Visualization Analysis & Design

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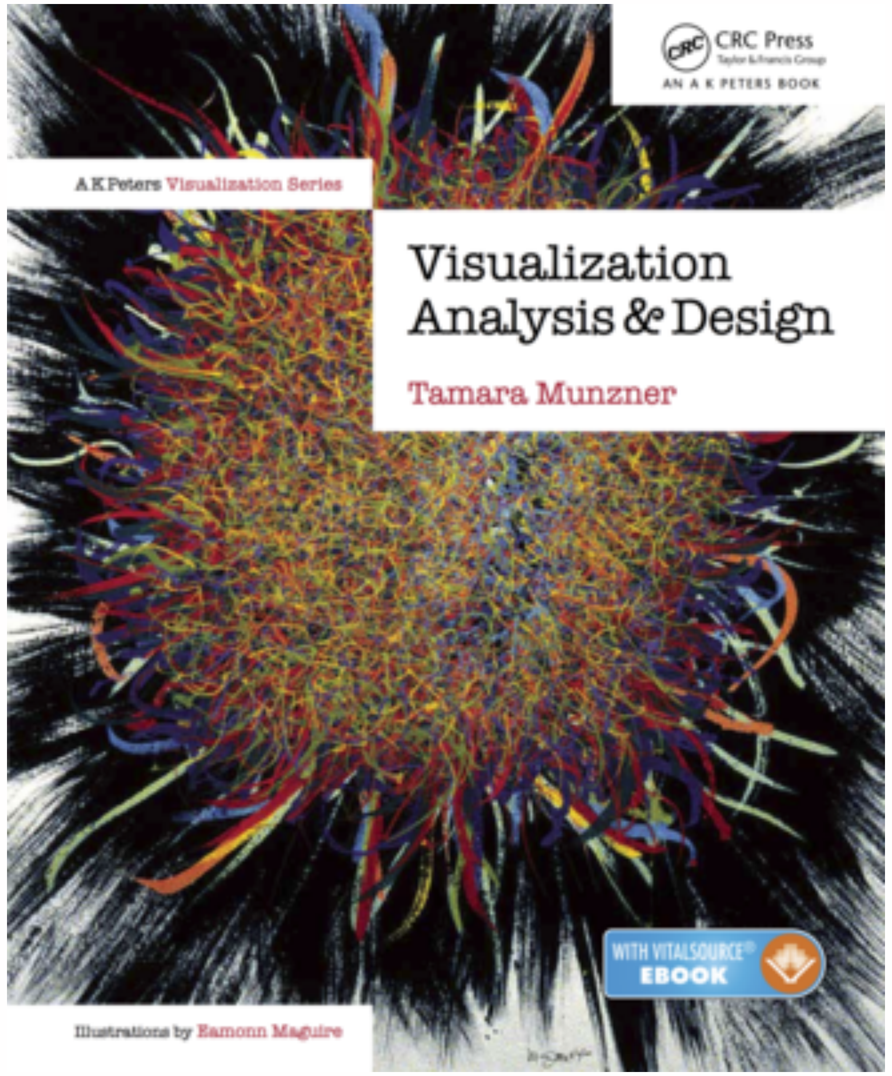


Graphics Interface 2016 Invited Talk
June 2 2016, Victoria BC

http://www.cs.ubc.ca/~tmm/talks.html#vad16gi

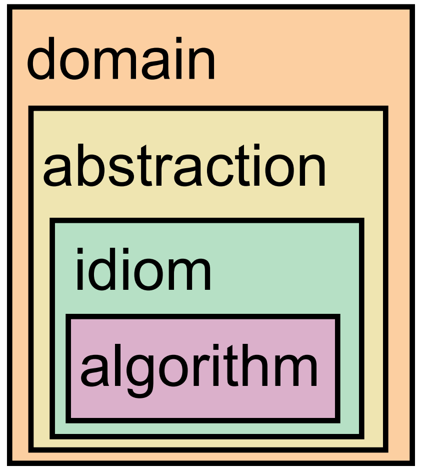
@tamaramunzner

Why talk about a textbook to a room of experts?

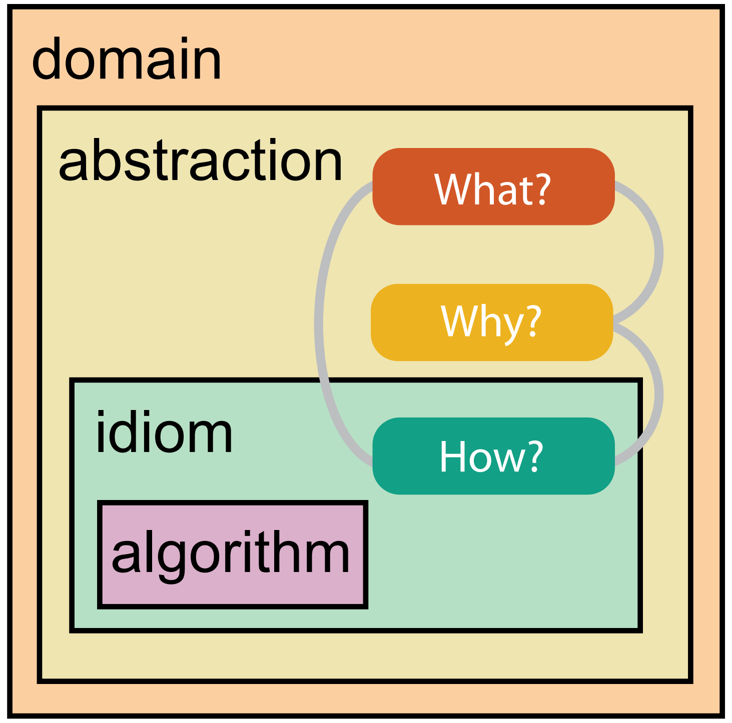
- many folks here in graphics or HCI, but few in visualization
  - my own roots in graphics, later added HCI quant methods, then HCI qual methods
- convince you of the value in thinking systematically about vis design
  - decompose into comprehensive framework of principles and design choices
  - situate specific examples within framework as concrete illustrations
- provide unified view that crosscuts entire field of visualization
  - infovis and scivis: addressing different kinds of data
  - visual analytics: interweave data analysis & transformation w/ interactive visual exploration
  - caveat: my own background in infovis shines through!

Analysis framework: Four levels, three questions

- *domain* situation
  – who are the target users?
- *abstraction*
  – translate from specifics of domain to vocabulary of vis
  - **what** is shown? **data abstraction**
    - often don't just draw what you're given: transform to new form
  - **why** is the user looking at it? **task abstraction**
- *idiom*
  - **how** is it shown?
    - **visual encoding idiom**: how to draw
    - **interaction idiom**: how to manipulate
- *algorithm*
  – efficient computation



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



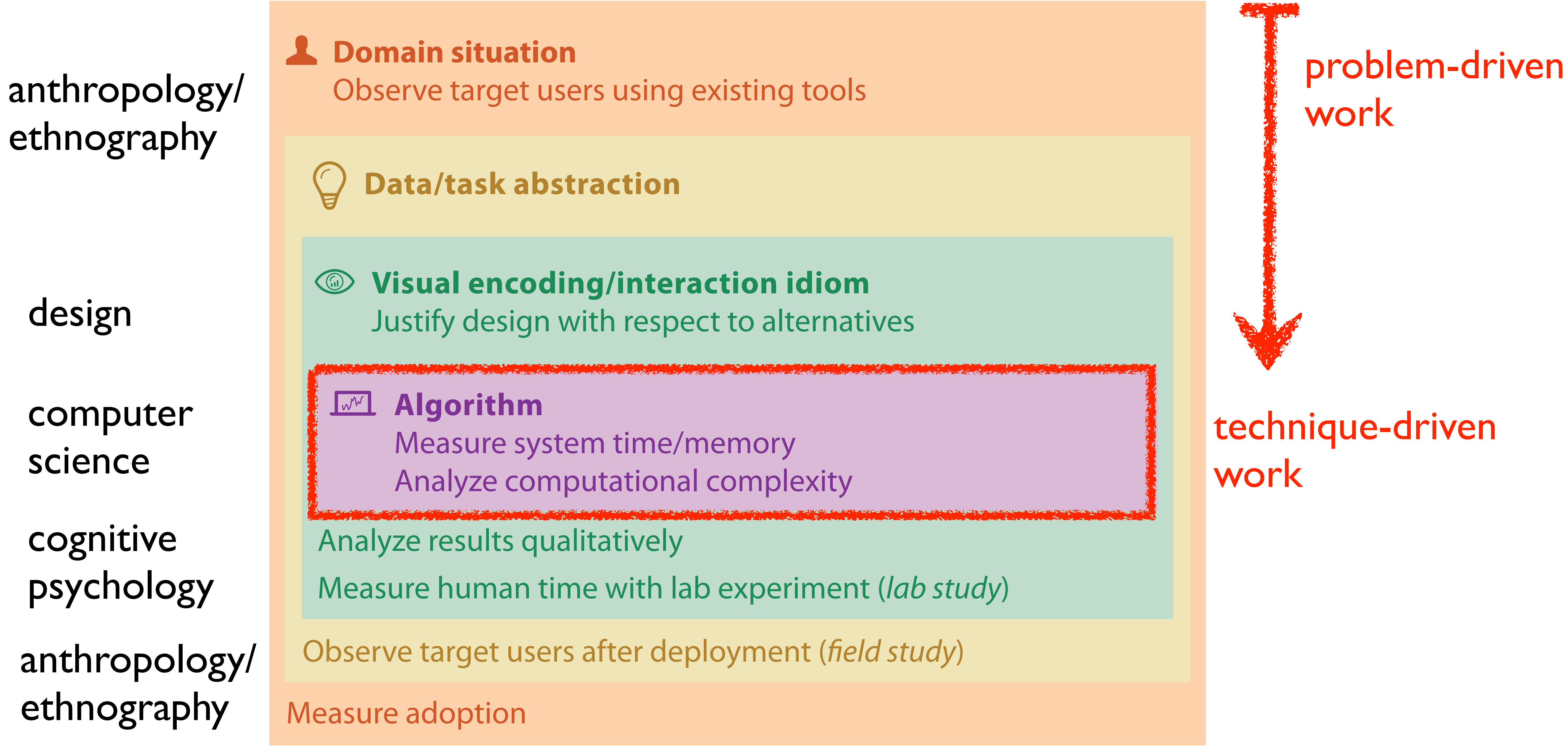
[A Multi-Level Typology of Abstract Visualization Tasks
Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]

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

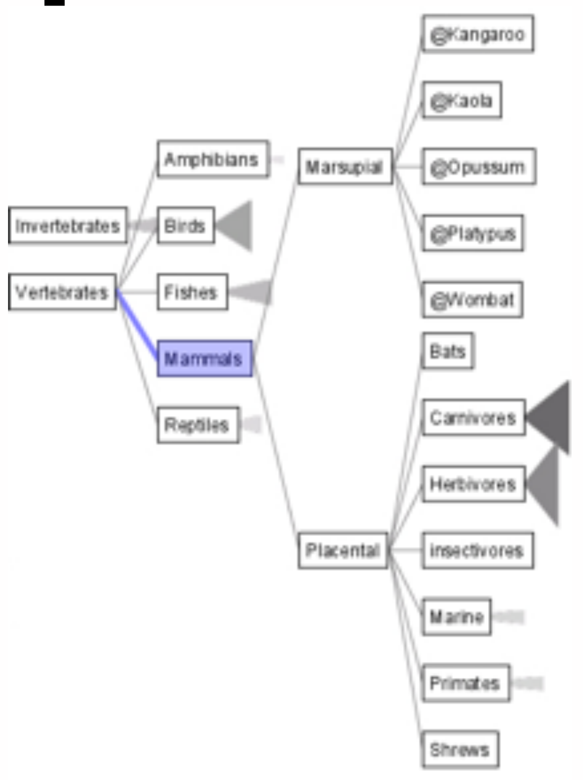


[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

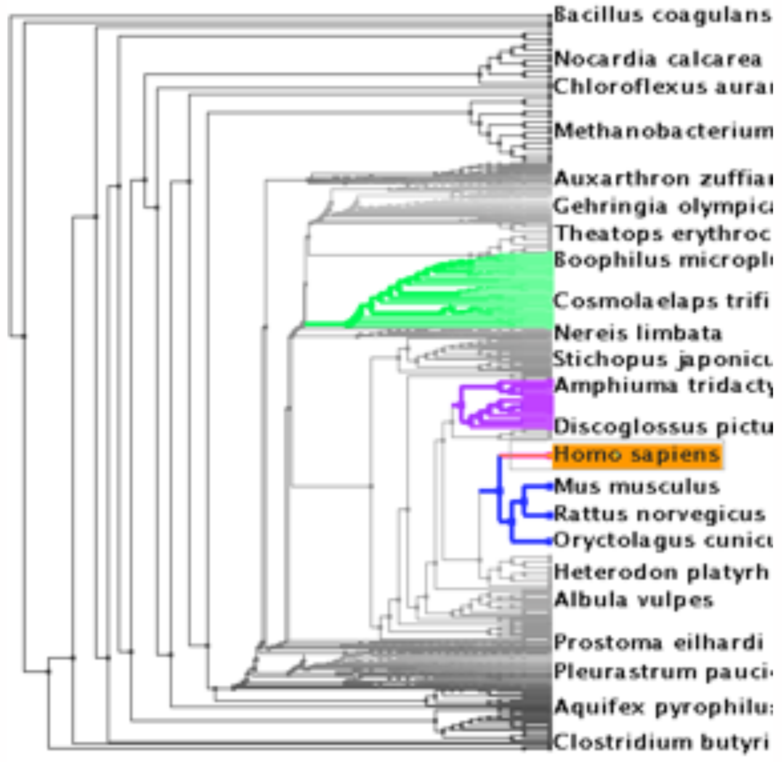
Why analyze?

- imposes a structure on huge design space
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new

SpaceTree



TreeJuxtaposer

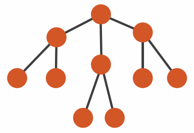


[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

[TreeJuxtaposer: Scalable Tree Comparison Using Focus +Context With Guaranteed Visibility. ACM Trans. on Graphics (Proc. SIGGRAPH) 22:453– 462, 2003.]

What?

➔ Tree



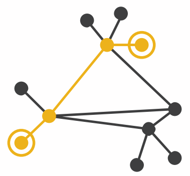
Why?

➔ Actions

→ Present → Locate → Identify

➔ Targets

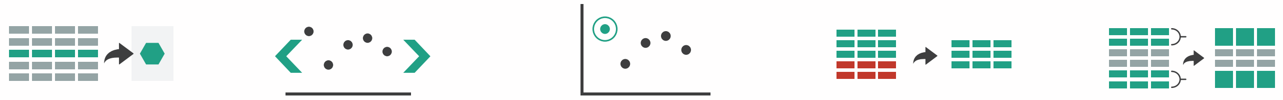
→ Path between two nodes



How?

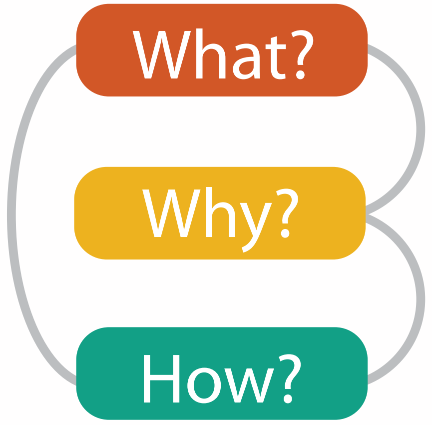
➔ SpaceTree

→ Encode → Navigate → Select → Filter → Aggregate



➔ TreeJuxtaposer

→ Encode → Navigate → Select → Arrange



What?

Why?

How?

What?

