Information Visualization
Data, Tasks, Nested Model
Ex: Abstractions

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Week 2: 15 September 2021

http://www.cs.ubc.ca/~tmm/courses/547-21

Course Logistics

Async so far

- last week
  - async read only
    - Course Logistics (no comments, no responses)
  - async read & comment
    - VAD Ch 1: Why Visualization? (comments only, no responses)
  - async discuss
    - self-intros
- this week
  - async read & comment & respond
    - VAD Ch 2: Data Abstraction
    - VAD Ch 3: Task Abstraction
    - paper: Nested Model [basis for VAD Ch 4]

Updates

- All students moved from waitlist to registered
- Official enrolment now 38
- Very likely to move to Forestry (FSC) 2330 starting next week
  - especially if ventilation here in SWNG 207 remains terrible!
- Stay tuned for Canvas marks updates

Discussion: Round 1

Exercise: Abstractions

Now: In-class design exercise, in small groups

- Abstractions
  - practice with data & task abstractions, on concrete example: Aid to Countries
  - crucial ideas: determine cardinalities/ranges
    - precondition for all decisions about visual encoding
- Small-group exercise: 60-ish min
  - breakout groups (4 people/group)
  - googledoc worksheets, as before
  - document in your group's googledoc w/ text as you go!
  - reportbacks, as before (intermediate and final)
    - I'll flip through googledocs, some questions for group spokesperson

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Discussion: Round 2

Next week

- to read & discuss (async, before next class)
  - VAD book, Ch 5: Marks & Channels
  - VAD book, Ch 6: Rules of Thumb
  - paper: Design Study Methodology

Backup/Reference Slides

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

Visualization defined & motivated

short version: alternate to next 3 slides

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

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

- human in the loop needs the details
  - doesn't know exactly what questions to ask in advance
  - longterm exploratory analysis
    - ***speed up*** through human-in-the-loop visual data analysis
  - presentation of known results
  - stepping stone towards automation: refining, trustbuilding
  - interplay between human judgement and automatic computation
- intended task, measurable definitions of effectiveness

Defining visualization (vis)

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

Why?...

Visualization (vis) defined & motivated

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

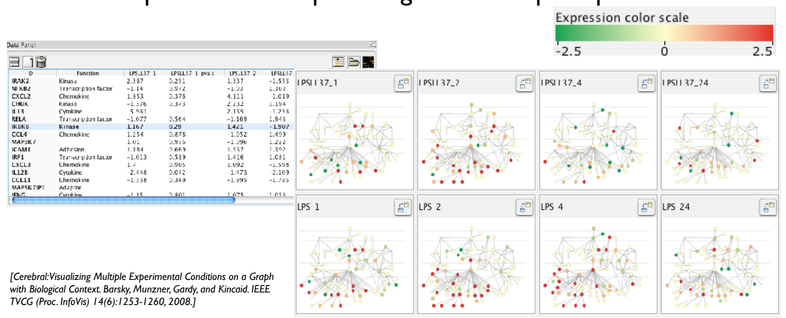
Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

- human in the loop needs the details & no trusted automatic solution exists
  - doesn't know exactly what questions to ask in advance
  - exploratory data analysis
    - ***speed up*** through human-in-the-loop visual data analysis
  - present known results to others
  - stepping stone towards automation
    - before model creation to provide understanding
    - during algorithm creation to refine, debug, set parameters
    - before or during deployment to build trust and monitor

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



[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.]

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

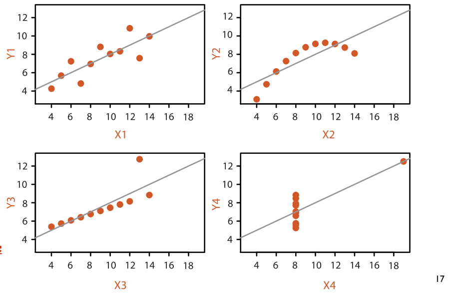
Why represent all the data?

