Information Visualization
Data, Tasks, Nested Model
Ex: Abstractions

Tamara Munzner
Department of Computer Science
University of British Columbia

Week 2: 11 September 2025

http://www.cs.ubc.ca/~tmm/courses/547-25

Course Logistics

Slides

- always posted, timing depends on presence of exercise/lecture spoilers
  - often right after class
  - sometimes before class

Last week

- last week async work
  - 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

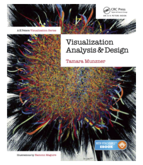
This week

- this week
  - async read & comment & respond
    - VAD Ch 2: Data Abstraction
    - VAD Ch 3: Task Abstraction
    - paper: Nested Model [basis for VAD Ch 4]
  - apologies for late Piazza posts, my mistake!
    - pushed back deadlines to Thu / today for comments, Fri / tomorrow for responses
- today
  - mini lecture: data
  - exercise round 1
  - mini lecture: nested model, paper types / reading, tasks
  - break
  - exercise 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
- normal deadlines
  - Tue noon round 1 comments
  - Thu noon round 2 responses

Mini-Lecture



Visualization Analysis & Design

Data Abstraction (Ch 2)

Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

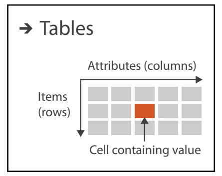
Data abstraction: Three operations

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

Dataset types

Tables: Items, Attributes

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



attributes: name, age, shirt size, fave fruit

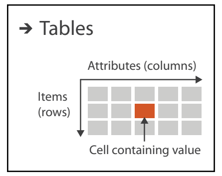
ID	Name	Age	Shirt Size	Favorite Fruit
1	Amy	8	S	Apple
2	Basil	7	S	Pear
3	Clara	9	M	Durian
4	Desmond	13	L	Elderberry
5	Ernest	12	L	Peach
6	Fanny	10	S	Lychee
7	George	9	M	Orange
8	Hector	8	L	Loquat
9	Ida	10	M	Pear
10	Amy	12	M	Orange

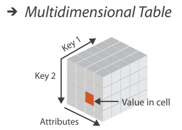
item: person

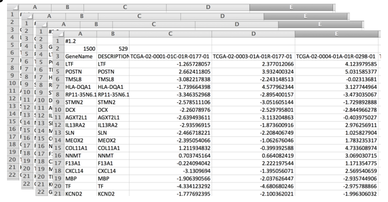
Dataset types

Tables: Items, Attributes

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



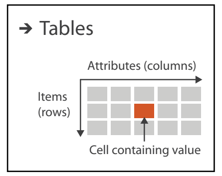


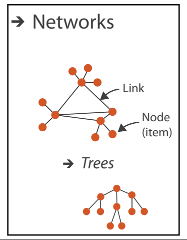


Dataset types

Tables: Items, Attributes

Networks & Trees: Items (nodes), Links, Attributes





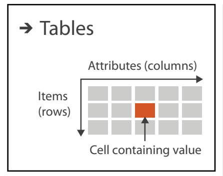
Dataset types

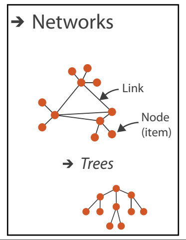
Tables: Items, Attributes

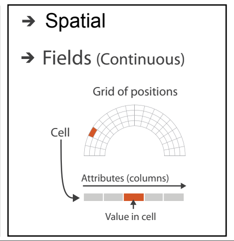
Networks & Trees: Items (nodes), Links, Attributes

Fields: Grids, Positions, Attributes

- 2D/geographic spatial data, maps & cartography
  - focus for this InfoVis course
- 3D volumetric & 2D/3D flow
  - focus in SciVis courses
  - just a small teaser today!

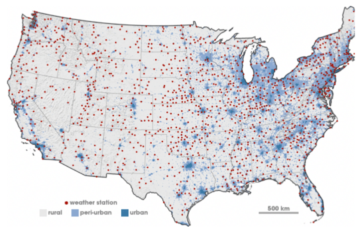


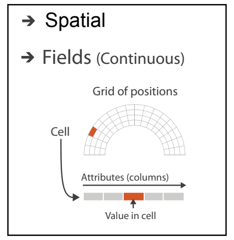




Spatial fields

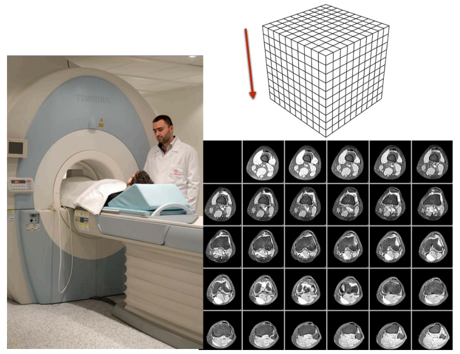
- attribute values associated w/ cells
- cell contains value from continuous domain
  - eg temperature, pressure, wind velocity
- measured or simulated





Spatial fields

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

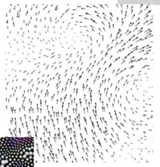


Spatial fields

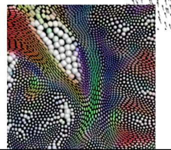
- attribute values associated w/ cells
- cell contains value from continuous domain
  - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
  - sampling: where attributes are measured
  - interpolation: how to model attributes elsewhere
  - grid types
- major divisions
 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

scalar

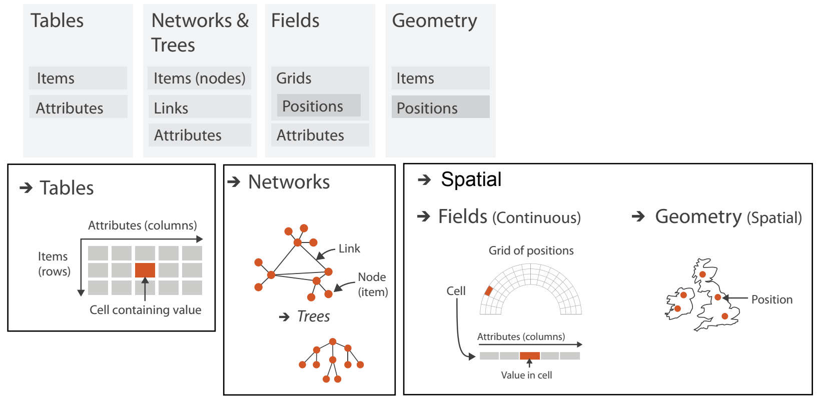
vector



tensor



Dataset types



Exercise: Data Abstraction

Exercise Part 1: Data Abstraction

- dataset: identify type & cardinality
- for each field: type, cardinality/range, note any surprises
  - range in actual dataset (vs docs, vs theoretical range)

DATA USER'S GUIDE

FIELD DESCRIPTIONS

Records in the AidData main table and research releases contain over 100 fields, but many of these are tailored for specialized project reports or research questions. For a complete list of fields and descriptions, please see the AidData User's Guide. Most users will find the most useful information in the following fields:

Donor name: Name of the donor country or multilateral organization. For more detailed information, use Implementing Agency and/or Financing Agency.