Datasets

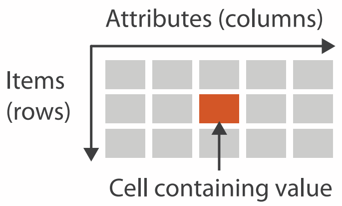
Data Types
- Items
- Attributes
- Links
- Positions
- Grids

Data and Dataset Types

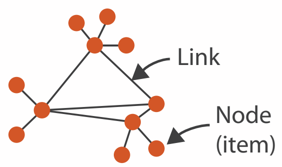
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

Dataset Types

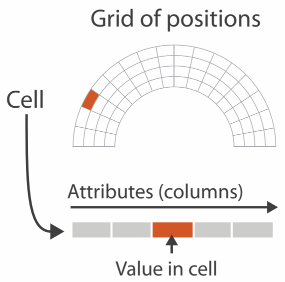
- Tables



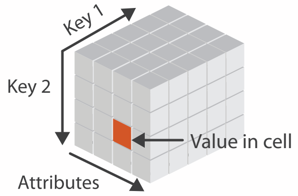
- Networks



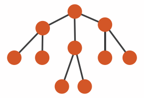
- Fields (Continuous)



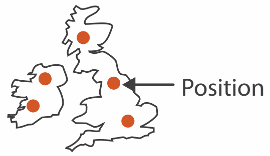
- *Multidimensional Table*



- *Trees*



- Geometry (Spatial)



Dataset Availability
- Static

- Dynamic

Attributes

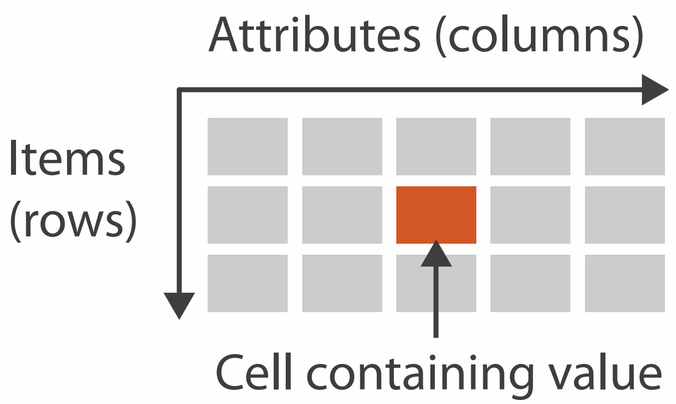
Attribute Types
- Categorical
- Ordered
  - *Ordinal*
  - *Quantitative*

Ordering Direction
- Sequential
- Diverging
- Cyclic

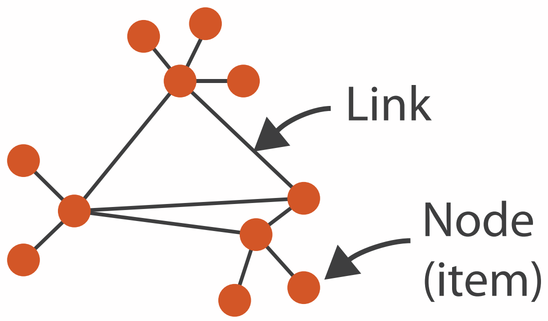
Types: Datasets and data

➔ Dataset Types

➔ Tables

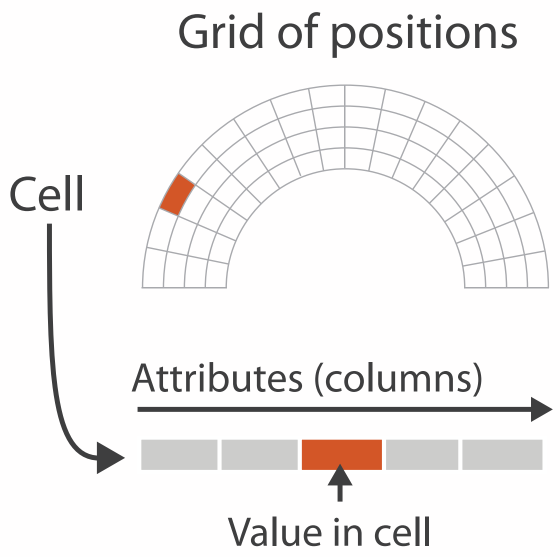


➔ Networks

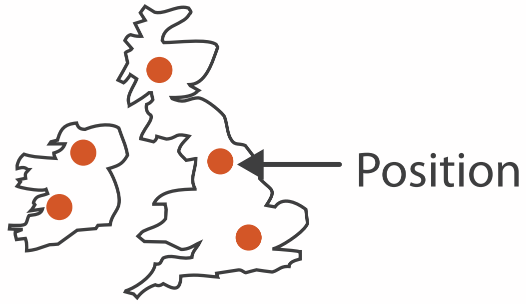


➔ Spatial

➔ Fields (Continuous)



➔ Geometry (Spatial)

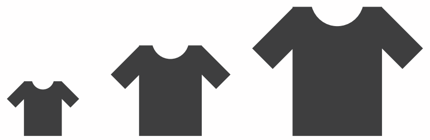


➔ Attribute Types

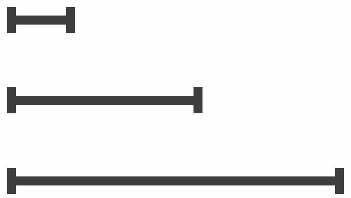
➔ Categorical

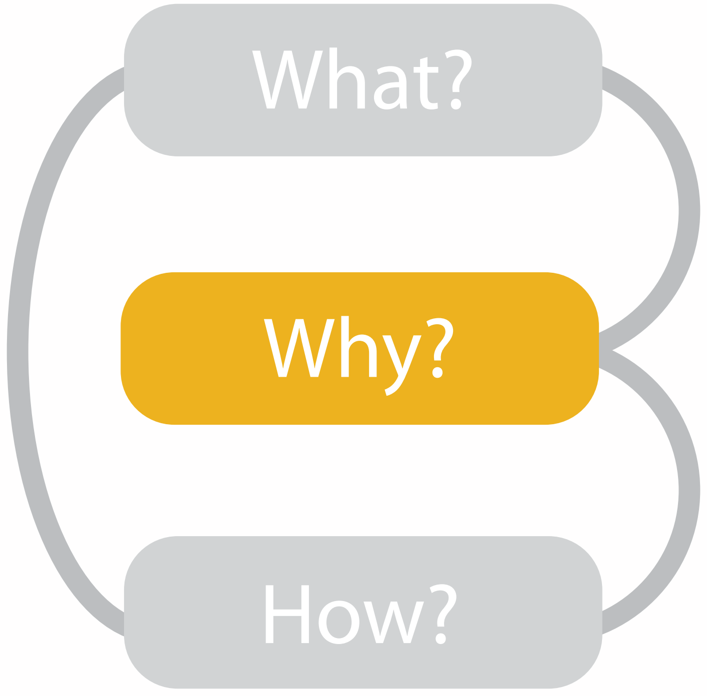
➔ Ordered

➔ *Ordinal*

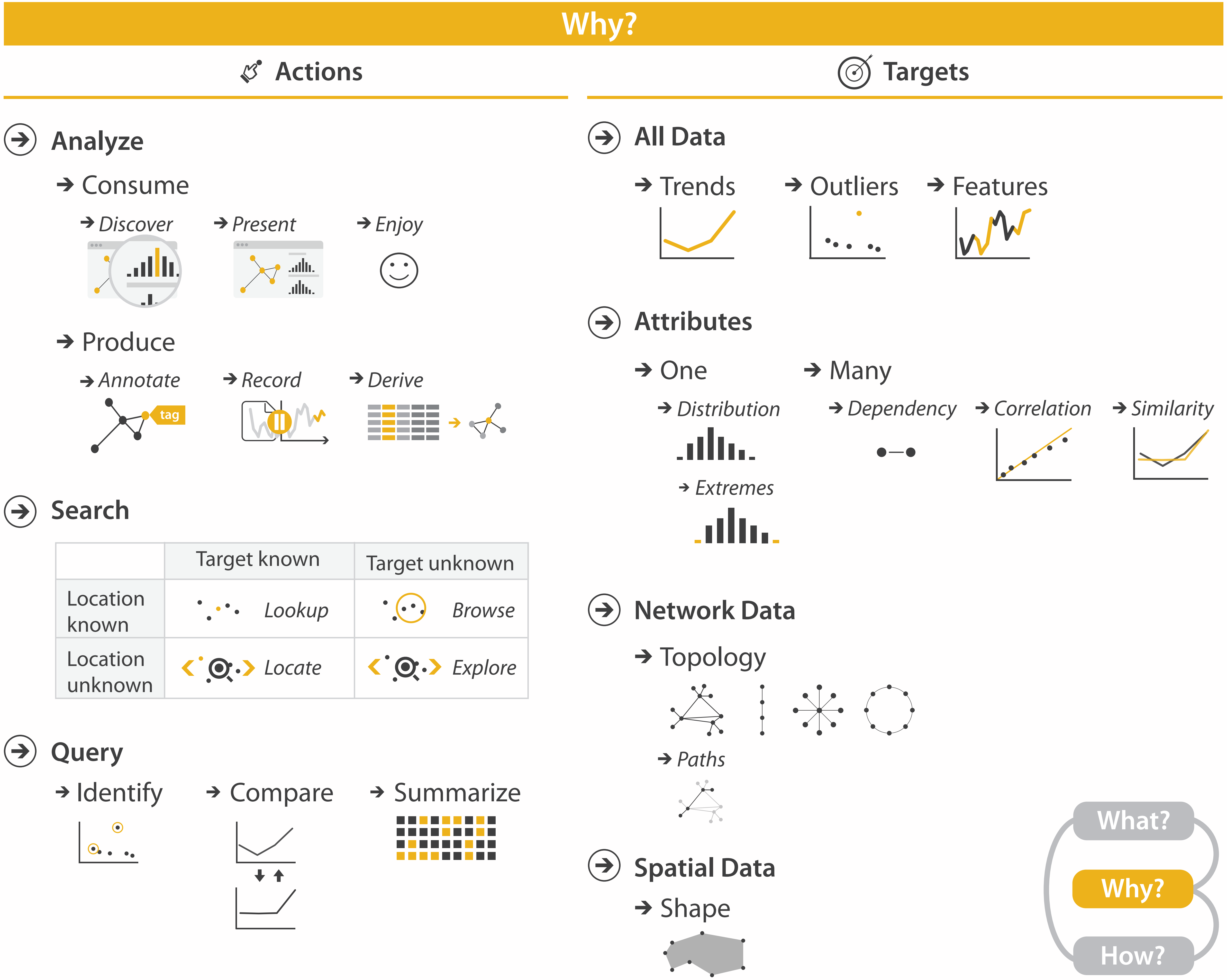


➔ *Quantitative*





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

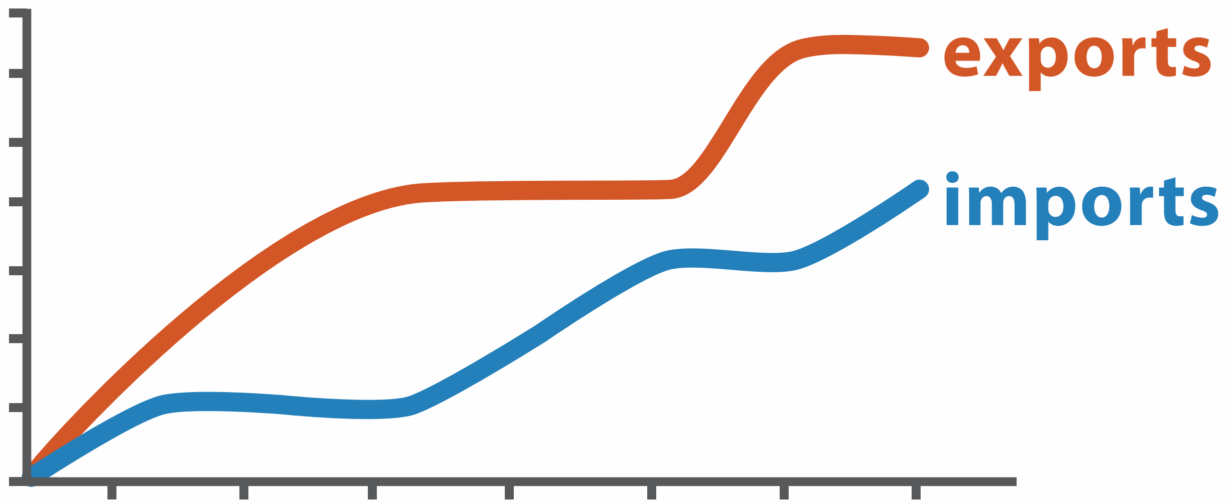


Actions: Analyze, Query

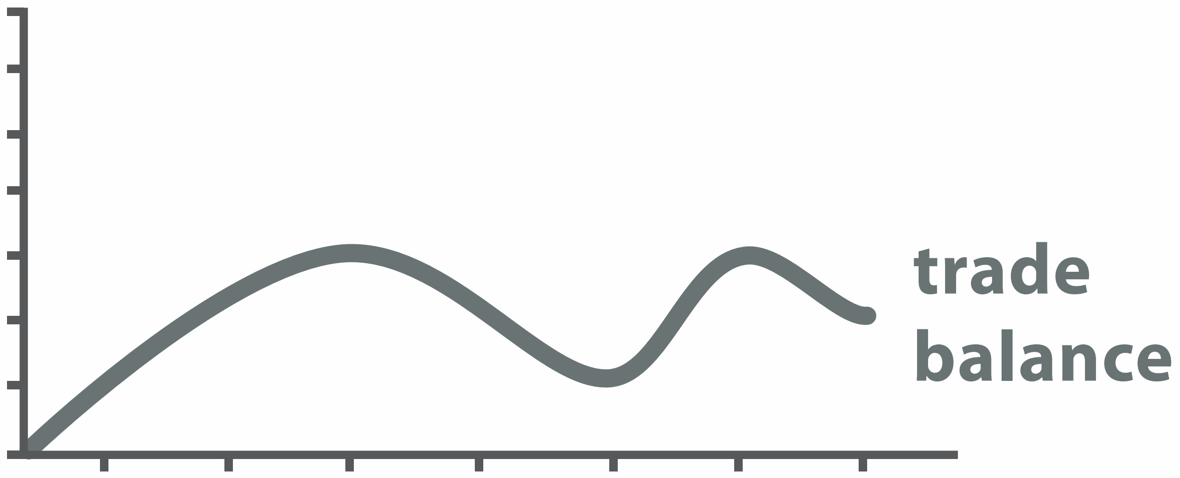
- analyze
  - consume
    - discover vs present
      - aka explore vs explain
    - enjoy
      - aka casual, social
  - produce
    - annotate, record, derive
- query
  - how much data matters?
    - one, some, all
- independent choices
  - analyze, query, (search)

Derive: Crucial Design Choice

- don't 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



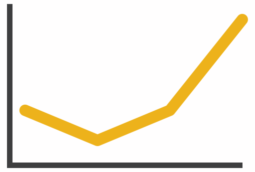
trade balance = exports − imports

Derived Data

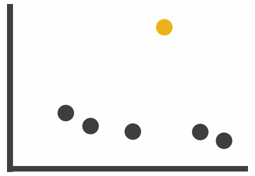
Targets

All Data

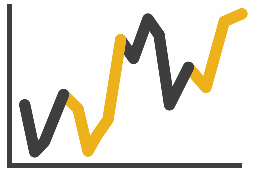
- Trends



- Outliers

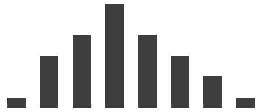


- Features

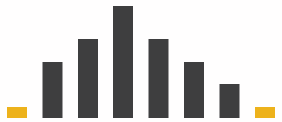


Attributes

- One
  - *Distribution*

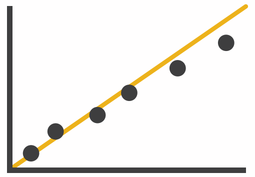


  - *Extremes*

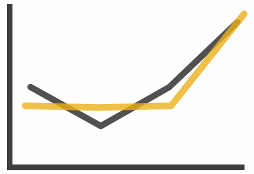


- Many
  - *Dependency*

  - *Correlation*

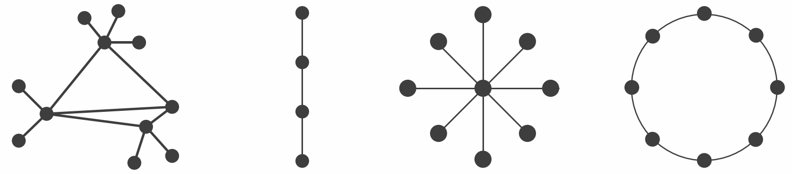


  - *Similarity*

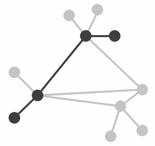


Network Data

- Topology

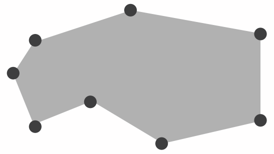


  - *Paths*



Spatial Data

- Shape



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?

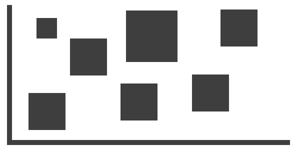
How to encode: Arrange space, map channels

Encode

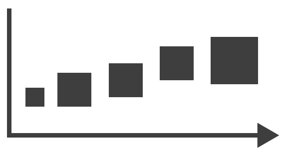
➔ Arrange

➔ Express

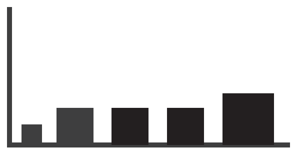
➔ Separate



➔ Order



➔ Align



➔ Use

➔ Map

from categorical and ordered attributes

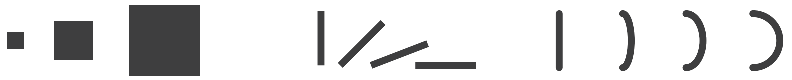
➔ Color

➔ *Hue*

➔ *Saturation*

➔ *Luminance*

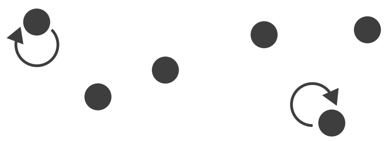
➔ Size, Angle, Curvature, ...



➔ Shape

➔ Motion

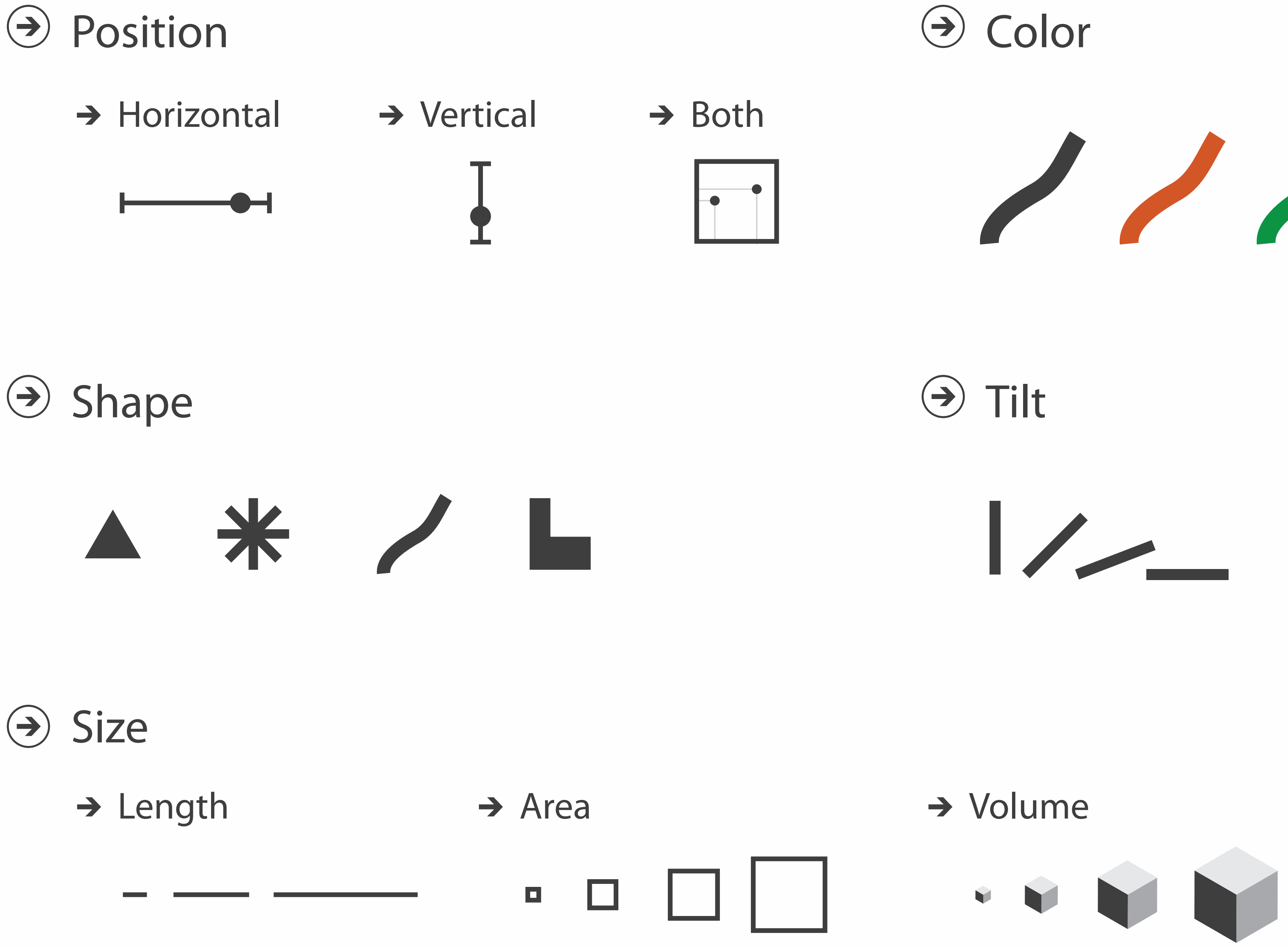
Direction, Rate, Frequency, ...



