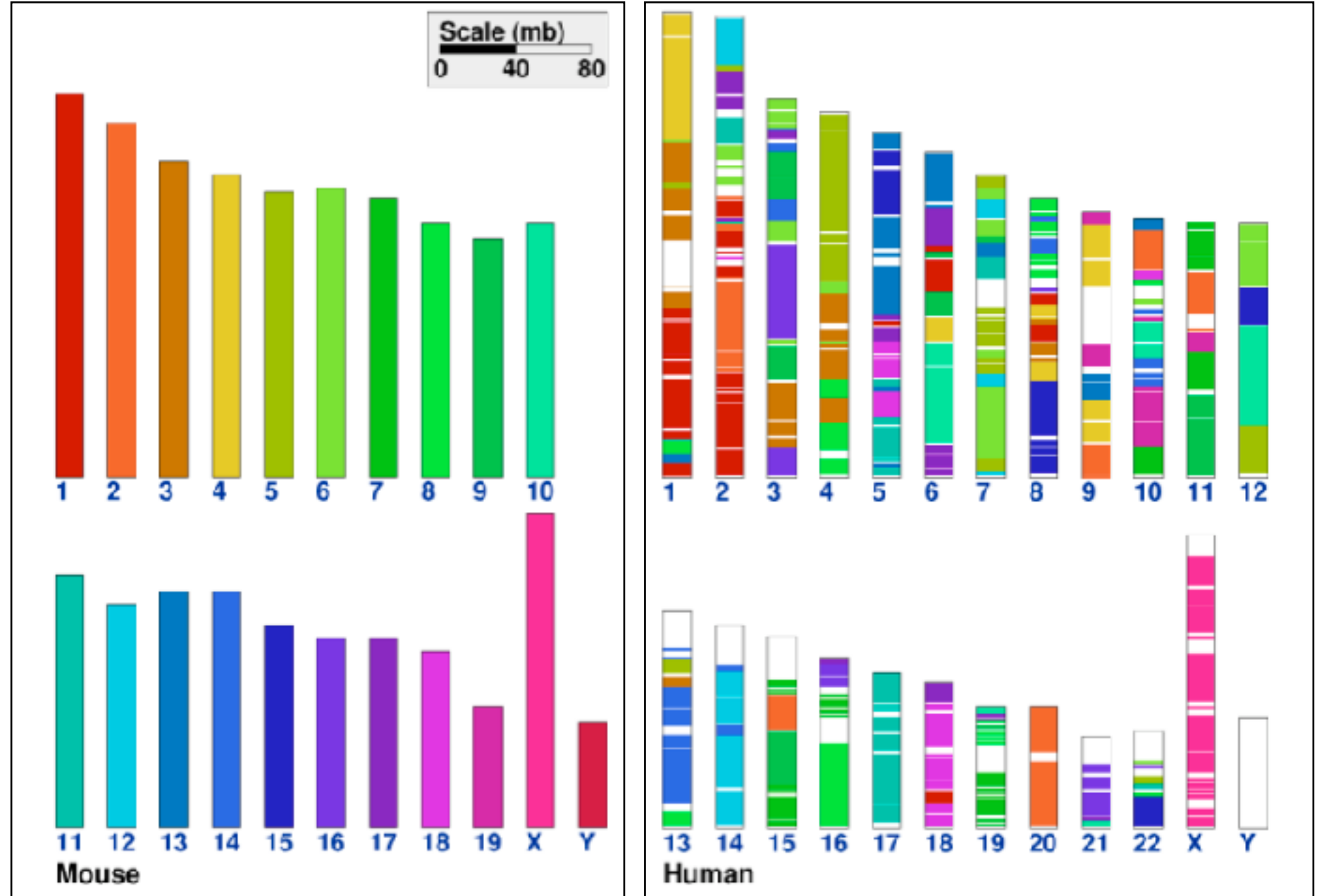
Categorical color: limited number of discriminable bins

- human perception built on relative comparisons
 - great if color contiguous



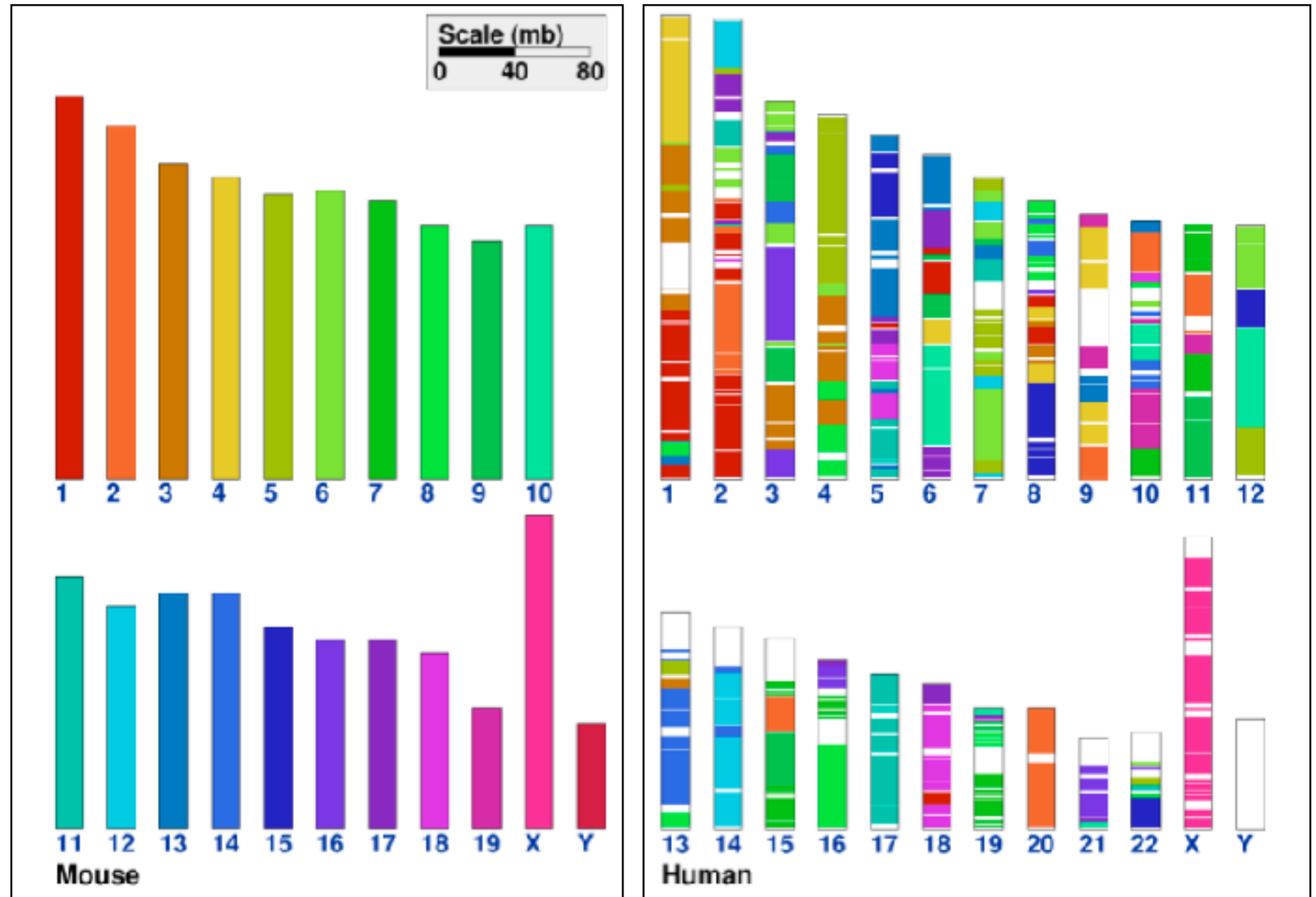
Categorical color: limited number of discriminable bins

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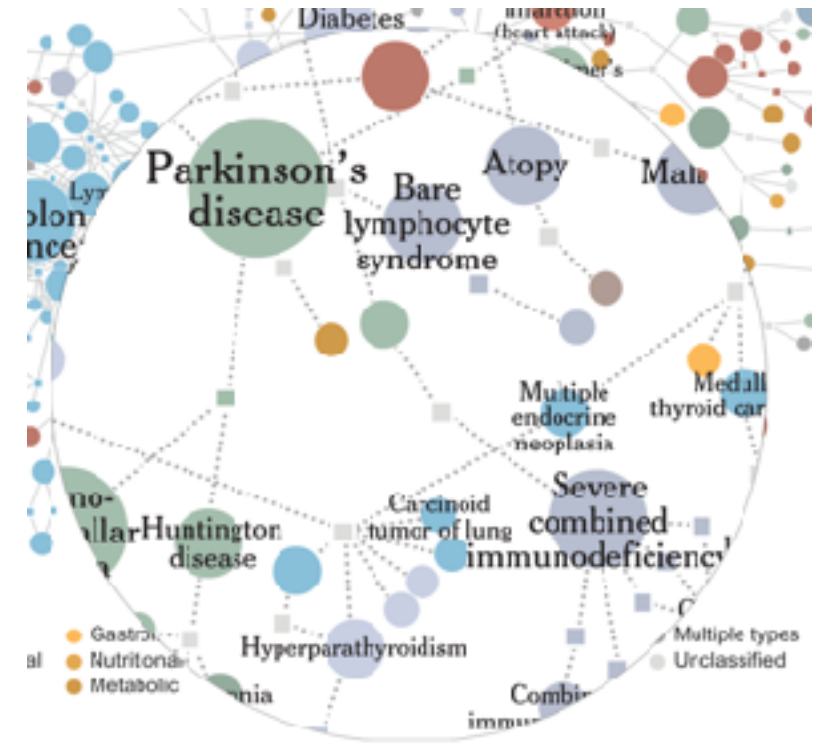
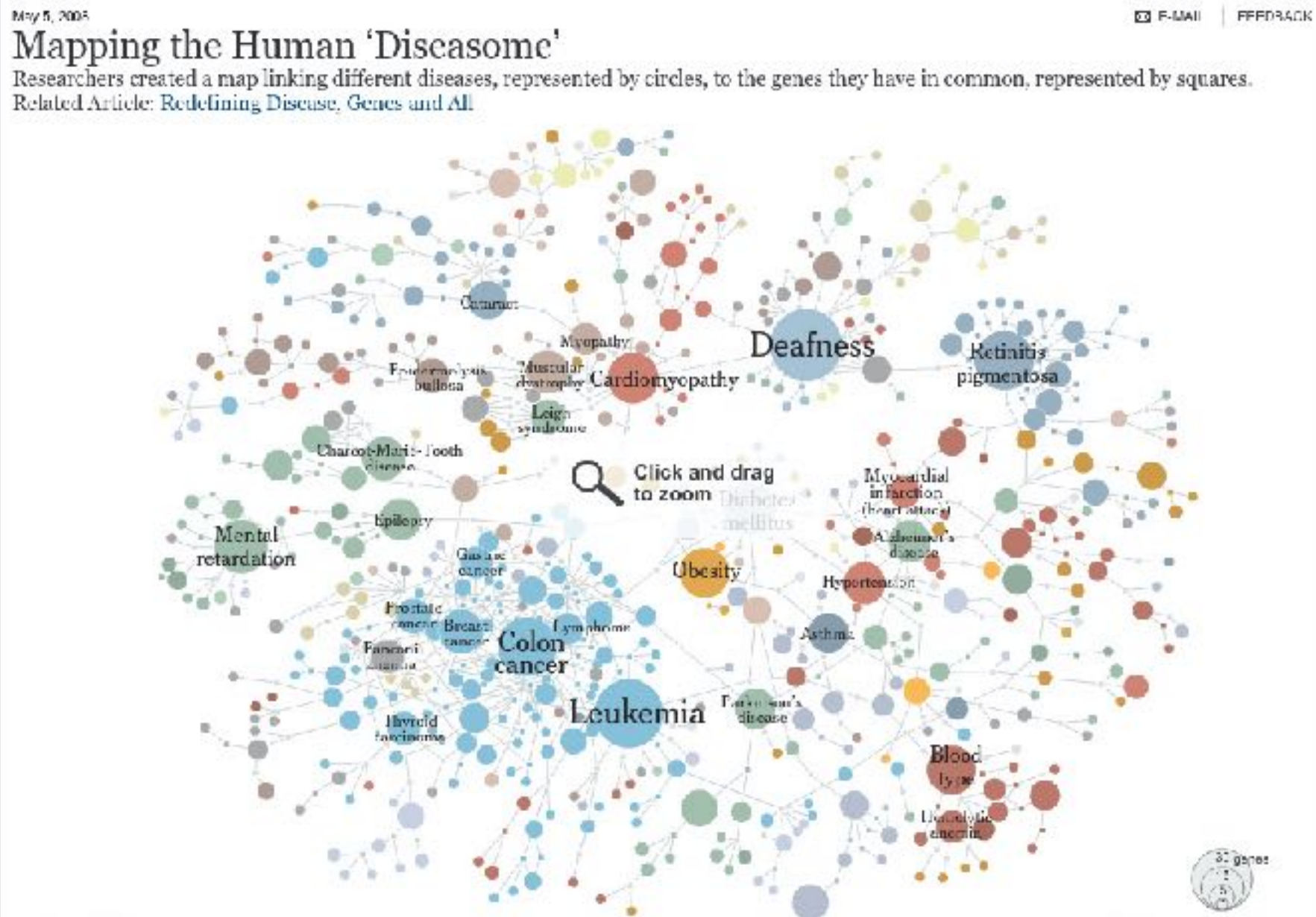
Categorical color: limited number of discriminable bins

- human perception built on relative comparisons
 - great if color contiguous
 - surprisingly bad for absolute comparisons
- noncontiguous small regions of color
 - fewer bins than you want
 - rule of thumb: 6-12 bins, including background and highlights

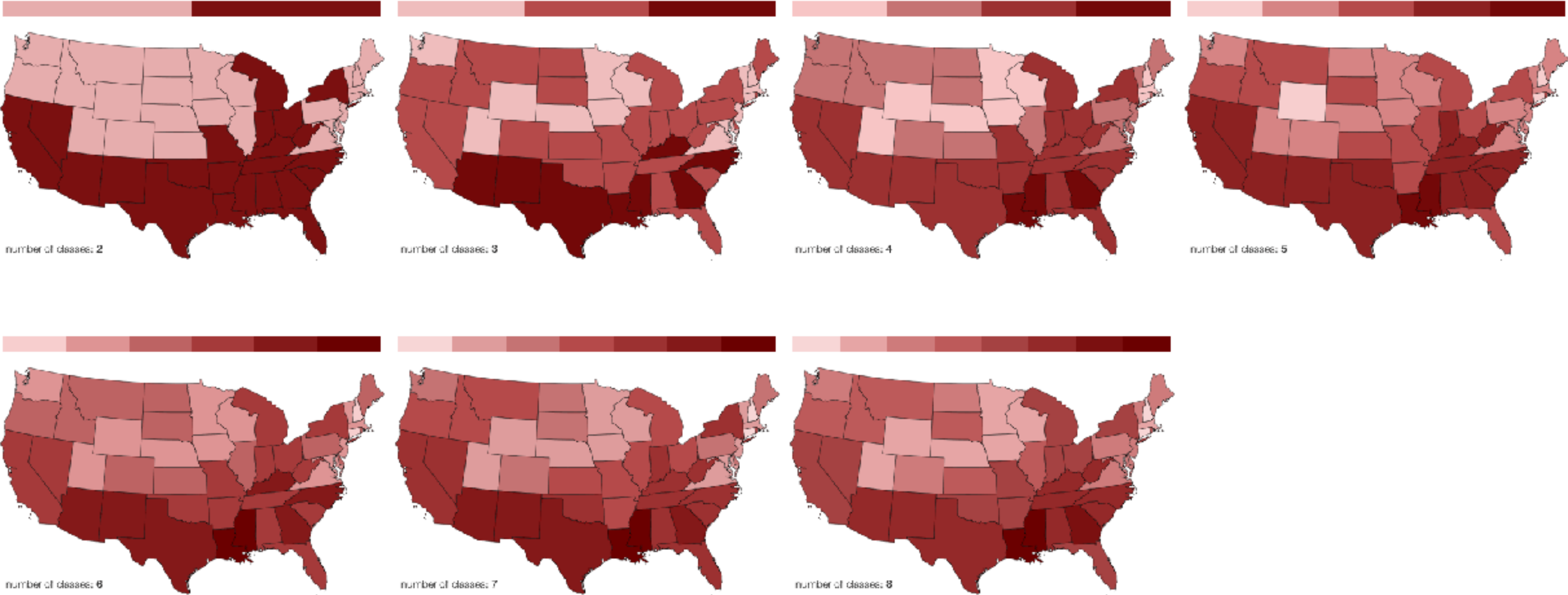


Categorical color: limited number of discriminable bins

- Cancer
- Connective tissue
- Cardiovascular
- Endocrine
- Gastrointestinal
- Ear, nose, throat
- Developmental
- Multiple types
- Bone
- Muscular
- Hematological
- Immunological
- Nutritional
- Ophthalmological
- Neurological
- Unclassified
- Skeletal
- Dermatological
- Renal
- Metabolic
- Respiratory
- Psychiatric



Ordered color: limited number of discriminable bins



Gregor Aisch, vis4.net/blog/posts/choropleth-maps/

Ordered color: Rainbow is poor default

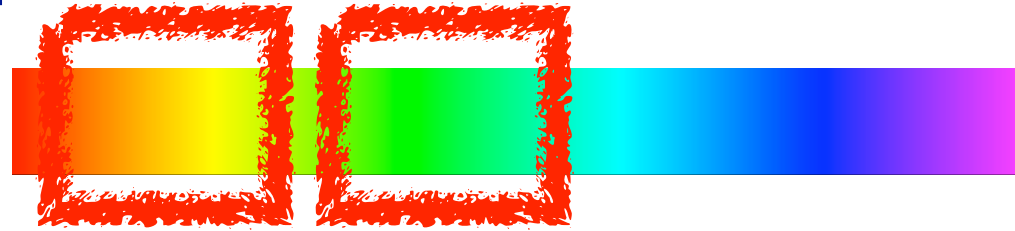
- problems

- perceptually unordered
- perceptually nonlinear



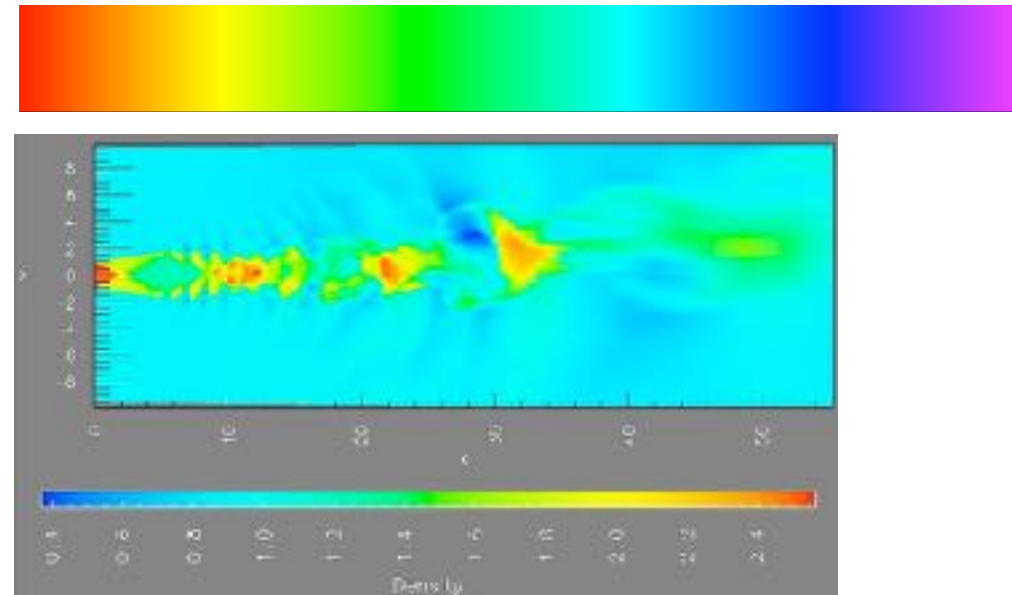
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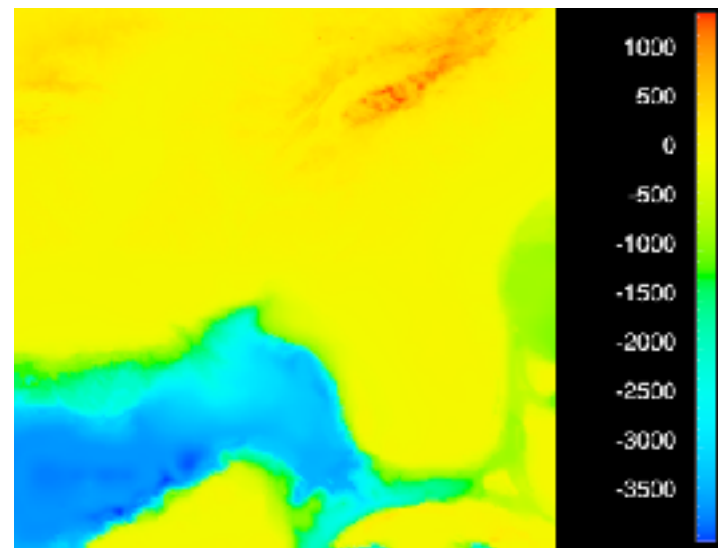


Ordered color: Rainbow is poor default

- problems
 - perceptually unordered
 - perceptually nonlinear
- benefits
 - fine-grained structure visible and nameable



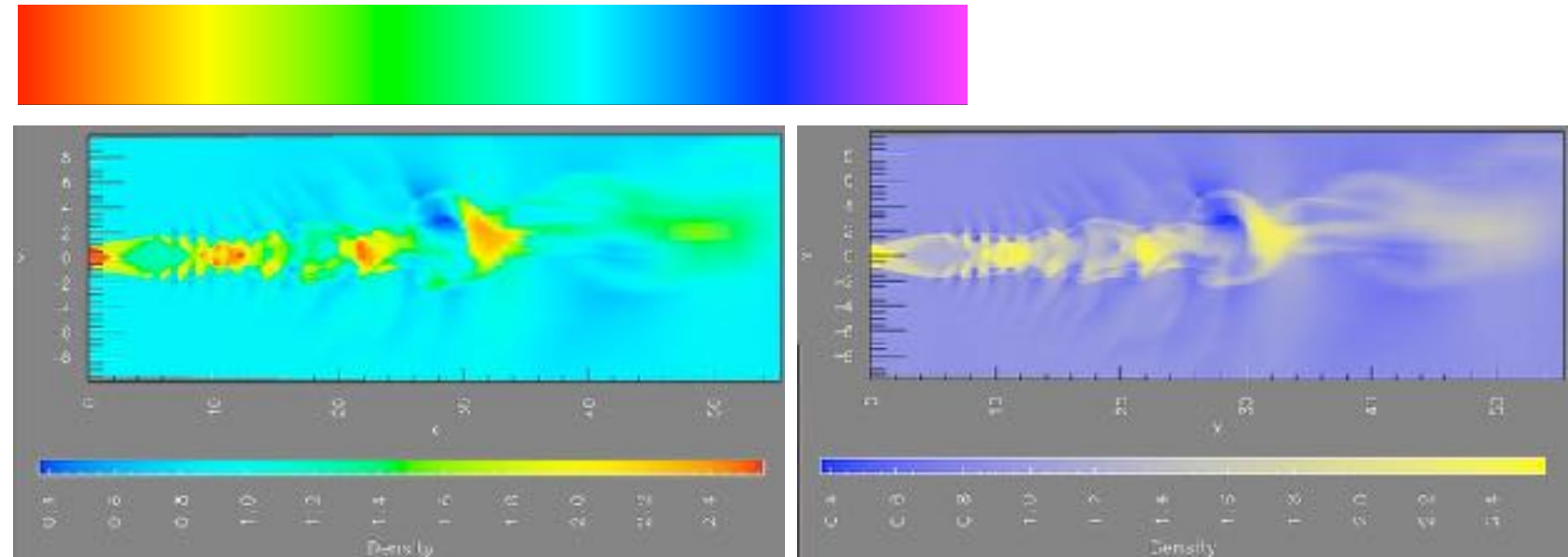
[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]



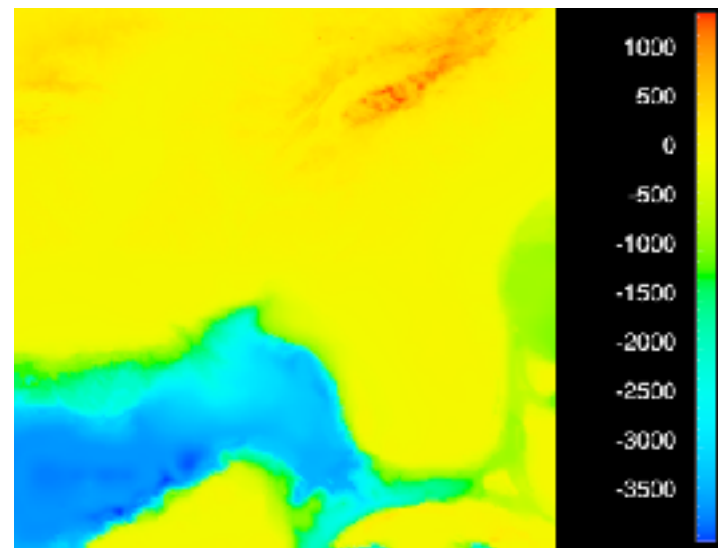
[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. <http://www.research.ibm.com/people/lloyd/color/color.HTM>]

Ordered color: Rainbow is poor default

- problems
 - perceptually unordered
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- benefits
 - fine-grained structure visible and nameable
- alternatives
 - large-scale structure: fewer hues



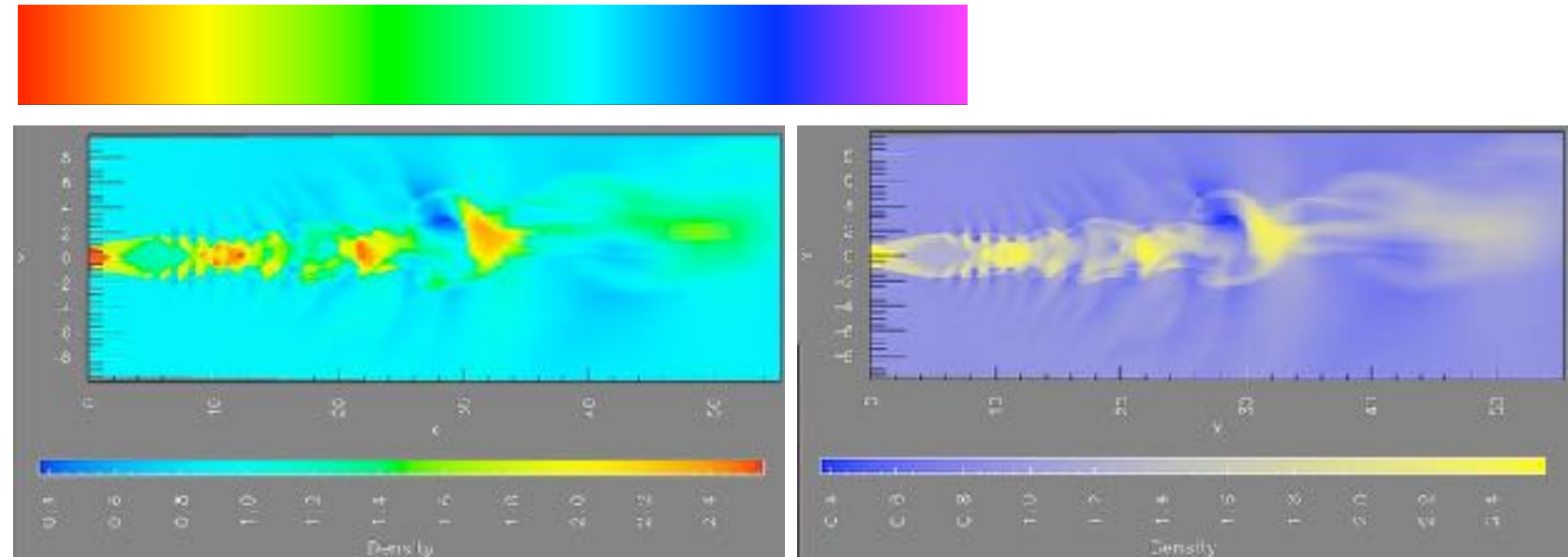
[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. *Proc. IEEE Visualization (Vis)*, pp. 118–125, 1995.]



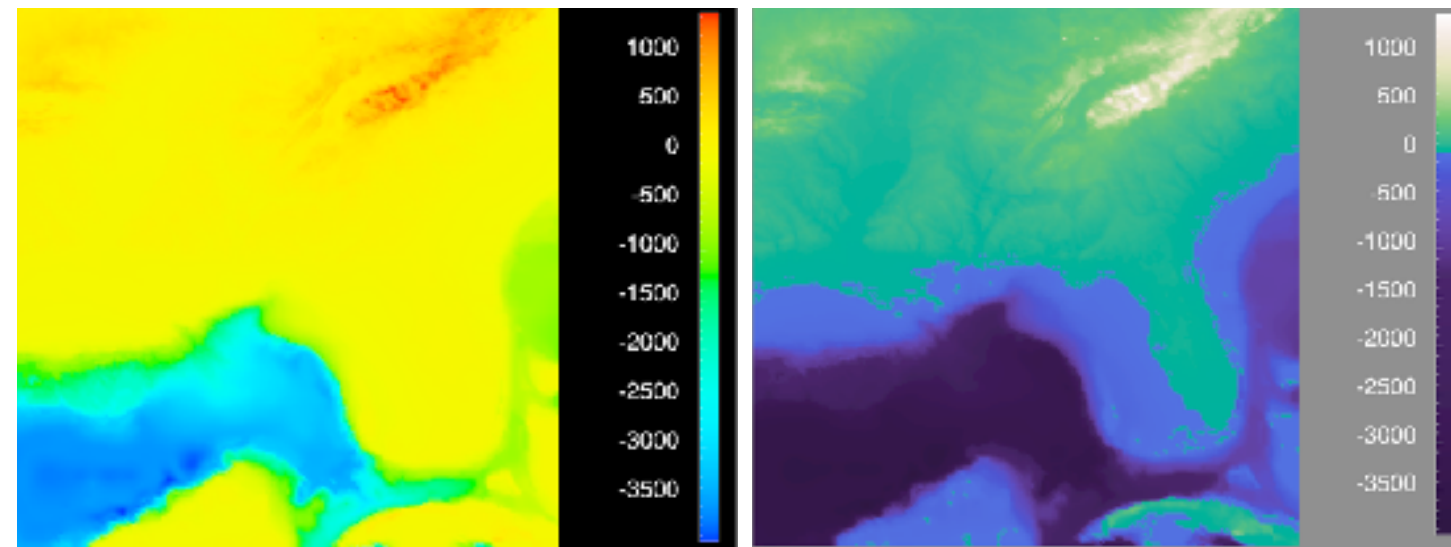
[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. <http://www.research.ibm.com/people/lloyd/color/color.HTM>]

Ordered color: Rainbow is poor default

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 - large-scale structure: fewer hues
 - fine structure: multiple hues with monotonically increasing luminance [eg viridis]



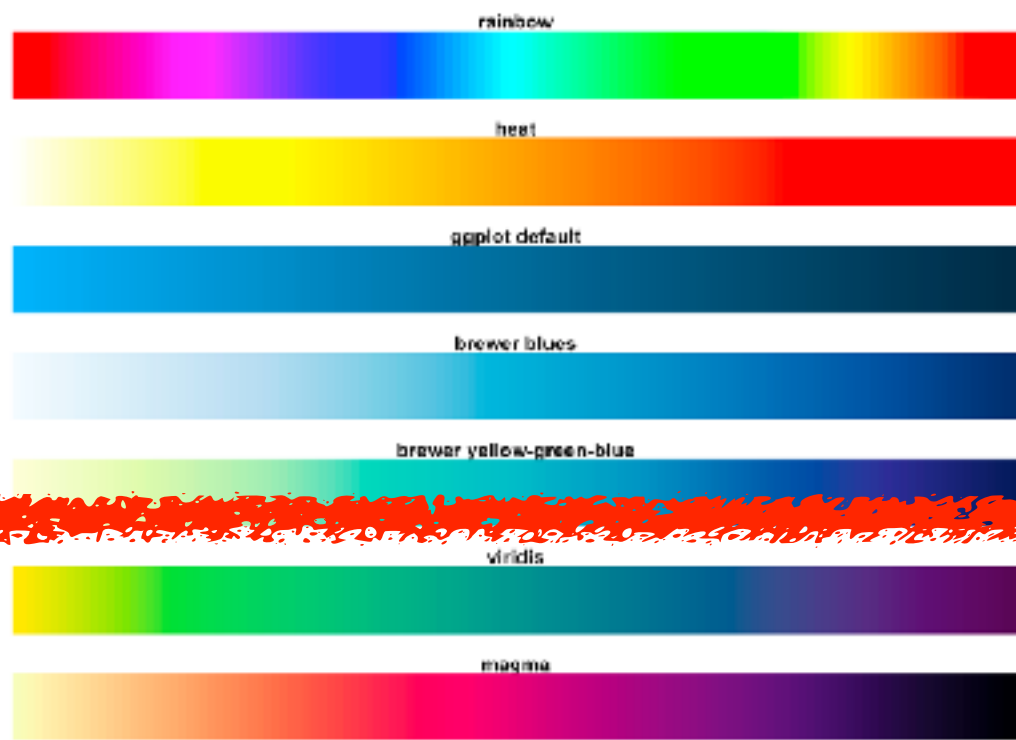
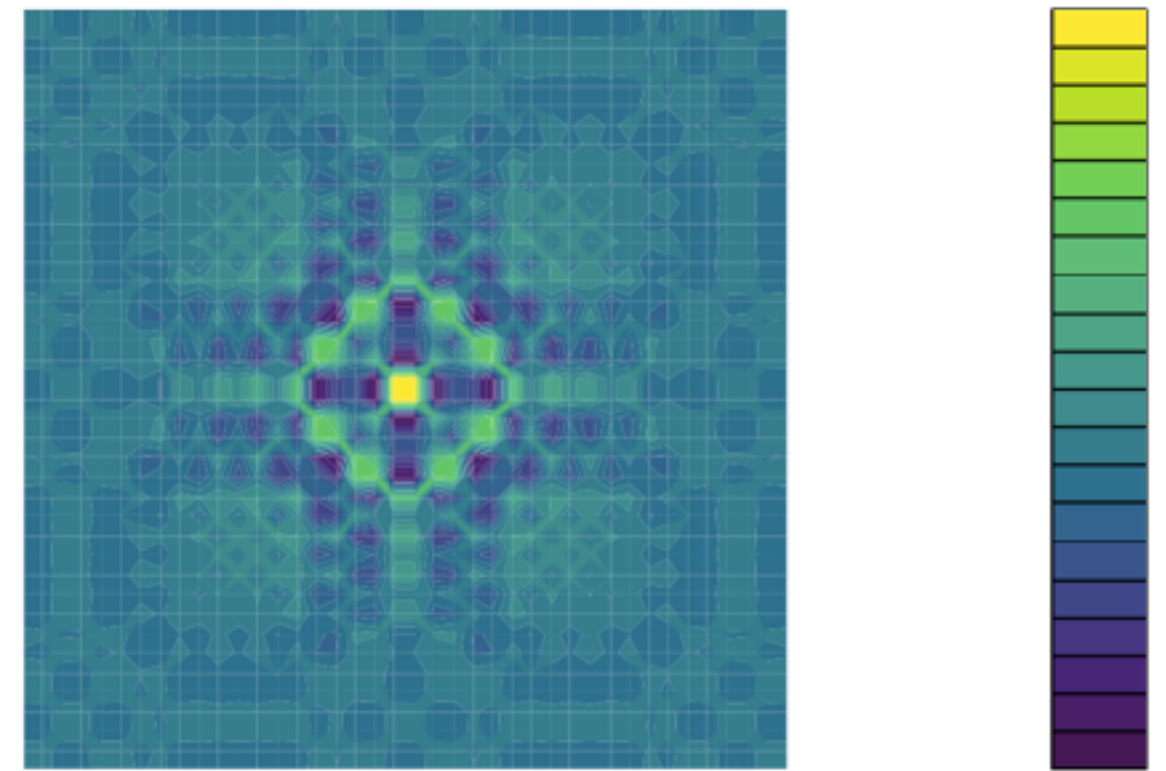
[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]



[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. <http://www.research.ibm.com/people/lloyd/color/color.HTM>]

Viridis / Magma: sequential colormaps

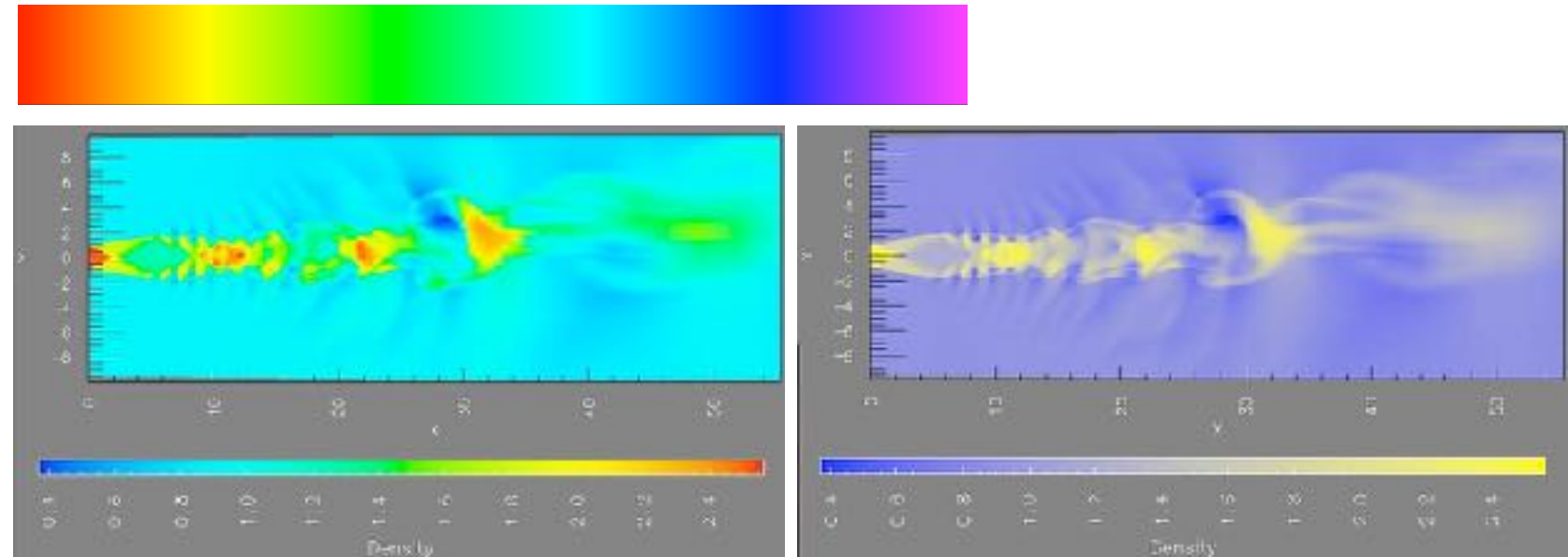
- monotonically increasing luminance, perceptually uniform
- colorful, colorblind-safe
 - R, python, D3



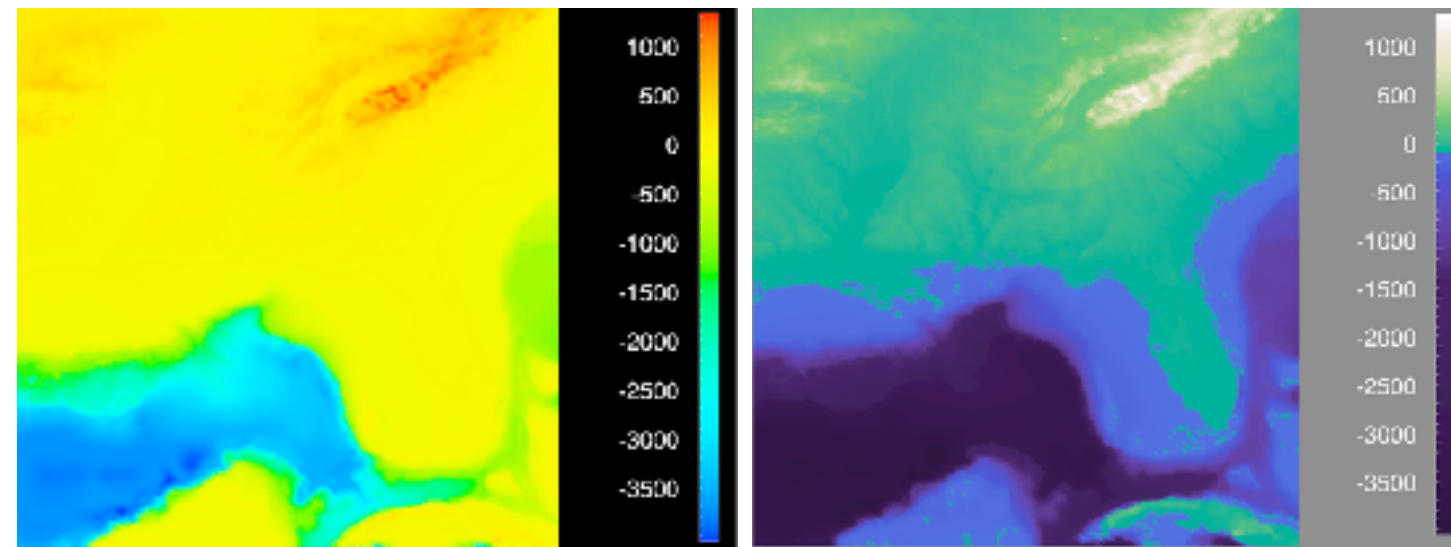
<https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>

Ordered color: Rainbow is poor default

- problems
 - perceptually unordered
 - perceptually nonlinear
- benefits
 - fine-grained structure visible and nameable
- alternatives
 - large-scale structure: fewer hues
 - fine structure: multiple hues with monotonically increasing luminance [eg viridis]
- legit for categorical
 - segmented saturated rainbow is good!



[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]



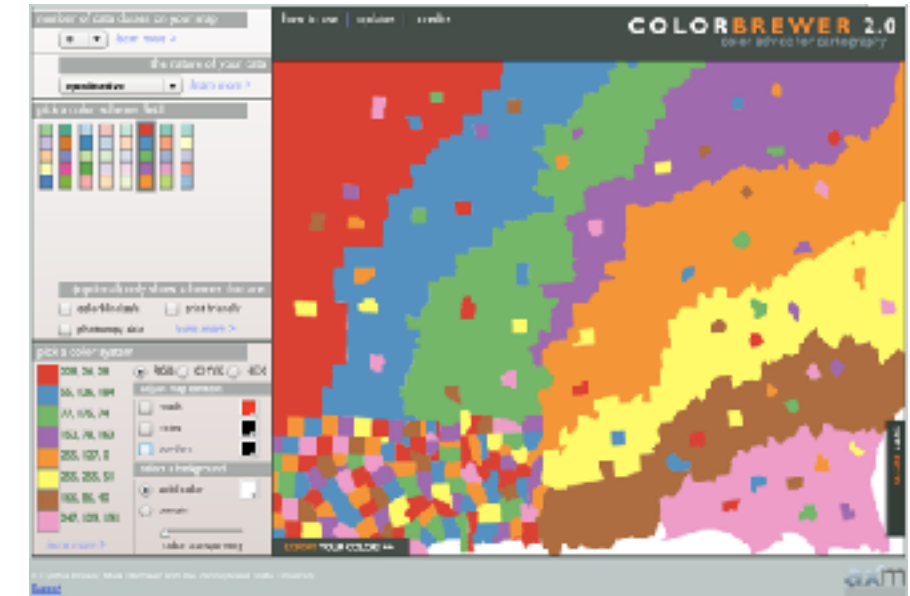
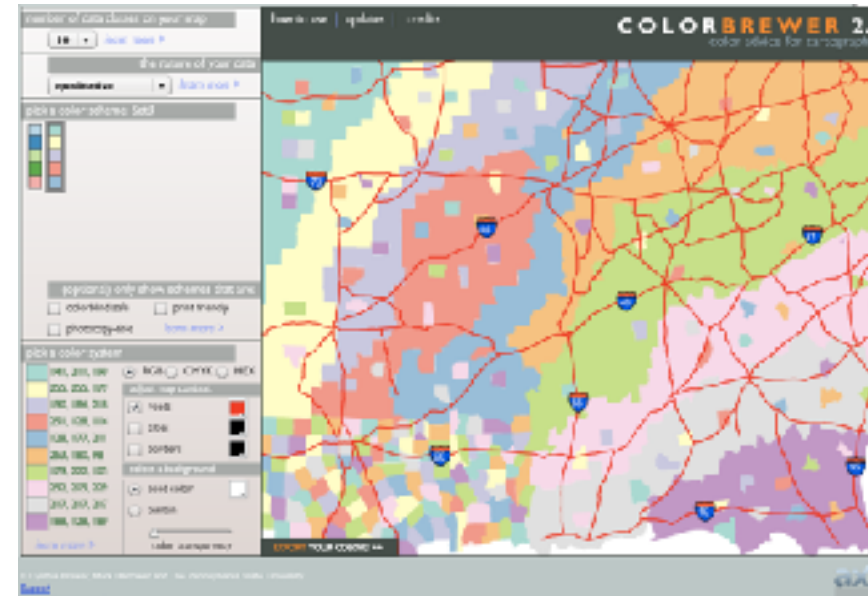
[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. <http://www.research.ibm.com/people/l/lloyd/color/color.HTM>]



[Transfer Functions in Direct Volume Rendering: Design, Interface, Interaction. Kindlmann. SIGGRAPH 2002 Course Notes]

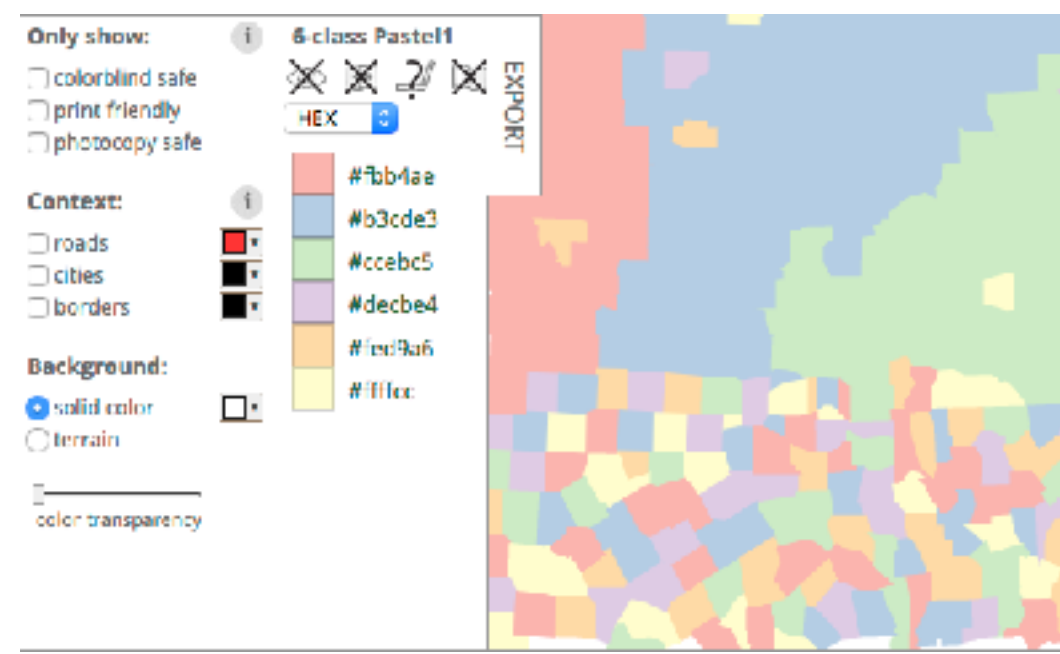
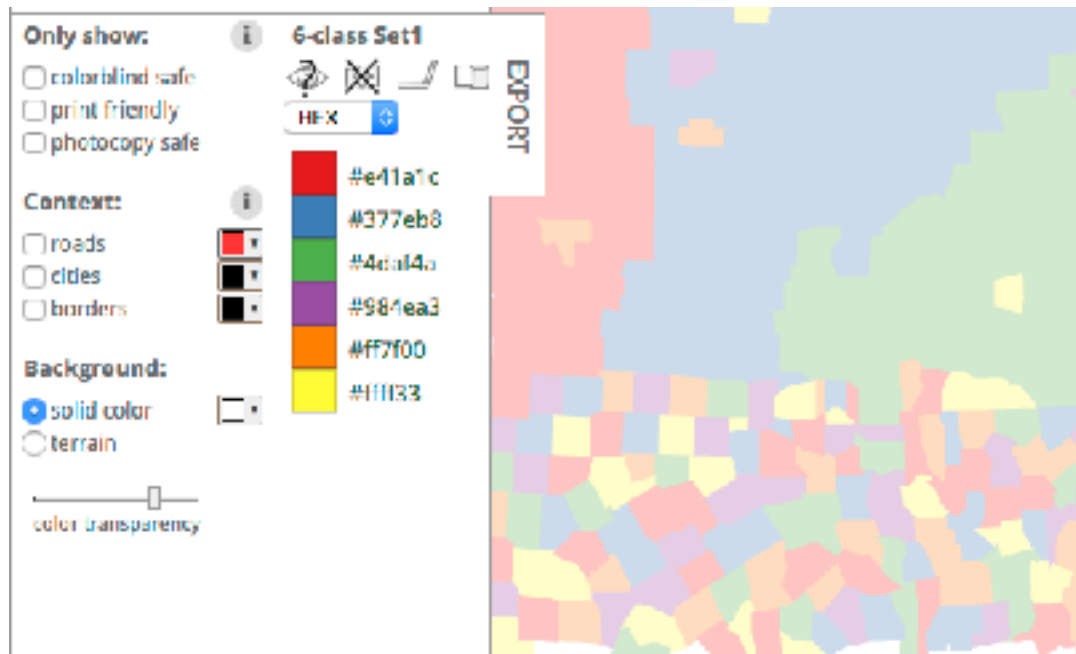
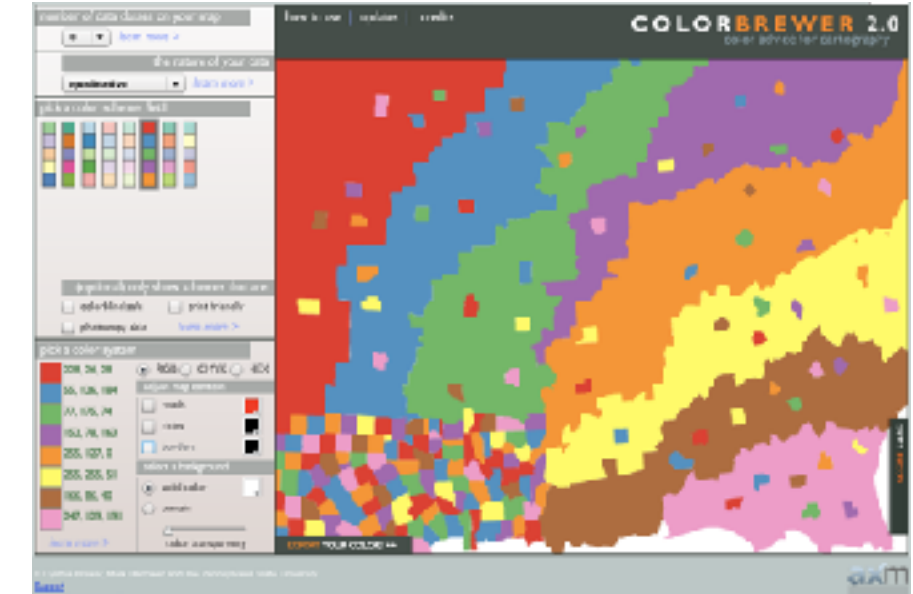
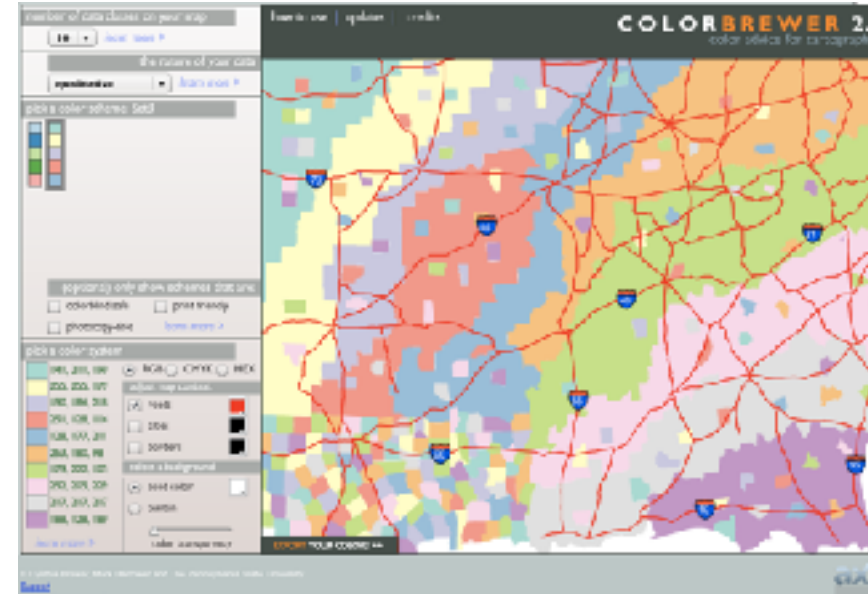
Interaction between channels: Not fully separable

- color channel interactions
 - size heavily affects salience
 - small regions need high saturation
 - large regions need low saturation



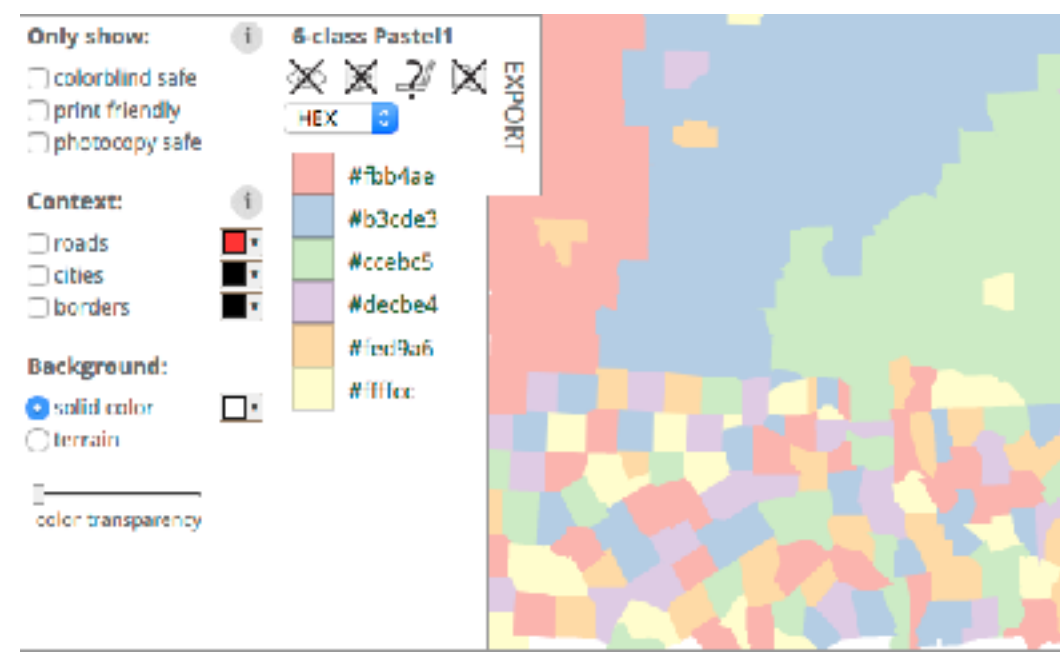
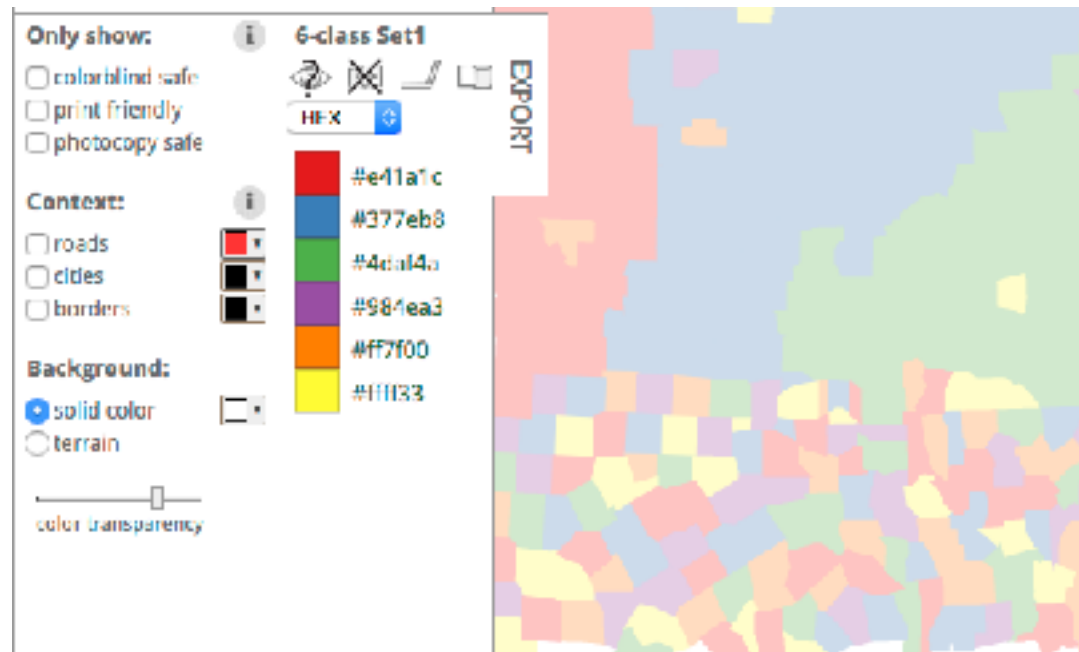
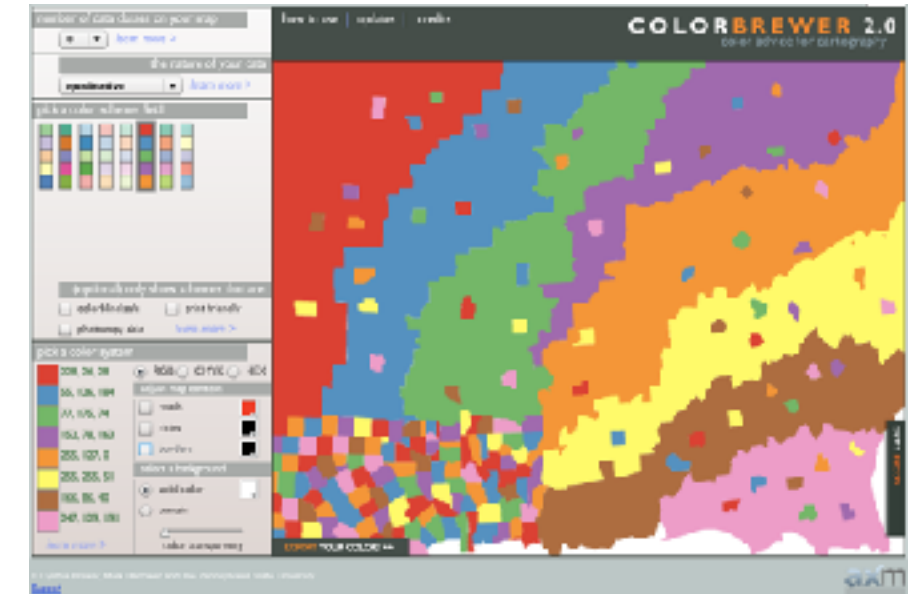
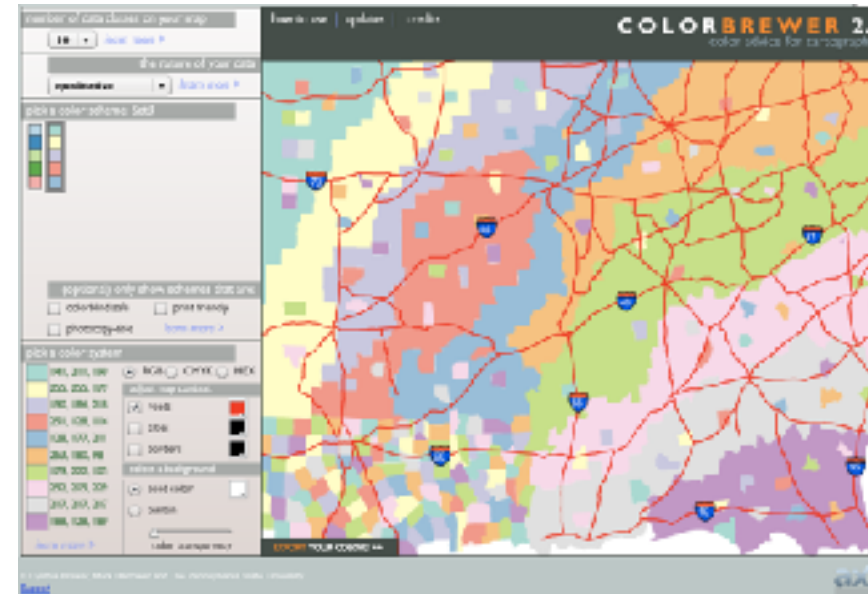
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- saturation & luminance:
 - not separable from each other!
 - also not separable from transparency



Interaction between channels: Not fully separable

- color channel interactions
 - size heavily affects salience
 - small regions need high saturation
 - large regions need low saturation
- saturation & luminance:
 - not separable from each other!
 - also not separable from transparency
 - small separated regions: 2 bins safest (use only one of these channels), 3-4 bins max
 - contiguous regions: many bins (use only one of these channels)



Color Palettes

Color palettes: univariate

→ Categorical



- categorical

- aim for maximum distinguishability
- aka *qualitative, nominal*



Color palettes: univariate

→ Categorical



Categorical

→ Ordered

→ *Sequential*

→ *Diverging*



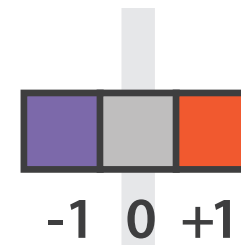
- diverging

- useful when data has meaningful "midpoint"
- use neutral color for midpoint
 - white, yellow, grey
- use saturated colors for endpoints

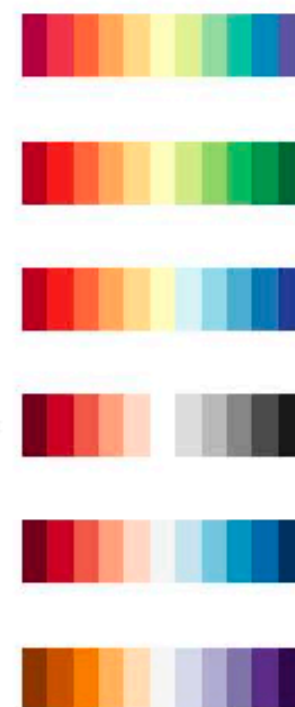
- sequential

- ramp luminance or saturation

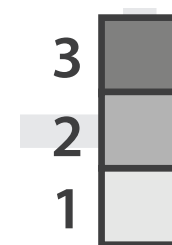
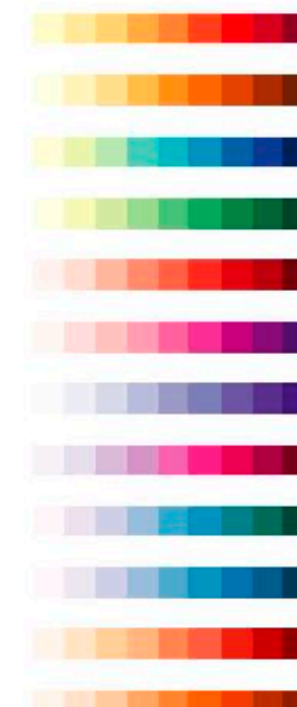
Diverging



diverging



sequential



Sequential

Color palettes: univariate

→ Categorical

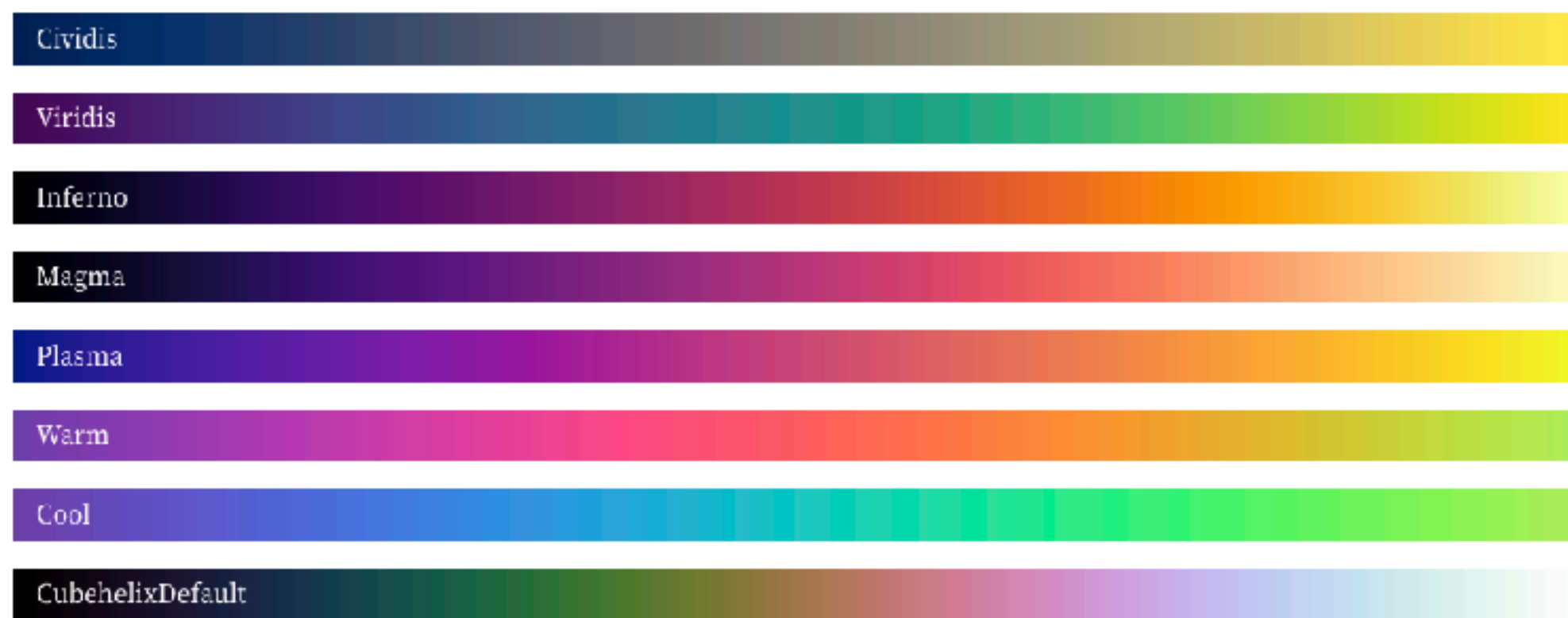


→ Ordered

→ *Sequential*



→ *Diverging*



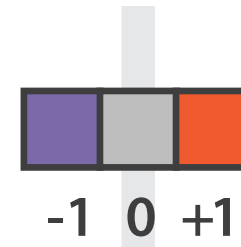
- diverging

- useful when data has meaningful "midpoint"
- use neutral color for midpoint
 - white, yellow, grey
- use saturated colors for endpoints

- sequential

- ramp luminance or saturation
- if multi-hue, good to order by luminance

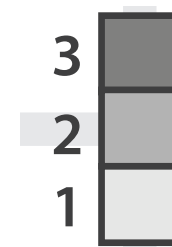
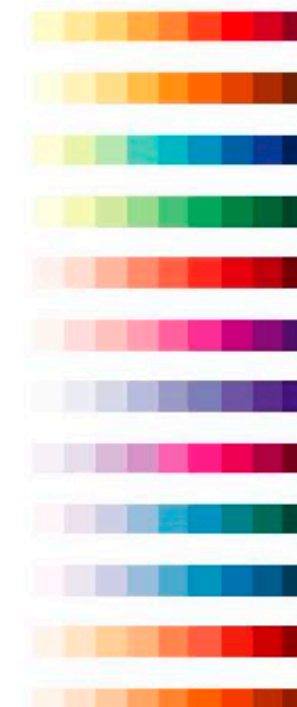
Diverging



diverging



sequential



Sequential

Color palettes: univariate

→ Categorical



→ Ordered

→ *Sequential*



→ *Diverging*



→ Cyclic



cyclic multihue



<https://github.com/d3/d3-scale-chromatic>

Color palette design considerations: univariate

segmented

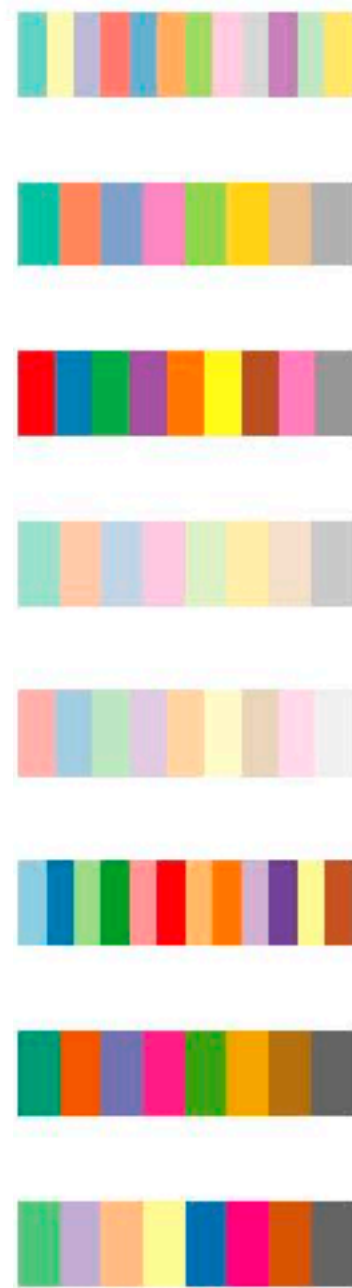
diverging



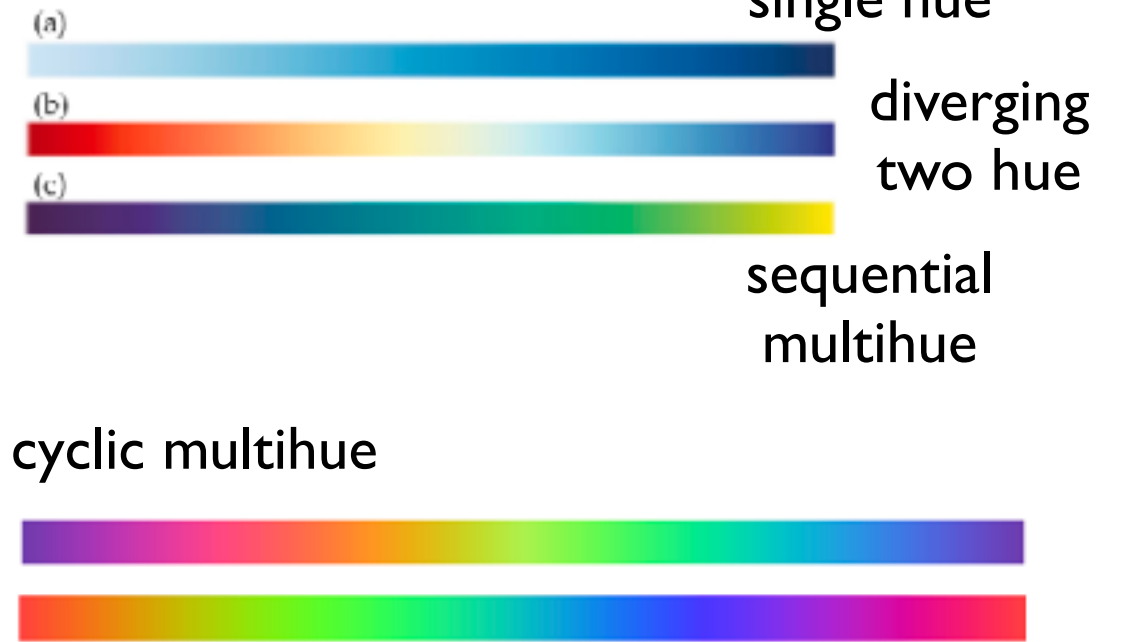
sequential



categorical



continuous



- segmented or continuous?
- diverging or sequential or cyclic?
- single-hue or two-hue or multi-hue?
- perceptually linear?
- ordered by luminance?
- colorblind safe?

Colormaps: bivariate

→ Categorical



→ Ordered

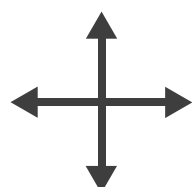
→ Sequential



→ Diverging



→ Bivariate



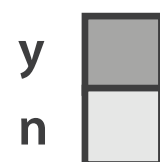
• bivariate best case

• binary in one of the directions



d3.schemePaired <>

Binary



Categorical

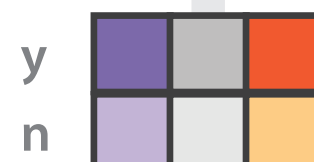


Binary



Categorical

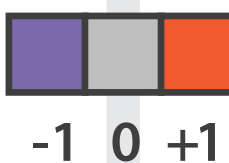
Diverging



Binary

-1 0 +1

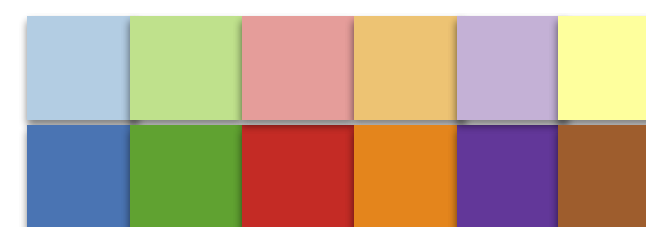
Diverging



-1 0 +1



Sequential



binary saturation

categorical hue

Colormaps: bivariate

→ Categorical



→ Ordered

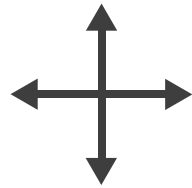
→ *Sequential*



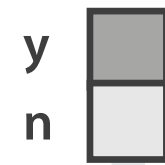
→ *Diverging*



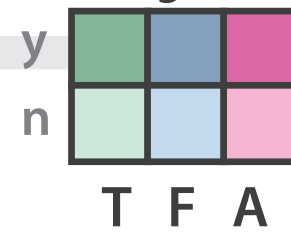
→ Bivariate



Binary



Categorical

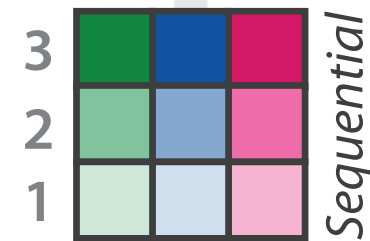


Binary

Categorical

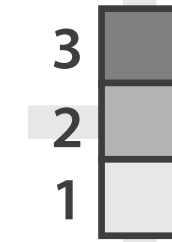


Categorical



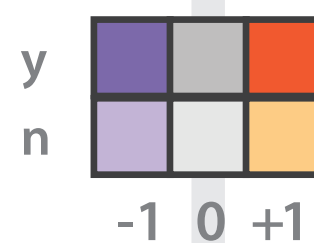
Sequential

Sequential

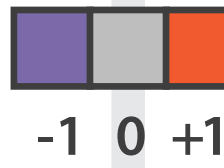


Diverging

Diverging



Binary



Colormaps

→ Categorical



→ Ordered

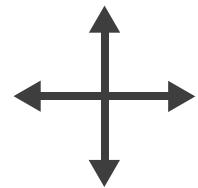
→ Sequential



→ Diverging

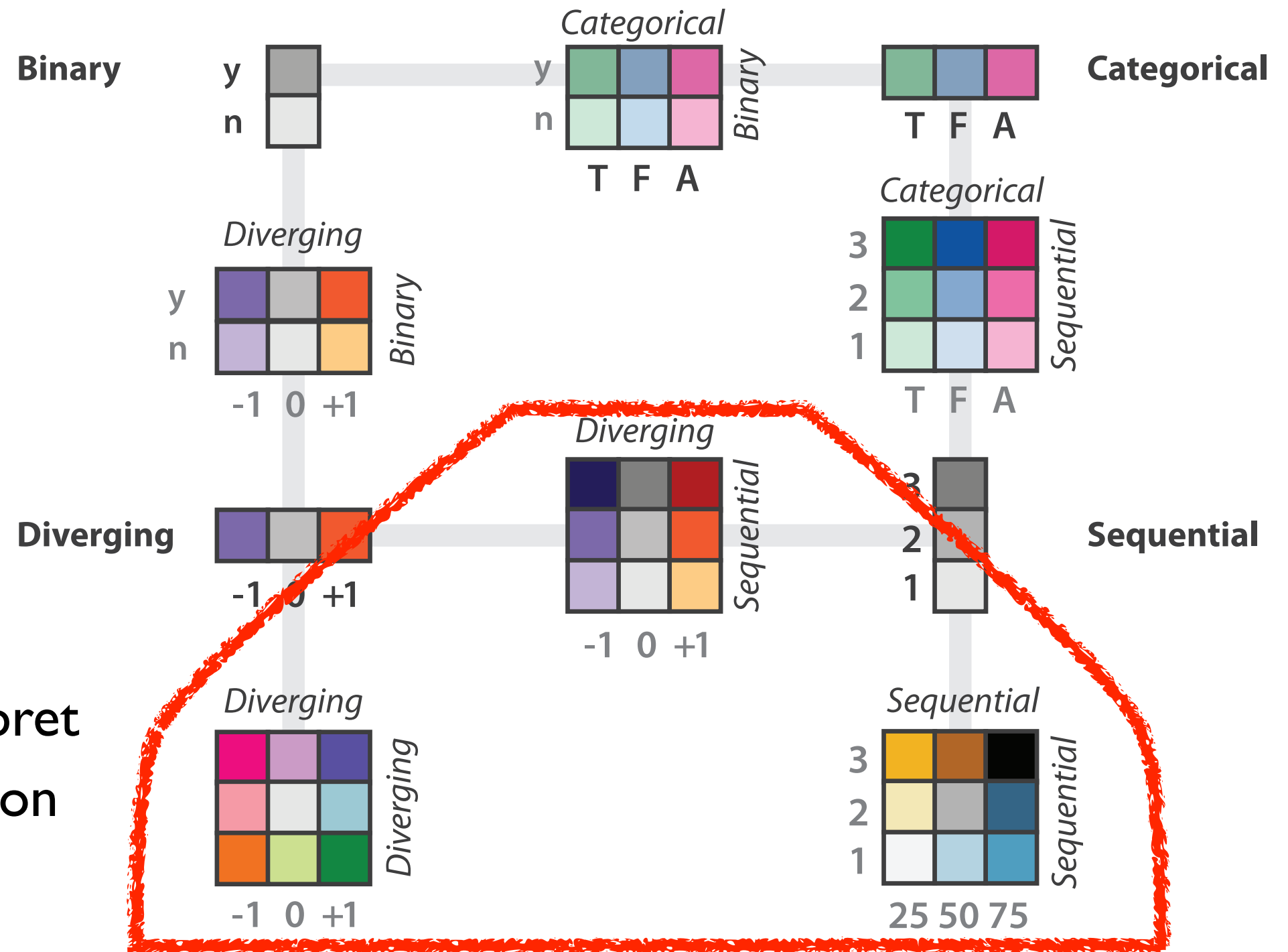


→ Bivariate



use with care!