Recipient name: Name of the recipient country or region. In some cases, Private Recipient, Beneficiary or Borrower may contain relevant information.

Year: Commitment year. Other date fields may also contain useful values, but Year is always populated.

Commitment Amount: Amount the donor has agreed to provide for the duration of the project, often disbursed over the following years. Note that there are actually several commitment amount fields:

Nominal/Current: As reported by the donor, in the reported currency. Current (USD): As reported by the donor, converted to nominal USD at the average exchange rate in effect in the commitment year. Constant (USD): The reported amount converted to USD and adjusted for inflation and exchange rate changes. Constant amounts are all presented in USD2009 (i.e. at 2009 prices and exchange rates). See the AidData User's Guide for conversion and deflation methods.

Title, Short Description, Long Description: These fields contain descriptive information as provided by the donor. Long descriptions range from only a few sentences to several paragraphs in length.

Purpose Code: AidData has developed a granular system of sector coding, which expands the OECD's purpose code scheme. However, coding is still underway. AidData researchers have coded projects from non-CRS sources and work is underway to add these codes to CRS-sourced data as well, but new codes have not yet been released for CRS projects. Therefore, CRS purpose codes for CRS-sourced records and AidData activity codes for non-CRS records should be used complementarily. See the AidData User's Guide for a full description of AidData's codes and how to use them.

Data Abstraction Reportbacks

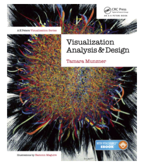
Data abstraction takeaways

- common attribute type confusions:
  - Year: quantitative vs ordinal, but never categorical
  - Purpose Code: definitely categorical, integer doesn't mean quant!
  - Purpose Name / Title / Description: categorical, not "string"
- takeaway: vis attribute types aren't just programming language data types
- discrepancies / surprises
  - cardinality of purpose codes (127) and descriptions (134 / 135) doesn't match
  - commitment amount of 15 cents with many significant digits, data quality issue?
  - range of 1991-2010 but no data for 1993 so cardinality is 18 not 19
  - many recipients set to "bilateral, unspecified" or other things that are not country/region
  - spelling / capitalization differences in categorical attributes
- takeaway: data dictionary is good starting point but always check reality, data may need cleaning/wrangling

Mini-Lecture

Visualization Analysis & Design

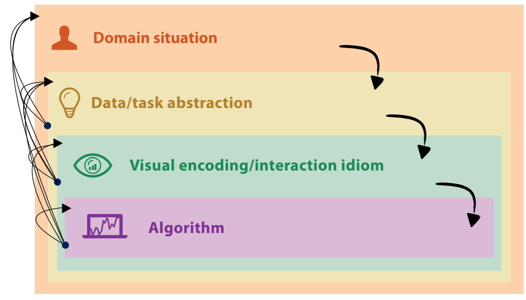
Analysis: Nested Model (Ch 4)



Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

Nested model: Iterative arrows not explicitly shown

- downstream: cascading effects
- upstream: iterative refinement

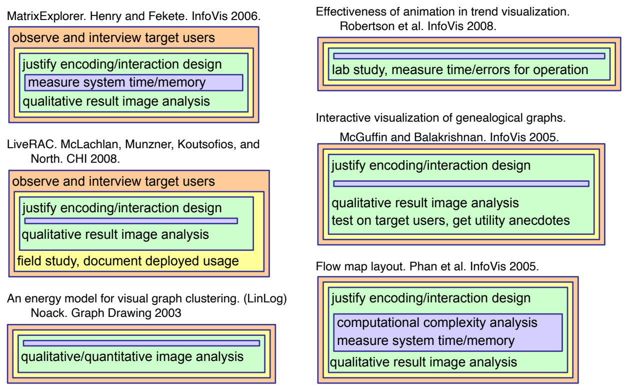


[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Reaction to problem: 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

Analysis examples: Single paper includes only subset of methods



Paper Types & Paper Reading

Paper types

- vis papers have many different structures
- paper types: each has different contributions, validation methods, structure
  - design studies
  - technique/algorithm
  - evaluation
  - model/taxonomy
  - system

  http://ieeevis.org/year/2017/info/call-participation/infovis-paper-types

- typical framing from 2004 - 2019
  - still common despite fine-grained contribution types from 2020 onwards

  https://ieeevis.org/year/2020/info/call-participation/paper-keywords

Paper types: Validation

- design studies
  - qualitative discussion of result images/videos
  - abstraction & idiom validation: case studies, field studies, design justification
- technique/algorithm
  - qualitative discussion of result images/videos
  - algorithm validation for algorithm papers: computational benchmarks
  - idiom validation for technique papers: controlled experiments
- evaluation
  - (controlled experiment as primary contribution)
- theory/model/taxonomy
  - *show power: descriptive, generative, evaluative, (~~predictive~~)*
- system
  - *show power for developer using system*

Paper structures

- typical research paper vs expectations for this course final report
  - more on implementation
  - novel research contribution not required

http://www.cs.ubc.ca/~tmm/courses/547-25/projectdesc.html#outlines

Reading visualization papers

- literature search
  - decide when to stop reading, according to your current concerns
- multi-pass strategy
  1. title
  2. abstract, authors/affiliation
  3. flip through, glance at figures, notice structure from section titles
  4. skim intro, results/discussion (maybe conclusion)
  5. fast read to get big ideas
     - if you don't get something, just keep going
  6. next pass to work through details
     - later parts may cast light on earlier parts
  7. deep read if necessary
     - if it's highly relevant to your needs
- *course readings: at least level 6*

Literature search for projects

- this course: I will give you some seed papers during our 1on1 meetings
- forwards vs backwards search
  - Google Scholar forward citations: a game changer!
  - only a subset of forwards & backwards citations will be what you need
- building up landscape
  - authors/affiliations will have more signal as you develop expertise

Usability

User testing vs validation

- Nested model paper defines validation broadly
  - human subjects studies AND computational benchmarks AND qualitative discussion of results
  - argues against considering usability testing as validation
  - validation as summative evaluation: does it work?
- but usability testing absolutely has value!
  - excellent for formative evaluation: how could it improve?

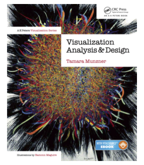
Guerilla/Discount Usability

- 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
- 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, 5th edition, 2019.
- 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.