Definitions: Marks and channels

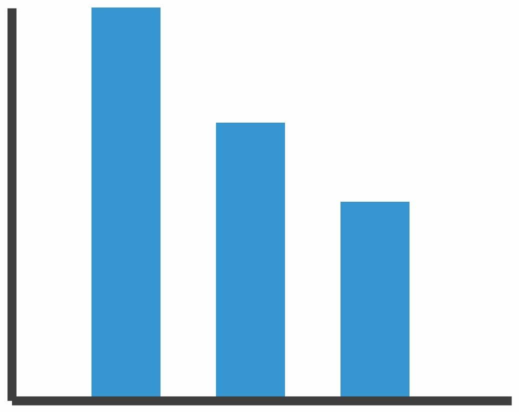
- marks
  - geometric primitives

- channels
  - control appearance of marks



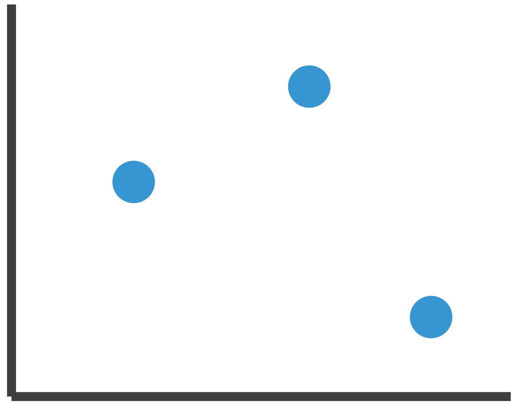
Encoding visually with marks and channels

- analyze idiom structure
  - as combination of marks and channels



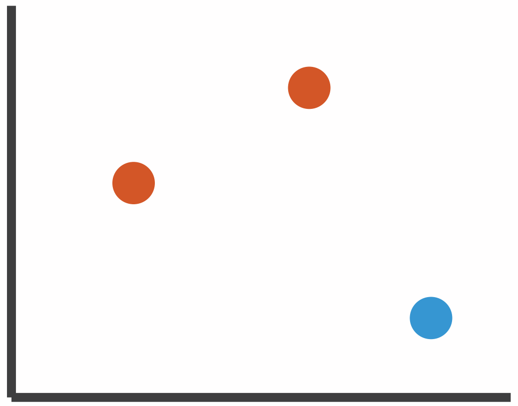
1:
vertical position

mark: line



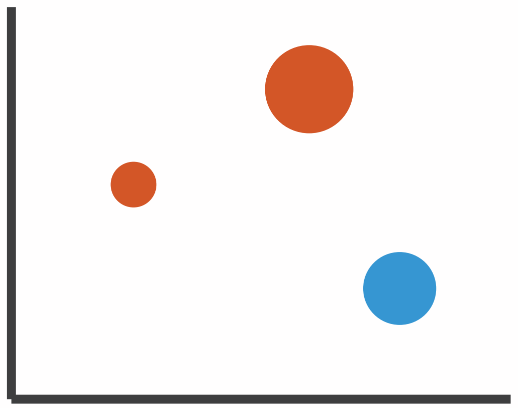
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

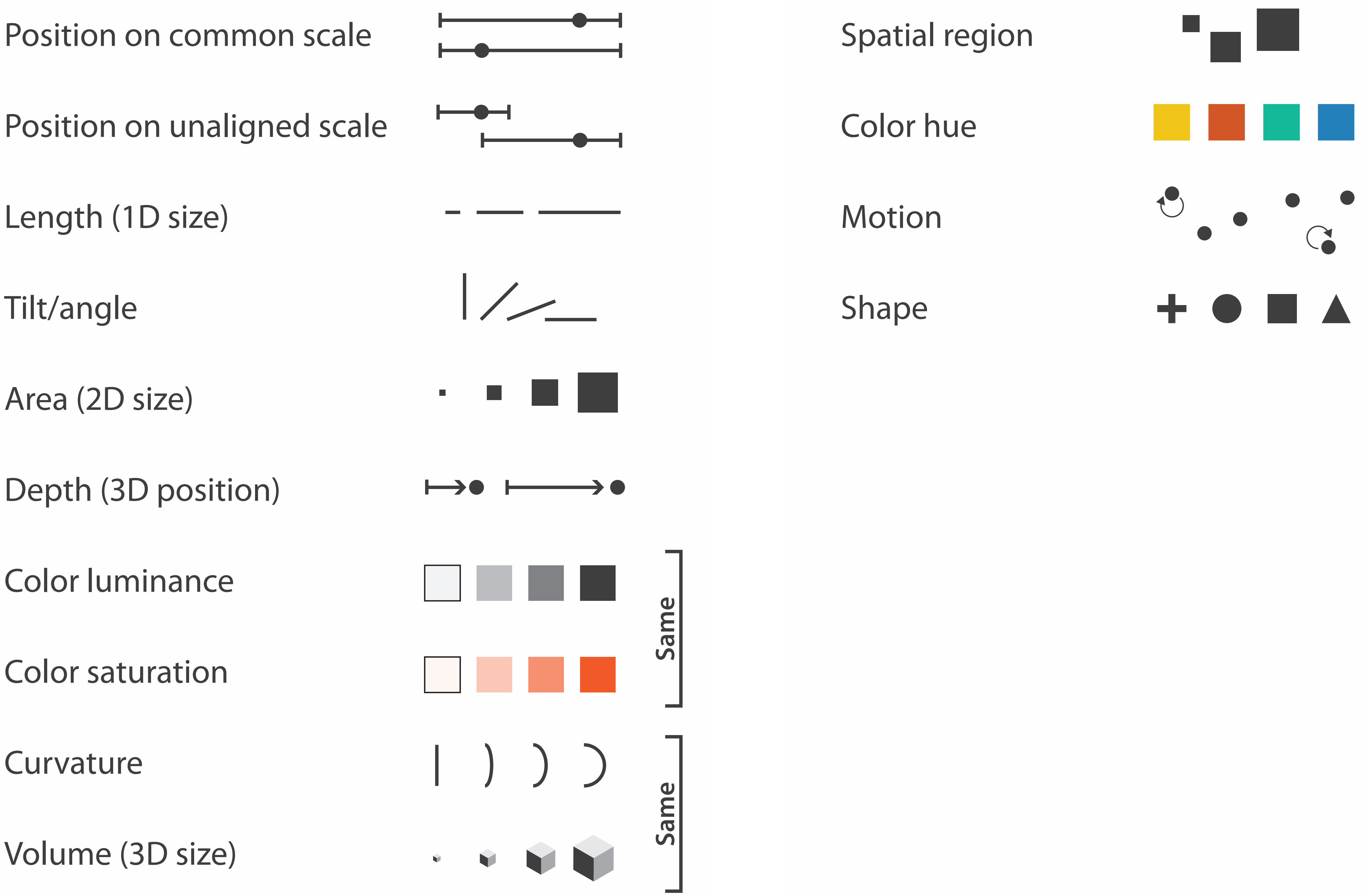
mark: point



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

mark: point

Channels


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
Spatial region
Color hue
Motion
Shape

Channels: Matching Types

Magnitude Channels: Ordered Attributes

Position on common scale

Position on unaligned scale

Length (1D size)

Tilt/angle

Area (2D size)

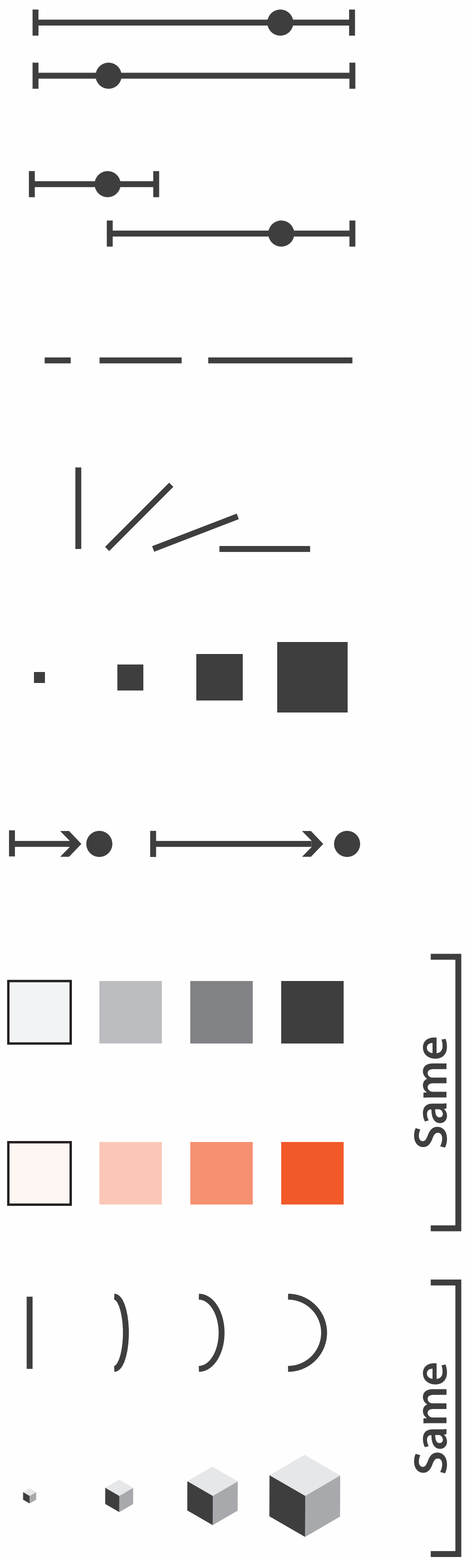
Depth (3D position)

Color luminance

Color saturation

Curvature

Volume (3D size)



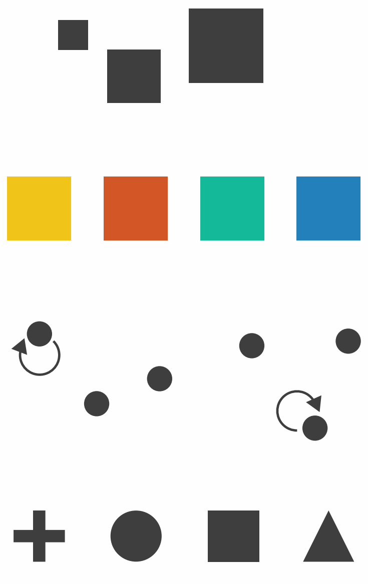
Identity Channels: Categorical Attributes

Spatial region

Color hue

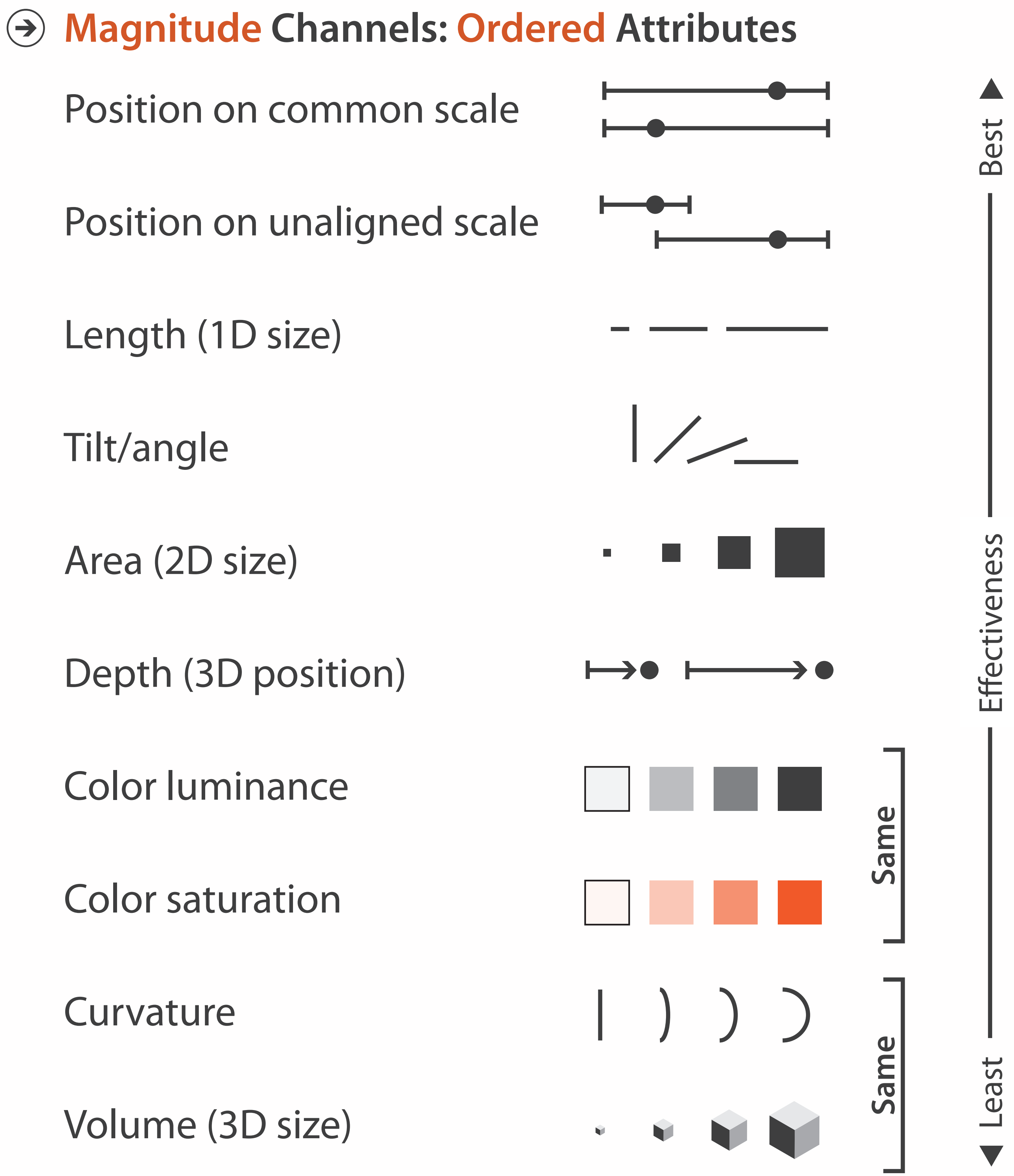
Motion

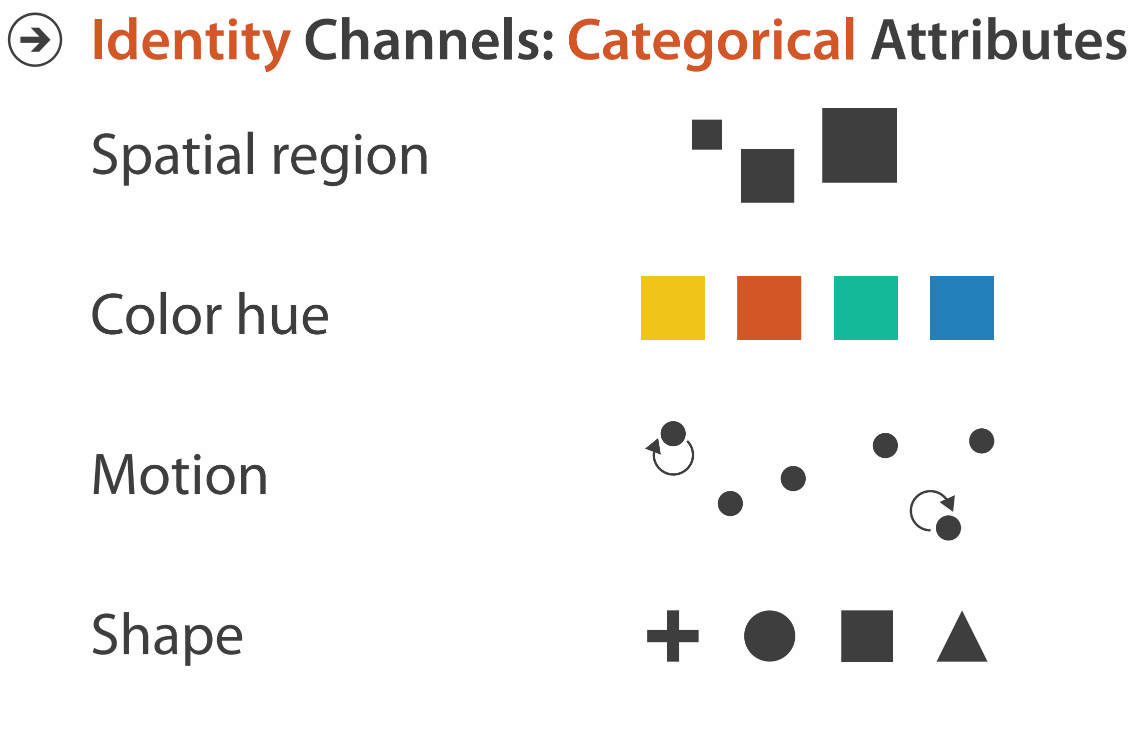
Shape



- expressiveness principle
  – match channel and data characteristics

Channels: Rankings





- expressiveness principle
  - match channel and data characteristics
- effectiveness principle
  - encode most important attributes with highest ranked channels