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



https://www.youtube.com/watch?v=DbJyPELmhJc

Same Stats, Different Graphs

Visualization defined & motivated

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

- suitable when human in the loop needs details
  - interplay between human judgement and automatic computation

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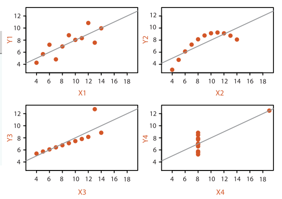
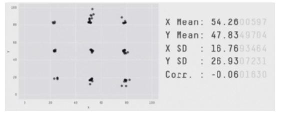


Datasaurus Dozen



Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing. CHI 2017. Matejka & Fitzmaurice

Why focus on tasks and effectiveness?

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

- effectiveness requires match between data/task and representation
  - set of representations is huge
  - many are ineffective mismatch for specific data/task combo
  - increases chance of finding good solutions if you understand full space of possibilities
- what counts as effective?
  - novel: enable entirely new kinds of analysis
  - faster: speed up existing workflows
- how to validate effectiveness
  - many methods, must pick appropriate one for your context

What resource limitations are we faced with?

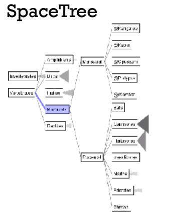
Vis designers must take into account three very different kinds of resource limitations: those of computers, of humans, and of displays.

- computational limits
  - processing time
  - system memory
- human limits
  - human attention and memory
- display limits
  - pixels are precious resource, the 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

Why analyze?

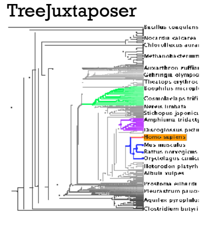
- imposes structure on huge design space
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new
  - most possibilities ineffective for particular task/data combination

SpaceTree

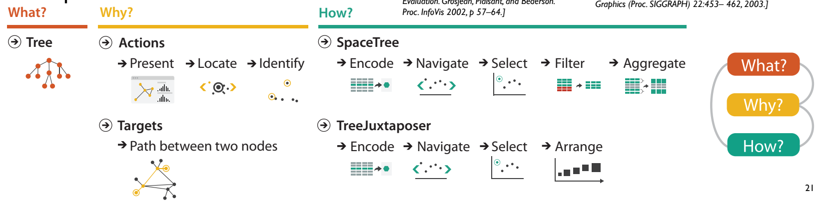


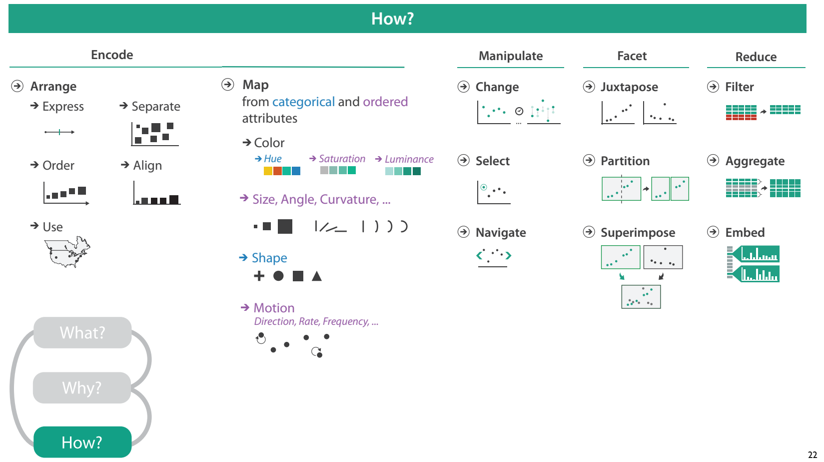
[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

