# Visualization Analysis & Design

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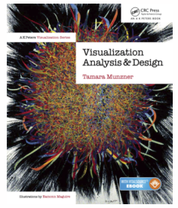



*Graphics Interface 2016 Invited Talk*
*June 2 2016, Victoria BC*

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

@tamaramunzner

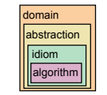
## Why talk about a textbook to a room of experts?

- 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!

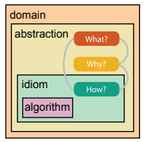


## Analysis framework: Four levels, three questions

- *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).]



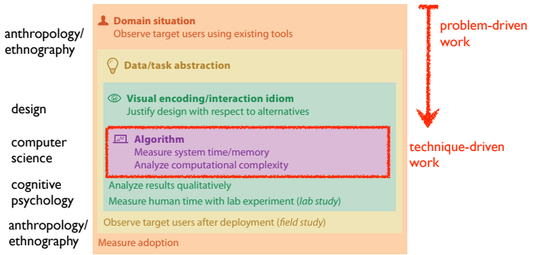
## Why is validation difficult?

- different ways to get it wrong at each level




## Why is validation difficult?

- solution: use methods from different fields at each level

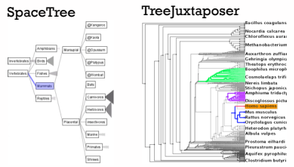



[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]



## Why analyze?

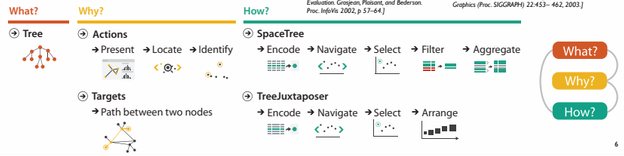
- imposes a structure on huge design space
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new



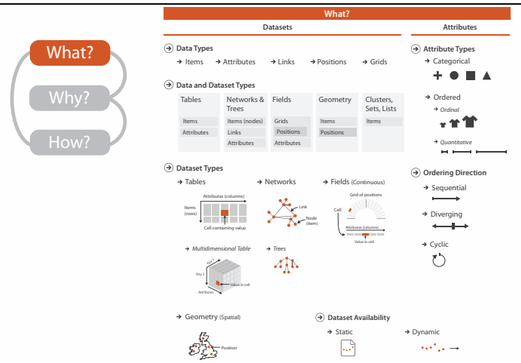

[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p. 57–64.]




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

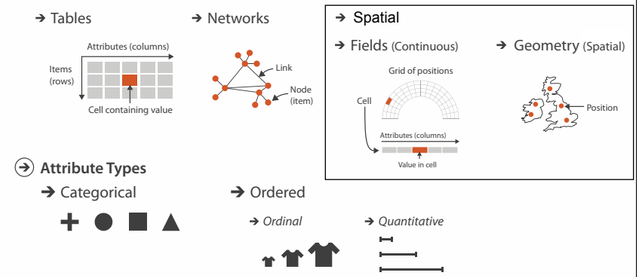




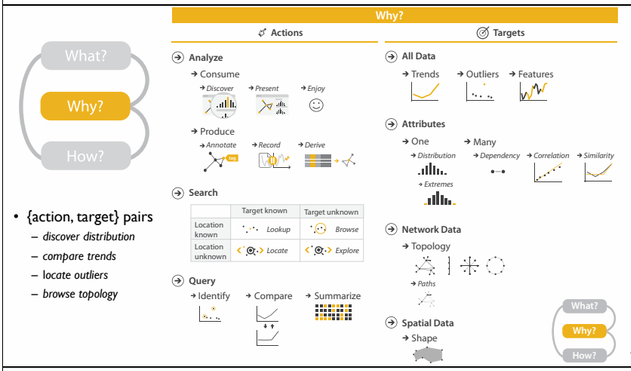






## Types: Datasets and data






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



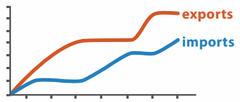
## Actions: Analyze, Query

- 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)

