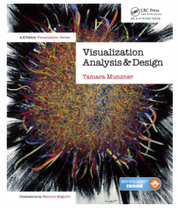
Visualization Analysis & Design

Tamara Munzner
Department of Computer Science
University of British Columbia



InformationPlus 2016 Keynote
June 16 2016, Vancouver BC

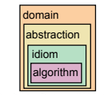
http://www.cs.ubc.ca/~tmm/talks.html#vad16infoplus **@tamaramunzner**

Why talk about a textbook to a room of experts?

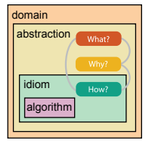
- convince you of the value in thinking systematically about vis design
  - decompose into comprehensive framework of principles and design choices
- provide unified view that crosscuts entire field of visualization
  - infovis and scivis: addressing different kinds of data
  - visual analytics: interweave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

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).]



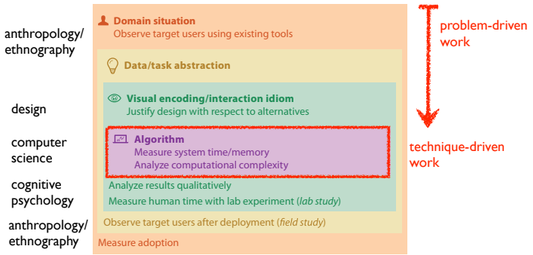
[A Multi-Level Typology of Abstract Visualization Tasks Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]

Why is validation difficult?

- different ways to get it wrong at each level

Why is validation difficult?

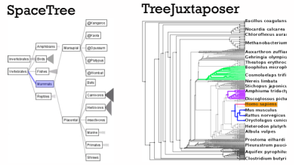
- solution: use methods from different fields at each level



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

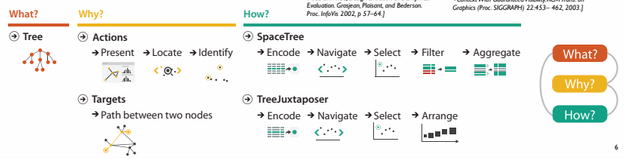
Why analyze?

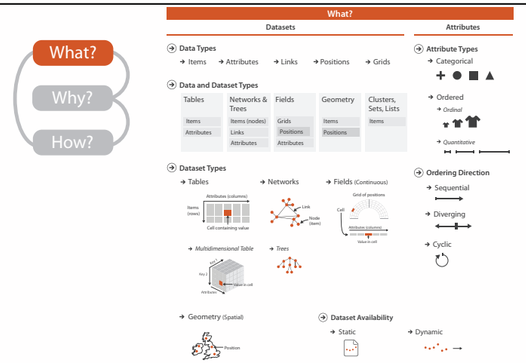
- imposes a structure on huge design space
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new



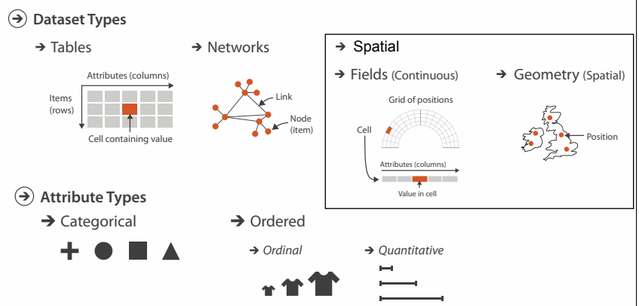
[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

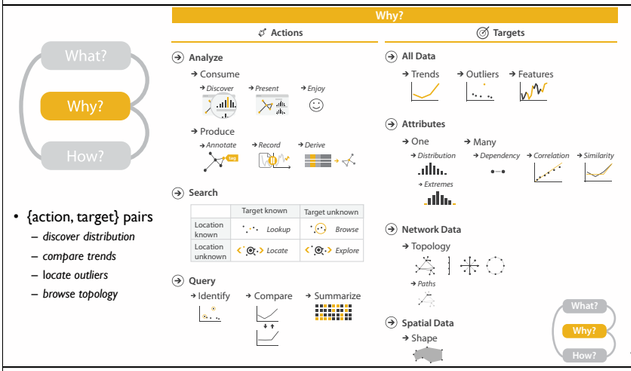
[TreeJuxtaposer: Scalable Tree Comparison Using Focus +Context With Guaranteed Visibility. ACM Trans. on Graphics (Proc. SIGGRAPH) 22:453–462, 2003.]