TreeJuxtaposer



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

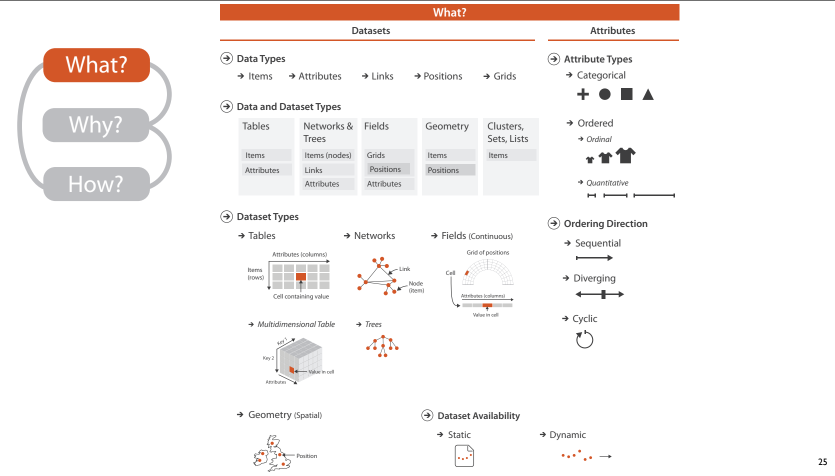




Further reading

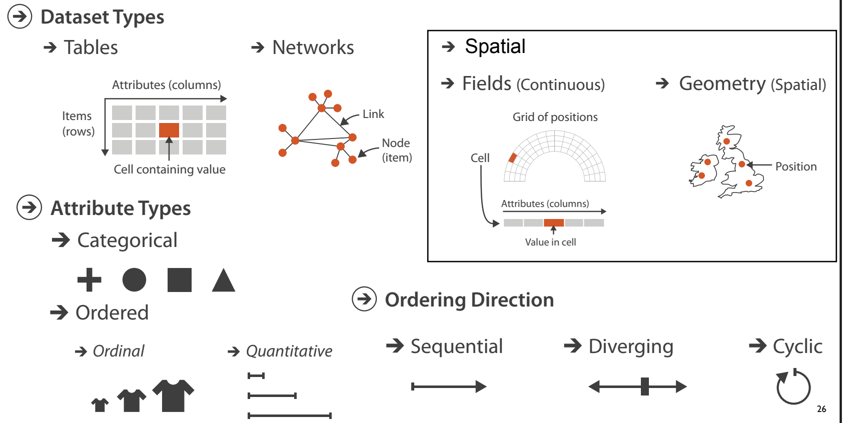
- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - Chap 1: What's Vis, and Why Do It?
- The Nature of External Representations in Problem Solving. Jiajie Zhang. Cognitive Science 21:2 (1997), 179-217.
- A Representational Analysis of Numeration Systems. Jiajie Zhang and Donald A. Norman. Cognition 57 (1995), 271-295.
- Why a Diagram Is (Sometimes) Worth Ten Thousand Words.. Jill H. Larkin and Herbert A. Simon. Cognitive Science 11:1 (1987), 65-99.
- Graphs in Statistical Analysis. F.J. Anscombe. American Statistician 27 (1973), 17-21.
- Design Study Methodology: Reflections from the Trenches and the Stacks. Michael Sedlmair, Miriah Meyer, and Tamara Munzner. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2012), 18(12):2431-2440, 2012.
- Information Visualization: Perception for Design, 3rd edition, Colin Ware, Morgan Kaufmann, 2013.
- Current approaches to change blindness Daniel J. Simons. Visual Cognition 7, 1/2/3 (2000), 1-15.
- Semiology of Graphics, Jacques Bertin, Gauthier-Villars 1967, EHESS 1998
- The Visual Display of Quantitative Information. Edward R. Tufte. Graphics Press, 1983.