Visualization Analysis & Design

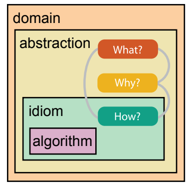


Task Abstraction (Ch 3)

Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

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

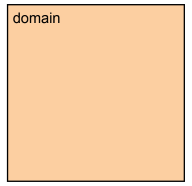


[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

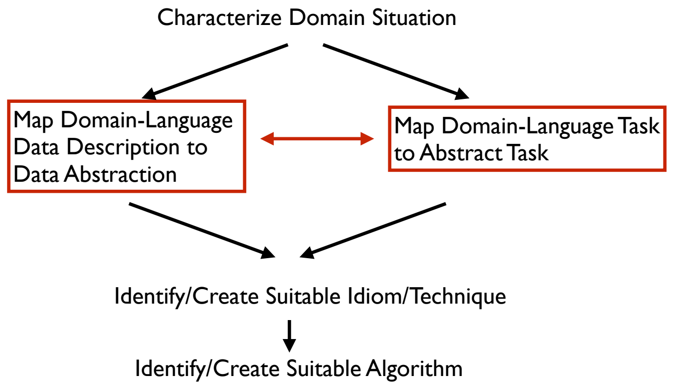
[A Multi-Level Typology of Abstract Visualization Tasks Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]

Domain characterization

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



Design process: Design studies

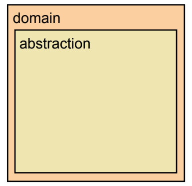


Example: Find good movies

- identify good movies in genres I like
- domain:
  - general population, movie enthusiasts

Abstraction: Data & task

- map *what* and *why* into generalized terms
  - identify tasks that users wish to perform, or already do
  - find data types that will support those tasks
    - possibly transform /derive if need be



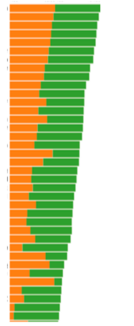
Example: Find good movies

- identify good movies in genres I like
- domain:
  - general population, movie enthusiasts
- task: what is a good movie for me?
  - highly rated by critics?
  - highly rated by audiences?
  - successful at the box office?
  - similar to movies I liked?
  - matches specific genres?
- data: (is it available?)
  - yes! data sources IMDB, Rotten Tomatoes...

Example: Find good movies

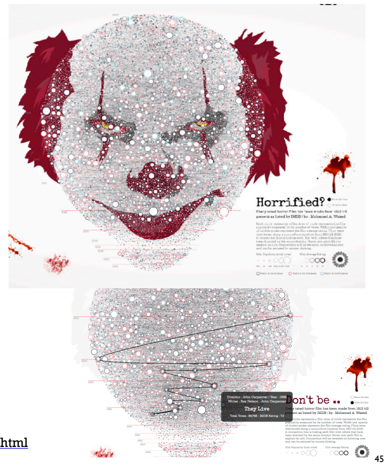
- one possible choice for data and tasks, in domain language
  - data: combine audience ratings and critic ratings
  - task: find high-scoring movies for specific genre
- abstractions?
  - attribute: audience & critic ratings
    - ordinal
      - levels: 3 or 5 or 10...
  - attribute: genre
    - categorical
      - levels: < 20
  - items: movies
    - items: millions
  - task: find extreme (high) values

one possible idiom
- stacked bar chart for ratings



Example: Horrified

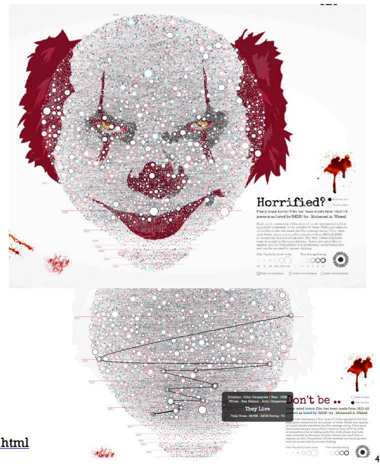
- same task: high-score movies
- slightly different data
  - 14K rated horror movies from IMDB



https://www.alhadaqa.com/wp-content/uploads/2020/04/horrified.html

Example: Horrified

- same task: high-score movies
- slightly different data
  - 14K rated horror movies from IMDB
- very different visual encoding idiom
  - circle per item (movie)
  - circle area = popularity
  - stroke width/opacity = avg rating
  - year made = vertical position
- interaction idiom
  - lines connect movies w/ same director, on mouseover



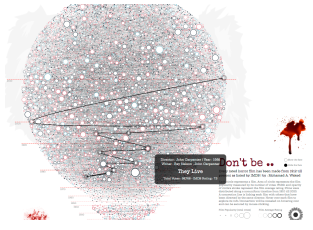
https://www.alhadaqa.com/wp-content/uploads/2020/04/horrified.html

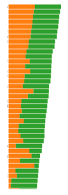
Task abstraction: Actions and targets

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

Example: Horrified vs stacked bars

- horrified: browse/explore
- stacked bars: locate/lookup
- which is better?
  - depends on goals / task
    - enjoy, social context, lots of time
    - find 2nd-best rated movie of all time
      - Jeopardy call, < 10 seconds to respond!