- bivariate can be very difficult to interpret
 - when multiple levels in each direction



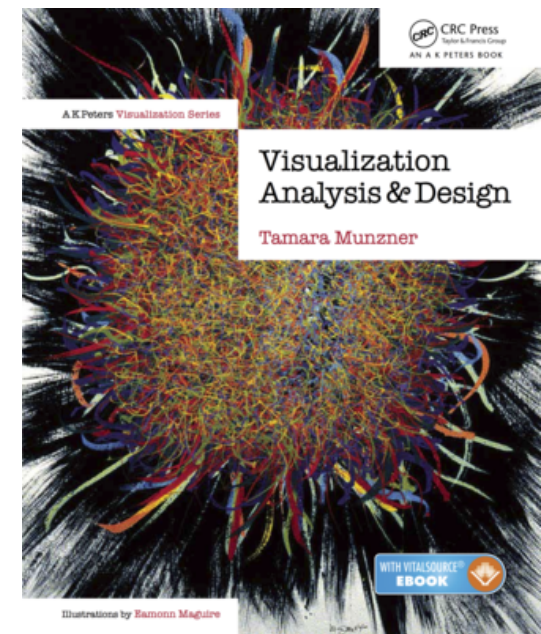
Visualization Analysis & Design

Color (Ch 10) II

Tamara Munzner

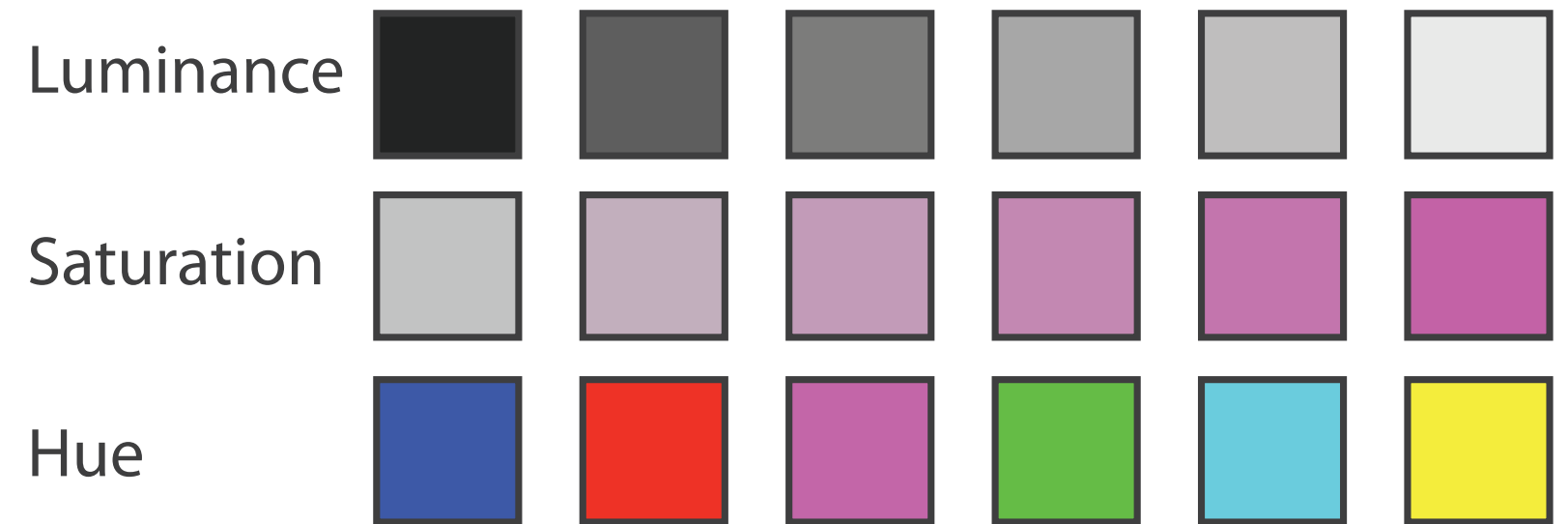
Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



Decomposing color

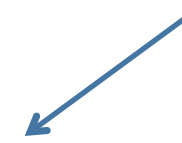
- decompose into three channels
 - ordered can show magnitude
 - **luminance**: how bright (B/W)
 - **saturation**: how colourful
 - categorical can show identity
 - **hue**: what color



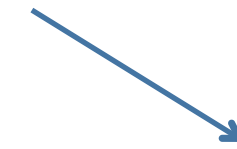
Color Deficiency

Luminance

- need luminance for edge detection
 - fine-grained detail only visible through luminance contrast
 - legible text requires luminance contrast!



Luminance information



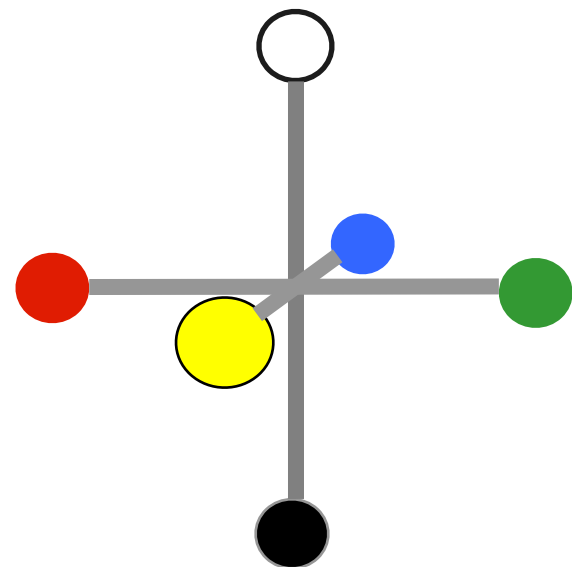
Saturation/hue information



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Opponent color and color deficiency

- perceptual processing before optic nerve
 - one achromatic luminance channel (L^*)
 - edge detection through luminance contrast
 - 2 chroma channels
 - red-green (a^*) & yellow-blue axis (b^*)



Luminance information



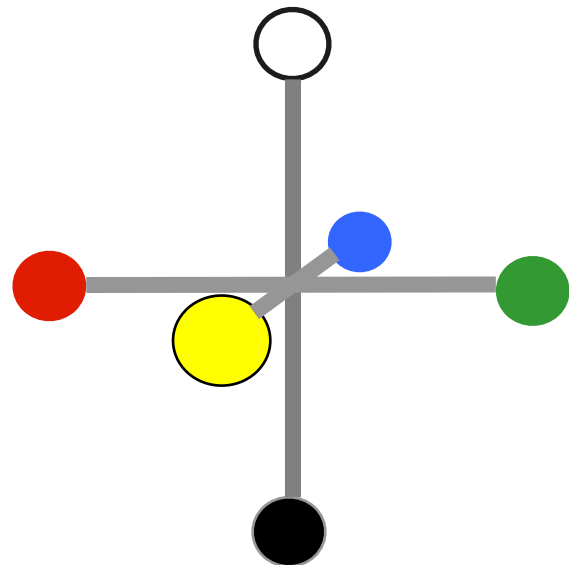
Chroma information



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Opponent color and color deficiency

- perceptual processing before optic nerve
 - one achromatic luminance channel (L^*)
 - edge detection through luminance contrast
 - 2 chroma channels
 - red-green (a^*) & yellow-blue axis (b^*)
- “colorblind”: degraded acuity, one axis
 - 8% of men are red/green color deficient
 - blue/yellow is rare



Luminance information



Chroma information



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Designing for color deficiency: Check with simulator



Normal vision



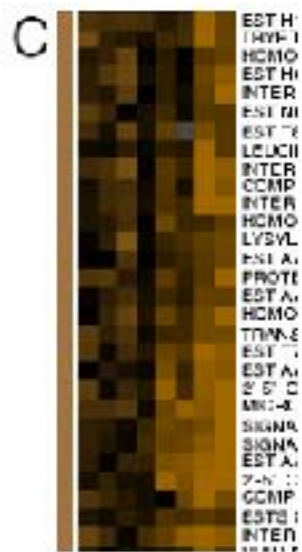
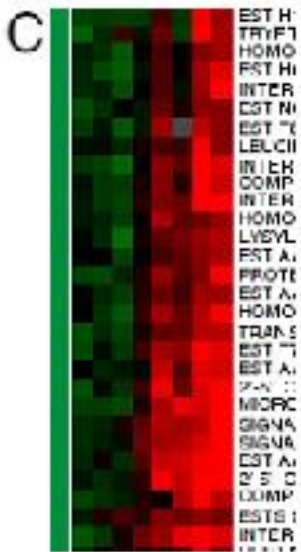
**Deuteranope
*green-weak***



**Protanope
*red-weak***



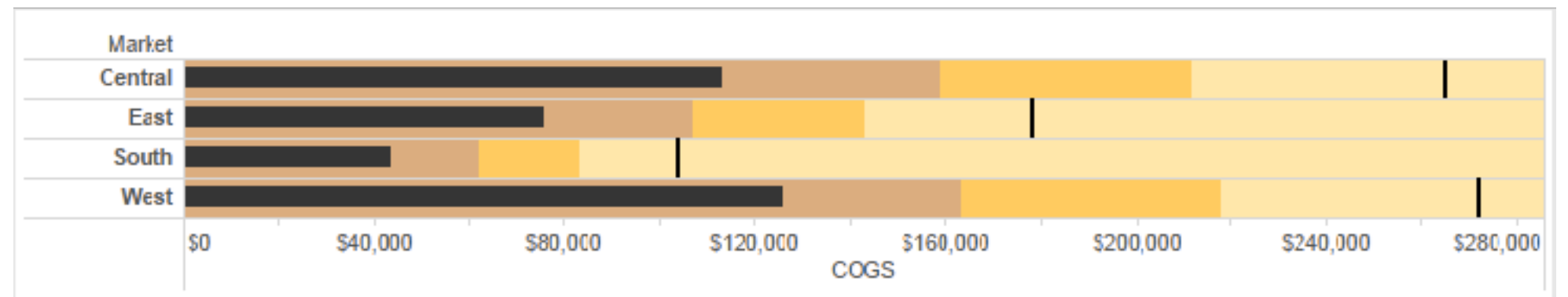
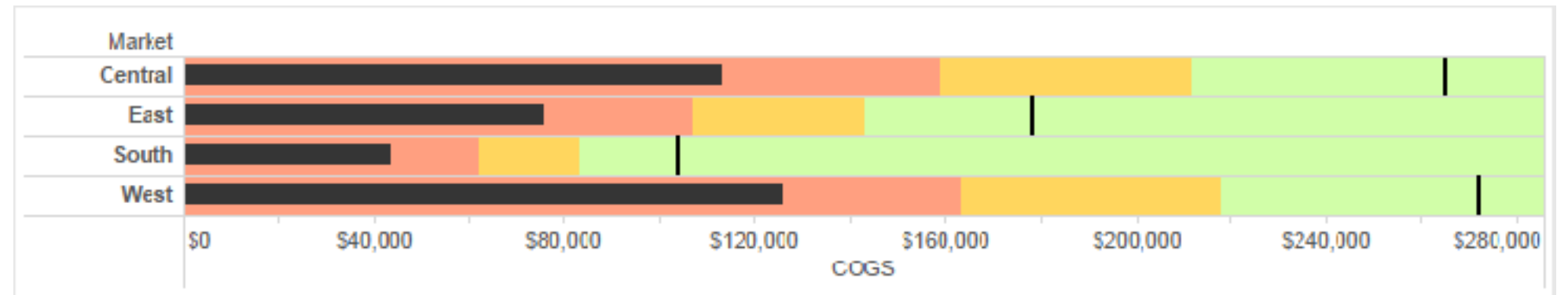
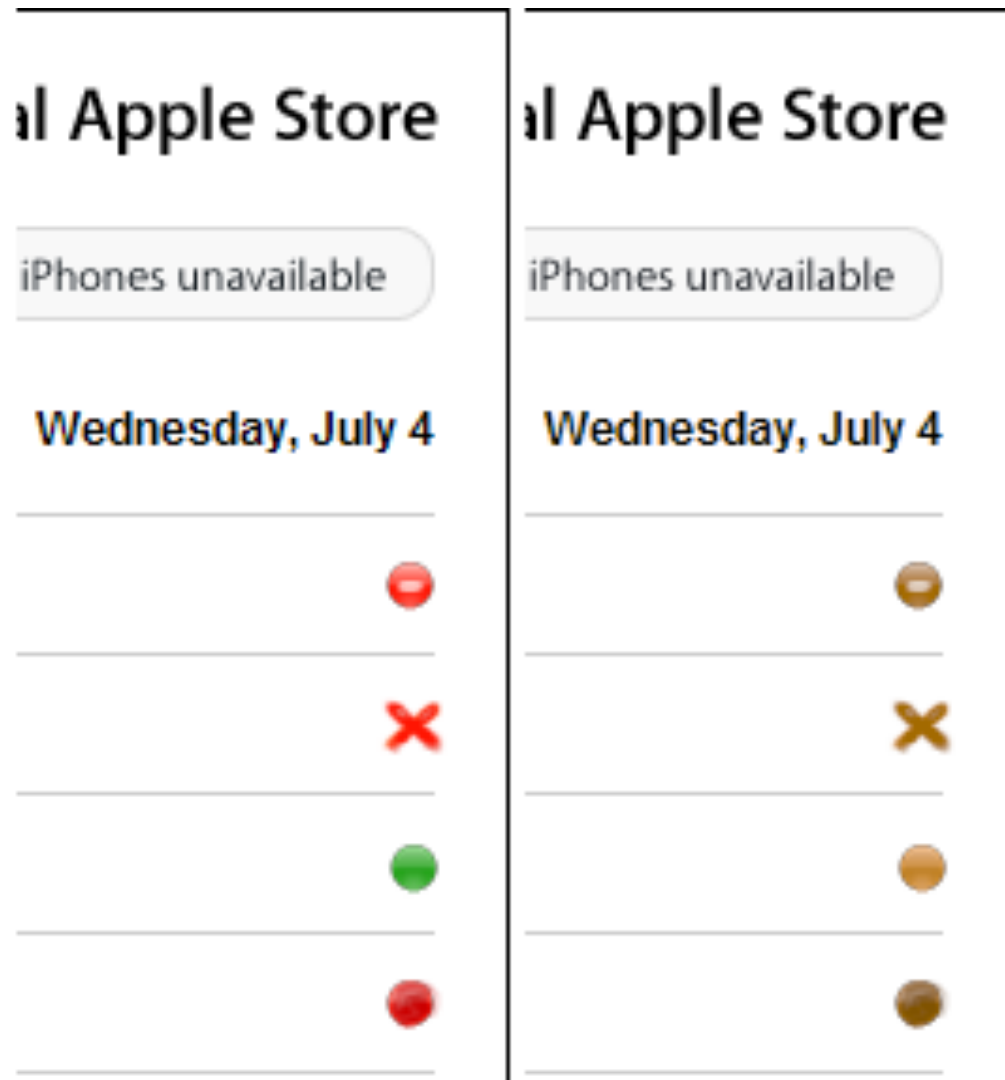
**Tritanope
*blue-weak***



<https://www.color-blindness.com/coblis-color-blindness-simulator/>

Designing for color deficiency: Avoid encoding by hue alone

- redundantly encode
 - vary luminance
 - change shape

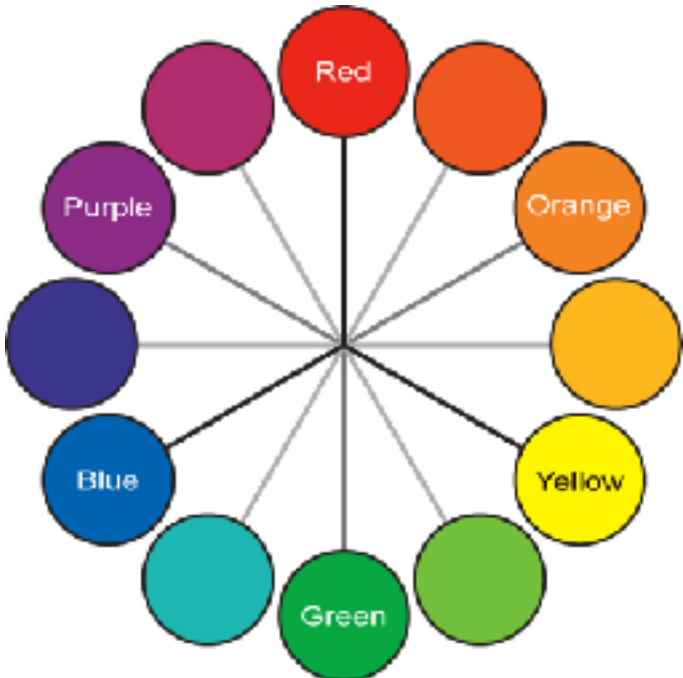


Deuteranope simulation

Change the shape

Vary luminance

Color deficiency: Reduces color to 2 dimensions



Normal



Protanope



Deuteranope



Tritanope

[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

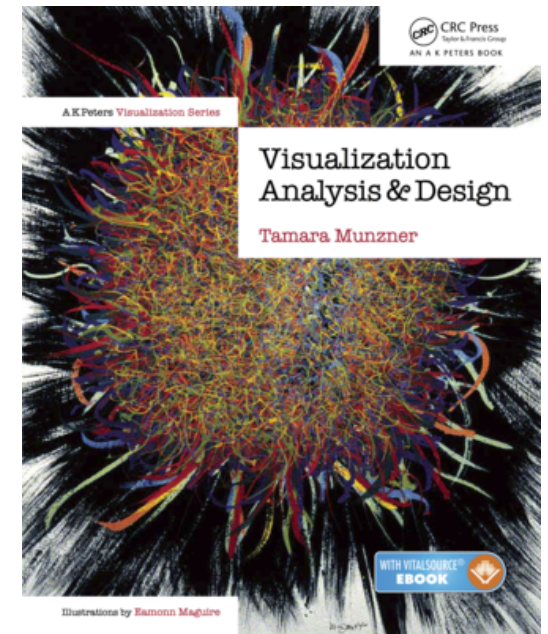
Visualization Analysis & Design

Color (Ch 10) III

Tamara Munzner

Department of Computer Science
University of British Columbia

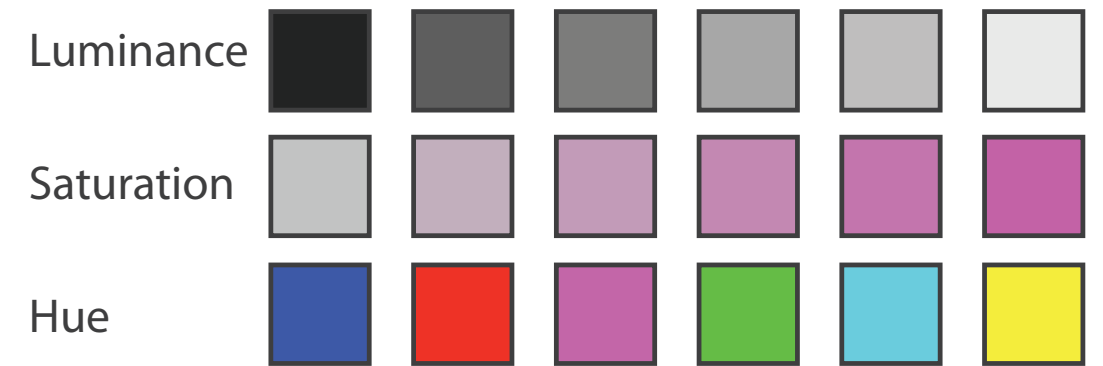
[@tamaramunzner](#)



Color Spaces

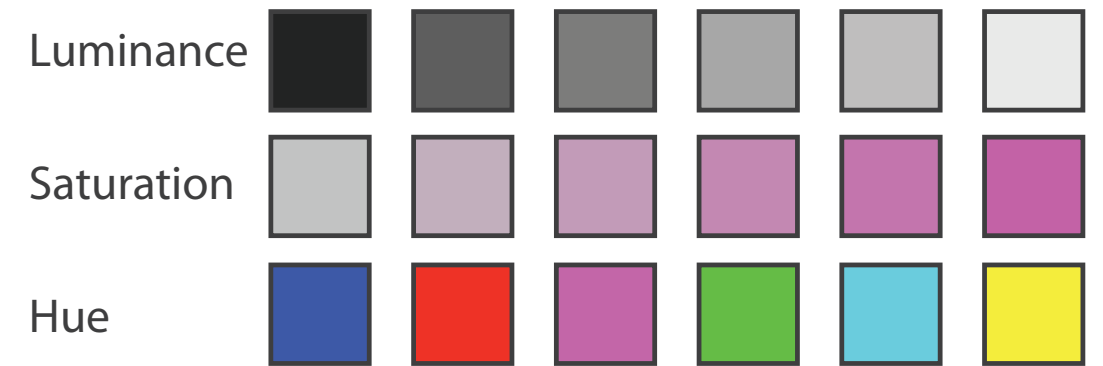
Many color spaces

- Luminance (L^*), hue (H), saturation (S)
 - good for encoding



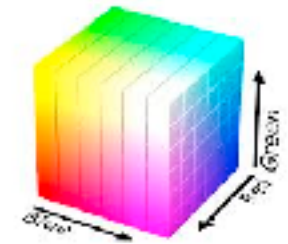
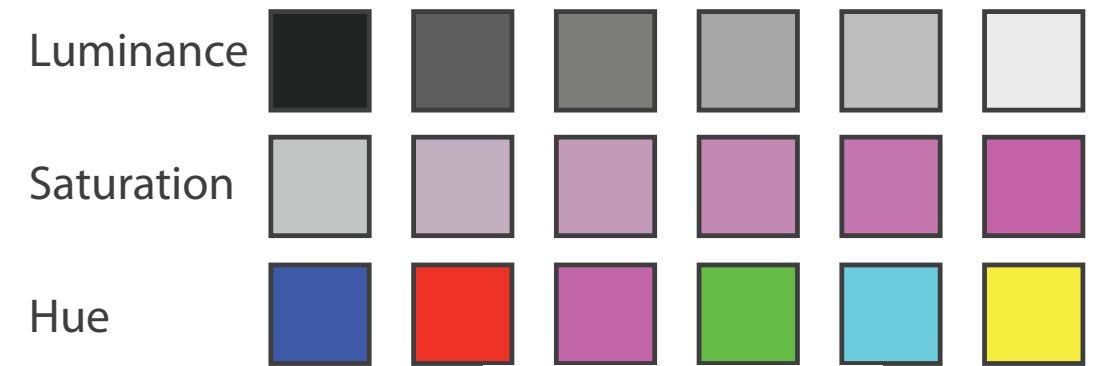
Many color spaces

- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace



Many color spaces

- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace
- RGB: good for display hardware

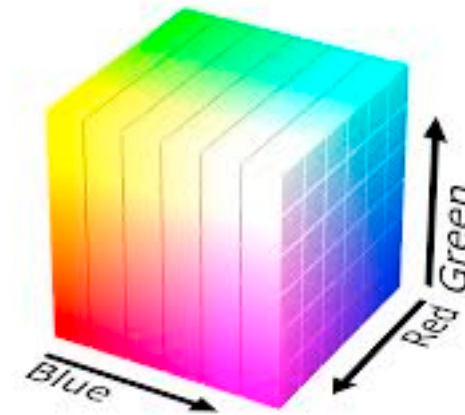


https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png

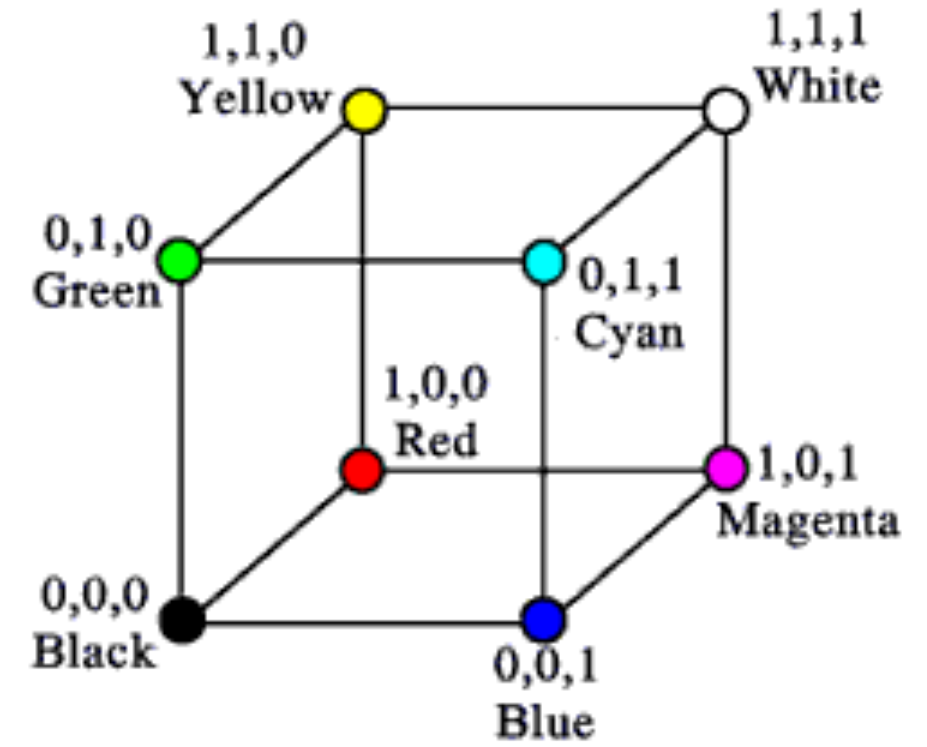
RGB

- RGB: good for display hardware

Corners of the RGB color cube



https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png

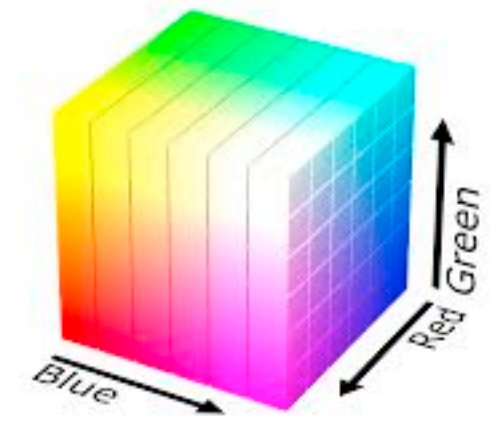
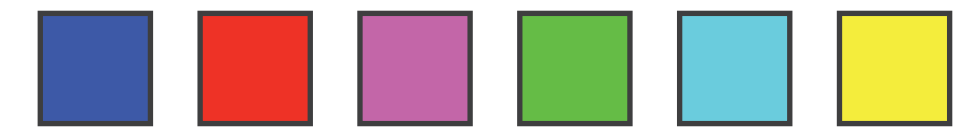


RGB

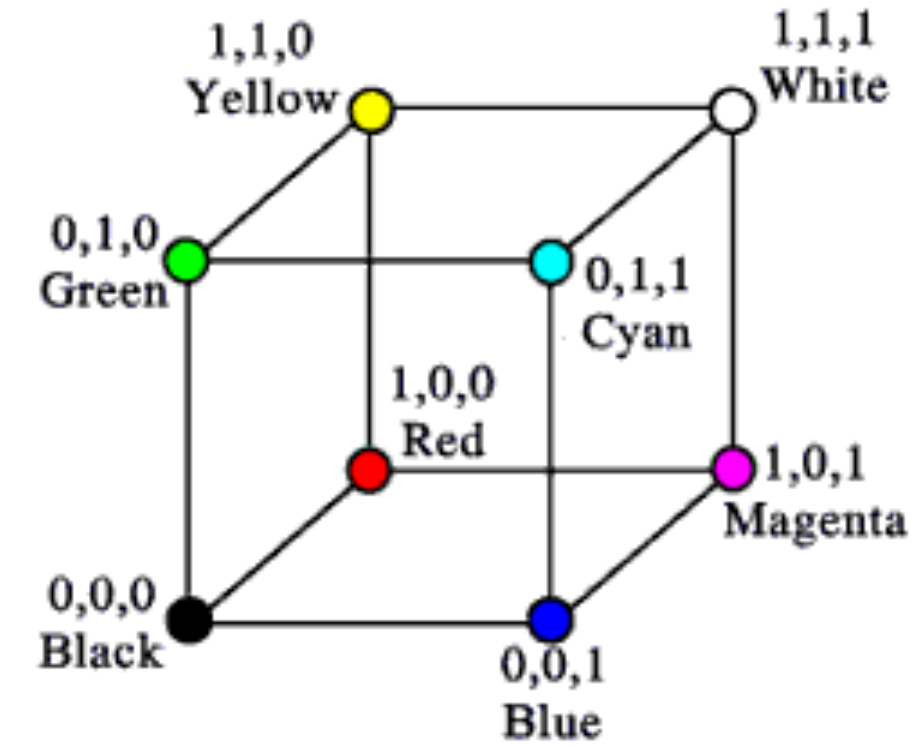
- RGB: good for display hardware

– poor for encoding & interpolation

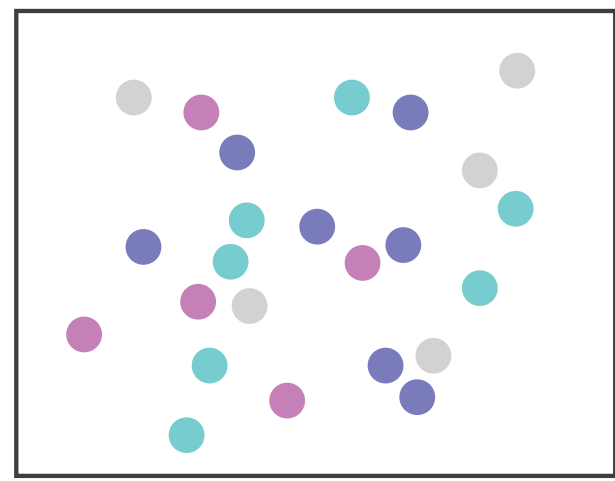
Corners of the RGB color cube



https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png



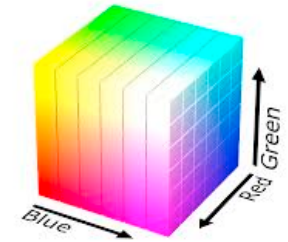
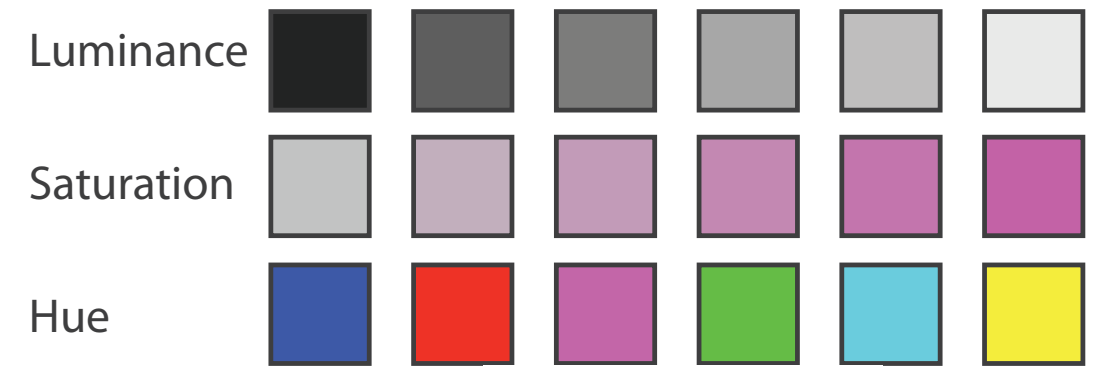
Red
+ Green



Major interference

Many color spaces

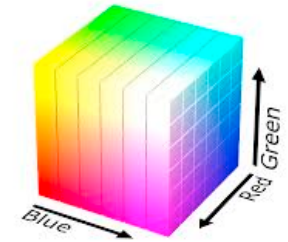
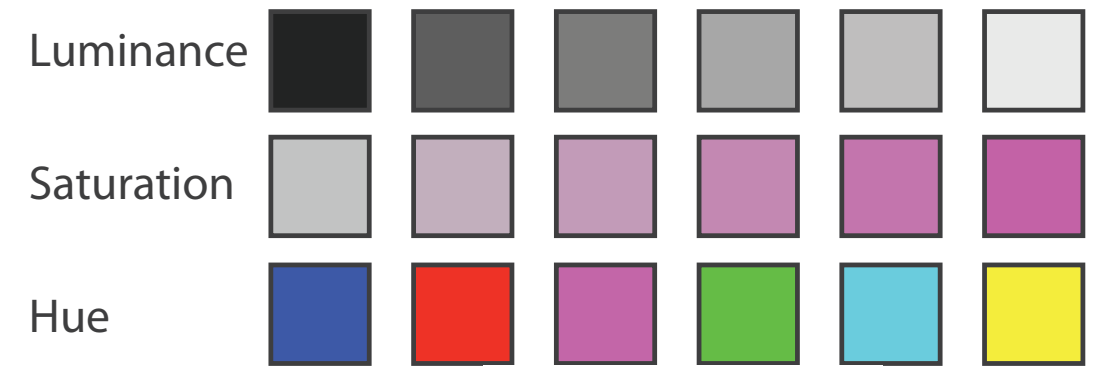
- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace
- RGB: good for display hardware
 - poor for encoding & interpolation



https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png

Many color spaces

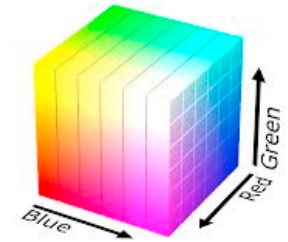
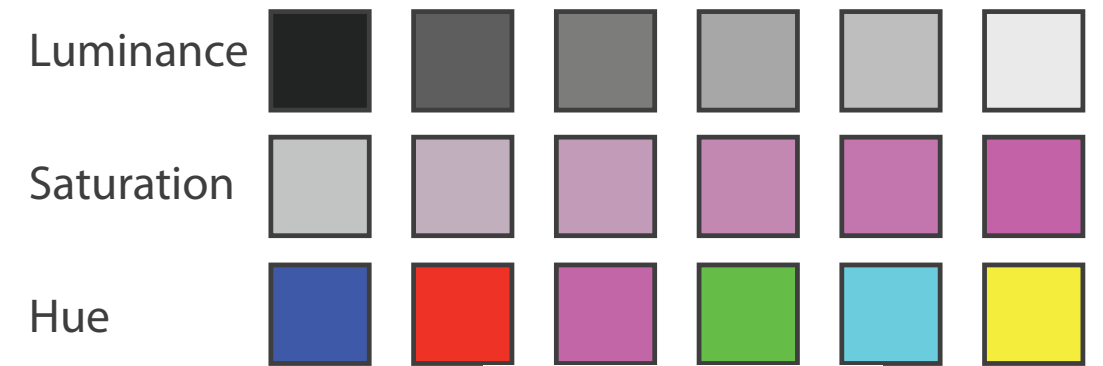
- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace
- RGB: good for display hardware
 - poor for encoding & interpolation
- CIE LAB ($L^*a^*b^*$): good for interpolation



https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png

Many color spaces

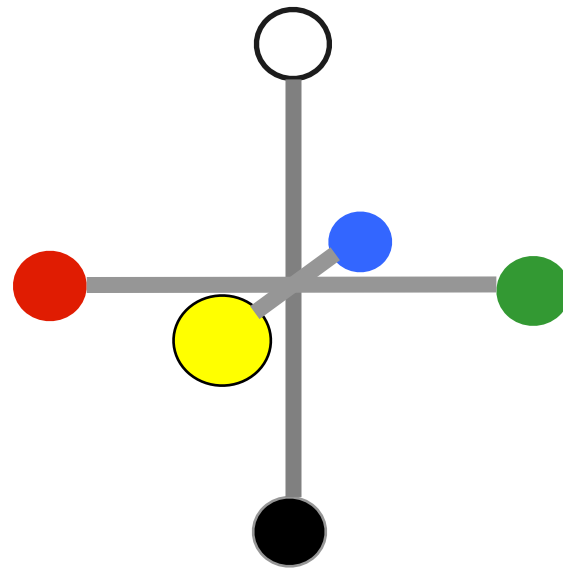
- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace
- RGB: good for display hardware
 - poor for encoding & interpolation
- CIE LAB ($L^*a^*b^*$): good for interpolation
 - hard to interpret, poor for encoding



https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png

Perceptual colorspace: L*a*b*

- perceptual processing before optic nerve
 - one achromatic luminance channel (L*)
 - edge detection through luminance contrast
 - 2 chroma channels
 - red-green (a*) & yellow-blue axis (b*)



Luminance information



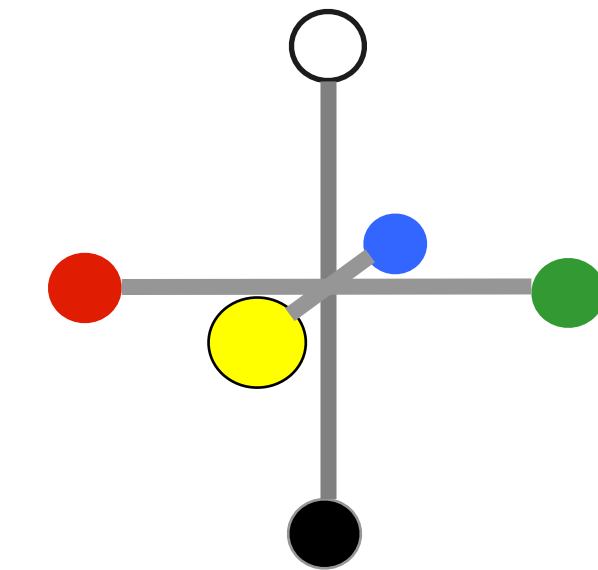
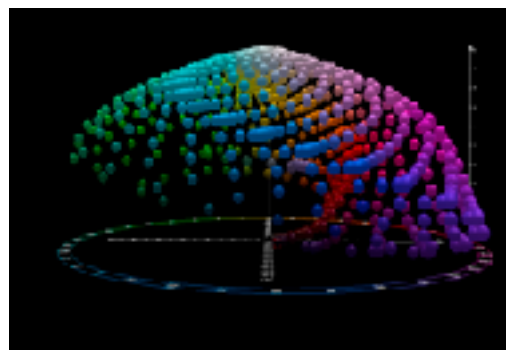
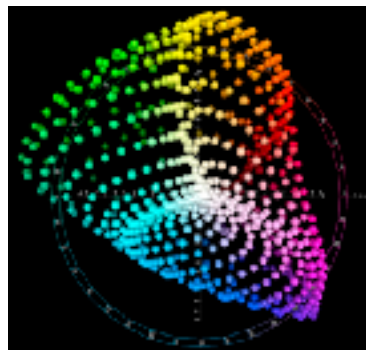
Chroma information



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Perceptual colorspace: L*a*b*

- perceptual processing before optic nerve
 - one achromatic luminance channel (L*)
 - edge detection through luminance contrast
 - 2 chroma channels
 - red-green (a*) & yellow-blue axis (b*)
- CIE LAB
 - perceptually uniform
 - great for interpolating
 - complex shape
 - poor for encoding



https://en.wikipedia.org/wiki/CIELAB_color_space



Luminance information



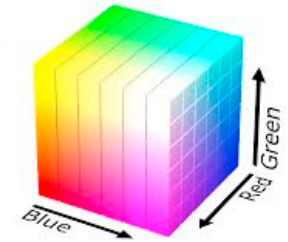
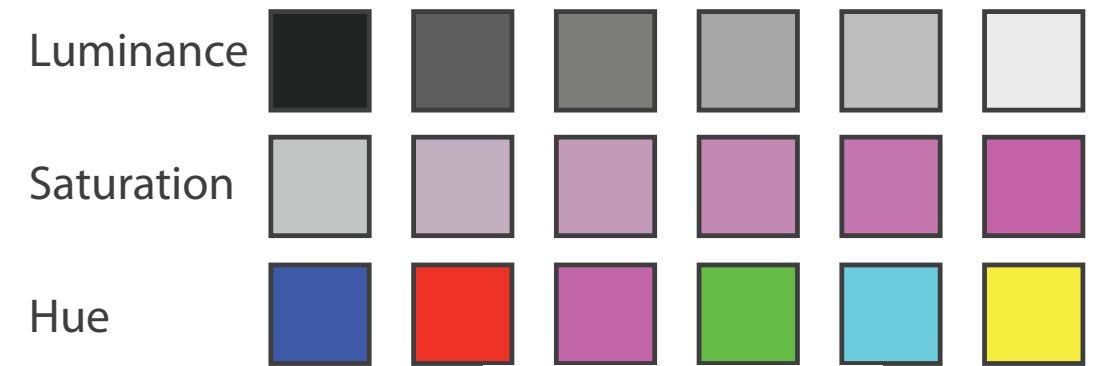
Chroma information



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Many color spaces

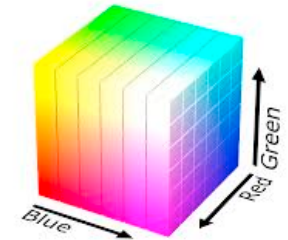
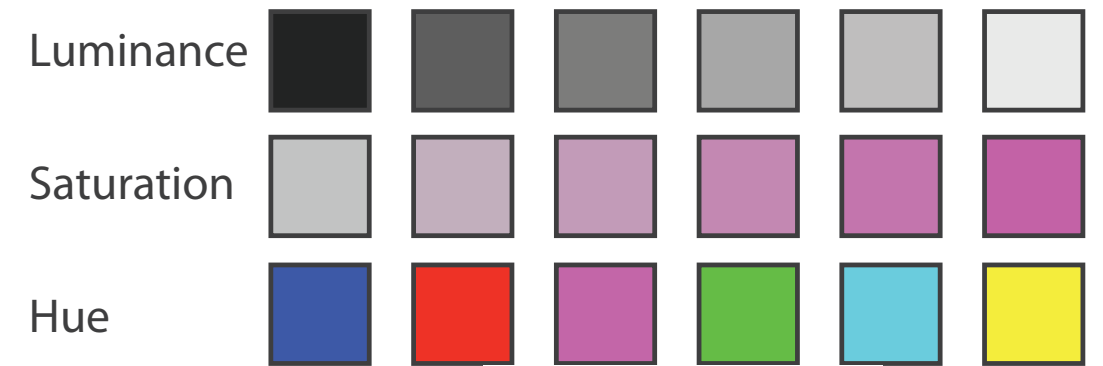
- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace
- RGB: good for display hardware
 - poor for encoding & interpolation
- CIE LAB ($L^*a^*b^*$): good for interpolation
 - hard to interpret, poor for encoding



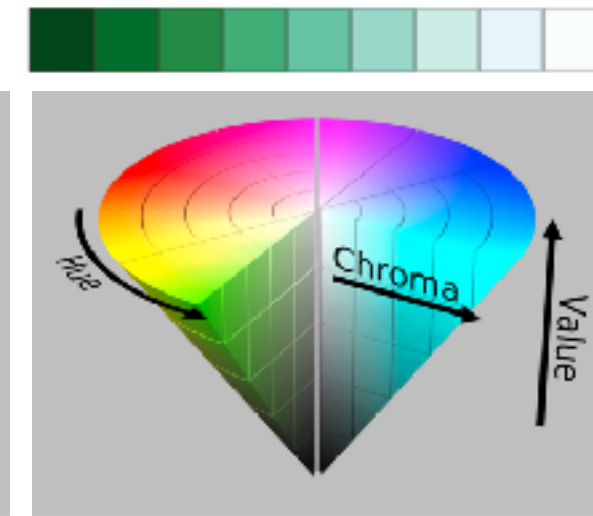
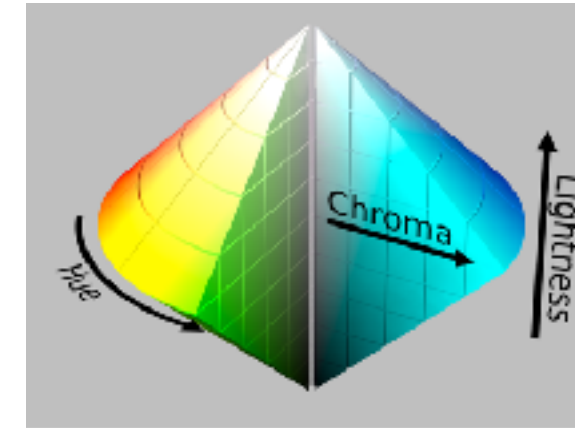
https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png

Many color spaces

- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
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- RGB: good for display hardware
 - poor for encoding & interpolation
- CIE LAB ($L^*a^*b^*$): good for interpolation
 - hard to interpret, poor for encoding
- HSL/HSV: somewhat better for encoding

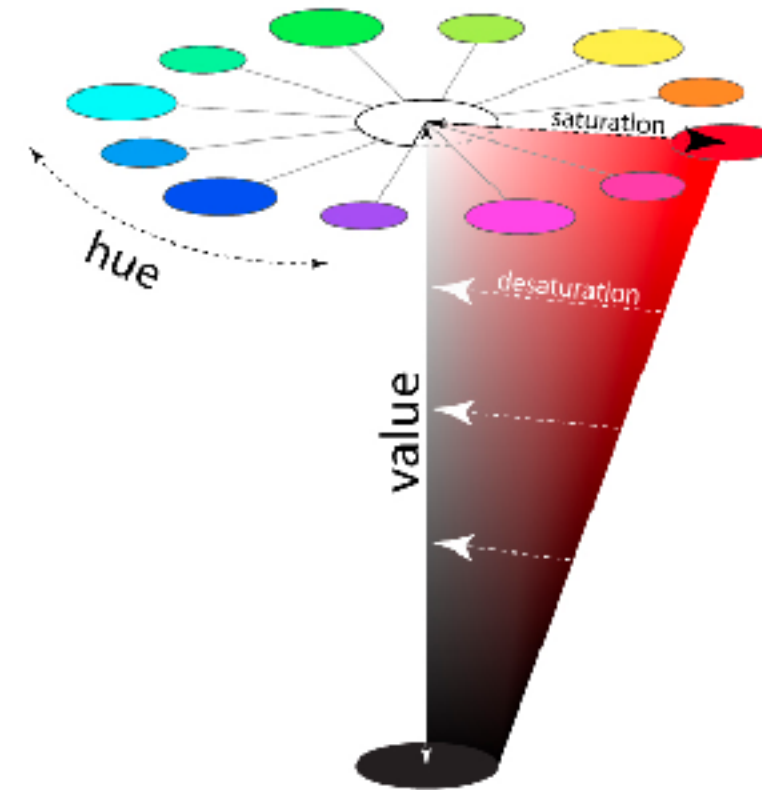
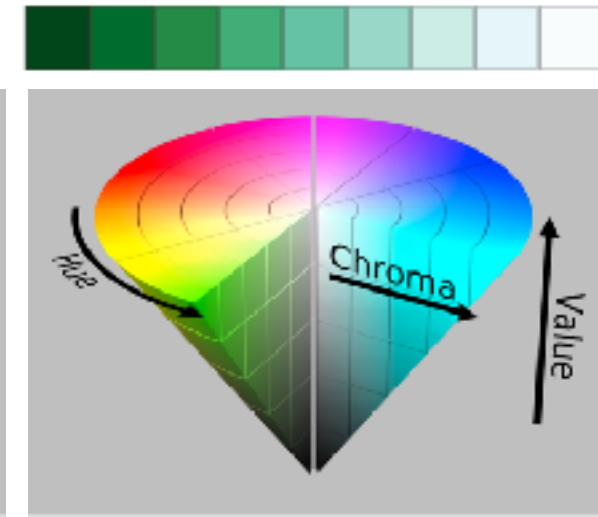
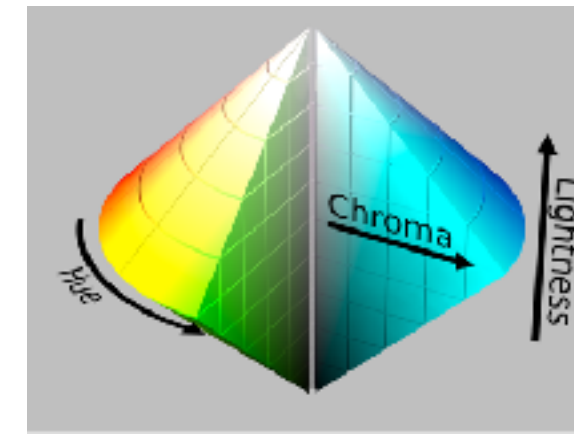


https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png



HSL/HSV

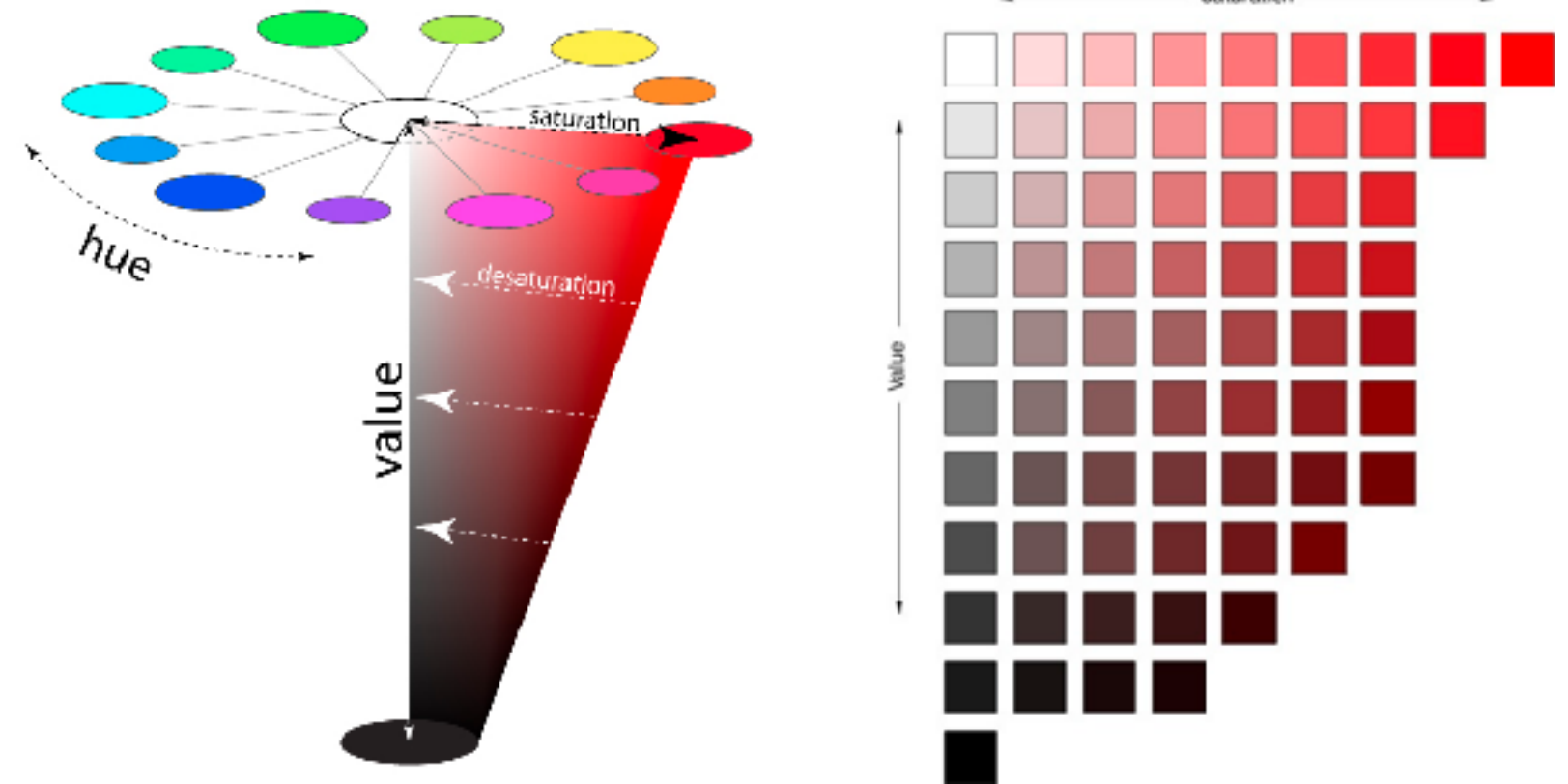
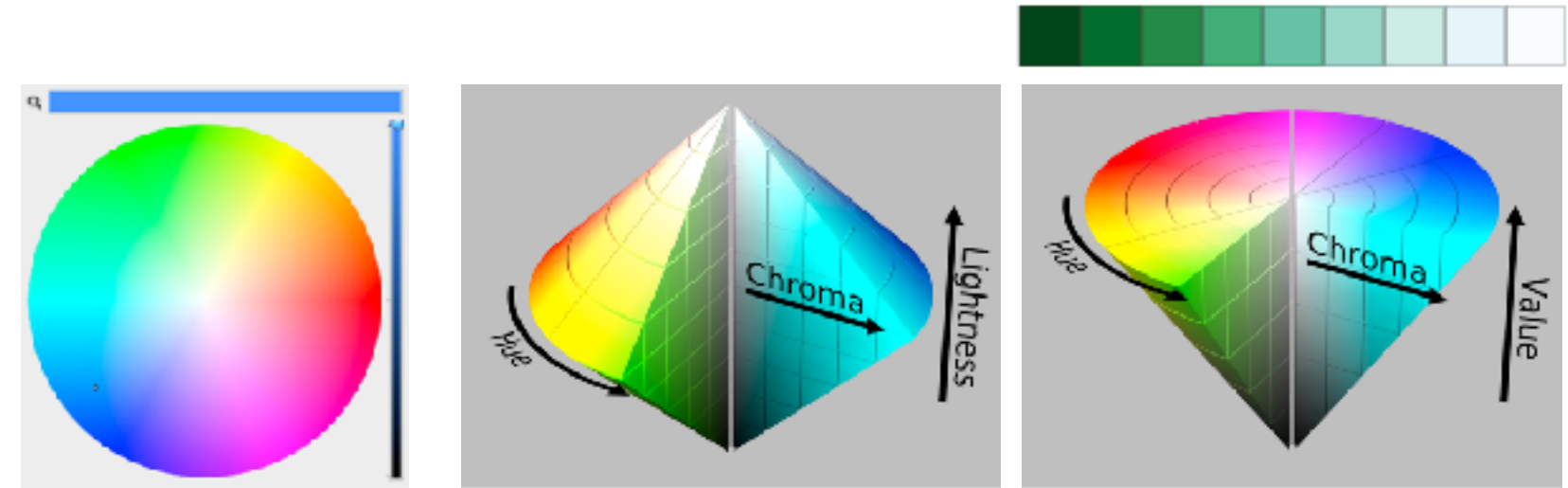
- HSL/HSV: somewhat better for encoding
 - hue/saturation wheel intuitive
- saturation
 - in HSV (single-cone) desaturated = white
 - in HSL (double-cone) desaturated = grey



<http://learn.leighcotnoir.com/artspeak/elements-color/hue-value-saturation/hsv8/>

HSL/HSV

- HSL/HSV: somewhat better for encoding
 - hue/saturation wheel intuitive
- saturation
 - in HSV (single-cone) desaturated = white
 - in HSL (double-cone) desaturated = grey
- luminance vs saturation
 - channels **not** very separable
 - typically not crucial to distinguish between these with encoding/decoding
 - key point is hue vs luminance/saturation

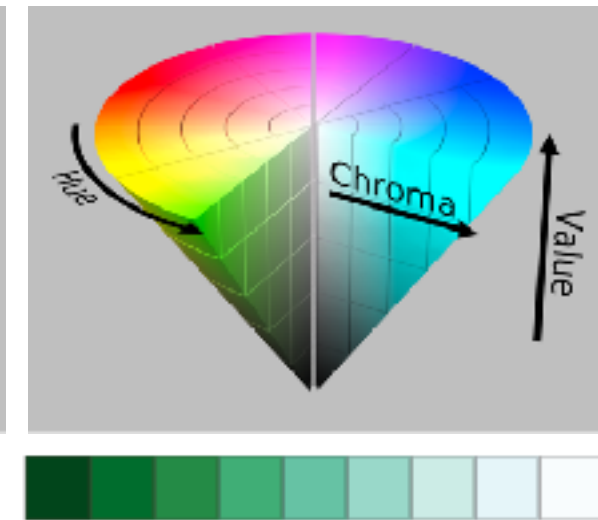
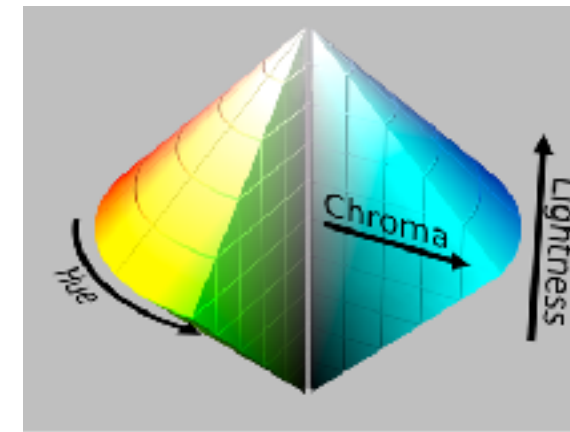


<http://learn.leighcotnoir.com/artspeak/elements-color/hue-value-saturation/hsv8/>

<http://learn.leighcotnoir.com/artspeak/elements-color/hue-value-saturation/hsv8/>

HSL/HSV: Pseudo-perceptual colorspace

- HSL better than RGB for encoding **but beware**
 - L lightness \neq L* luminance



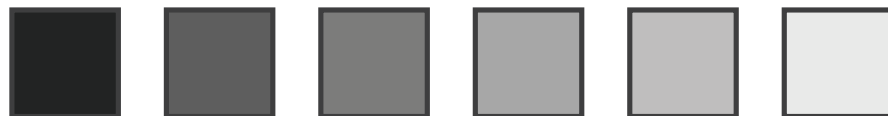
Corners of the RGB color cube



L from HLS
All the same



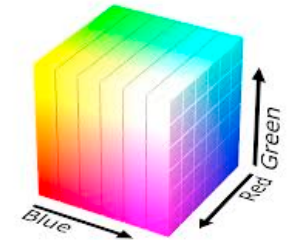
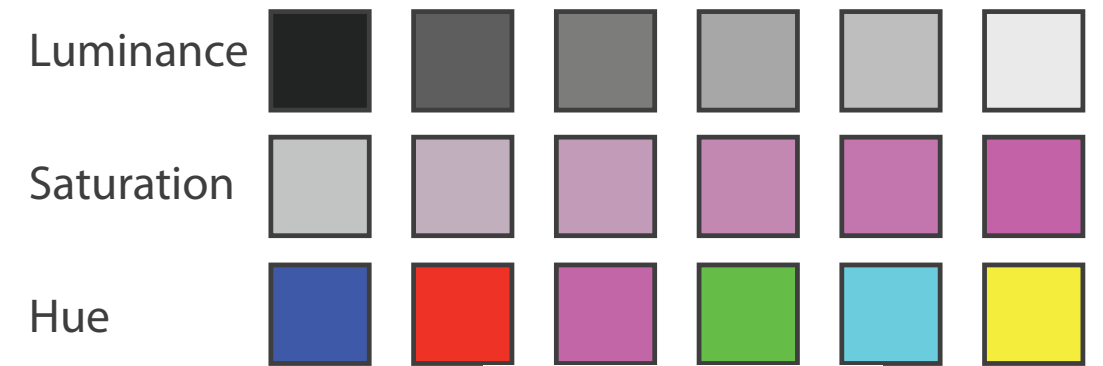
Luminance values



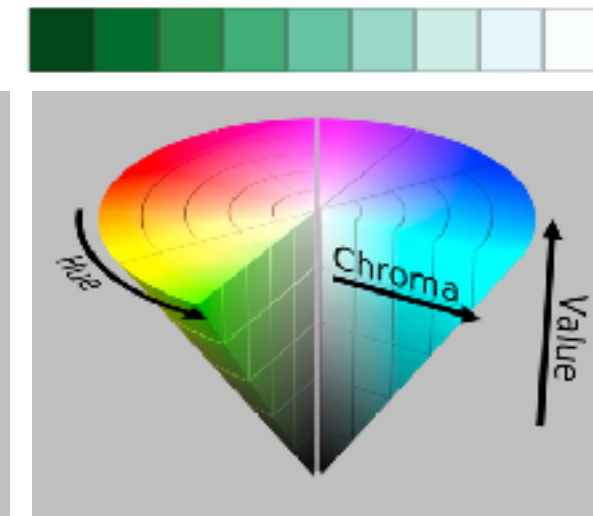
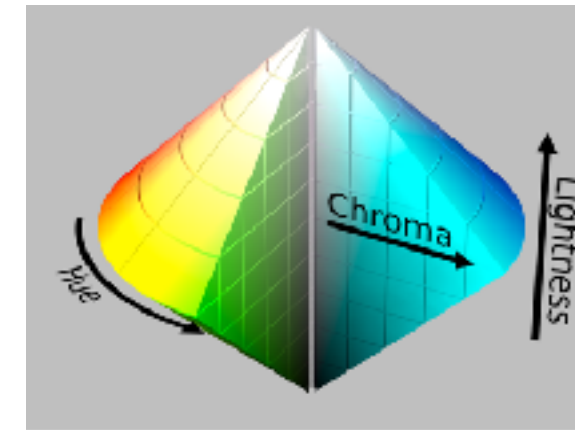
[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Many color spaces

- Luminance (L^*), hue (H), saturation (S)
 - good for encoding
 - but not standard graphics/tools colorspace
- RGB: good for display hardware
 - poor for encoding & interpolation
- CIE LAB ($L^*a^*b^*$): good for interpolation
 - hard to interpret, poor for encoding
- HSL/HSV: somewhat better for encoding
 - hue/saturation wheel intuitive
 - beware: only pseudo-perceptual!
 - lightness (L) or value (V) \neq luminance (L^*)



https://commons.wikimedia.org/wiki/File:RGB_color_solid_cube.png



Color Contrast & Naming

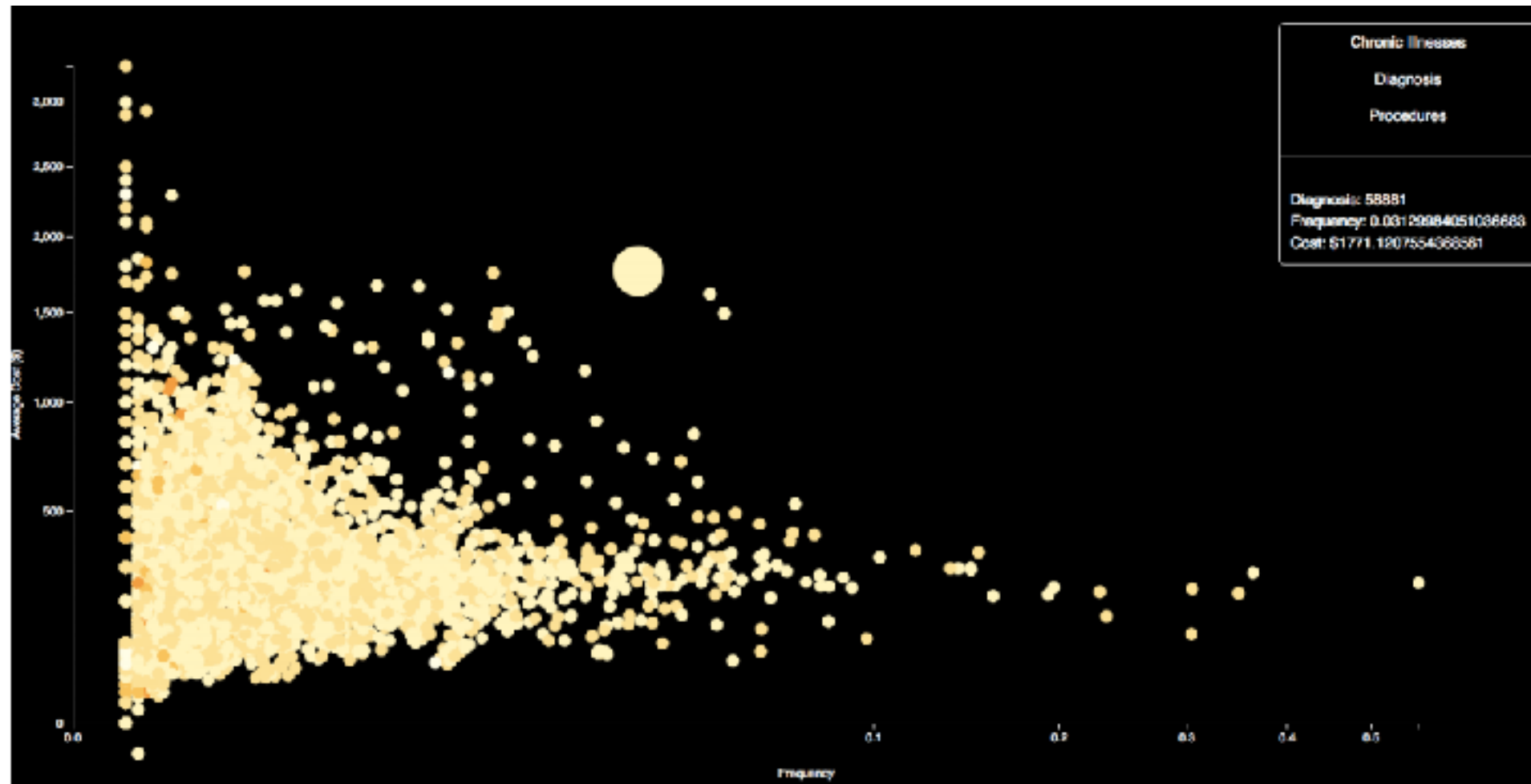
Interaction with the background

Contrast
The difference
between foreground
and bakground colors
determines text
legibility.