Ch 2. What: Data Abstraction

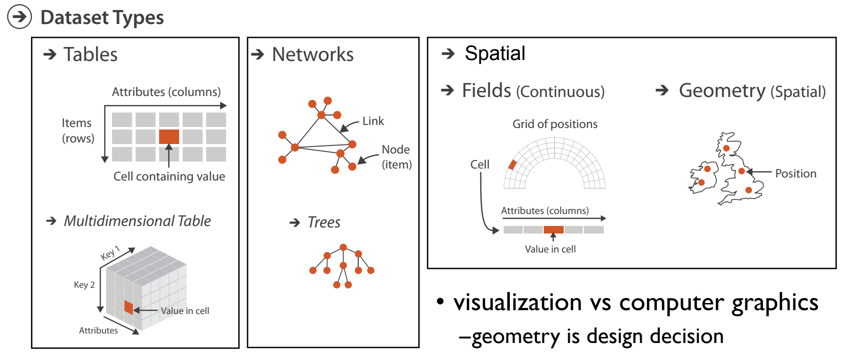


Types: Datasets and data

short version: alternate to next 3 slides

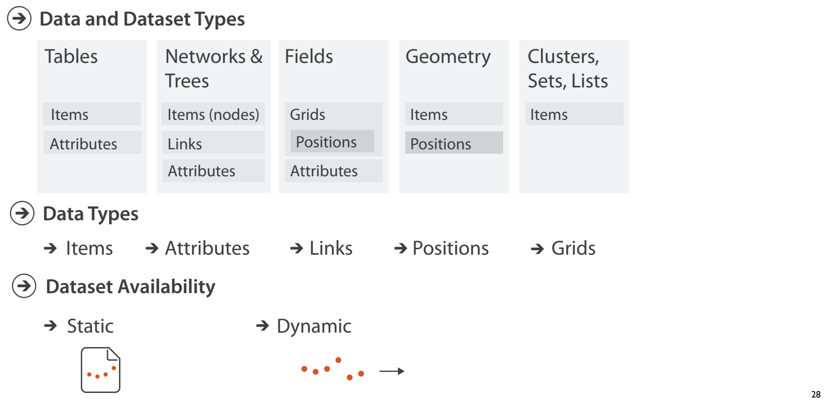


Three major datatypes

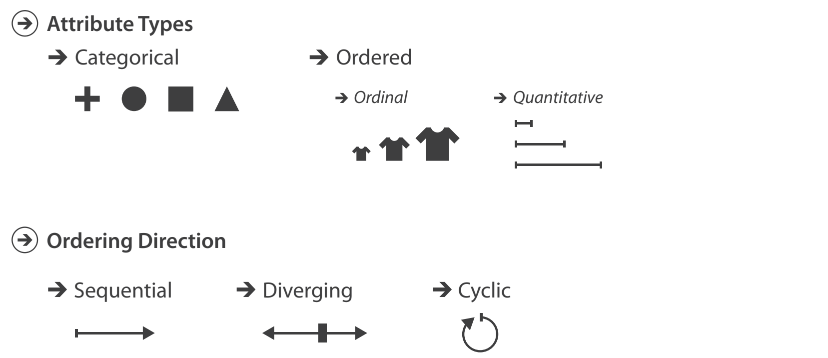


- visualization vs computer graphics
  - geometry is design decision

Dataset and data types



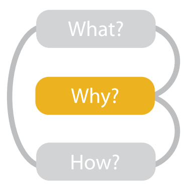
Attribute types



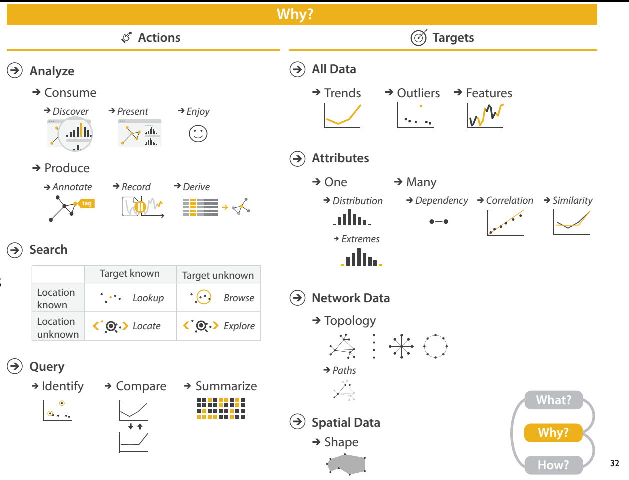
Further reading, full Ch 2

- Readings in Information Visualization: Using Vision To Think, Chapter 1. Stuart K. Card, Jock Mackinlay, and Ben Shneiderman. Morgan Kaufmann, 1999.
- Rethinking Visualization: A High-Level Taxonomy. InfoVis 2004, p 151-158, 2004.
- The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations Ben Shneiderman, Proc. 1996 IEEE Visual Languages
- Data Visualization: Principles and Practice, 2nd ed. Alexandru Telea, CRC Press, 2014.
- Interactive Data Visualization: Foundations, Techniques, and Applications, 2nd ed. Matthew O. Ward, Georges Grinstein, Daniel Keim. CRC Press, 2015.
- The Visualization Handbook. Charles Hansen and Chris Johnson, eds. Academic Press, 2004.