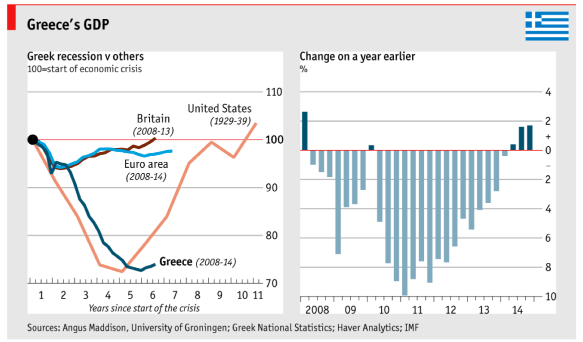




http://alhadaqa.com/2019/10/horrified/

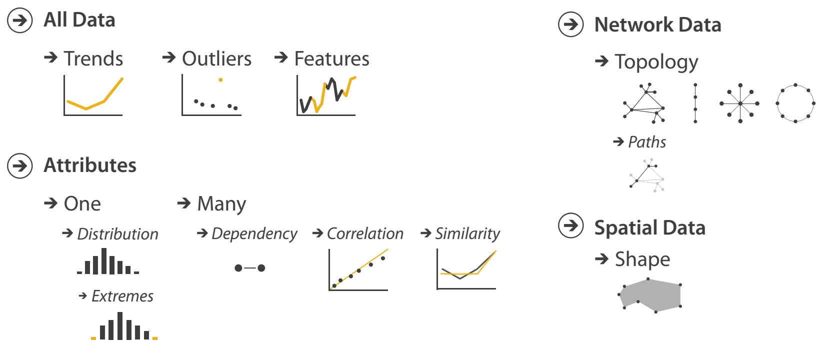
Example: Economics

- task: compare and derive
- data: derive change



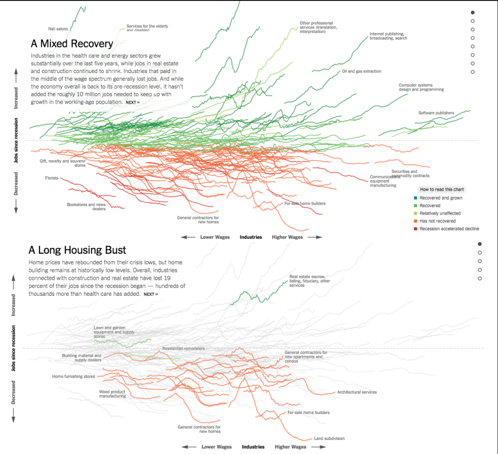
The Economist

Task abstraction: Targets

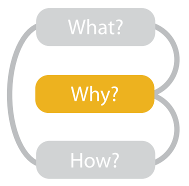


Examples: Job market

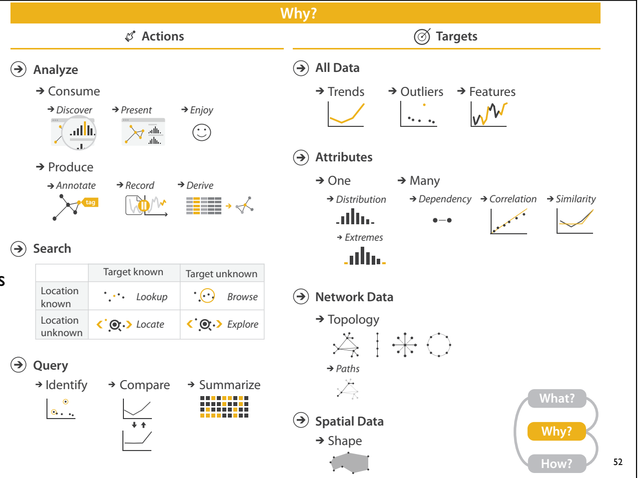
- trends
  - how did job market develop since recession overall?
- outliers
  - real estate related jobs



https://www.nytimes.com/interactive/2014/06/05/upshot/how-the-recession-reshaped-the-economy-in-255-charts.html



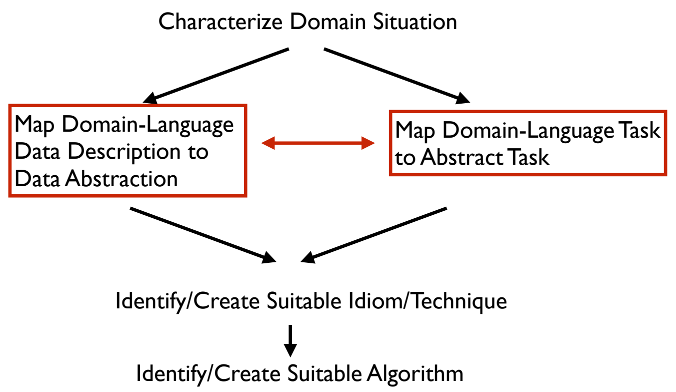
- {action, target} pairs
  - *discover distribution*
  - *compare trends*
  - *locate outliers*
  - *browse topology*



Abstraction

- these {action, target} pairs are good starting point for vocabulary
  - but **often** you'll need more precision!
  - use as springboard for thinking, not comprehensive list
- not covered in book chapter:
  need to connect task to data ***through pointers to specific attributes***
  - diagram shows only task categories, with first (most abstract) part of target
  - "find extreme value" is a category of task, but not enough to just say that
    - extreme value ***of what attribute***?

Design Process: Design studies



Abstraction process: multi-pass approach

1. write down the task, in the most natural ("domain") language
2. find the actions (verbs) and targets (nouns + items/attributes)
3. create data abstraction for each target item/attribute
   - then it's legitimate to use in the abstracted version of the task
   - might need to recursively define other words along the way, or derive data
   - include cardinality/range for attributes in the abstraction
4. create task abstraction for each action/target pair: consider how to translate action into more generic ("abstract") words
   - either from the set of verbs from Tasks chapter, or come up with new ones
5. iterate as needed: consider what other words/ideas could be abstracted
   - you might also derive some data at this stage

Exercise: Data/Task Abstraction

Break: 3:45-3:55

Exercise Part 2: Task/data abstraction in genomics

You have been approached by a geneticist to help with a visualization problem. She has gene expression data (data that measures the activity of the genes) for 500 genes across 30 cancer tissue samples. She is applying an experimental drug to see whether the cancer tissue dies as she hopes, but she finds that only some samples show the desired effect. She believes that the difference between the samples is caused by differential expression (different activity levels) of genes in a particular pathway (series of genes directly connected step by step through linked activity) within an interaction network of genes (all known linkages between genes based on previous research). She would like to understand which genes are likely to cause the difference, and what role they play in that pathway.

Exercise: Part 2 Walkthrough

Genomics example, steps 1-3

1. Within selected pathway, consider differential gene expression between cancer tissue samples that died and those that did not, & find role of those genes in the pathway.
2. Within selected **pathway**, **consider** differential **gene expression between cancer tissue samples** that **died** and those that **lived,** & **find role** of those **genes** in **pathway**
3. abstract the targets
   - **pathway**
     - subgraph of **gene network**
       - **gene network**: nodes are **genes**, links are known **interactions** between genes
         - » **gene**: 500 items
         - » interactions: ?? items
   - **gene expression [expression]**
     - expression: attribute attached to **gene**: quantitative, ?? range
   - **cancer tissue samples [samples], died/lived**
     - **samples**: table of 30 items
     - **survival**: attribute attached to sample: categorical (binary), yes/no

Genomics example, steps 4-6

4. abstract the actions
   - **consider ... between: compare**
   - **find role... in pathway: explore topology (of pathway)**
5. Within selected **pathway**, **compare** differential **expression** of **samples** according to **survival,** & **explore pathway topology around** those **genes**
6. consider what other ideas/words need abstracting
   - **differential** expression of samples: connecting up **samples** & **genes**
     - for each sample, we have expression data for each of 500 genes
     - multidimensional table: {sample, gene} as categorical keys, expression as quant values
   - **those** genes: derive group of genes (DiffGroup)
     - find genes where expression levels are different between samples with survival = true vs survival = false, for genes on selected pathway, and put them into a group
     - for each gene in DiffGroup, explore topological neighbourhood in pathway

Backup/Reference Slides

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

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.

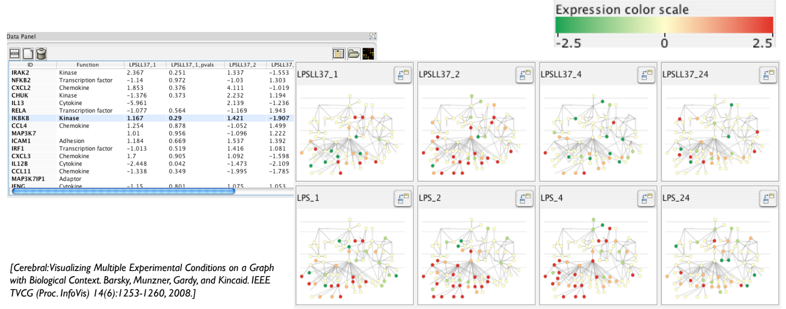
Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

- 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

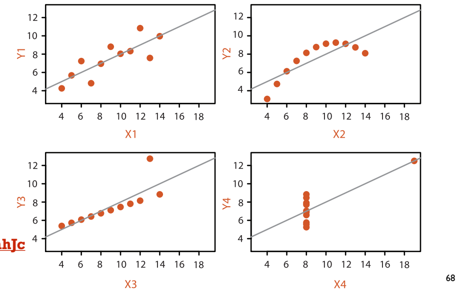
Why represent all the data?