Hello	Hello	Hello	Hello	Hello	Hello	Hello
Hello	Hello	Hello	Hello	Hello	Hello	Hello
Hello	Hello	Hello	Hello	Hello	Hello	Hello
Hello	Hello	Hello	Hello	Hello	Hello	Hello
Hello	Hello	Hello	Hello	Hello	Hello	Hello

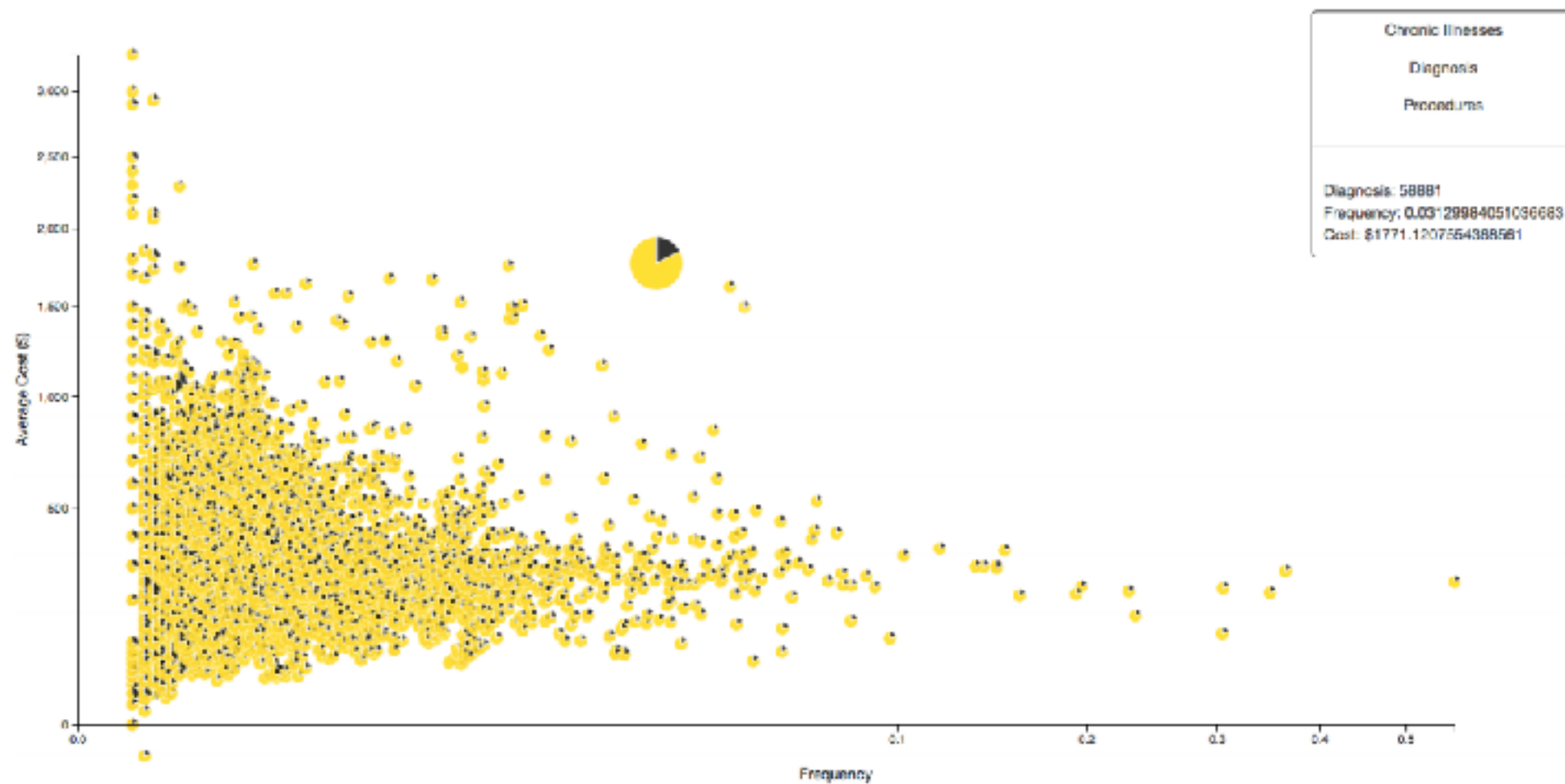
Interaction with the background: tweaking yellow for visibility

- marks with high luminance on a background with low luminance



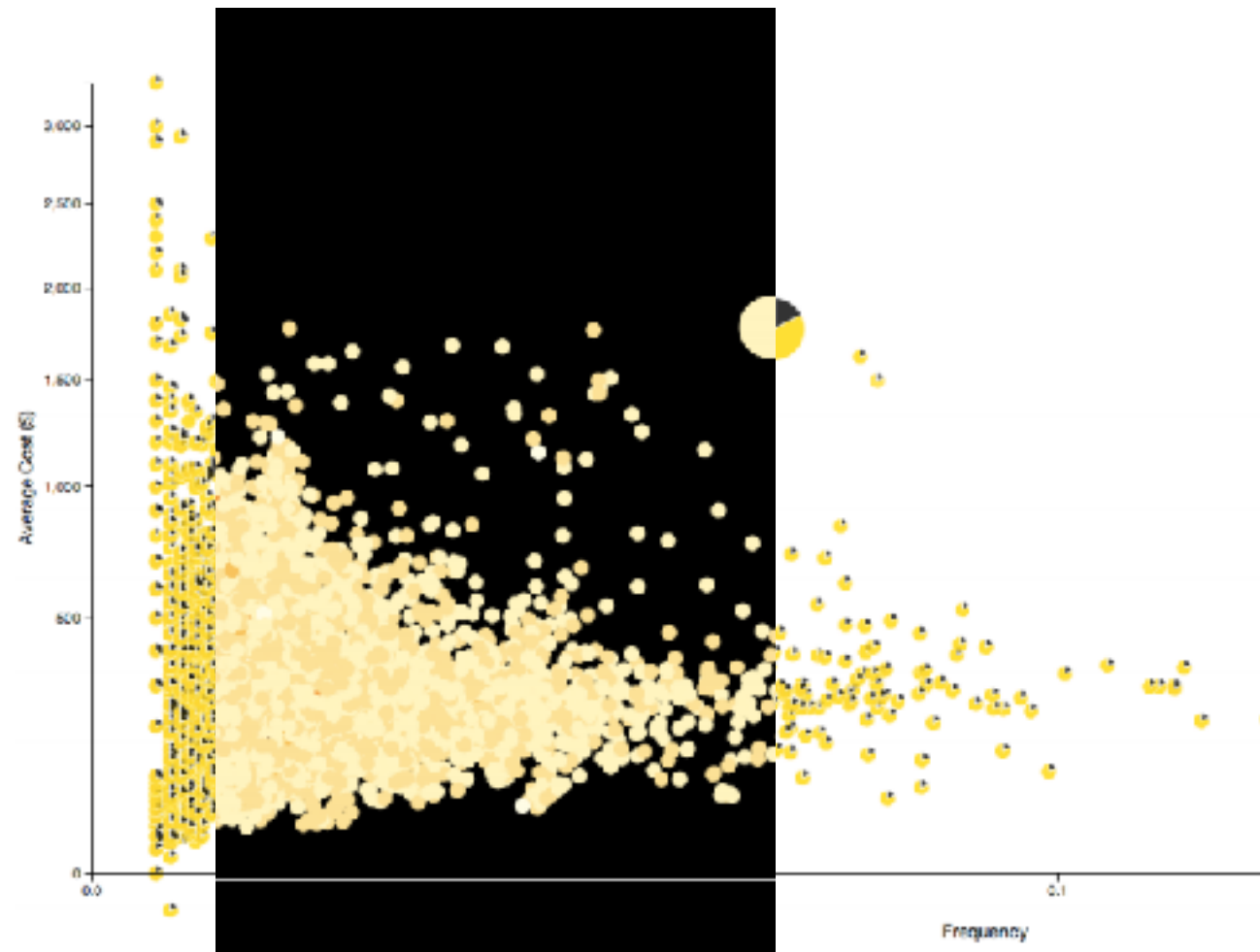
Interaction with the background: tweaking yellow for visibility

- marks with medium luminance on a background with high luminance



Interaction with the background: tweaking yellow for visibility

- change luminance of marks depending on background



Color/Lightness constancy: Illumination conditions

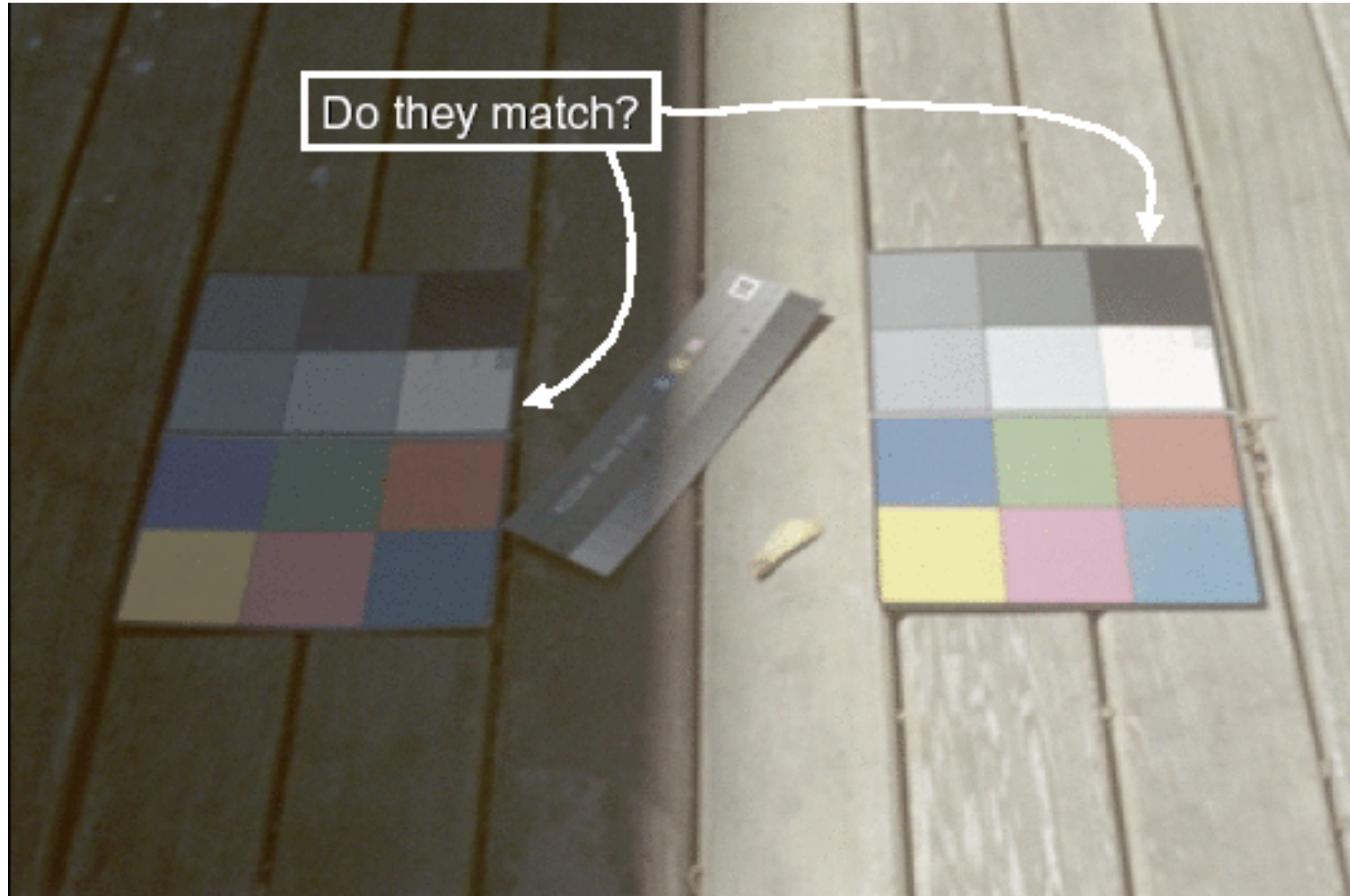


Image courtesy of John McCann via Maureen Stone

Color/Lightness constancy: Illumination conditions

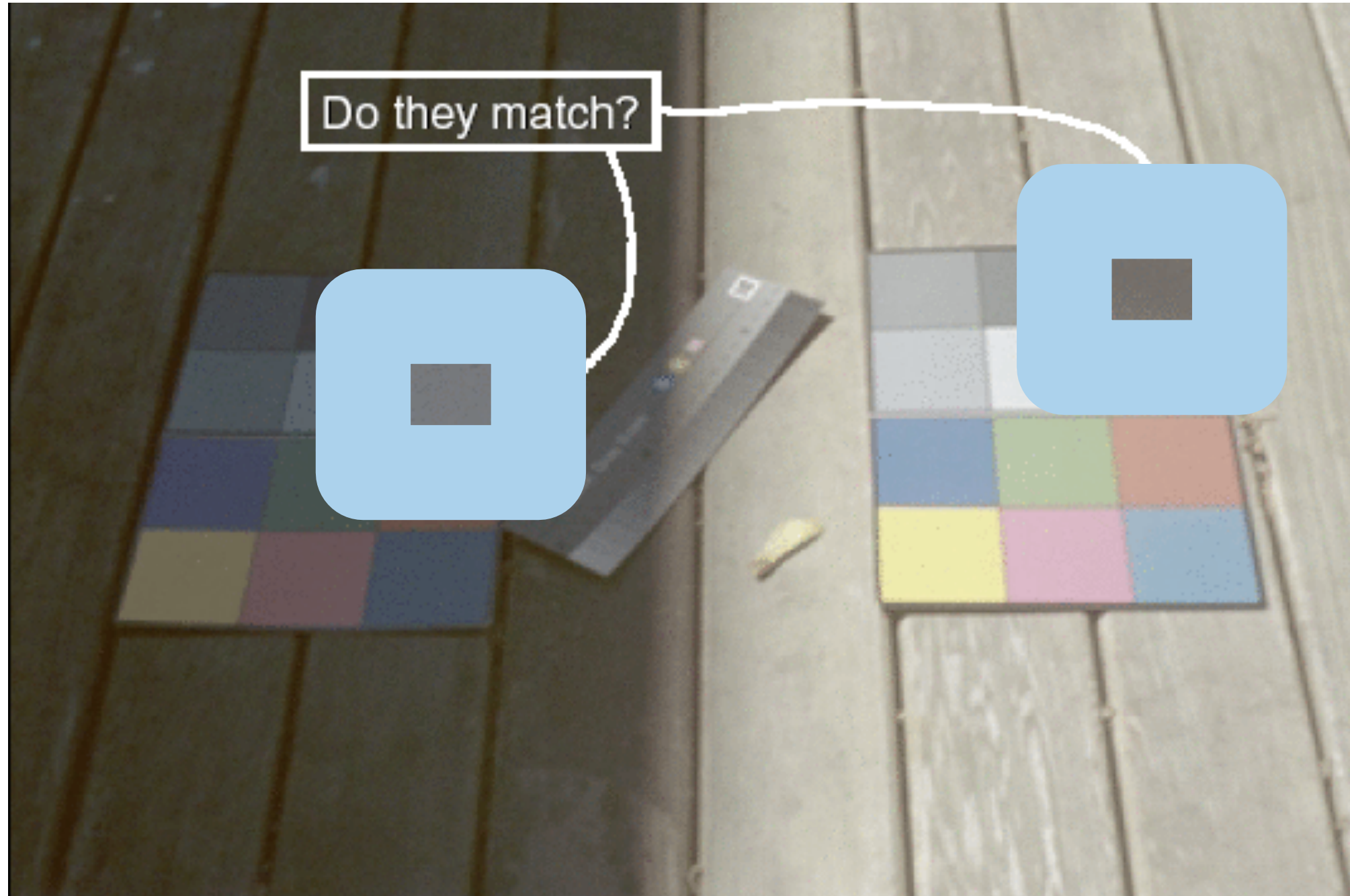
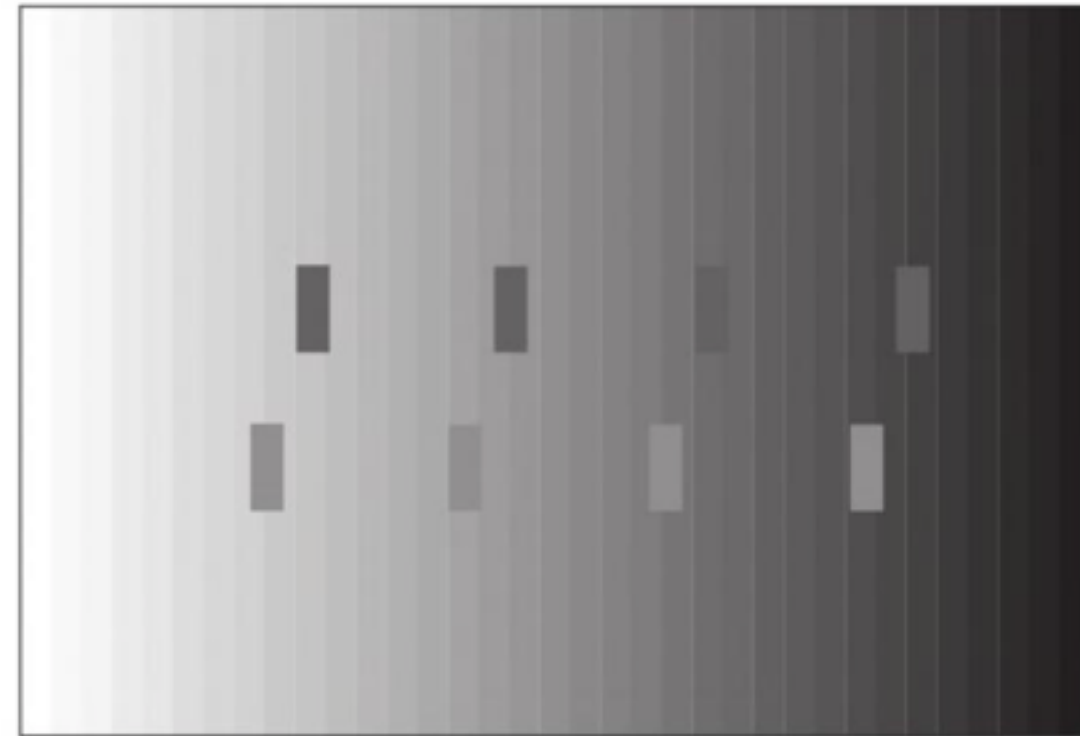
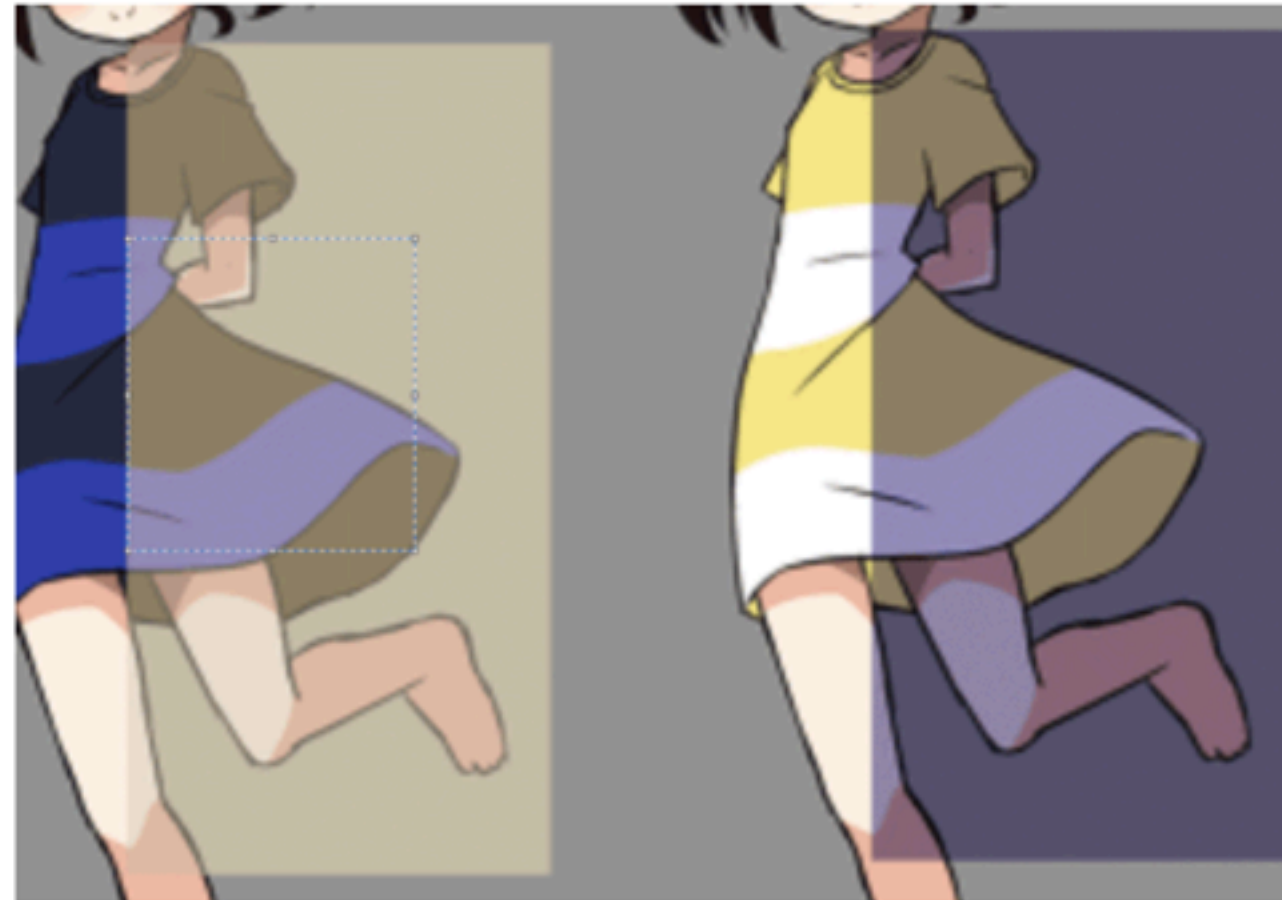


Image courtesy of John McCann via Maureen Stone

Contrast with background



Contrast with background



Black and blue? White and gold?

<https://imgur.com/hxJjUQB>

https://en.wikipedia.org/wiki/The_dress

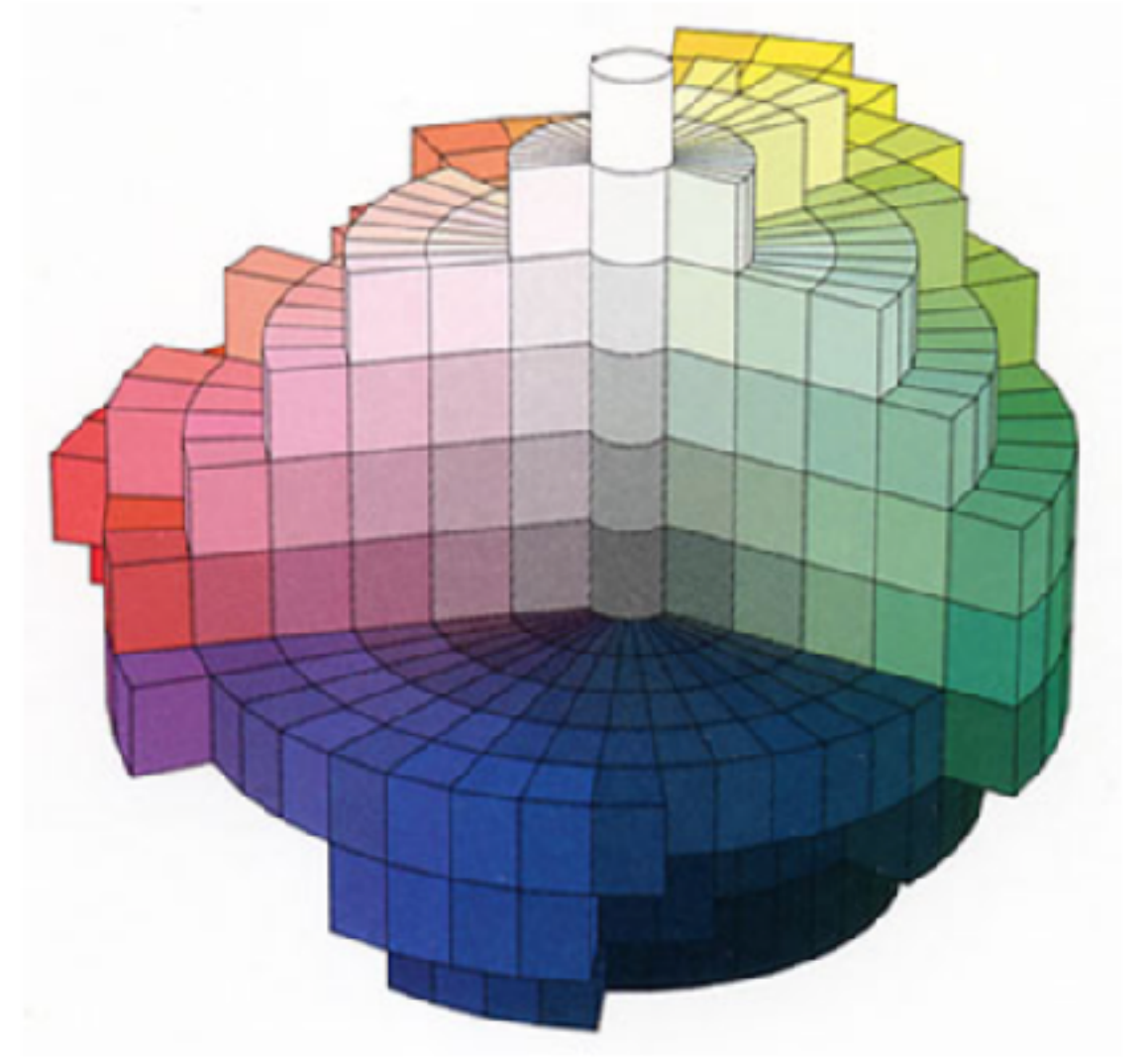
Bezold Effect: Outlines matter



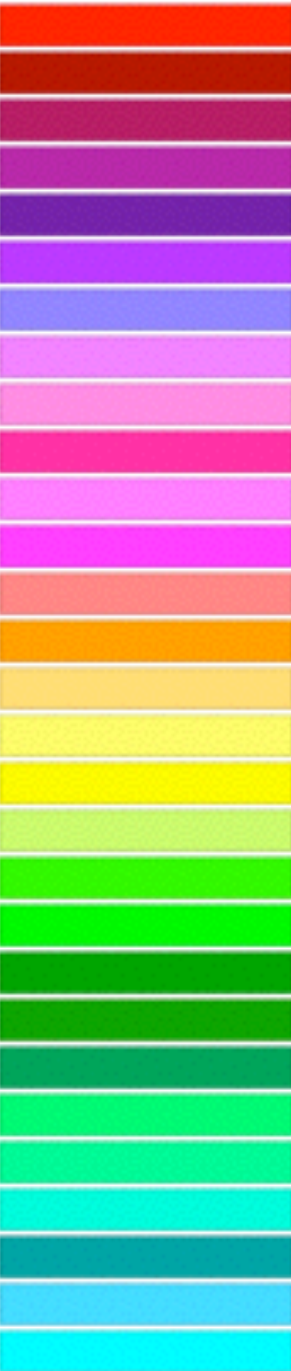
[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Color Appearance

- given L , a^* , b^* , can we tell what color it is?
 - no, it depends
- chromatic adaptation
- luminance adaptation
- simultaneous contrast
- spatial effects
- viewing angle
- ...



Color naming



Color naming

Color names if you're a girl...

Color names if you're a guy...

Maraschino	[Red]	Red
Cayenne	[Dark Red]	Purple
Maroon	[Maroon]	
Plum	[Purple]	
Eggplant	[Dark Purple]	
Grape	[Light Purple]	Pink
Orchid	[Light Blue]	
Lavender	[Light Pink]	
Carnation	[Pink]	Orange
Strawberry	[Bright Pink]	
Bubblegum	[Light Pink]	
Magenta	[Magenta]	
Salmon	[Salmon]	Yellow
Tangerine	[Orange]	
Cantaloupe	[Light Orange]	Green
Banana	[Yellow]	
Lemon	[Yellow]	Blue
Honeydew	[Light Green]	
Lime	[Light Green]	
Spring	[Bright Green]	
Clover	[Dark Green]	
Fern	[Dark Green]	
Moss	[Dark Green]	
Flora	[Bright Green]	
Sea Foam	[Light Green]	Blue
Spindrift	[Cyan]	
Teal	[Teal]	
Sky	[Light Blue]	
Turquoise	[Turquoise]	

Doghouse Diaries
"We take no as an answer."

Color naming

Actual color names
if you're a girl ...

Actual color names
if you're a guy ...



<https://blog.xkcd.com/2010/05/03/color-survey-results/>

Color naming

- nameability affects
 - communication
 - memorability
- can integrate into color models
 - in addition to perceptual considerations

Actual color names
if you're a girl ...

Actual color names
if you're a guy ...



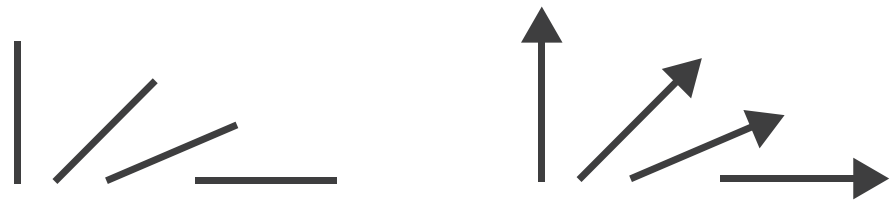
Color is just part of vision system

- Does not help perceive
 - Position
 - Shape
 - Motion
 - ...

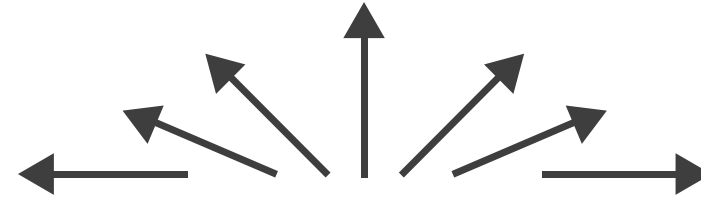
Map Other Channels

Angle / tilt / orientation channel

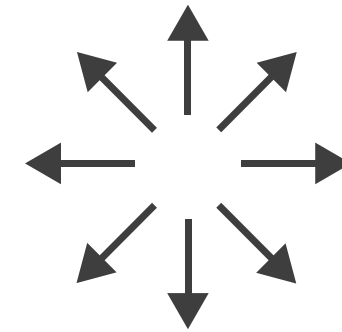
- different mappings depending on range used



Sequential ordered
line mark or arrow glyph



Diverging ordered
arrow glyph



Cyclic ordered
arrow glyph

- nonlinear accuracy
 - high: exact horizontal, vertical, diagonal (0, 45, 90 degrees)
 - lower: other orientations (eg 37 vs 38 degrees)

Map other channels

- size
 - aligned length best
 - length accurate
 - 2D area ok
 - 3D volume poor

➞ Size

➞ Length



➞ Area



➞ Volume

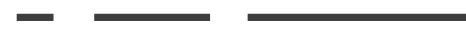


Map other channels

- size
 - aligned length best
 - length accurate
 - 2D area ok
 - 3D volume poor
- shape
 - complex combination of lower-level primitives
 - many bins

➔ Size

➔ Length



➔ Area



➔ Volume



➔ Shape

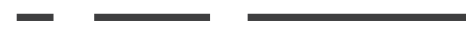


Map other channels

- **size**
 - aligned length best
 - length accurate
 - 2D area ok
 - 3D volume poor
- **shape**
 - complex combination of lower-level primitives
 - many bins
- **motion**
 - highly separable against static
 - great for highlighting (binary)
 - use with care to avoid irritation

➔ Size

➔ Length



➔ Area



➔ Volume

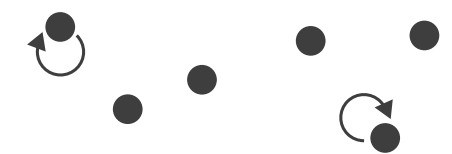


➔ Shape



➔ Motion

➔ Motion
*Direction, Rate,
Frequency, ...*



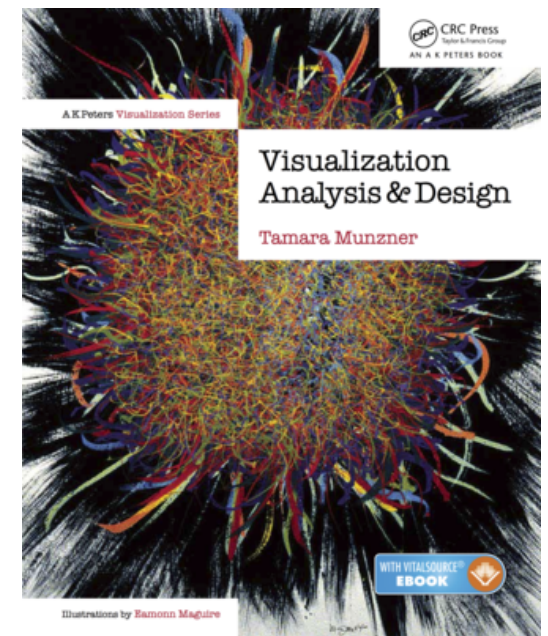
Visualization Analysis & Design

Interactive Views (Ch 11/12)

Tamara Munzner

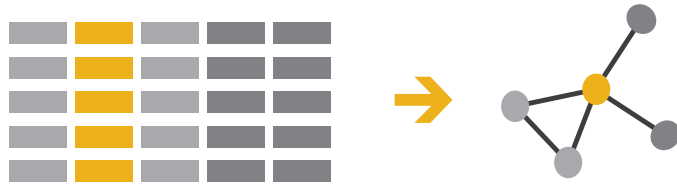
Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



How to handle complexity: I previous strategy

→ *Derive*



- derive new data to show within view

How to handle complexity: 1 previous strategy + 2 more

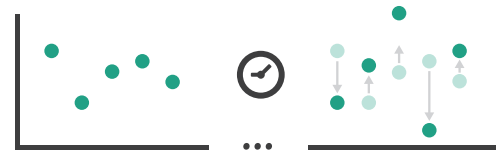
→ *Derive*



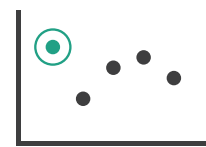
- derive new data to show within view
- change view over time
- facet across multiple views

Manipulate

→ Change



→ Select

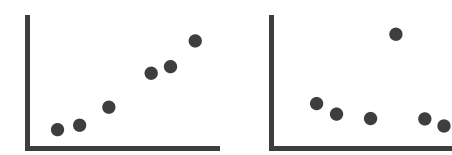


→ Navigate

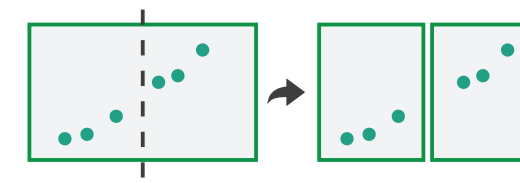


Facet

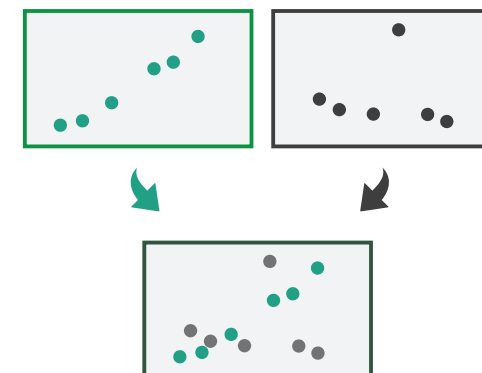
→ Juxtapose



→ Partition



→ Superimpose



Manipulate View

Manipulate

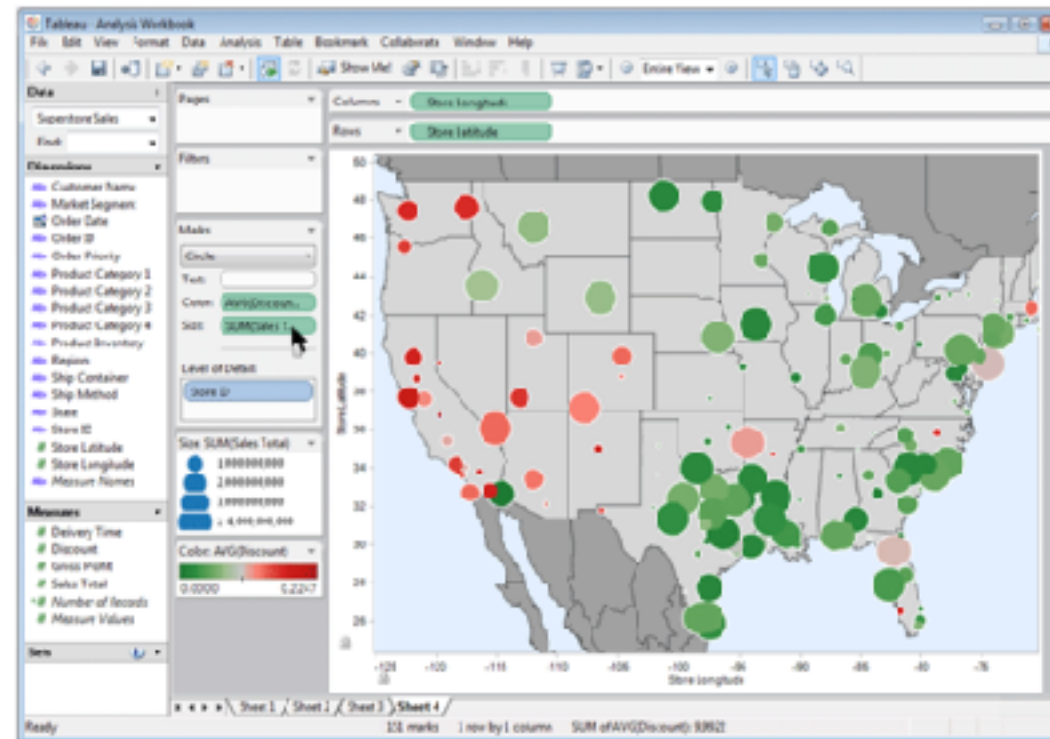
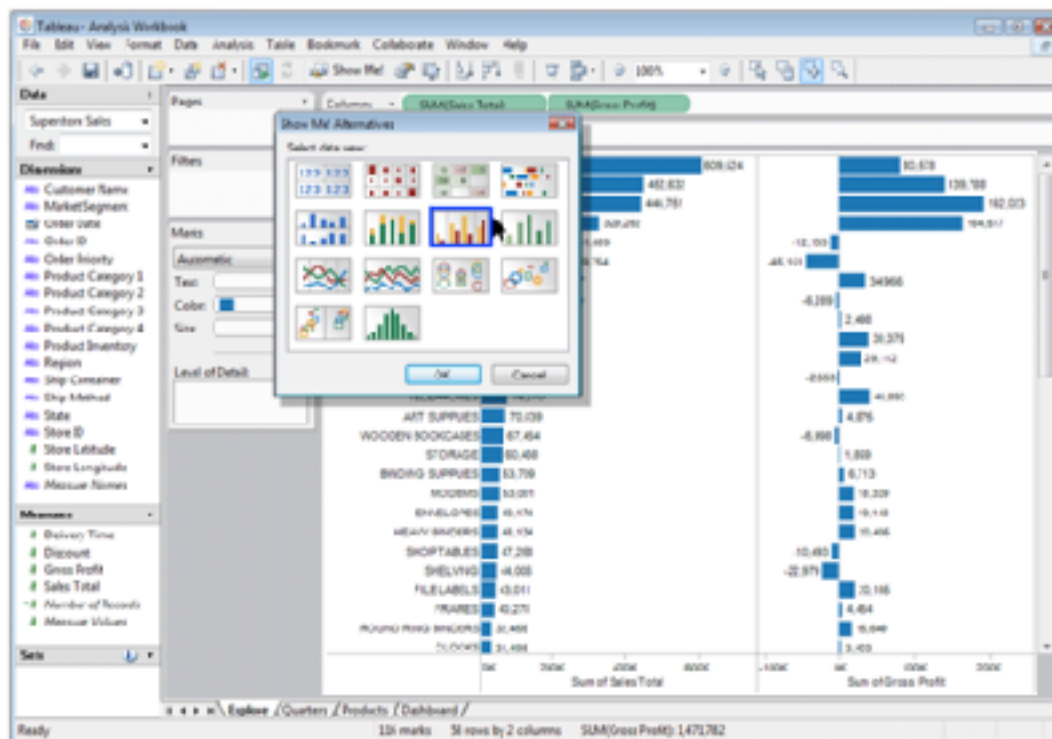
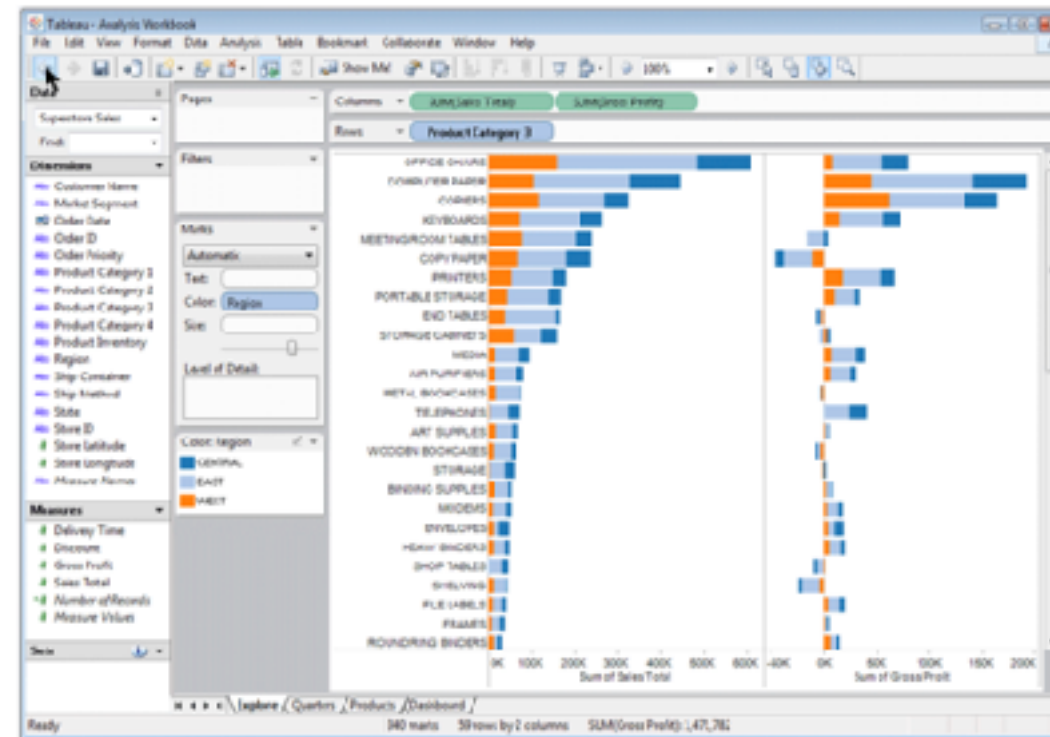
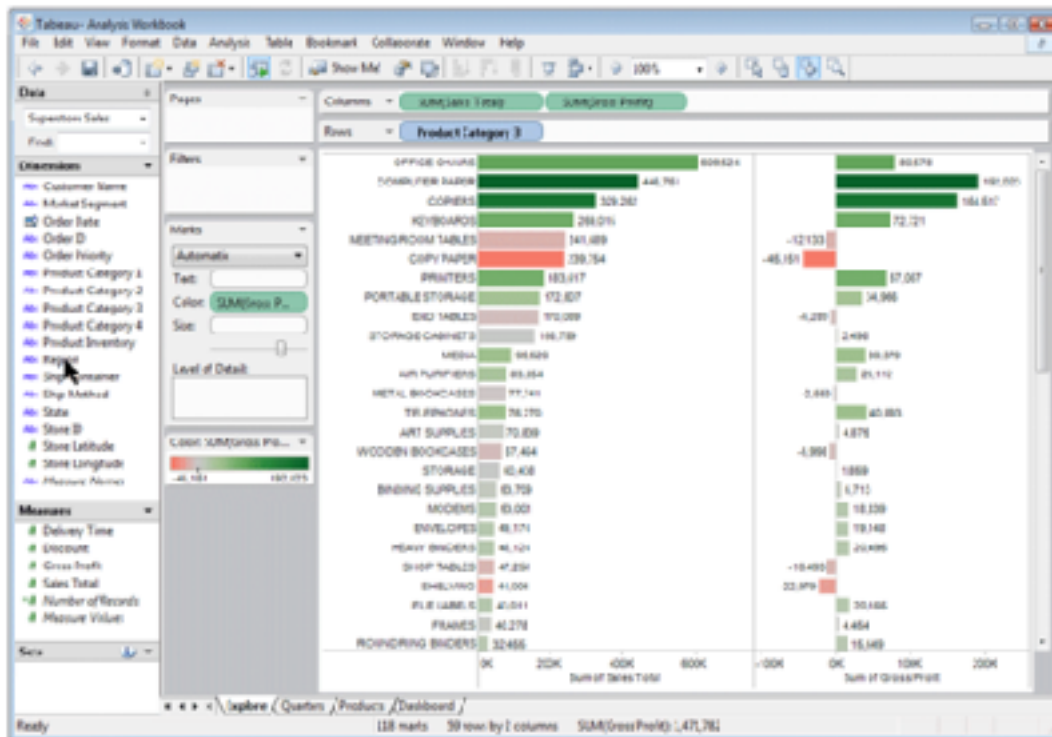
→ Change over Time



Change over time

- change any of the other choices
 - encoding itself
 - parameters
 - arrange: rearrange, reorder
 - aggregation level, what is filtered...
 - interaction entails change
- powerful & flexible

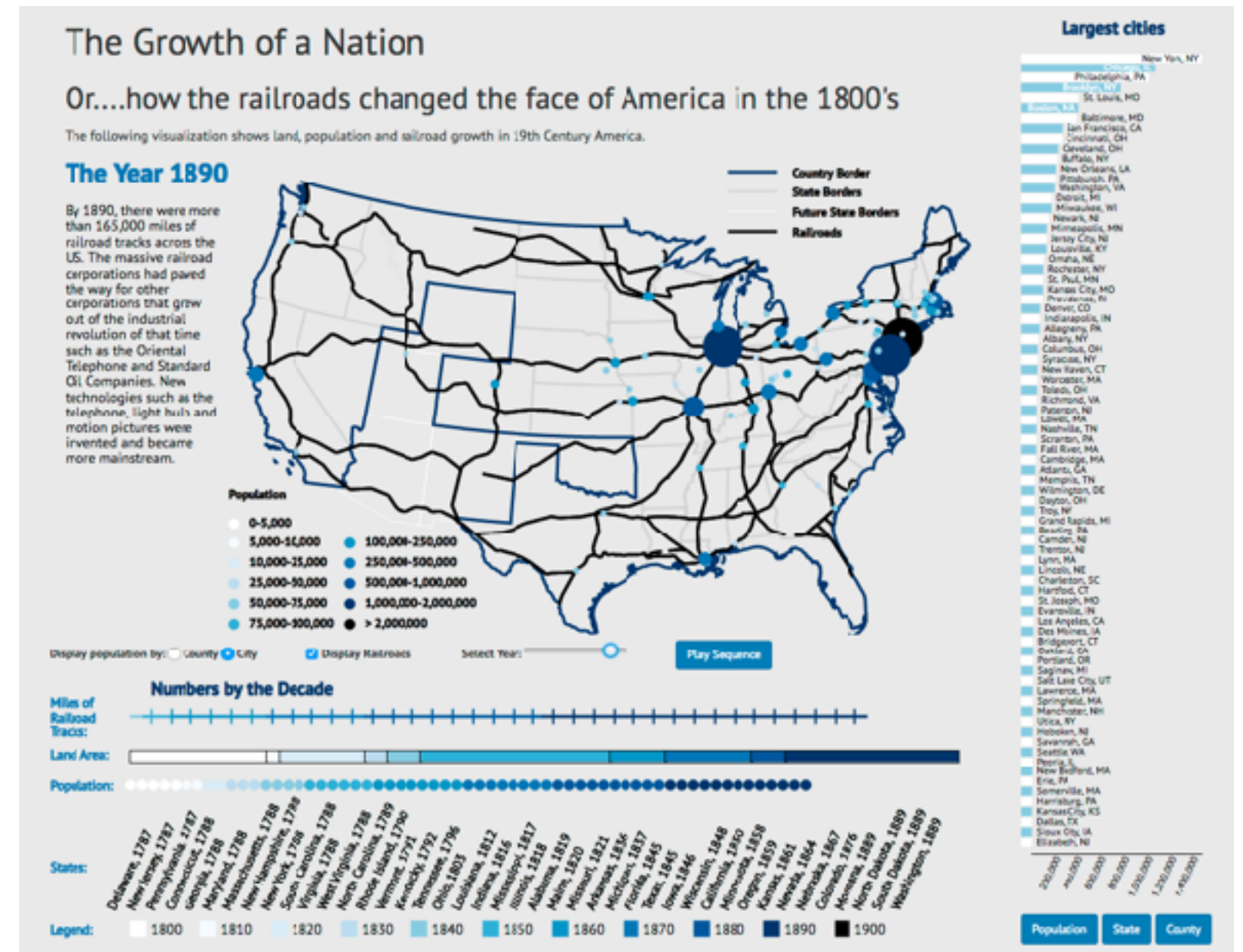
Idiom: Re-encode



made with Tableau, <http://tableausoftware.com>

Idiom: Change parameters

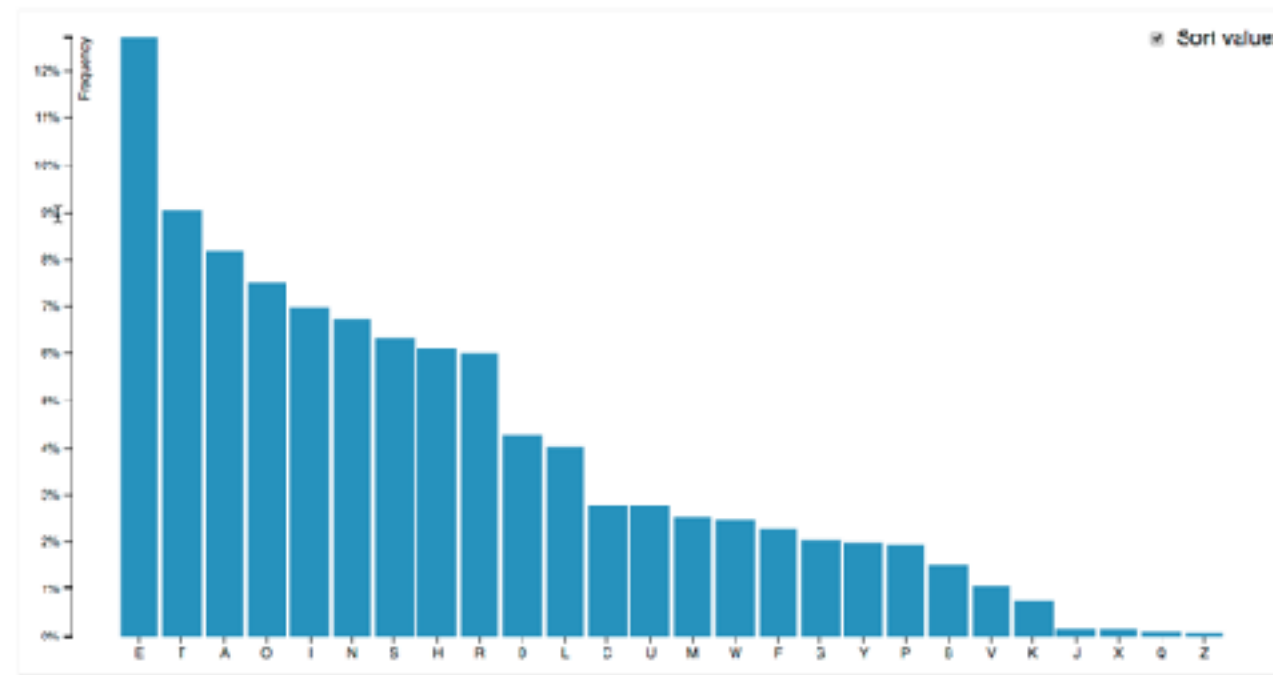
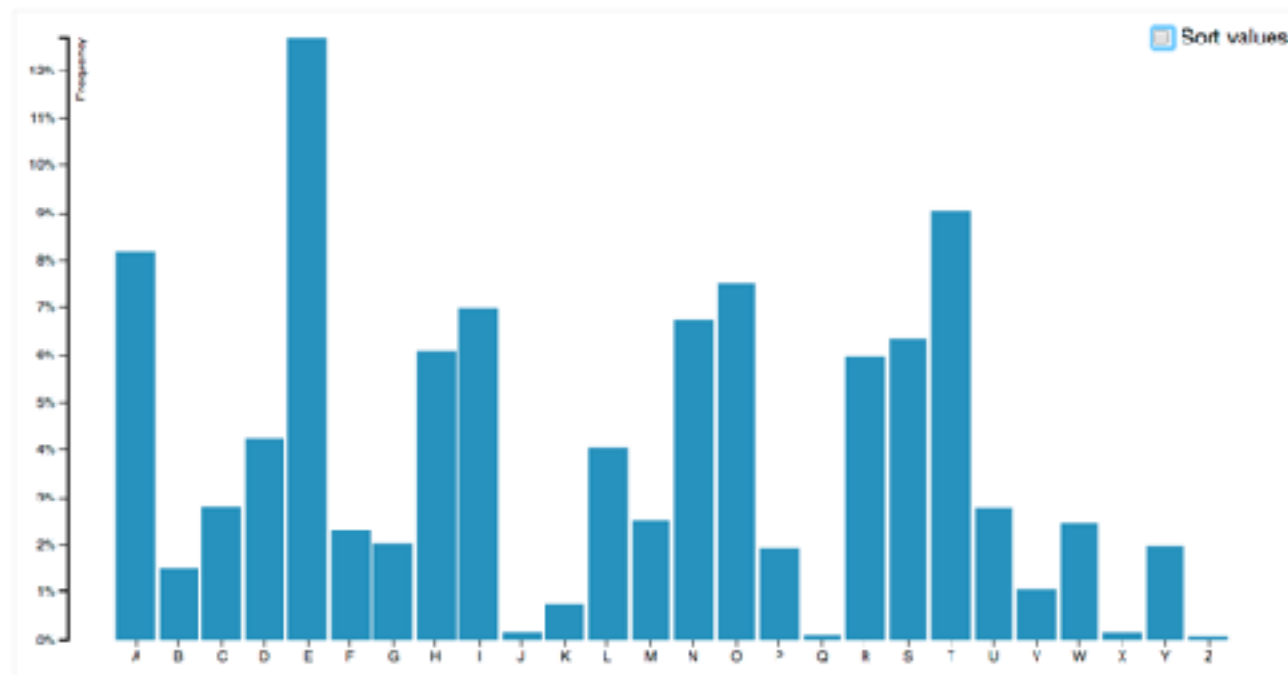
- widgets and controls
 - sliders, buttons, radio buttons, checkboxes, dropdowns/comboboxes
- pros
 - clear affordances, self-documenting (with labels)
- cons
 - uses screen space
- design choices
 - separated vs interleaved
 - controls & canvas



[Growth of a Nation](<http://laurenwood.github.io/>)
made with D3

Idiom: **Change order/arrangement**

- what: simple table
- how: data-driven reordering
- why: find extreme values, trends



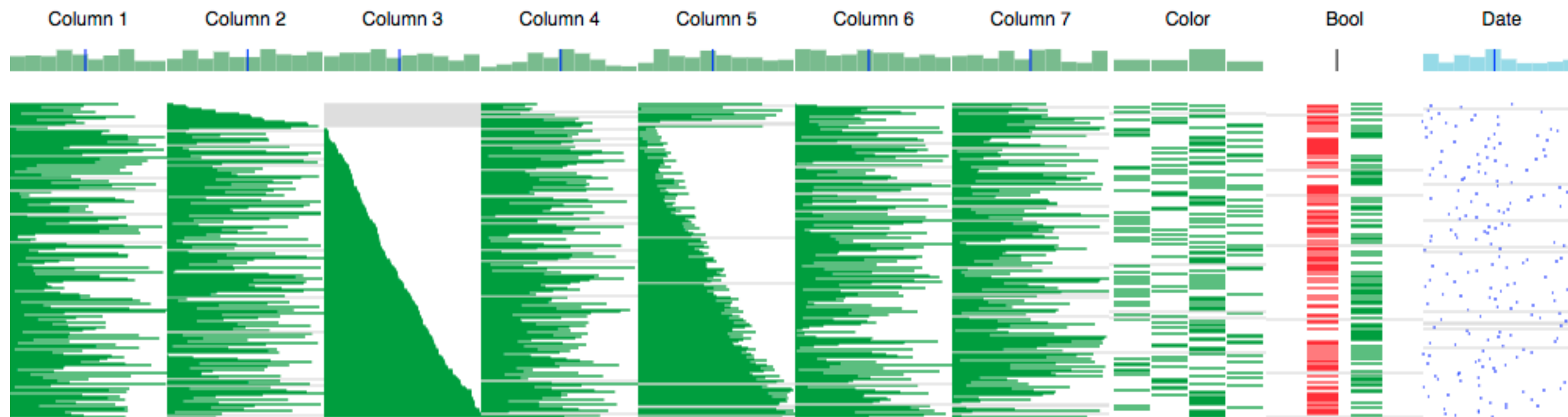
[Sortable Bar Chart] <https://observablehq.com/@d3/sortable-bar-chart>

made with D3

Idiom: **Reorder**

System: **DataStripes**

- what: table with many attributes
- how: data-driven reordering by selecting column
- why: find correlations between attributes



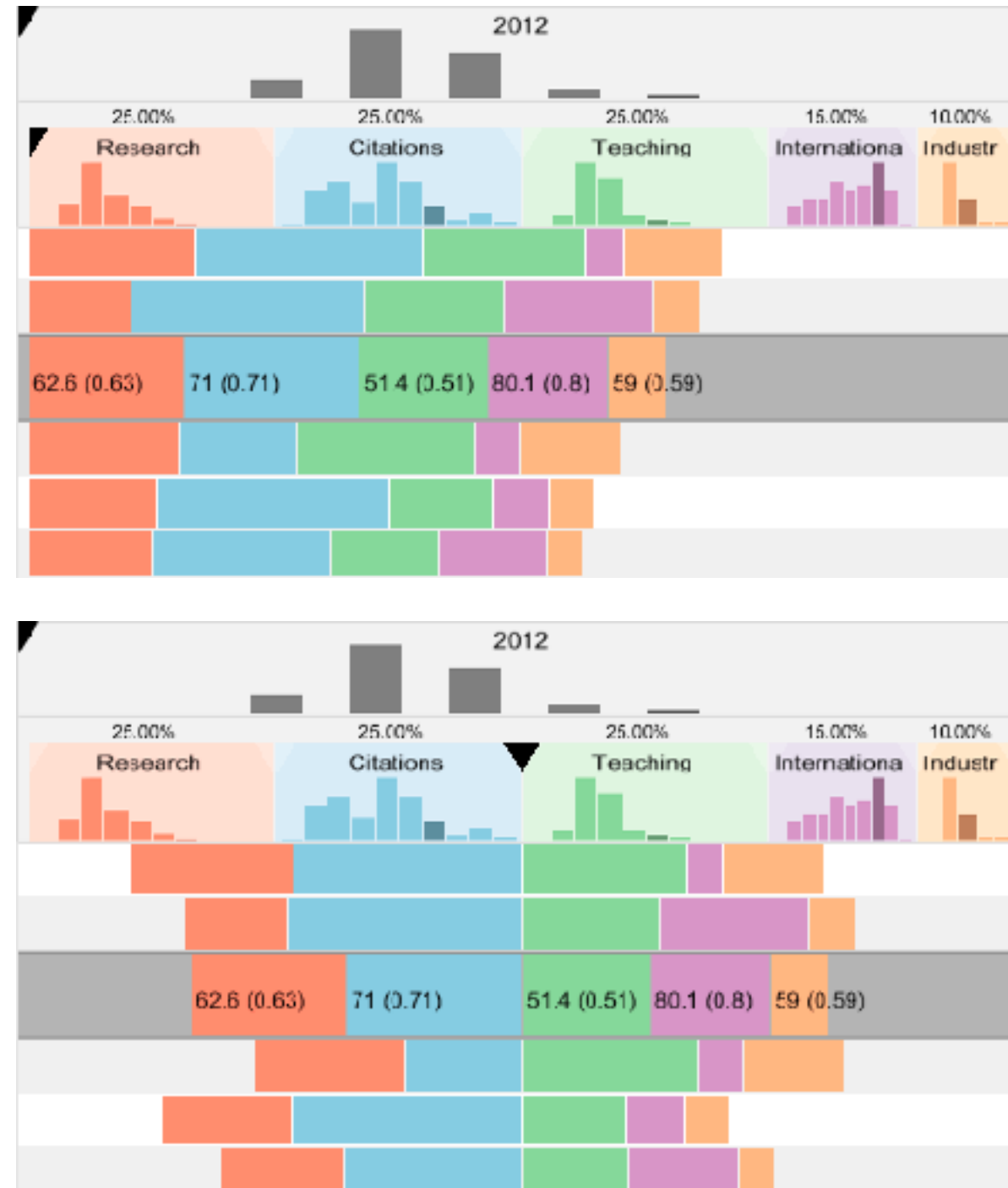
[\[http://carlmanaster.github.io/datastripes/\]](http://carlmanaster.github.io/datastripes/)

made with D3

Idiom: **Change alignment**

System: **LineUp**

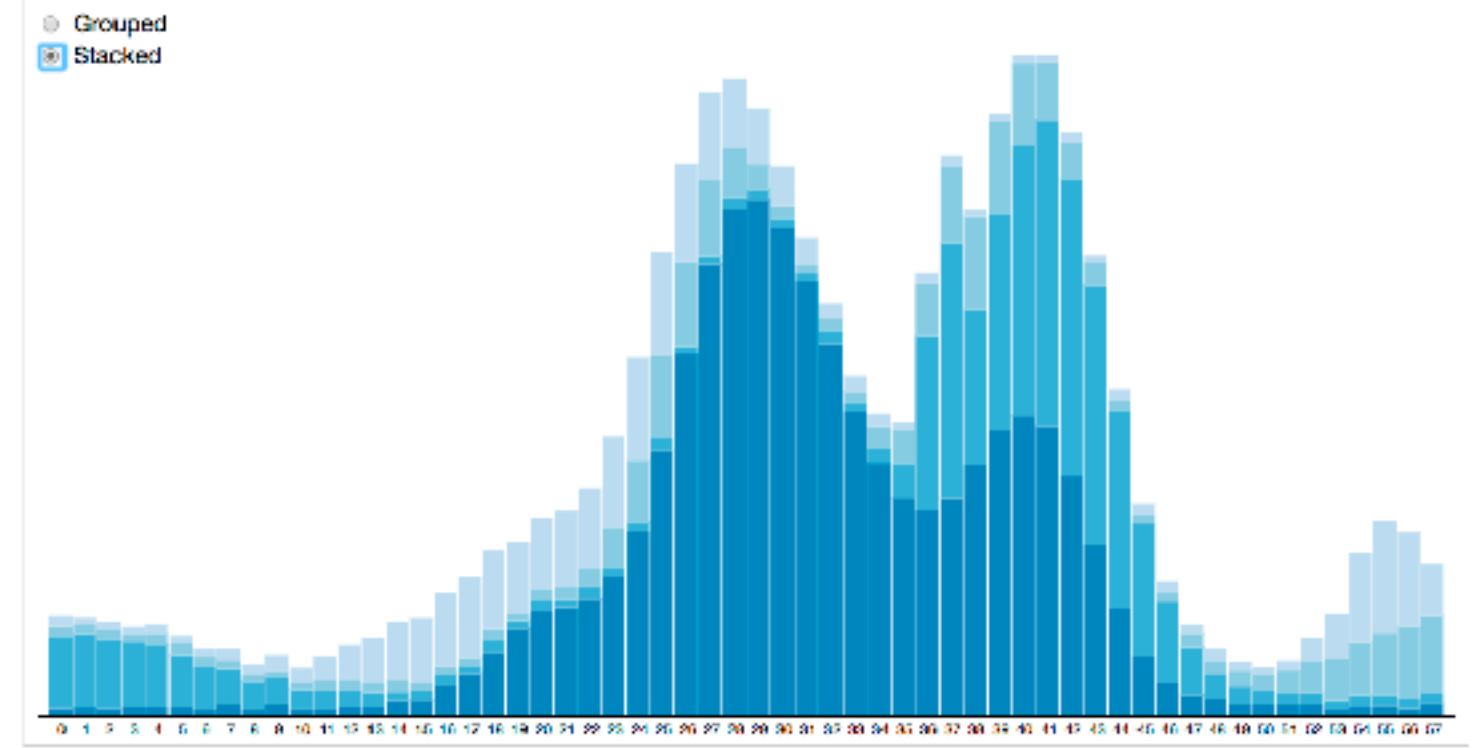
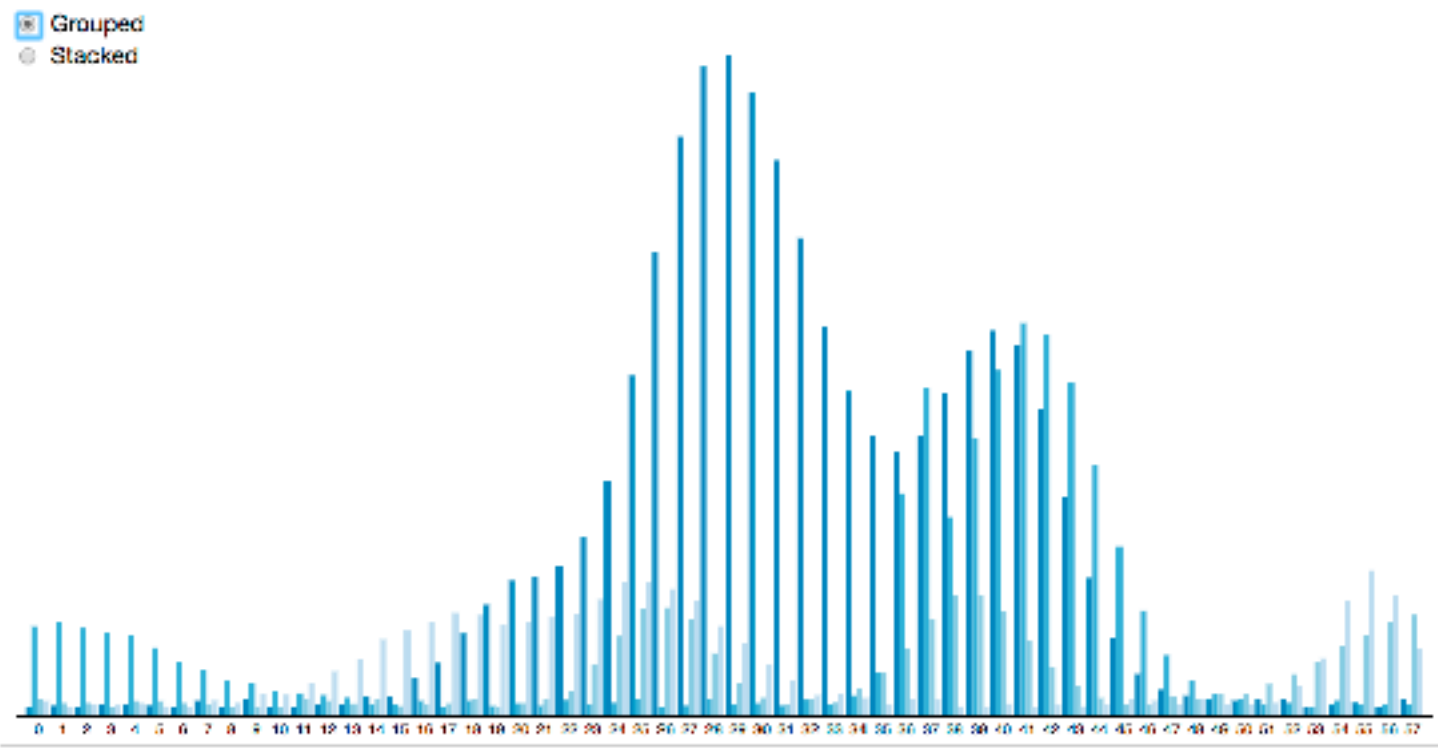
- stacked bars
 - easy to compare
 - first segment
 - total bar
- align to different segment
 - supports flexible comparison



[LineUp: Visual Analysis of Multi-Attribute Rankings. Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286.]

Idiom: **Animated transitions - visual encoding change**

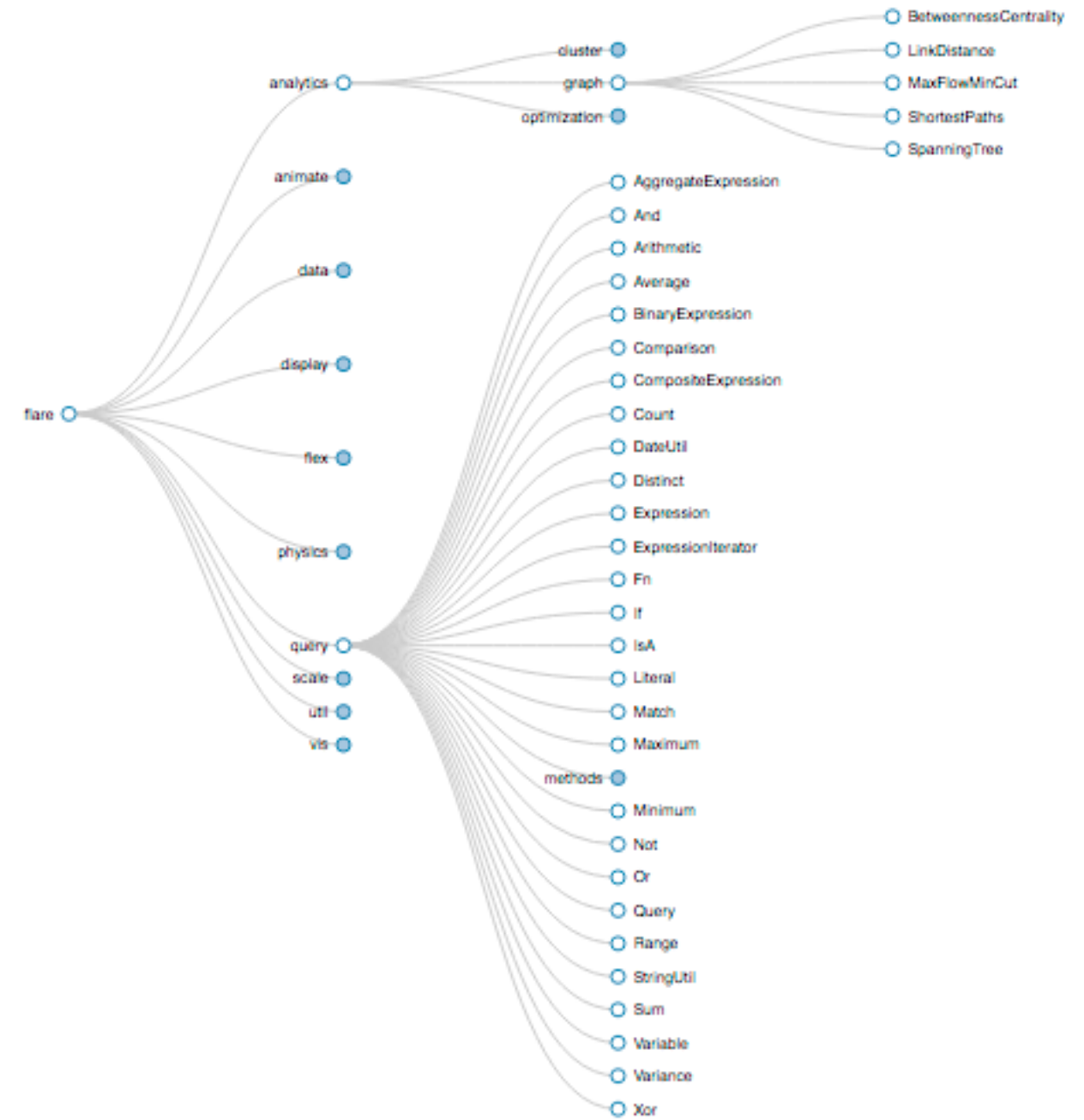
- smooth transition from one state to another
 - alternative to jump cuts, supports item tracking
 - best case for animation
 - staging to reduce cognitive load



[Stacked to Grouped Bars] <https://observablehq.com/@d3/stacked-to-grouped-bars>

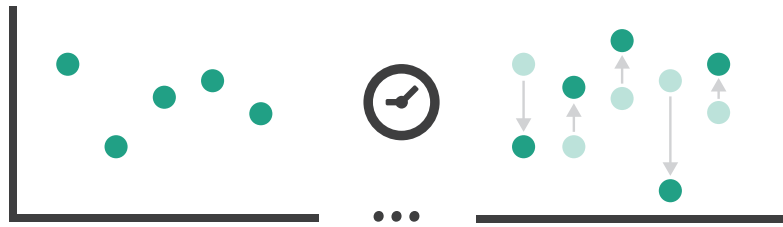
Idiom: **Animated transition** - tree detail

- animated transition
 - network drilldown/rollup

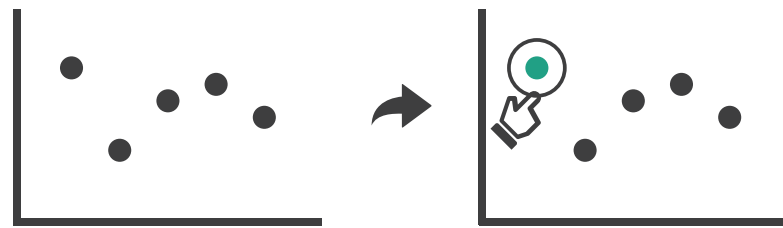


Manipulate

→ Change over Time

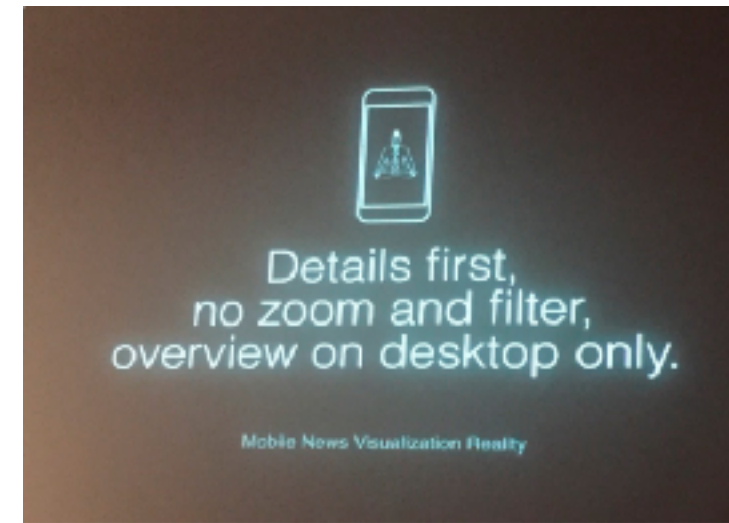


→ Select



Interaction technology

- what do you design for?
 - mouse & keyboard on desktop?
 - large screens, hover, multiple clicks
 - touch interaction on mobile?
 - small screens, no hover, just tap
 - gestures from video / sensors?
 - ergonomic reality vs movie bombast
 - eye tracking?



Data visualization and the news - Gregor Aisch (37 min)
vimeo.com/182590214

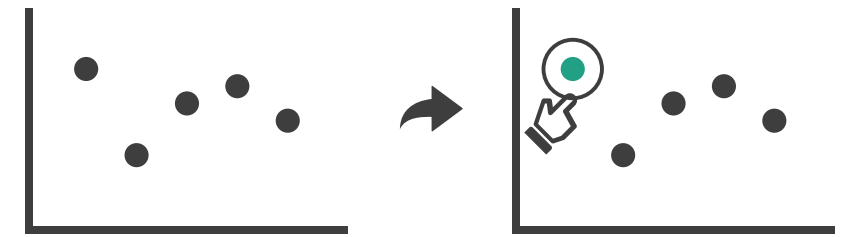


I Hate Tom Cruise - Alex Kauffmann (5 min)
www.youtube.com/watch?v=QXLfT9sFcbc

Selection

- selection: basic operation for most interaction
- design choices
 - how many selection types?
 - interaction modalities
 - click/tap (heavyweight) vs hover (lightweight but not available on most touchscreens)
 - multiple click types (shift-click, option-click, ...)
 - proximity beyond click/hover (touching vs nearby vs distant)
 - application semantics
 - adding to selection set vs replacing selection
 - can selection be null?
 - ex: toggle so nothing selected if click on background
 - primary vs secondary (ex: source/target nodes in network)
 - group membership (add/delete items, name group, ...)

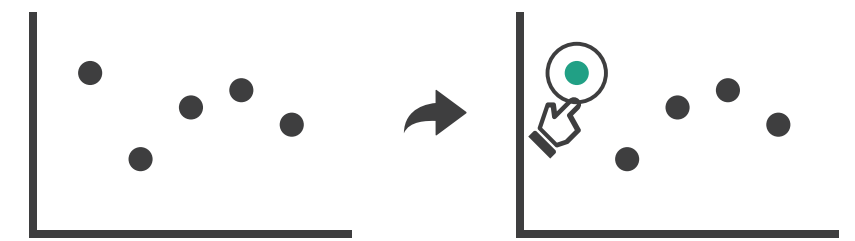
➔ Select



Highlighting

- highlight: change visual encoding for selection targets
 - visual feedback closely tied to but separable from selection (interaction)
- design choices: typical visual channels
 - change item color
 - but hides existing color coding
 - add outline mark
 - change size (ex: increase outline mark linewidth)
 - change shape (ex: from solid to dashed line for link mark)
- unusual channels: motion
 - motion: usually avoid for single view
 - with multiple views, could justify to draw attention to other views

➔ Select

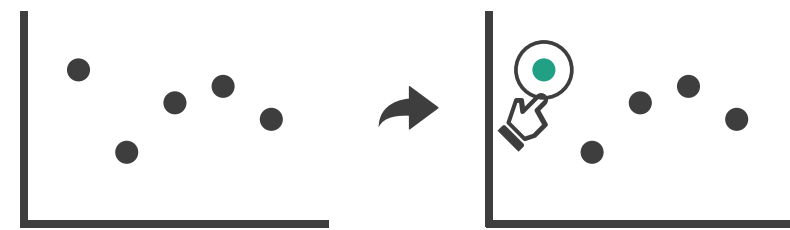


Manipulate

→ Change over Time



→ Select

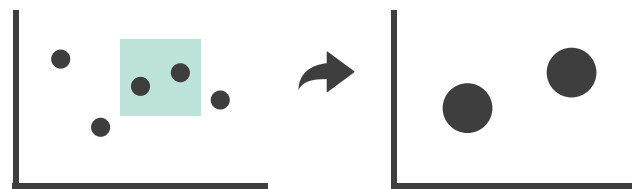


→ Navigate

→ Item Reduction

→ Zoom

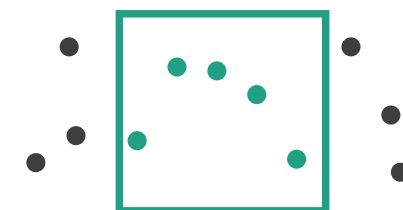
Geometric or *Semantic*



→ Pan/Translate

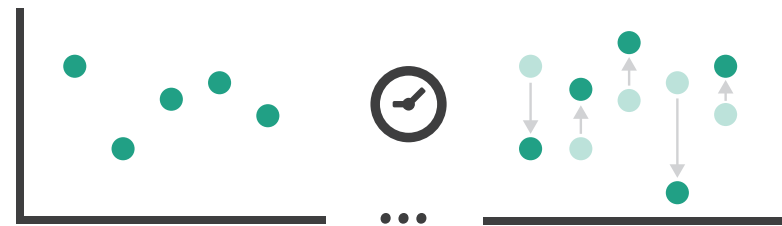


→ Constrained



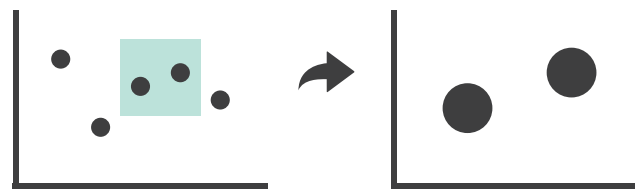
Manipulate

→ Change over Time



→ Navigate

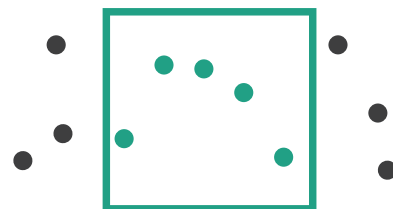
→ Zoom
Geometric



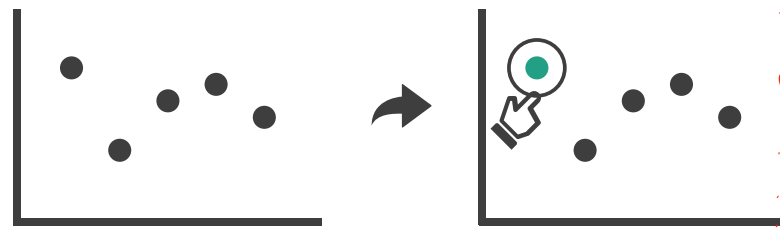
→ Pan/Translate



→ Constrained



→ Select

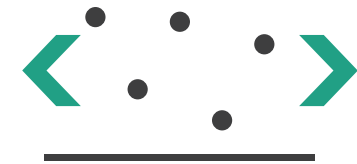


Navigate: Changing viewpoint/visibility

- change viewpoint
 - changes which items are visible within view
- camera metaphor
 - pan/translate/scroll
 - move up/down/sideways

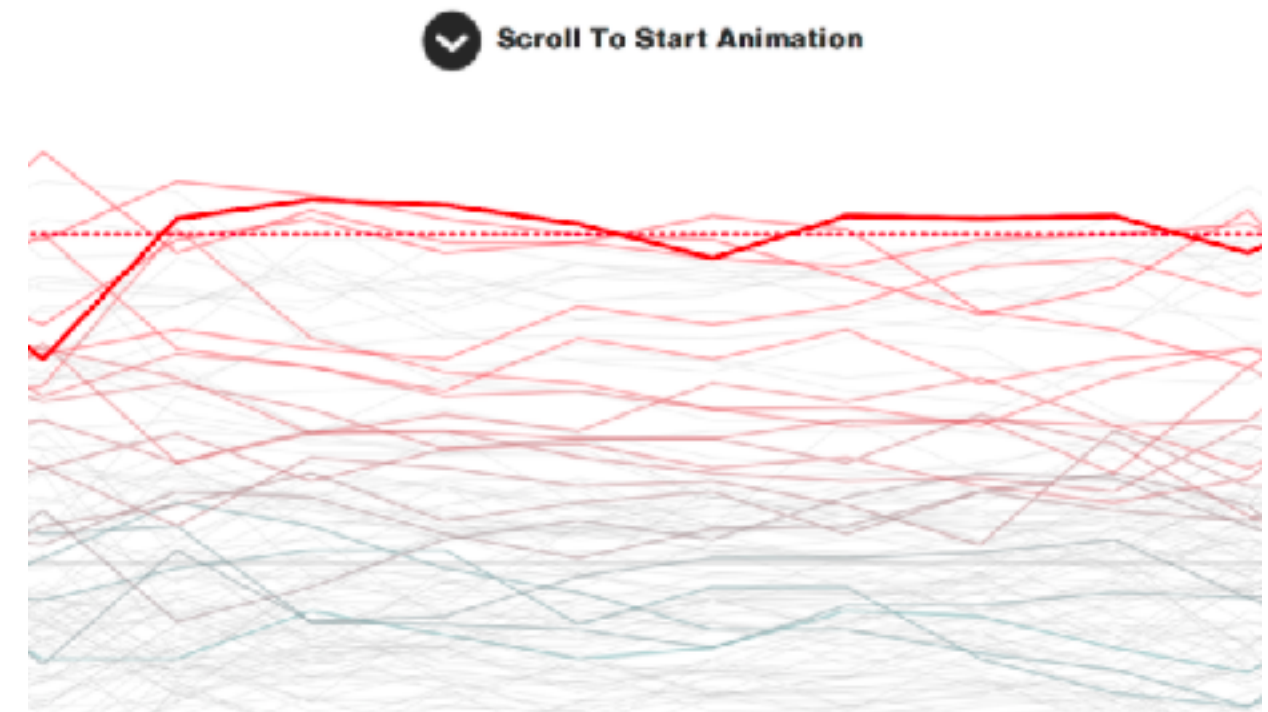
➔ Navigate

➔ *Pan/Translate*



Idiom: Scrollytelling

- how: navigate page by scrolling (panning down)
- pros:
 - familiar & intuitive, from standard web browsing
 - linear (only up & down) vs possible overload of click-based interface choices
- cons:
 - full-screen mode may lack affordances
 - scrolljacking, no direct access
 - unexpected behaviour
 - continuous control for discrete steps



[How to Scroll, Bostock](<https://bost.ocks.org/mike/scroll/>)

<https://eagereyes.org/blog/2016/the-scrollytelling-scourge>

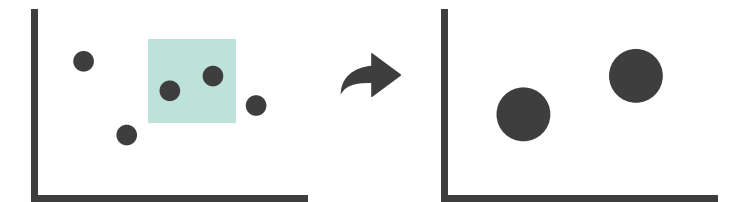
Navigate: Changing viewpoint/visibility

- change viewpoint
 - changes which items are visible within view
- camera metaphor
 - pan/translate/scroll
 - move up/down/sideways
 - rotate/spin
 - typically in 3D
 - zoom in/out
 - enlarge/shrink world == move camera closer/further
 - geometric zoom: standard, like moving physical object

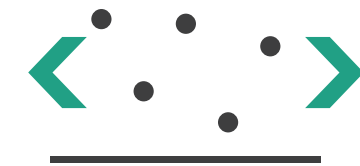
➔ Navigate

➔ *Zoom*

Geometric



➔ *Pan/Translate*



Navigate: Unconstrained vs constrained

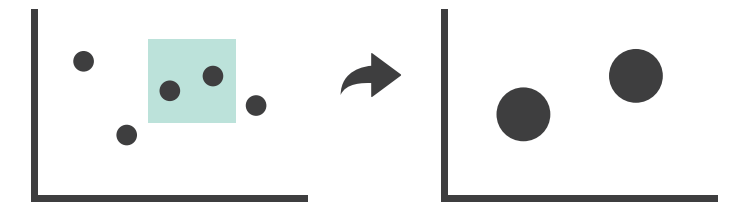
- unconstrained navigation
 - easy to implement for designer
 - hard to control for user
 - easy to overshoot/undershoot
- constrained navigation
 - typically uses animated transitions
 - trajectory automatically computed based on selection
 - just click; selection ends up framed nicely in final viewport

➔ Navigate

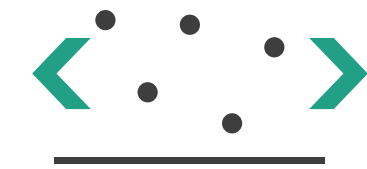
➔ Item Reduction

➔ Zoom

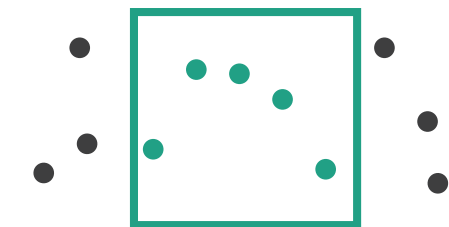
Geometric or *Semantic*



➔ Pan/Translate



➔ Constrained



Idiom: **Animated transition + constrained navigation**

- example: geographic map
 - simple zoom, only viewport changes, shapes preserved

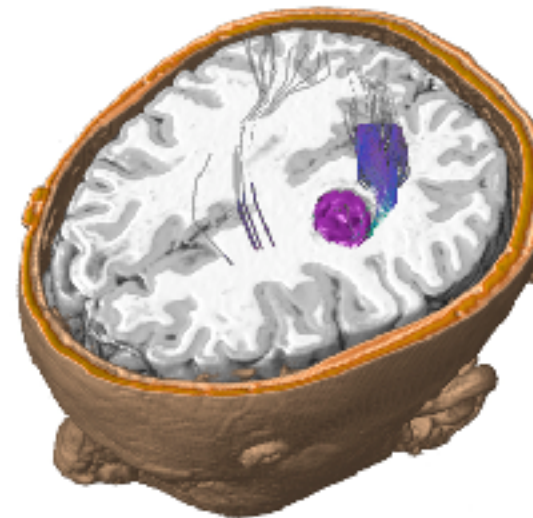
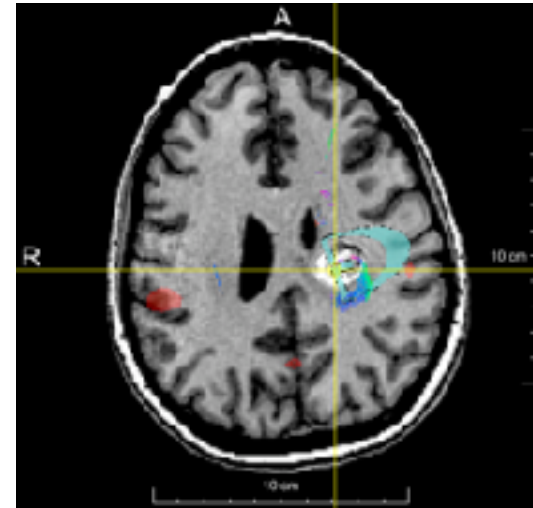
Zoom to Bounding Box



[Zoom to Bounding Box] <https://observablehq.com/@d3/zoom-to-bounding-box>

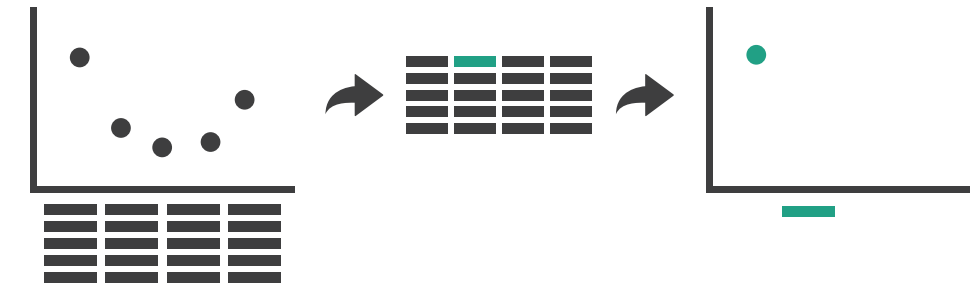
Navigate: Reducing attributes

- continuation of camera metaphor
 - slice
 - show only items matching specific value for given attribute: slicing plane
 - axis aligned, or arbitrary alignment
 - cut
 - show only items on far side of plane from camera
 - project
 - change mathematics of image creation
 - orthographic
 - perspective
 - many others: Mercator, cabinet, ...