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

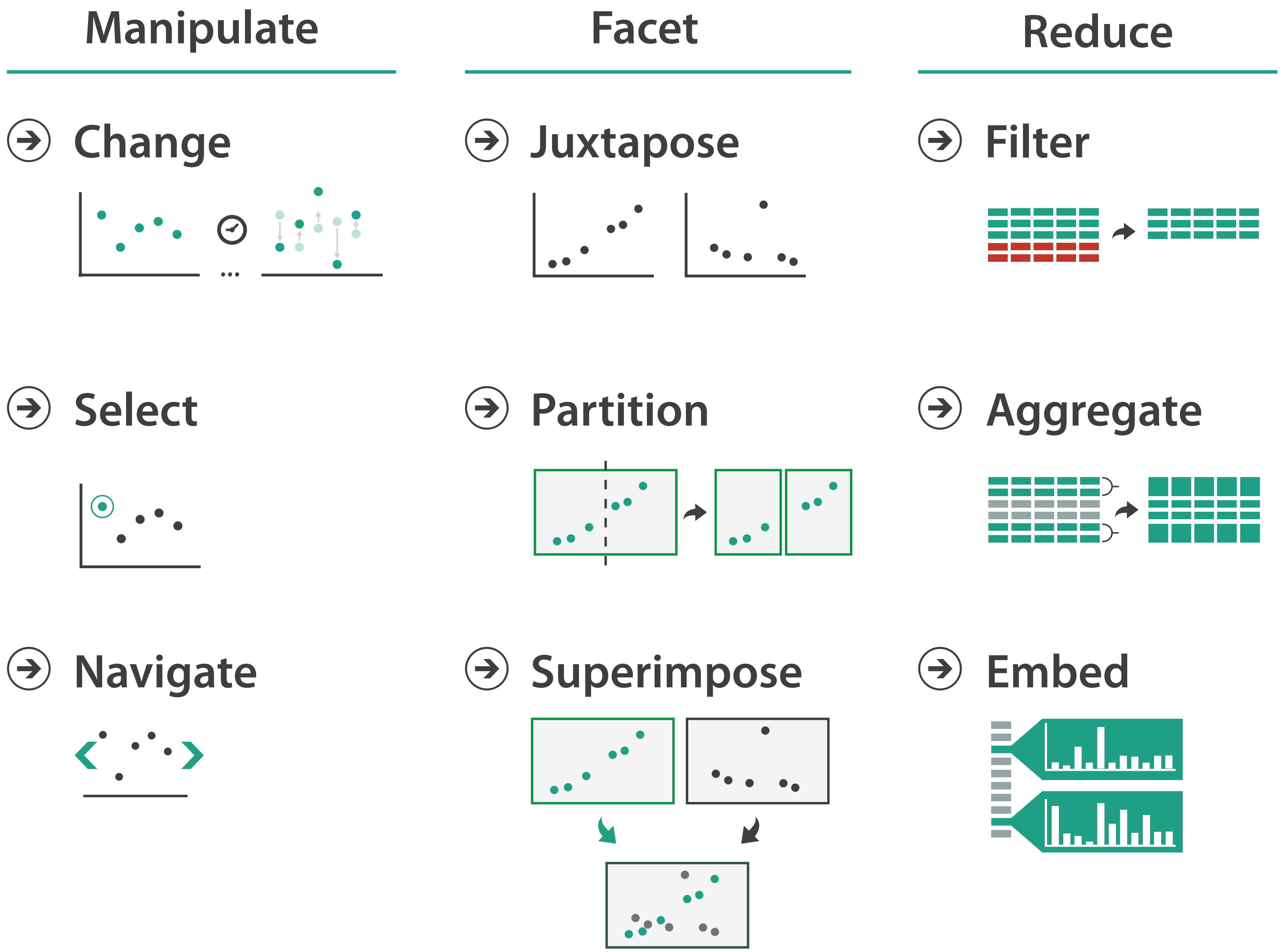
Reduce
- Filter
- Aggregate
- Embed

What?

Why?

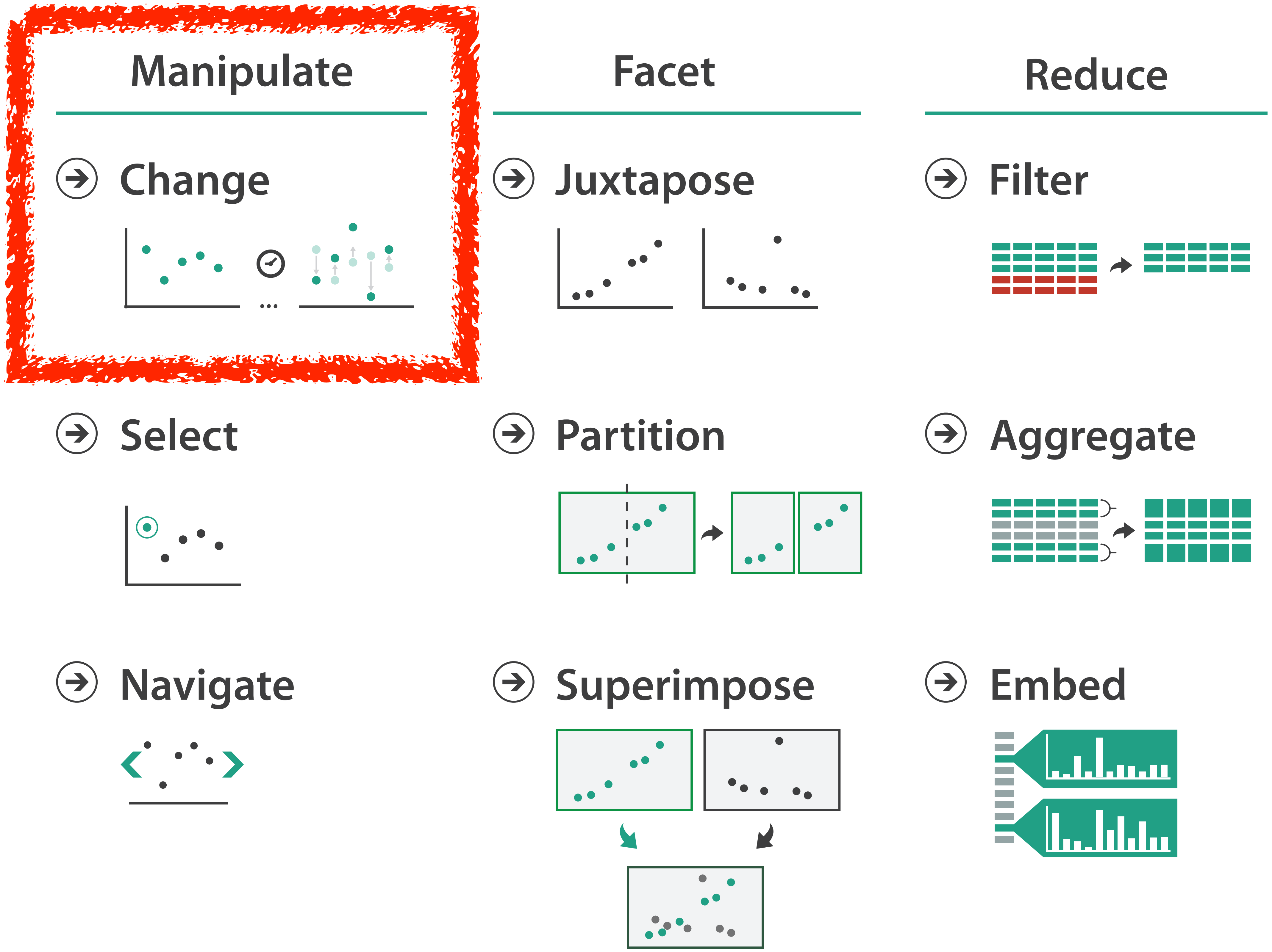
How?

How to handle complexity: 3 more strategies + 1 previous



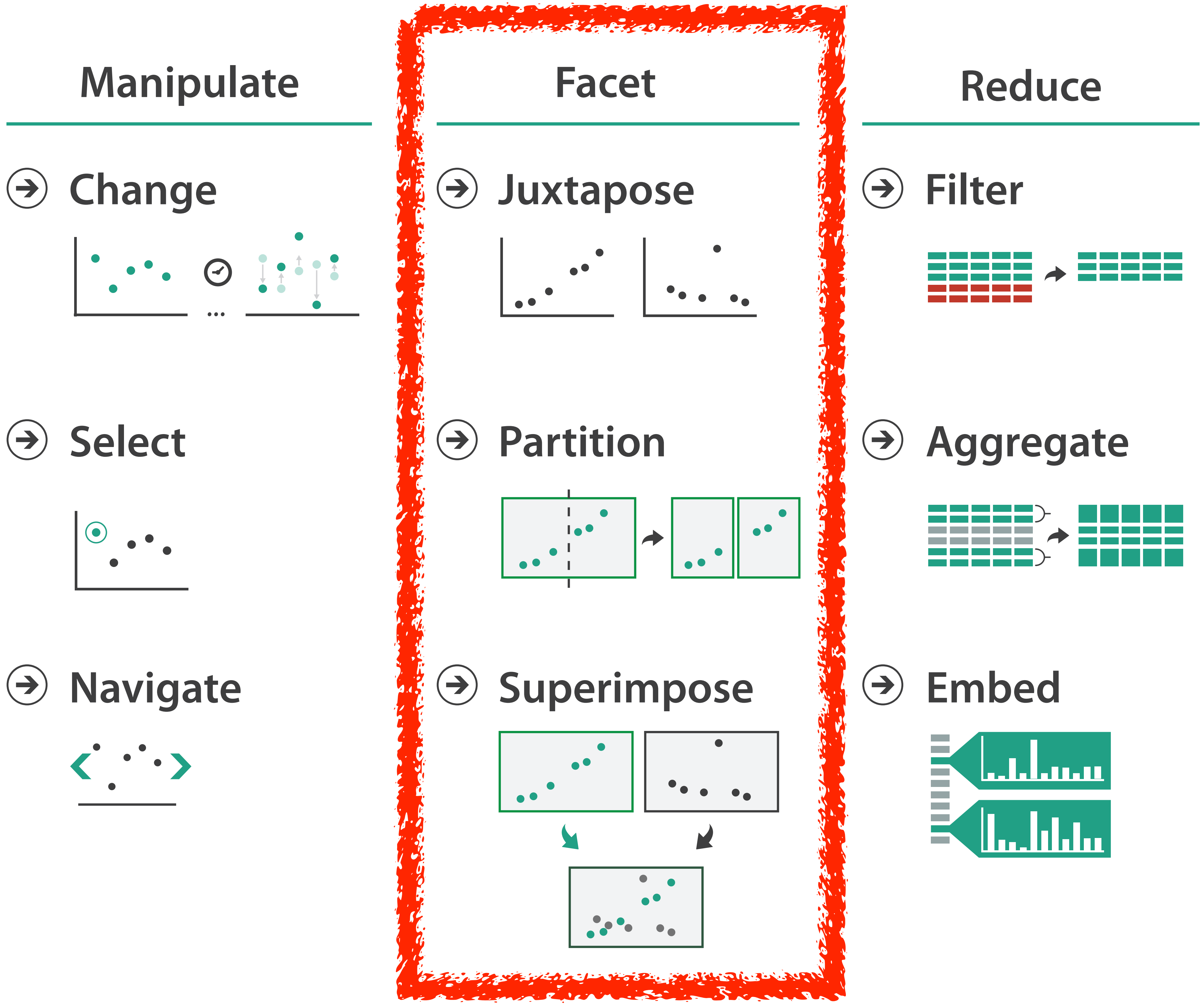
- change view over time
- facet across multiple views
- reduce items/attributes within single view
- derive new data to show within view

How to handle complexity: 3 more strategies + 1 previous



- change over time
  - most obvious & flexible of the 4 strategies

How to handle complexity: 3 more strategies + 1 previous

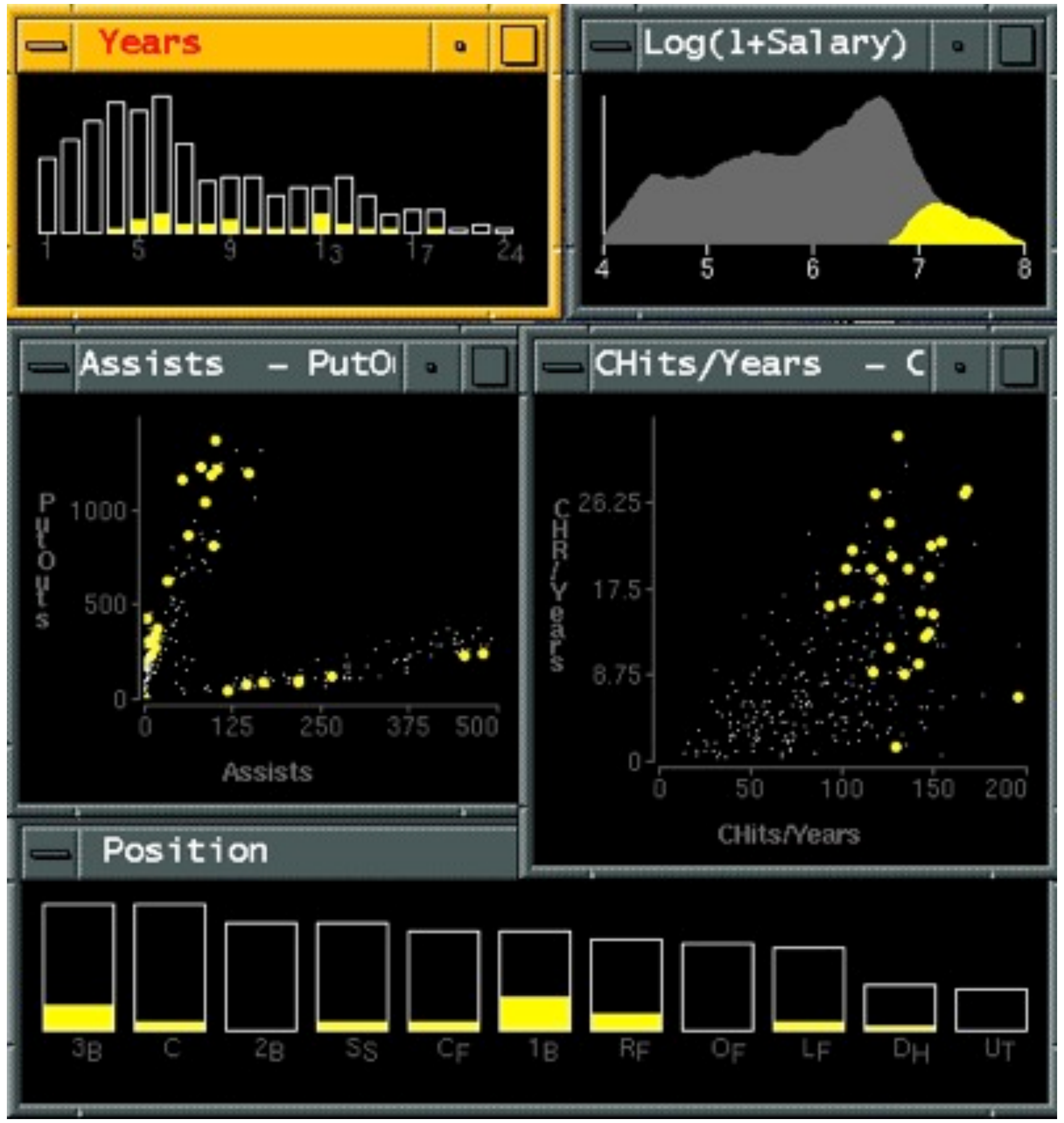


- facet data across multiple views

Idiom: **Linked highlighting** System: **EDV**

- see how regions contiguous in one view are distributed within another
  - powerful and pervasive interaction idiom