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

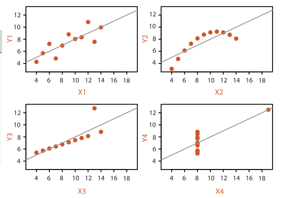
Visualization defined & motivated

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

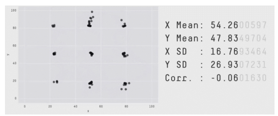
- suitable when human in the loop needs details
  - interplay between human judgement and automatic computation

Anscombe's Quartet

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



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?

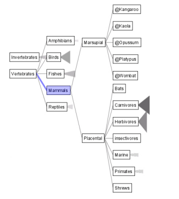
Vis designers must take into account three very different kinds of resource limitations: those of computers, of humans, and of displays.

- 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?

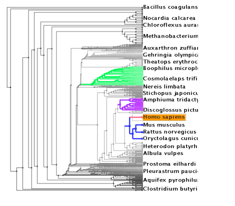
- imposes structure on huge design space
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new
  - most possibilities ineffective for particular task/data combination

SpaceTree

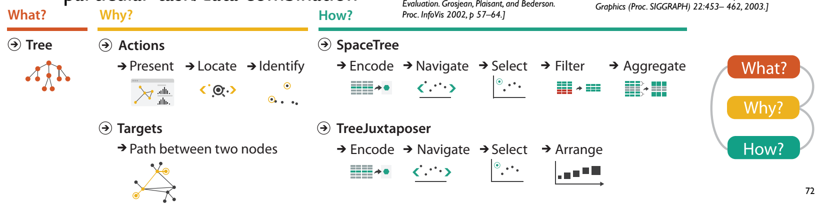


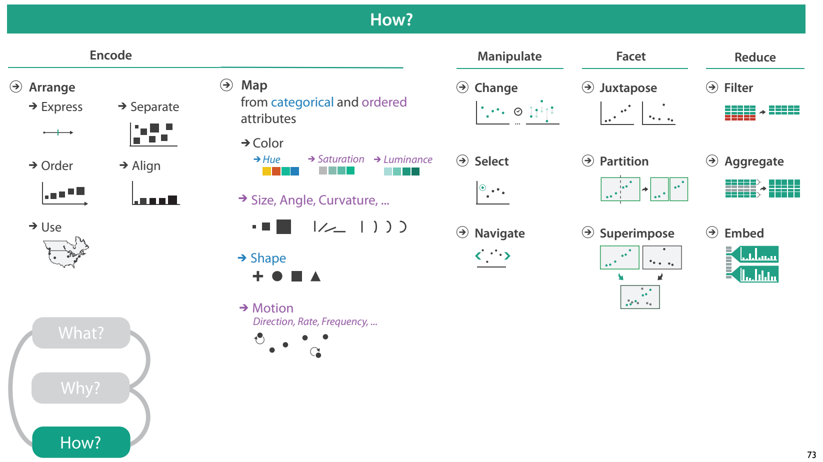
[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

TreeJuxtaposer



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

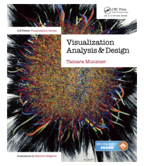




Further reading

- 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.

Visualization Analysis & Design



Data Abstraction (Ch 2)

Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

What does data mean?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

Basil, 7, S, Pear

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

Basil, 7, S, Pear

- What about this data?

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

Basil, 7, S, Pear

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

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

Basil, 7, S, Pear

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

What does data mean?

14, 2.6, 30, 30, 15, 100001

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

Basil, 7, S, Pear

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

Now what?

- semantics: real-world meaning

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

Now what?

- semantics: real-world meaning

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

Now what?

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

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

Items & Attributes

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

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

Items & Attributes

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

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

item: person

Items & Attributes

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

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

item: person

Items & Attributes

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

attributes: name, age, shirt size, fave fruit

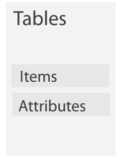
Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

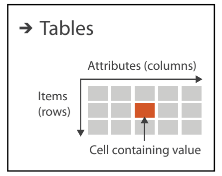
Other data types

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

Dataset types



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

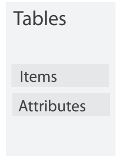


attributes: name, age, shirt size, fave fruit

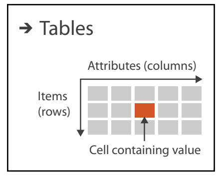
Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

Dataset types



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



attributes: name, age, shirt size, fave fruit

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

item: person

Table

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Table

item

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Table

item

attribute

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Table

item

cell

attribute

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

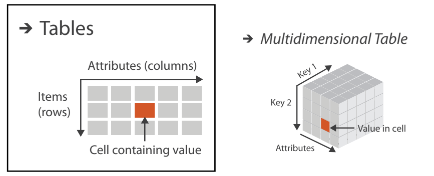
Dataset types

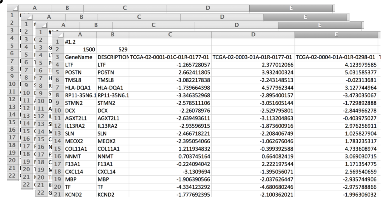
Tables

Items

Attributes

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



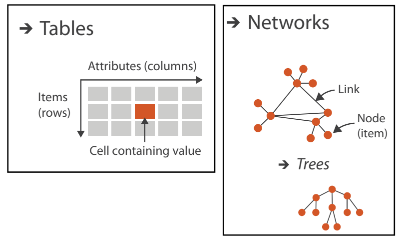


Dataset types

Tables: Items, Attributes

Networks & Trees: Items (nodes), Links, Attributes

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

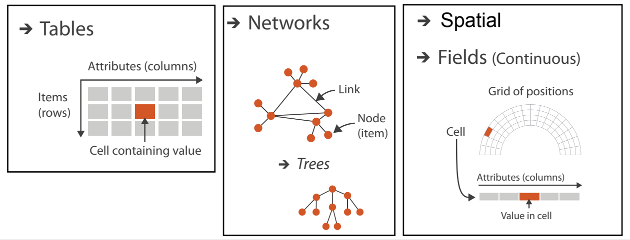


Dataset types

Tables: Items, Attributes

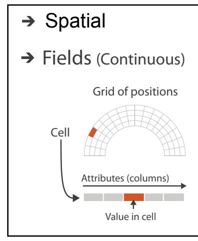
Networks & Trees: Items (nodes), Links, Attributes

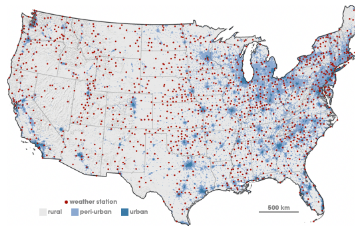
Fields: Grids, Positions, Attributes



Spatial fields

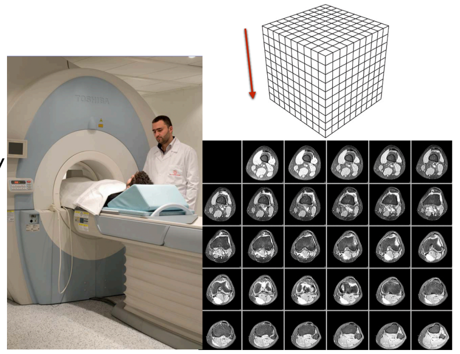
- attribute values associated w/ cells
- cell contains value from continuous domain
  - eg temperature, pressure, wind velocity
- measured or simulated