Types: Datasets and data





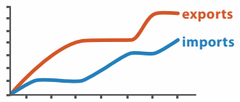
- {action, target} pairs
  - *discover distribution*
  - *compare trends*
  - *locate outliers*
  - *browse topology*

Actions: Analyze, Query

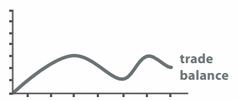
- analyze
  - consume
    - discover vs present
      - aka explore vs explain
    - enjoy
      - aka casual, social
  - produce
    - annotate, record, derive
- query
  - how much data matters?
    - one, some, all
- independent choices
  - analyze, query, (search)

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



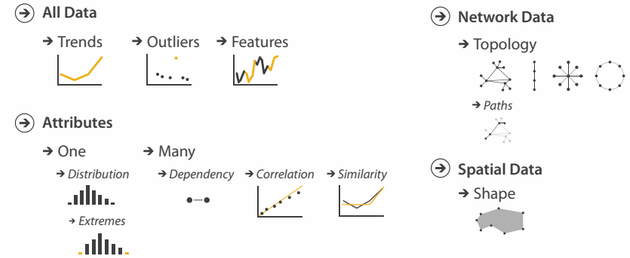
Original Data

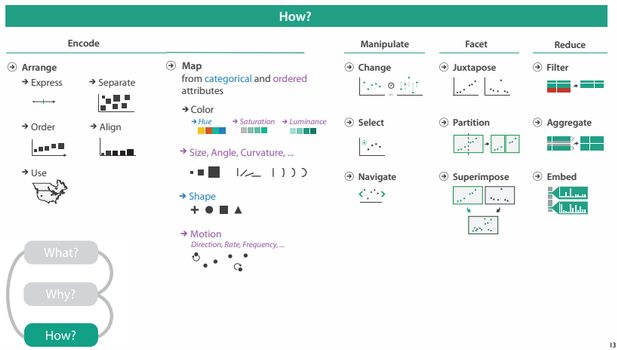


trade balance = exports − imports

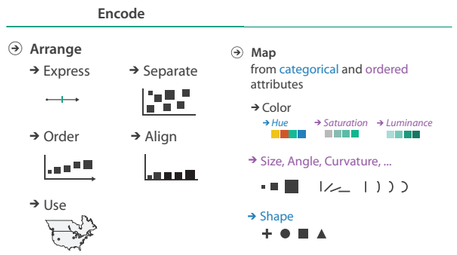
Derived Data

Targets



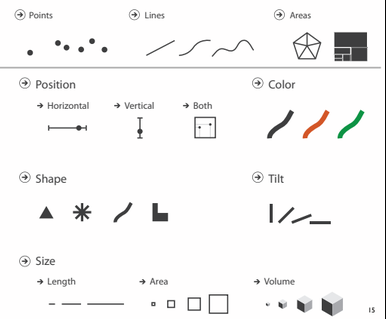


How to encode: Arrange space, map channels



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 horizontal position	vertical position horizontal position color hue	vertical position horizontal position color hue 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

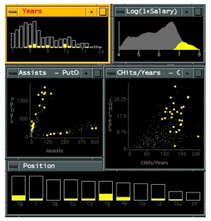
→ Derive

- 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**

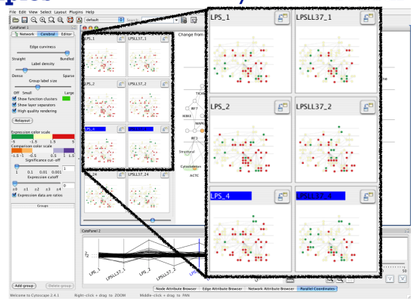
- encoding: same
- data: subset shared
- navigation: shared
  - bidirectional linking
- differences
  - viewpoint
  - (size)
- ***overview-detail***