- encoding: different
- data: all shared



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

Idiom: **bird's-eye maps**

System: **Google Maps**

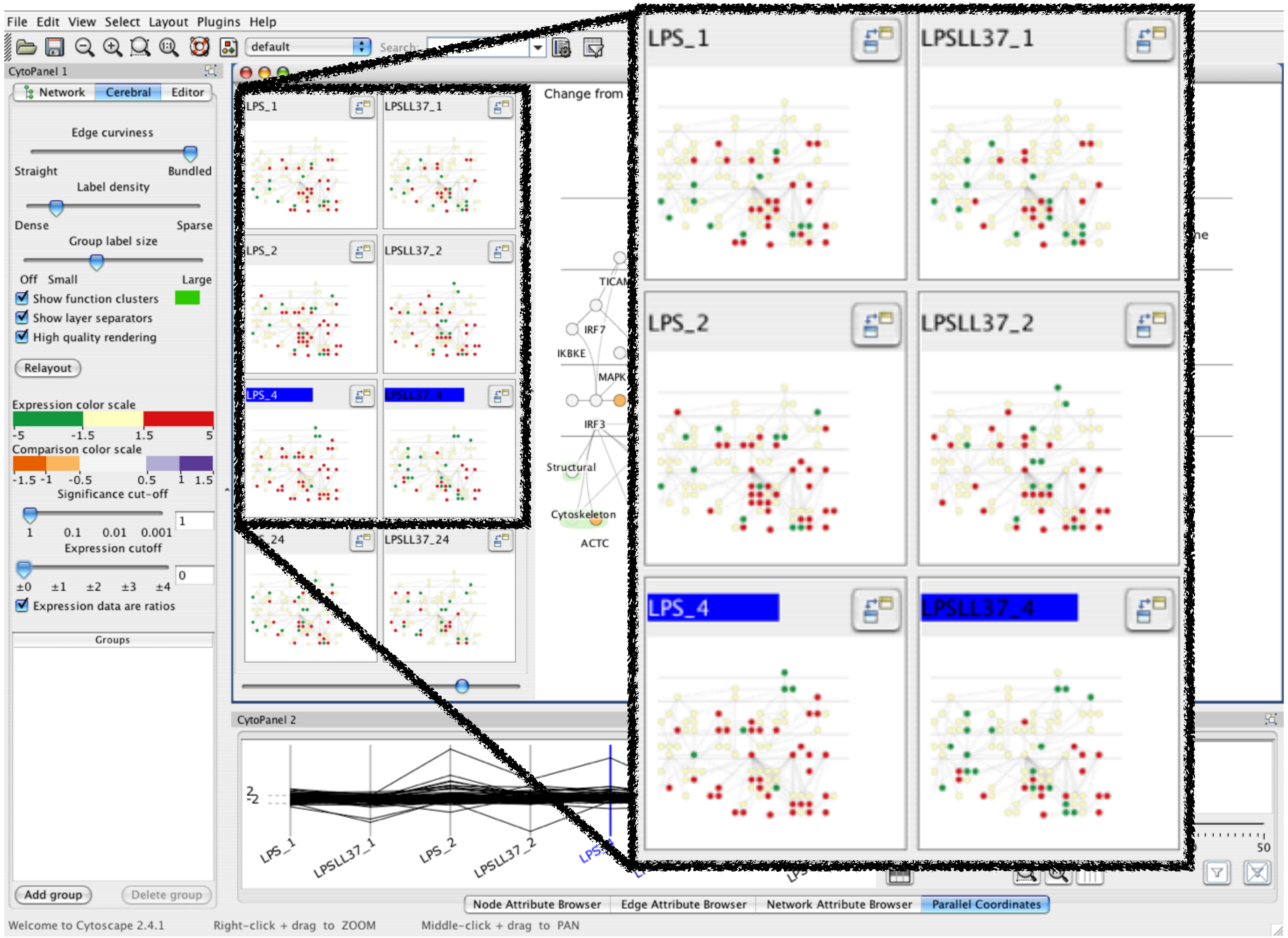
- encoding: same
- data: subset shared
- navigation: shared
  - bidirectional linking
- differences
  - viewpoint
  - (size)
- ***overview-detail***

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

Idiom: **Small multiples**

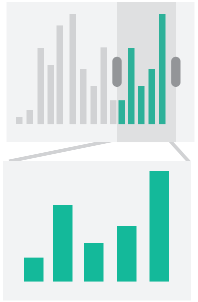
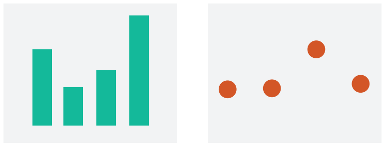
System: **Cerebral**

- encoding: same
- data: none shared
  - different attributes for node colors
  - (same network layout)
- navigation: shared



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

Coordinate views: Design choice interaction

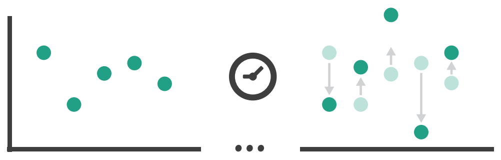
		Data		
		All	Subset	None
Encoding	Same	Redundant	 Overview/ Detail	 Small Multiples
	Different	 Multiform	 Multiform, Overview/ Detail	No Linkage

- why juxtapose views?
  - benefits: eyes vs memory
    - lower cognitive load to move eyes between 2 views than remembering previous state with single changing view
  - costs: display area, 2 views side by side each have only half the area of one view

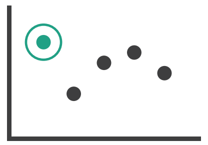
How to handle complexity: 3 more strategies + 1 previous

Manipulate

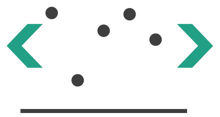
→ Change



→ Select

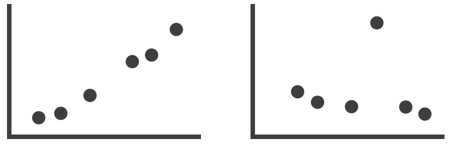


→ Navigate

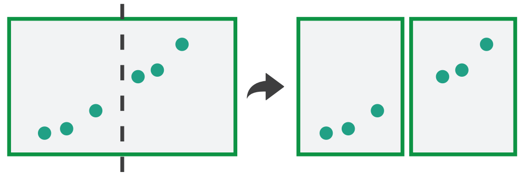


Facet

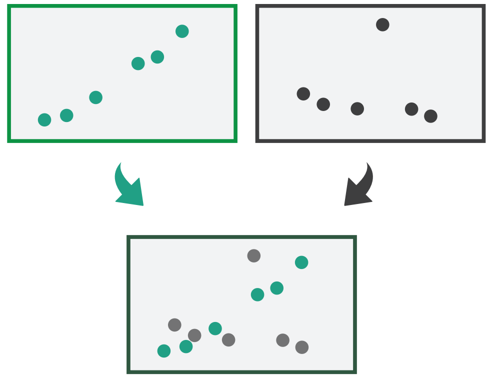
→ Juxtapose



→ Partition

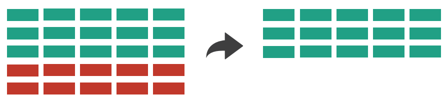


→ Superimpose

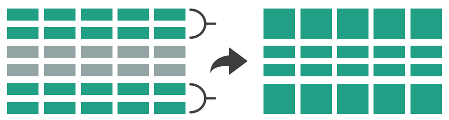


Reduce

→ Filter

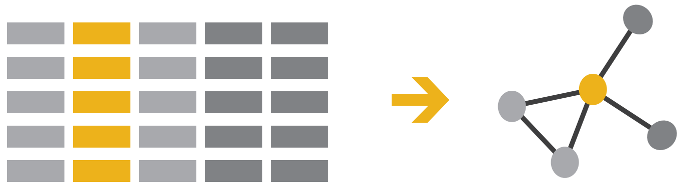


→ Aggregate



→ Embed

→ *Derive*

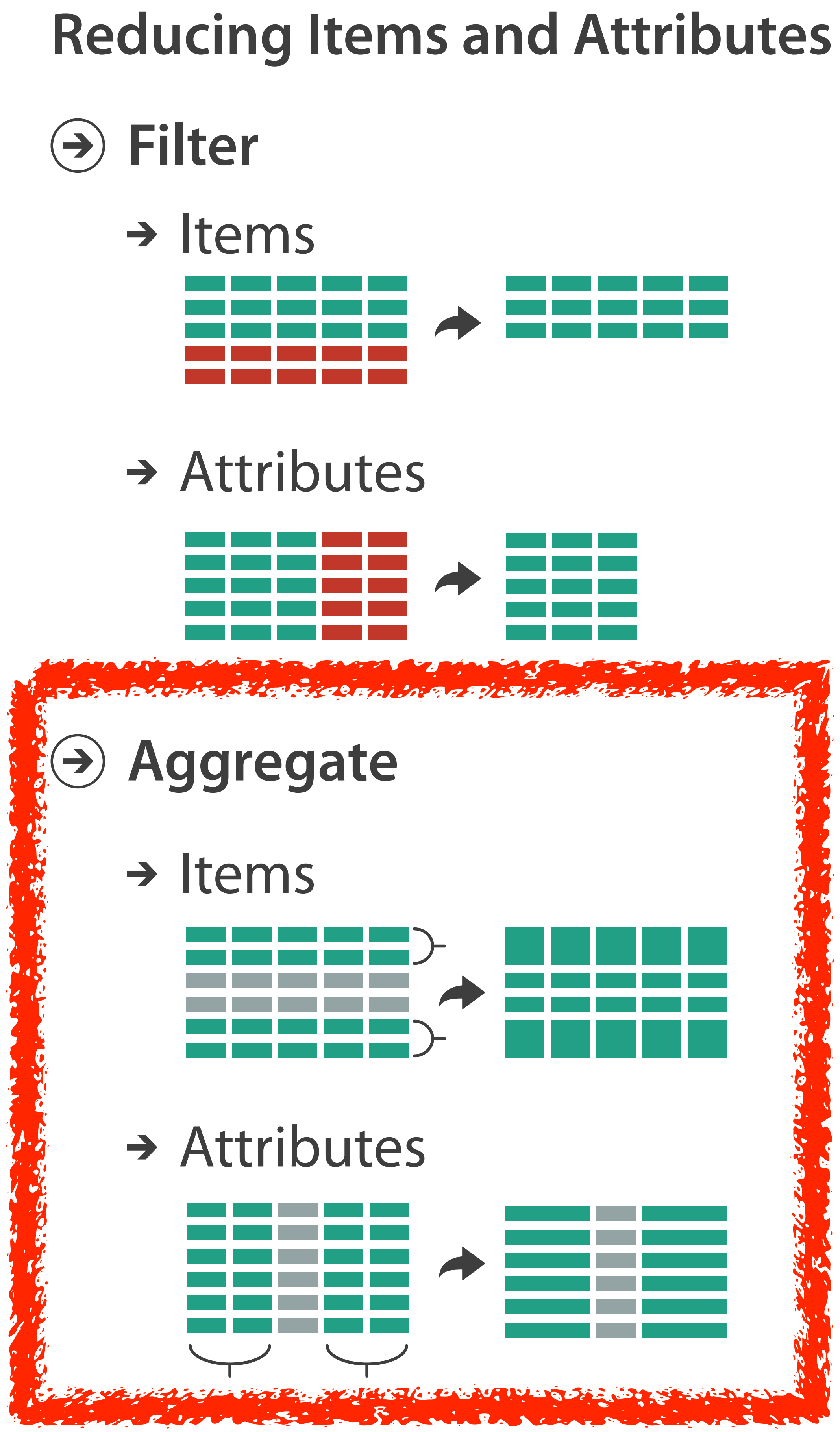


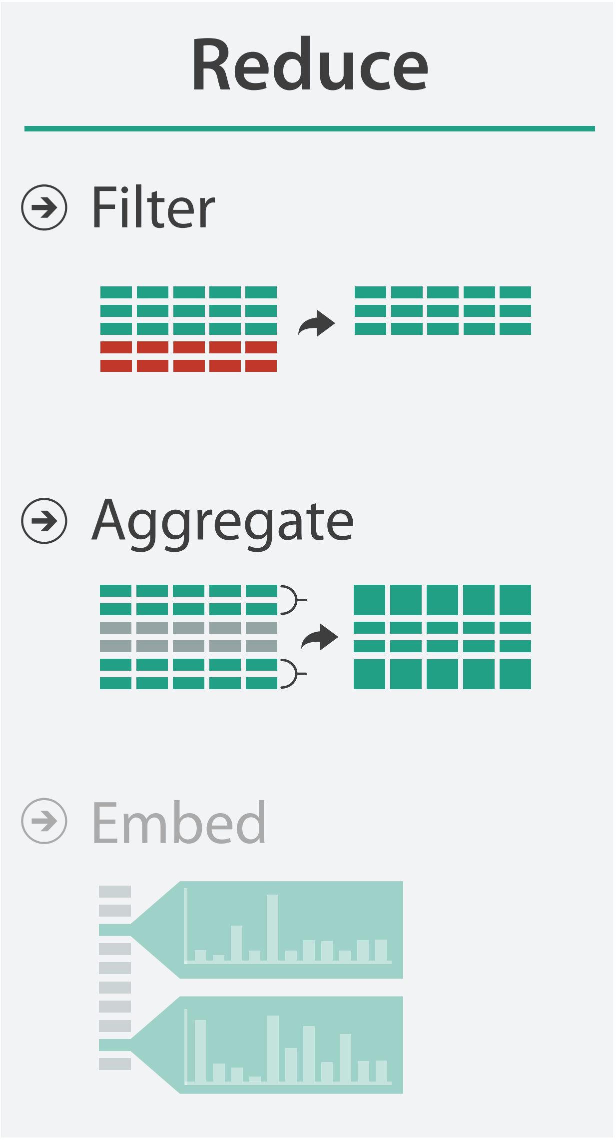
- reduce what is shown within single view

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

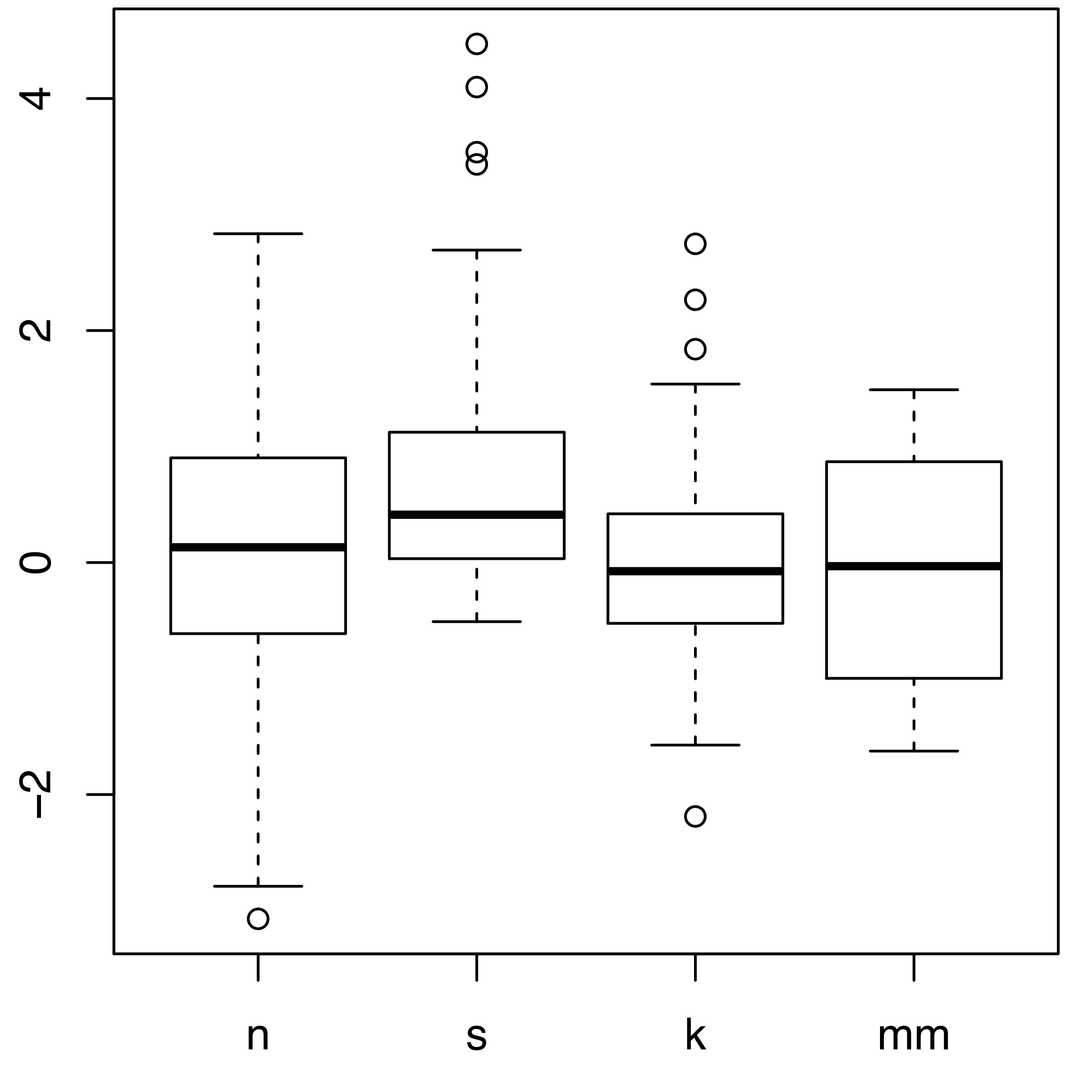
- not mutually exclusive
  - combine filter, aggregate
  - combine reduce, facet, change, derive





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

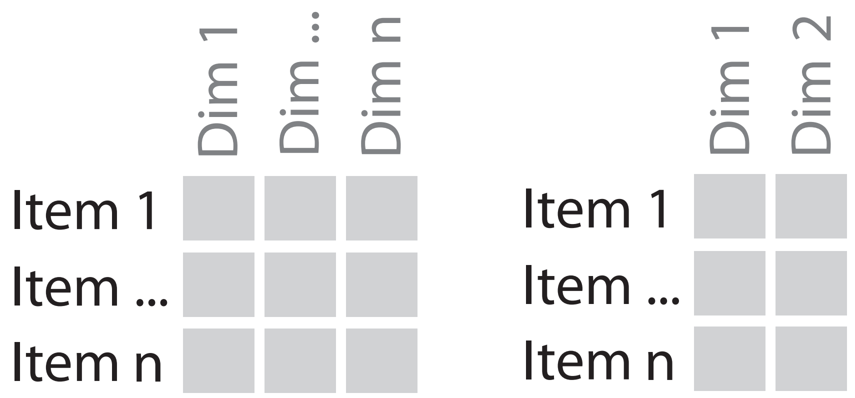


[40 years of boxplots. Wickham and Stryjewski. 2012. had.co.nz]

Idiom: **Dimensionality reduction for documents**

- attribute aggregation
  - derive low-dimensional target space from high-dimensional measured space