Spatial fields

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

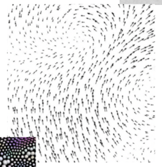


Spatial fields

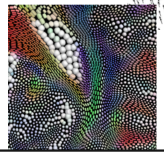
- attribute values associated w/ cells
- cell contains value from continuous domain
  - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
  - sampling: where attributes are measured
  - interpolation: how to model attributes elsewhere
  - grid types
- major divisions
 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

scalar

vector



tensor



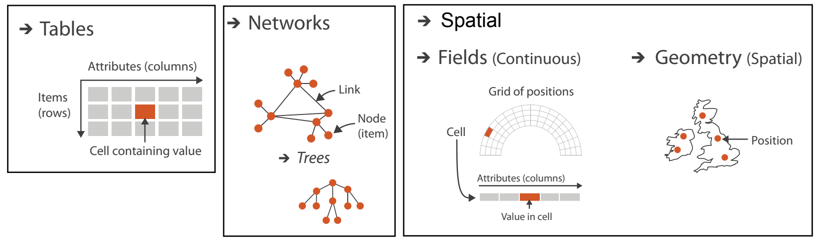
Dataset types

Tables: Items, Attributes

Networks & Trees: Items (nodes), Links, Attributes

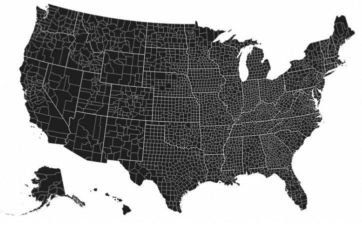
Fields: Grids, Positions, Attributes

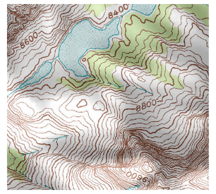
Geometry: Items, Positions



Geometry

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





Dataset types

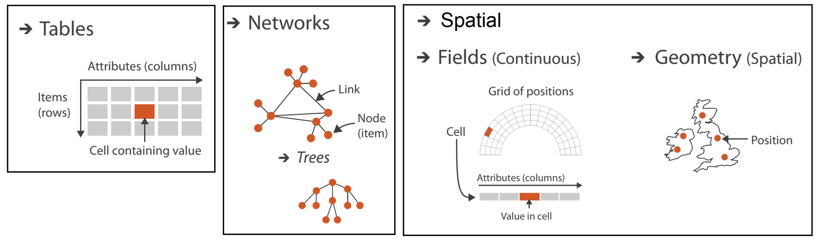
Tables: Items, Attributes

Networks & Trees: Items (nodes), Links, Attributes

Fields: Grids, Positions, Attributes

Geometry: Items, Positions

Clusters, Sets, Lists: Items

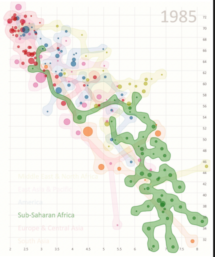


Collections

- how we group items

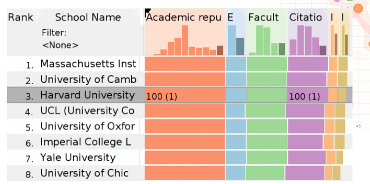
Collections

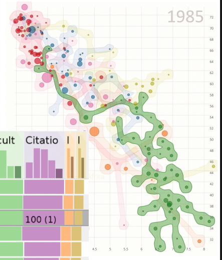
- how we group items
- sets
  - unique items, unordered



Collections

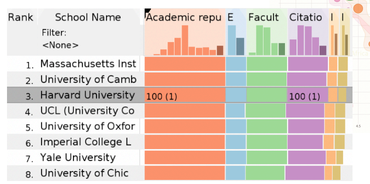
- how we group items
- sets
  - unique items, unordered
- lists
  - ordered, duplicates possible

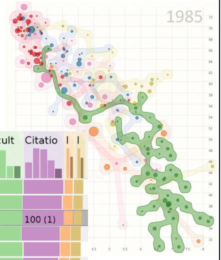


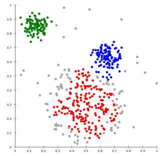


Collections

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







Dataset and data types

Data and Dataset Types

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

Data Types

→ Items → Attributes → Links → Positions → Grids

Attribute types

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

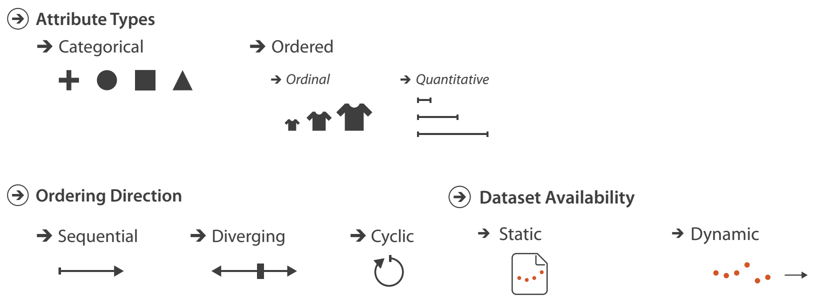
Table

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

categorical
ordinal
quantitative

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06

Other data concerns



Data abstraction: Three operations

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

Data vs conceptual models

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

Data vs conceptual model, example

Data vs conceptual model, example

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

Data vs conceptual model, example

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

Data vs conceptual model, example

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

Data vs conceptual model, example

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

Data vs conceptual model, example

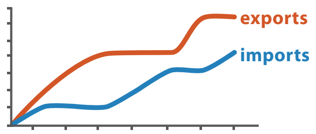
- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions
  - continuous to 2 significant figures: quantitative
    - task: forecasting the weather
  - hot, warm, cold: ordinal
    - task: deciding if bath water is ready

Data vs conceptual model, example

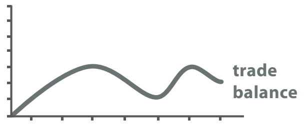
- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions
  - continuous to 2 significant figures: quantitative
    - task: forecasting the weather
  - hot, warm, cold: ordinal
    - task: deciding if bath water is ready
  - above freezing,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