- Visualization Toolkit: An Object-Oriented Approach to 3D Graphics, 4th ed. Will Schroeder, Ken Martin, and Bill Lorensen. Kitware 2006.
- The Structure of the Information Visualization Design Space. Stuart Card and Jock Mackinlay, Proc. InfoVis 97.
- Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases (extended paper) Chris Stolte, Diane Tang and Pat Hanrahan. IEEE TVCG 8(1):52-65 2002.
- Visualization of Time-Oriented Data. Wolfgang Aigner, Silvia Miksch, Heidrun Schumann, Chris Tominski. Springer 2011.

Ch 3. Why: Task Abstraction



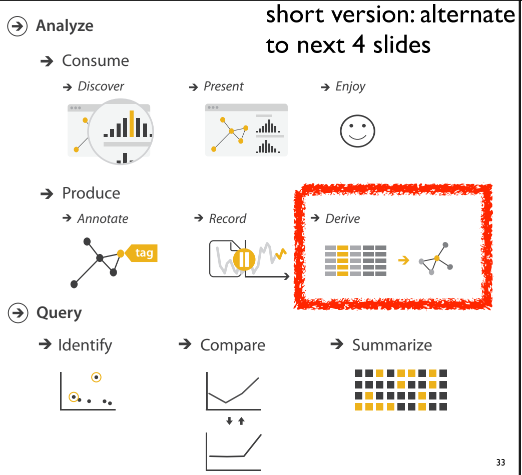
- {action, target} pairs
  - *discover distribution*
  - *compare trends*
  - *locate outliers*
  - *browse topology*



Actions: Analyze, Query

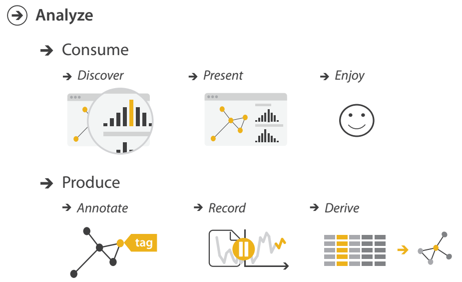
short version: alternate to next 4 slides

- 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)



Actions: Analyze

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



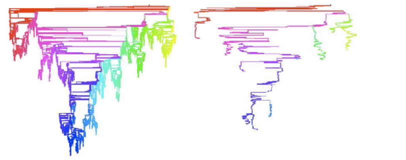
Derive

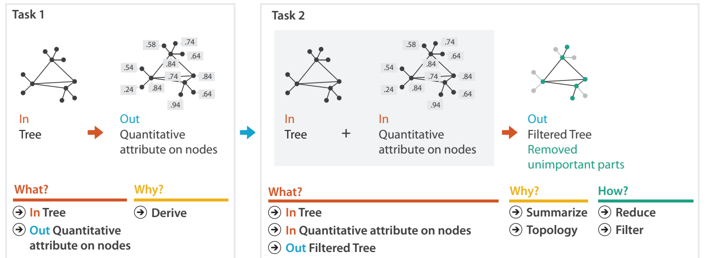
- don't just draw what you're given!
  - decide what the right thing to show is
  - create it with a series of transformations from the original dataset
  - draw that
- one of the four major strategies for handling complexity