Task 1



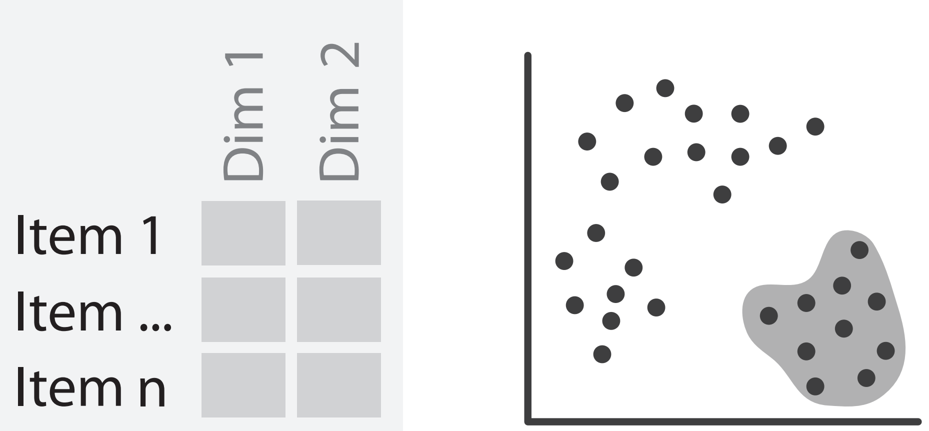
In
HD data

Out
2D data

What?
- **In High-dimensional data**
- **Out 2D data**

Why?
- **Produce**
- **Derive**

Task 2



In
2D data

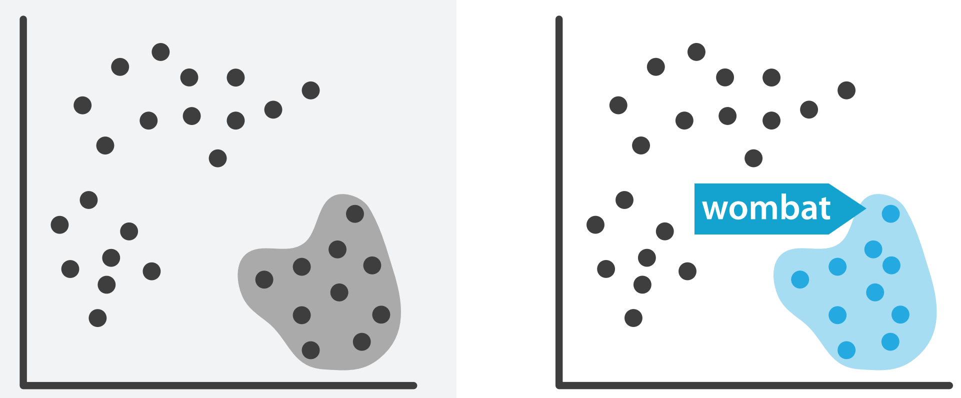
Out
Scatterplot
Clusters & points

What?
- **In 2D data**
- **Out Scatterplot**
- **Out Clusters & points**

Why?
- **Discover**
- **Explore**
- **Identify**

How?
- **Encode**
- **Navigate**
- **Select**

Task 3

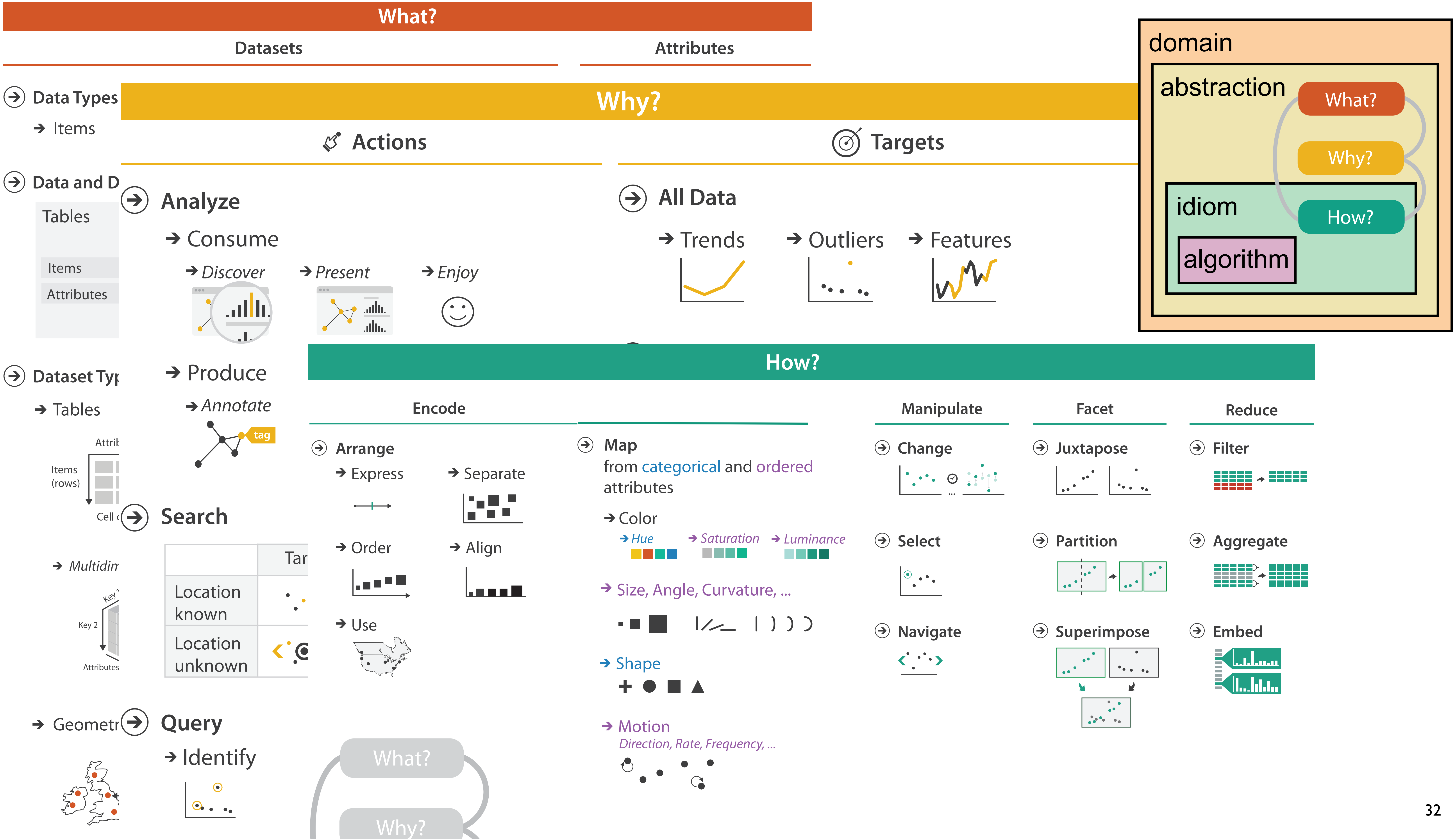


In
Scatterplot
Clusters & points

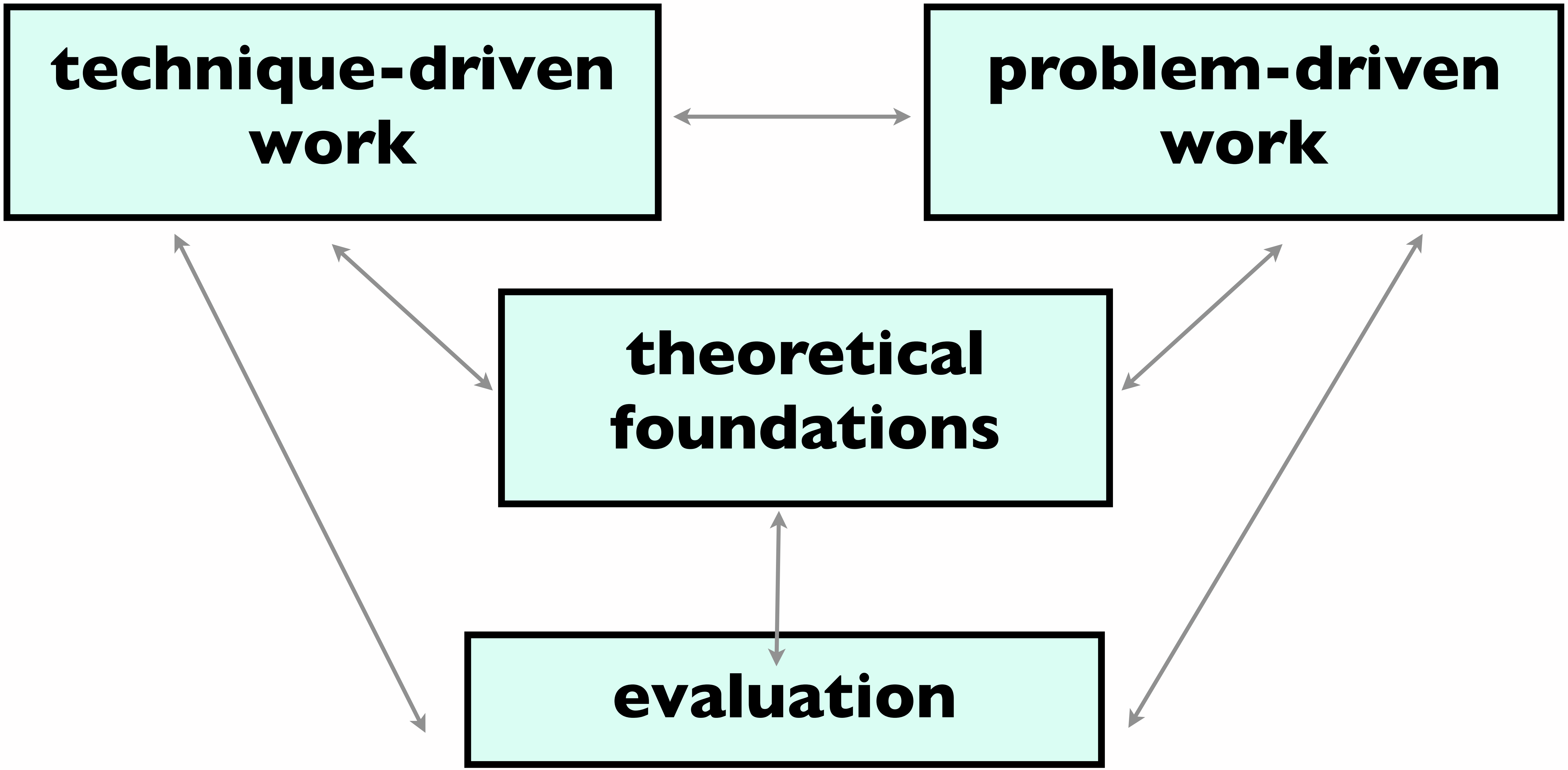
Out
Labels for
clusters

What?
- **In Scatterplot**
- **In Clusters & points**
- **Out Labels for clusters**

Why?
- **Produce**
- **Annotate**


What?
Datasets
Attributes
Data Types
Items
Data and D
Tables
Items
Attributes
Dataset Typ
Tables
Attrib
Items (rows)
Cell c
Multidim
Key 2
Attributes
Geometr
Why?
Actions
Targets
Analyze
Consume
Discover
Present
Enjoy
Produce
Annotate
tag
Search
Tar
Location known
Location unknown
Query
Identify
All Data
Trends
Outliers
Features
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?
domain
abstraction
What?
Why?
idiom
How?
algorithm

A quick taste of my own work!



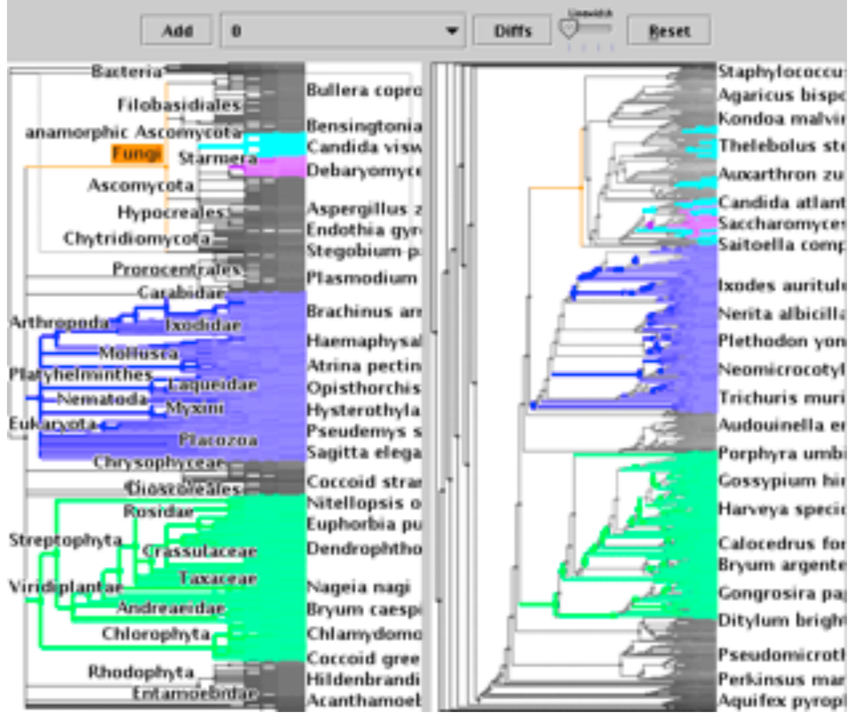
Technique-driven: Graph drawing

T

F

E

P



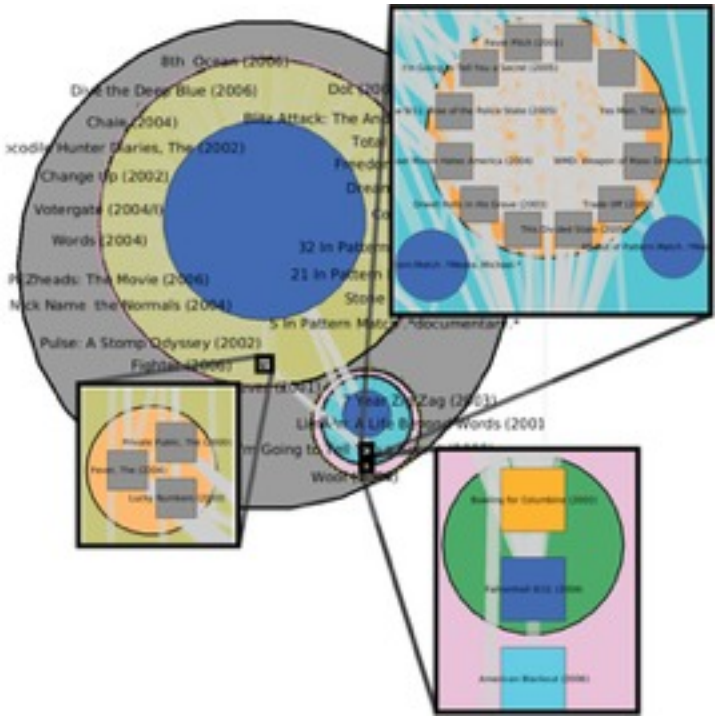
TreeJuxtaposer

James Slack

Kristian Hildebrand

Daniel Archambault

David Auber
(Bordeaux)



TopoLayout
SPF
Grouse
GrouseFlocks
TugGraph

Evaluation: Graph drawing

T

P

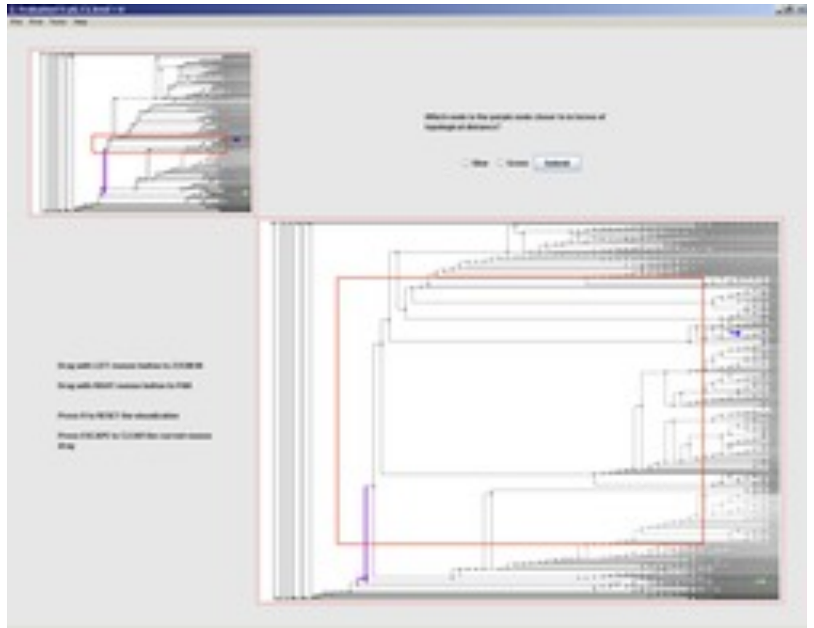
F

E

Dmitry Nekrasovski

Adam Bodnar

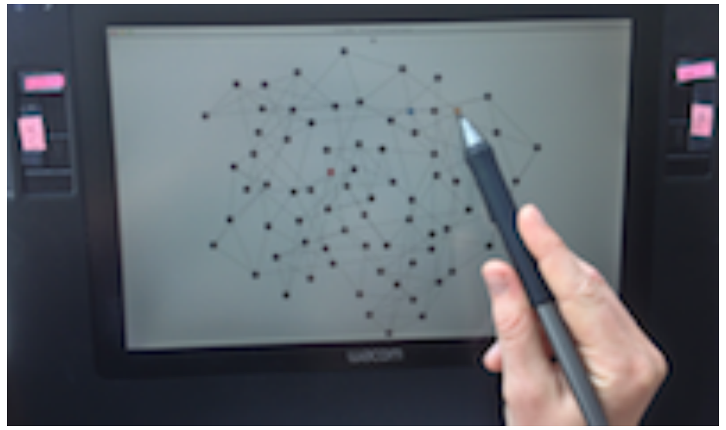
Joanna McGrenere (UBC)



Stretch and squish navigation

Jessica Dawson

Joanna McGrenere (UBC)