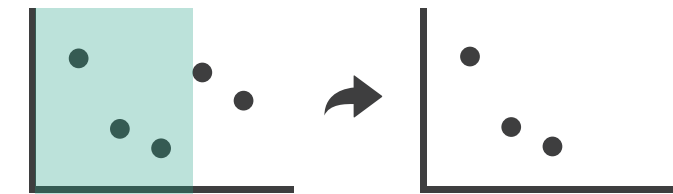


→ Attribute Reduction

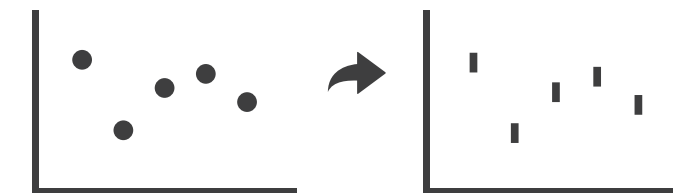
→ *Slice*



→ *Cut*



→ *Project*



Interaction benefits

- interaction pros
 - major advantage of computer-based vs paper-based visualization
 - flexible, powerful, intuitive
 - exploratory data analysis: change as you go during analysis process
 - fluid task switching: different visual encodings support different tasks
 - animated transitions provide excellent support
 - empirical evidence that animated transitions help people stay oriented

Interaction limitations

- interaction has a time cost
 - sometimes minor, sometimes significant
 - degenerates to human-powered search in worst case
- remembering previous state imposes cognitive load
- controls may take screen real estate
 - or invisible functionality may be difficult to discover (lack of affordances)
- users may not interact as planned by designer
 - NYTimes logs show ~90% don't interact beyond scrollytelling - Aisch, 2016

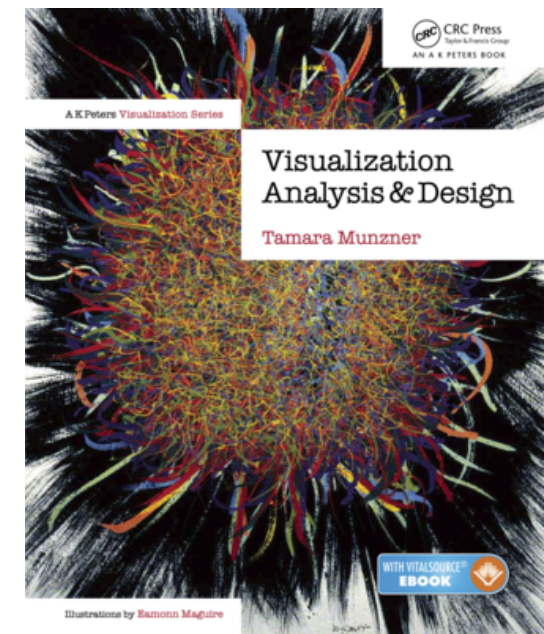
Visualization Analysis & Design

Interactive Views (Ch 11/12) II

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



How to handle complexity: 1 previous strategy + 2 more

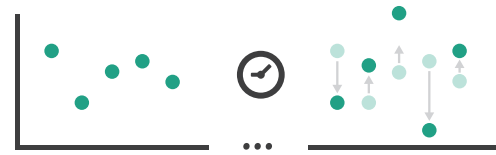
→ *Derive*



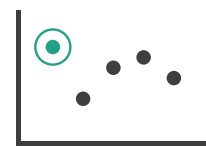
- derive new data to show within view
- change view over time
- facet across multiple views

Manipulate

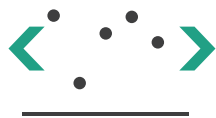
→ Change



→ Select

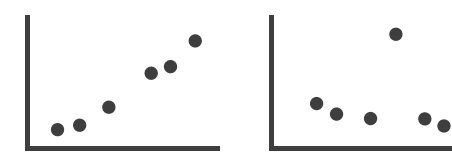


→ Navigate

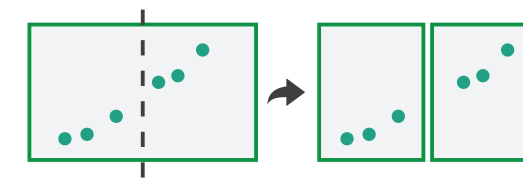


Facet

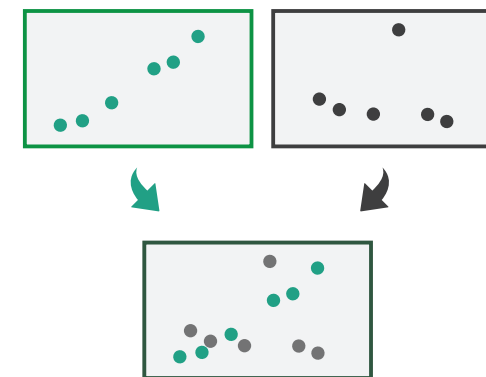
→ Juxtapose



→ Partition



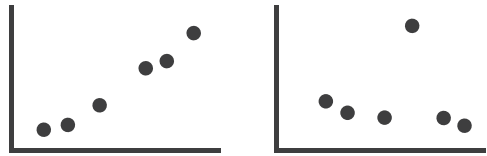
→ Superimpose



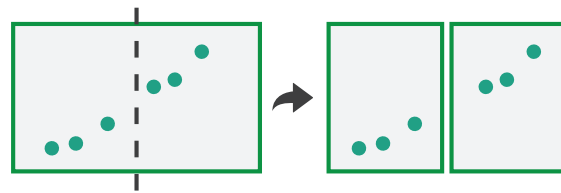
Multiple Views

Facet

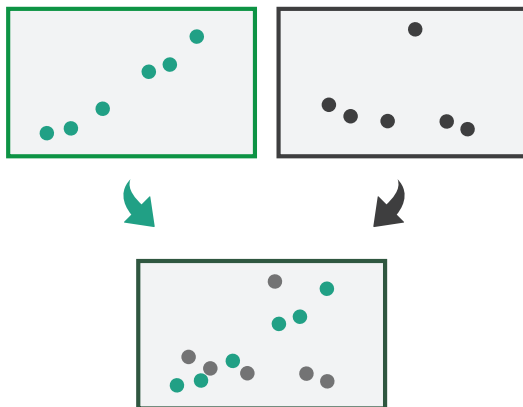
→ Juxtapose



→ Partition

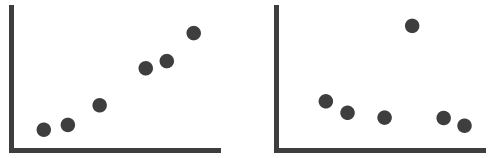


→ Superimpose

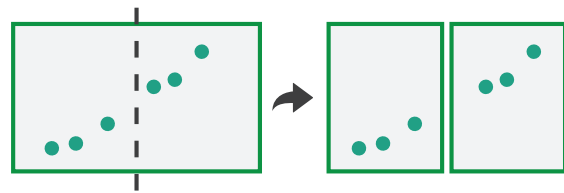


Facet

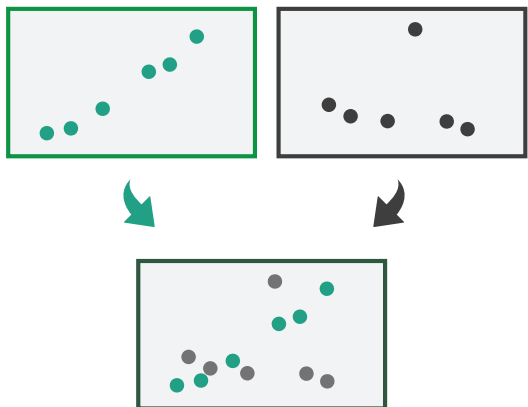
→ Juxtapose



→ Partition



→ Superimpose



Juxtapose and coordinate views

→ Share Encoding: Same/Different

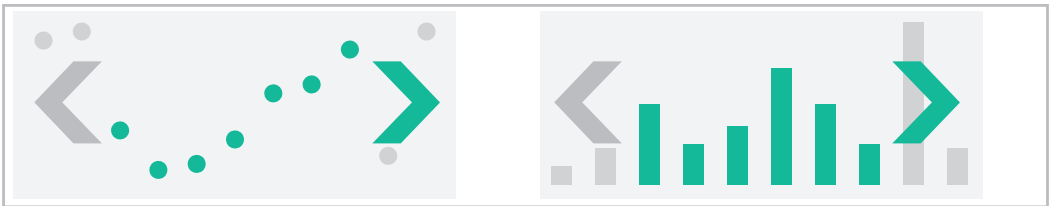
→ *Linked Highlighting*



→ Share Data: All/Subset/None



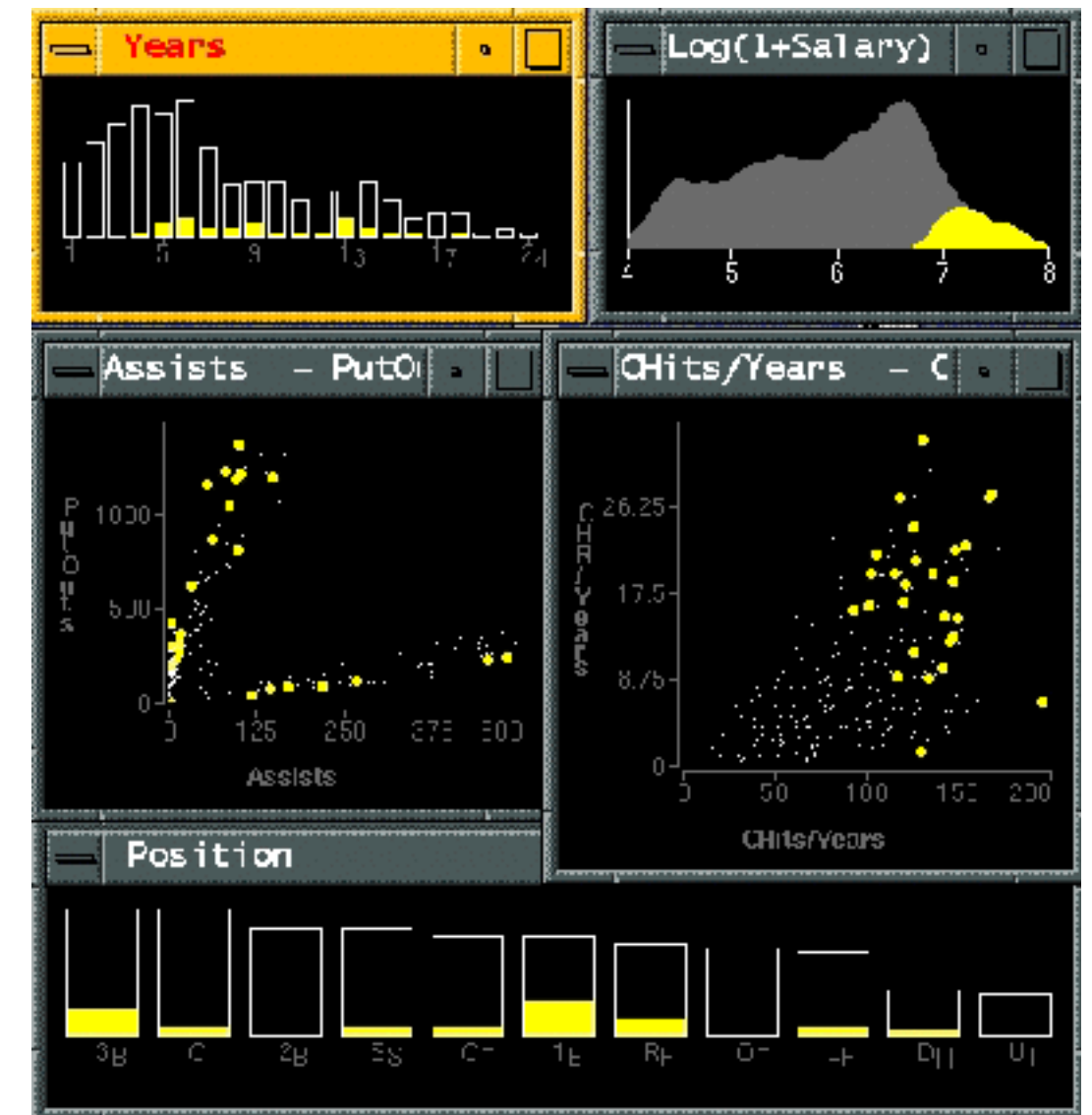
→ Share Navigation



Idiom: **Linked highlighting**

System: **EDV**

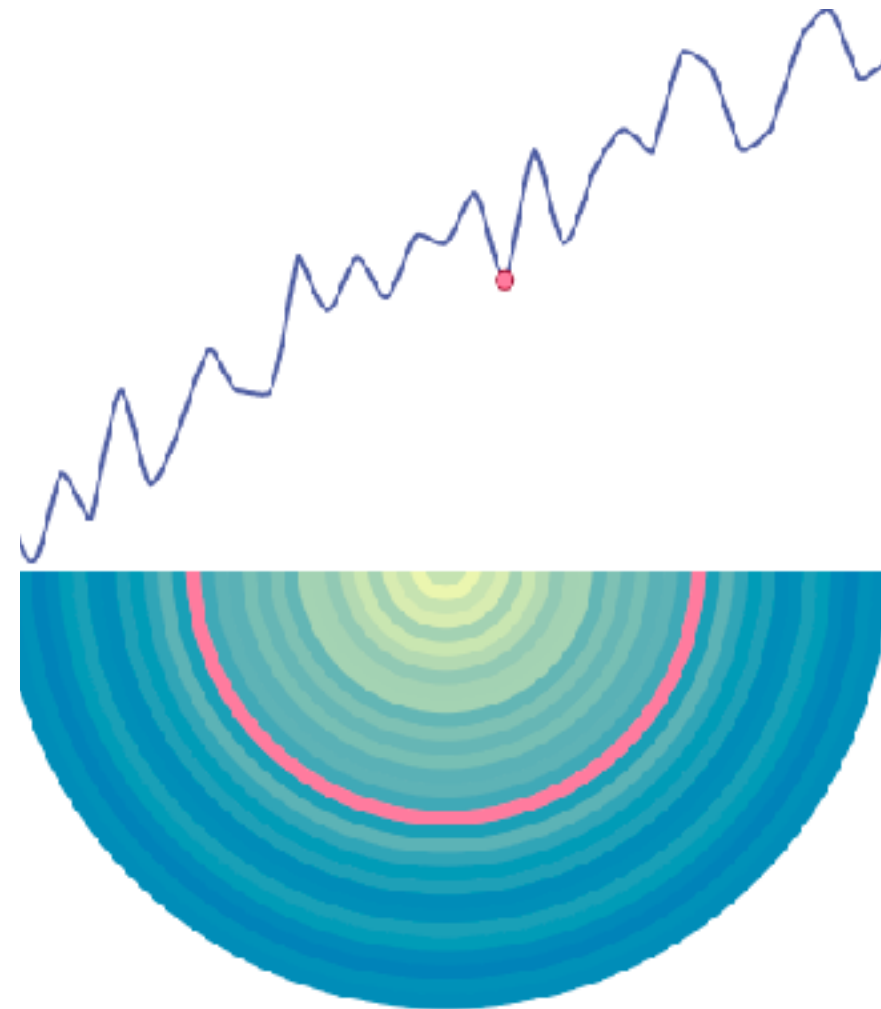
- see how regions contiguous in one view are distributed within another
 - powerful and pervasive interaction idiom
- encoding: different
 - *multiform*
- data: all shared
 - all **items** shared
 - different **attributes** across the views
- aka: brushing and linking



[Visual Exploration of Large Structured Datasets. Wills.
Proc. New Techniques and Trends in Statistics (NTTS), pp. 237–246. IOS Press, 1995.]

Linked views: Directionality

- unidirectional vs bidirectional linking
 - bidirectional almost always better!



<http://pbeshai.github.io/linked-highlighting-react-vega-redux/>

<https://medium.com/@pbesh/linked-highlighting-with-react-d3-js-and-reflux-16e9c0b2210b>

Idiom: Overview-detail views

- encoding: same or different
 - ex: same (birds-eye map)
- data: subset shared
 - viewpoint differences: subset of data items
- navigation: shared
 - bidirectional linking
- other differences
 - (window size)

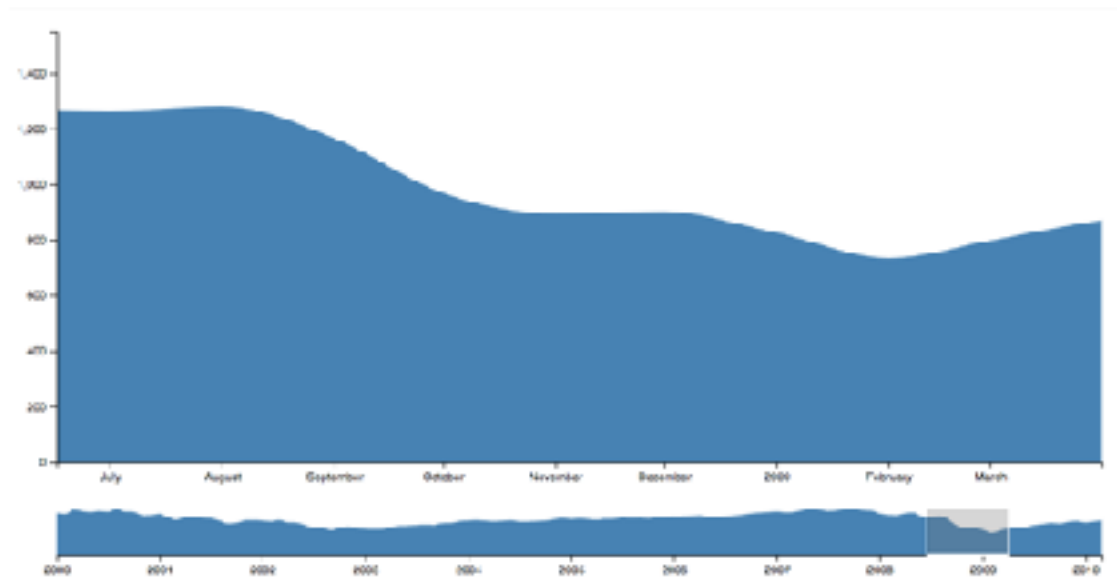
System: Google Maps



[A Review of Overview+Detail, Zooming, and Focus+Context Interfaces.
Cockburn, Karlson, and Bederson. *ACM Computing Surveys* 41:1 (2008), 1–31.]

Idiom: Overview-detail navigation

- encoding: same or different
- data: subset shared
- navigation: shared
 - unidirectional linking
 - select in small overview, change extent in large detail view



<https://observablehq.com/@uwdata/interaction>

Idiom: Tooltips

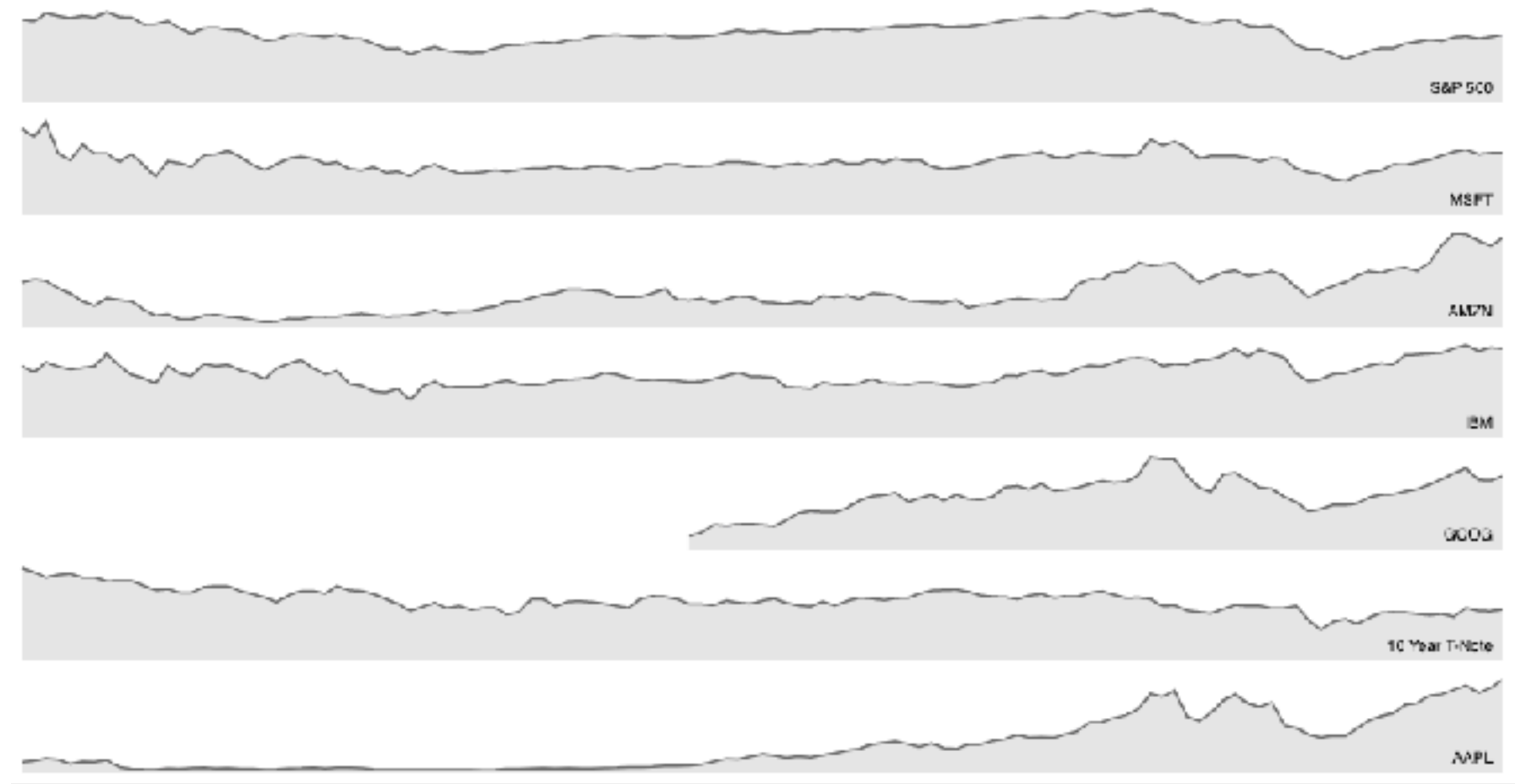
- popup information for selection
 - hover or click
 - specific case of detail view:
provide useful additional detail on demand
 - beware: does not support overview!
 - always consider if there's a way to visually encode directly to provide overview
 - “If you make a rollover or tooltip, assume nobody will see it. If it's important, make it explicit.”
 - Gregor Aisch, NYTimes



[\[https://www.highcharts.com/demo/dynamic-master-detail\]](https://www.highcharts.com/demo/dynamic-master-detail)

Idiom: **Small multiples**

- encoding: same
 - ex: line charts
- data: none shared
 - different slices of dataset
 - items or attributes
 - ex: stock prices for different companies



Interactive small multiples

- linked highlighting:
analogous item/attribute
across views
 - same year highlighted across all charts if hover within any chart

The Rise and Decline of Ask MetaFilter

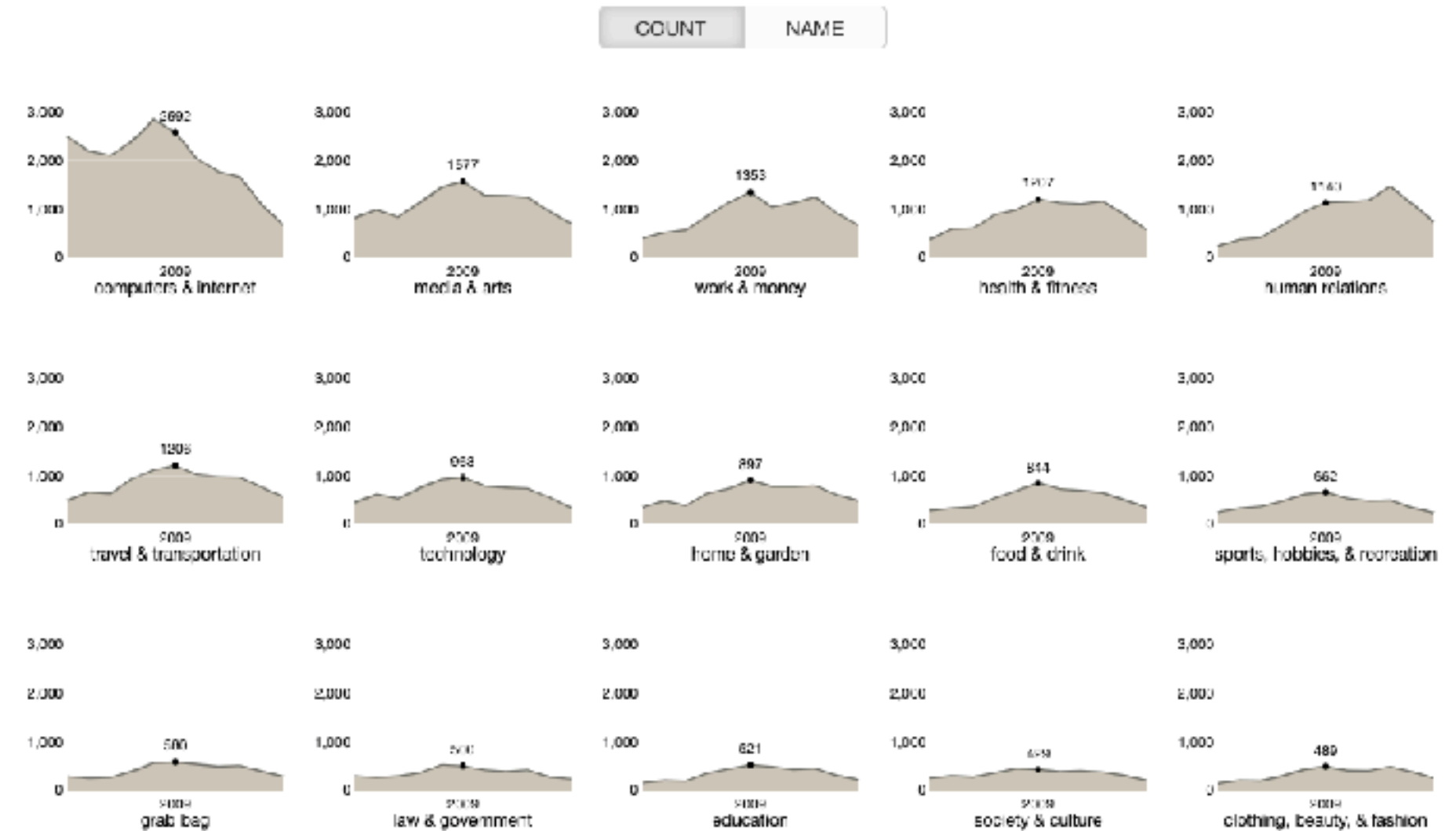
Metafilter's revenue has been on the decline, but has its content dried up as well?

Here we look at new posts on Ask Metafilter by category.

Categories like computers & internet have been dropping in use for a long time, most likely due to competition like Stack Overflow.

Other smaller categories have had consistent use patterns until more recently.

Disclaimer: 2014 is included, even though the year is not over yet.



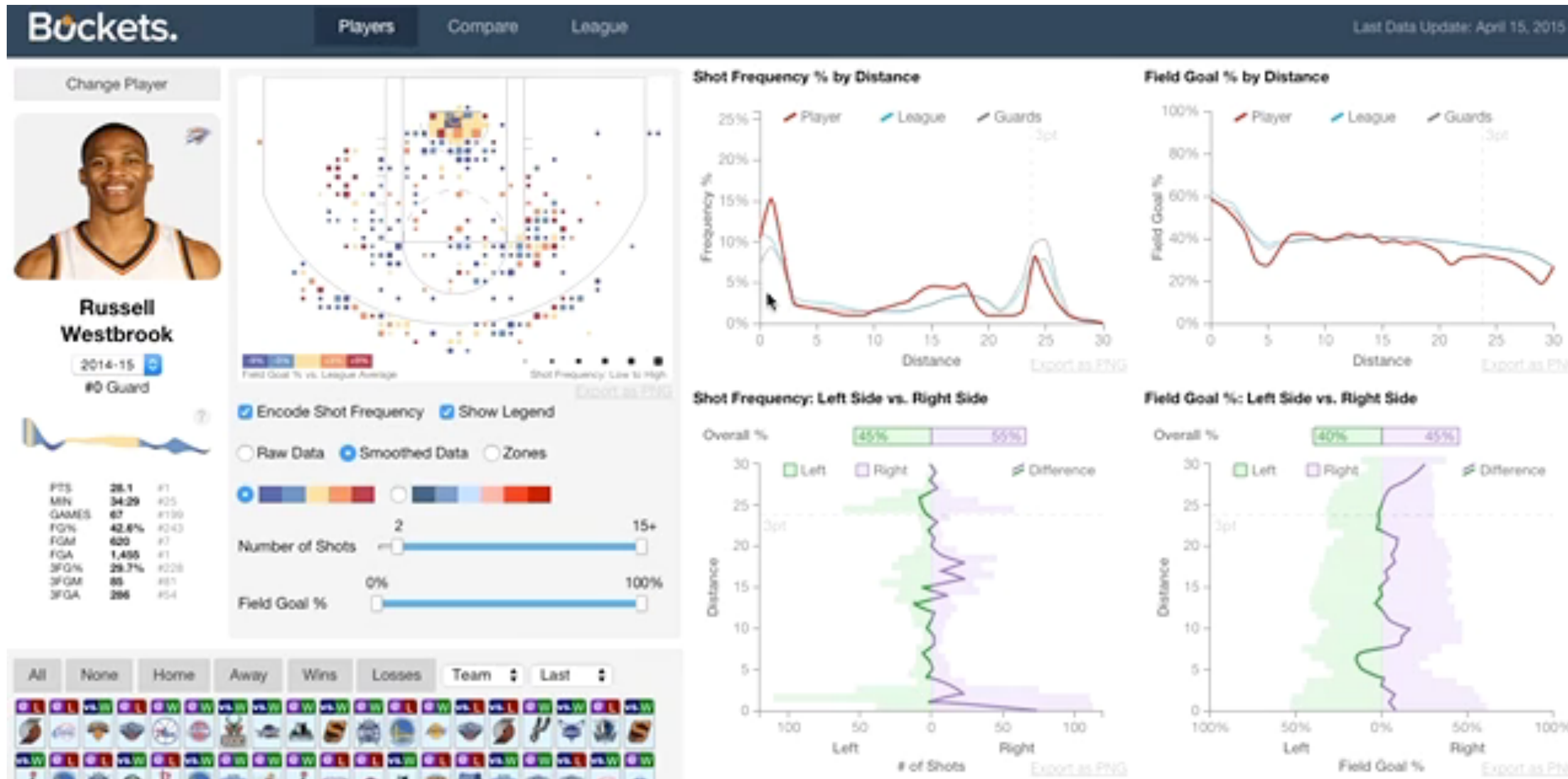
[\[https://bl.ocks.org/ColinEberhardt/3c780088c363d1515403f50a87a87121\]](https://bl.ocks.org/ColinEberhardt/3c780088c363d1515403f50a87a87121)

[\[https://blog.scottlogic.com/2017/04/05/interactive-responsive-small-multiples.html\]](https://blog.scottlogic.com/2017/04/05/interactive-responsive-small-multiples.html)

[\[http://projects.flowingdata.com/tut/linked_small_multiples_demo/\]](http://projects.flowingdata.com/tut/linked_small_multiples_demo/)

Example: Combining many interaction idioms

System: **Buckets**

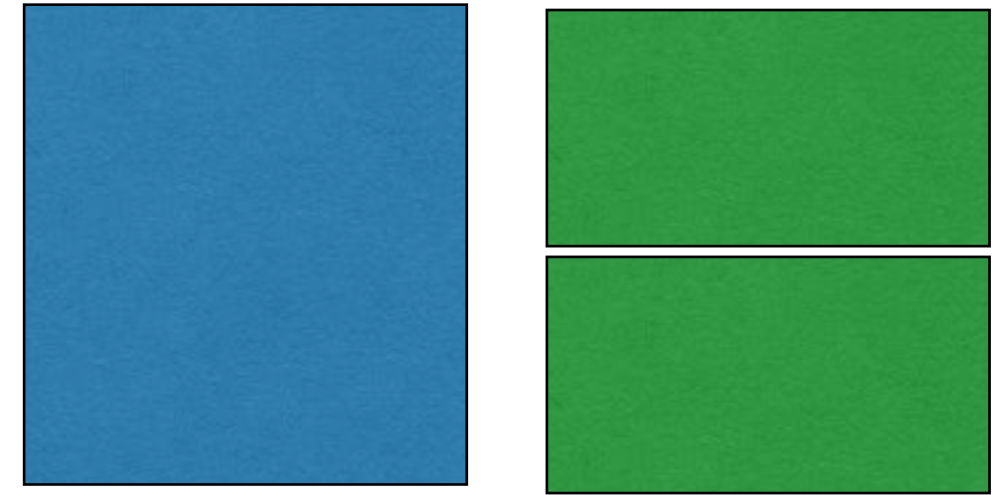


- multiform
- multidirectional linked highlighting of small multiples
- tooltips

<http://buckets.peterbeshai.com/>

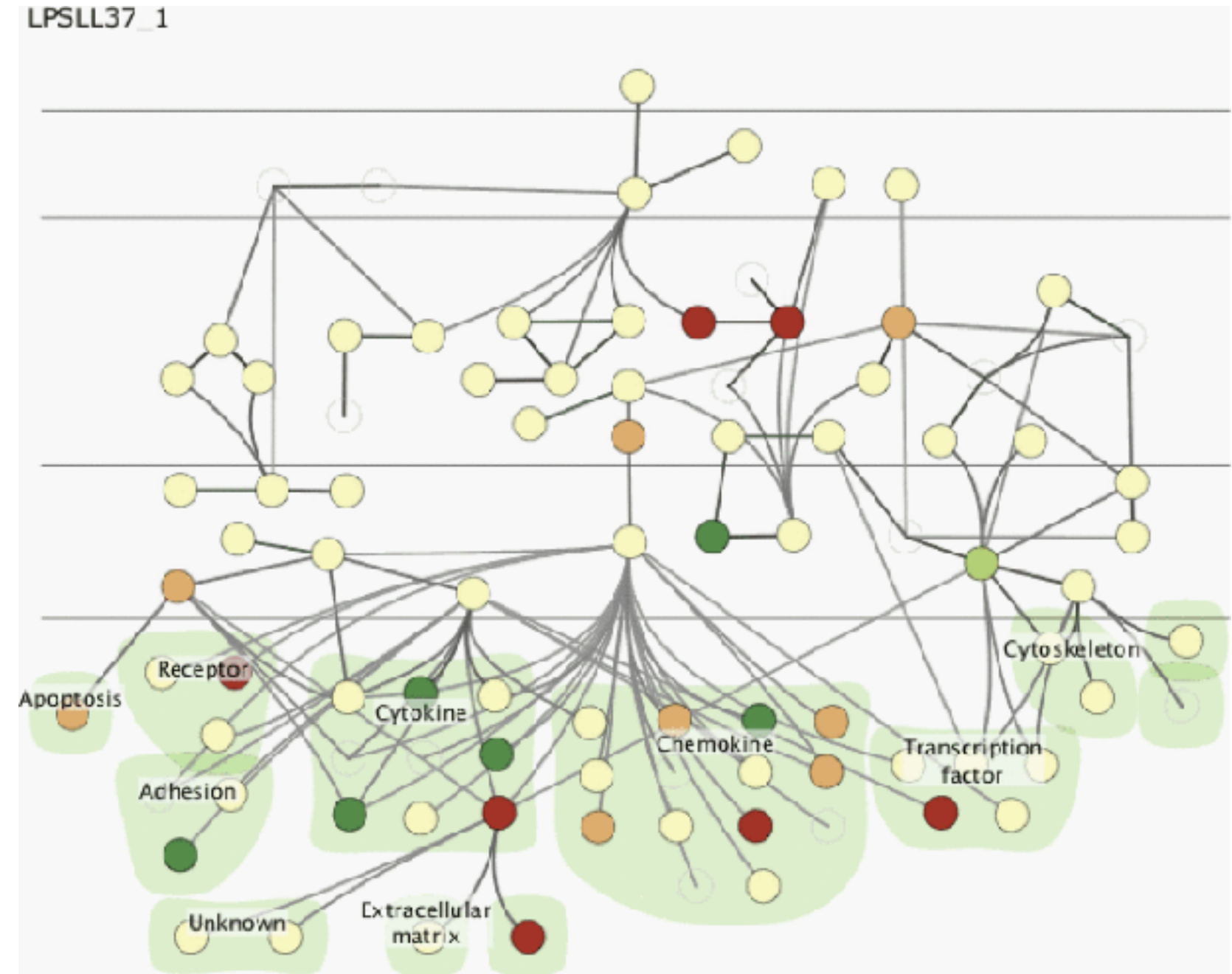
Juxtapose views: tradeoffs

- juxtapose costs
 - display area
 - 2 views side by side: each has only half the area of one view
- juxtapose benefits
 - cognitive load: eyes vs memory
 - lower cognitive load: move eyes between 2 views
 - higher cognitive load: compare single changing view to memory of previous state



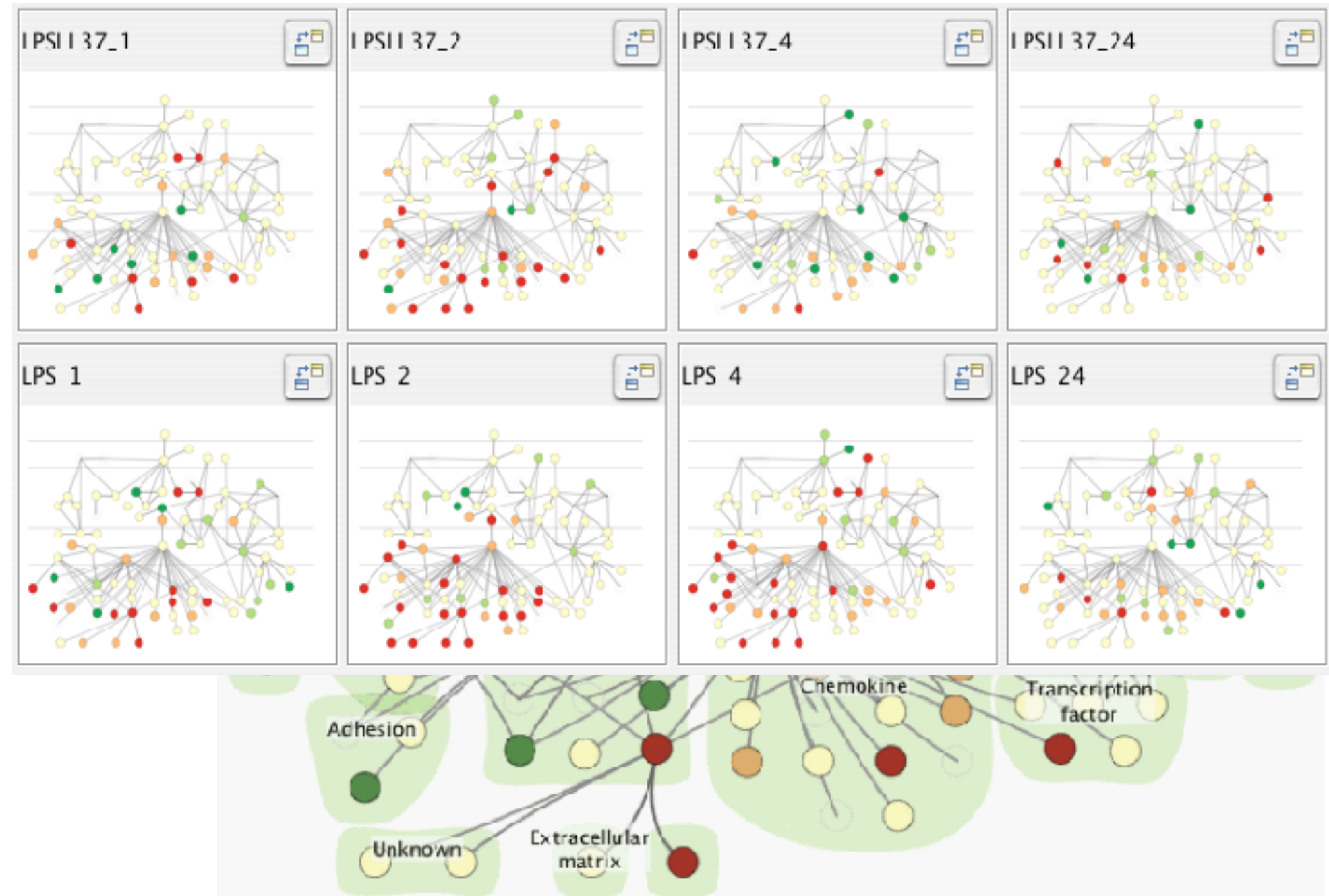
Juxtapose vs animate

- animate: hard to follow if many scattered changes or many frames
 - vs easy special case: animated transitions

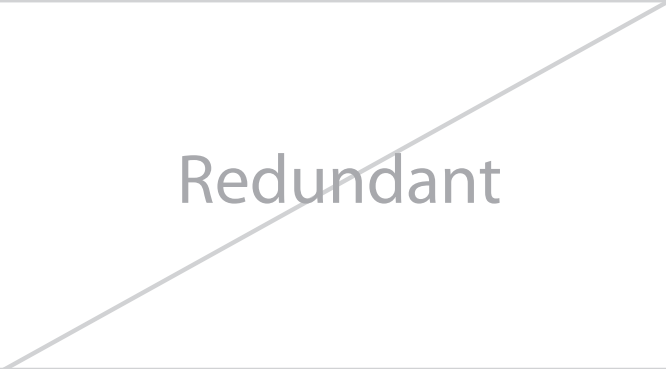
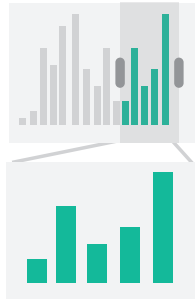
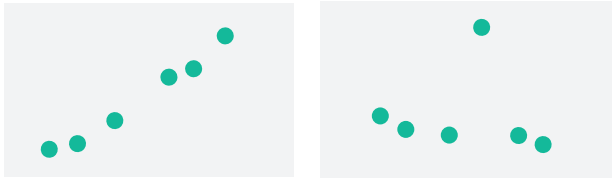





Juxtapose vs animate

- animate: hard to follow if many scattered changes or many frames
 - vs easy special case: animated transitions
- juxtapose: easier to compare across small multiples
 - different conditions (color), same gene (layout)



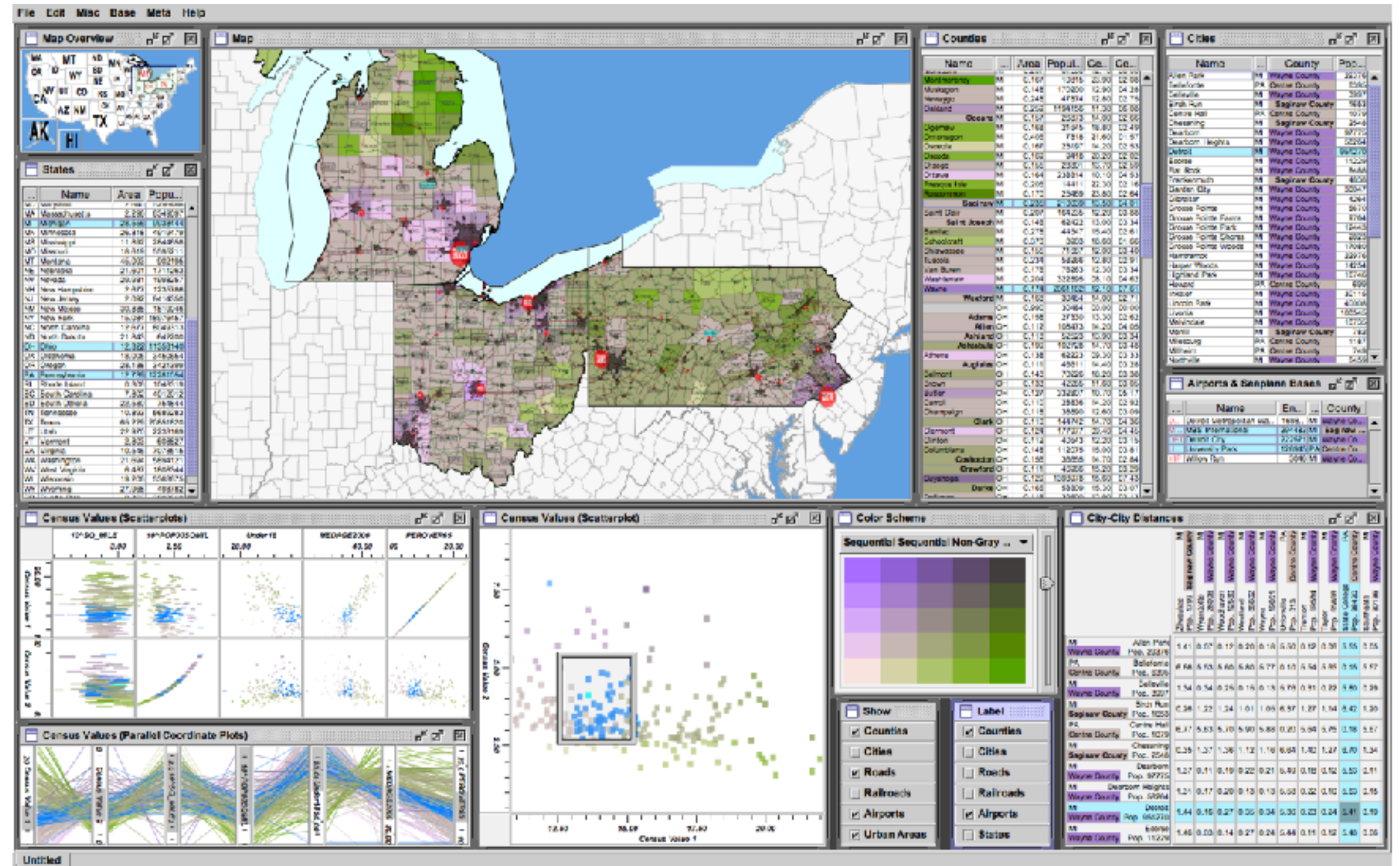
View coordination: Design choices

		Data		
		All	Subset	None
Encoding	Same	<p>Redundant</p> 	 <p>Overview/ Detail</p>	 <p>Small Multiples</p>
	Different	 <p>Multiform</p>	 <p>Multiform, Overview/ Detail</p>	<p>No Linkage</p> 

Idiom: Reorderable lists

System: Improvise

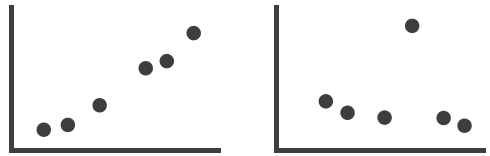
- list views
 - easy lookup
 - useful when linked to other views
- how many views is ok vs too complex?
 - open research question



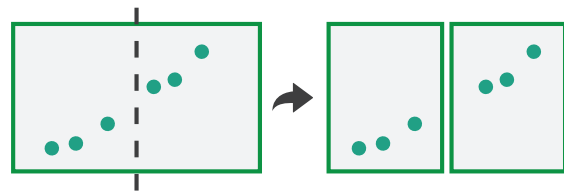
[Building Highly-Coordinated Visualizations In Improvise. Weaver. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 159–166, 2004.]

Facet

→ Juxtapose



→ Partition



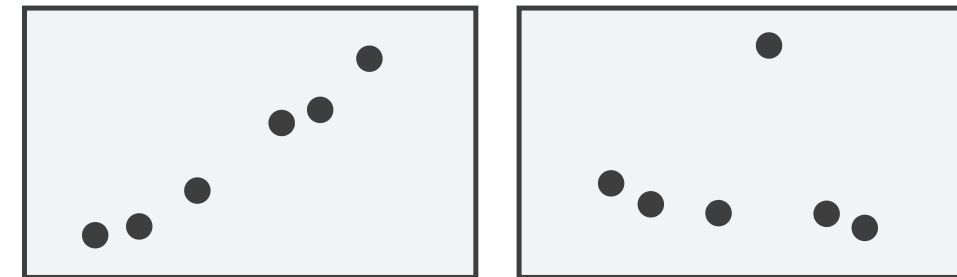
→ Superimpose



Partition into views

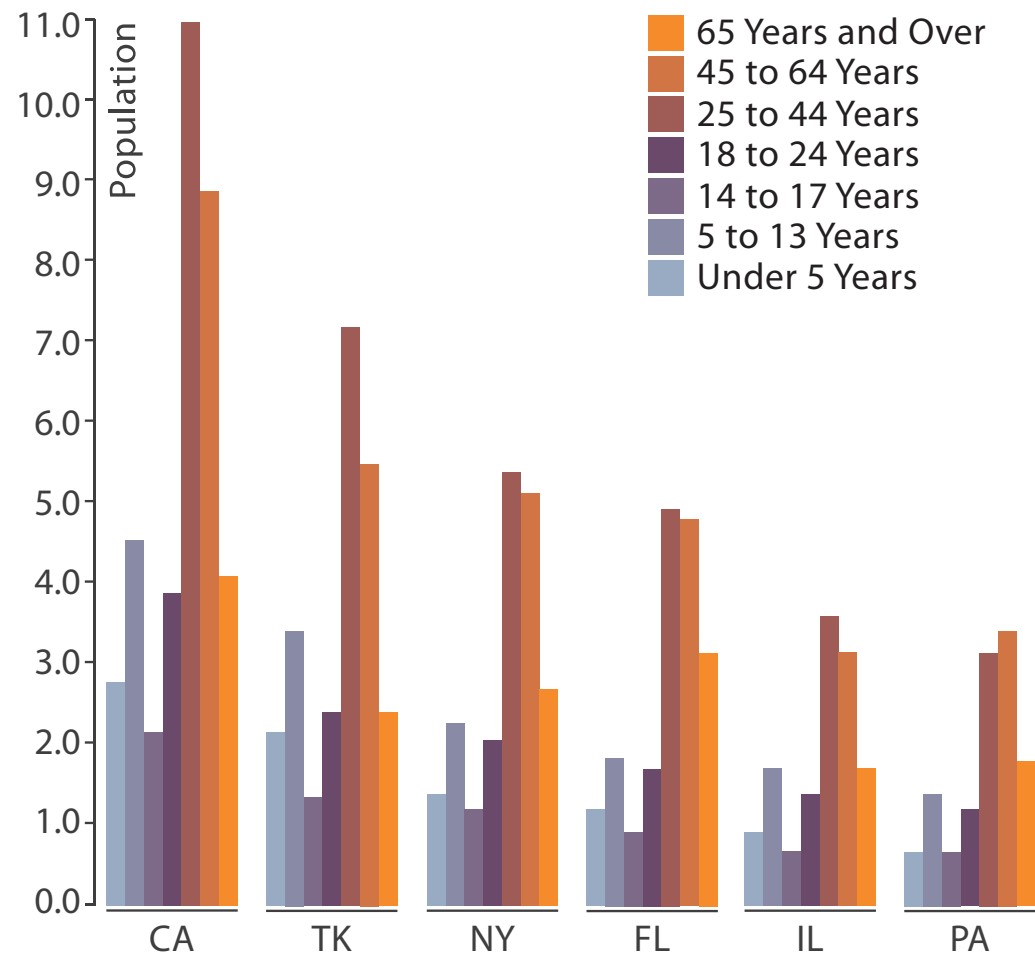
- how to divide data between views
 - split into regions by attributes
 - encodes association between items using spatial proximity
 - order of splits has major implications for what patterns are visible

➔ Partition into Side-by-Side Views



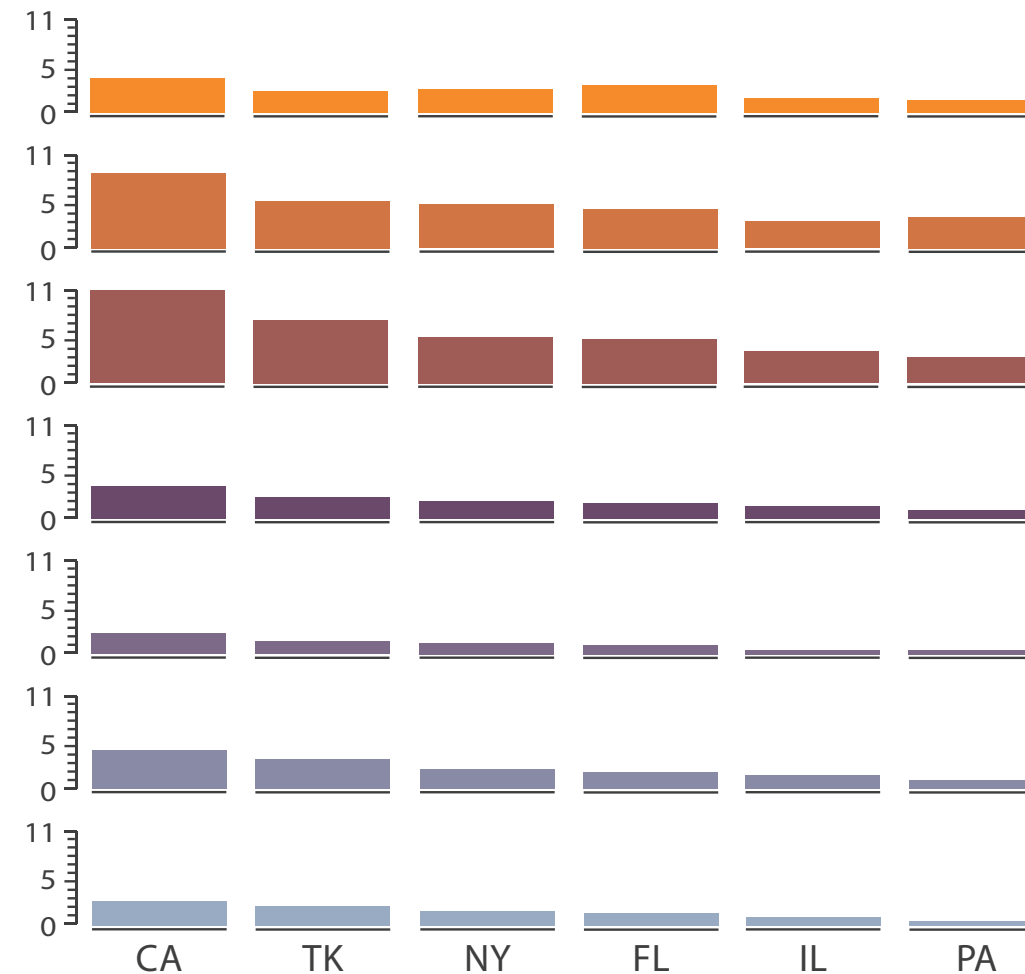
Partitioning: Grouped vs small-multiple bars

- single bar chart with grouped bars
 - split by state into regions
 - complex glyph within each region showing all ages
 - compare: easy within state, hard across ages



[<https://observablehq.com/@d3/grouped-bar-chart>]

- small-multiple bar charts
 - split by age into regions
 - one chart per region
 - compare: easy within age, harder across states

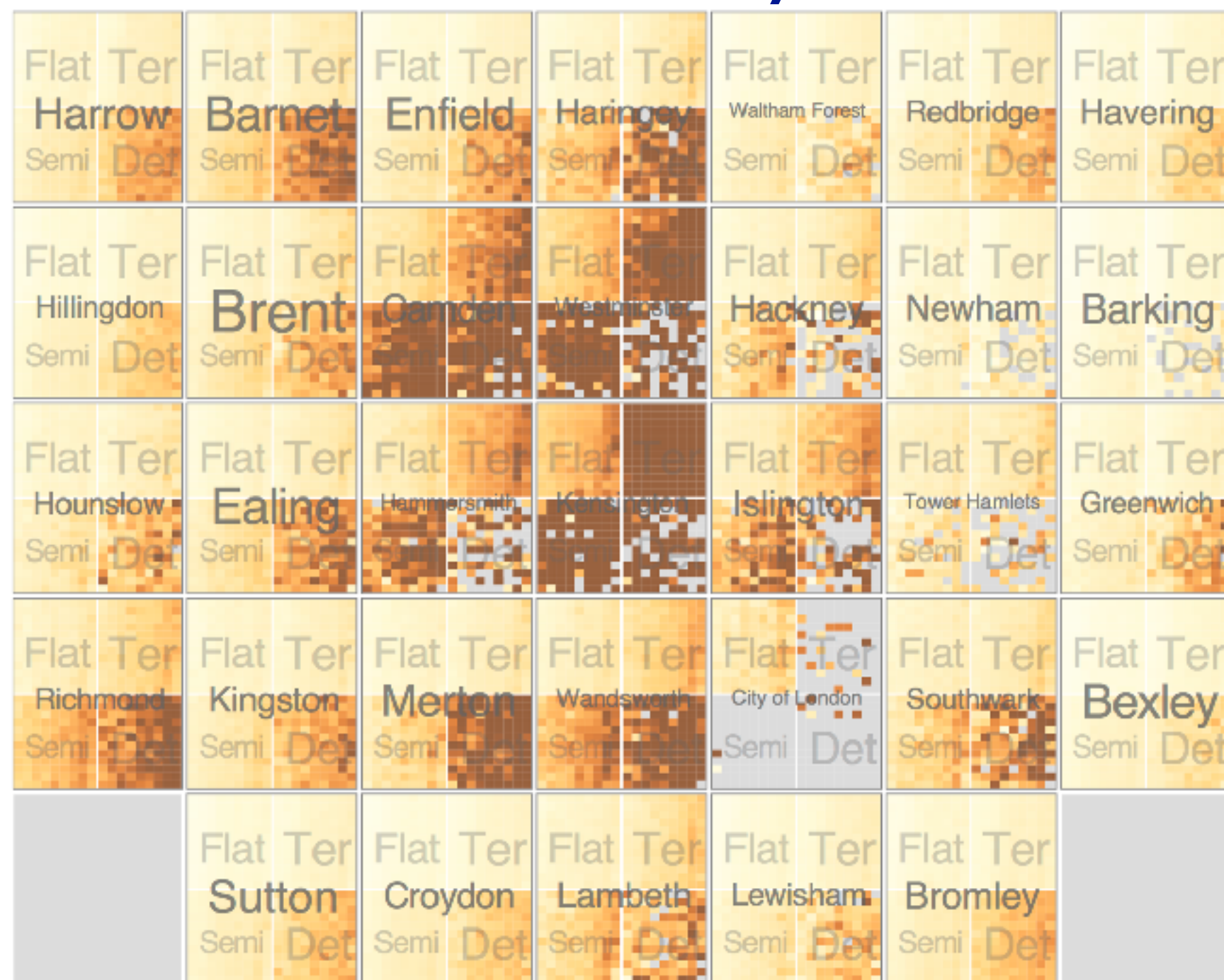


[<https://bl.ocks.org/mbostock/4679202>]

Partitioning: Recursive subdivision

System: **HIVE**

- split by neighborhood
- then by type
 - flat, terrace, semi-detached, detached
- then time
 - years as rows
 - months as columns
- color by price
- neighborhood patterns
 - where it's expensive
 - where you pay much more for detached type



Partitioning: Recursive subdivision

System: **HIVE**

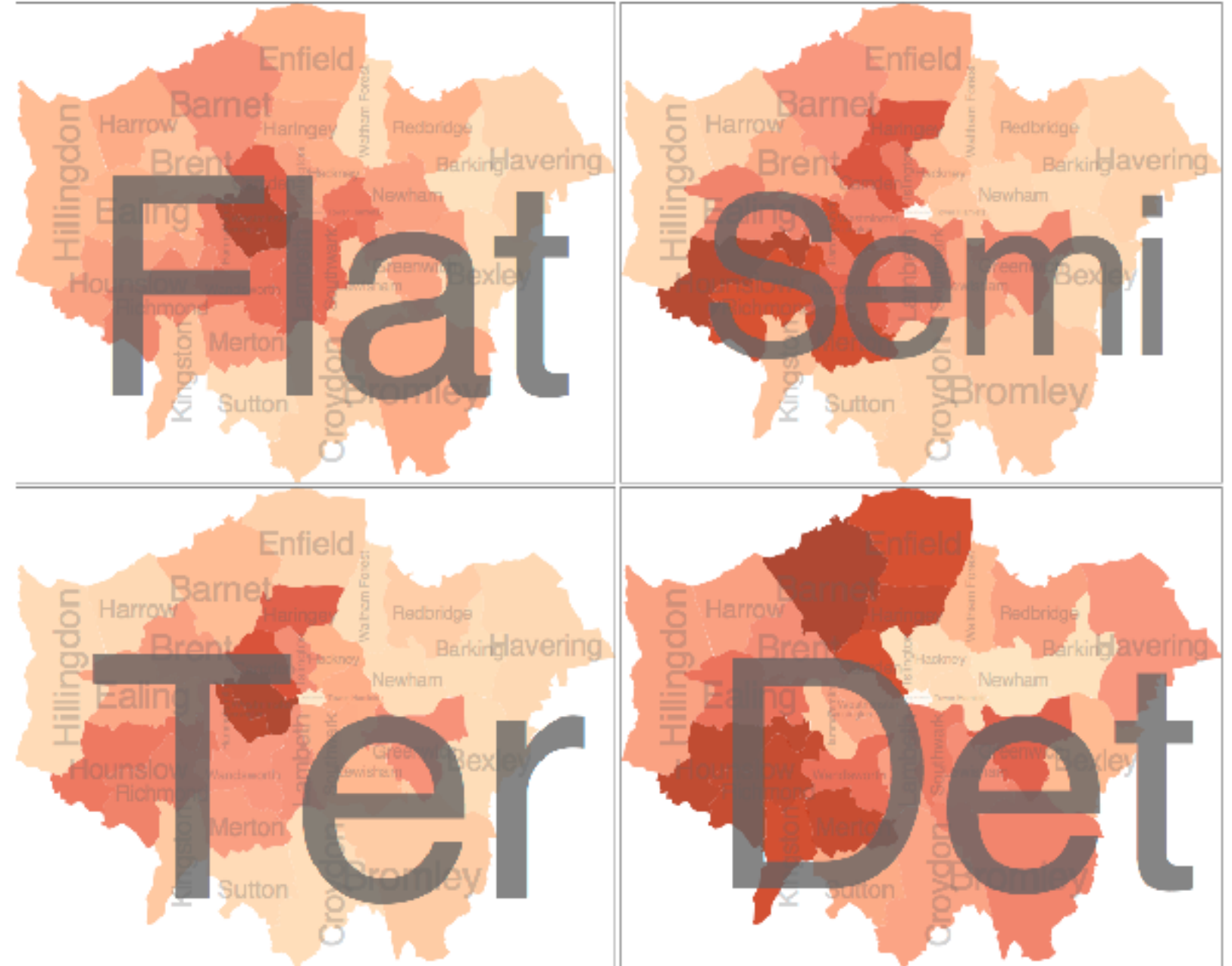
- switch order of splits
 - type then neighborhood
- switch color
 - by price variation
- type patterns
 - within specific type, which neighborhoods inconsistent



Partitioning: Recursive subdivision

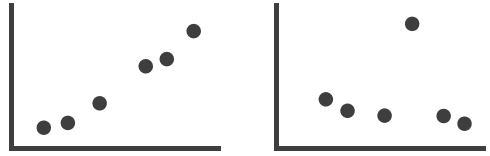
- different encoding for second-level regions
 - choropleth maps

System: **HIVE**

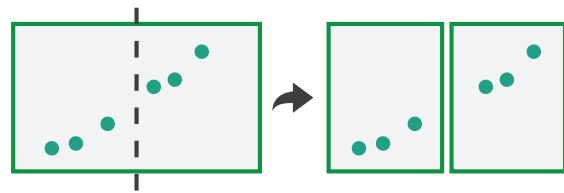


Facet

→ Juxtapose



→ Partition



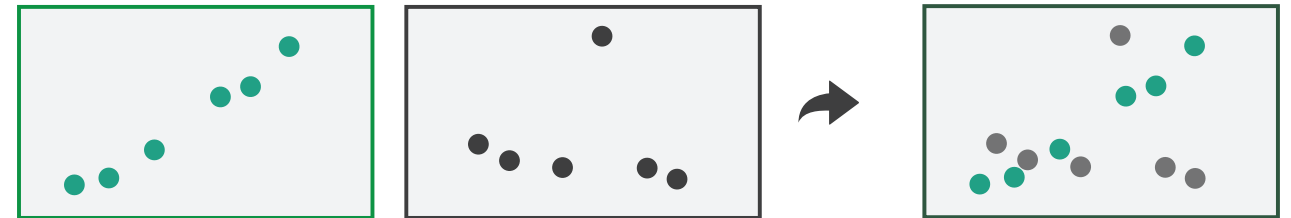
→ Superimpose



Superimpose layers

- layer: set of objects spread out over region
 - each set is visually distinguishable group
 - extent: whole view
- design choices
 - how many layers, how to distinguish?
 - encode with different, nonoverlapping channels
 - two layers achievable, three with careful design
 - small static set, or dynamic from many possible?

➔ Superimpose Layers



Static visual layering

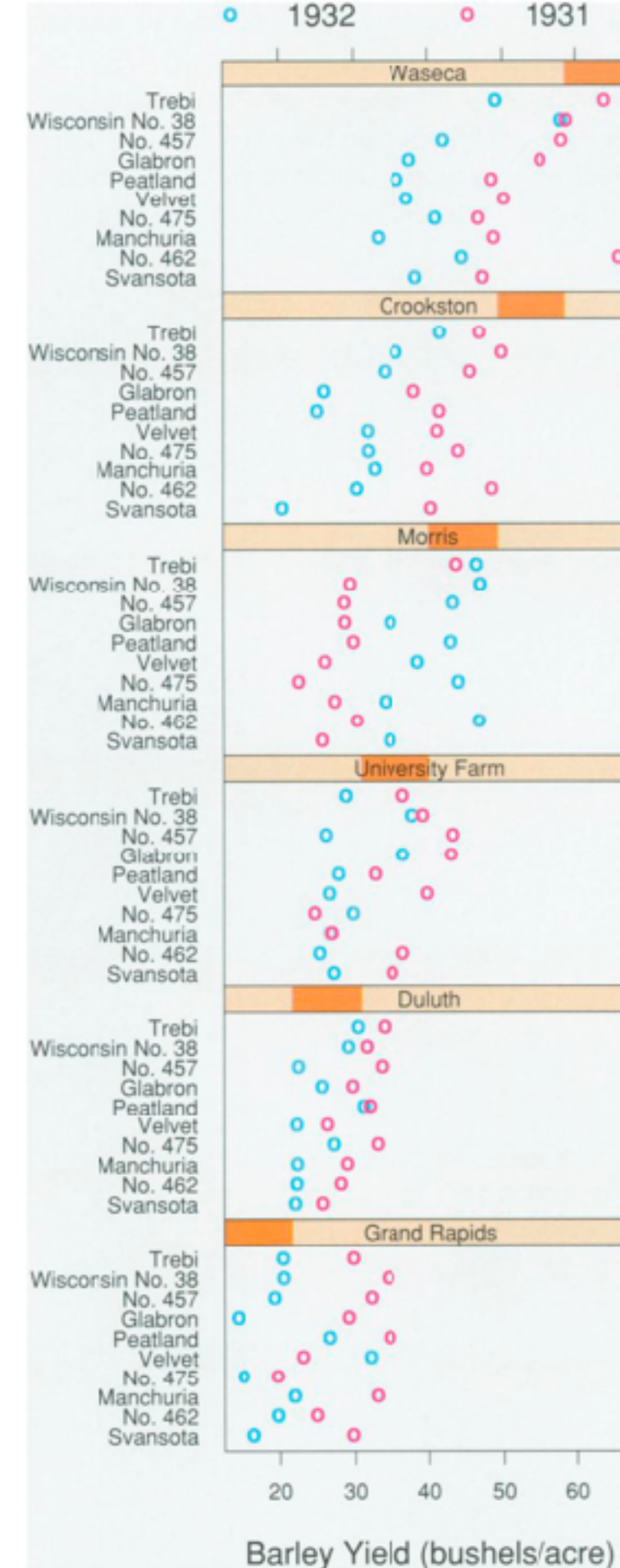
- foreground layer: roads
 - hue, size distinguishing main from minor
 - high luminance contrast from background
- background layer: regions
 - desaturated colors for water, parks, land areas
- user can selectively focus attention



[Get it right in black and white. Stone. 2010.
<http://www.stonesc.com/wordpress/2010/03/get-it-right-in-black-and-white>]

Idiom: Trellis plots

- superimpose within same frame
 - color code by year
- partitioning
 - split by site, rows are barley varieties
- main-effects ordering
 - derive value of median for group
 - order rows within view by variety median
 - order views themselves by site median



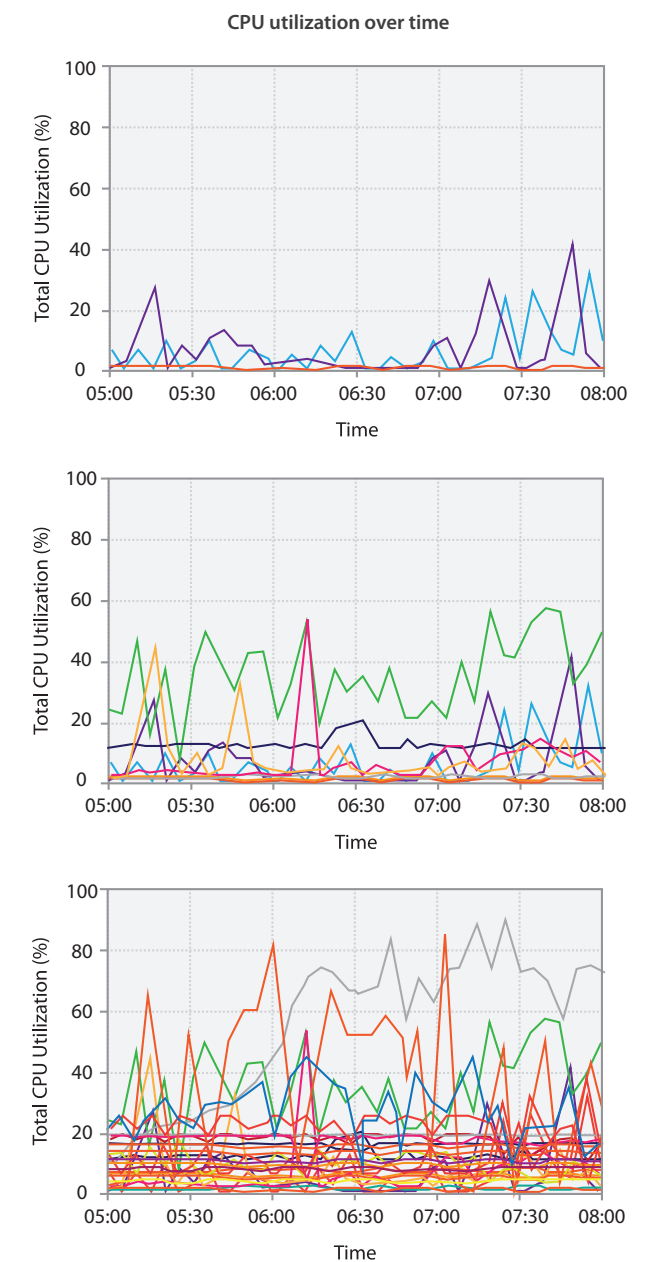
[The Visual Design and Control of Trellis Display. Becker, Cleveland, & Shyu.
Journal of Computational and Graphical Statistics 5(2):123-155 1996.]