Analysis example: Derive one attribute

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

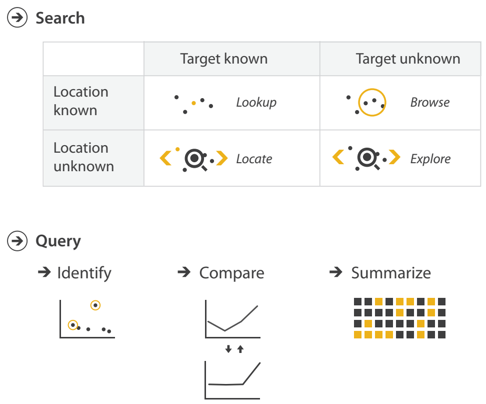
[Using Strahler numbers for real time visual exploration of huge graphs. Auber. Proc. Intl. Conf. Computer Vision and Graphics, pp. 56–69, 2002.]



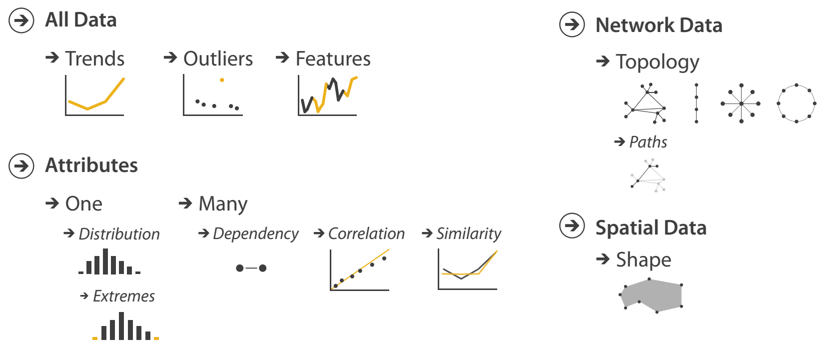


Actions: Search, query

- what does user know?
  - target, location
- how much of the data matters?
  - one, some, all
- independent choices for each of these three levels
  - analyze, search, query
  - mix and match



Why: Targets



Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 2: What: Data Abstraction*
  - *Chap 3: Why: Task Abstraction*
- *A Multi-Level Typology of Abstract Visualization Tasks.* Brehmer and Munzner. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis) 19:12 (2013), 2376–2385.
- *Low-Level Components of Analytic Activity in Information Visualization.* Amar, Eagan, and Stasko. Proc. IEEE InfoVis 2005, p 111–117.
- *A taxonomy of tools that support the fluent and flexible use of visualizations.* Heer and Shneiderman. Communications of the ACM 55:4 (2012), 45–54.
- *Rethinking Visualization: A High-Level Taxonomy.* Tory and Möller. Proc. IEEE InfoVis 2004, p 151–158.
- Visualization of Time-Oriented Data. Aigner, Miksch, Schumann, and Tominski. Springer, 2011.