Search set model of path tracing

Technique-driven: Dimensionality reduction

T

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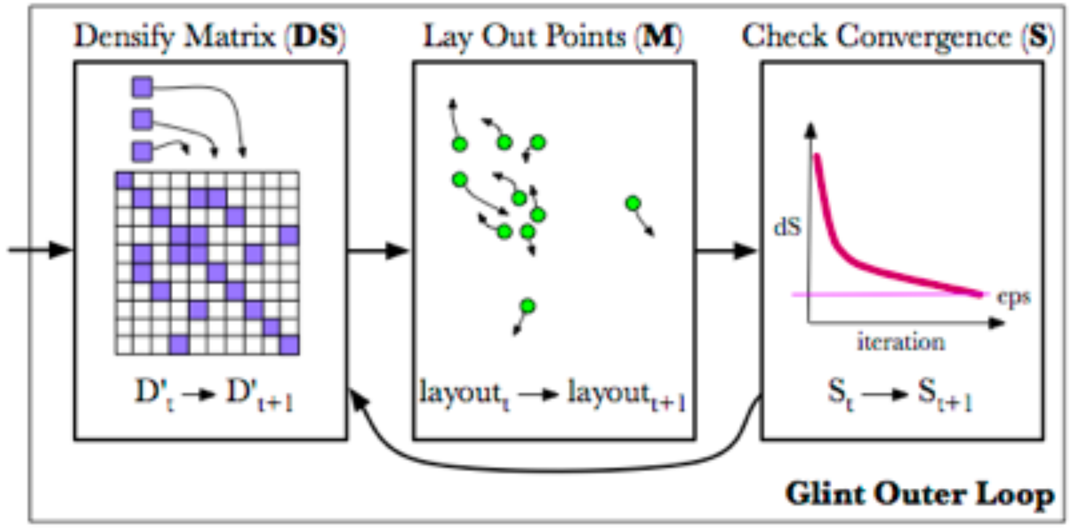
E

P

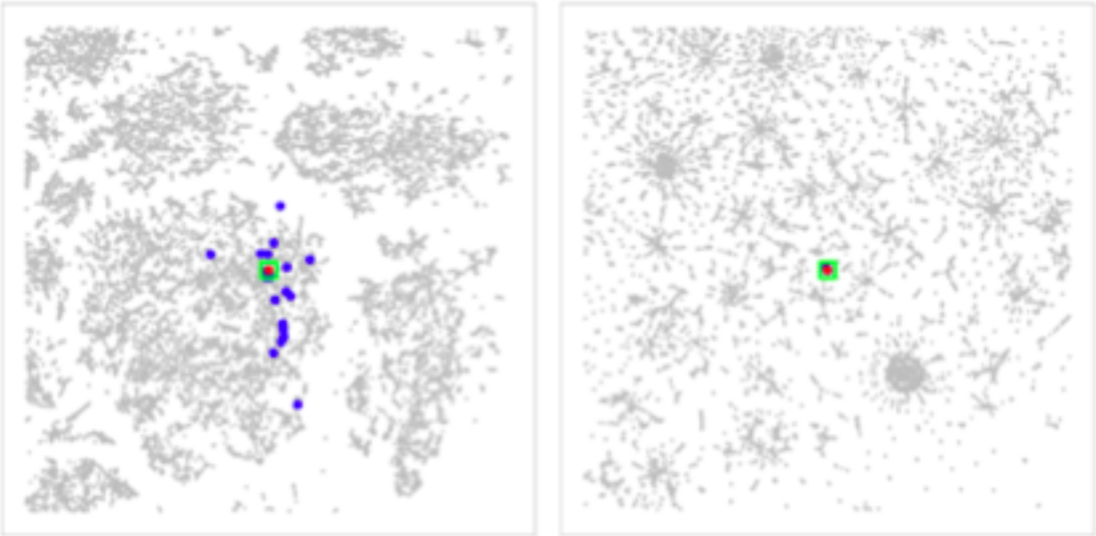
Stephen Ingram

Glimmer

DimStiller



Glint



QSNE

Evaluation: Dimensionality reduction

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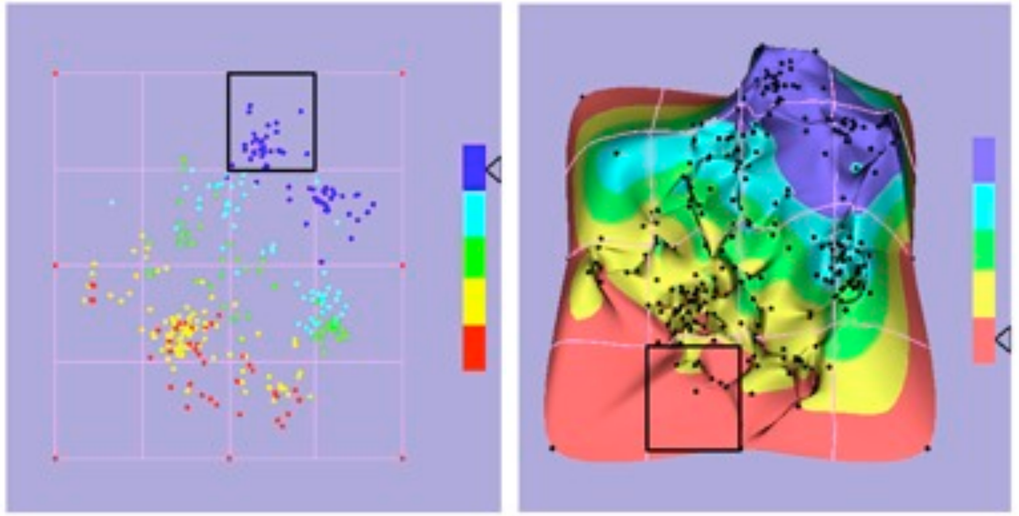
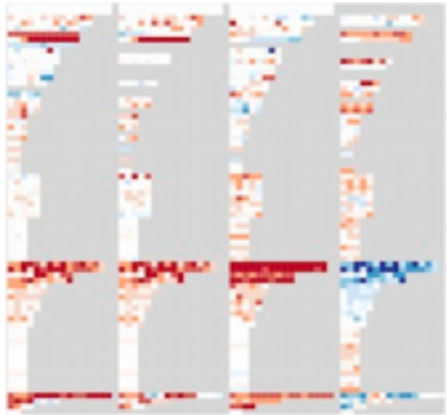
Melanie Tory



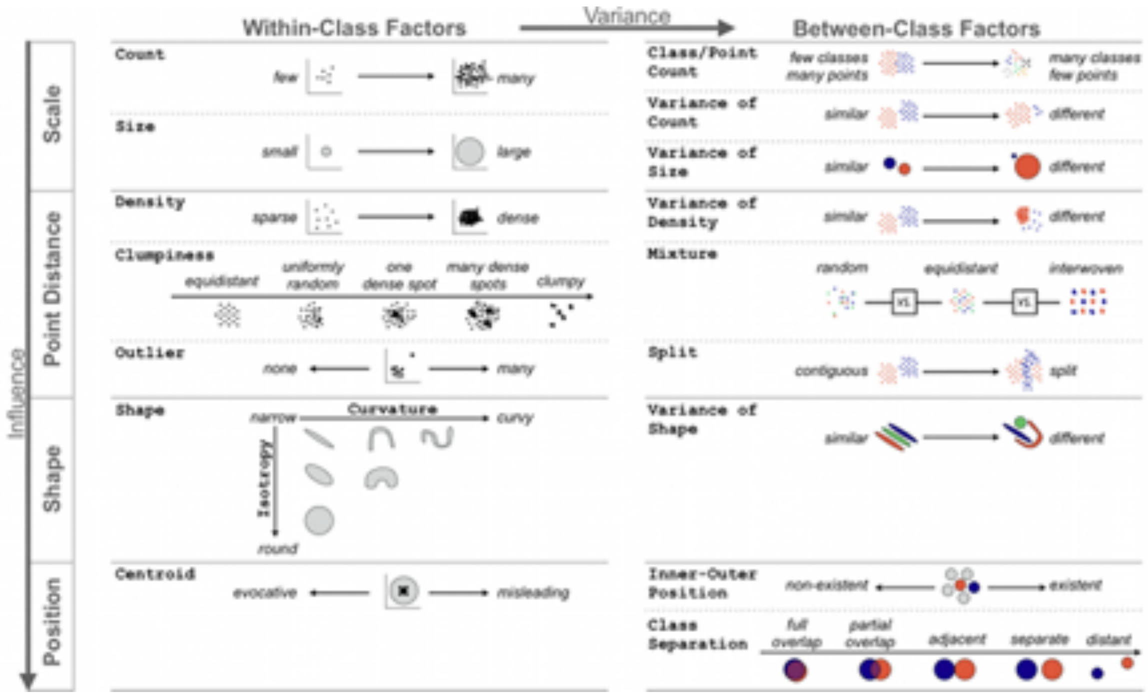
Points vs landscapes for dimensionally reduced data



Guidance on DR & scatterplot choices

Michael Sedlmair

Melanie Tory (UVic)



Taxonomy of cluster separation factors

Problem-driven: Genomics

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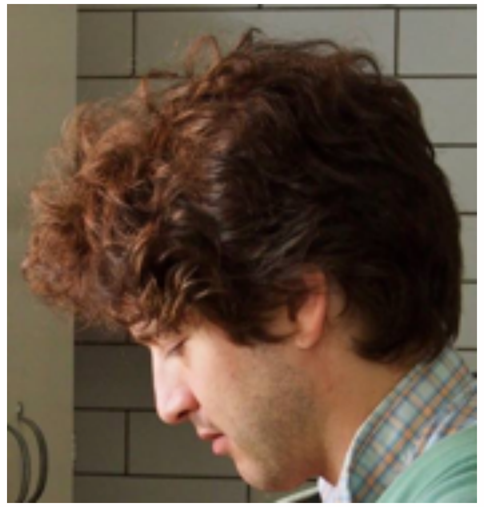
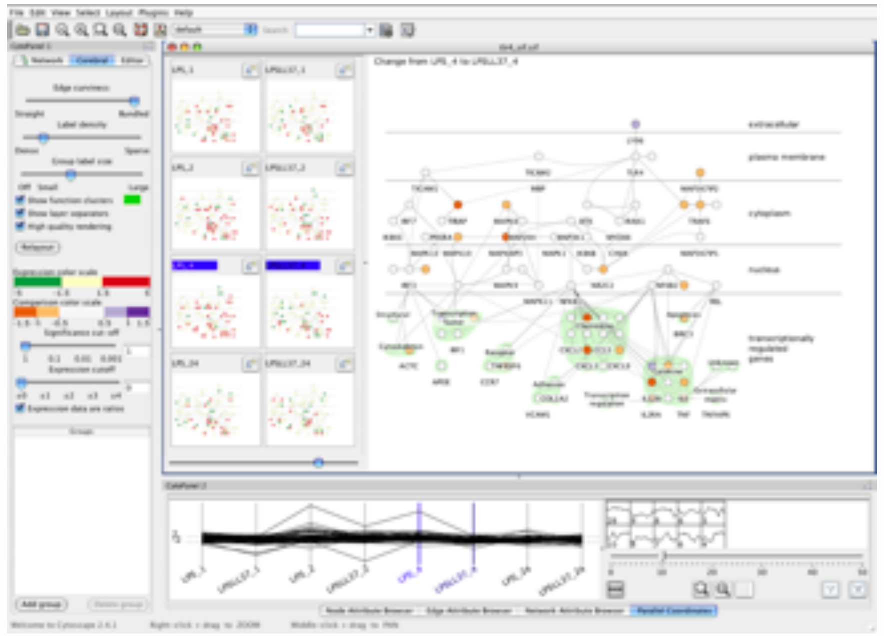
Aaron Barsky



Jenn Gardy
(Microbio)

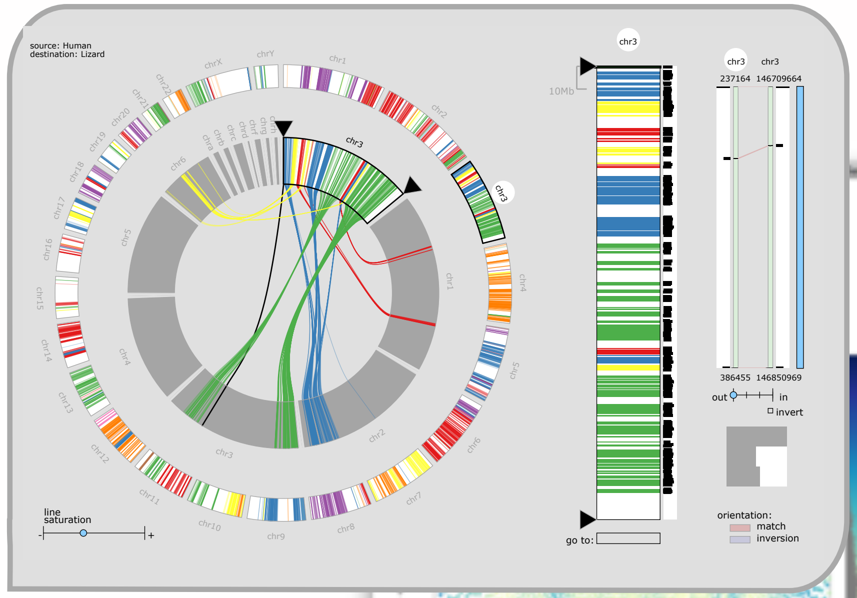
Robert Kincaid
(Agilent)



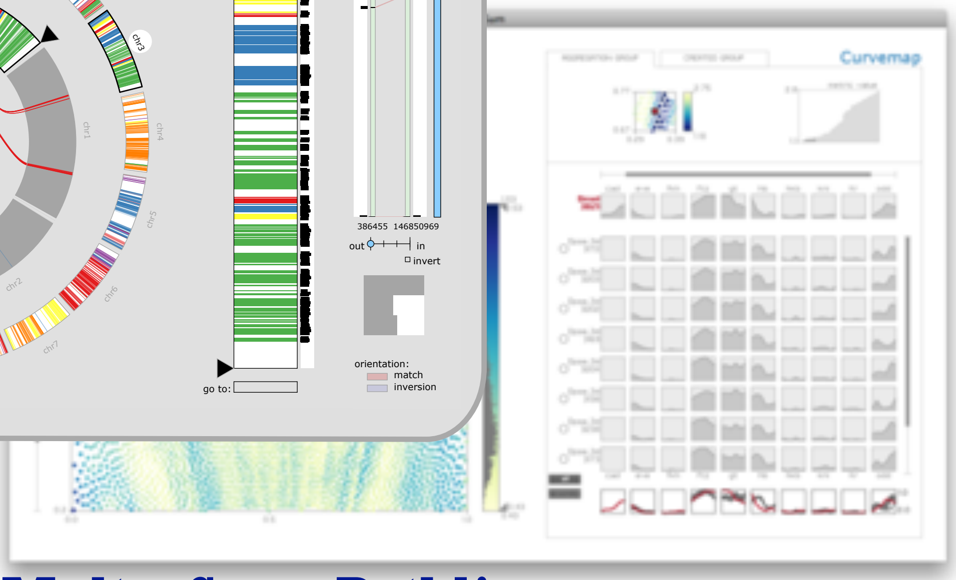
Cerebral

Miriah Meyer

Hanspeter Pfister
(Harvard)



MizBee



MulteeSum, Pathline

Problem-driven: Genomics, fisheries

T

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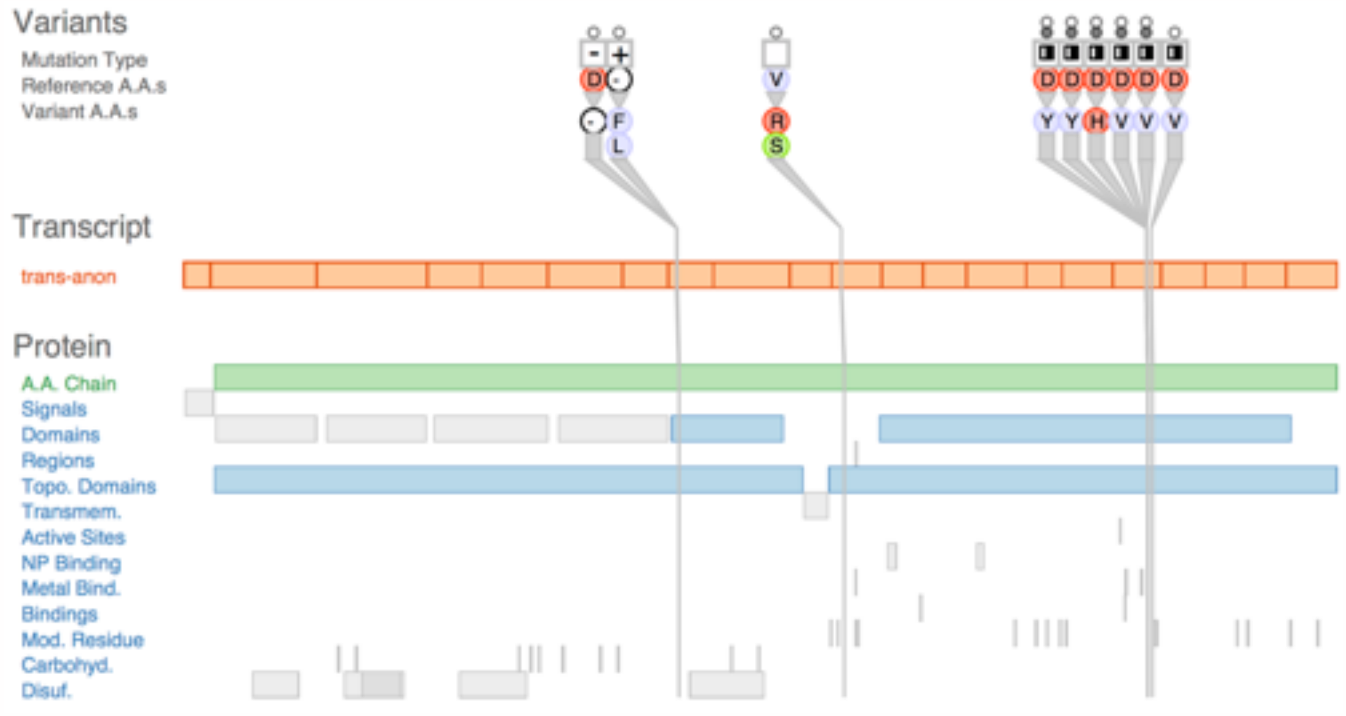
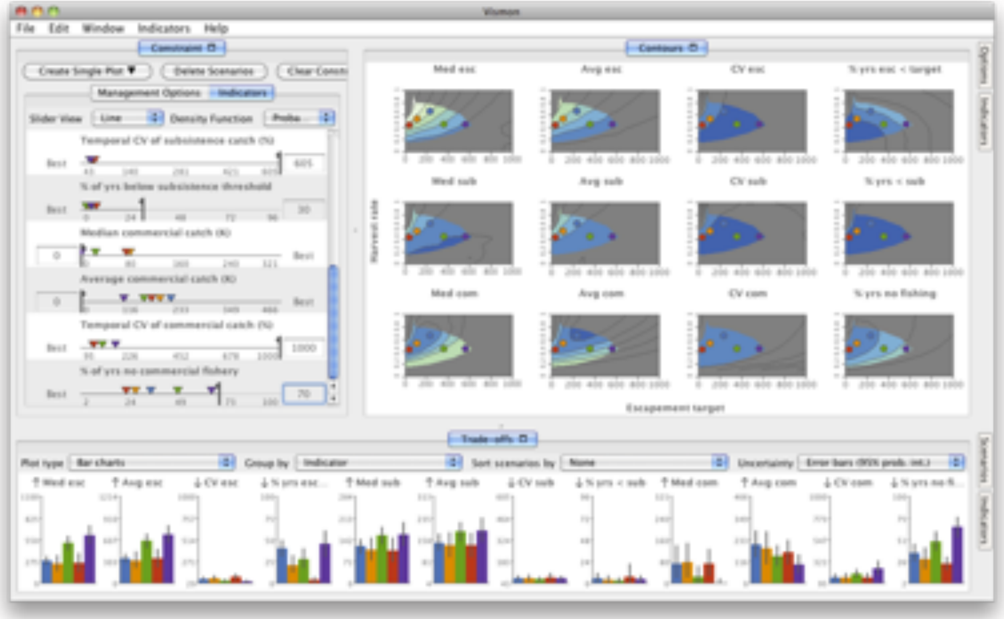
P