Superimposing limits (static)

- few layers, more lines
 - up to a few dozen lines
 - but not hundreds
- superimpose vs juxtapose: empirical study
 - same size: all multiples, vs single superimposed
 - superimposed: local tasks
 - juxtaposed: global tasks, esp. for many charts



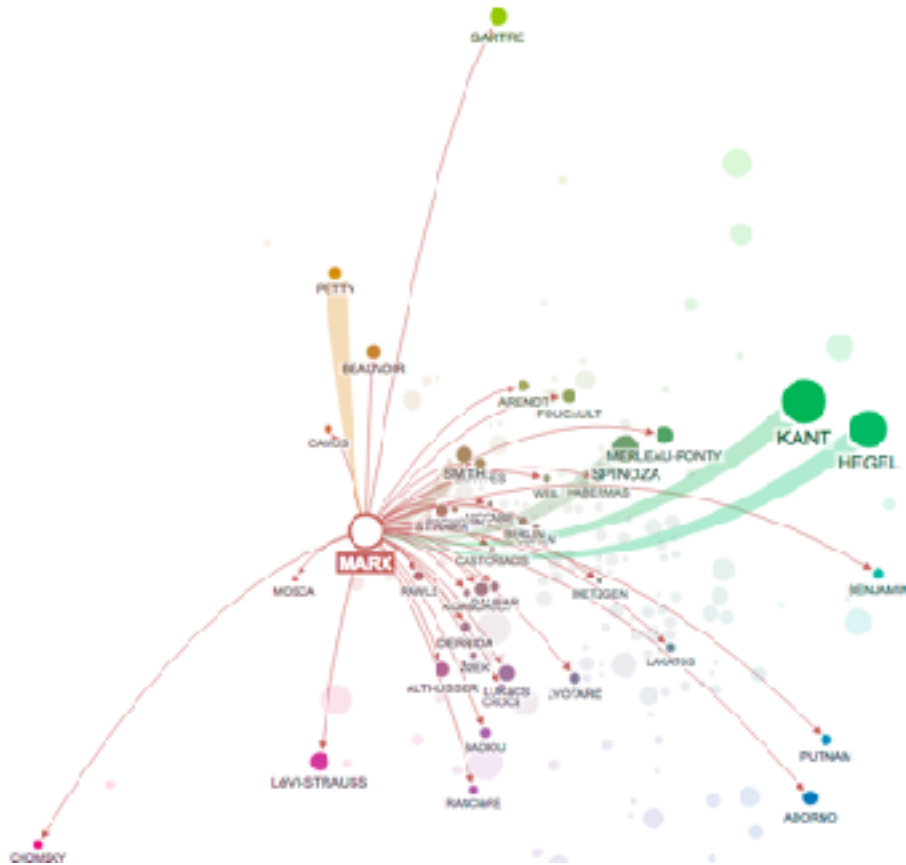
[Graphical Perception of Multiple Time Series. Javed, McDonnel, and Elmqvist. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE InfoVis 2010) 16:6 (2010), 927–934.]



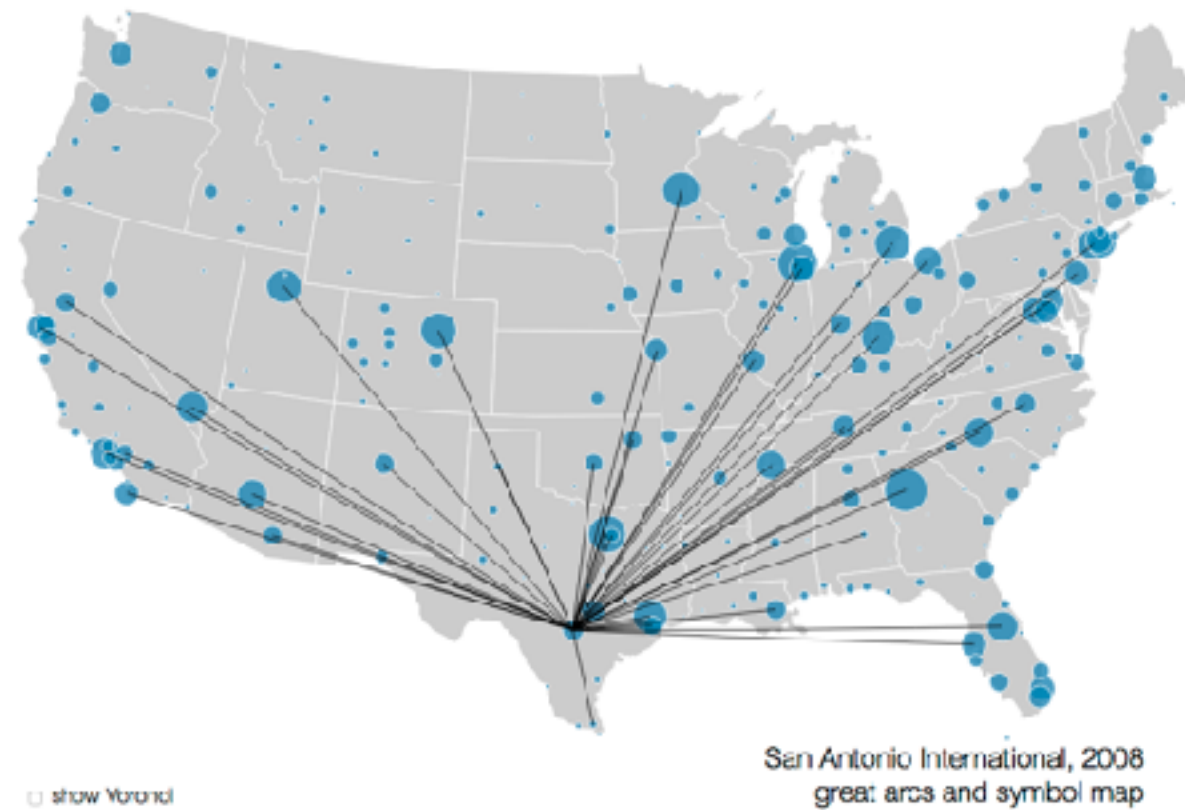
Dynamic visual layering

- interactive, based on selection
- one-hop neighbour highlighting

click (heavyweight)



hover (fast)



<https://mariandoerk.de/edgemaps/demo/>

<http://mbostock.github.io/d3/talk/20111116/airports.html>

How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



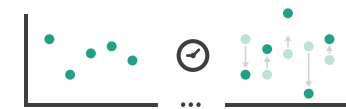
→ Motion

Direction, Rate, Frequency, ...

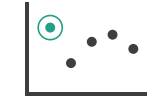


Manipulate

→ Change



→ Select



→ Navigate

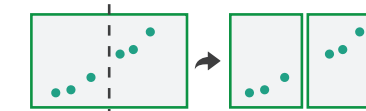


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

→ Filter



→ Aggregate



→ Embed

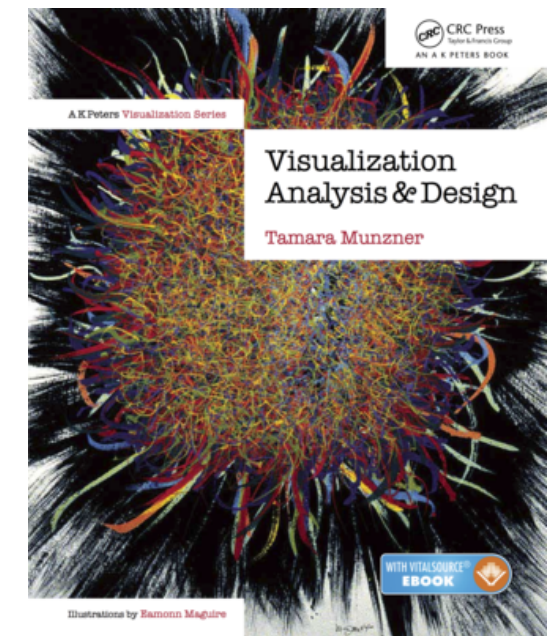


What?

Why?

How?

Visualization Analysis & Design



Reduce: Aggregation & Filtering (Ch 13)

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)

How to handle complexity: 3 previous strategies

→ *Derive*

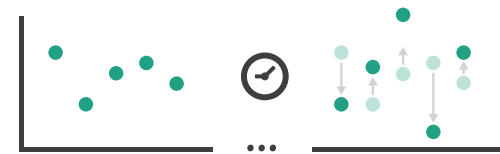


- derive new data to show within view
- change view over time
- facet across multiple views

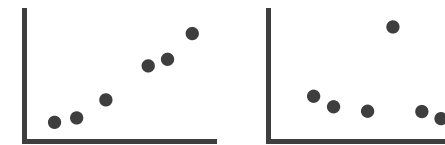
Manipulate

Facet

→ Change



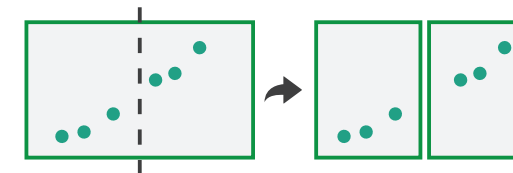
→ Juxtapose



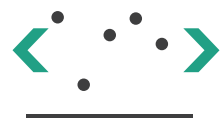
→ Select



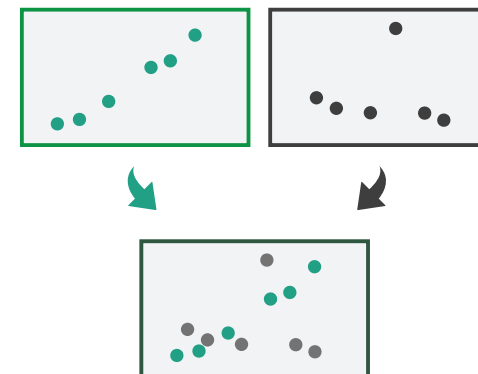
→ Partition



→ Navigate



→ Superimpose



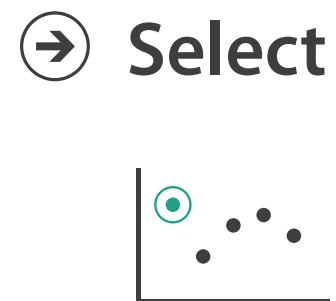
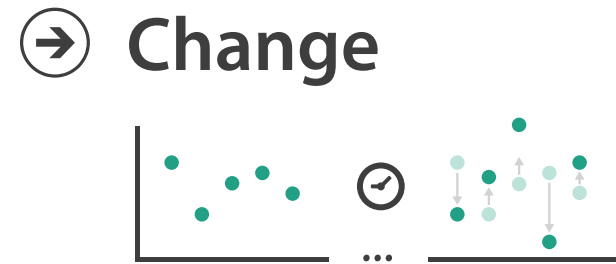
How to handle complexity: 3 previous strategies + 1 more

→ *Derive*

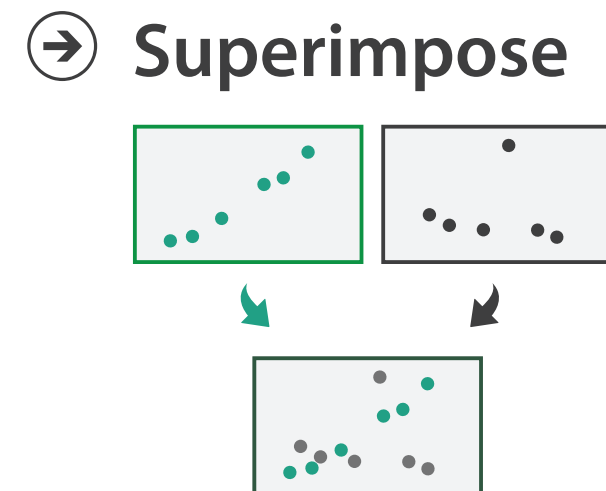
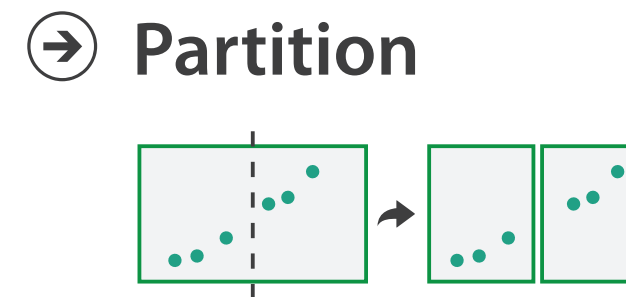


- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

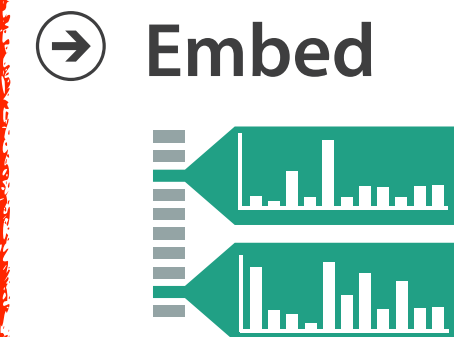
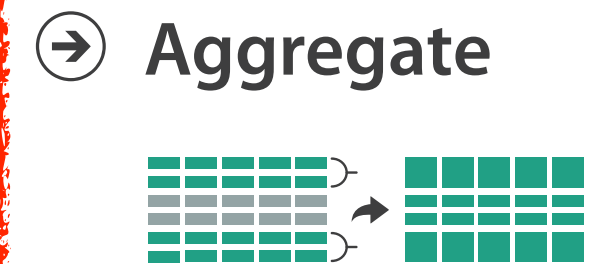
Manipulate



Facet



Reduce



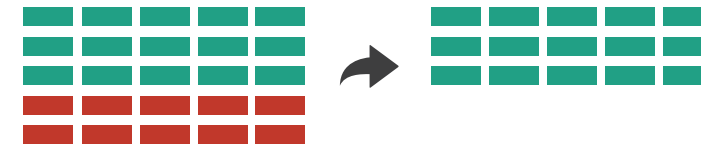
Reduce items and attributes

- reduce/increase: inverses
- filter
 - pro: straightforward and intuitive
 - to understand and compute
 - con: out of sight, out of mind

Reducing Items and Attributes

→ Filter

→ Items



→ Attributes



Reduce items and attributes

- reduce/increase: inverses
- filter
 - pro: straightforward and intuitive
 - to understand and compute
 - con: out of sight, out of mind
- aggregation
 - pro: inform about whole set
 - con: difficult to avoid losing signal
- not mutually exclusive
 - combine filter, aggregate
 - combine reduce, change, facet

Reducing Items and Attributes

① Filter

→ Items

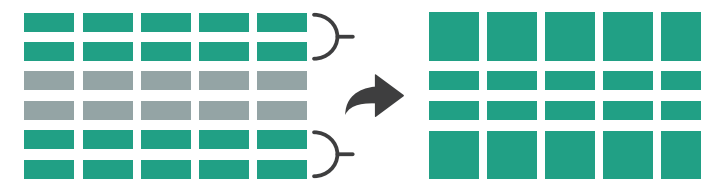


→ Attributes

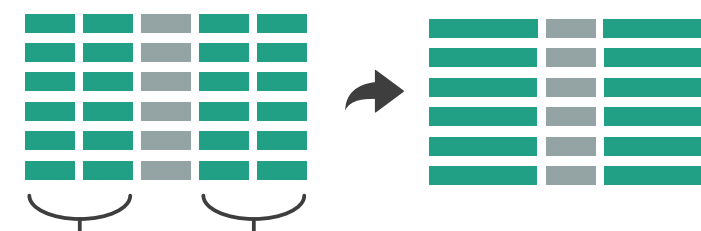


② Aggregate

→ Items



→ Attributes



Filter

- eliminate some elements
 - either items or attributes
- according to what?
 - any possible function that partitions dataset into two sets
 - attribute values bigger/smaller than x
 - noise/signal
- filters vs queries
 - query: start with nothing, add in elements
 - filters: start with everything, remove elements
 - best approach depends on dataset size

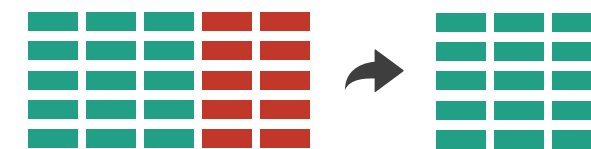
Reducing Items and Attributes

① Filter

→ Items

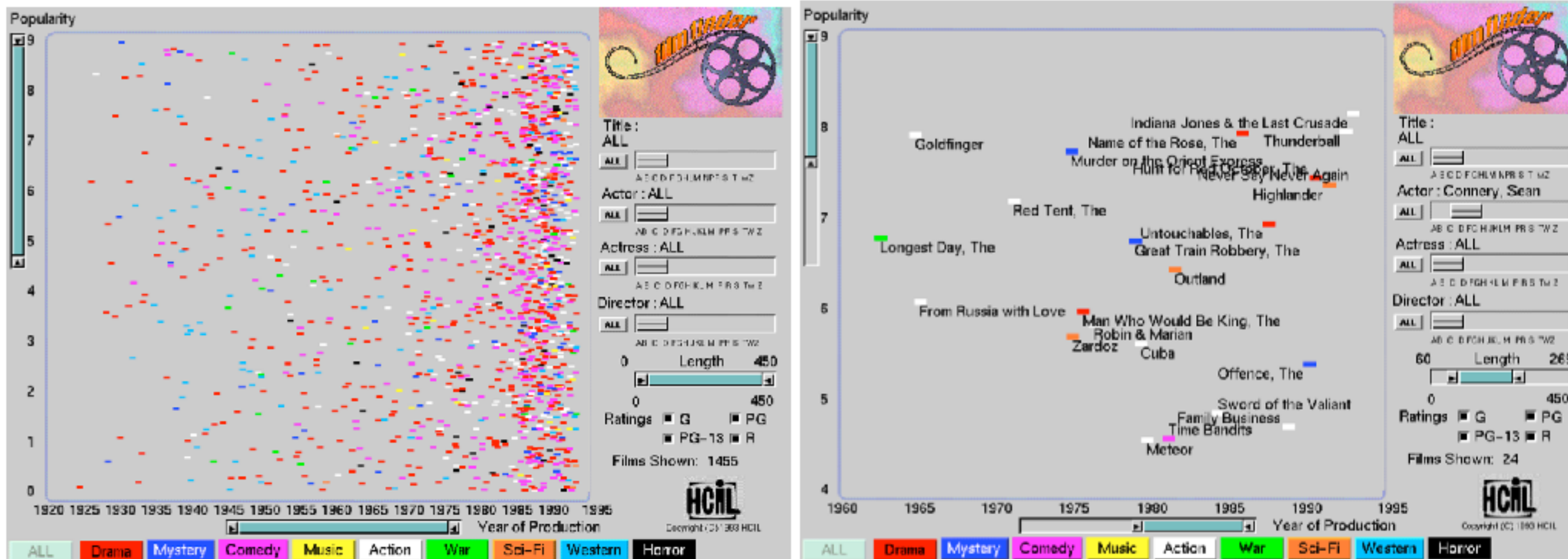


→ Attributes



Idiom: FilmFinder

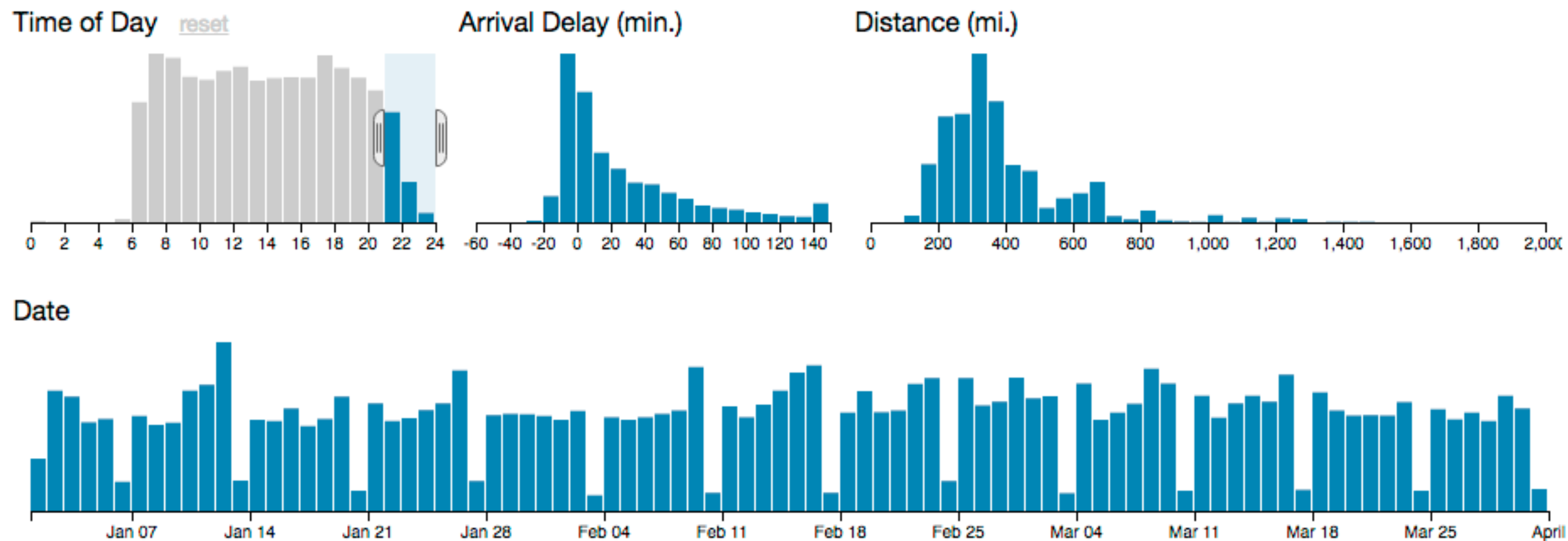
- dynamic queries/filters for items
 - tightly coupled interaction and visual encoding idioms, so user can immediately see results of action



Idiom: **cross filtering**

System: **Crossfilter**

- item filtering
- coordinated views/controls combined
 - all scented histogram bisliders update when any ranges change



<http://square.github.io/crossfilter/>

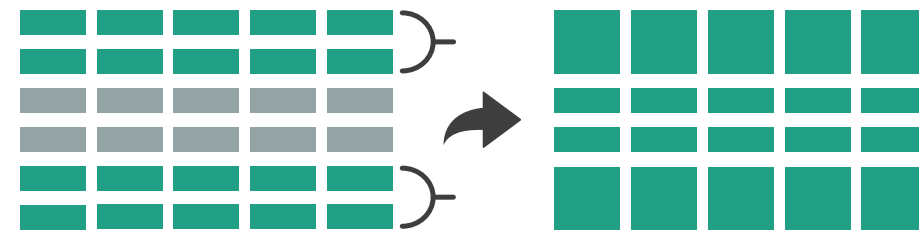
<https://observablehq.com/@uwdata/interaction>

Aggregate

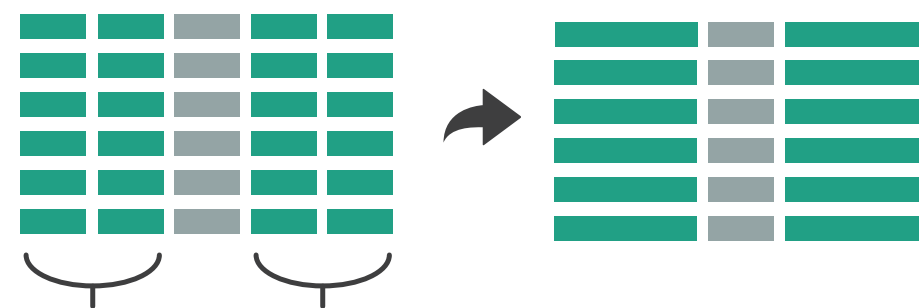
- a group of elements is represented by a smaller number of derived elements

➔ Aggregate

➔ Items

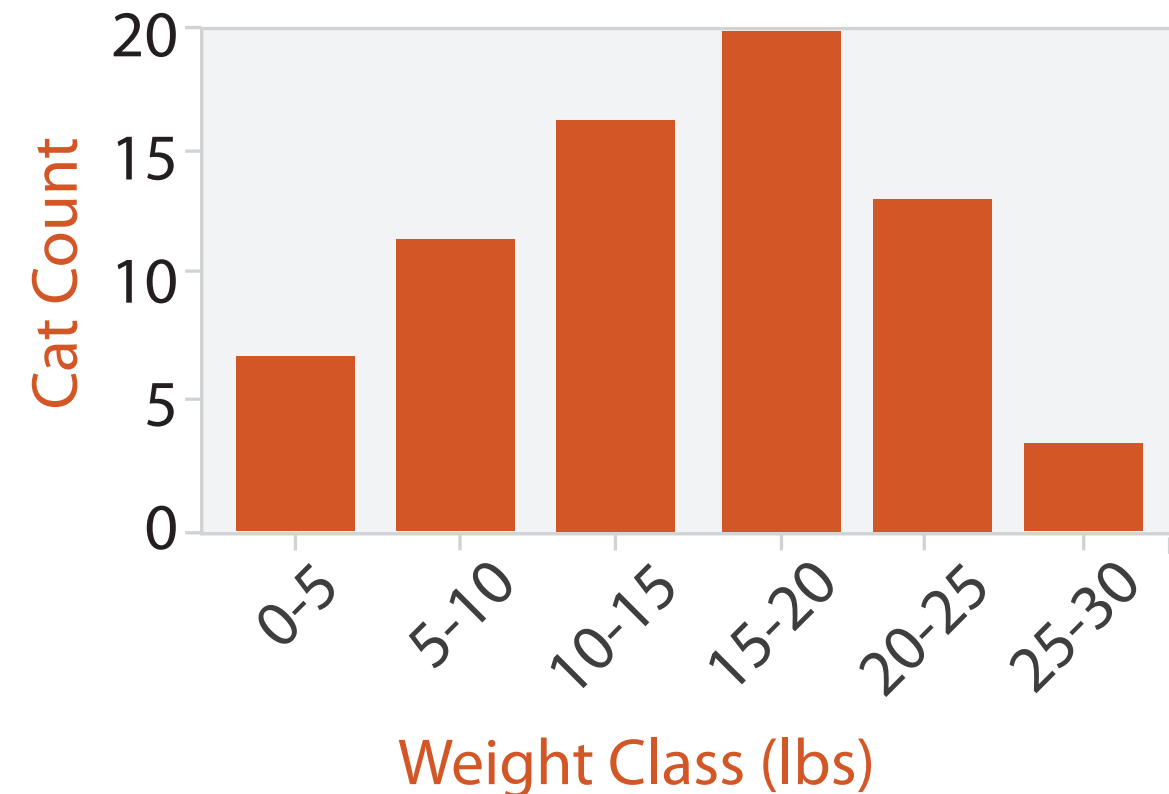


➔ Attributes



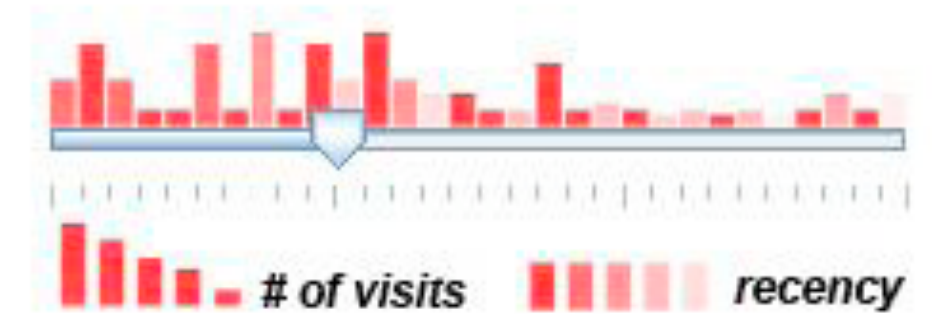
Idiom: **histogram**

- static item aggregation
- task: find distribution
- data: table
- derived data
 - new table: keys are bins, values are counts
- bin size crucial
 - pattern can change dramatically depending on discretization
 - opportunity for interaction: control bin size on the fly



Idiom: **scented widgets**

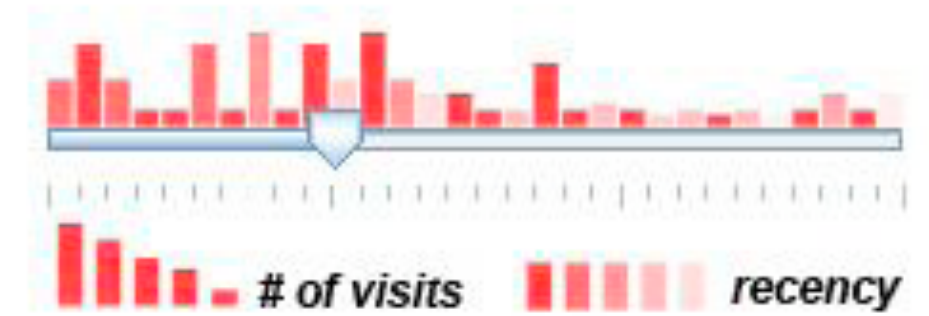
- augmented widgets show *information scent*
 - better cues for *information foraging*: show whether value in drilling down further vs looking elsewhere
- concise use of space: histogram on slider



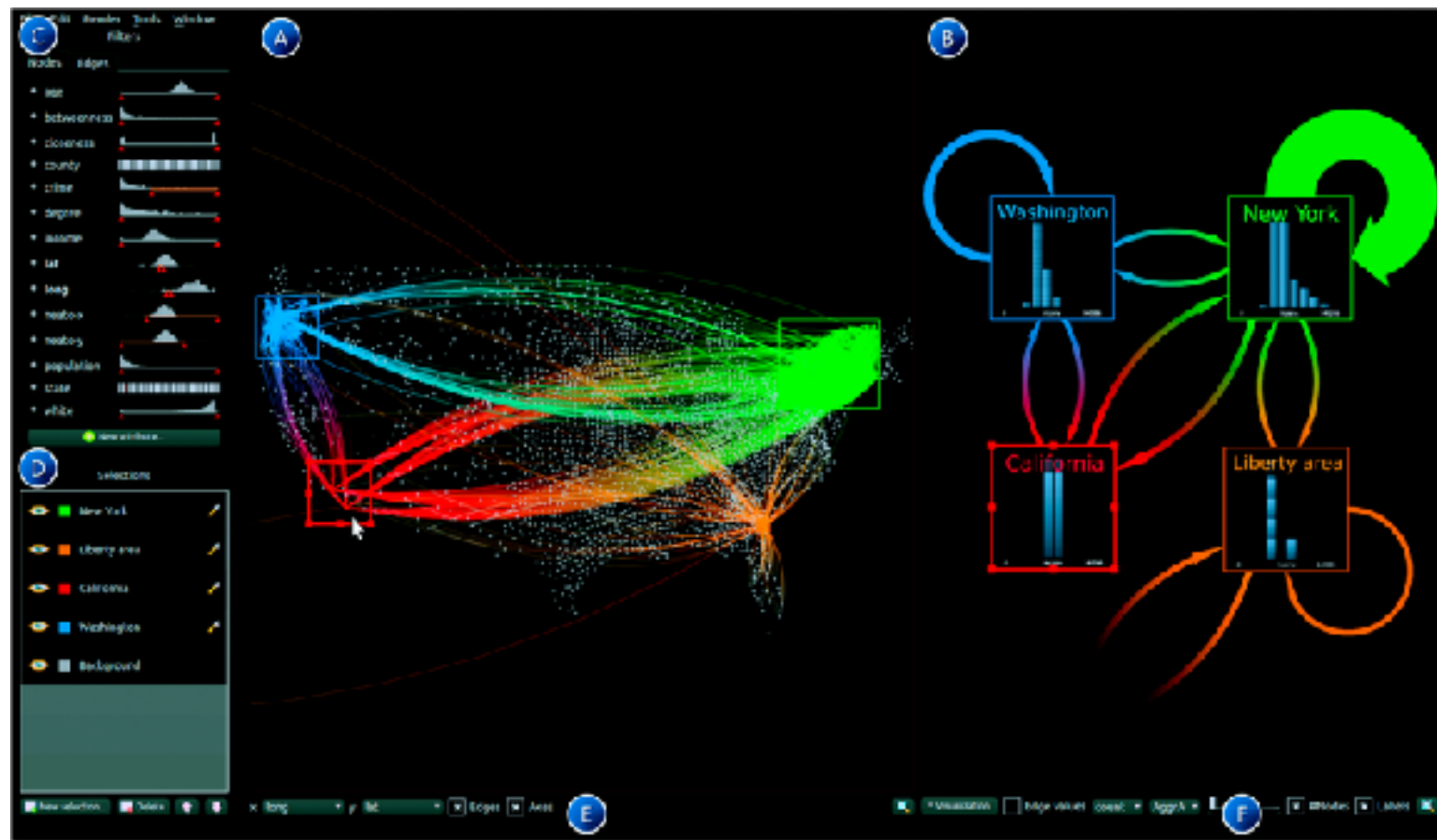
[Scented Widgets: Improving Navigation Cues with Embedded Visualizations. Willett, Heer, and Agrawala. IEEE TVCG (Proc. InfoVis 2007) 13:6 (2007), 1129–1136.]

Idiom: scented widgets

- augmented widgets show *information scent*
 - better cues for *information foraging*: show whether value in drilling down further vs looking elsewhere
- concise use of space: histogram on slider



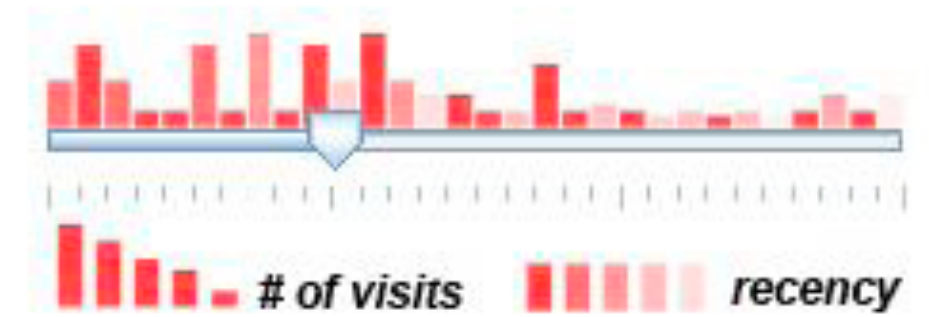
[Scented Widgets: Improving Navigation Cues with Embedded Visualizations. Willett, Heer, and Agrawala. IEEE TVCG (Proc. InfoVis 2007) 13:6 (2007), 1129–1136.]



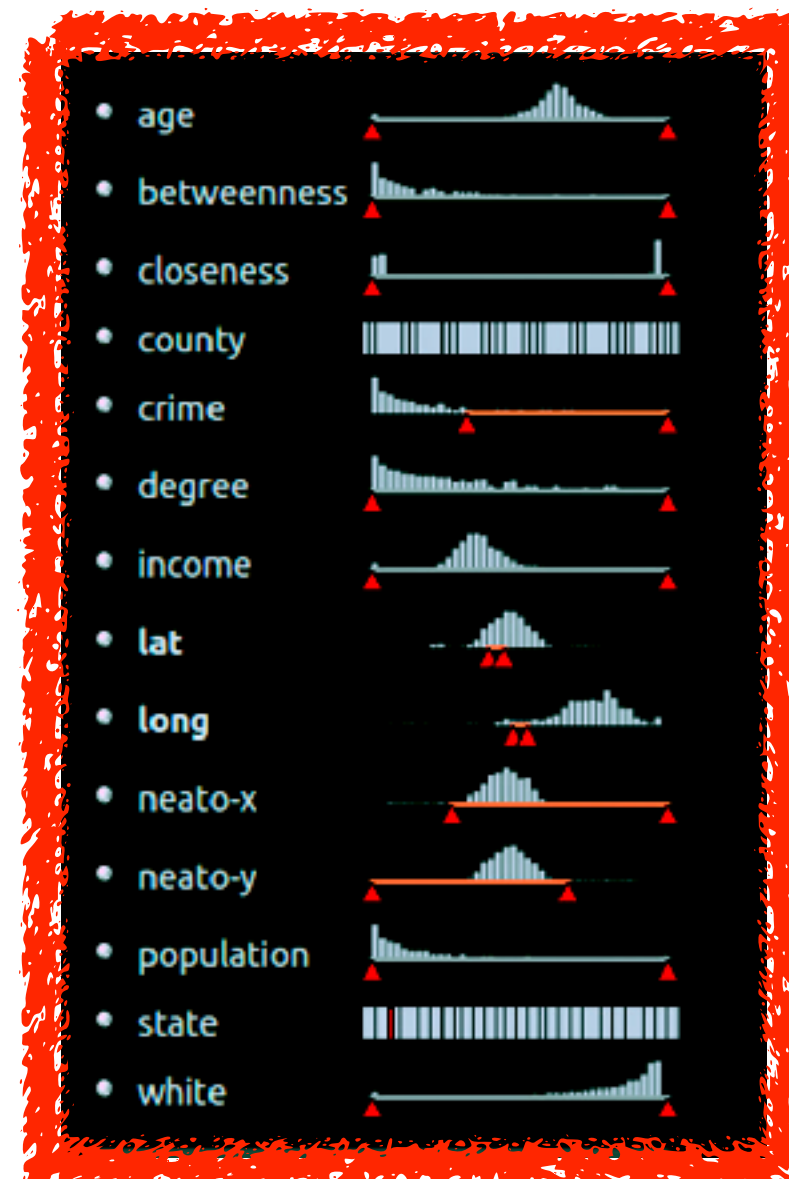
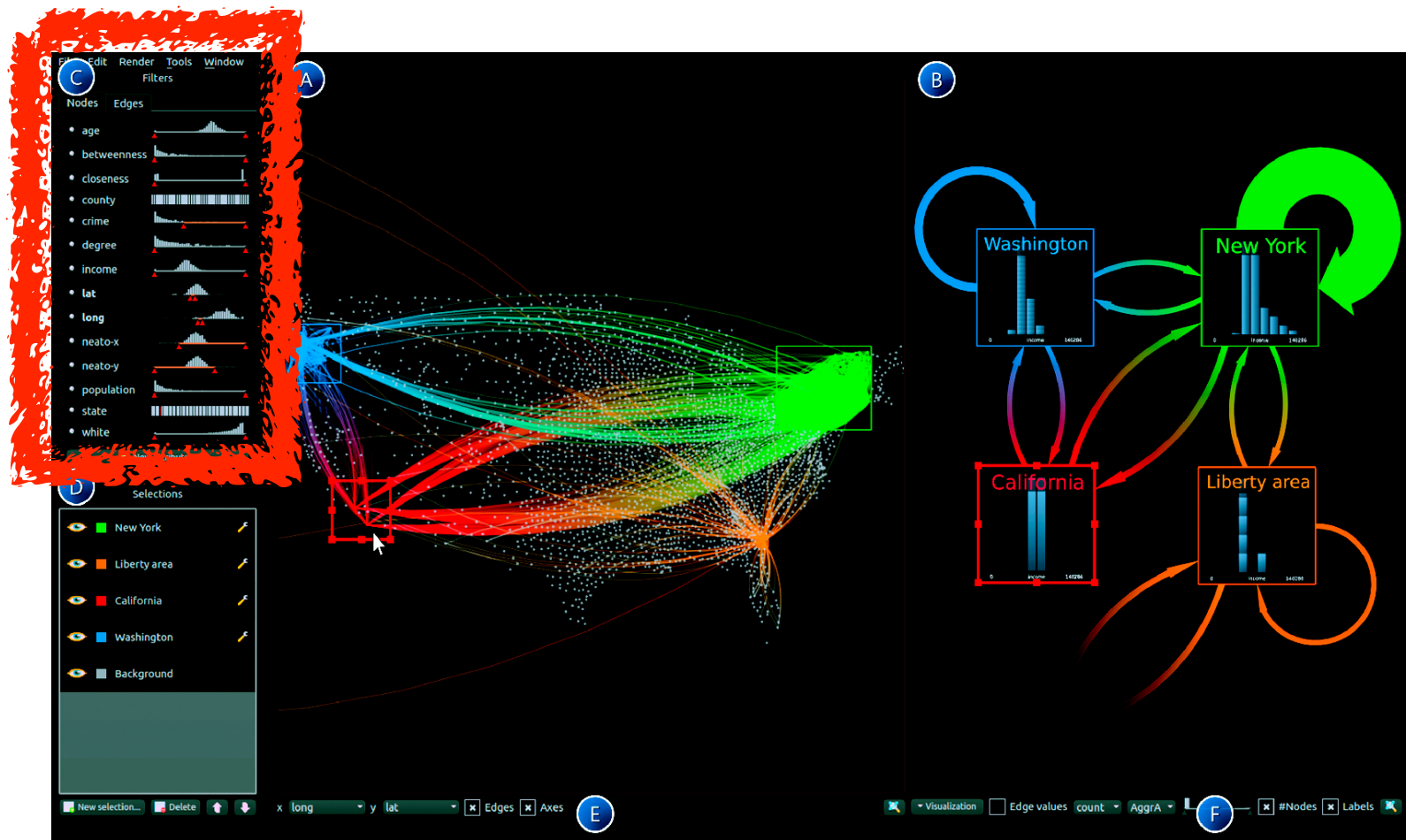
[Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations. van den Elzen, van Wijk, IEEE TVCG 20(12): 2014 (Proc. InfoVis 2014).]

Idiom: scented widgets

- augmented widgets show *information scent*
 - better cues for *information foraging*: show whether value in drilling down further vs looking elsewhere
- concise use of space: histogram on slider

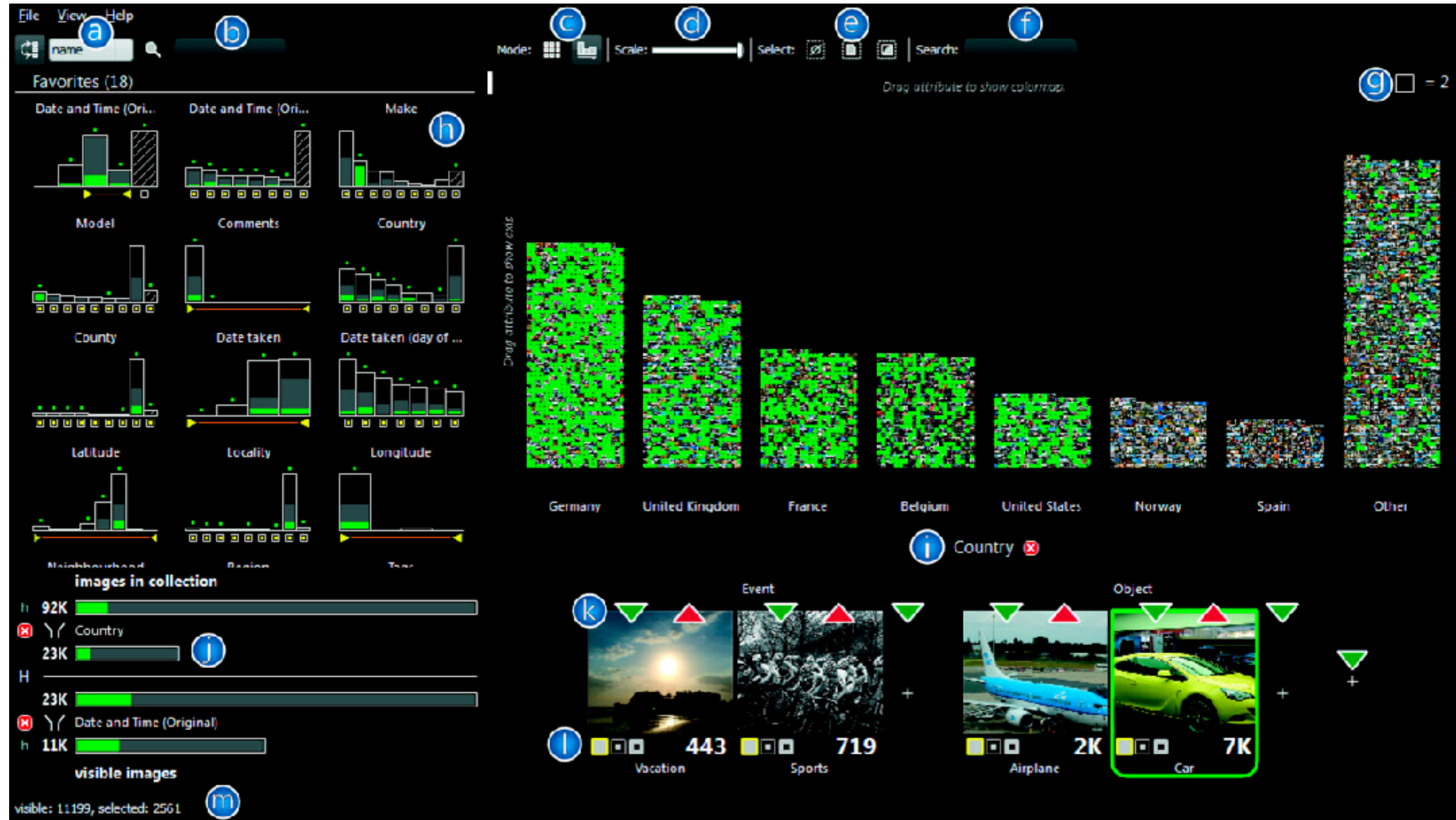


[Scented Widgets: Improving Navigation Cues with Embedded Visualizations. Willett, Heer, and Agrawala. IEEE TVCG (Proc. InfoVis 2007) 13:6 (2007), 1129–1136.]



[Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations. van den Elzen, van Wijk, IEEE TVCG 20(12): 2014 (Proc. InfoVis 2014).]

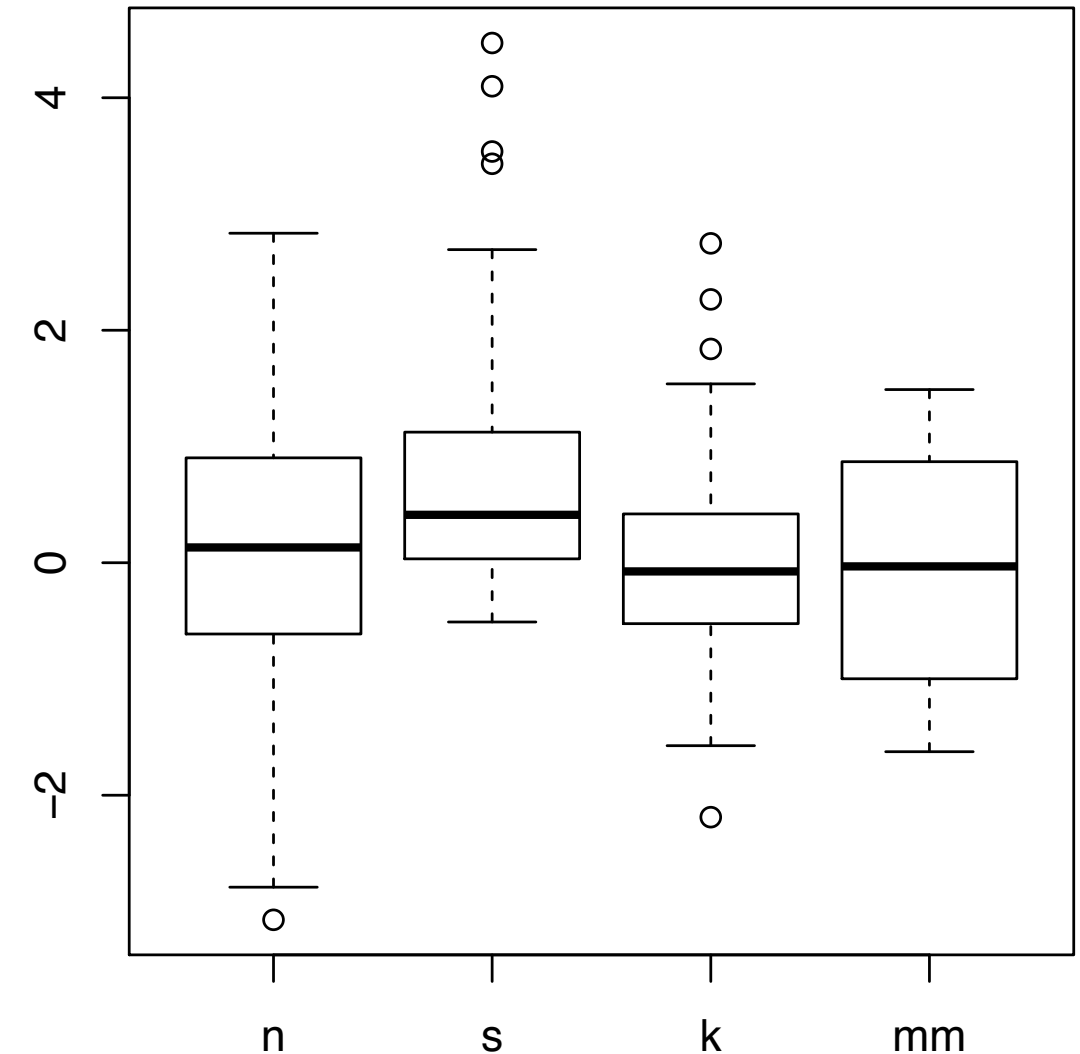
Scented histogram bisliders: detailed



[ICLIC: Interactive categorization of large image collections. van der Corput and van Wijk. Proc. PacificVis 2016.]

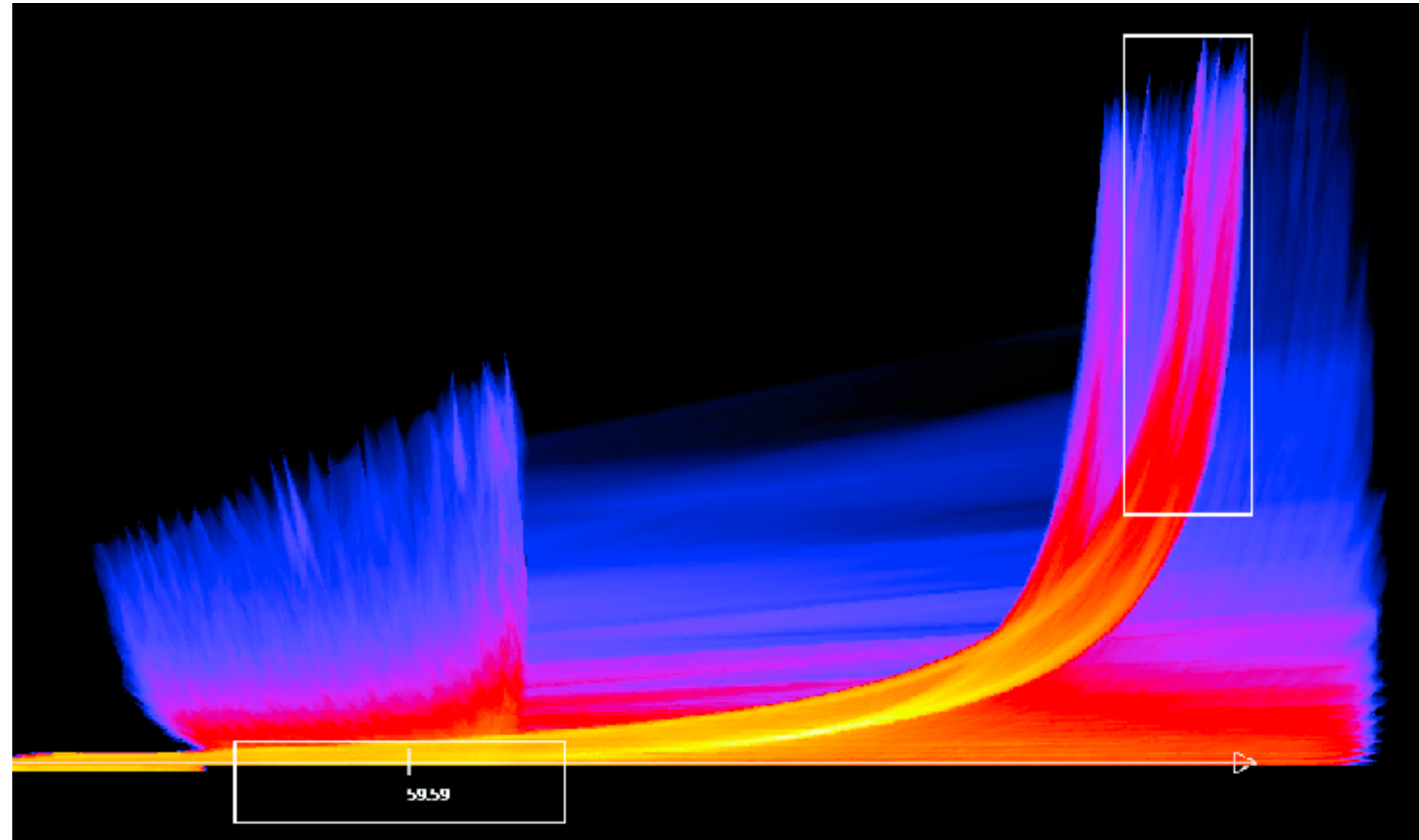
Idiom: **boxplot**

- static item aggregation
- task: find distribution
- data: table
- derived data
 - 5 quant attribs
 - median: central line
 - lower and upper quartile: boxes
 - lower upper fences: whiskers
 - values beyond which items are outliers
 - outliers beyond fence cutoffs explicitly shown
- scalability
 - unlimited number of items!



Idiom: Continuous scatterplot

- static item aggregation
- data: table
- derived data: table
 - key attribs x,y for pixels
 - quant attrib: overplot density
- dense space-filling 2D matrix
- color:
sequential categorical hue +
ordered luminance colormap
- scalability
 - no limits on overplotting:
millions of items



[Continuous Scatterplots. Bachthaler and Weiskopf.
IEEE TVCG (Proc. Vis 08) 14:6 (2008), 1428–1435. 2008.]

Spatial aggregation

- MAUP: Modifiable Areal Unit Problem

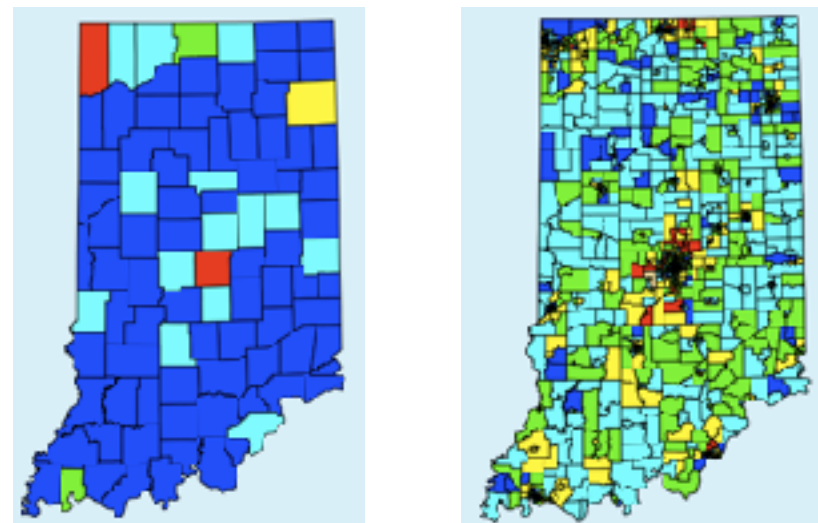
- changing boundaries of cartographic regions can yield dramatically different results

- zone effects



[http://www.e-education.psu.edu/geog486/l4_p7.html, Fig 4.cg.6]

- scale effects

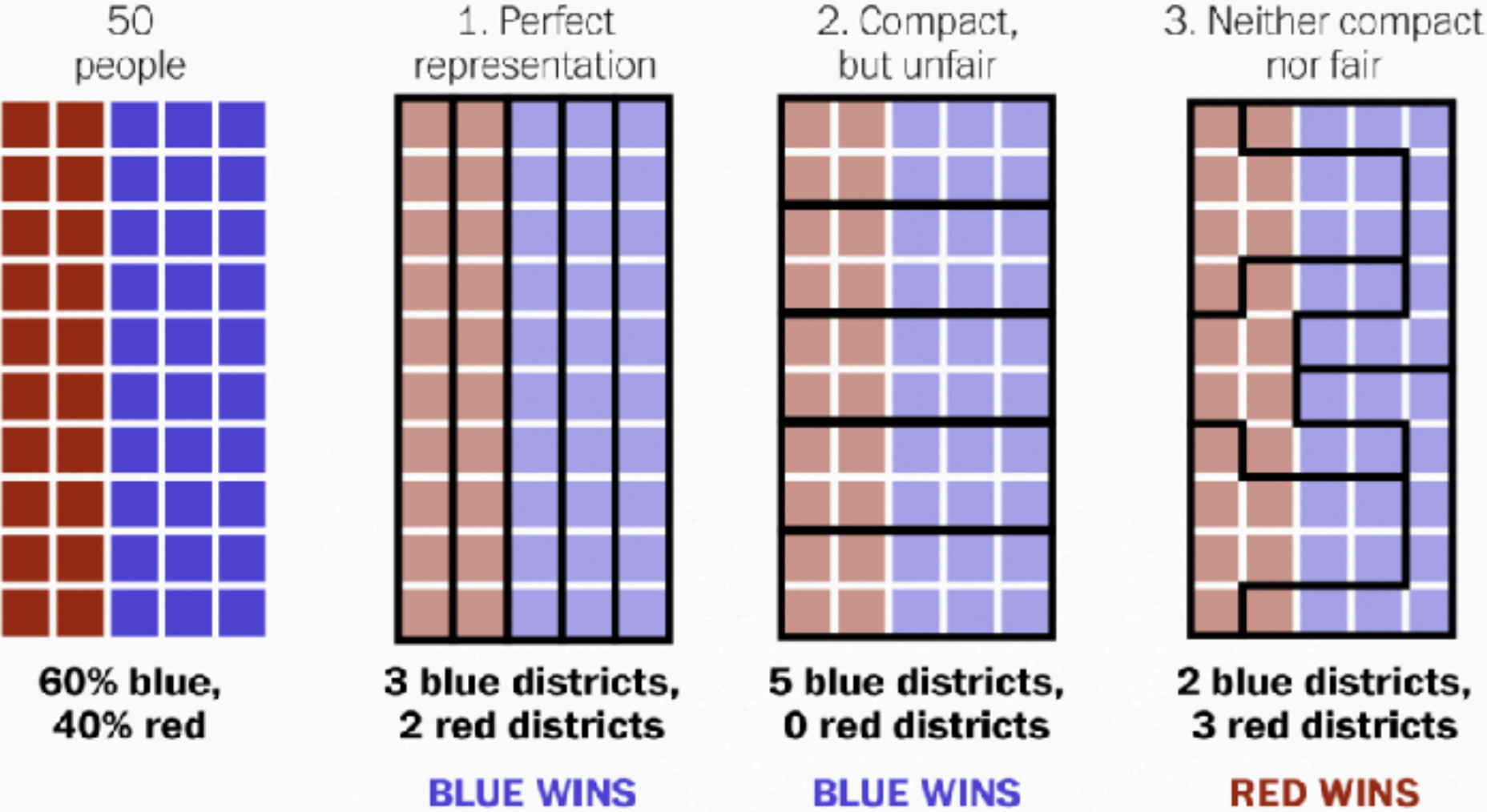


<https://blog.cartographica.com/blog/2011/5/19/the-modifiable-areal-unit-problem-in-gis.html>

Gerrymandering: MAUP for political gain

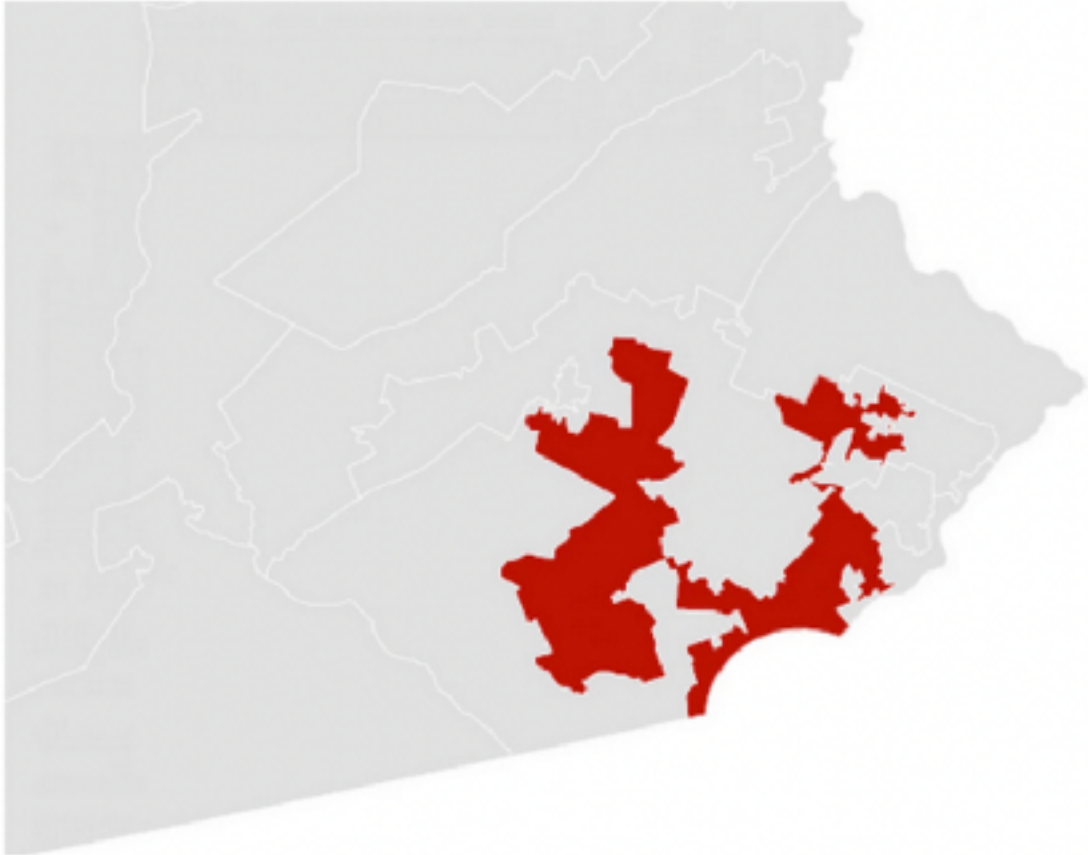
Gerrymandering, explained

Three different ways to divide 50 people into five districts



WASHINGTONPOST.COM/WONKBLOG

Adapted from Stephen Nass



A real district in Pennsylvania:
Democrats won 51% of the vote but only 5 out of 18 house seats

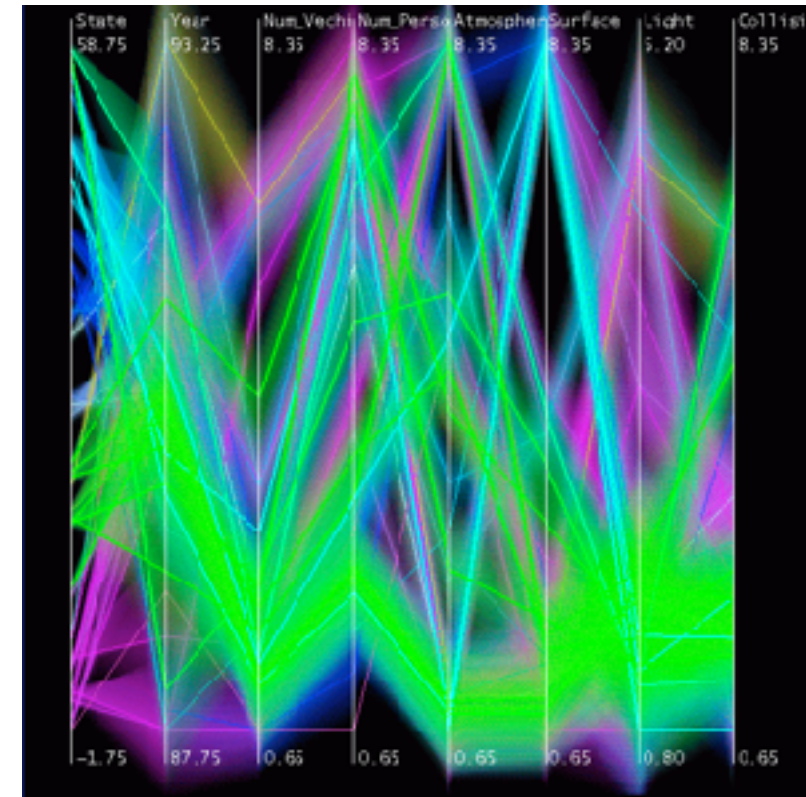
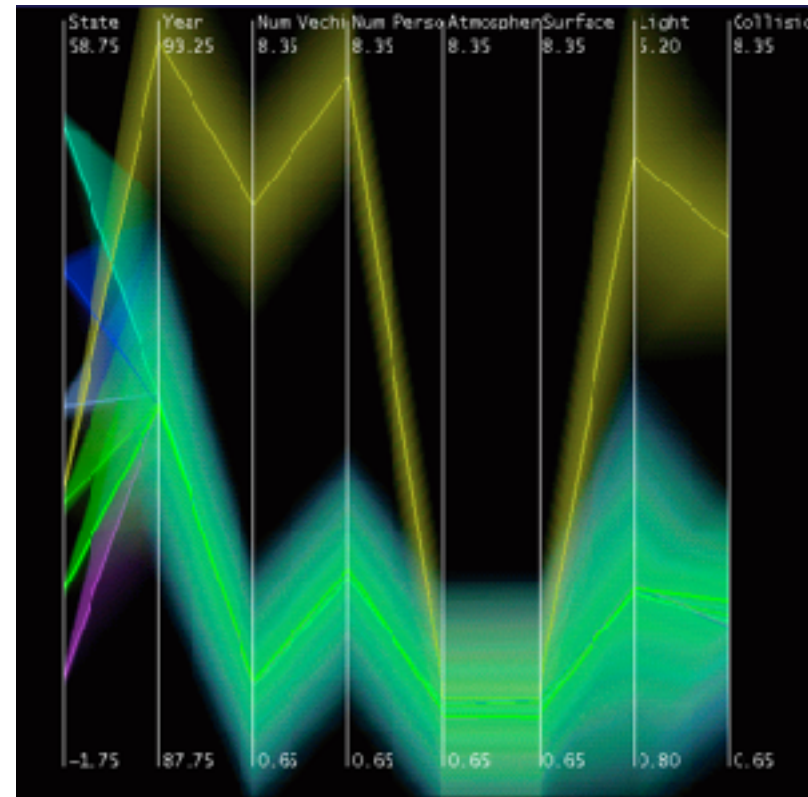
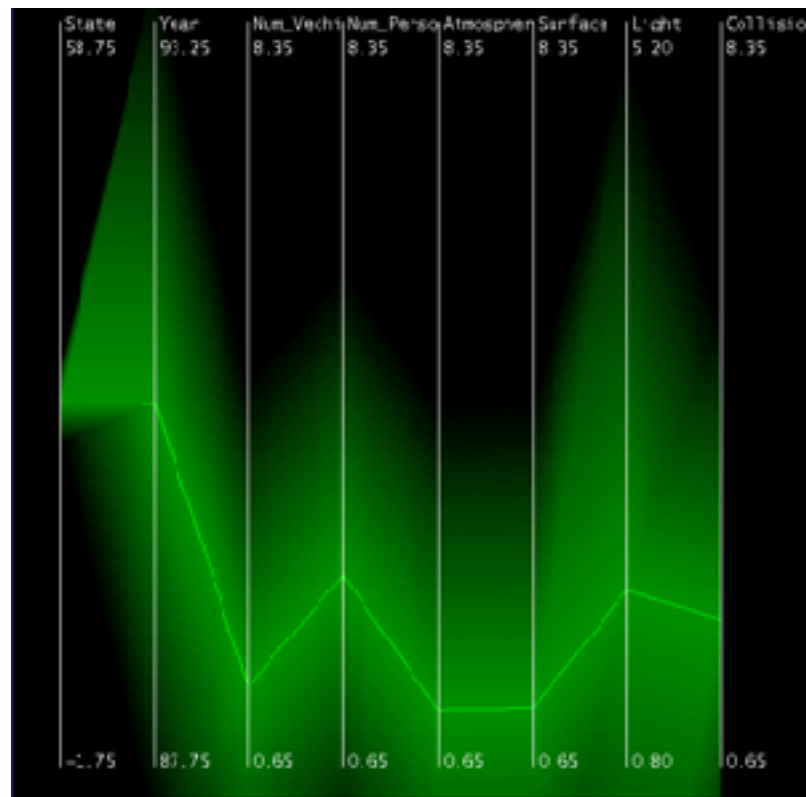
<https://www.washingtonpost.com/news/wonk/wp/2015/03/01/this-is-the-best-explanation-of-gerrymandering-you-will-ever-see/>

Dynamic aggregation: Clustering

- **clustering: classification of items into similar bins**
 - based on similarity measure
 - hierarchical algorithms produce "similarity tree": cluster hierarchy
 - agglomerative clustering: start w/ each node as own cluster, then iteratively merge
- **cluster hierarchy: derived data used w/ many dynamic aggregation idioms**
 - cluster more homogeneous than whole dataset
 - statistical measures & distribution more meaningful

Idiom: Hierarchical parallel coordinates

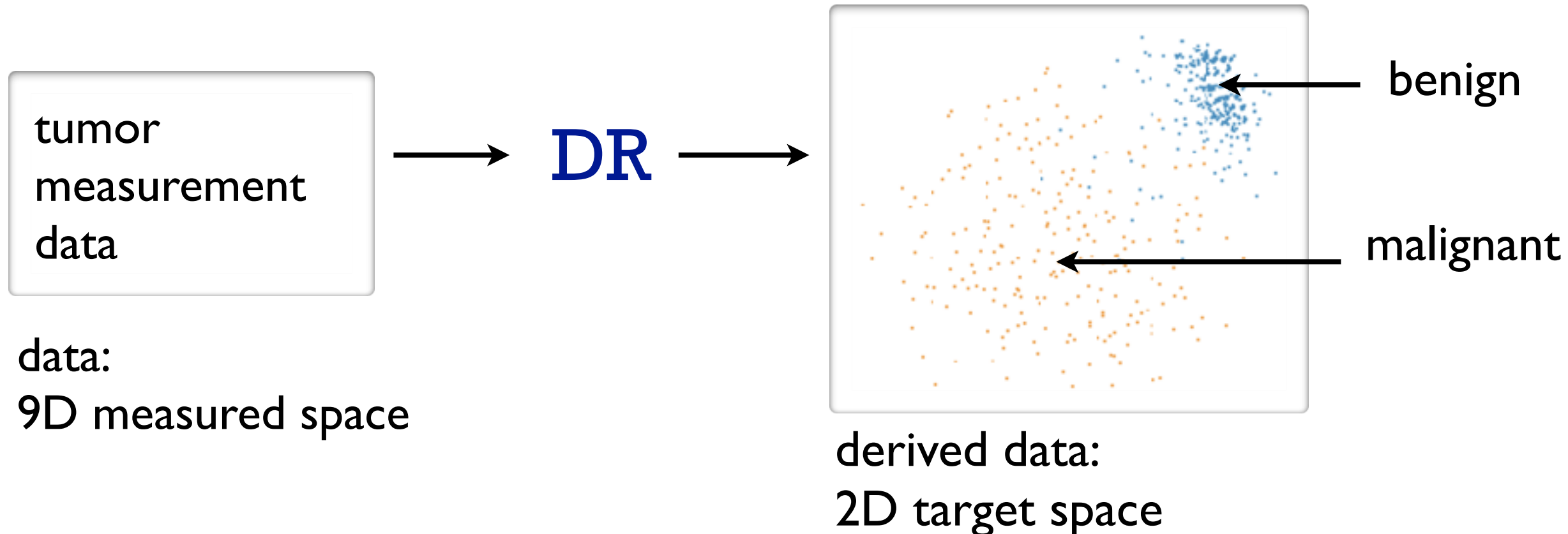
- dynamic item aggregation
- derived data: **cluster hierarchy**
- encoding:
 - cluster band with variable transparency, line at mean, width by min/max values
 - color by proximity in hierarchy



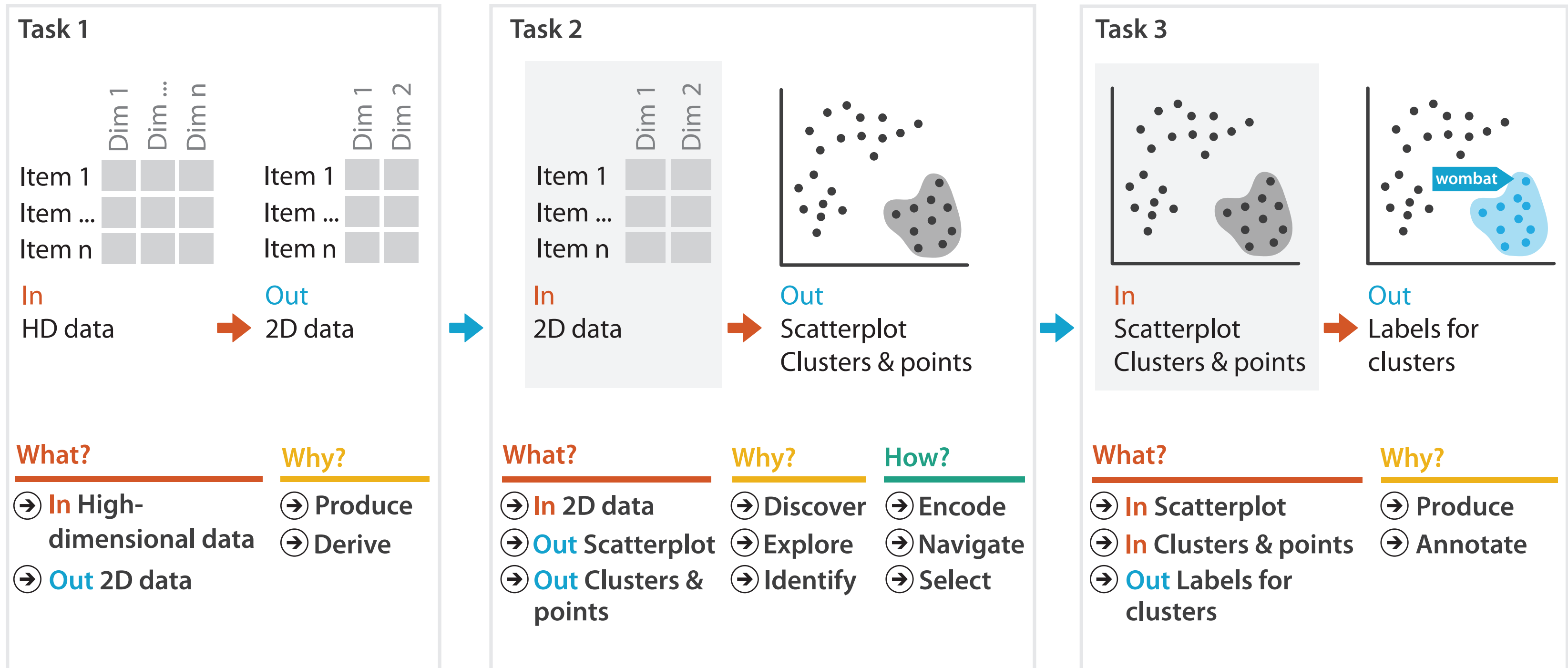
[Hierarchical Parallel Coordinates for Exploration of Large Datasets. Fua, Ward, and Rundensteiner. Proc. IEEE Visualization Conference (Vis '99), pp. 43– 50, 1999.]

Attribute aggregation: Dimensionality reduction

- attribute aggregation
 - derive low-dimensional target space from high-dimensional measured space
 - capture most of variance with minimal error
 - use when you can't directly measure what you care about
 - true dimensionality of dataset conjectured to be smaller than dimensionality of measurements
 - latent factors, hidden variables



Idiom: Dimensionality reduction for documents



How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



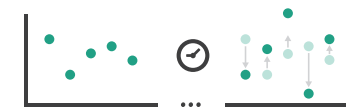
→ Motion

Direction, Rate, Frequency, ...

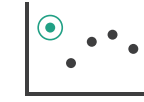


Manipulate

→ Change



→ Select

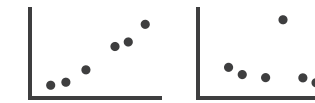


→ Navigate

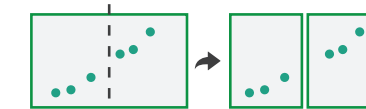


Facet

→ Juxtapose



→ Partition



→ Superimpose

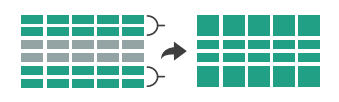


Reduce

→ Filter



→ Aggregate



→ Embed



What?

Why?

How?