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- A characterization of the scientific data analysis process. Rebecca R. Springmeyer, Meera M. Blattner, and Nelson M. Max. Proc. Vis 1992, p 235-252.
- Low-Level Components of Analytic Activity in Information Visualization. Robert Amar, James Eagan, and John Stasko. Proc. InfoVis 05, pp. 111-117.
- Task taxonomy for graph visualization. Bongshin Lee, Catherine Plaisant, Cynthia Sims Parr, Jean-Daniel Fekete, and Nathalie Henry. Proc. BELIV 2006.
- Interactive Dynamics for Visual Analysis. Jeffrey Heer and Ben Shneiderman. Communications of the ACM, 55(4), pp. 45-54, 2012.
- What does the user want to see?: what do the data want to be? A. Johannes Pretorius and Jarke J. van Wijk. Information Visualization 8(3):153-166, 2009.
- Chapter 1, Readings in Information Visualization: Using Vision to Think. Stuart Card, Jock Mackinlay, and Ben Shneiderman, Morgan Kaufmann 1999.
- An Operator Interaction Framework for Visualization Systems. Ed H. Chi and John T. Riedl. Proc. InfoVis 1998, p 63-70.
- Nominal, Ordinal, Interval, and Ratio Typologies are Misleading. Paul F. Velleman and Leland Wilkinson. The American Statistician 47(1):65-72, 1993.
- Rethinking Visualization: A High-Level Taxonomy. Melanie Tory and Torsten Möller, Proc. InfoVis 2004, pp. 151-158.
- SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Catherine Plaisant, Jesse Grosjean, and Ben B. Bederson. Proc. InfoVis 2002.
- TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility Tamara Munzner, Francois Guimbretiere, Serdar Tasiran, Li Zhang, and Yunhong Zhou. SIGGRAPH 2003.
- Feature detection in linked derived spaces. Chris Henze. Proc. Visualization (Vis) 1998, p 87-94.
- Using Strahler numbers for real time visual exploration of huge graphs. David Auber. Intl Conf. Computer Vision and Graphics, 2002, p 56-69.

Ch 4. Analysis: Four Levels for Validation

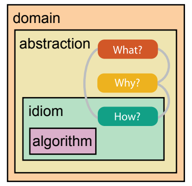
How to evaluate a visualization: So many methods, how to pick?

- Computational benchmarks?
  - quant: system performance, memory
- User study in lab setting?
  - quant: (human) time and error rates, preferences
  - qual: behavior/strategy observations
- Field study of deployed system?
  - quant: usage logs
  - qual: interviews with users, case studies, observations
- Analysis of results?
  - quant: metrics computed on result images
  - qual: consider what structure is visible in result images
- Justification of choices?
  - qual: perceptual principles, best practices

Nested model: Four levels of visualization design

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

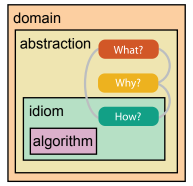
- *domain situation*
  - who are the target users?
- *abstraction*
  - translate from specifics of domain to vocabulary of visualization
    - **what** is shown? **data** abstraction
    - **why** is the user looking at it? **task** abstraction
- *idiom*
  - **how** is it shown?
    - **visual encoding** idiom: how to draw
    - **interaction** idiom: how to manipulate
- *algorithm*
  - efficient computation



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

Nested model: Four levels of visualization design

- *domain situation*
  - who are the target users?
- *abstraction*
  - translate from specifics of domain to vocabulary of visualization
    - **what** is shown? **data** abstraction
    - **why** is the user looking at it? **task** abstraction
      - often must transform data, guided by task
- *idiom*
  - **how** is it shown?
    - **visual encoding** idiom: how to draw
    - **interaction** idiom: how to manipulate
- *algorithm*
  - efficient computation



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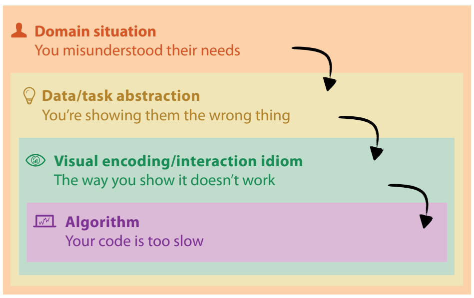
[A Multi-Level Typology of Abstract Visualization Tasks *Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).*]