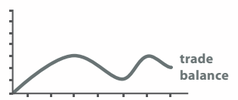



## Derive: Crucial Design Choice

- 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

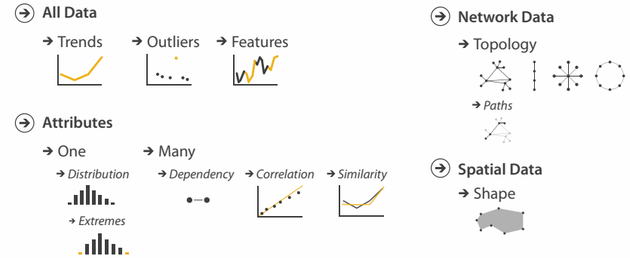



*trade balance = exports − imports*

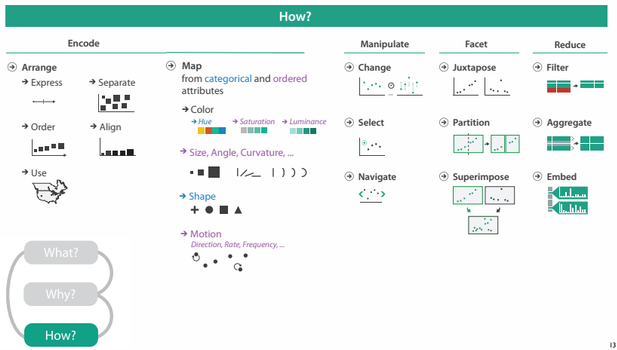
Derived Data



## Targets

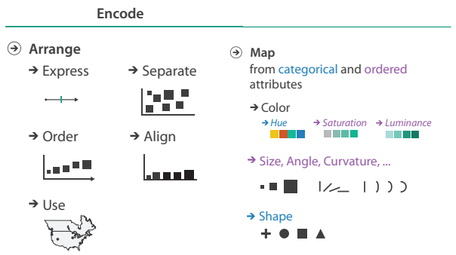






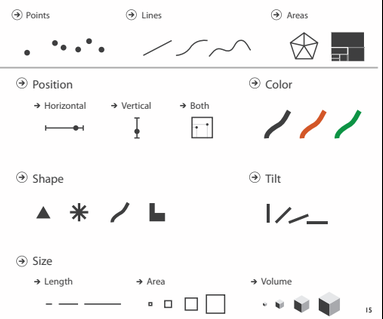

## How to encode: Arrange space, map channels






## 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: | 2: | 3: | 4: |
|---|---|---|---|
| vertical position | vertical position<br>horizontal position | vertical position<br>horizontal position<br>color hue | vertical position<br>horizontal position<br>color hue<br>size (area) |
| mark: line | mark: point | mark: point | 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)

Spatial region
Color hue
Motion
Shape

Same



# 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)

Same

**Identity Channels: Categorical Attributes**

Spatial region
Color hue
Motion
Shape

- expressiveness principle
  - 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

Best → Least Effectiveness

**Identity Channels: Categorical Attributes**

Spatial region
Color hue
Motion
Shape

Same

- 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

**Manipulate**

- Change
- Select
- Navigate

**Facet**

- Juxtapose
- Partition
- Superimpose

**Reduce**

- Filter
- Aggregate
- Embed

→ Derive

- 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

**Manipulate**

- Change
- Select
- Navigate

**Facet**

- Juxtapose
- Partition
- Superimpose

**Reduce**

- Filter
- Aggregate
- Embed

→ Derive

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



# How to handle complexity: 3 more strategies + 1 previous

**Manipulate**

- Change
- Select
- Navigate

**Facet**

- Juxtapose
- Partition
- Superimpose

**Reduce**

- Filter
- Aggregate
- Embed

→ Derive

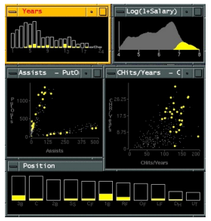
- facet data across multiple views



# 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***

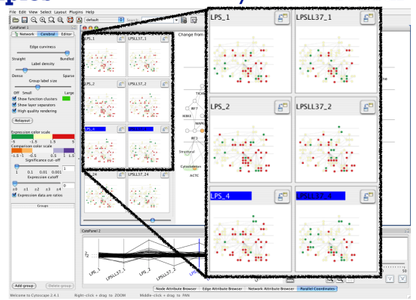

*[A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1–31.]*



# 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

| Encoding | Data: All | Data: Subset | Data: None |
|---|---|---|---|
| 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

**Reducing Items and Attributes**

**Filter**
- Items
- Attributes

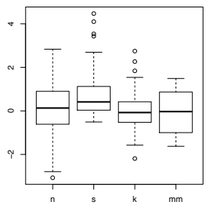
**Aggregate**
- Items
- Attributes

**Reduce**
- Filter
- Aggregate
- Embed



# 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

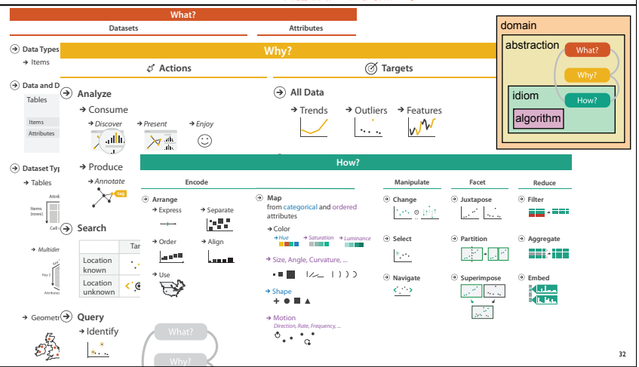
**Task 1**
Dim 1 … Dim n
Item 1 … Item n
In: HD data → Out: 2D data