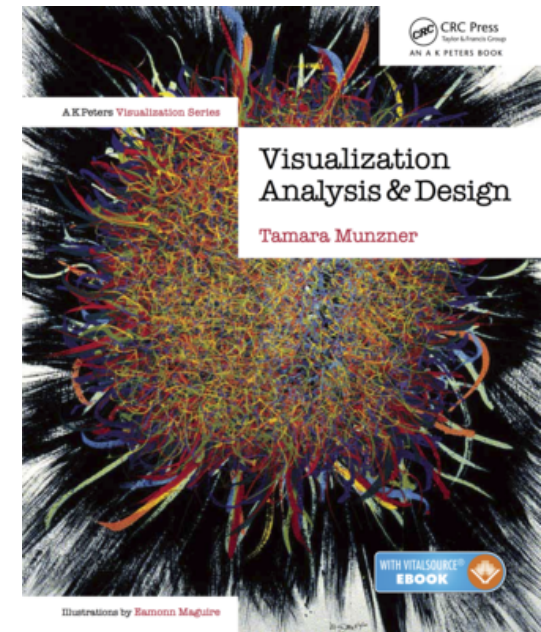
Visualization Analysis & Design

Embed: Focus+Context (Ch 14)

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)



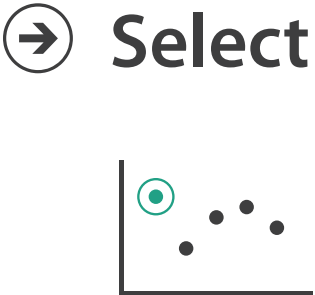
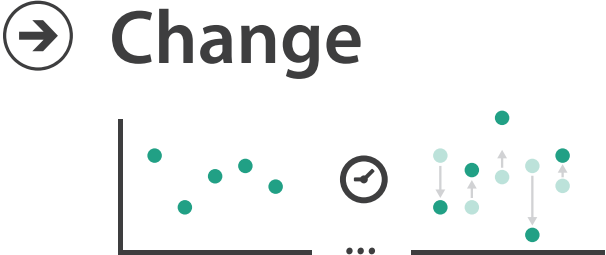
How to handle complexity: 4 strategies

→ *Derive*

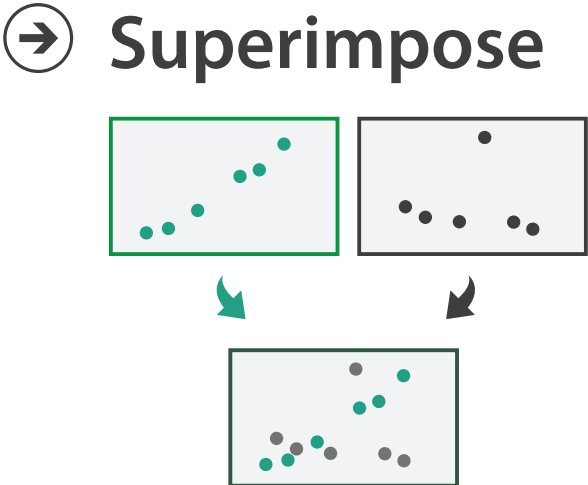
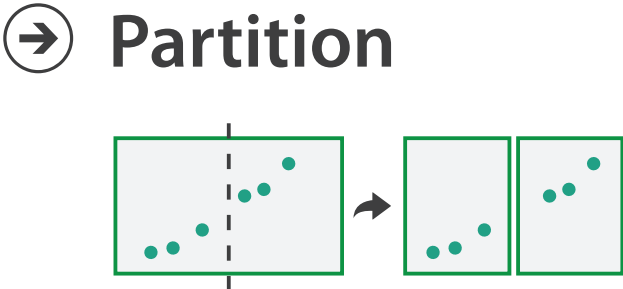


- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

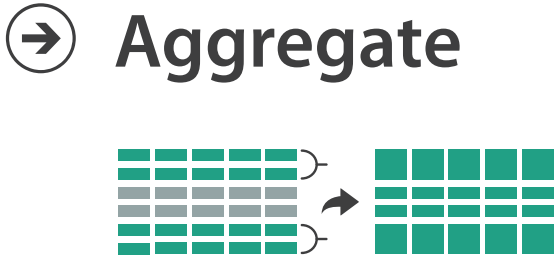
Manipulate



Facet



Reduce



Embed: Focus+Context

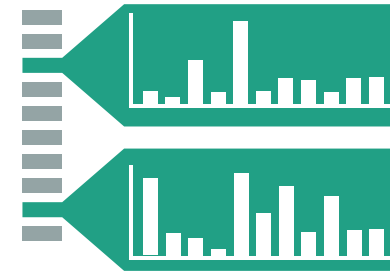
- combine focus + context info within single view
 - vs standard navigation within view
 - vs multiple views

Embed: Focus+Context

- combine focus + context info within single view
 - vs standard navigation within view
 - vs multiple views
- elide data
 - selectively filter and aggregate

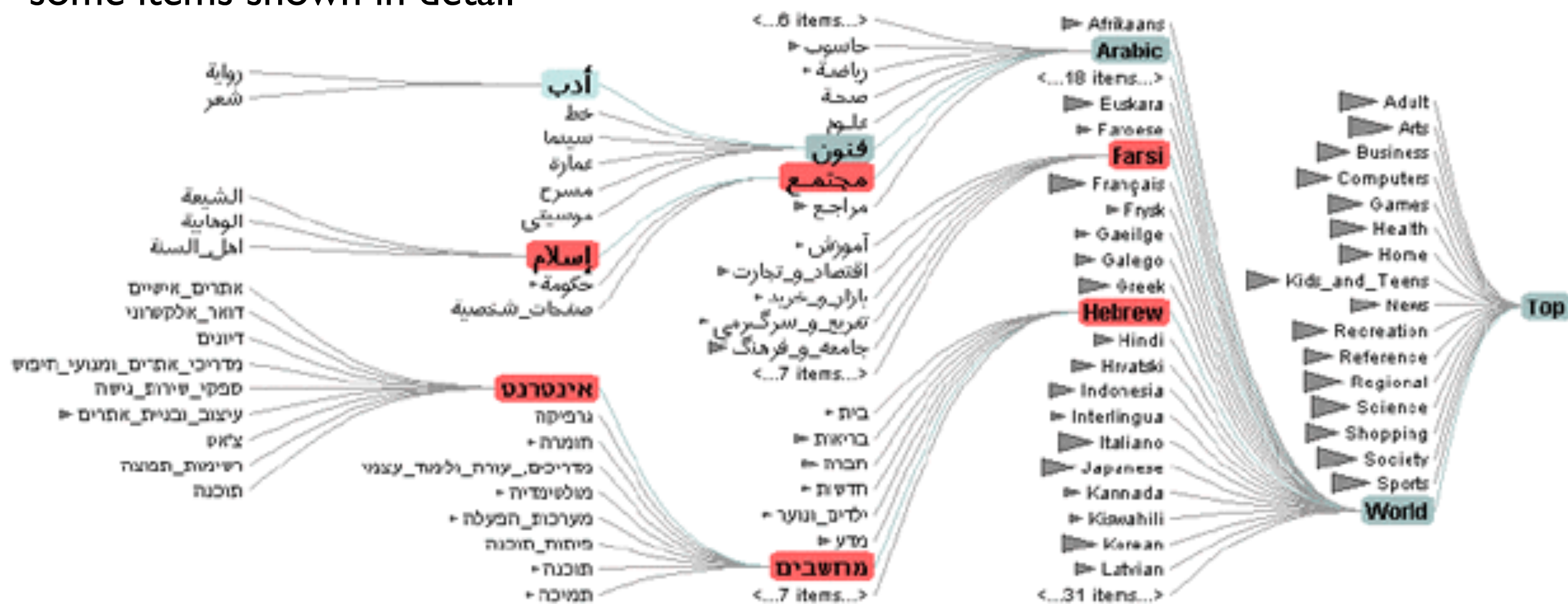
➔ Embed

➔ Elide Data



Idiom: **DOITrees Revisited**

- focus+context choice: elide
 - some items dynamically filtered out
 - some items dynamically aggregated together
 - some items shown in detail



[DOITrees Revisited: Scalable, Space-Constrained Visualization of Hierarchical Data. Heer and Card. Proc. Advanced Visual Interfaces (AVI), pp. 421–424, 2004.]

Embed: Focus+Context

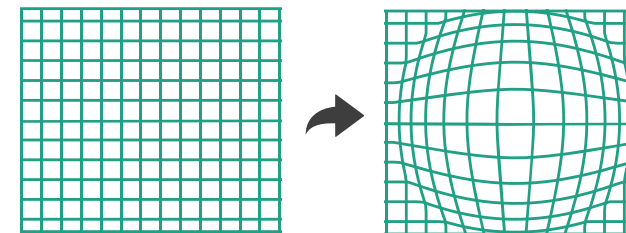
- combine focus + context info within single view
 - vs standard navigation within view
 - vs multiple views
- elide data
 - selectively filter and aggregate
- distort geometry
 - carefully chosen to integrate F+C

→ Embed

→ Elide Data

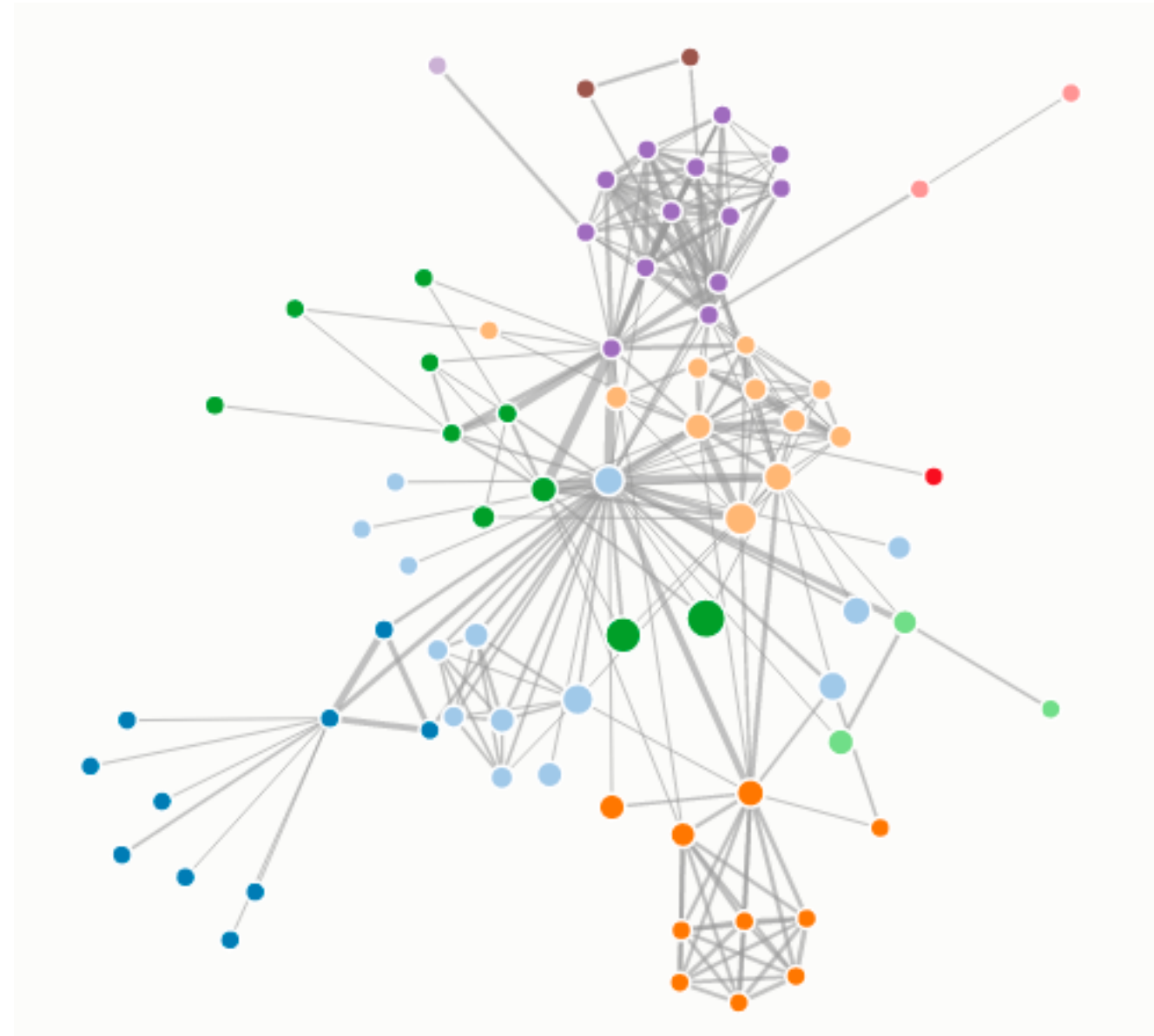


→ Distort Geometry



Idiom: **Fisheye Lens**

- F+C choice: distort geometry
 - shape: radial
 - focus: single extent
 - extent: local
 - metaphor: draggable lens



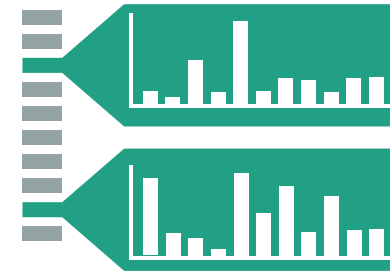
[D3 Fisheye Lens] <https://bost.ocks.org/mike/fisheye/>

Embed: Focus+Context

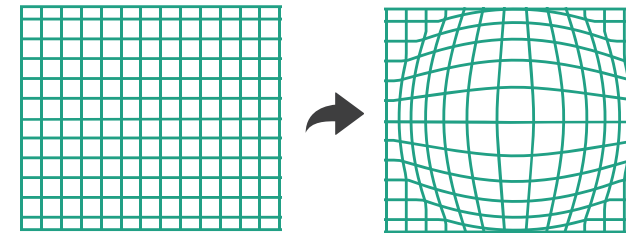
- combine focus + context info within single view
 - vs standard navigation within view
 - vs multiple views
- elide data
 - selectively filter and aggregate
- distort geometry:
design choices
 - region shape: radial, rectilinear, complex
 - how many regions: one, many
 - region extent: local, global
 - interaction metaphor

→ Embed

→ Elide Data



→ Distort Geometry



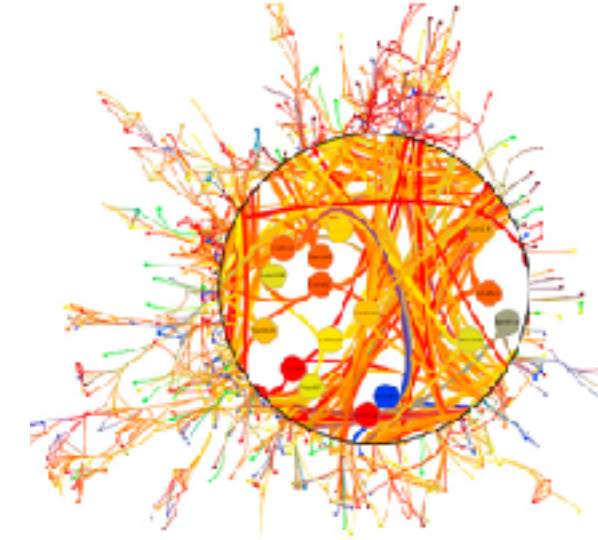
Distortion costs and benefits

- **benefits**
 - combine focus and context information in single view
- **costs**
 - length comparisons impaired
 - topology comparisons unaffected: connection, containment
 - effects of distortion unclear if original structure unfamiliar
 - object constancy/tracking may be impaired

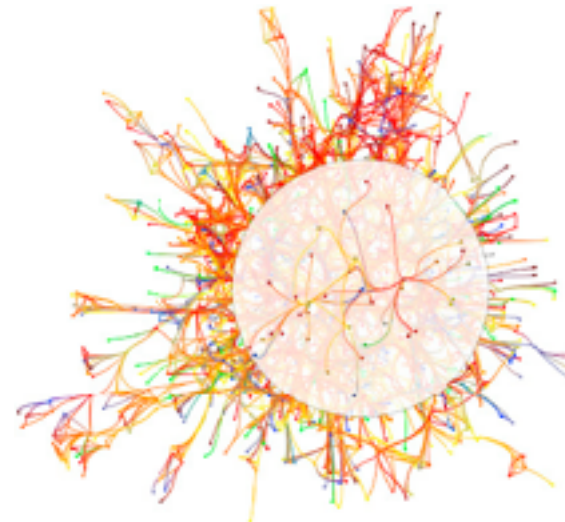
fisheye lens



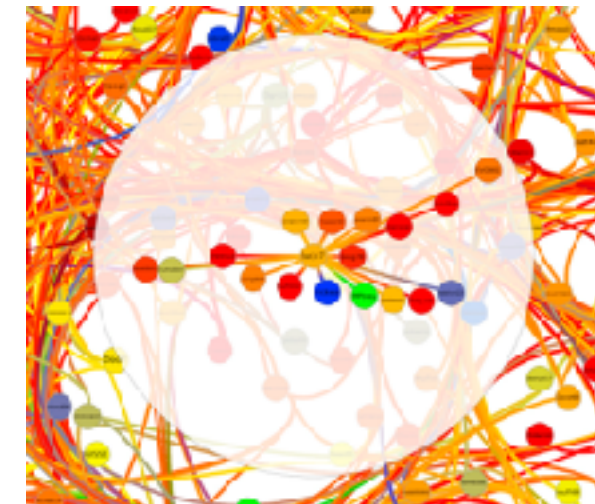
magnifying lens



neighborhood layering



Bring and Go



How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



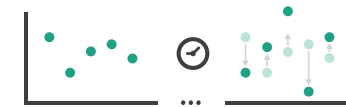
→ Motion

Direction, Rate, Frequency, ...

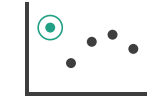


Manipulate

→ Change



→ Select

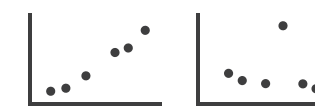


→ Navigate

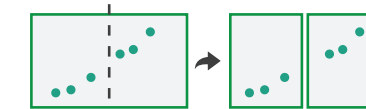


Facet

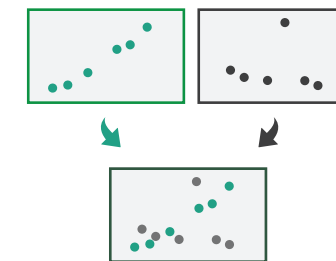
→ Juxtapose



→ Partition



→ Superimpose



Reduce

→ Filter



→ Aggregate



→ Embed



What?

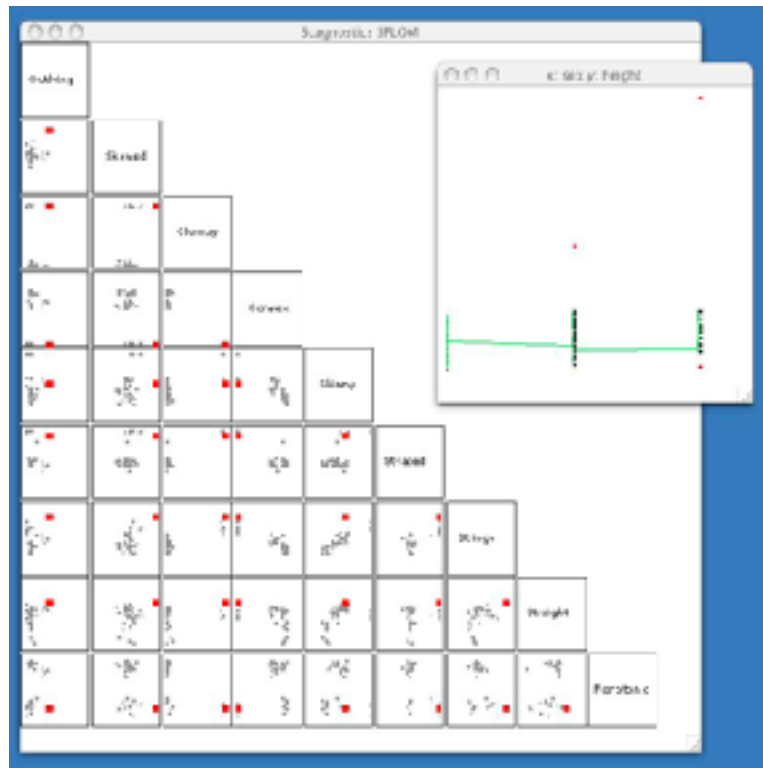
Why?

How?

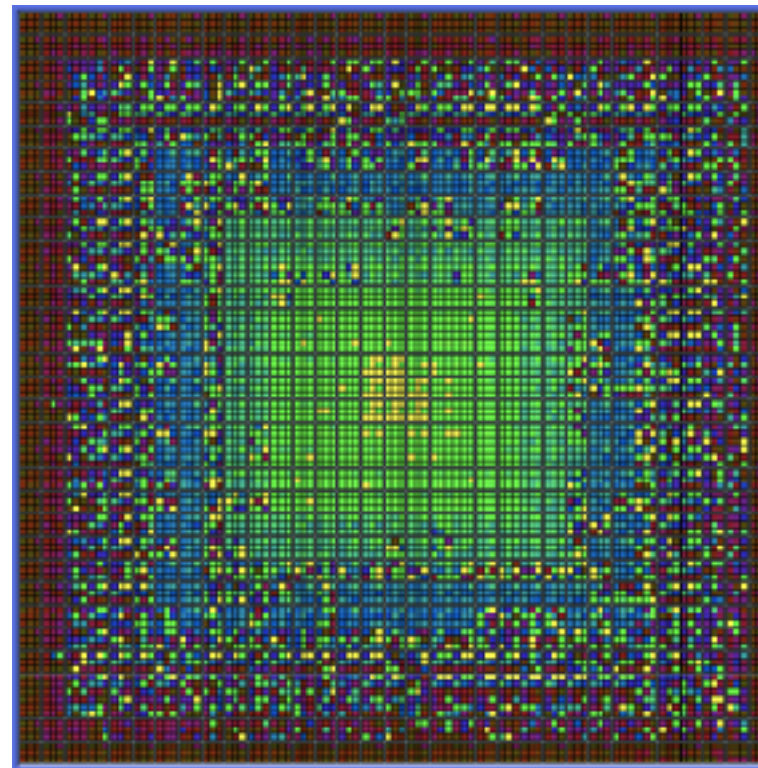
Ch 15: Analysis Case Studies

Analysis Case Studies

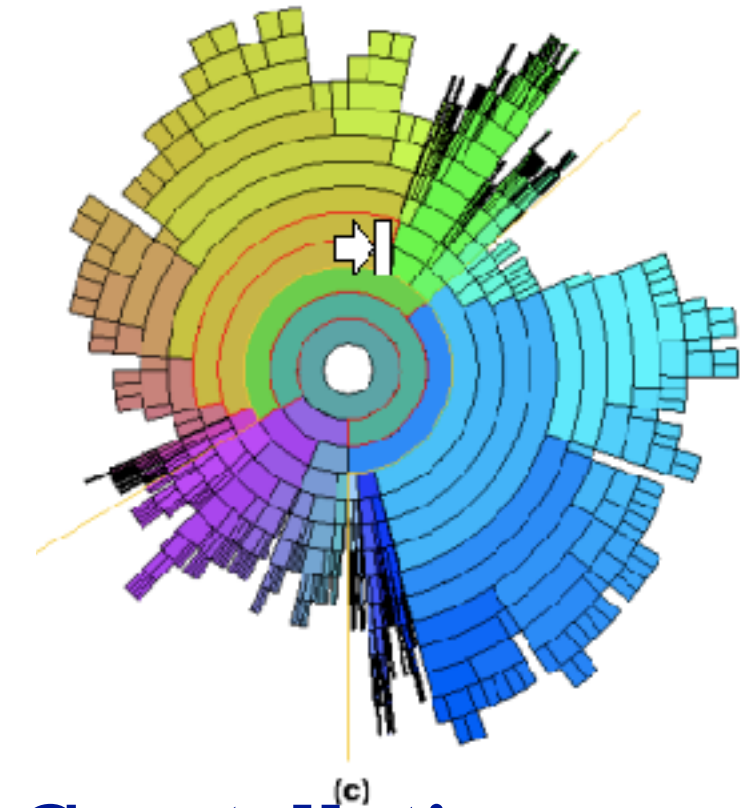
Scagnostics



VisDB



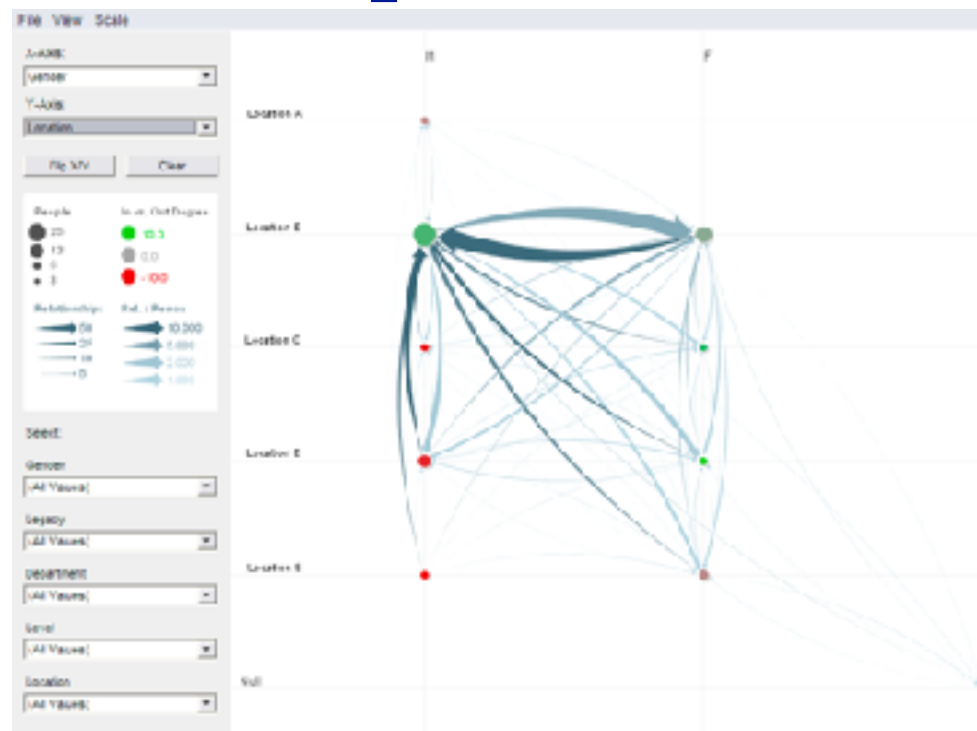
InterRing



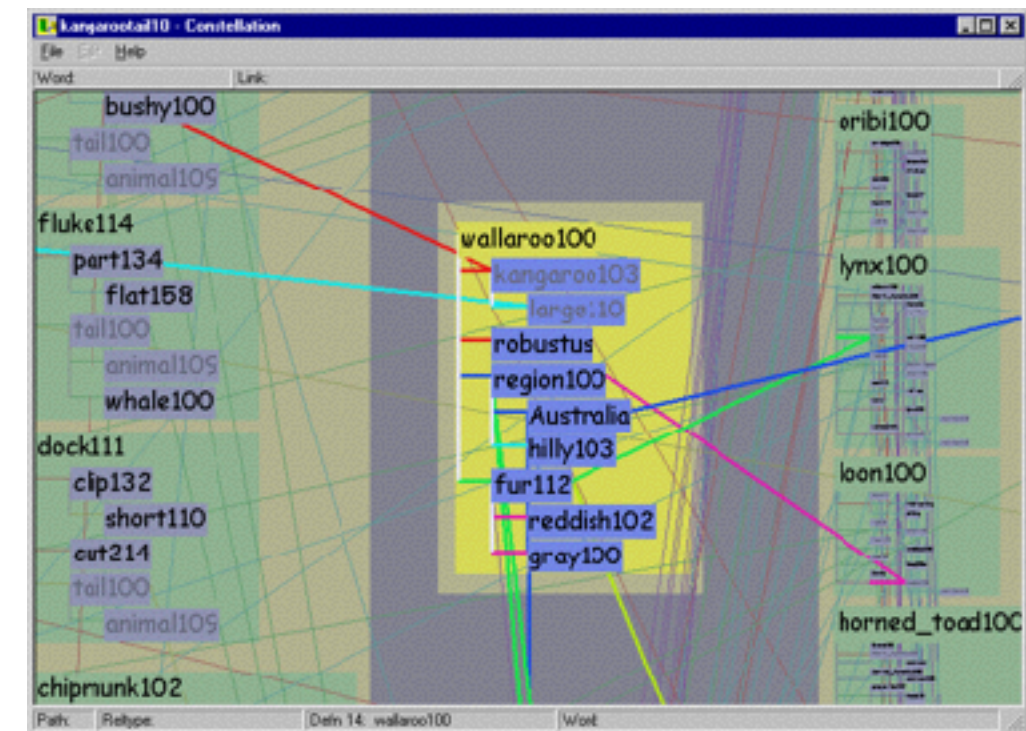
HCE



PivotGraph

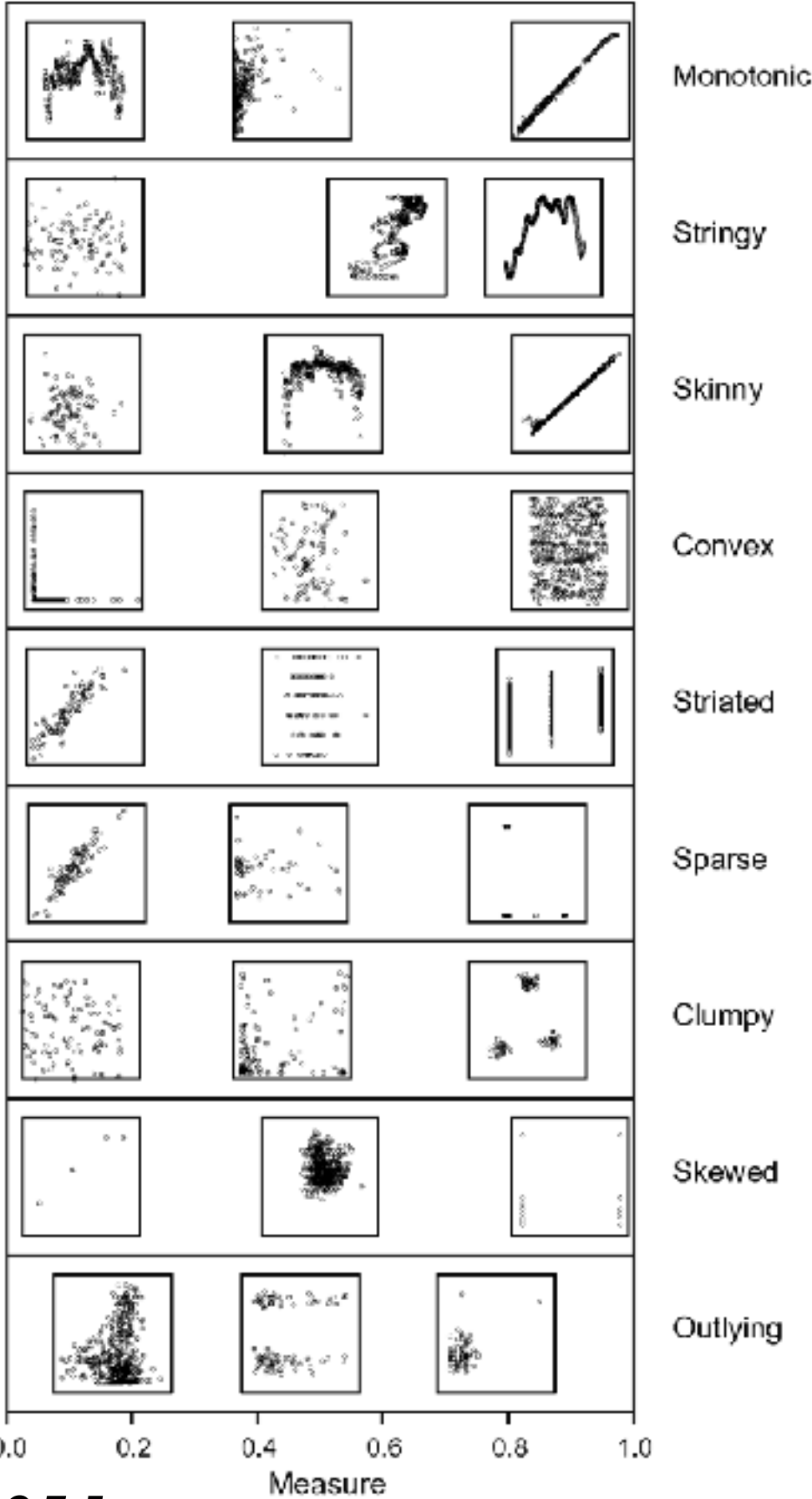
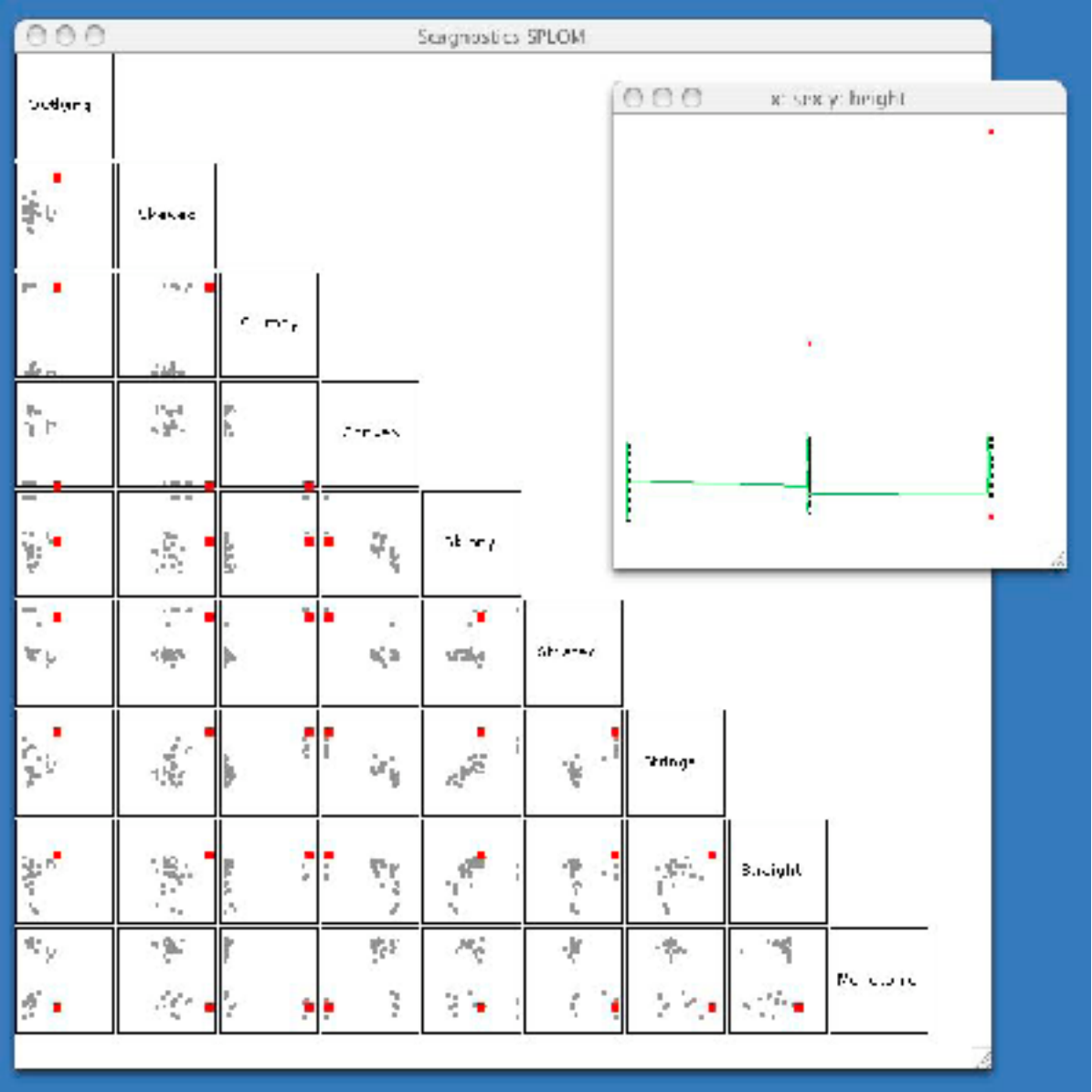


Constellation



Graph-Theoretic Scagnostics

- scatterplot diagnostics
 - scagnostics SPLOM: each point is one original scatterplot



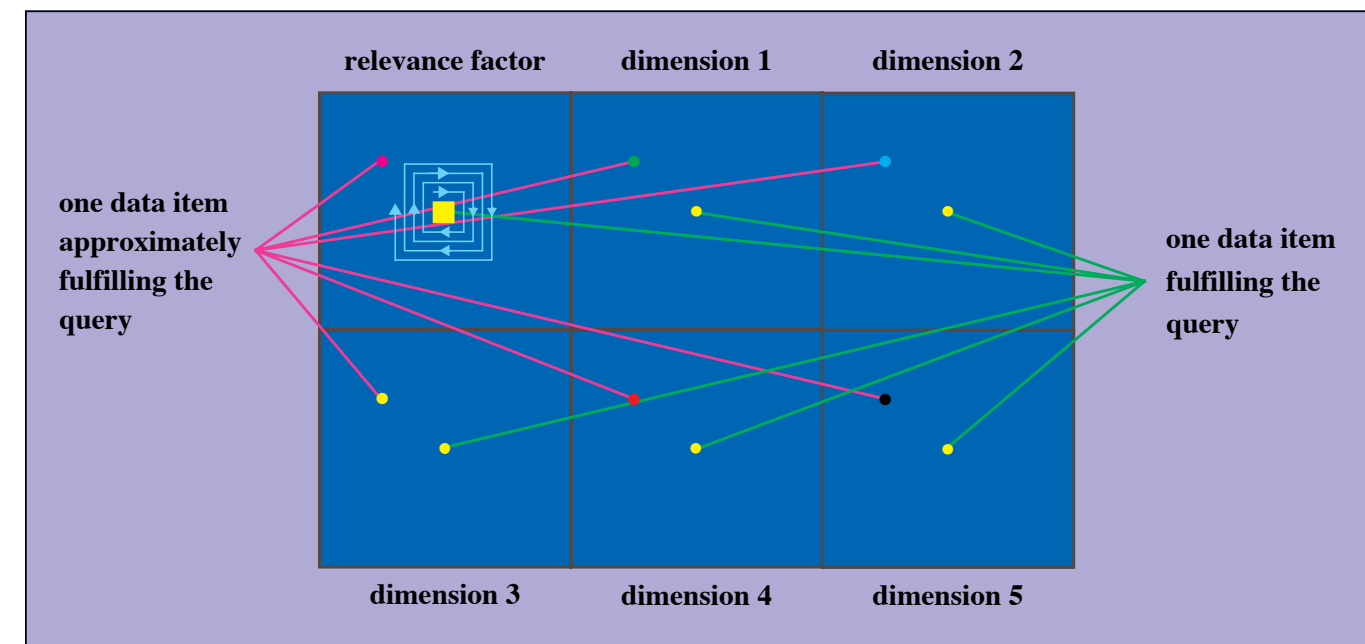
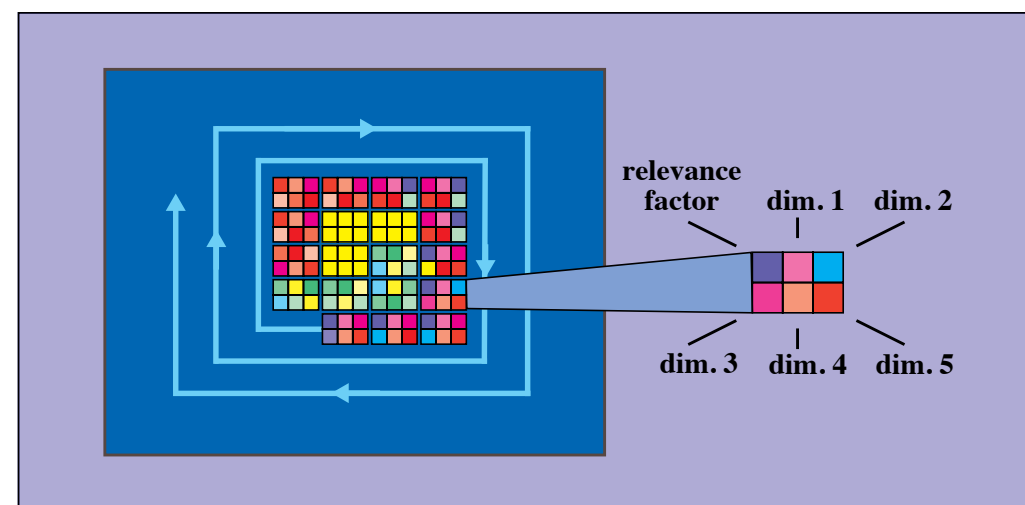
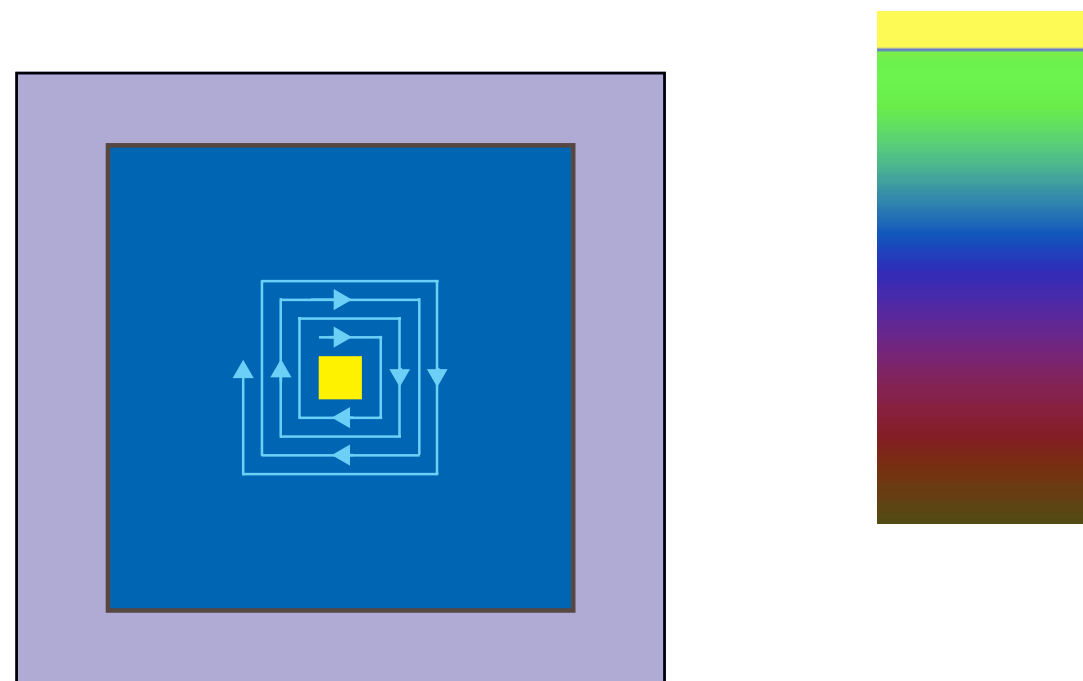
[Graph-Theoretic Scagnostics Wilkinson, Anand, and Grossman. Proc InfoVis 05.]

Scagnostics analysis

System	Scagnostics
What: Data	Table.
What: Derived	Nine quantitative attributes per scatterplot (pairwise combination of original attributes).
Why: Tasks	Identify, compare, and summarize; distributions and correlation.
How: Encode	Scatterplot, scatterplot matrix.
How: Manipulate	Select.
How: Facet	Juxtaposed small-multiple views coordinated with linked highlighting, popup detail view.
Scale	Original attributes: dozens.

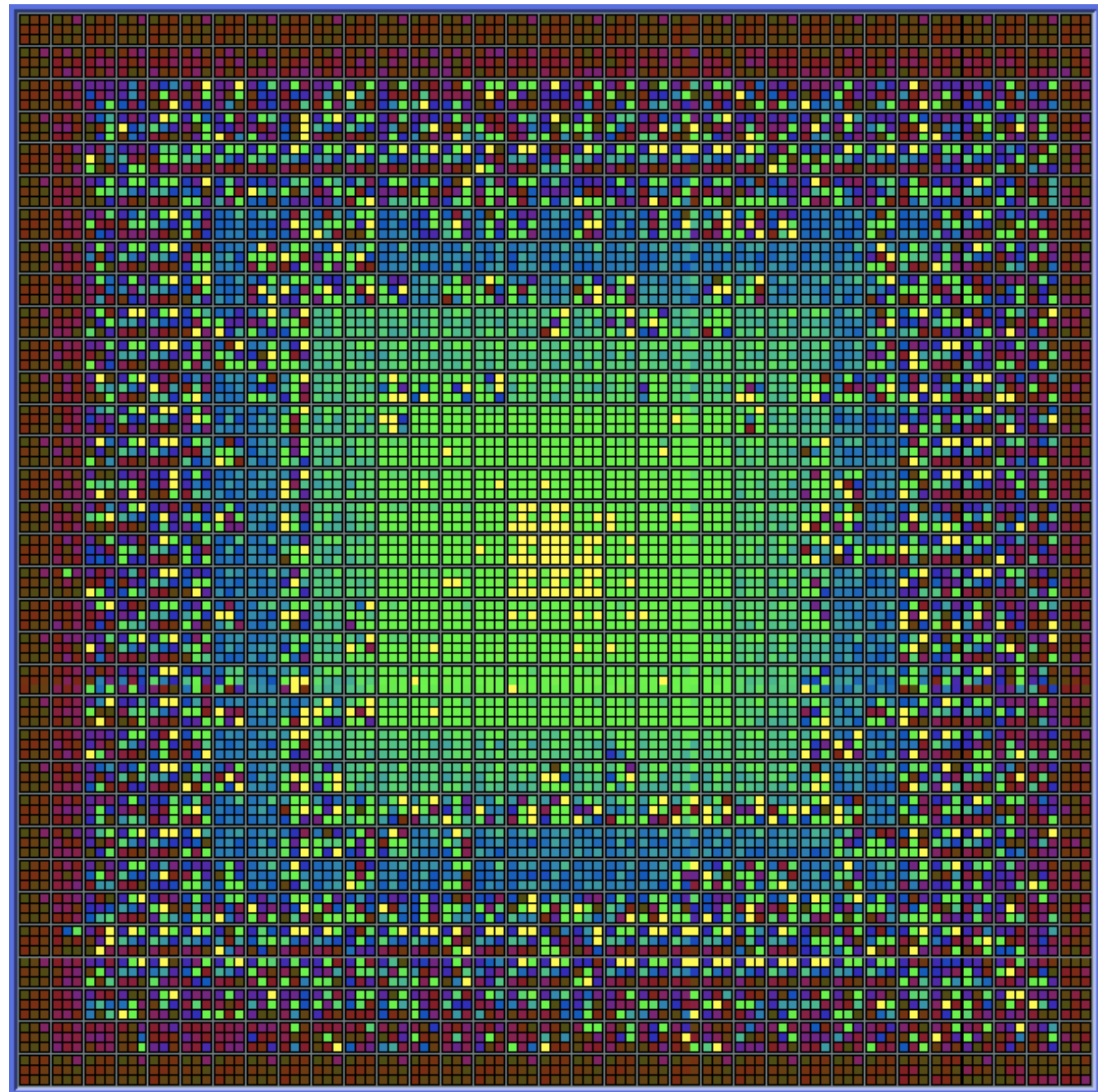
VisDB

- table: draw pixels sorted, colored by relevance
- group by attribute or partition by attribute into multiple views



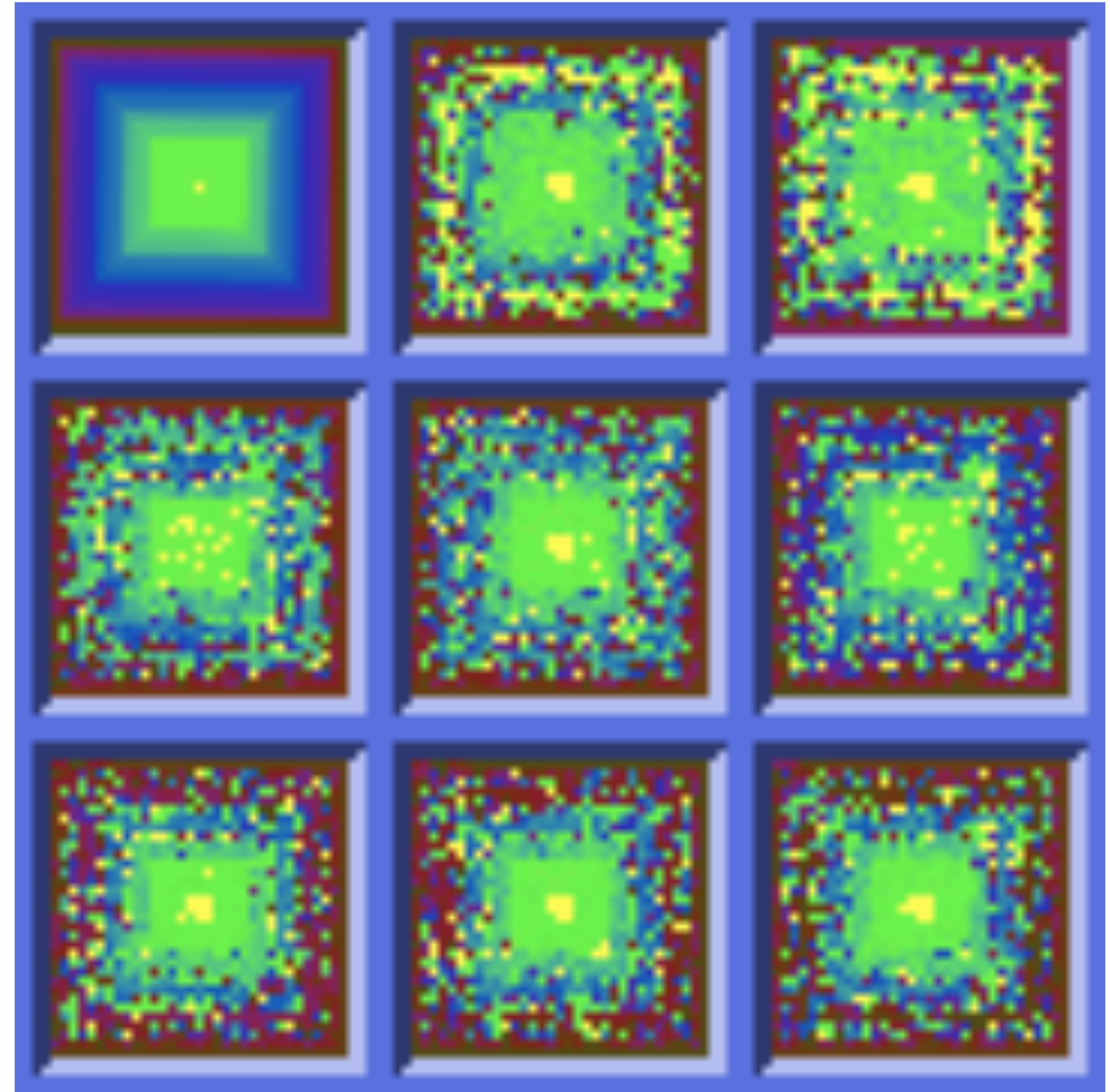
VisDB Results

- partition into many small regions: dimensions grouped together



VisDB Results

- partition into small number of views
 - inspect each attribute

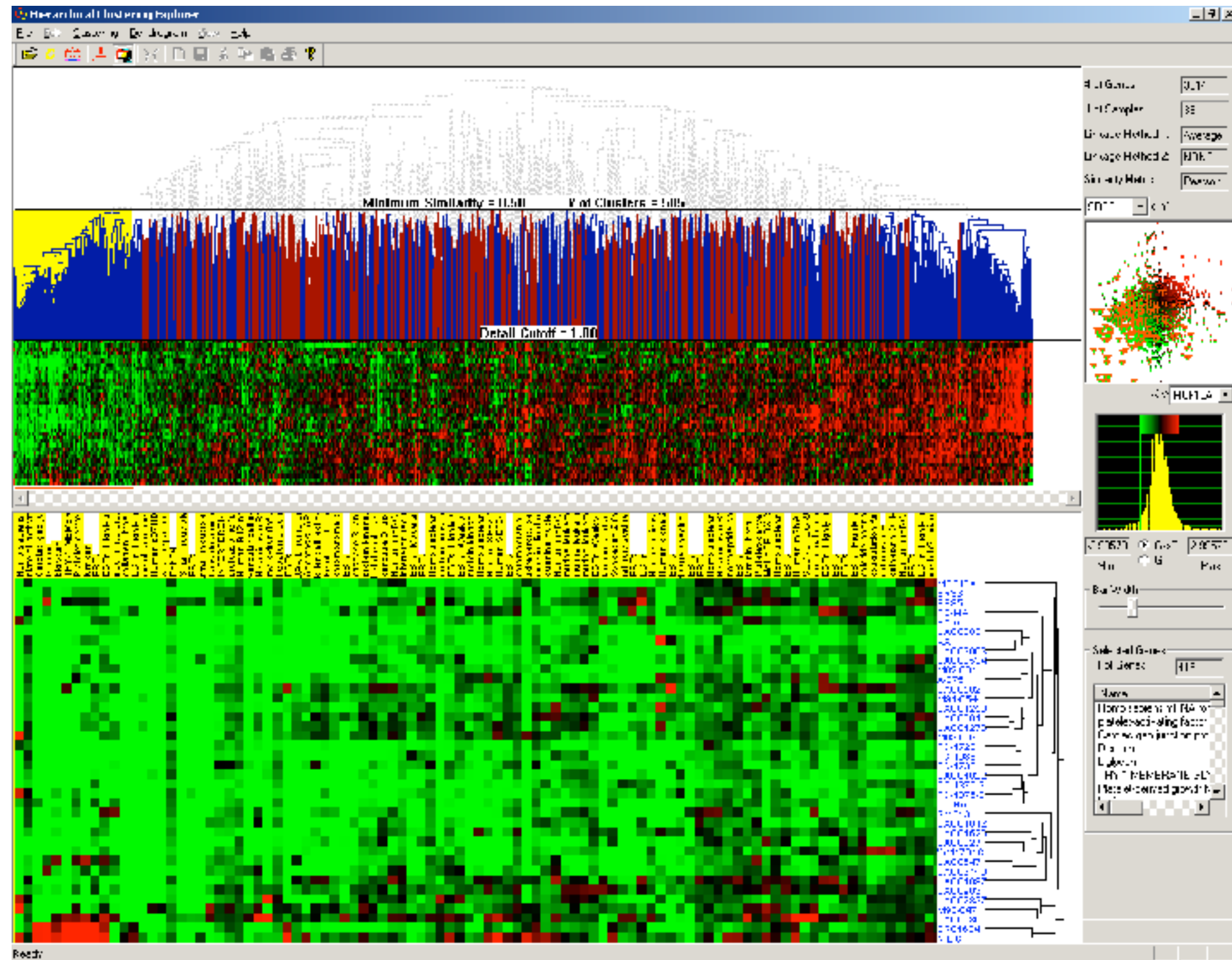


VisDB Analysis

System	VisDB
What: Data	Table (database) with k attributes; query returning table subset (database query).
What: Derived	$k + 1$ quantitative attributes per original item: query relevance for the k original attributes plus overall relevance.
Why: Tasks	Characterize distribution within attribute, find groups of similar values within attribute, find outliers within attribute, find correlation between attributes, find similar items.
How: Encode	Dense, space-filling; area marks in spiral layout; colormap: categorical hues and ordered luminance.
How: Facet	Layout 1: partition by attribute into per-attribute views, small multiples. Layout 2: partition by items into per-item glyphs.
How: Reduce	Filtering
Scale	Attributes: one dozen. Total items: several million. Visible items (using multiple views, in total): one million. Visible items (using glyphs): 100,000

Hierarchical Clustering Explorer

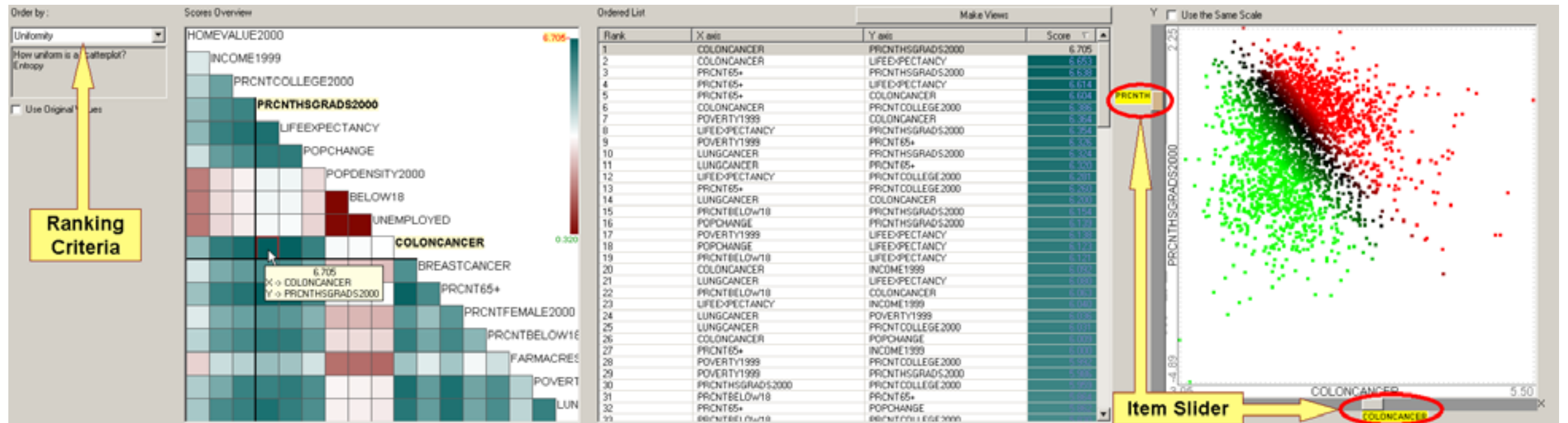
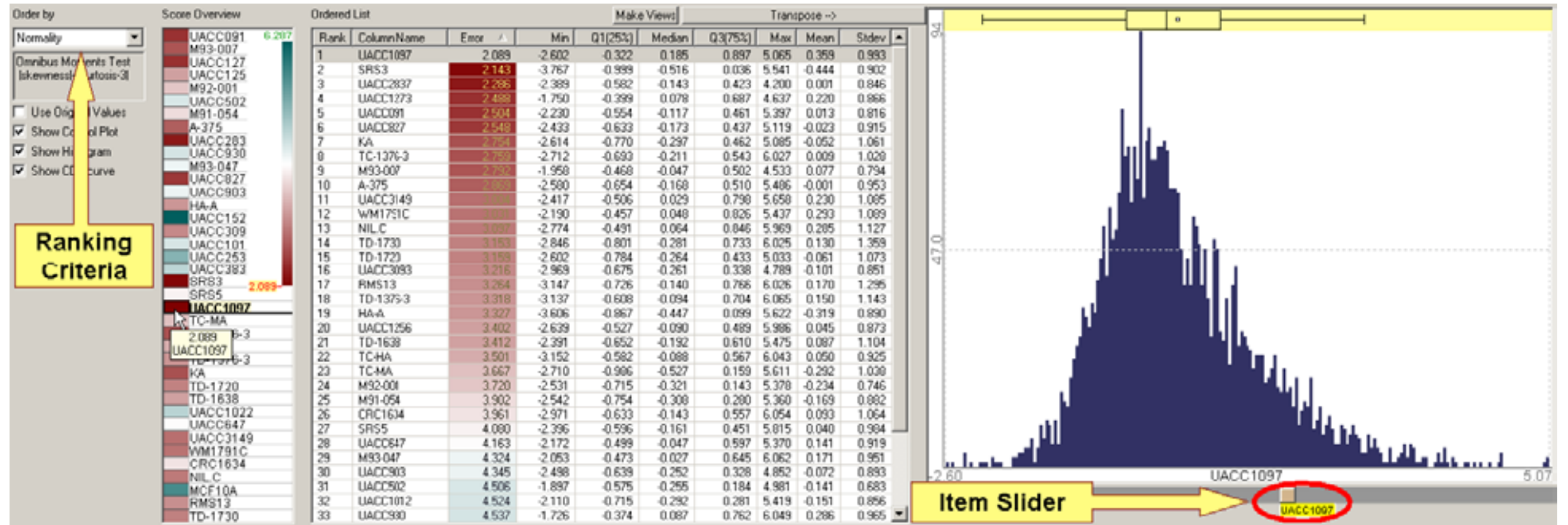
- heatmap, dendrogram
- multiple views



[Interactively Exploring Hierarchical Clustering Results. Seo and Shneiderman, *IEEE Computer* 35(7): 80-86 (2002)]

HCE

- rank by feature idiom
 - 1D list
 - 2D matrix



A rank-by-feature framework for interactive exploration of multidimensional data. Seo and Shneiderman. *Information Visualization* 4(2): 96-113 (2005)

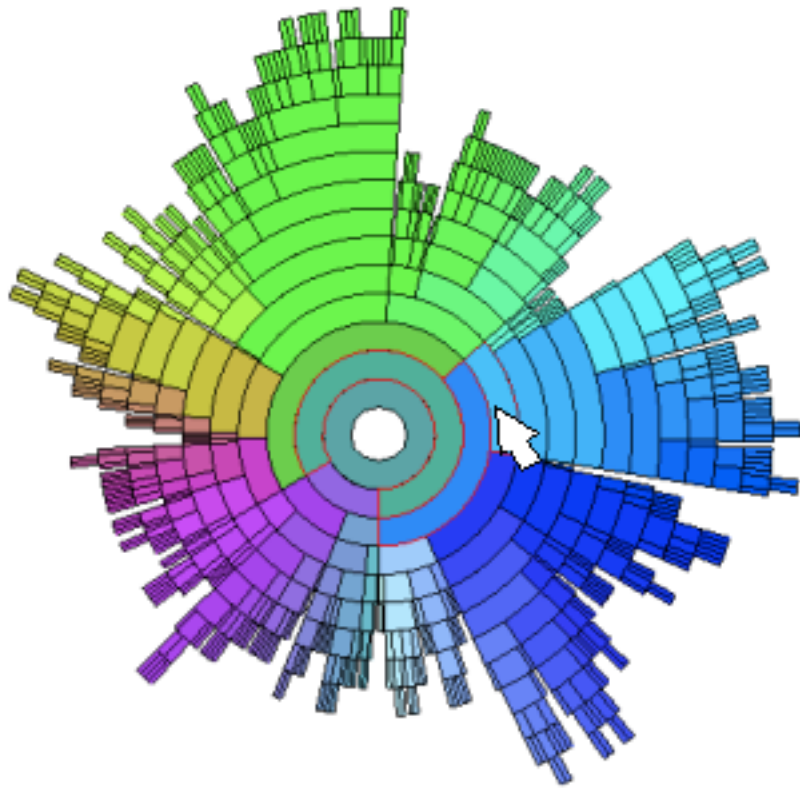


A rank-by-feature framework for interactive exploration of multidimensional data. Seo and Shneiderman. *Information Visualization* 4(2): 96-113 (2005)

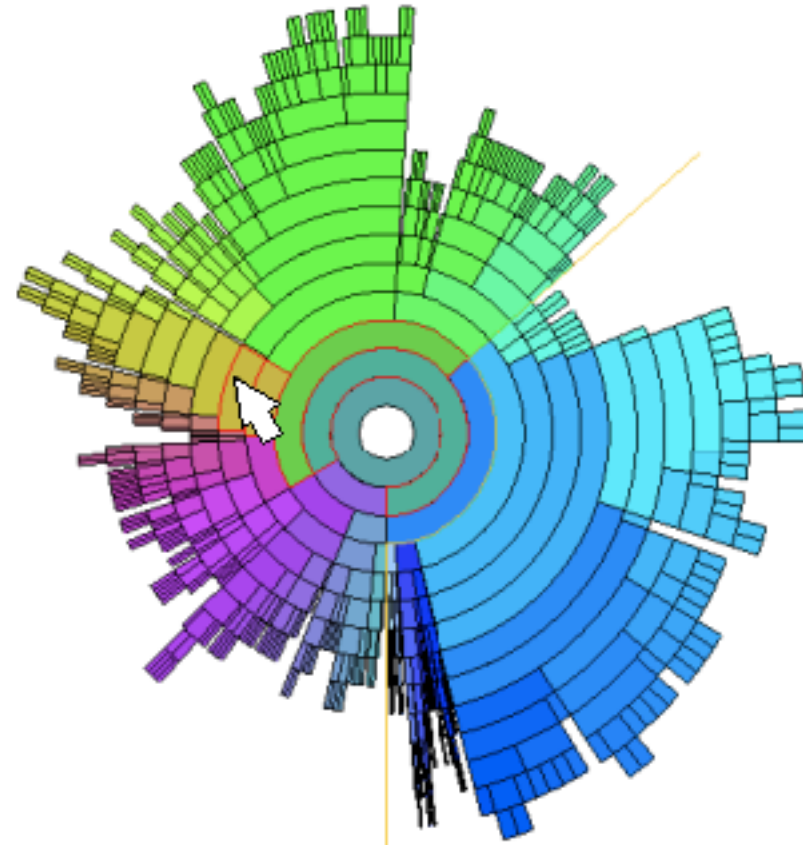
HCE Analysis

System	Hierarchical Clustering Explorer (HCE)
What: Data	Multidimensional table: two categorical key attributes (genes, conditions); one quantitative value attribute (gene activity level in condition).
What: Derived	Hierarchical clustering of table rows and columns (for cluster heatmap); quantitative derived attributes for each attribute and pairwise attribute combination; quantitative derived attribute for each ranking criterion and original attribute combination.
Why: Tasks	Find correlation between attributes; find clusters, gaps, outliers, trends within items.
How: Encode	Cluster heatmap, scatterplots, histograms, boxplots. Rank-by-feature overviews: continuous diverging colormaps on area marks in reorderable 2D matrix or 1D list alignment.
How: Reduce	Dynamic filtering; dynamic aggregation.
How: Manipulate	Navigate with pan/scroll.
How: Facet	Multiform with linked highlighting and shared spatial position; overview–detail with selection in overview populating detail view.
Scale	Genes (key attribute): 20,000. Conditions (key attribute): 80. Gene activity in condition (quantitative value attribute): $20,000 \times 80 = 1,600,000$.

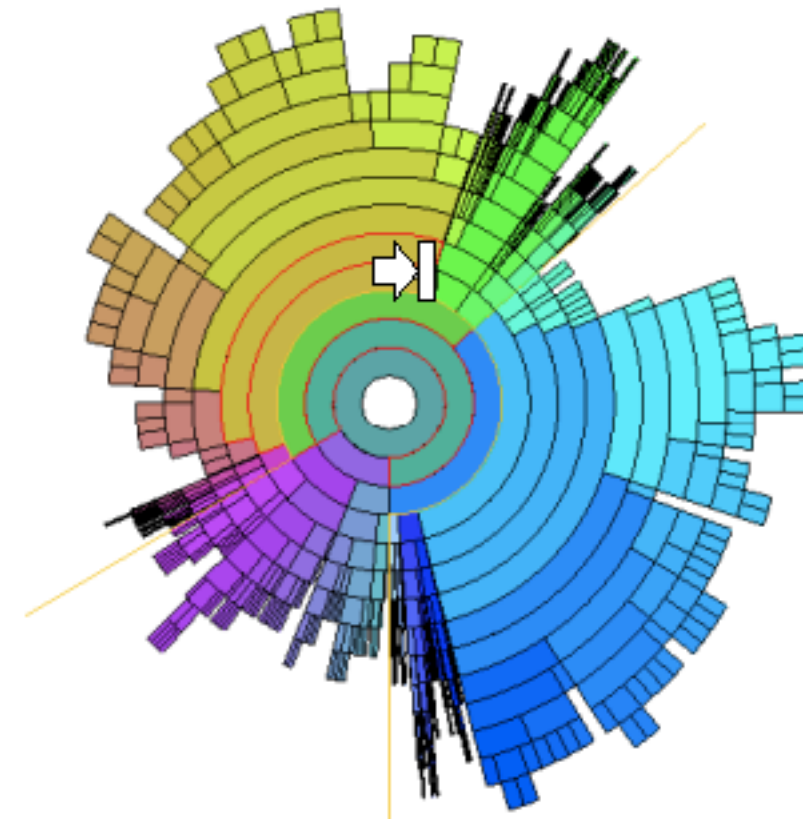
InterRing



original hierarchy



blue subtree expanded



tan subtree expanded

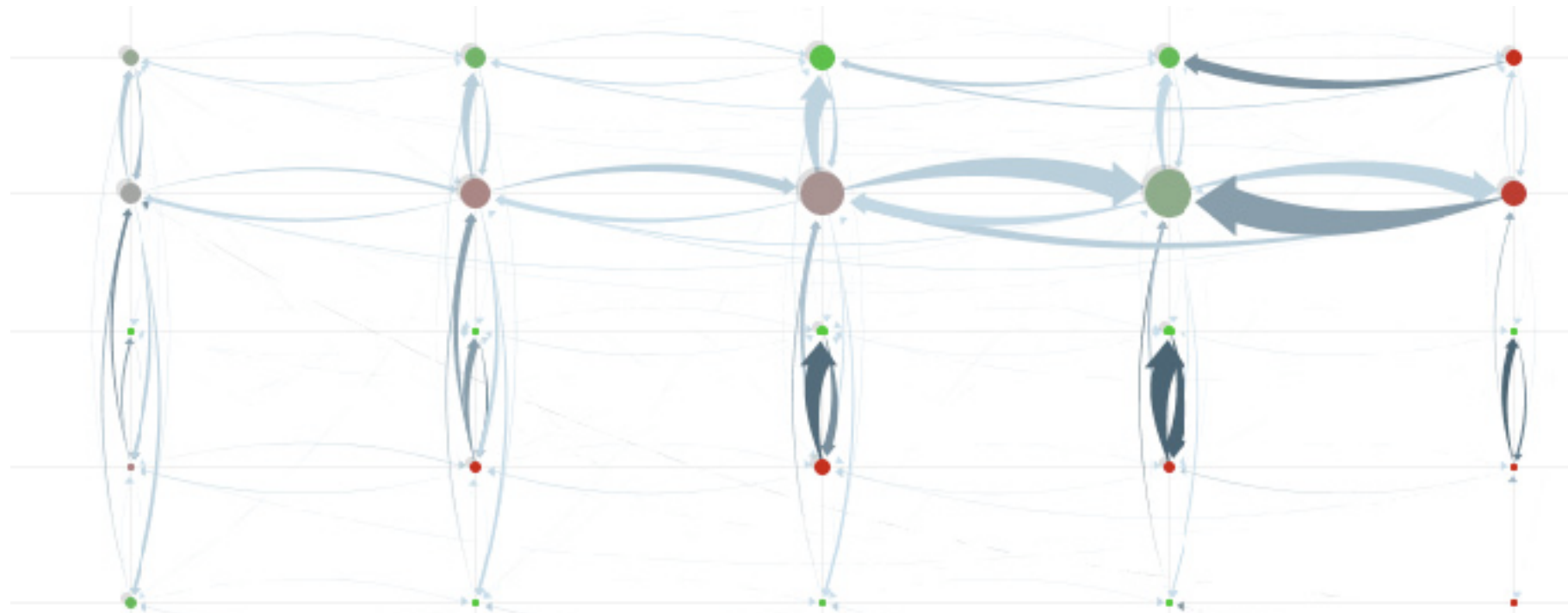
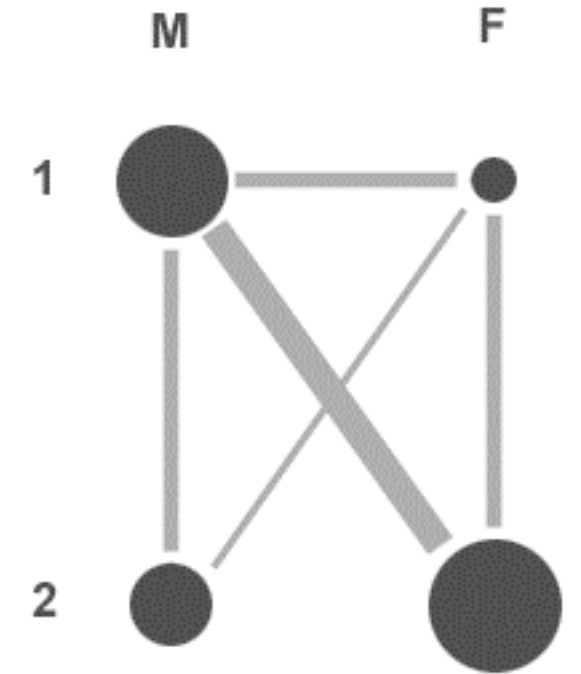
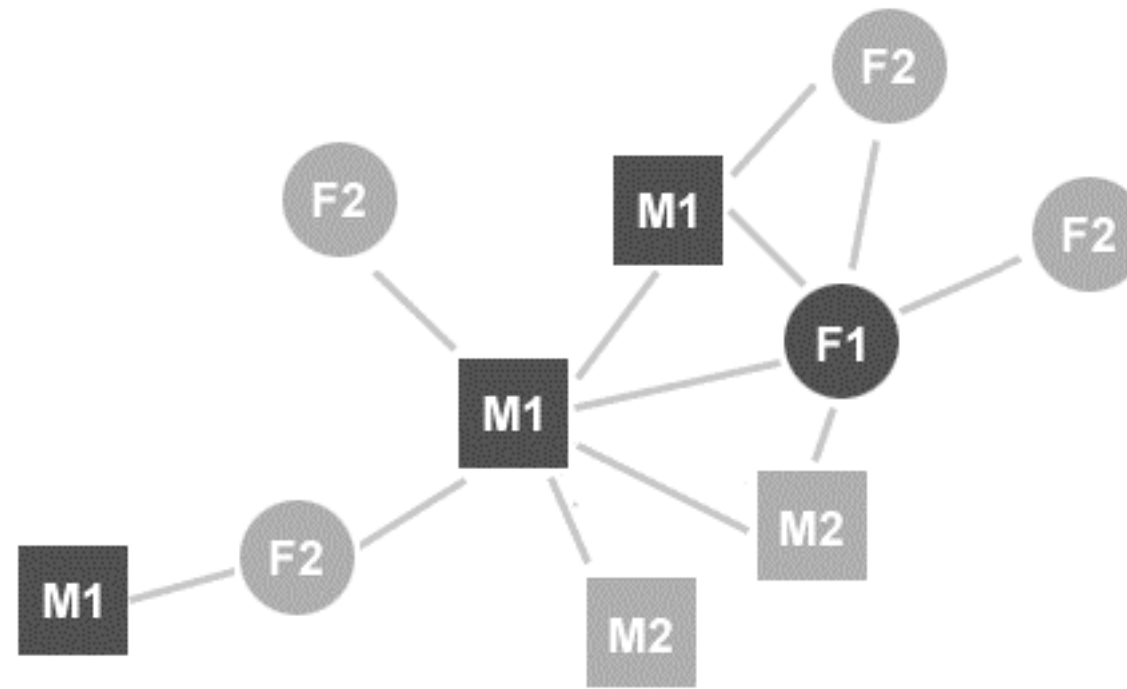
*[InterRing: An Interactive Tool for Visually Navigating and Manipulating Hierarchical Structures.
Yang, Ward, Rundensteiner. Proc. InfoVis 2002, p 77-84.]*

InterRing Analysis

System	InterRing
What: Data	Tree.
Why: Tasks	Selection, rollup/drilldown, hierarchy editing.
How: Encode	Radial, space-filling layout. Color by tree structure.
How: Facet	Linked coloring and highlighting.
How: Reduce	Embed: distort; multiple foci.
Scale	Nodes: hundreds if labeled, thousands if dense. Levels in tree: dozens.

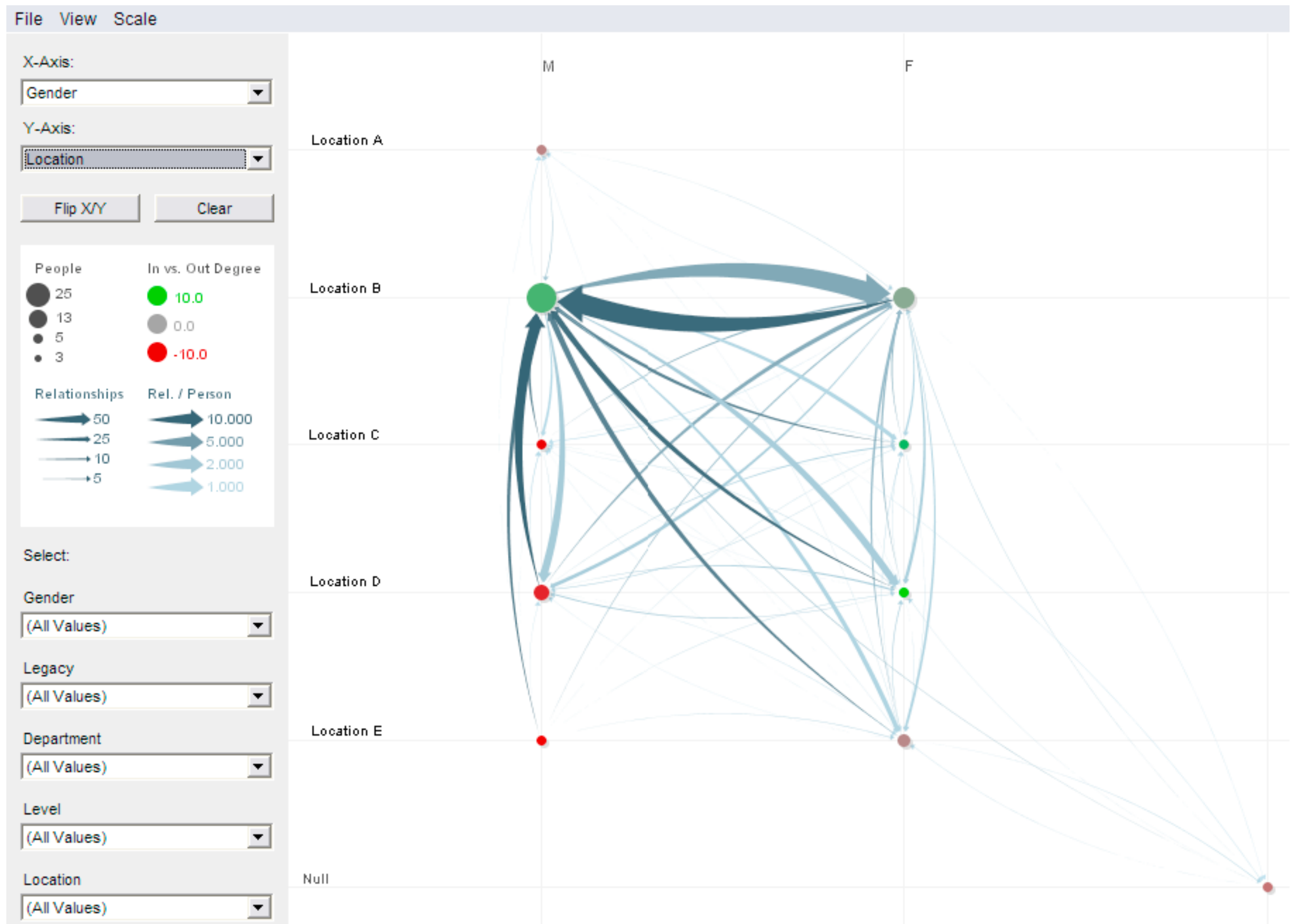
PivotGraph

- derived rollup network



[Visual Exploration of Multivariate Graphs, Martin Wattenberg, CHI 2006.]