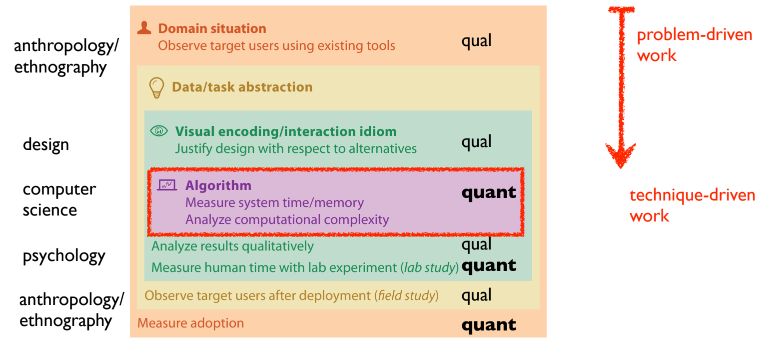
Different threats to validity at each level

- cascading effects downstream



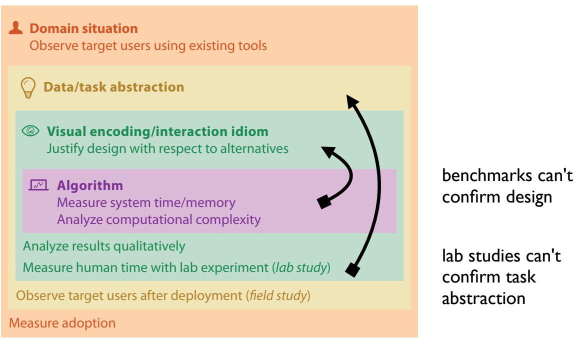
Interdisciplinary: need methods from different fields at each level

- mix of qual and quant approaches (typically)



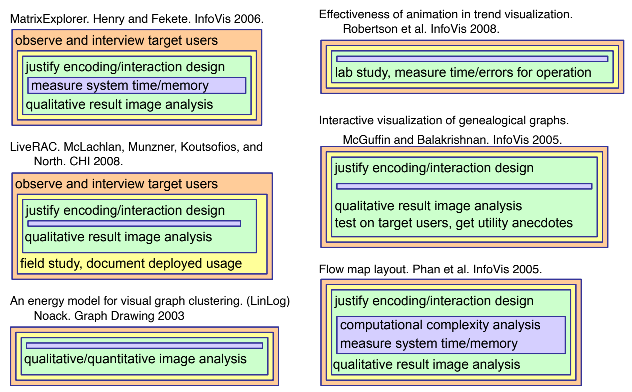
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Mismatches: Common problem



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

Analysis examples: Single paper includes only subset of methods



Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 4: Analysis: Four Levels for Validation*
- Storks Deliver Babies (p= 0.008). Robert Matthews. Teaching Statistics 22(2):36-38, 2000.
- The Earth is spherical (p < 0.05): alternative methods of statistical inference. Kim J. Vicente and Gerard L. Torenvliet. Theoretical Issues in Ergonomics Science, 1(3):248-271, 2000.
- The Prospects for Psychological Science in Human-Computer Interaction. Allen Newell and Stuart K. Card. Journal Human-Computer Interaction 1(3):209-242, 1985.
- How to do good research, get it published in SIGKDD and get it cited!, Eamonn Keogh, SIGKDD Tutorial 2009.
- False-Positive Psychology: Undisclosed Flexibility in Data Collection and Analysis Allows Presenting Anything as Significant. Joseph P. Simmons, Leif D. Nelson and Uri Simonsohn. Psychological Science 22(11):1359-1366, 2011.
- Externalisation - how writing changes thinking.. Alan Dix. Interfaces, Autumn 2008.

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/
- Interaction Design: Beyond Human-Computer Interaction
  - Preece, Sharp, Rogers. Wiley, 4th edition, 2015.
- About Face: The Essentials of Interaction Design
  - Cooper, Reimann, Cronin, Noessel. Wiley, 4th edition, 2014.
- Task-Centered User Interface Design. Lewis & Rieman, 1994
  - http://hcibib.org/tcuid/
- Designing with the Mind in Mind. Jeff Johnson. Morgan Kaufmann, 2nd, 2014.