Joel Ferstay

Cydney Nielsen
(BC Cancer)



Variant View



Vismon

Maryam Booshehrian

Torsten Moeller
(SFU)

Problem-driven: Many domains

T

F

E

P

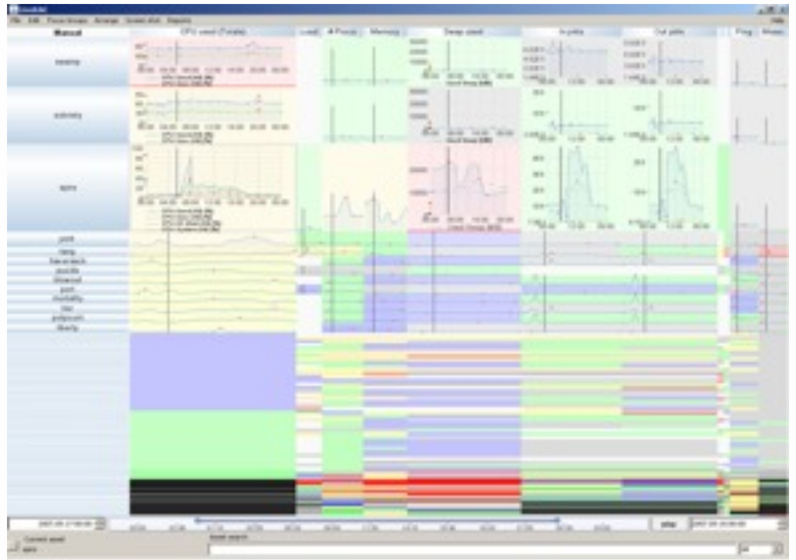
SessionViewer: web log analysis

Heidi Lam

Diane Tang
(Google)

Peter McLachlan

Stephen North
(AT&T Research)



LiveRAC: systems time-series

Evaluation: Focus+Context

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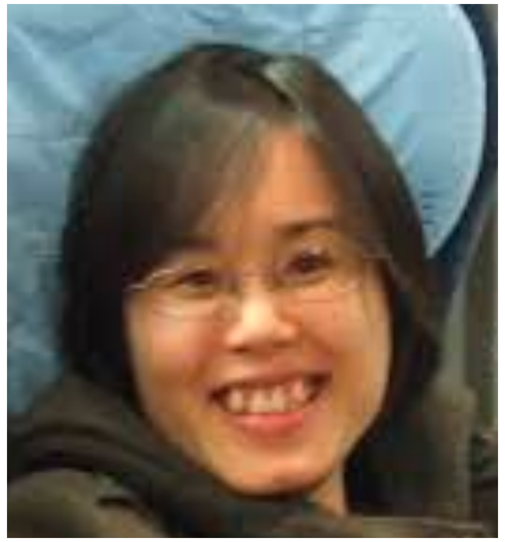
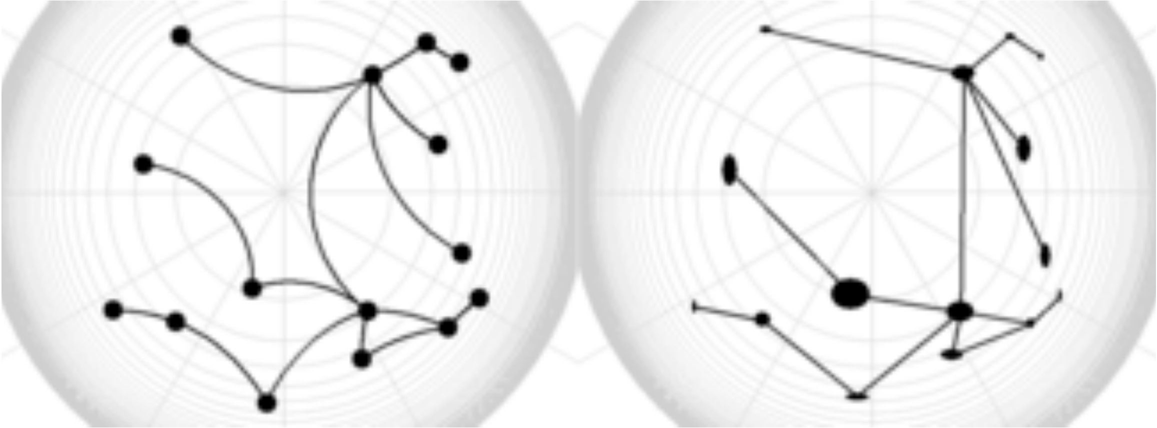
Heidi Lam

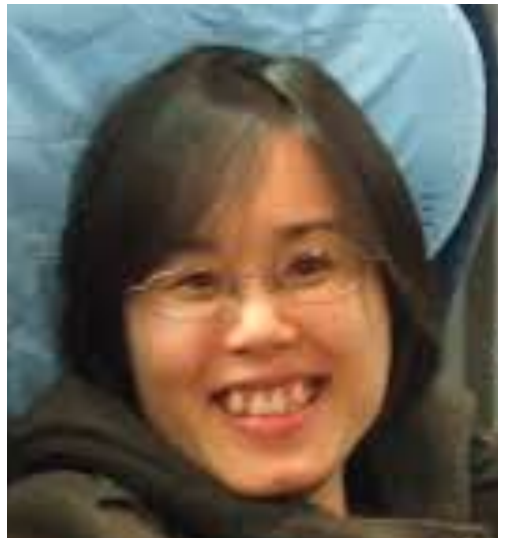


Ron Rensink
(UBC)

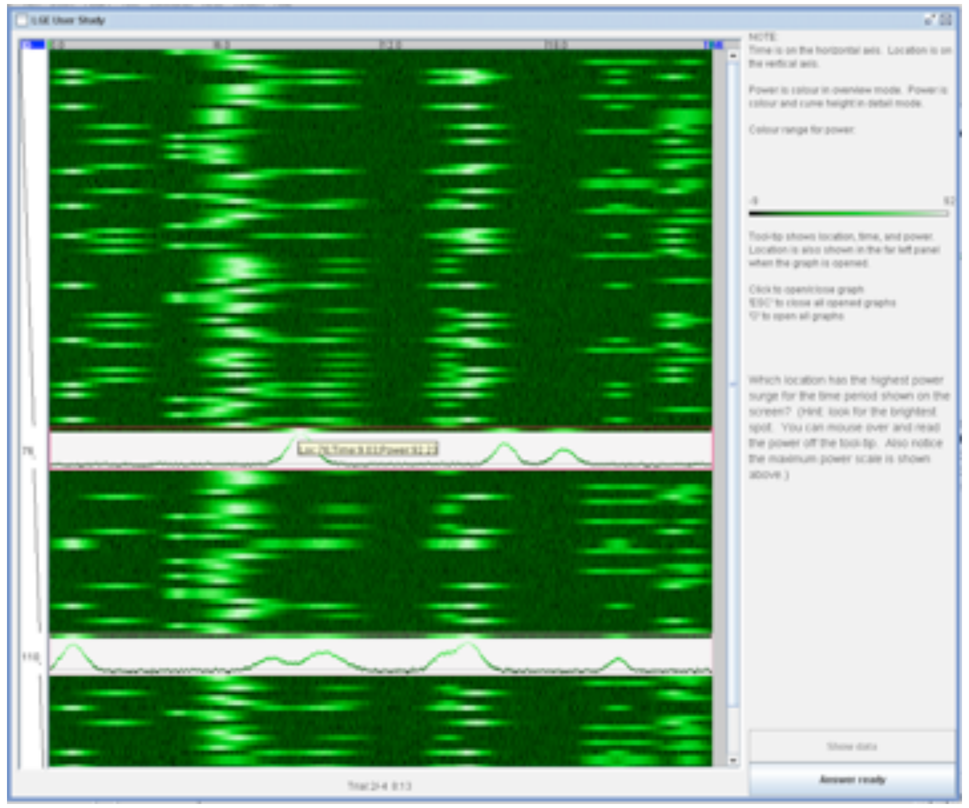


Distortion impact on search/memory

Heidi Lam



Robert Kincaid
(Agilent)



Separate vs integrated views

Journalism

T

F

E

P

Matt Brehmer

Stephen Ingram

Jonathan Stray
(Assoc Press)

Overview

Johanna Fulda
(Sud. Zeitung)

Matt Brehmer

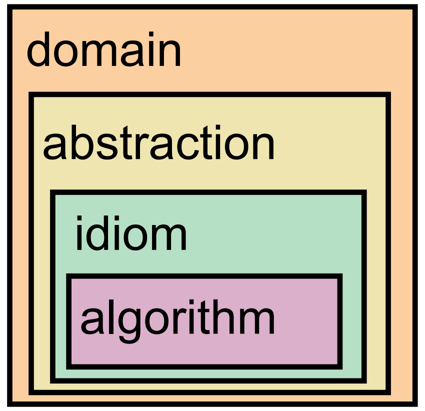
TimeLineCurator

Theoretical foundations

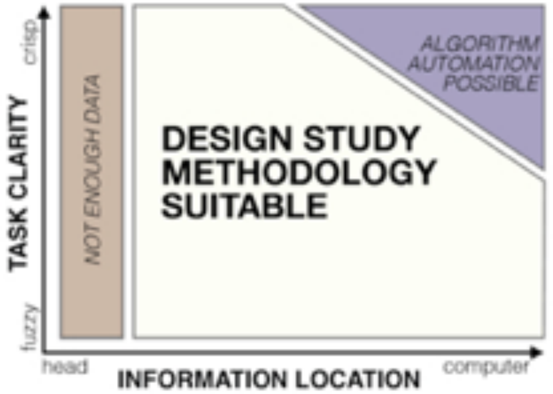
T F E P

- Visual Encoding Pitfalls
  - Unjustified Visual Encoding
  - Hammer In Search Of Nail
  - 2D Good, 3D Better
  - Color Cacophony
  - Rainbows Just Like In The Sky
- Strategy Pitfalls
  - What I Did Over My Summer
  - Least Publishable Unit
  - Dense As Plutonium
  - Bad Slice and Dice

Papers Process & Pitfalls



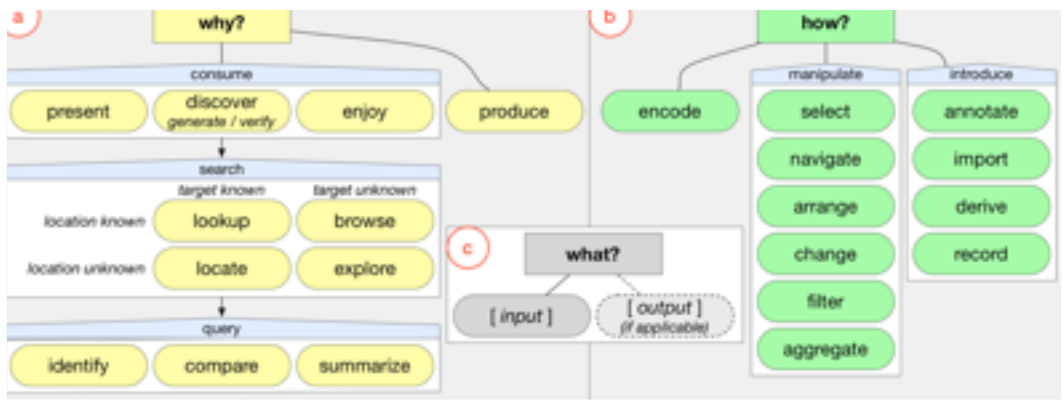
Nested Model



Design Study Methodology

Michael Sedlmair

Miriah Meyer



Abstract Tasks

Matt Brehmer

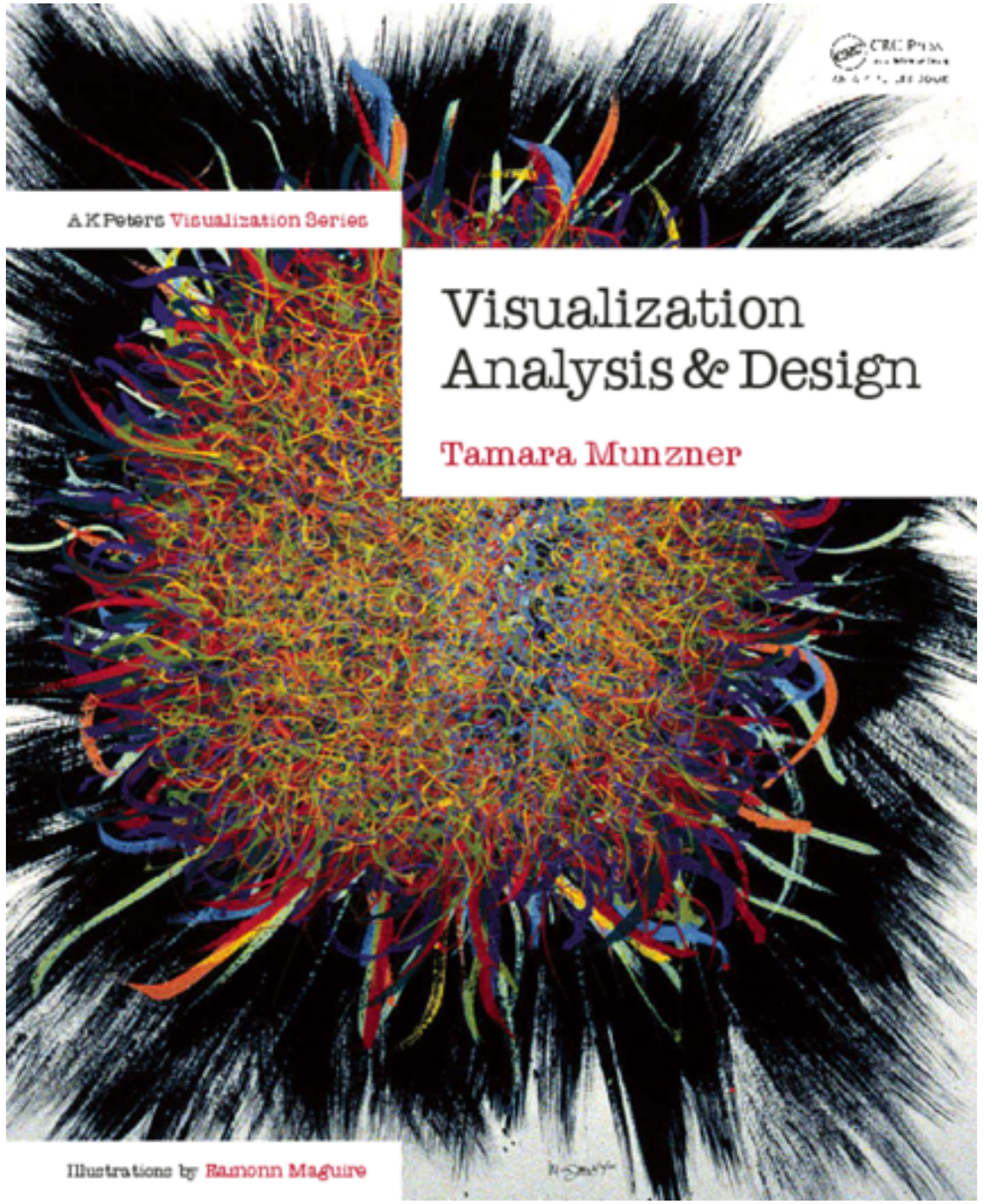
More Information

@tamaramunzner

- this talk
  http://www.cs.ubc.ca/~tmm/talks.html#vad16gi

- book page (including tutorial lecture slides)
  http://www.cs.ubc.ca/~tmm/vadbook
  – 20% promo code for book+ebook combo: HVN17
  – http://www.crcpress.com/product/isbn/9781466508910
  – illustrations: Eamonn Maguire

- papers, videos, software, talks, courses
  http://www.cs.ubc.ca/group/infovis
  http://www.cs.ubc.ca/~tmm



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