[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

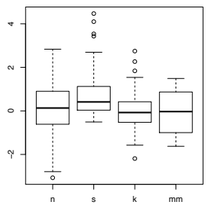
Filter
- Items
- Attributes

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**

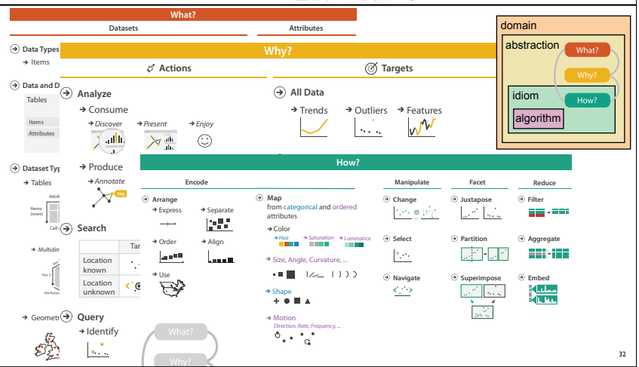
- attribute aggregation
  - derive low-dimensional target space from high-dimensional measured space

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

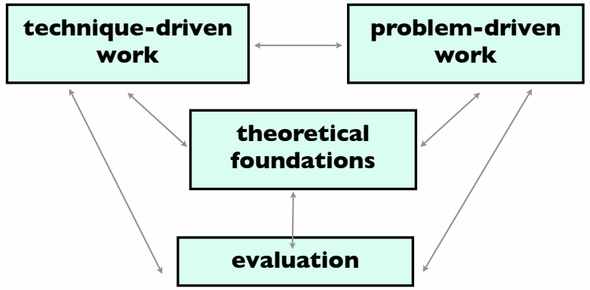
Task 2
Dim 1 Dim 2
Item 1 … Item n
In: 2D data → Out: Scatterplot Clusters & points

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		

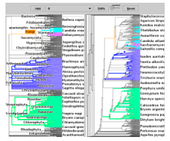


A quick taste of my own work!



Technique-driven: Graph drawing

T F P E



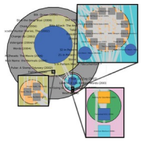
James Slack

Kristian Hildebrand

TreeJuxtaposer

Daniel Archambault

David Auber (Bordeaux)



TopoLayout
SPF
Grouse
GrouseFlocks
TugGraph

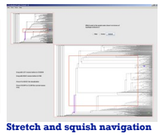
Evaluation: Graph drawing

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

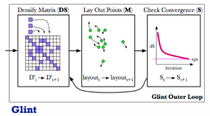
Technique-driven: Dimensionality reduction

T F P E

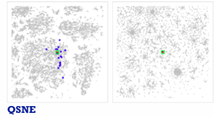
Stephen Ingram

Glimmer

DimStiller



Glint

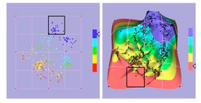


QSNE

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

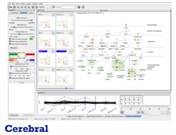
Problem-driven: Genomics

T F P E

Aaron Barsky

Jenn Gardy (Microbio)

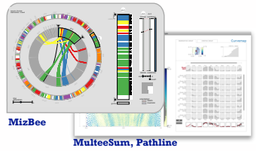
Robert Kincaid (Agilent)



Cerebral

Miriah Meyer

Hanspeter Pfister (Harvard)



MizBee

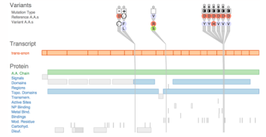
MulteeSum, Pathline

Problem-driven: Genomics, fisheries

T F P E

Joel Ferstay

Cydney Nielsen (BC Cancer)



Variant View

Vismon

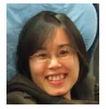
Maryam Booshehrian

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#vad16infoplus
- 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.