**Task 2**
Dim 1 Dim 2
Item 1 … Item n
In: 2D data → Out: Scatterplot Clusters & points

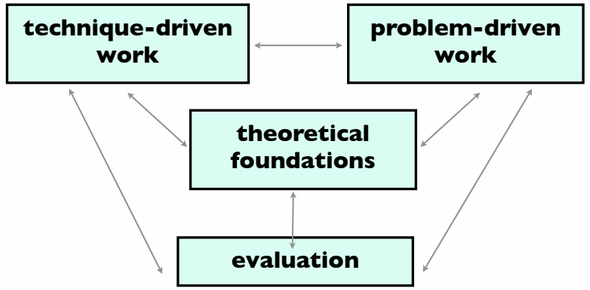
**Task 3**
In: Scatterplot Clusters & points → Out: Labels for clusters

| What? | Why? | How? |
|---|---|---|
| In: High-dimensional data | Produce | Encode |
| Out: 2D data | Derive | Navigate |
| | | Select |
| In: 2D data | | Discover |
| Out: Scatterplot | | Explore |
| Out: Clusters & points | | Identify |
| In: Scatterplot | Produce | |
| In: Clusters & points | Annotate | |
| Out: Labels for clusters | | |





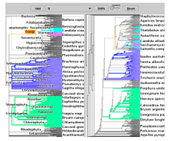
## A quick taste of my own work!






## Technique-driven: Graph drawing

T F P E



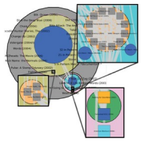
James Slack

Kristian Hildebrand

**TreeJuxtaposer**

Daniel Archambault

David Auber (Bordeaux)



**TopoLayout**
**SPF**
**Grouse**
**GrouseFlocks**
**TugGraph**



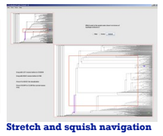
## Evaluation: Graph drawing

T F P E

Dmitry Nekrasovski

Adam Bodnar

Joanna McGrenere (UBC)



**Stretch and squish navigation**

Jessica Dawson

Joanna McGrenere (UBC)

**Search set model of path tracing**



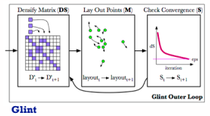
## Technique-driven: Dimensionality reduction

T F P E

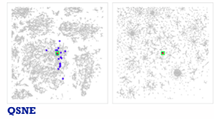
Stephen Ingram

**Glimmer**

**DimStiller**




**Glint**



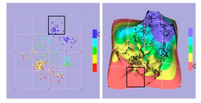
**QSNE**



## Evaluation: Dimensionality reduction

T F P E

Melanie Tory

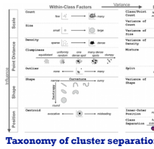


**Points vs landscapes for dimensionally reduced data**

**Guidance on DR & scatterplot choices**

Michael Sedlmair

Melanie Tory (UVic)



**Taxonomy of cluster separation factors**



## Problem-driven: Genomics

T F P E

Aaron Barsky

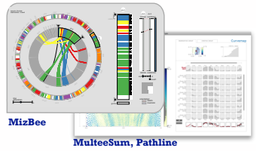
Jenn Gardy (Microbio)

Robert Kincaid (Agilent)

**Cerebral**

Miriah Meyer

Hanspeter Pfister (Harvard)



**MizBee**

**MulteeSum, Pathline**



## Problem-driven: Genomics, fisheries

T F P E

Joel Ferstay

Cydney Nielsen (BC Cancer)

**Variant View**

**Vismon**

Maryam Booshehrian

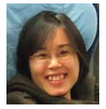
Torsten Moeller (SFU)



## Problem-driven: Many domains

T F P E

Heidi Lam



Diane Tang (Google)



**SessionViewer: web log analysis**

Peter McLachlan



Stephen North (AT&T Research)





**LiveRAC: systems time-series**



## Evaluation: Focus+Context

T F P E

Heidi Lam



Ron Rensink (UBC)





**Distortion impact on search/memory**

Heidi Lam



Robert Kincaid (Agilent)





**Separate vs integrated views**



## Journalism

T F P E

Matt Brehmer



Stephen Ingram



Jonathan Stray (Assoc Press)





**Overview**

Johanna Fulda (Sud. Zeitung)



Matt Brehmer





**TimeLineCurator**



## Theoretical foundations

T F P E

- 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.*