PivotGraph



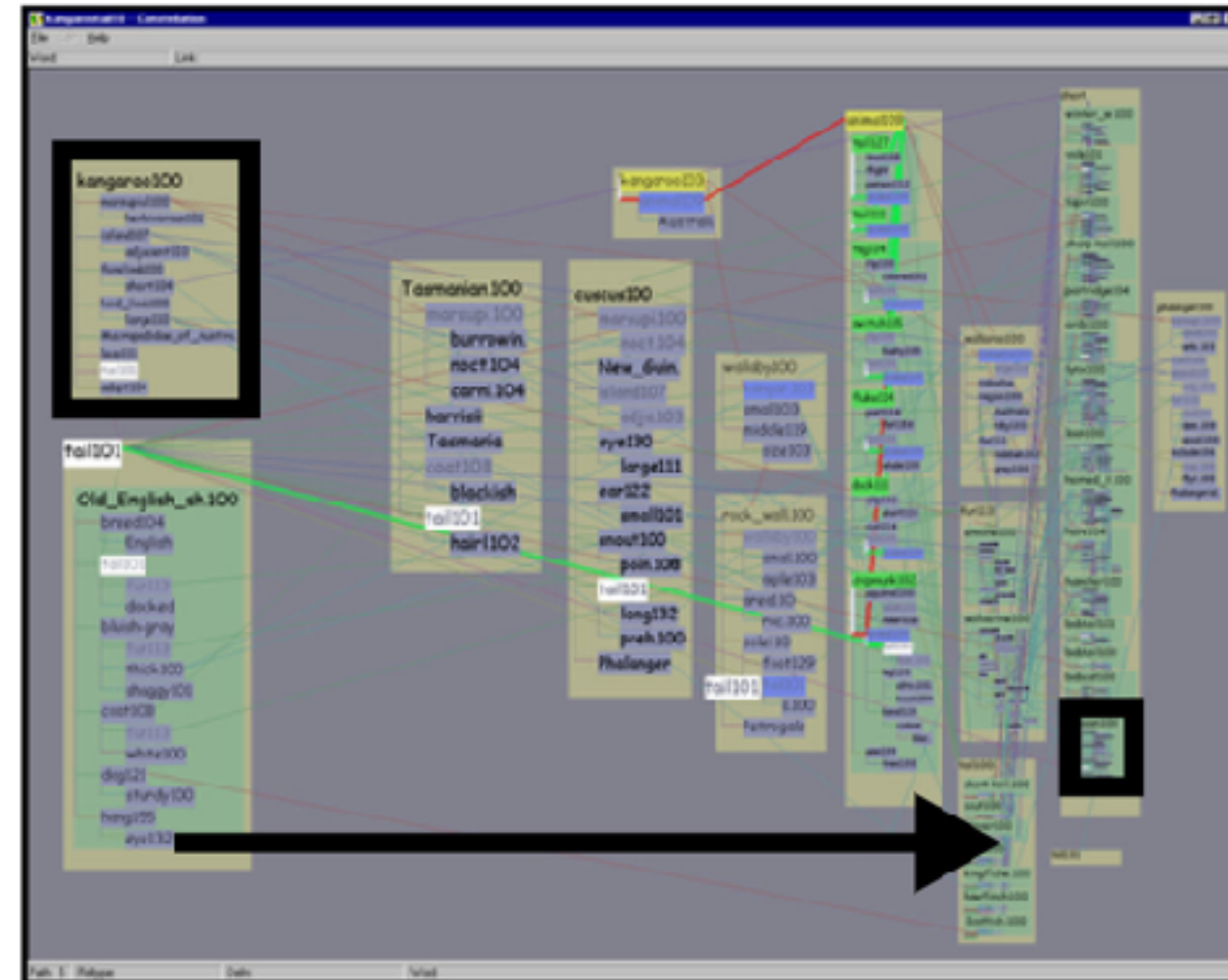
[Visual Exploration of Multivariate Graphs, Martin Wattenberg, CHI 2006.]

PivotGraph Analysis

Idiom	PivotGraph
What: Data	Network.
What: Derived	Derived network of aggregate nodes and links by roll-up into two chosen attributes.
Why: Tasks	Cross-attribute comparison of node groups.
How: Encode	Nodes linked with connection marks, size.
How: Manipulate	Change: animated transitions.
How: Reduce	Aggregation, filtering.
Scale	Nodes/links in original network: unlimited. Roll-up attributes: 2. Levels per roll-up attribute: several, up to one dozen.

Analysis example: Constellation

- data
 - multi-level network
 - node: word
 - link: words used in same dictionary definition
 - subgraph for each definition
 - not just hierarchical clustering
 - paths through network
 - query for high-weight paths between 2 nodes
 - quant attrib: plausibility

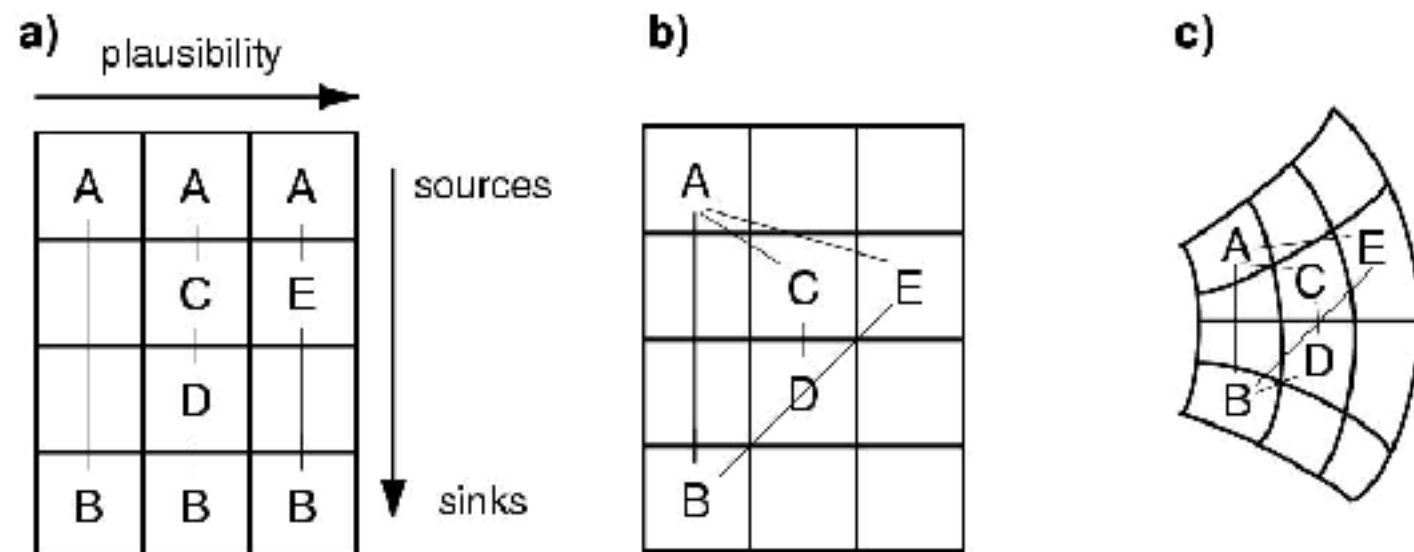
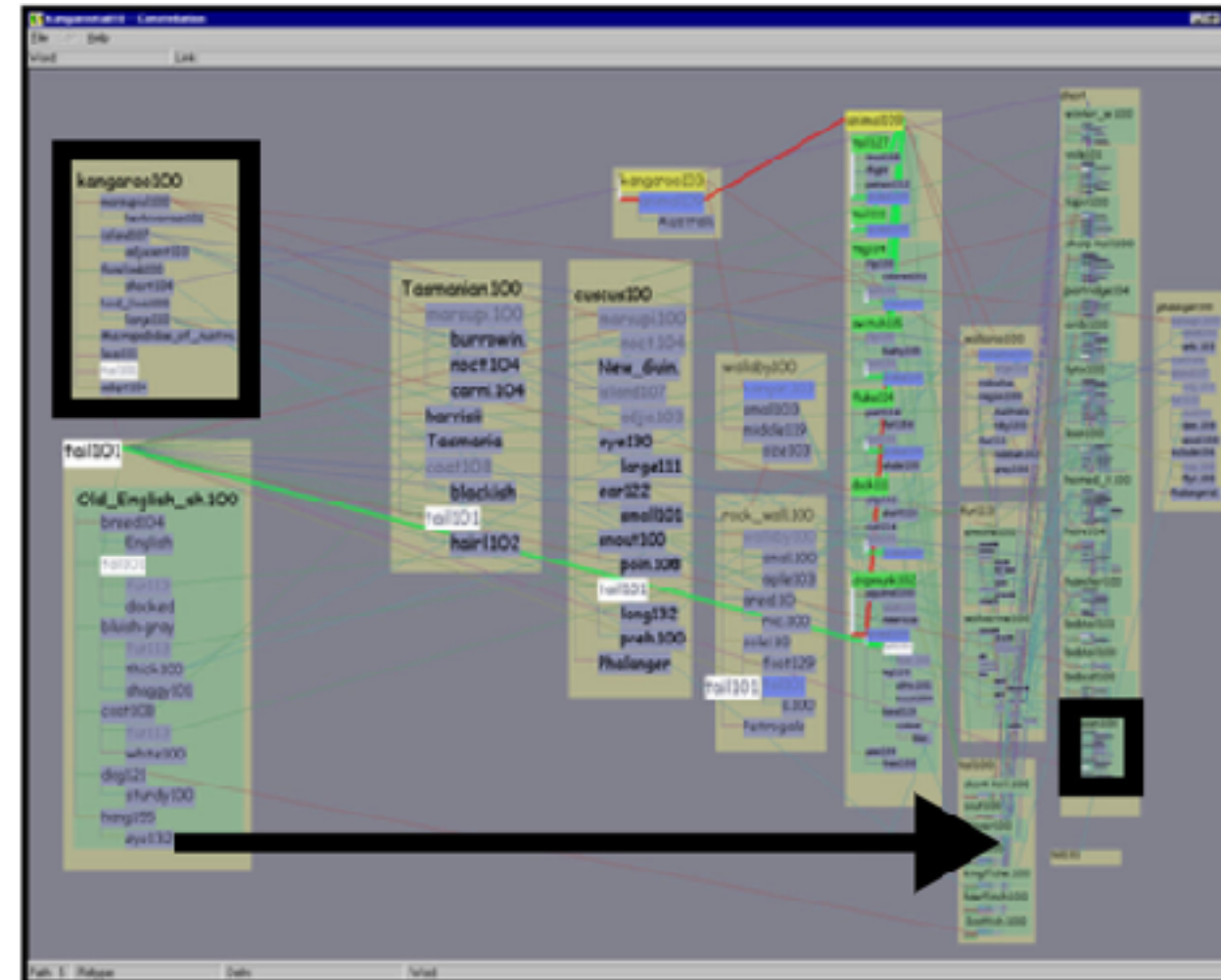


[Interactive Visualization of Large Graphs and Networks. Munzner. Ph.D. Dissertation, Stanford University, June 2000.]

[Constellation: A Visualization Tool For Linguistic Queries from MindNet. Munzner, Guimbretière and Robertson. Proc. IEEE Symp. InfoVis 1999, p. 132-135.]

Using space: Constellation

- visual encoding
 - link connection marks between words
 - link containment marks to indicate subgraphs
 - encode plausibility with horiz spatial position
 - encode source/sink for query with vert spatial position
- spatial layout
 - curvilinear grid: more room for longer low-plausibility paths

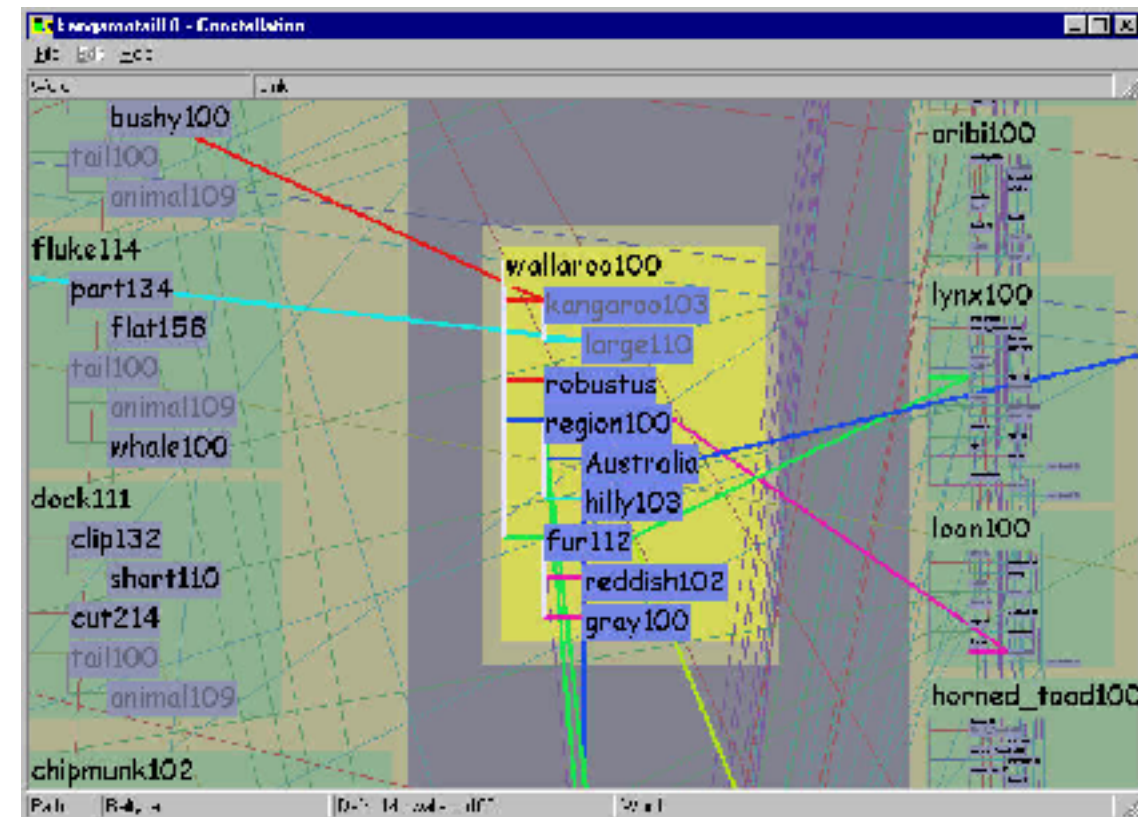
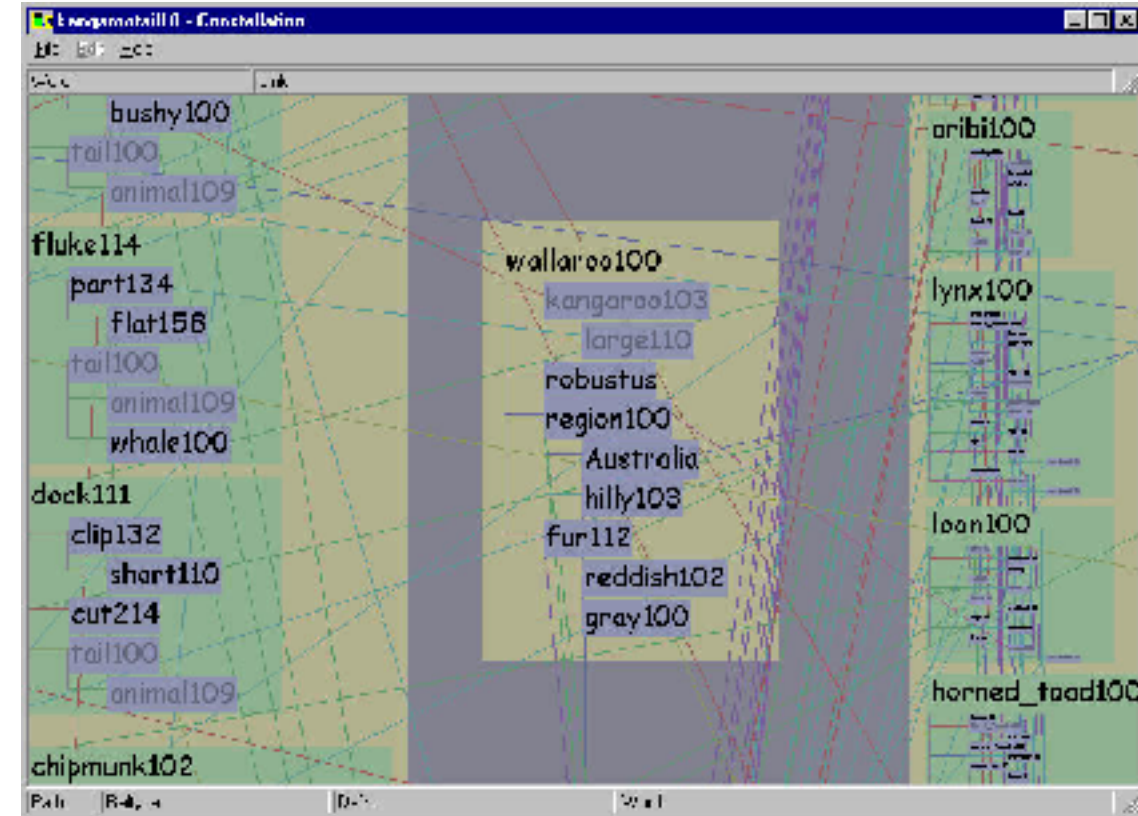


Using space: Constellation

- edge crossings
 - cannot easily minimize instances, since position constrained by spatial encoding
 - instead: minimize perceptual impact
- views: superimposed layers
 - dynamic foreground/background layers on mouseover, using color
 - four kinds of constellations
 - definition, path, link type, word
 - not just 1-hop neighbors

<https://youtu.be/7sJC3QVpSkQ>

[Interactive Visualization of Large Graphs and Networks. Munzner. Ph.D. Dissertation, Stanford University, June 2000.]



Constellation Analysis

System	Constellation
What: Data	Three-level network of paths, subgraphs (definitions), and nodes (word senses).
Why: Tasks	Discover/verify: browse and locate types of paths, identify and compare.
How: Encode	Containment and connection link marks, horizontal spatial position for plausibility attribute, vertical spatial position for order within path, color links by type.
How: Manipulate	Navigate: semantic zooming. Change: Animated transitions.
How: Reduce	Superimpose dynamic layers.
Scale	Paths: 10–50. Subgraphs: 1–30 per path. Nodes: several thousand.

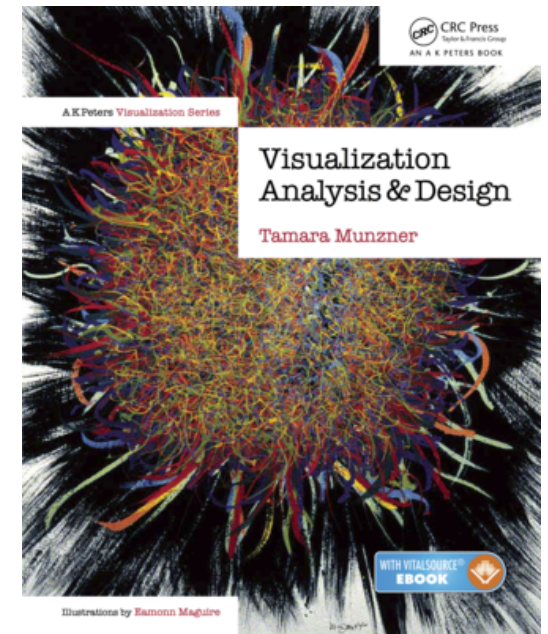
Visualization Analysis & Design

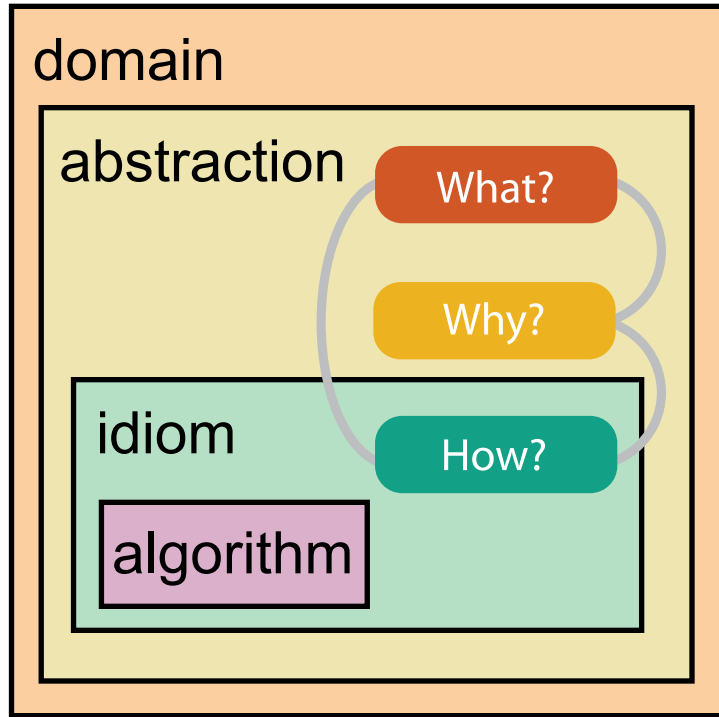
Wrapup

Tamara Munzner

Department of Computer Science
University of British Columbia

[@tamaramunzner](#)





What?

Datasets

→ Data Types

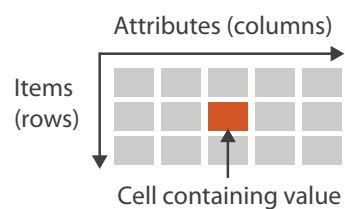
→ Items → Attributes → Links → Positions → Grids

→ Data and Dataset Types

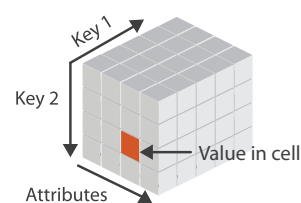
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

→ Dataset Types

→ Tables



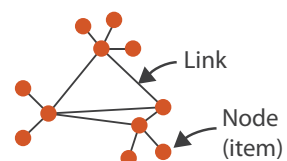
→ Multidimensional Table



→ Geometry (Spatial)



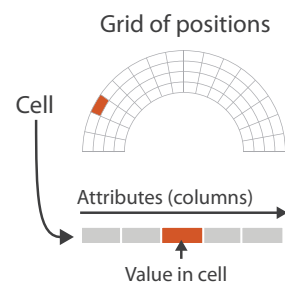
→ Networks



→ Trees



→ Fields (Continuous)



Attributes

→ Attribute Types

→ Categorical



→ Ordered

→ Ordinal



→ Quantitative



→ Ordering Direction

→ Sequential



→ Diverging



→ Cyclic



domain

abstraction

What?

Why?

idiom

How?

algorithm

What?

Datasets

Attributes

Why?

Actions

Targets

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

All Data

→ Trends



→ Outliers



→ Features



Attributes

→ One

→ Distribution



→ Extremes

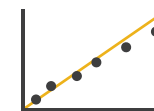


→ Many

→ Dependency



→ Correlation

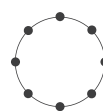
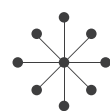


→ Similarity



Network Data

→ Topology



→ Paths



domain

abstraction

What?

Why?

idiom

How?

algorithm

What?

Datasets

Attributes

Why?

Actions

Targets

How?

Encode

Manipulate

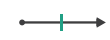
Facet

Reduce

Arrange

→ Express

→ Separate



→ Order

→ Align



→ Use



Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape

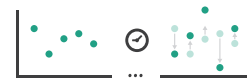


→ Motion

Direction, Rate, Frequency, ...



Change



Select



Navigate



Juxtapose



Partition



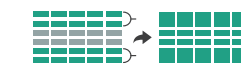
Superimpose



Filter



Aggregate



Embed



What?

Why?

How?

domain

abstraction

What?

Why?

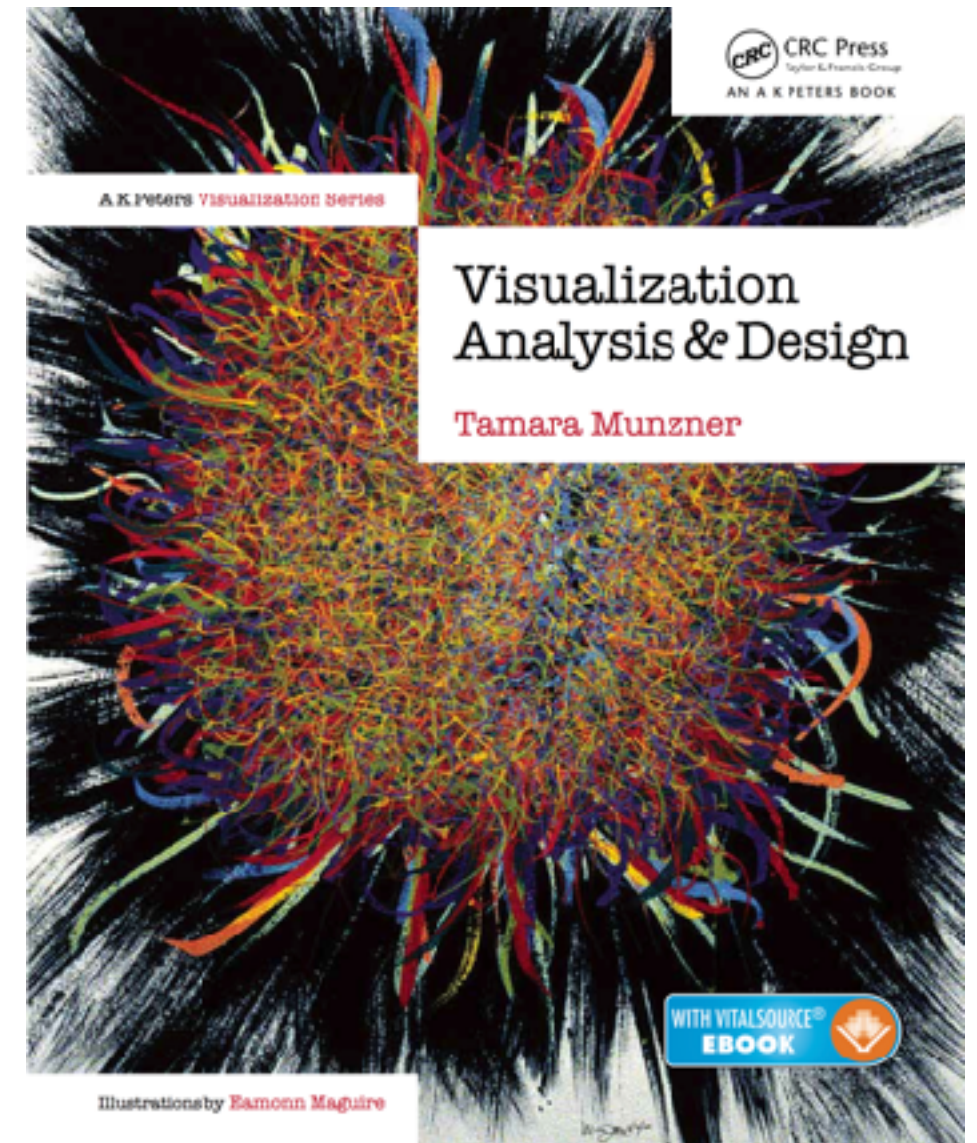
How?

idiom

algorithm

More information

- book
 - <http://www.cs.ubc.ca/~tmm/vadbook>
 - 20% promo code for book+ebook combo: HVN17
 - <http://www.crcpress.com/product/isbn/9781466508910>
 - illustration acknowledgement: Eamonn Maguire
- full courses, papers, videos, software, talks
 - <http://www.cs.ubc.ca/group/infovis>
 - <http://www.cs.ubc.ca/~tmm>



Visualization Analysis and Design. Munzner. CRC Press, AK Peters Visualization Series, 2014.

Credits

- Drawing on lectures from many others including
 - Alex Lex & Miriah Meyer, Utah, <http://dataviscourse.net/>
 - Maureen Stone, StoneSoup/Tableau, Color in Information Display (VIS 2006)
 - Ben Jones, UW/Tableau
 - Hanspeter Pfister, Harvard, <http://cs171.org/>
 - Jeff Heer, Washington
 - Enrico Bertini, NYU Tandon
 - Marti Hearst, UC Berkeley
 - Pat Hanrahan, Stanford

Big Picture & Other Synthesis

Ch 2

What?

Datasets

Attributes

→ Data Types

- Items
- Attributes
- Links
- Positions
- Grids

→ Attribute Types

- Categorical



- Ordered

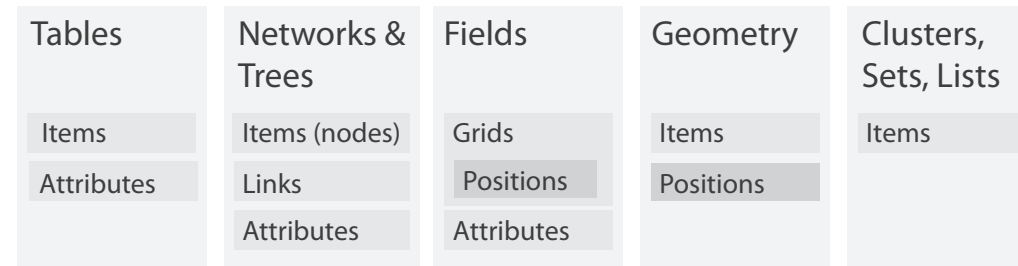
- Ordinal



- Quantitative

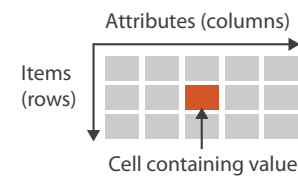


→ Data and Dataset Types

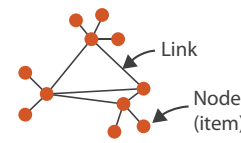


→ Dataset Types

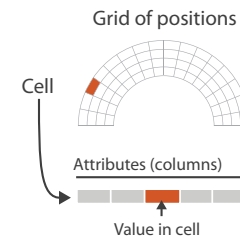
- Tables



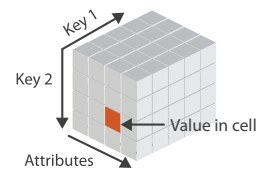
- Networks



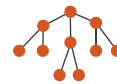
- Fields (Continuous)



- Multidimensional Table



- Trees



- Geometry (Spatial)



→ Ordering Direction

- Sequential



- Diverging



- Cyclic

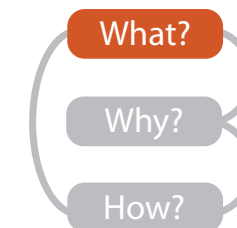


→ Dataset Availability

- Static



- Dynamic



Actions

Targets

→ Analyze

→ Consume

→ Discover



→ Present



→ Enjoy



→ Produce

→ Annotate



→ Record



→ Derive



→ Search

	Target known	Target unknown
Location known	<i>Lookup</i>	<i>Browse</i>
Location unknown	<i>Locate</i>	<i>Explore</i>

→ Query

→ Identify



→ Compare



→ Summarize



→ All Data

→ Trends



→ Outliers



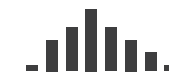
→ Features



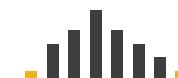
→ Attributes

→ One

→ Distribution



→ Extremes

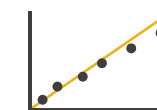


→ Many

→ Dependency



→ Correlation

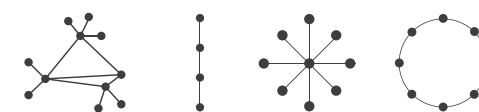


→ Similarity



→ Network Data

→ Topology

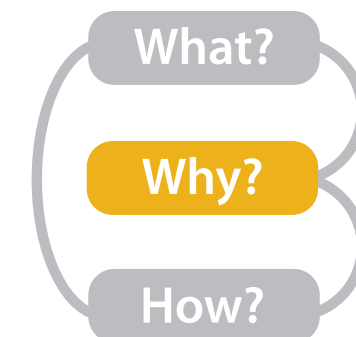


→ Paths



→ Spatial Data

→ Shape




Domain situation

Observe target users using existing tools

Data/task abstraction

 **Visual encoding/interaction idiom**
Justify design with respect to alternatives

 **Algorithm**
Measure system time/memory
Analyze computational complexity

Analyze results qualitatively

Measure human time with lab experiment (*lab study*)

Observe target users after deployment (*field study*)

Measure adoption

Ch 5

Channels: Expressiveness Types and Effectiveness Ranks

➔ 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)



Same

Same

Same

Most

Effectiveness

Least

➔ Identity Channels: Categorical Attributes

Spatial region



Color hue



Motion



Shape



Ch 6

- **No unjustified 3D**
 - Power of the plane
 - Disparity of depth
 - Occlusion hides information
 - Perspective distortion dangers
 - Tilted text isn't legible
- **No unjustified 2D**
- **Eyes beat memory**
- **Resolution over immersion**
- **Overview first, zoom and filter, details on demand**
- **Responsiveness is required**
- **Function first, form next**

Ch 7

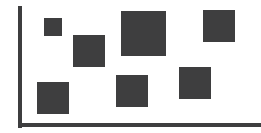
Arrange Tables

→ Express Values



→ Separate, Order, Align Regions

→ Separate



→ Order



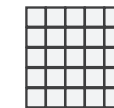
→ Align



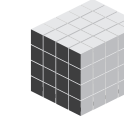
→ 1 Key *List*



→ 2 Keys *Matrix*



→ 3 Keys *Volume*

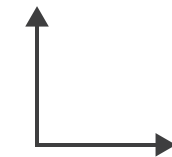


→ Many Keys *Recursive Subdivision*



→ Axis Orientation

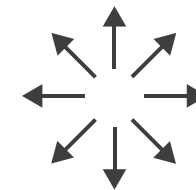
→ Rectilinear



→ Parallel

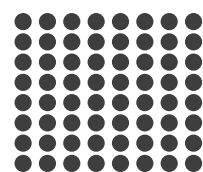


→ Radial



→ Layout Density

→ Dense



→ Space-Filling



→ Use Given

→ Geometry

→ *Geographic*

→ *Other Derived*

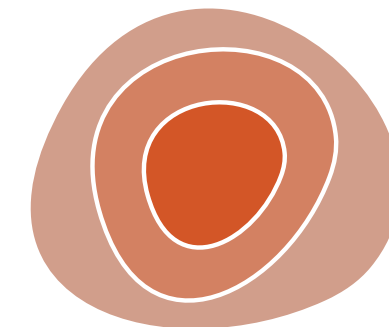


→ Spatial Fields

→ *Scalar Fields (one value per cell)*

→ *Isocontours*

→ *Direct Volume Rendering*



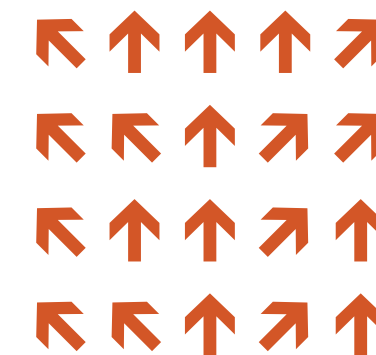
→ *Vector and Tensor Fields (many values per cell)*

→ *Flow Glyphs (local)*

→ *Geometric (sparse seeds)*

→ *Textures (dense seeds)*

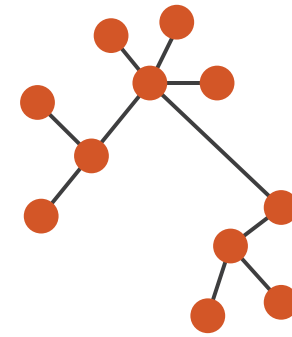
→ *Features (globally derived)*



Arrange Networks and Trees

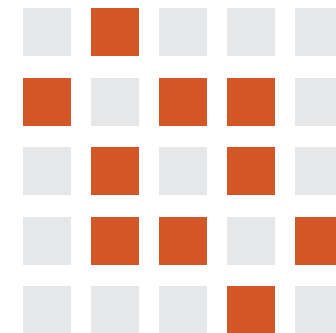
→ **Node–Link Diagrams**
Connection Marks

✓ NETWORKS ✓ TREES



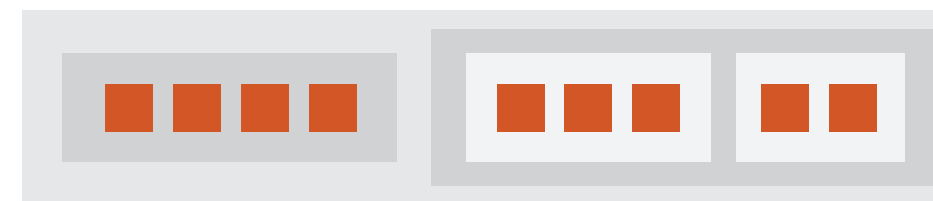
→ **Adjacency Matrix**
Derived Table

✓ NETWORKS ✓ TREES



→ **Enclosure**
Containment Marks

✗ NETWORKS ✓ TREES



→ Color

→ Color Encoding



→ Color Map

→ Categorical



→ Ordered

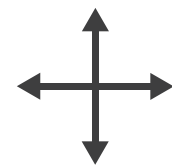
→ Sequential



→ Diverging



→ Bivariate



→ Size, Angle, Curvature, ...

→ Length



→ Angle



→ Area



→ Curvature



→ Volume

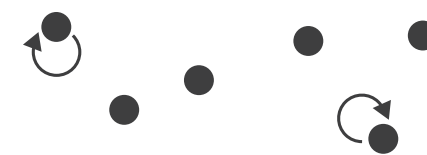


→ Shape

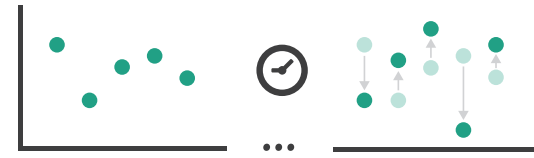


→ Motion

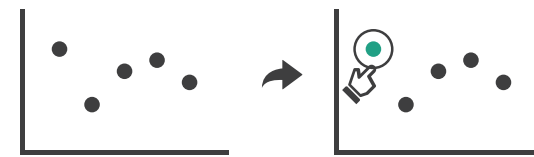
→ Motion
Direction, Rate,
Frequency, ...



→ Change over Time



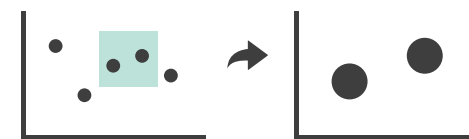
→ Select



→ Navigate

→ Item Reduction

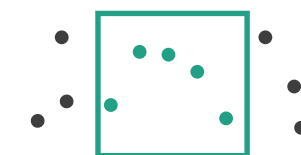
→ Zoom *Geometric or Semantic*



→ Pan/Translate

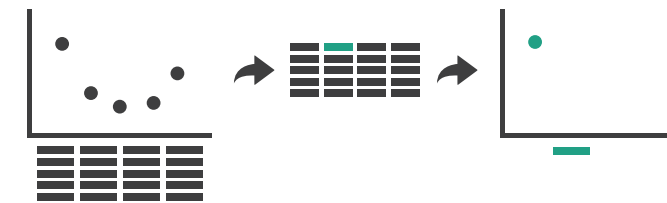


→ Constrained

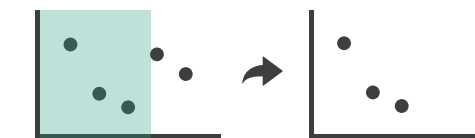


→ Attribute Reduction

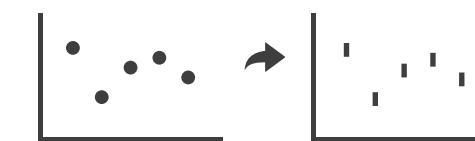
→ Slice



→ Cut



→ Project



➔ Juxtapose and Coordinate Multiple Side-by-Side Views

➔ Share Encoding: Same/Different

➔ *Linked Highlighting*



➔ Share Data: All/Subset/None

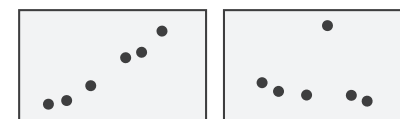


➔ Share Navigation



		Data		
		All	Subset	None
Encoding	Same	Redundant	Overview/ Detail	Small Multiples
	Different	Multiform	Multiform, Overview/ Detail	No Linkage

➔ Partition into Side-by-Side Views



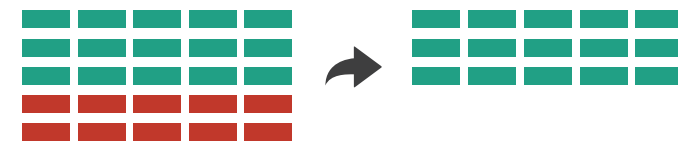
➔ Superimpose Layers



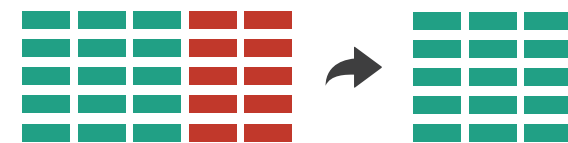
Reducing Items and Attributes

① Filter

→ Items

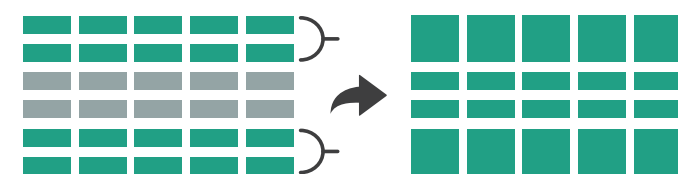


→ Attributes

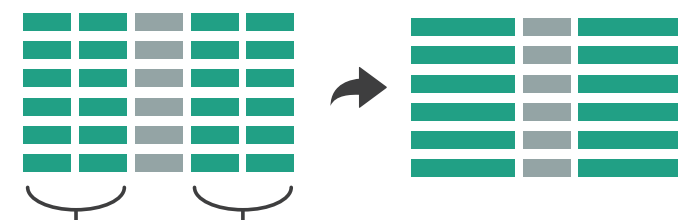


② Aggregate

→ Items




→ Attributes

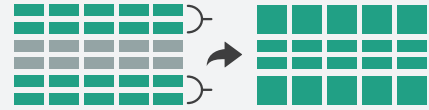


Reduce


① Filter



② Aggregate



③ Embed



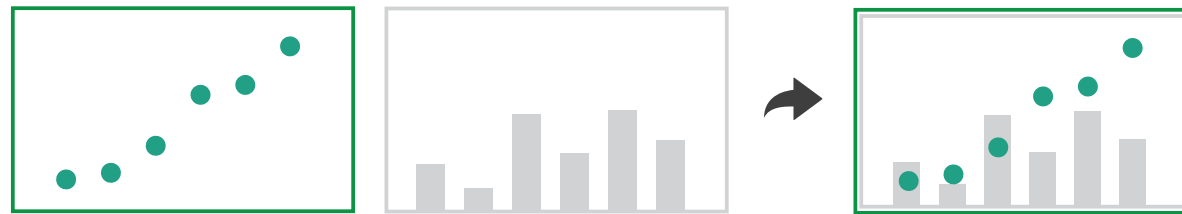
Ch 14

➔ Embed

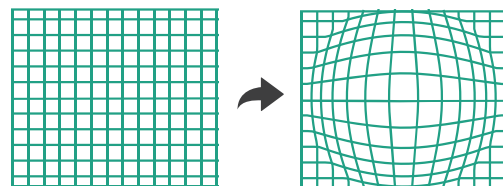
➔ Elide Data



➔ Superimpose Layer



➔ Distort Geometry



Reduce

➔ Filter



➔ Aggregate

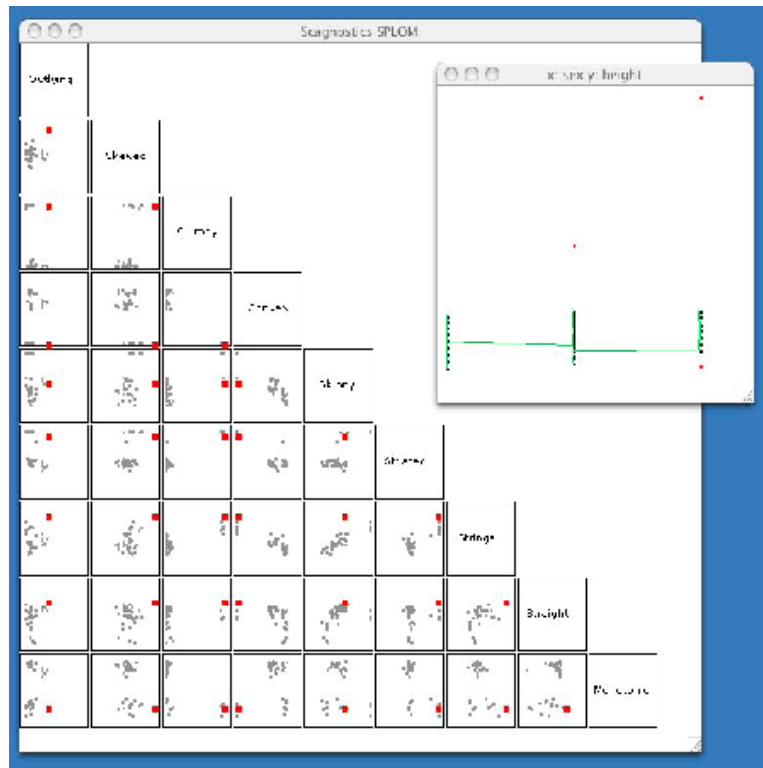


➔ Embed

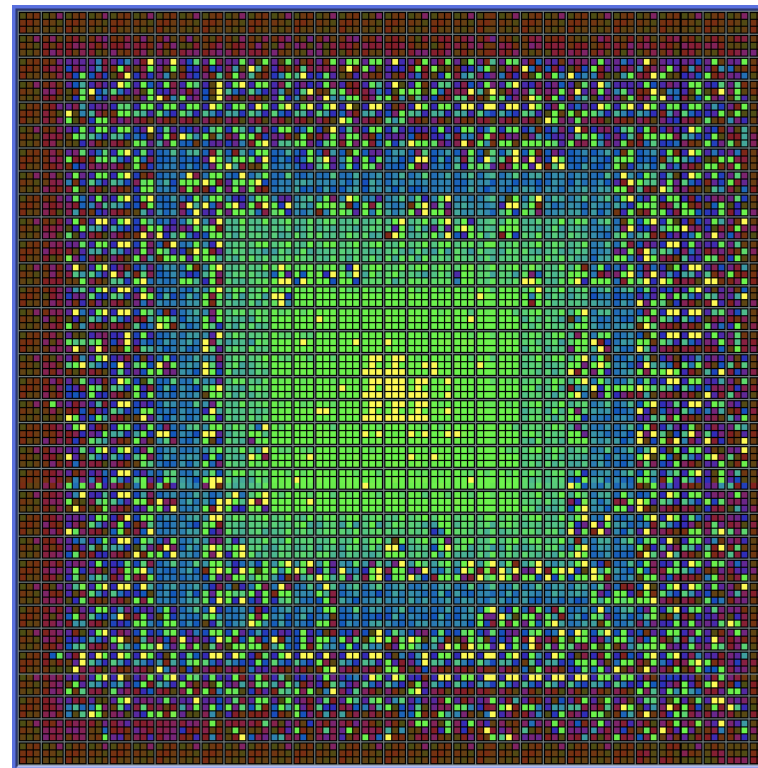


Ch 15

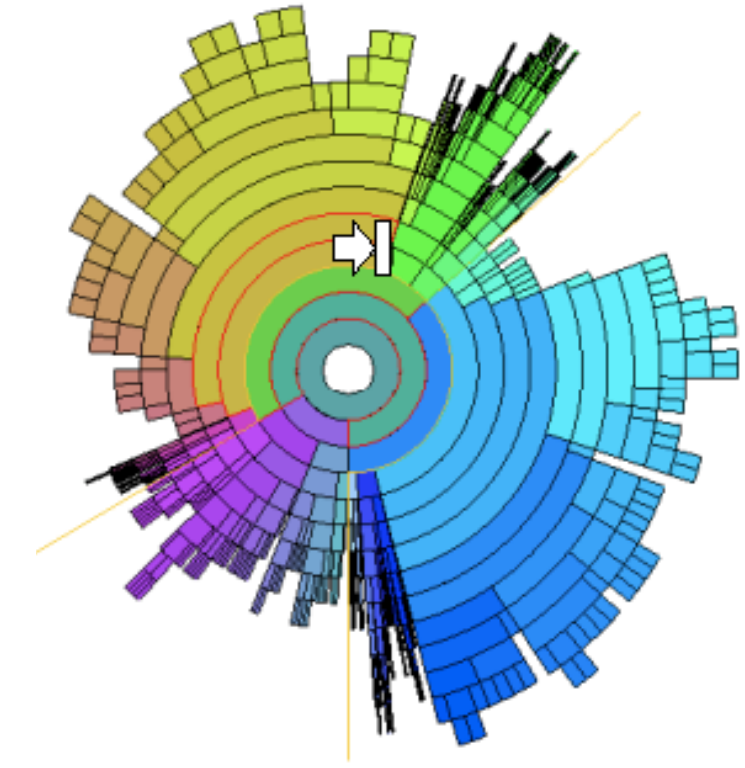
Scagnostics



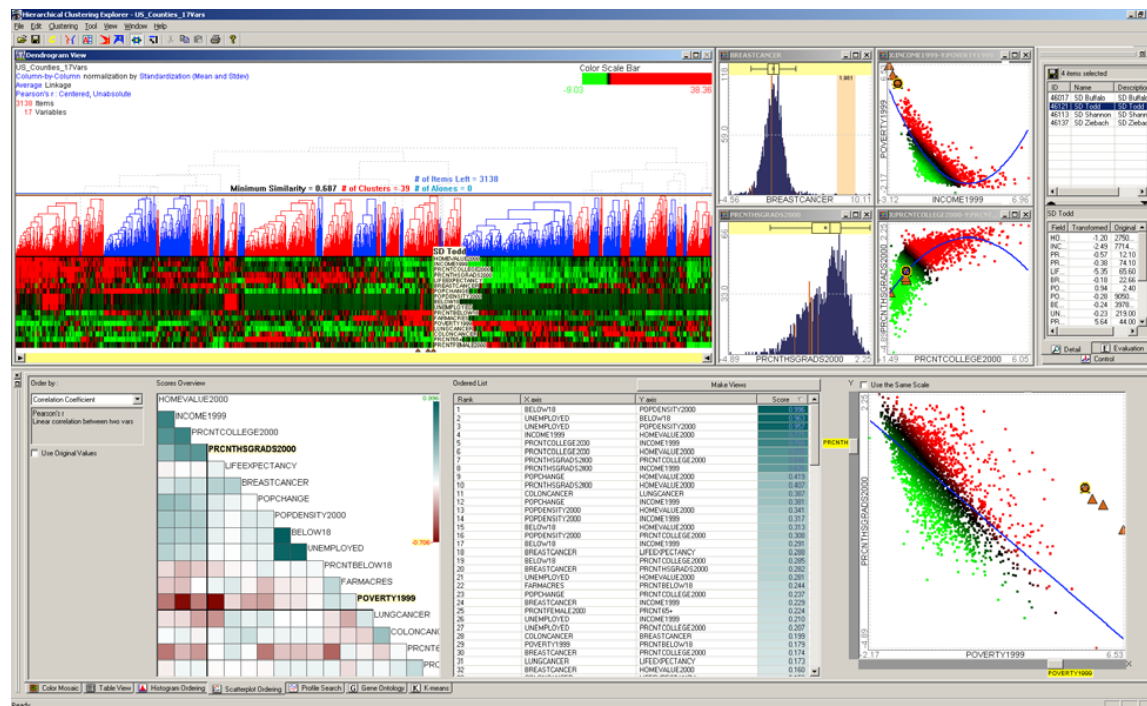
VisDB



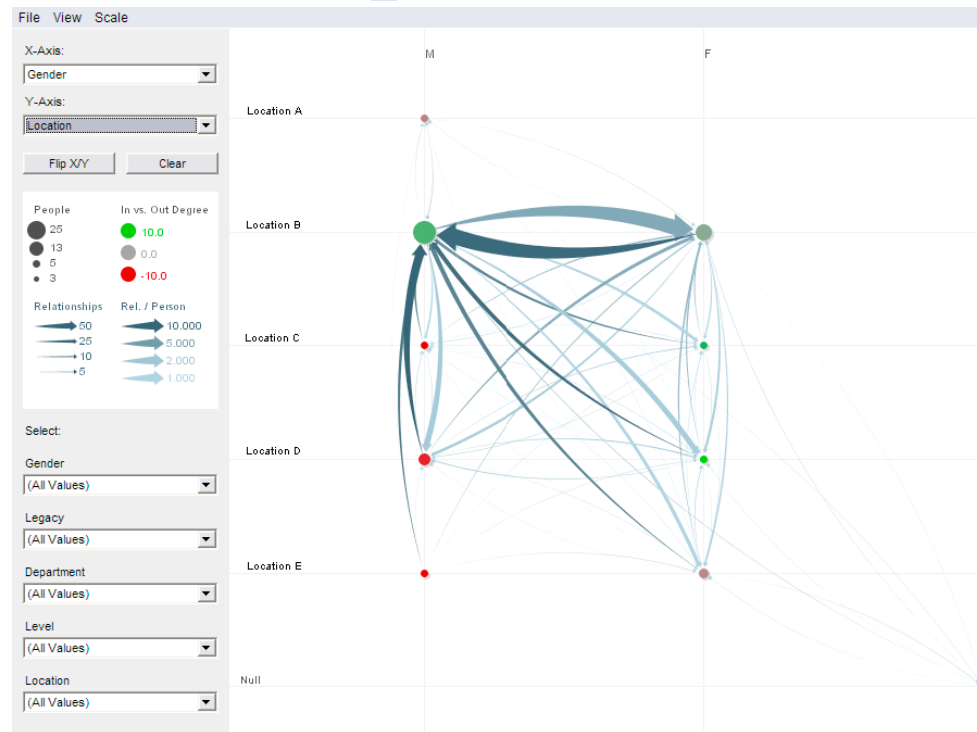
InterRing



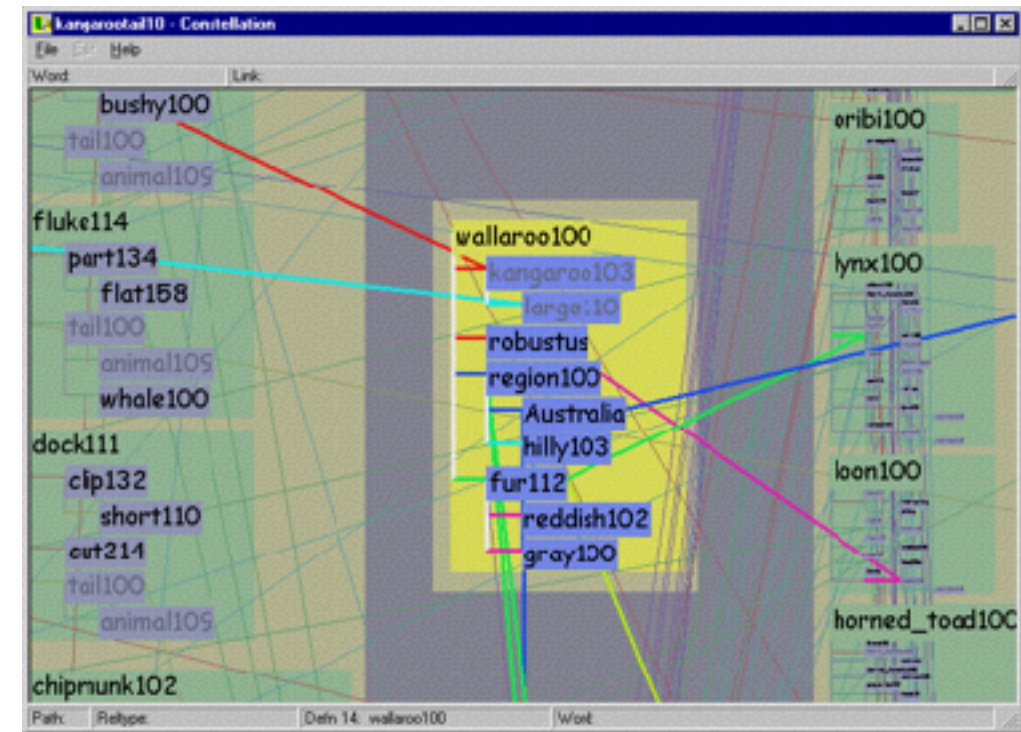
HCE



PivotGraph

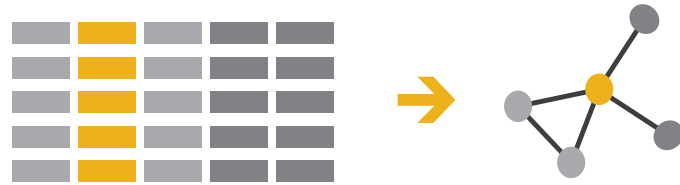


Constellation



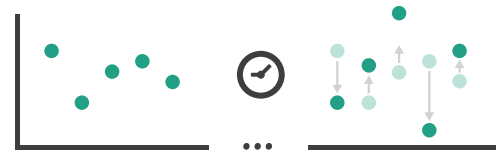
How to handle complexity: 4 families of strategies

→ *Derive*

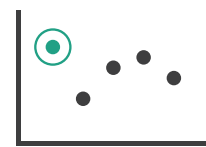


Manipulate

→ Change



→ Select

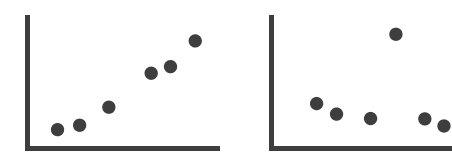


→ Navigate

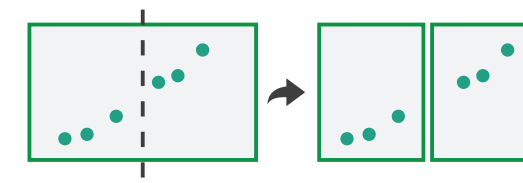


Facet

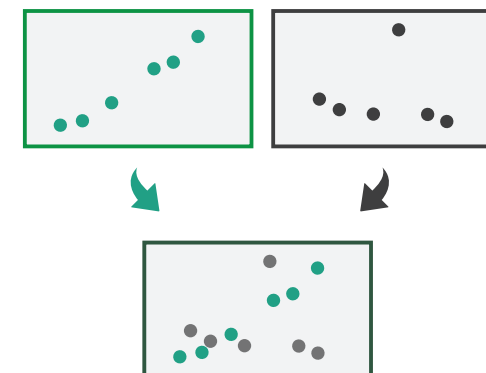
→ Juxtapose



→ Partition

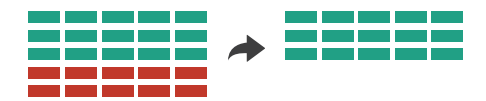


→ Superimpose

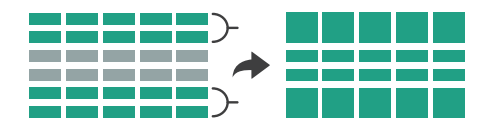


Reduce

→ Filter



→ Aggregate



→ Embed



- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

Further Reading

Further reading: Ch 1

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Guerilla/Discount Usability

- grab a few people and watch them use your interface
 - even 3-5 gives substantial coverage of major usability problems
 - agile/lean qualitative, vs formal quantitative user studies
 - goal is not statistical significance!
- think-aloud protocol
 - contextual inquiry (conversations back and forth) vs fly on the wall (you're silent)

Further reading, usability

- **7 Step Guide to Guerrilla Usability Testing, Markus Piper**
 - <https://userbrain.net/blog/7-step-guide-guerrilla-usability-testing-diy-usability-testing-method>
- **The Art of Guerrilla Usability Testing, David Peter Simon**
 - <http://www.uxbooth.com/articles/the-art-of-guerrilla-usability-testing/>
- **Discount Usability: 20 Years, Jakob Nielsen**
 - <https://www.nngroup.com/articles/discount-usability-20-years/>
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- Designing with the Mind in Mind: Simple Guide to Understanding User Interface Design Rules. Jeff Johnson. Morgan Kaufmann, 2010.
– *Chap 12: We Have Time Requirements*
- The Non-Designer's Design Book. 3rd edition. Robin Williams. Peachpit Press, 2008.

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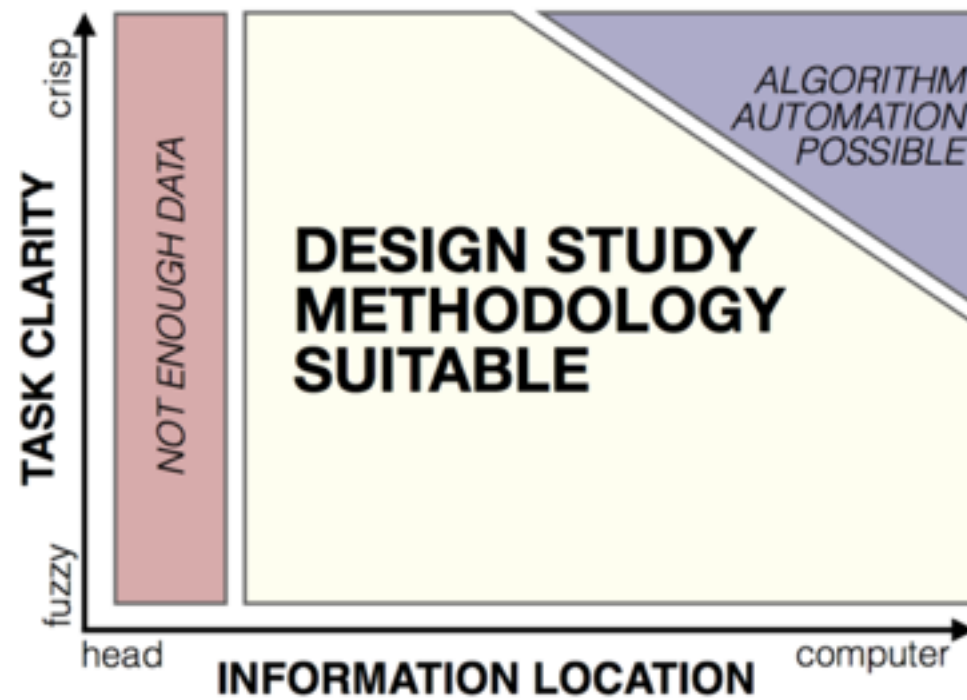
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Design Study Methodology



Michael Sedlmair



Miriah Meyer



Design Study Methodology

Reflections from the Trenches and from the Stacks

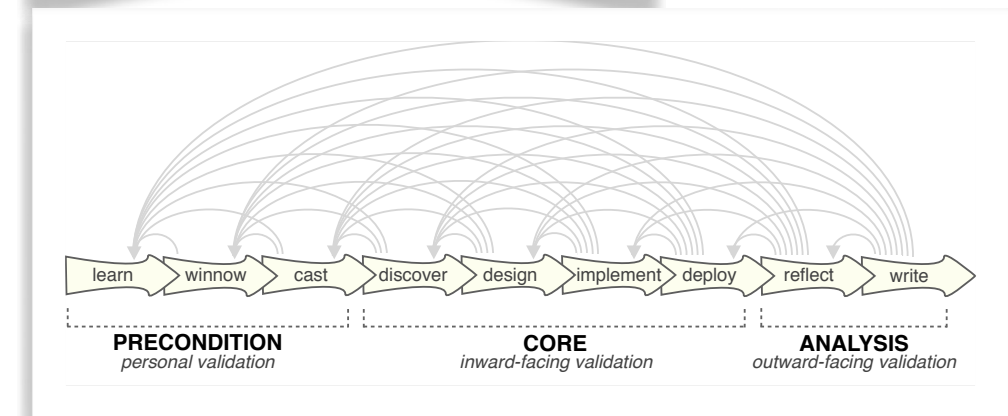
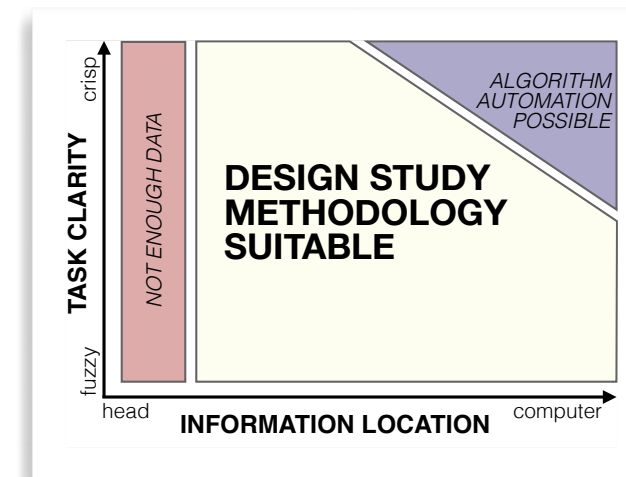
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Tamara Munzner
@tamaramunzner



Methodology for problem-driven work

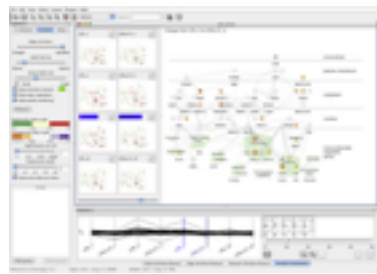
- definitions
- 9-stage framework
- 32 pitfalls & how to avoid them
- comparison to related methodologies



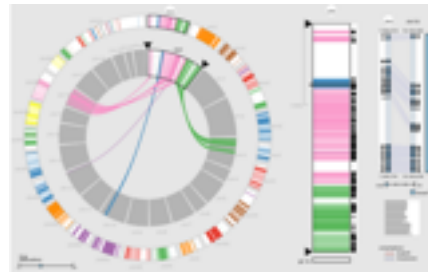
PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
PF-5	insufficient time available from potential collaborators	winnow
PF-6	no need for visualization: problem can be automated	winnow
PF-7	researcher expertise does not match domain problem	winnow
PF-8	no need for research: engineering vs. research project	winnow
PF-9	no need for change: existing tools are good enough	winnow



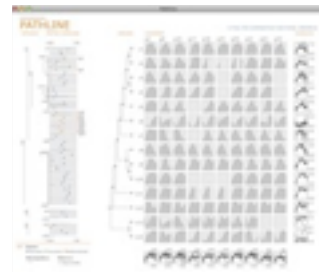
Lessons learned from the trenches: 21 between us