Derived attributes

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



Original Data



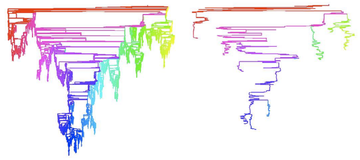
trade balance = exports − imports

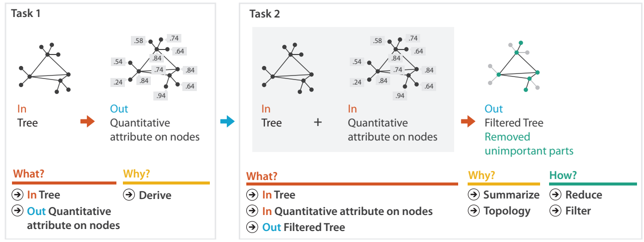
Derived Data

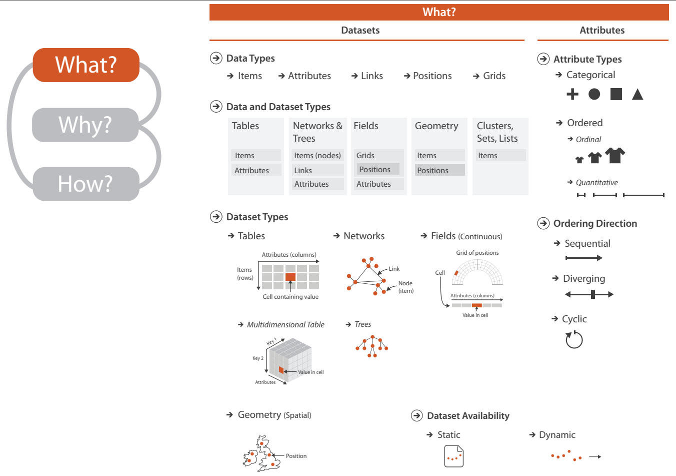
Analysis example: Derive one attribute

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

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





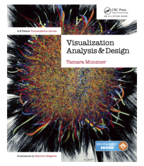


Further reading, full Ch 2

- 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.

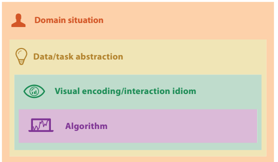
Visualization Analysis & Design

Task Abstraction (Ch 3)



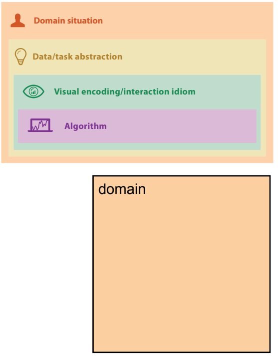
Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

From domain to abstraction



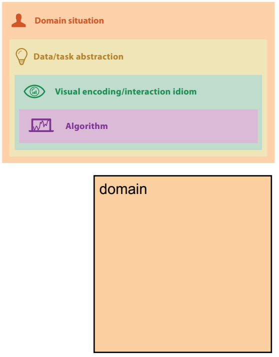
From domain to abstraction

- domain characterization:
  details of application domain



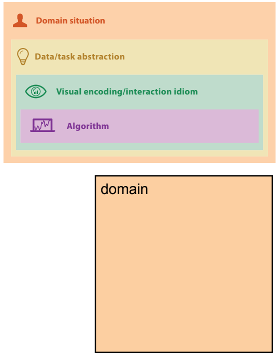
From domain to abstraction

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



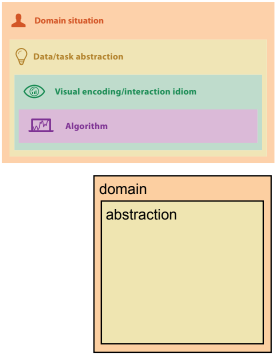
From domain to abstraction

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



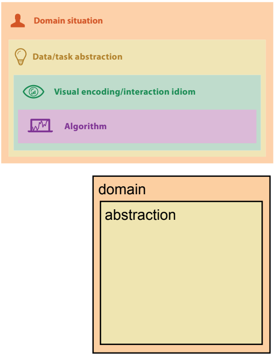
From domain to abstraction

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

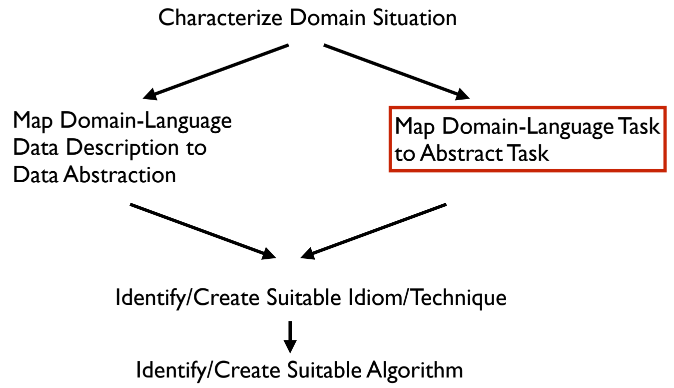


From domain to abstraction

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



Design process



Task abstraction: Actions and targets

- very high-level pattern

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

Task abstraction: Actions and targets

- very high-level pattern
- actions
  - analyze
    - high-level choices
  - search
    - find a known/unknown item
  - query
    - find out about characteristics of item

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

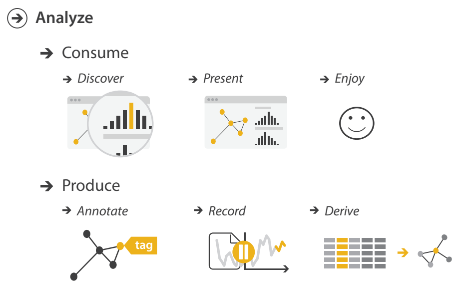
Task abstraction: Actions and targets

- very high-level pattern
- actions
  - analyze
    - high-level choices
  - search
    - find a known/unknown item
  - query
    - find out about characteristics of item
- targets
  - what is being acted on

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

Actions: Analyze

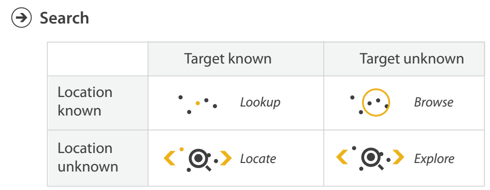
- consume
  - discover vs present
    - classic split
    - aka explore vs explain
  - enjoy
    - newcomer
    - aka casual, social
- produce
  - annotate, record
  - derive
    - crucial design choice