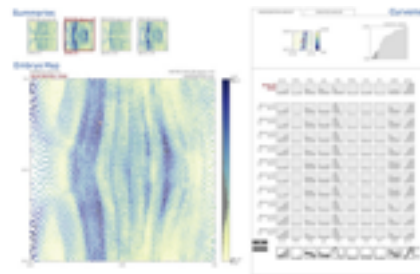
Cerebral
genomics



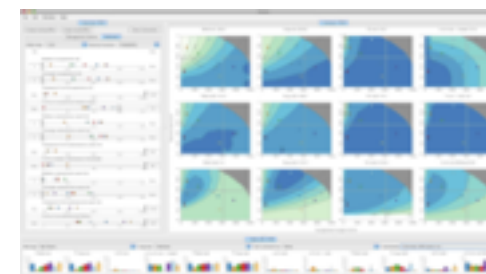
MizBee
genomics



Pathline
genomics



MulteeSum
genomics



Vismon
fisheries management



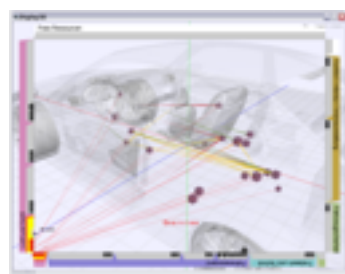
QuestVis
sustainability



WiKeVis
in-car networks



MostVis
in-car networks



Car-X-Ray
in-car networks



ProgSpy2010
in-car networks



ReEx
in-car networks



Cardiogram
in-car networks



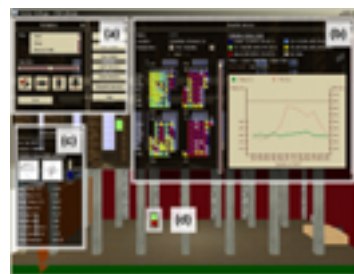
AutobahnVis
in-car networks



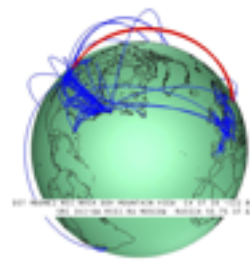
VisTra
in-car networks



Constellation
linguistics



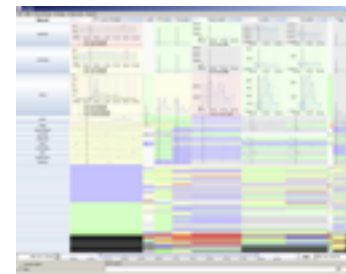
LibVis
cultural heritage



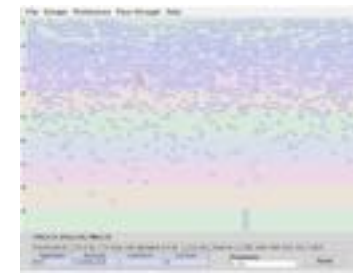
Caidants
multicast



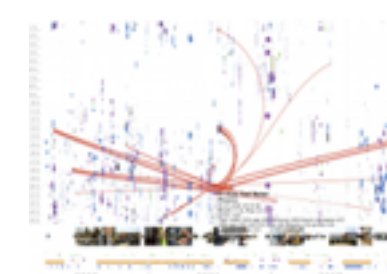
SessionViewer
web log analysis



LiveRAC
server hosting

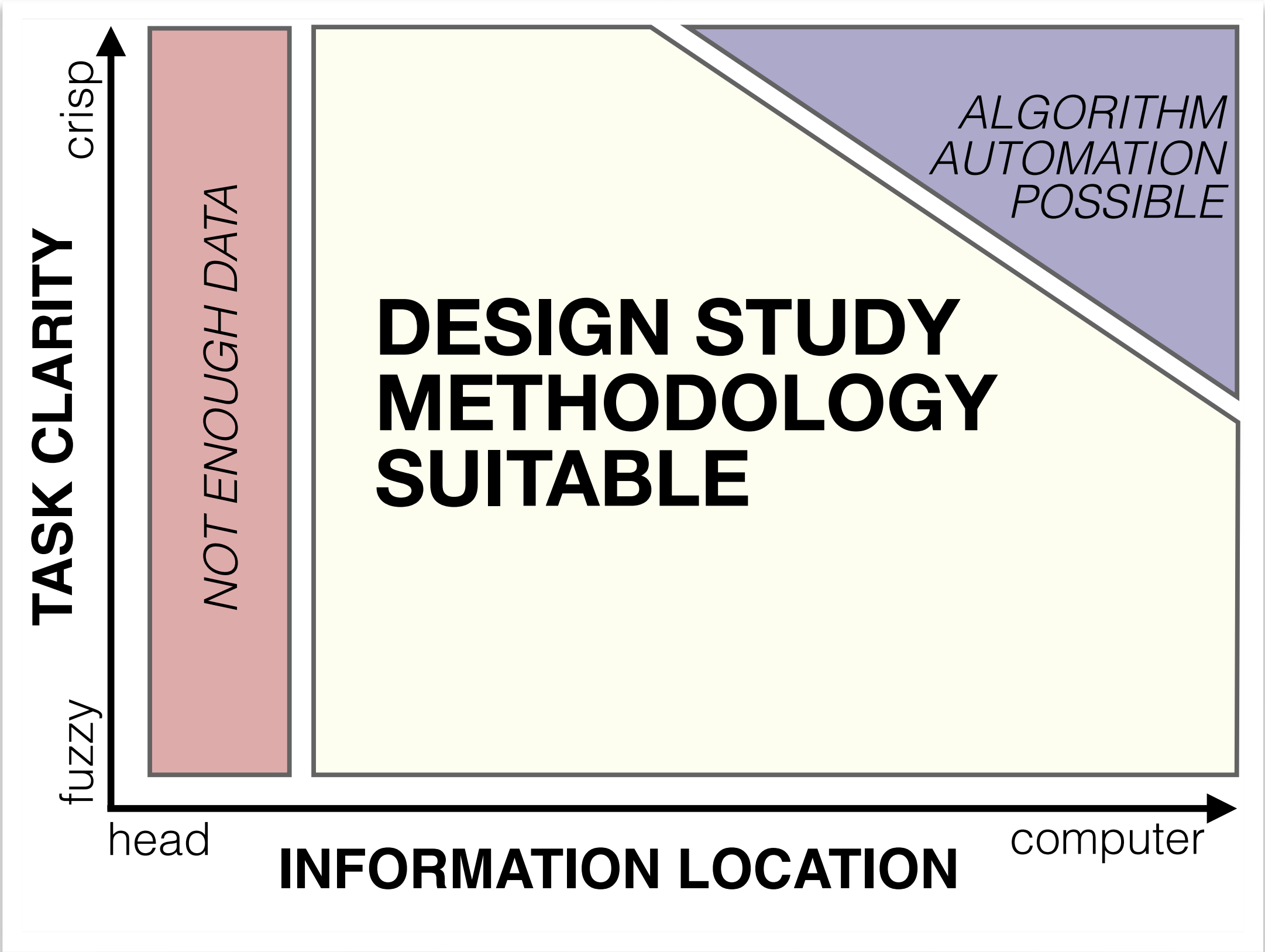


PowerSetViewer
data mining

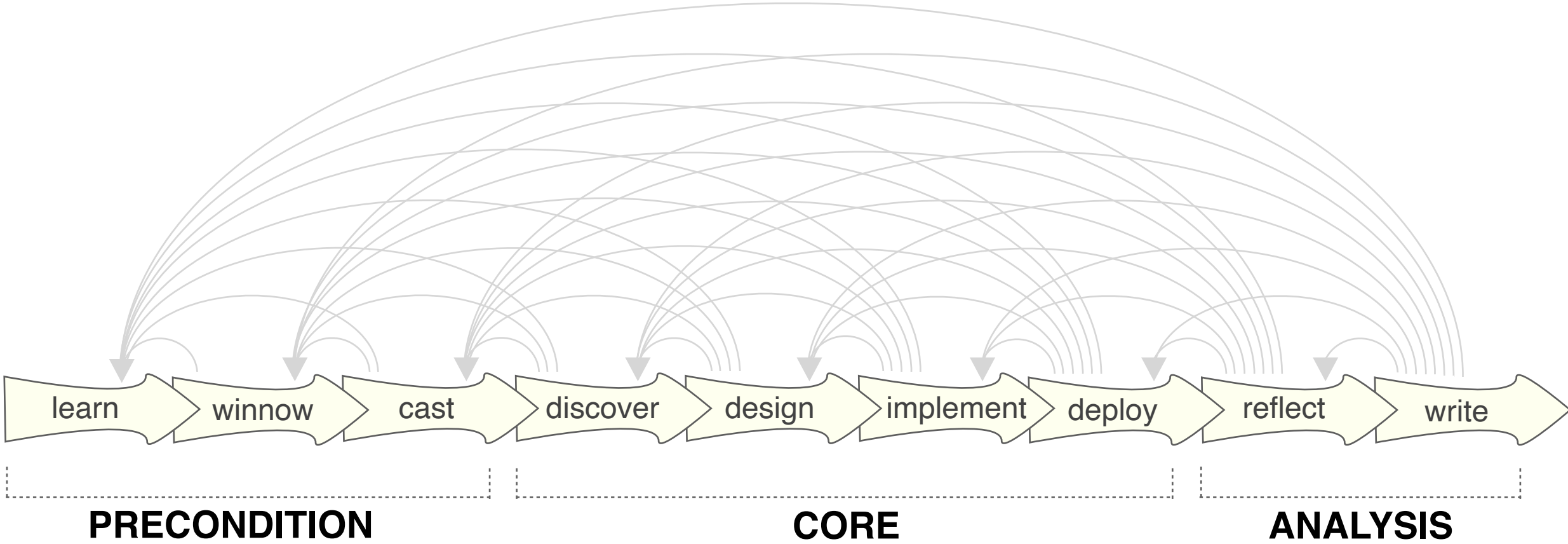


LastHistory
music listening

Design study methodology: definitions

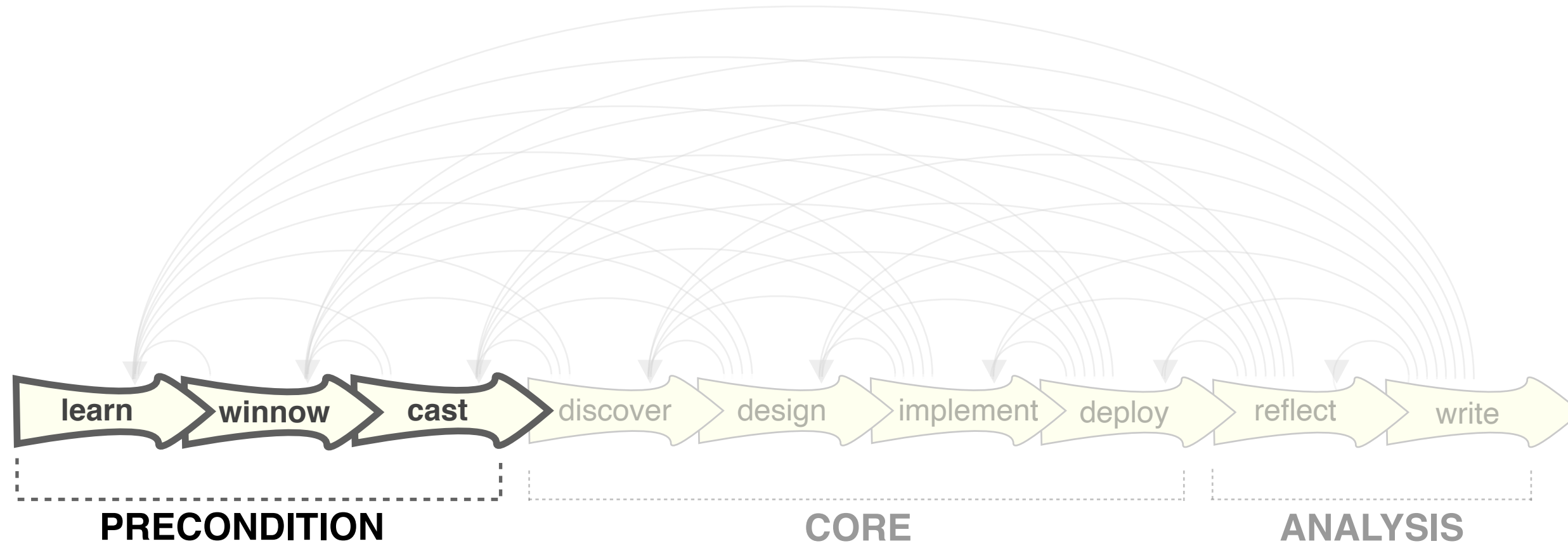


9 stage framework



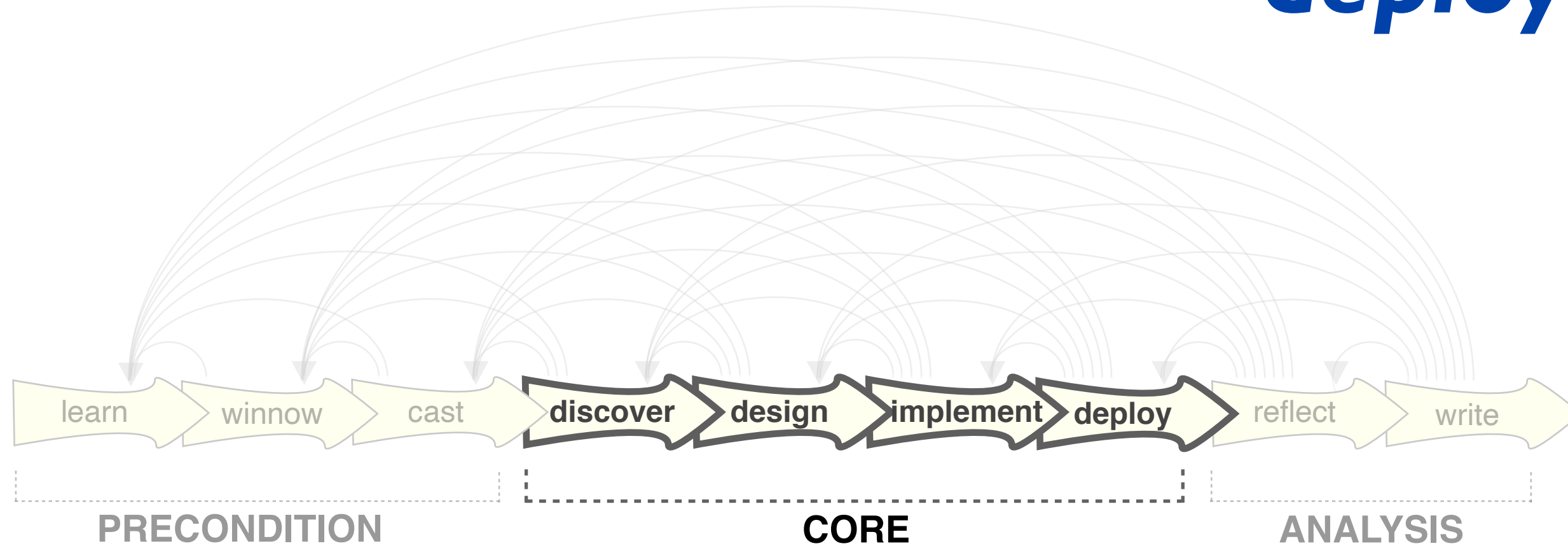
9-stage framework

learn
winnow
cast



9-stage framework

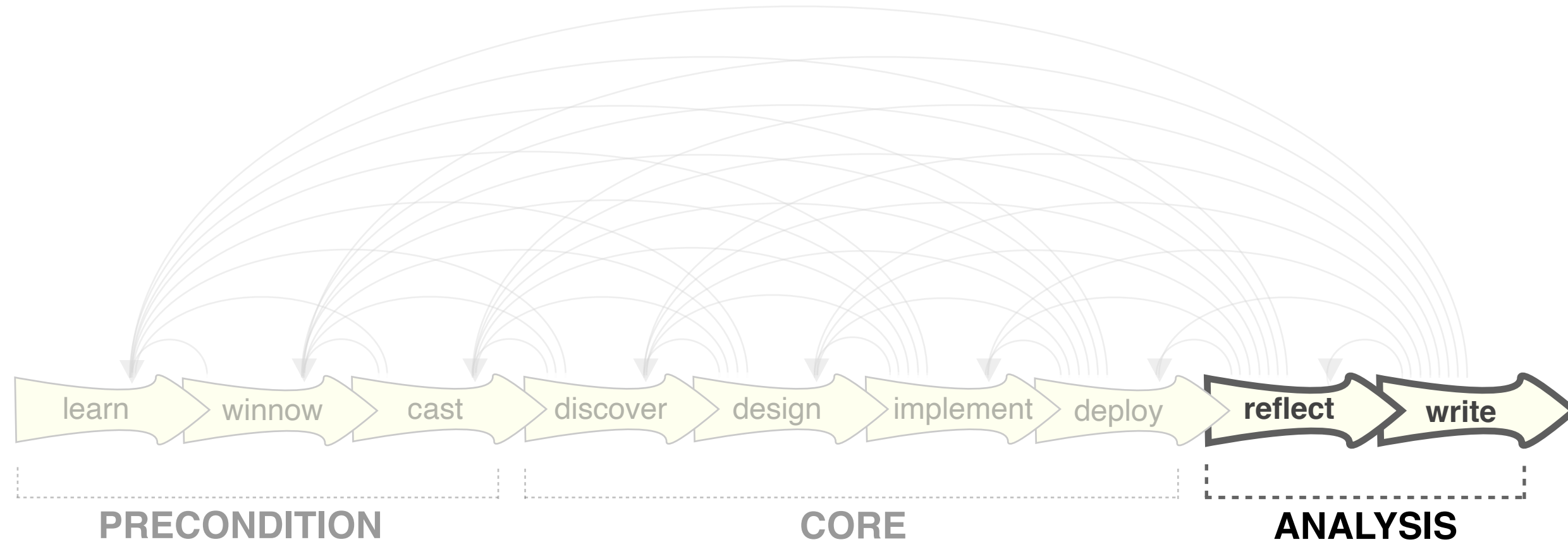
discover
design
implement
deploy



9-stage framework

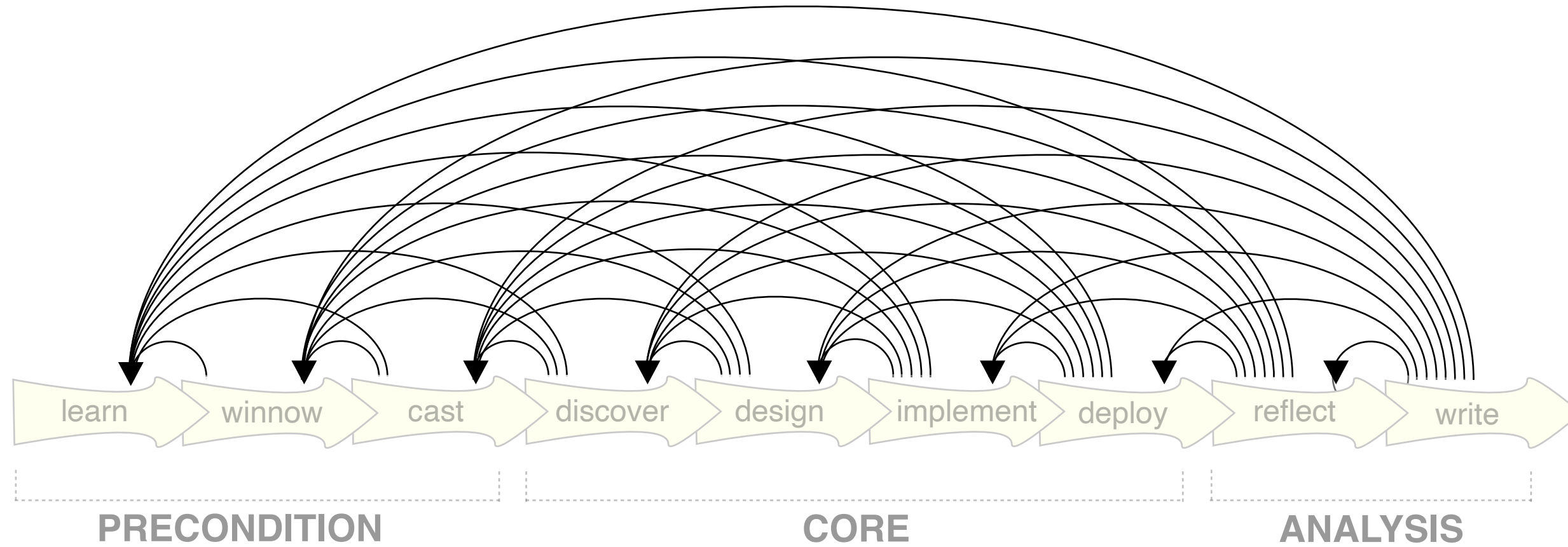
- guidelines: confirm, refine, reject, propose

reflect
write



9-stage framework

iterative



Design study methodology: 32 pitfalls

- and how to avoid them

PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
PF-5	insufficient time available from potential collaborators	winnow
PF-6	no need for visualization: problem can be automated	winnow
PF-7	researcher expertise does not match domain problem	winnow
PF-8	no need for research: engineering vs. research project	winnow
PF-9	no need for change: existing tools are good enough	winnow

I'm a domain expert!
Wanna collaborate?



Of course!!!



considerations



Have **data**?
Have **time**?
Have **need**?
...



roles



Are you a **user**???

... or maybe a **fellow tool builder?**

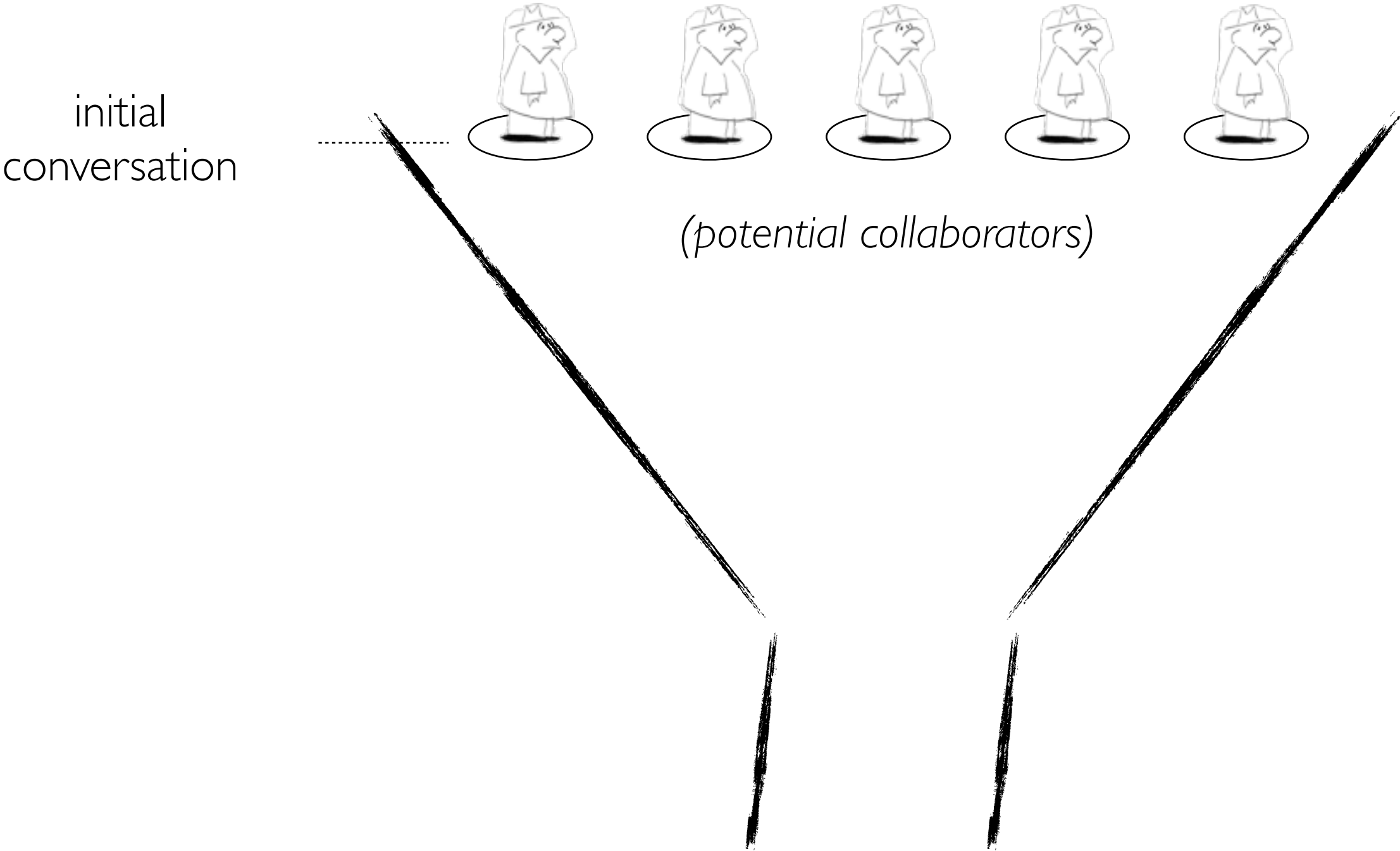


METAPHOR

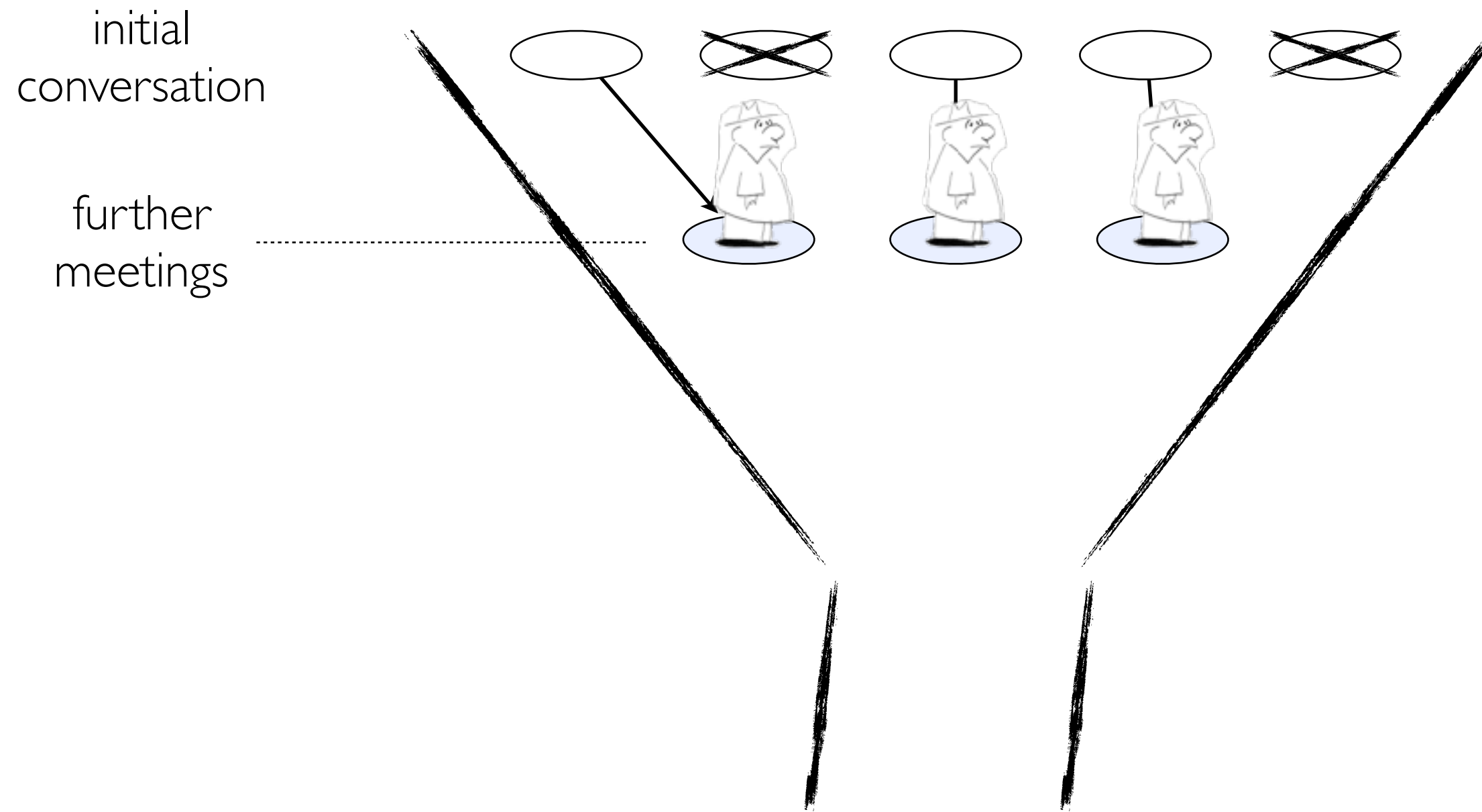
Winnowing



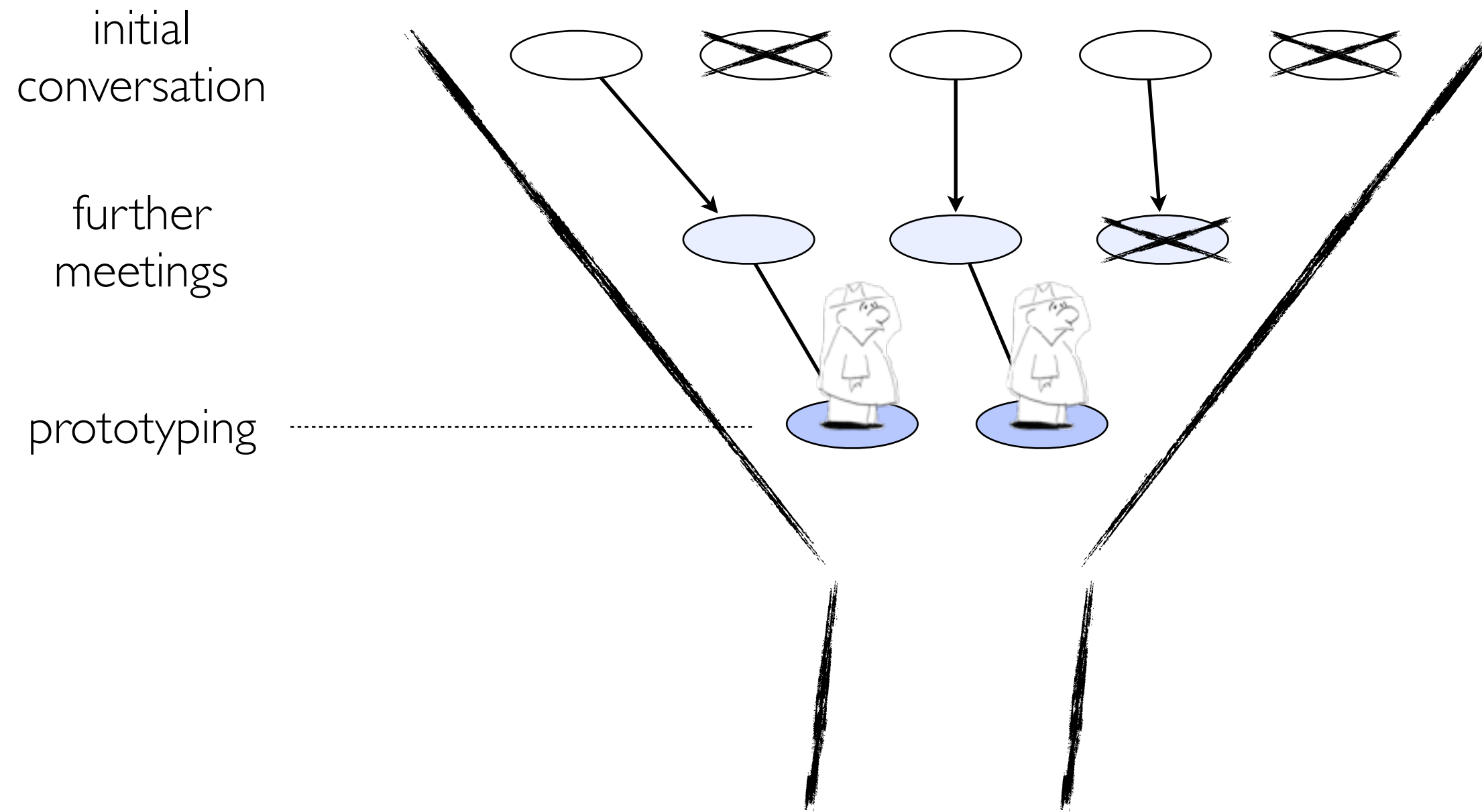
Collaborator winnowing



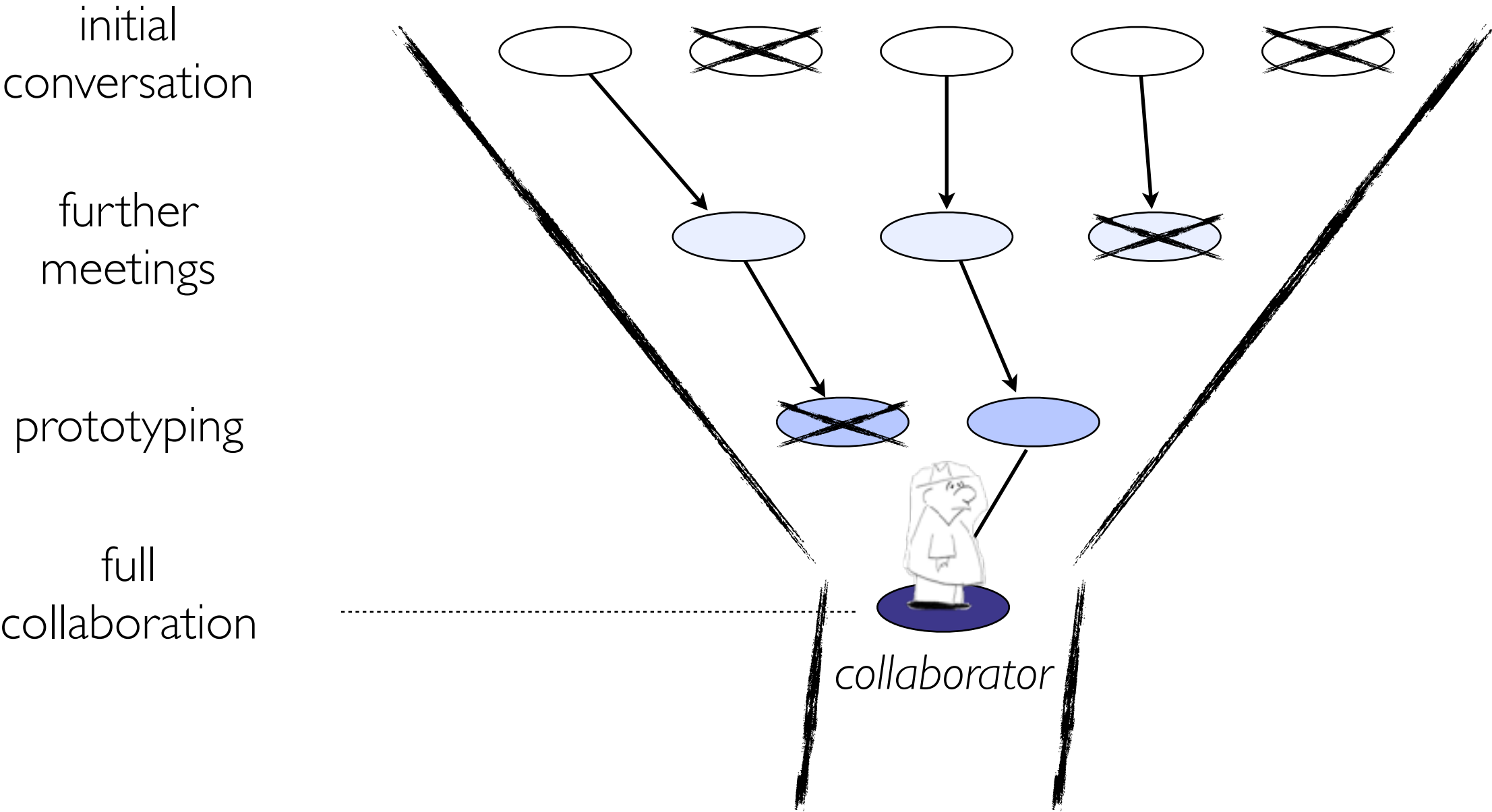
Collaborator winnowing



Collaborator winnowing



Collaborator winnowing



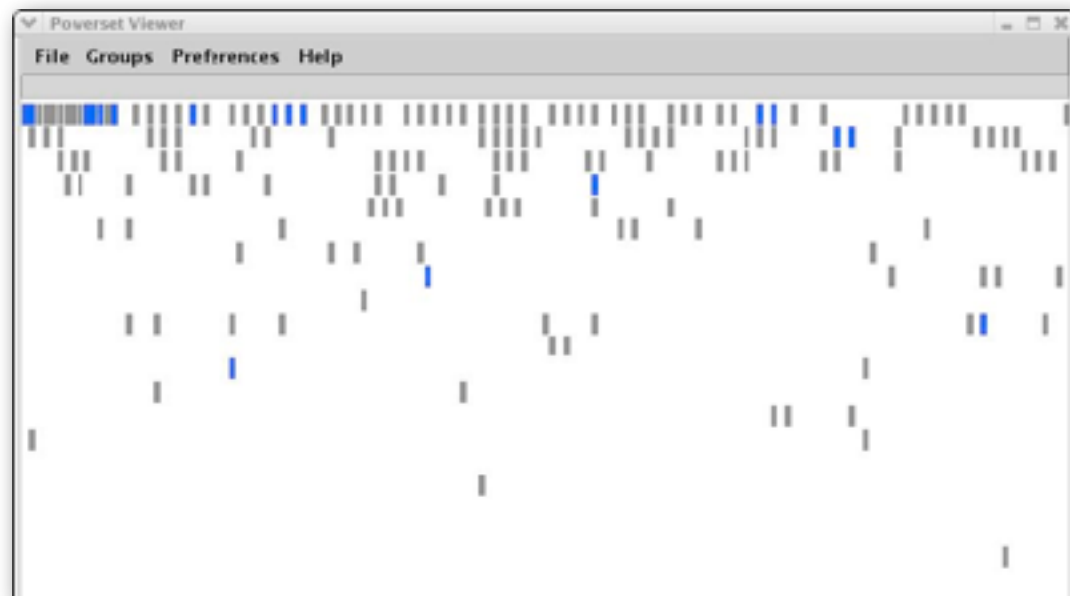
Collaborator winnowing



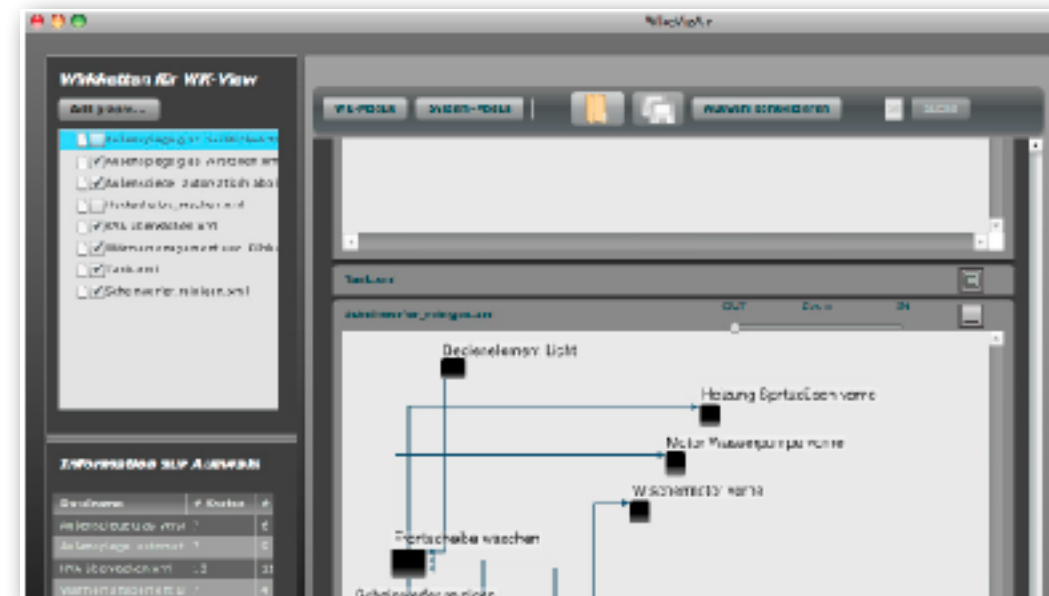
EXAMPLE FROM THE TRENCHES

Premature Collaboration!

PowerSet Viewer
2 years / 4 researchers



WikeVis
0.5 years / 2 researchers



EXAMPLE FROM THE TRENCHES

Premature Collaboration!

PowerSet Viewer
2 years / 4 researchers

WikeVis
0.5 years / 2 researchers



- Fellow tool builders
- Data promised

Design study methodology: 32 pitfalls

PF-10	no real/important/recurring task	winnow
PF-11	no rapport with collaborators	winnow
PF-12	not identifying front line analyst and gatekeeper before start	cast
PF-13	assuming every project will have the same role distribution	cast
PF-14	mistaking fellow tool builders for real end users	cast
PF-15	ignoring practices that currently work well	discover
PF-16	expecting <i>just talking</i> or <i>fly on wall</i> to work	discover
PF-17	experts focusing on visualization design vs. domain problem	discover
PF-18	learning their problems/language: too little / too much	discover
PF-19	abstraction: too little	design
PF-20	premature design commitment: consideration space too small	design

PITFALL

**PREMATURE DESIGN
COMMITMENT**

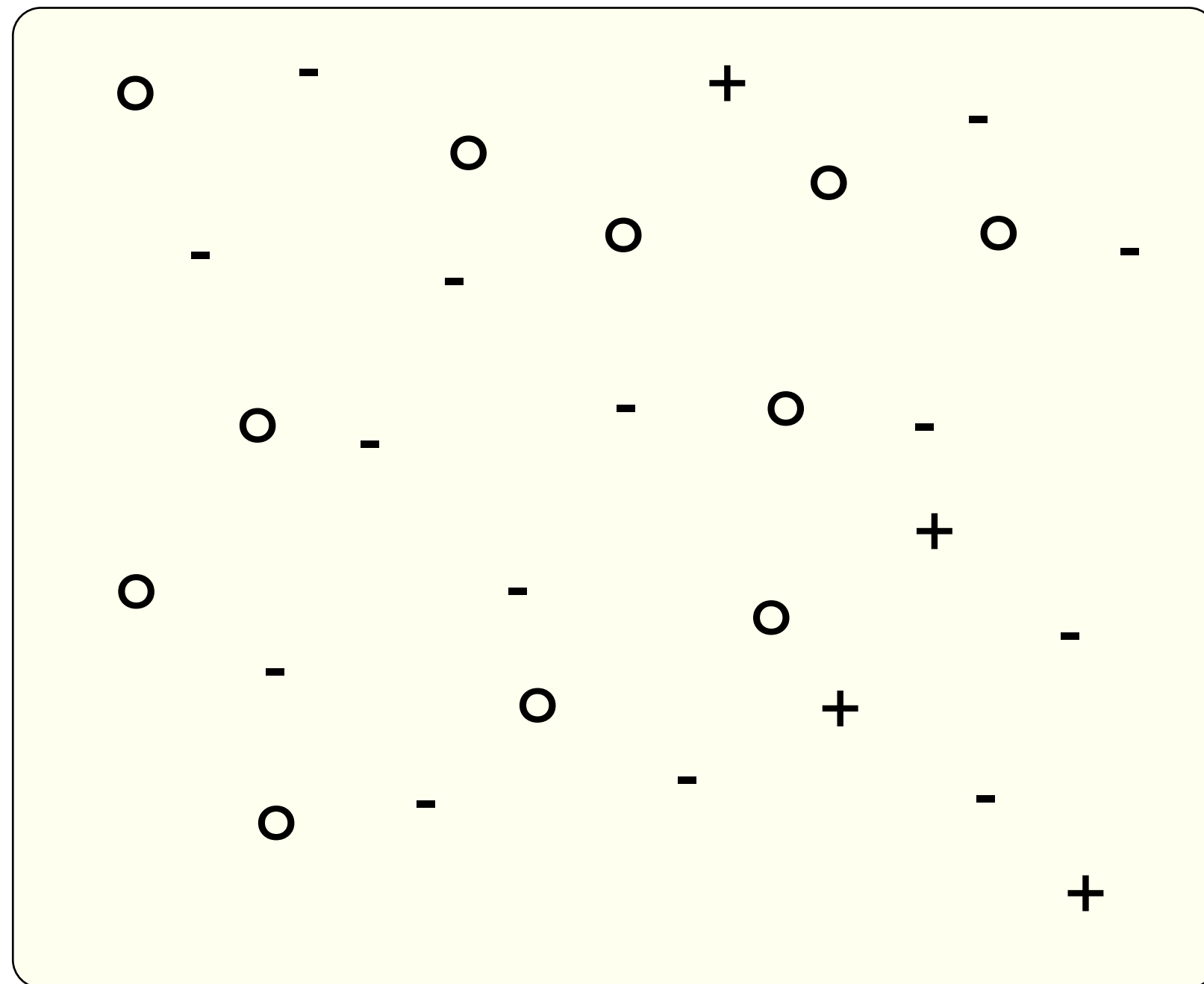
Of course they need the cool
technique I built last year!



MR. VIS

METAPHOR

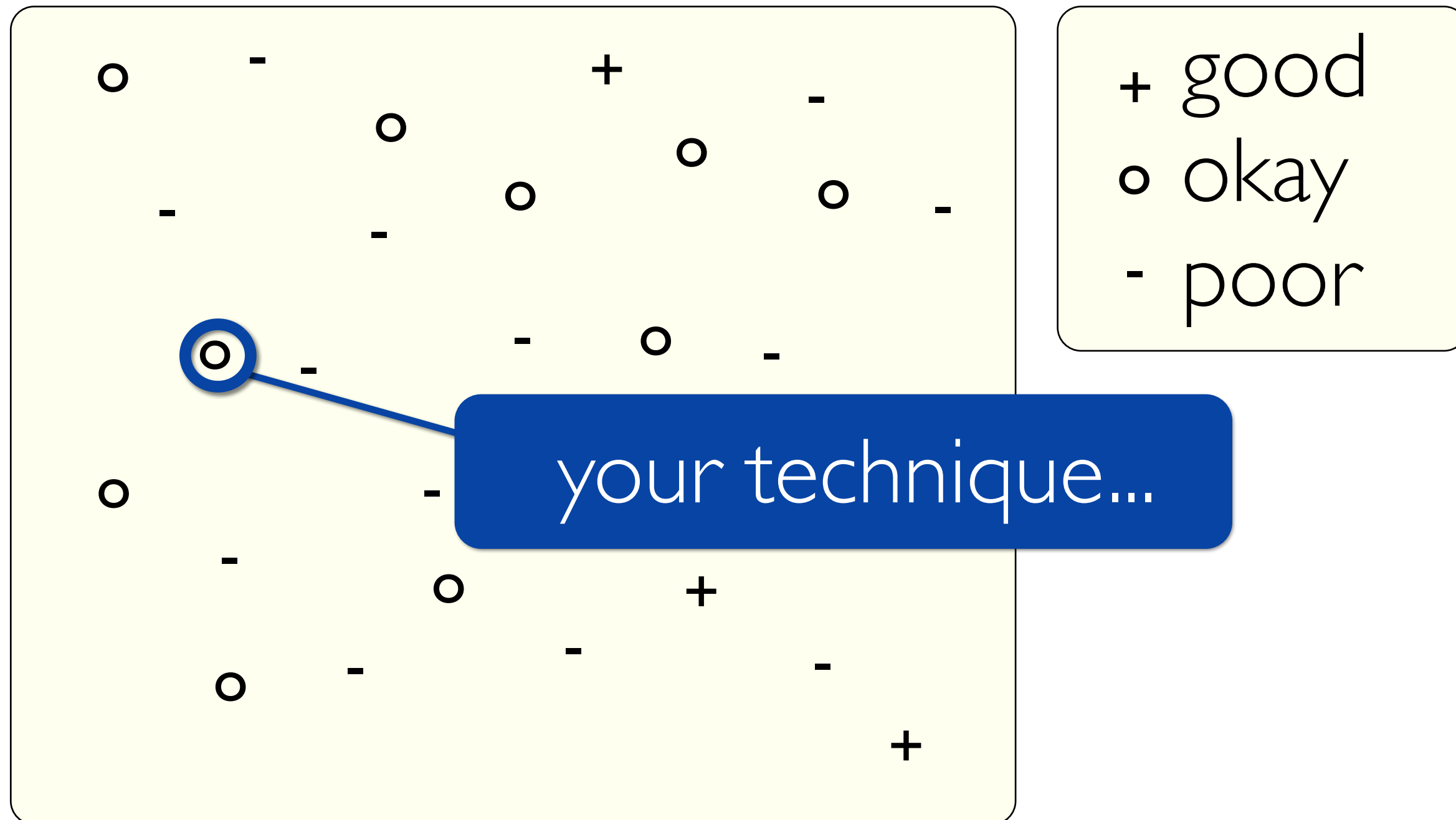
Design Space



+ good
o okay
- poor

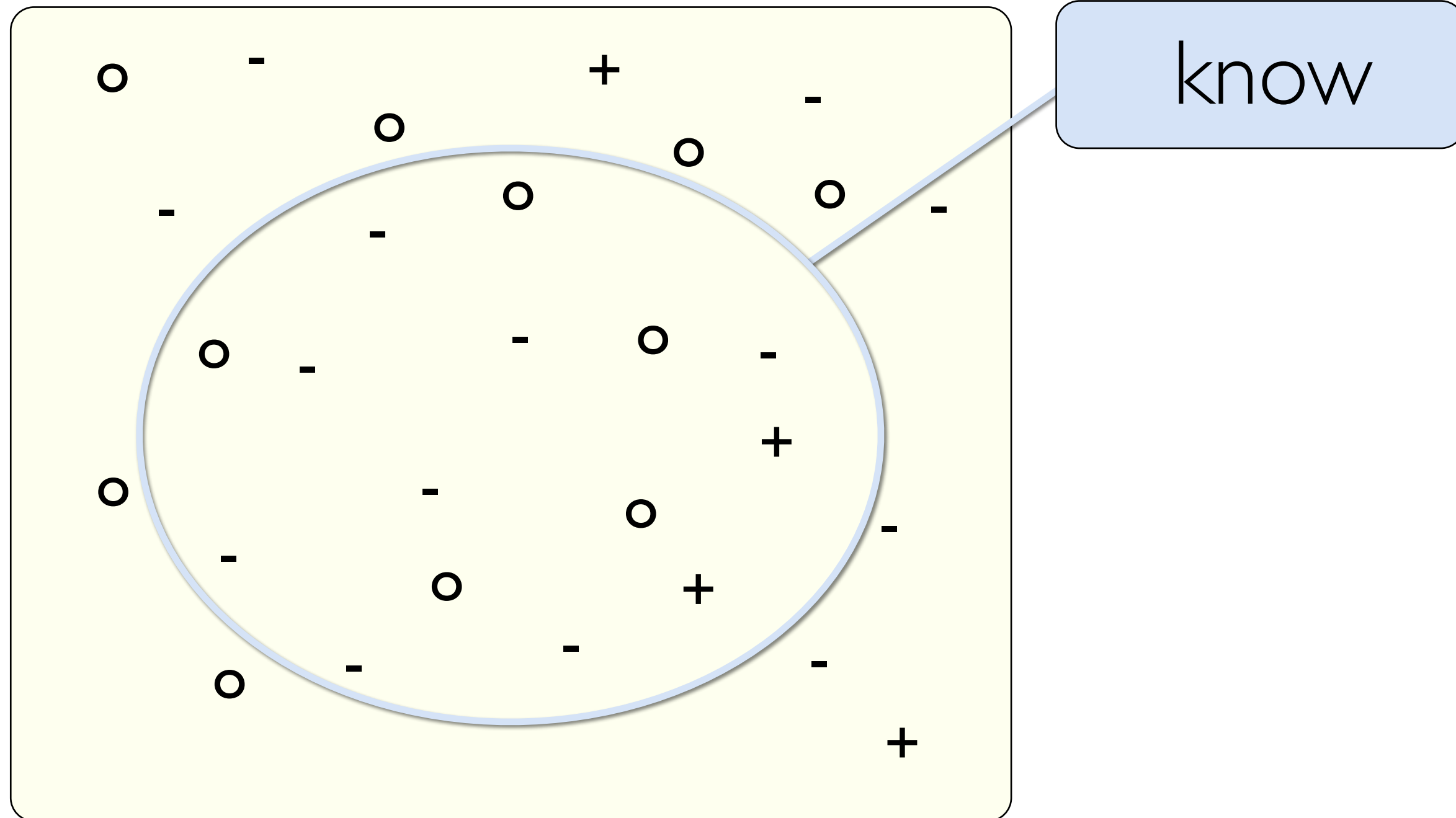
METAPHOR

Design Space



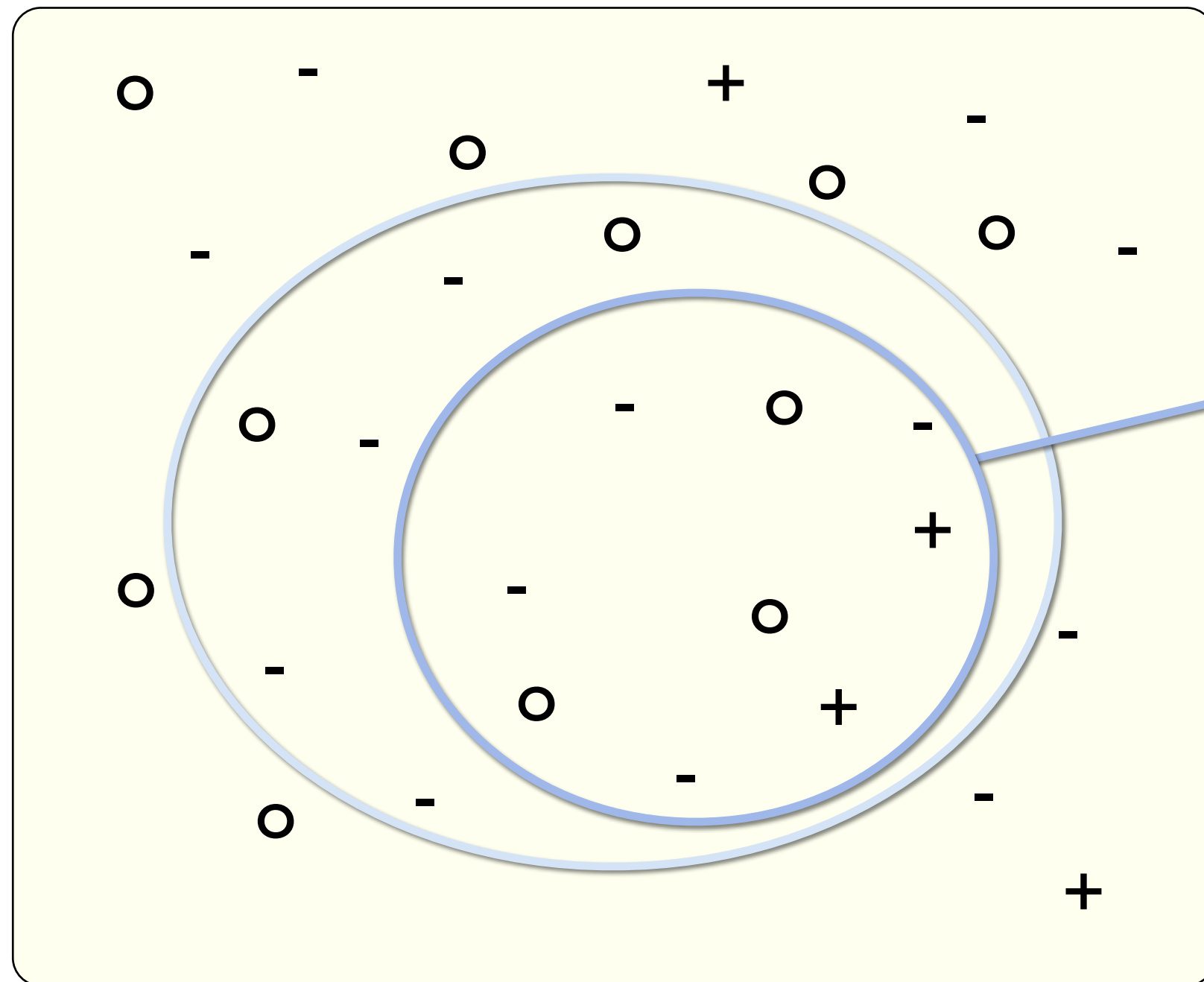
METAPHOR

Design Space



METAPHOR

Design Space

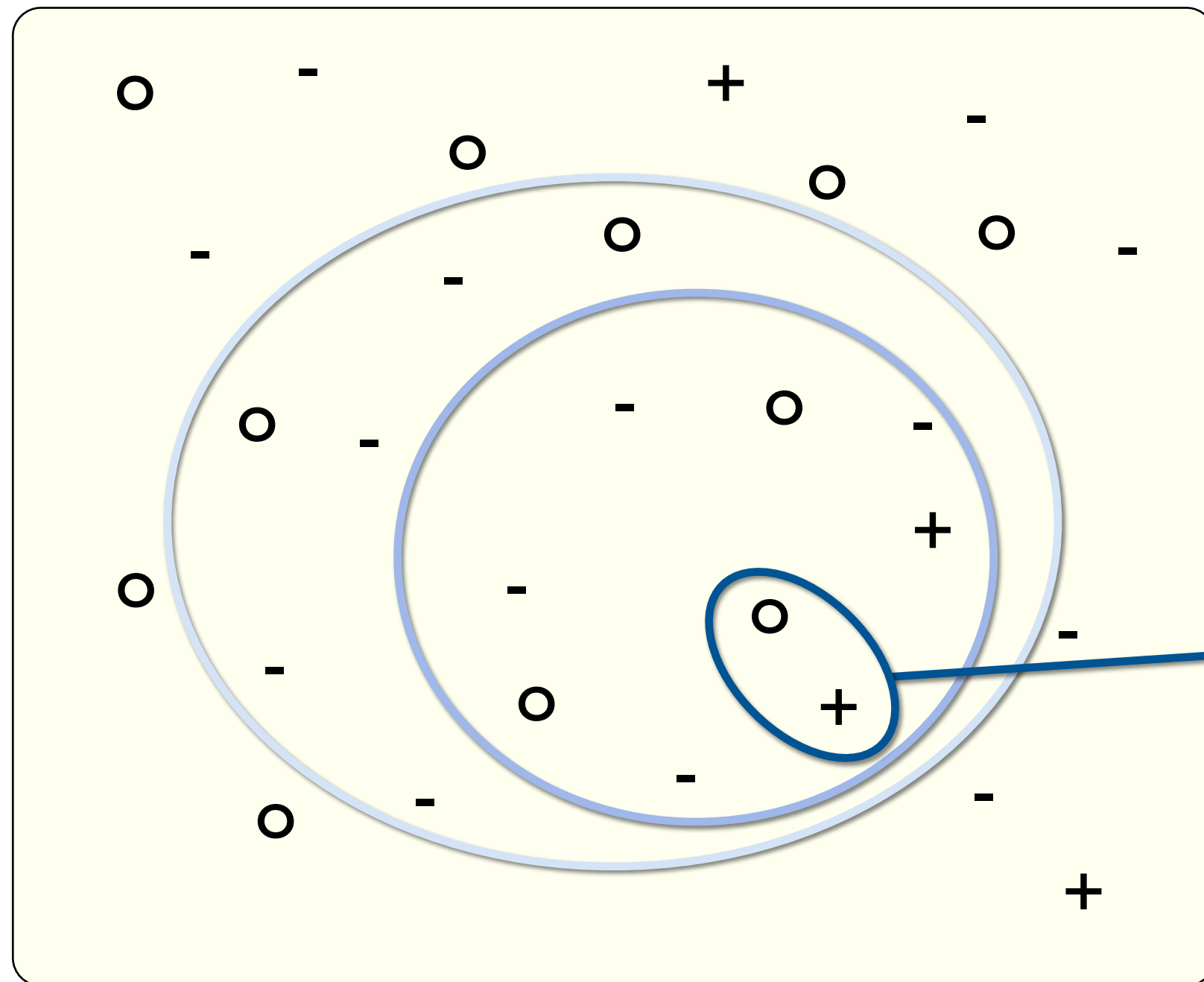


know

consider

METAPHOR

Design Space



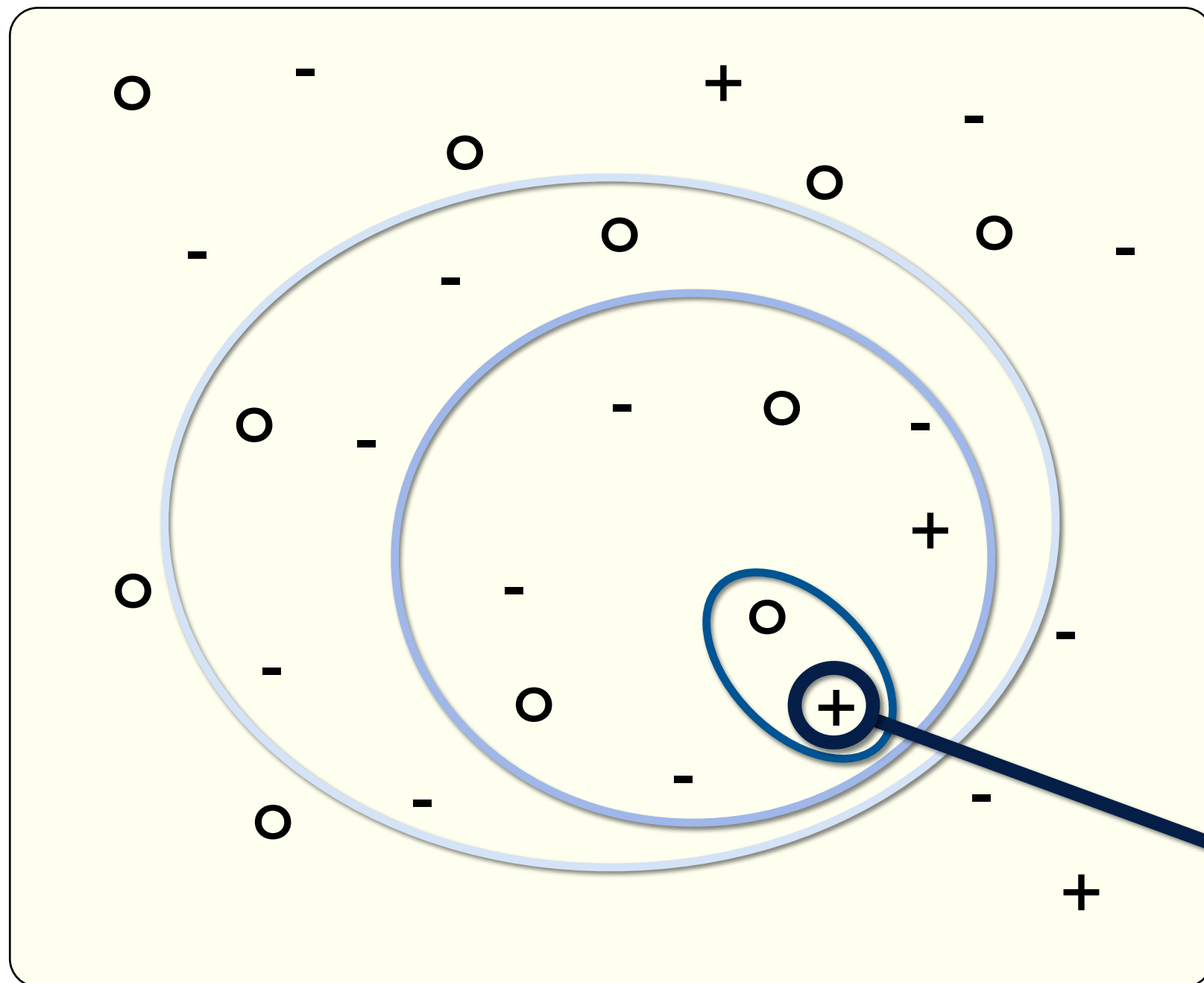
know

consider

propose

METAPHOR

Design Space



know

consider

propose

select

METAPHOR

Design Space



+ good
o okay
- poor

consider

propose

select

Design study methodology: 32 pitfalls

PF-21	mistaking technique-driven for problem-driven work	design
PF-22	nonrapid prototyping	implement
PF-23	usability: too little / too much	implement
PF-24	premature end: insufficient deploy time built into schedule	deploy
PF-25	usage study not case study: non-real task/data/user	deploy
PF-26	<i>liking</i> necessary but not sufficient for validation	deploy
PF-27	failing to improve guidelines: confirm, refine, reject, propose	reflect
PF-28	insufficient writing time built into schedule	write
PF-29	no technique contribution \neq good design study	write
PF-30	too much domain background in paper	write
PF-31	story told chronologically vs. focus on final results	write
PF-32	premature end: win race vs. practice music for debut	write

PITFALL

**PREMATURE
PUBLISHING**

I can write a design study
paper in a week!



MR. VIS

“writing is research”

[Wolcott: Writing up qualitative research, 2009]

METAPHOR

Horse Race vs. Music Debut

Must be first!



technique-driven

Am I ready?

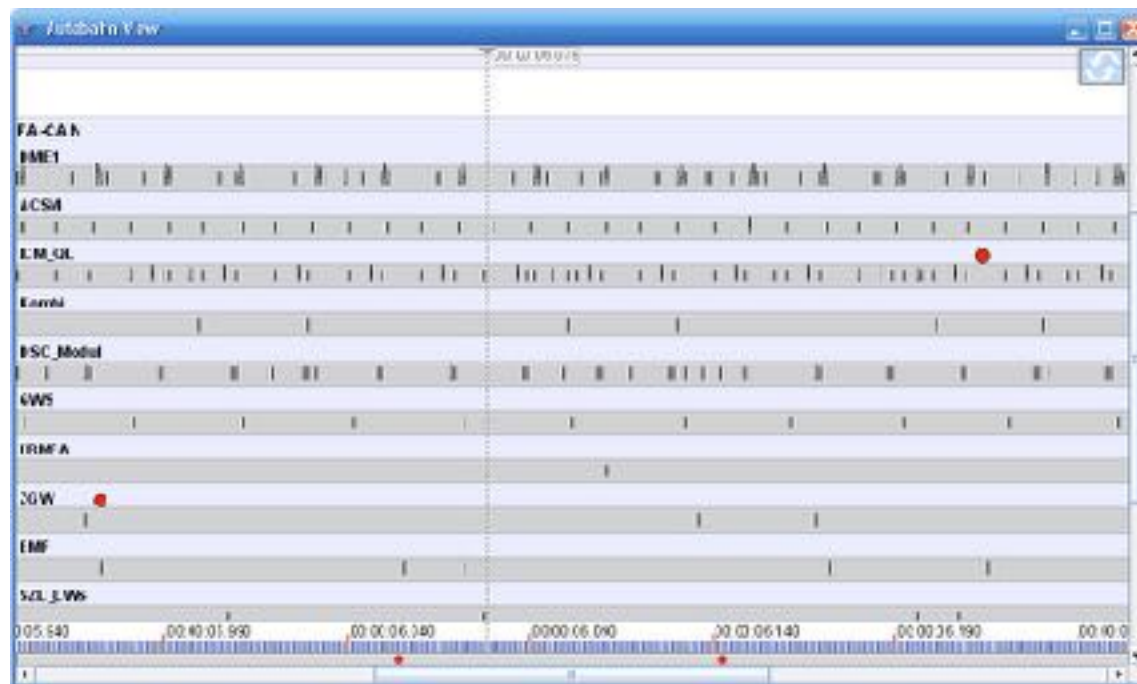


problem-driven

EXAMPLE FROM THE TRENCHES

Don't step on your own toes!

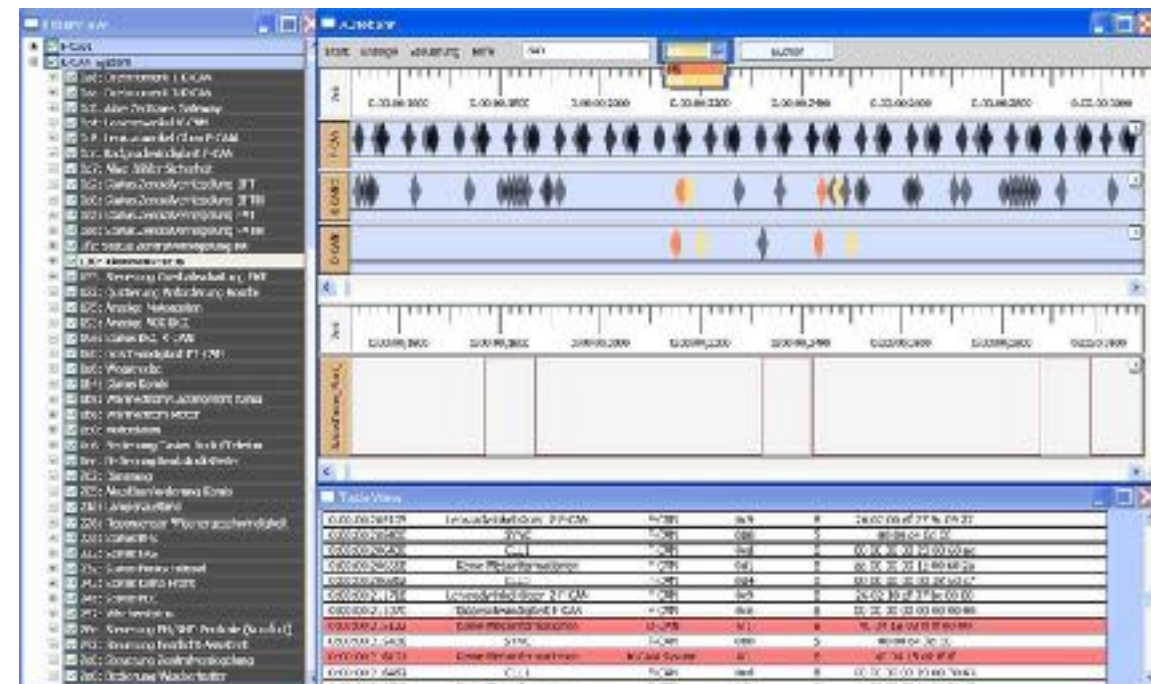
First design round published



AutobahnVis 1.0

[Sedlmair et al., Smart Graphics, 2009]

Subsequent work not stand-alone paper



AutobahnVis 2.0

[Sedlmair et al., Information Visualization 10(3), 2011]

Reflections from the stacks: Wholesale adoption inappropriate

- ethnography
 - rapid, goal-directed fieldwork
- grounded theory
 - not empty slate: vis background is key
- action research
 - aligned
 - intervention as goal
 - transferability not reproducibility
 - personal involvement is key
 - opposition
 - translation of participant concepts into visualization language
 - researcher lead not facilitate design
 - orthogonal to vis concerns: participants as writers, adversarial to status quo, postmodernity



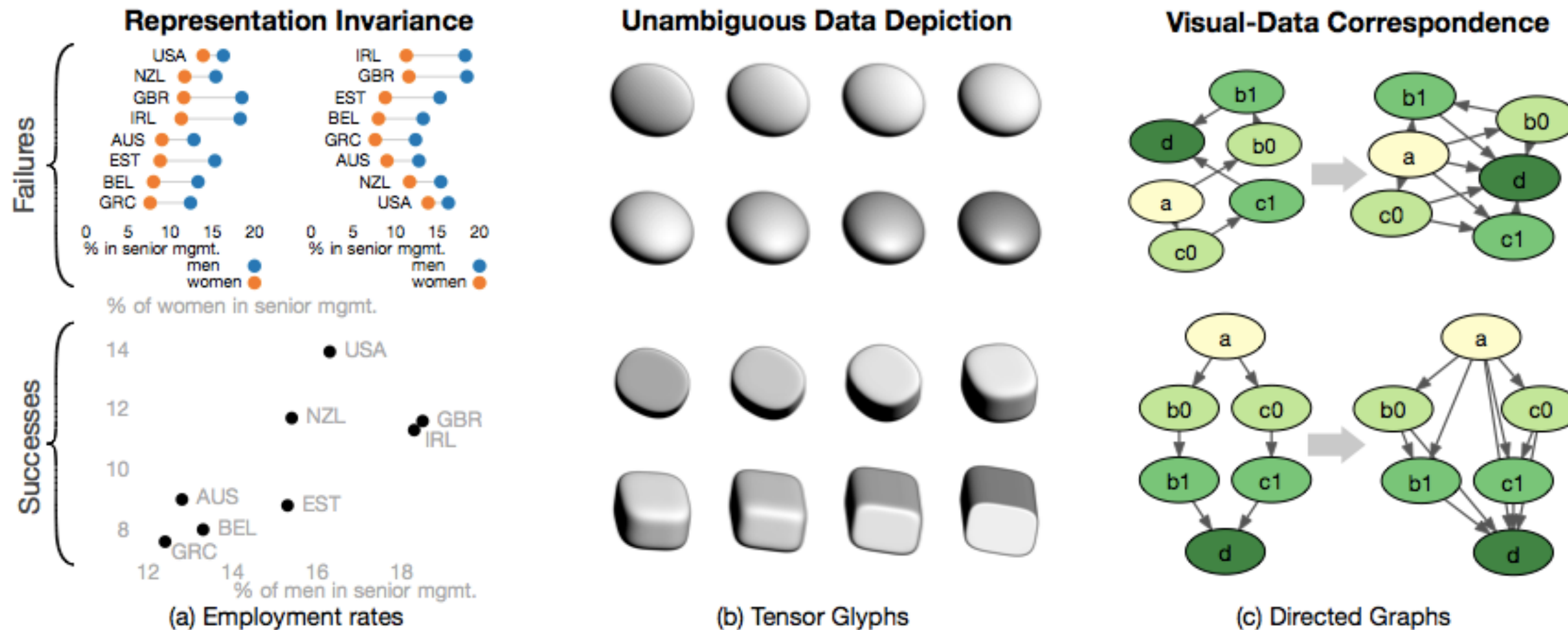
Next Steps

What-Why-How Analysis

- this approach is not the only way to analyze visualizations!
 - one specific framework intended to help you think
 - other frameworks support different ways of thinking
 - following: one interesting example

Algebraic Process for Visualization Design

- which mathematical structures in data are preserved and reflected in vis
 - negation, permutation, symmetry, invariance



[Fig 1. An Algebraic Process for Visualization Design. Carlos Scheidegger and Gordon Kindlmann. *IEEE TVCG (Proc. InfoVis 2014)*, 20(12):2181-2190.]

Algebraic process: Vocabulary

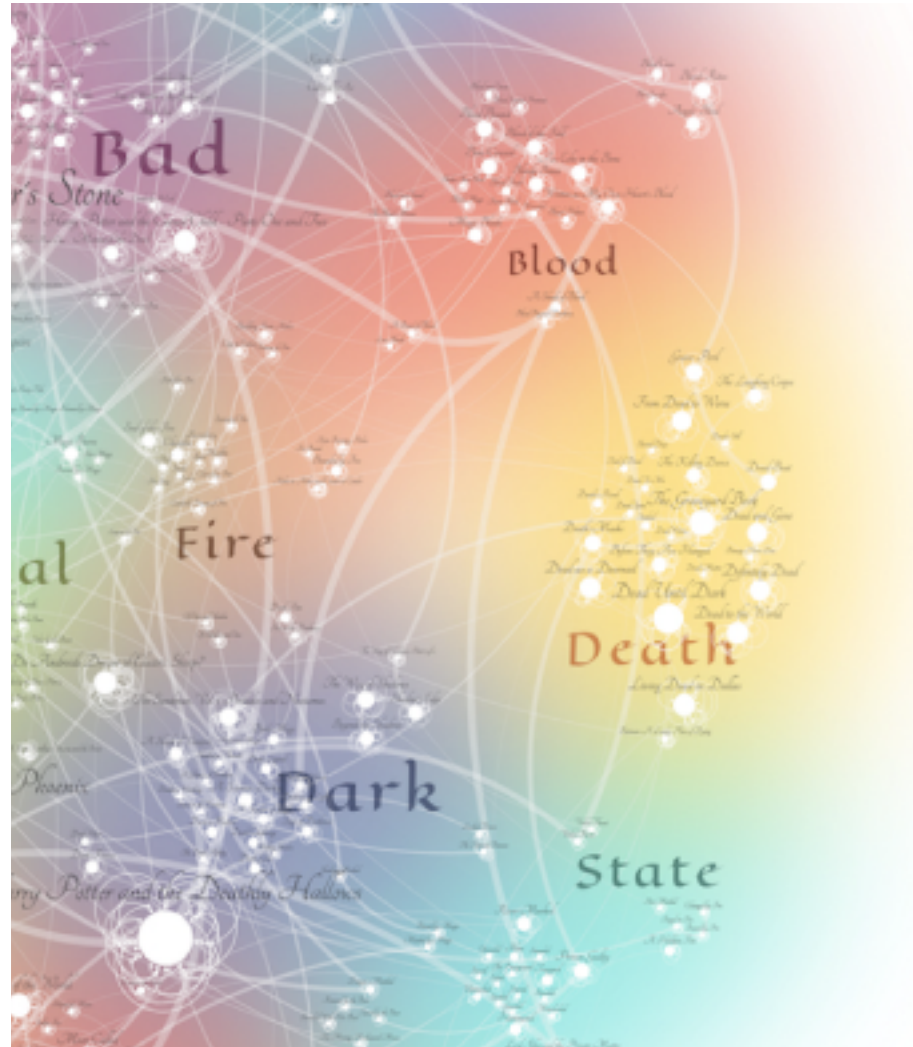
- **invariance** violation: single dataset, many visualizations
 - **hallucinator**
- **unambiguity** violation: many datasets, same vis
 - data change invisible to viewer
 - **confuser**
- **correspondence** violation:
 - can't see change of data in vis
 - **jumbler**
 - salient change in vis not due to significant change in data
 - **misleader**
 - match mathematical structure in data with visual perception
- we can X the data; can we Y the image?
 - are important data changes well-matched with obvious visual changes?

Visual Design Process In Depth: **Dear Data**



<http://www.dear-data.com/by-week/>

Visual Design Process In Depth: **Data Sketches**



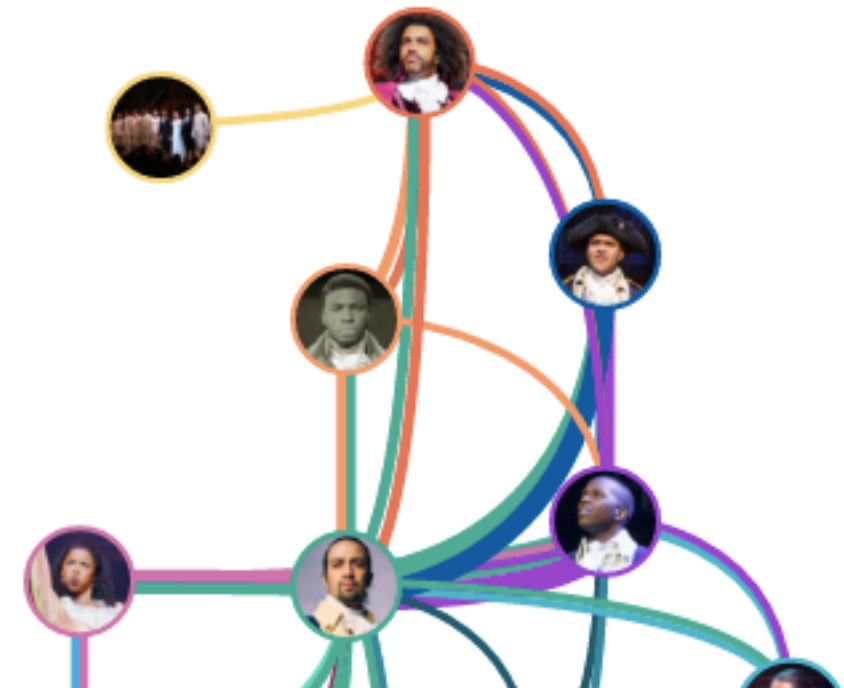
November Books

Searching for patterns in Fantasy titles and musical lyrics

[Read more...](#)

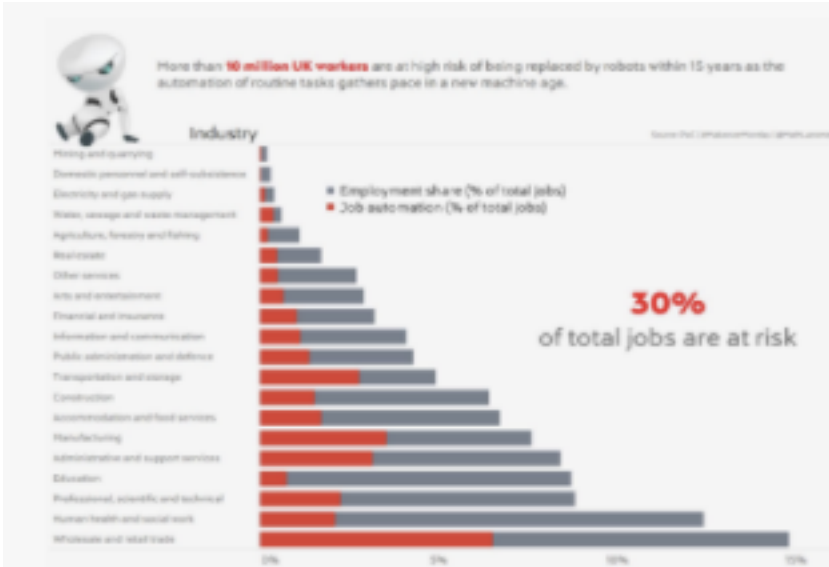
c2 c3 *m1/m2/m3* *l1 l2 l3*

Relationship **Death**
r1 *r2* *d1*



<http://www.datasketch.es/>

Redesign En Masse: **Makeover Mondays**



Week 14 – Millions of UK workers at risk of being replaced by robots

Apr 7, 2017

During week 14 we looked at job automation and the potential impact of robots and AI on the UK employment market.



Week 13 – The Secret of Success

Mar 31, 2017

Week 13 took a look at a Russian survey about the secret of success. Dot plot, bump charts, bar charts, radar charts. This week had it all! Plus seven lessons to take on board.



Week 12 – March Madness

Mar 24, 2017

We looked at March Madness data for week 12, highlighting the phenomenon that is US college basketball. Quite a few vizzes showed the passion that

In-Class Exercise

Scenario

- data: room occupancy rates
 - 1 room
 - occupancy measured every 5 min, duration 1 day
- task: characterize space usage pattern

- design
 - propose idioms (visual encoding, interaction)
 - justify idiom choice

Consider

- **what's the cardinality of the data?**
- **is a single static chart good enough?**
- **should you derive any useful additional data?**

Cardinality

- Marshall: 68 cities * 40 years * 4 crime types = 10,880
- Wine: 130K * 4 = 650,000
 - spatial (hierarchical), quantitative, categorical, free-form text

Scenario

- data: room occupancy rates
 - 20 rooms
 - measured every 5 min, duration 1 day
- task: compare space usage patterns between rooms
- design
 - propose idioms (visual encoding, interaction)
 - justify idiom choice

Consider

- what's the cardinality of the data?
- is a single static chart good enough?
- should you derive any useful additional data?
- **what are trade-offs between**
 - **filtering to see one chart at a time**
 - **showing all side by side with small multiples**
 - **superimposing all on top of each other**

Scenario

- data: room occupancy rates in building
 - 1 building: 200 rooms across 4 floors
 - measured every 5 min, duration 1 day
 - time series + floor plans
- task: characterize space usage patterns
 - trends, outliers
- design
 - propose & justify idioms

Consider

- what's the cardinality of the data?
- is a single static chart good enough?
- should you derive any useful additional data?
- what are trade-offs between
 - filtering to see one chart at a time
 - showing side by side with small multiples
 - superimposing on top of each other
- **multi-scale structure to exploit? aggregate, zoom, slice/dice, filter?**

Scenario

- data: room occupancy rates in building
 - 1 building: 200 rooms across 4 floors
 - measured every 5 min, duration 1 **year**
 - time series + floor plans + **room sizes**
- task: characterize space usage patterns
 - trends, outliers
- design
 - propose & justify idioms

Consider

- what's the cardinality of the data?
- is a single static chart good enough?
- should you derive any useful additional data?
- what are trade-offs between
 - filtering to see one chart at a time
 - showing side by side with small multiples
 - superimposing on top of each other
- multi-scale structure to exploit? aggregate, zoom, slice/dice, filter?
- **can you normalize the data? should you - always vs on demand?**
- **how to handle multi-scale space and multi-scale time?**

Scenario

- data: currency exchange rates
 - 30 countries (each against CAD)
 - measured every 5 min, duration 5 years
 - time series + country names + continent names (+ map shapefiles) + country populations
- task: find groups of similarly-performing currencies

- design
 - propose & justify idioms

Consider

- what's the cardinality of the data?
- is a single static chart good enough?
- should you derive any useful additional data?
- what are trade-offs between
 - filtering to see one chart at a time
 - showing side by side with small multiples
 - superimposing on top of each other
- multi-scale structure to exploit? aggregate, zoom, slice/dice, filter?
- can you normalize the data? should you - always vs on demand?
- how to handle multi-scale space and multi-scale time?
- **is spatial information germane or extraneous?**

Scenario

- data: CPU usage across many machines
 - 100 machines, belonging to 20 companies
 - measured every 5 min, duration 1 month
 - time series + company name + company location (country)
- task: capacity planning for machine room

- design
 - propose & justify idioms

Scenario

- data: many metrics across many machines
 - 100 machines, belonging to 20 companies
 - 4 metrics measured every 5 min, duration 1 month
 - CPU, memory, disk I/O, network traffic
 - time series + company name + company sector (finance/tech/entertainment/other)
- task: forensic analysis to determine possible causes of crashes

- design
 - propose & justify idioms