Actions: Search

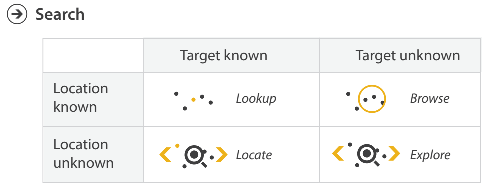
Actions: Search

- what does user know?
  - target, location



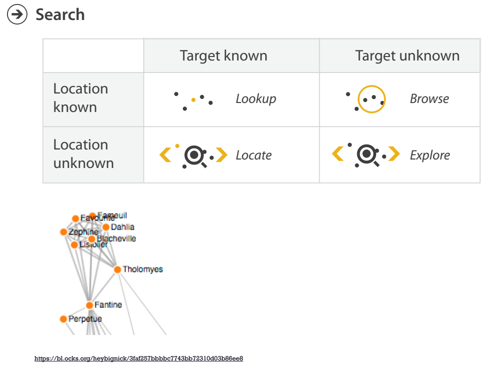
Actions: Search

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



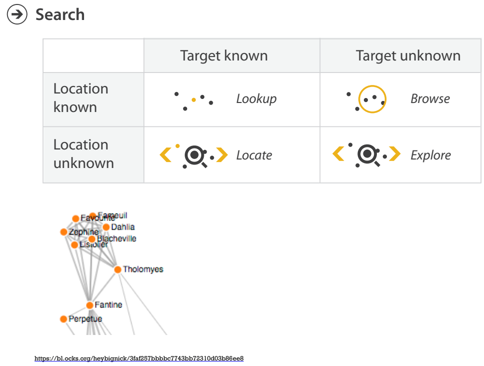
Actions: Search

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



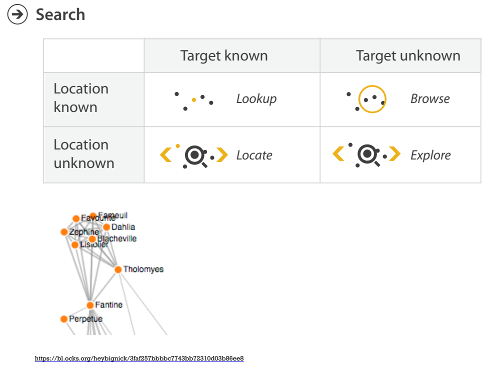
Actions: Search

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



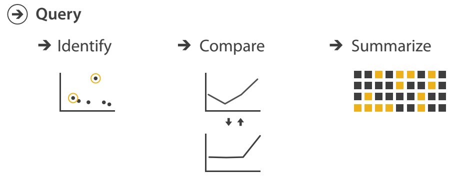
Actions: Search

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



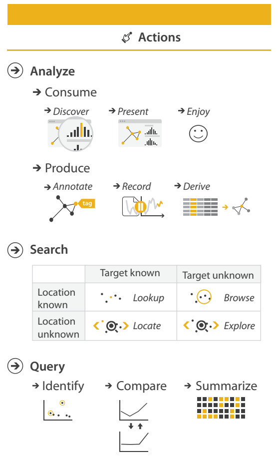
Actions: Query

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



Actions

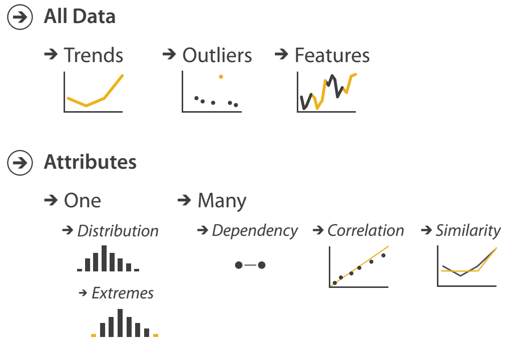
- independent choices for each of these three levels
  - analyze, search, query
  - mix and match



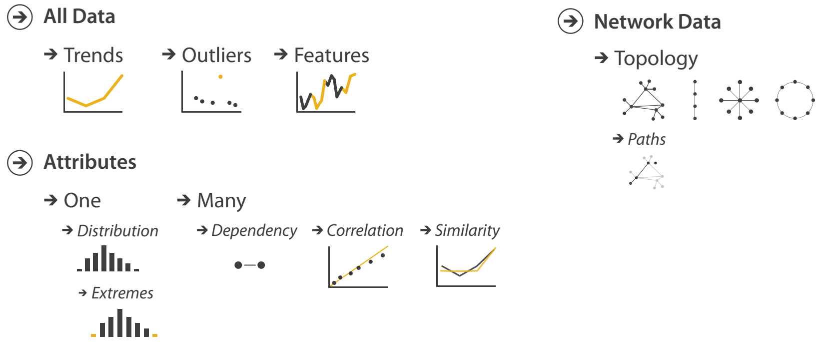
Task abstraction: Targets

Task abstraction: Targets

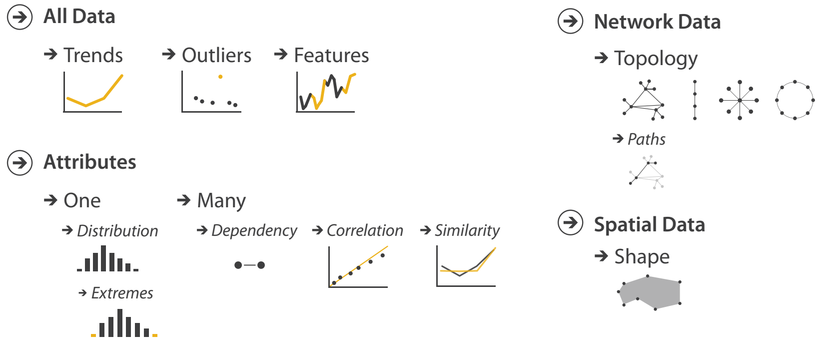
Task abstraction: Targets



Task abstraction: Targets



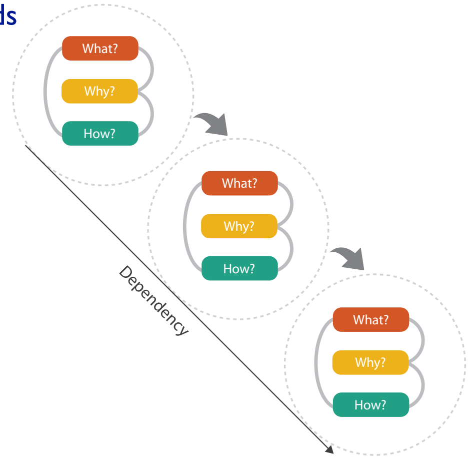
Task abstraction: Targets

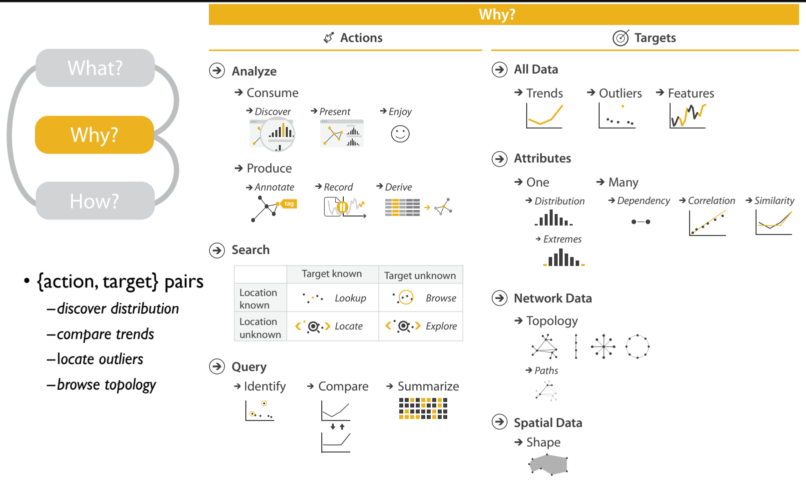


Abstraction

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

Means and ends





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

Further reading

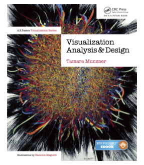
- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 2: What: Data Abstraction*
  - *Chap 3: Why: Task Abstraction*
- *A Multi-Level Typology of Abstract Visualization Tasks.* Brehmer and Munzner. IEEE Trans. Visualization and Computer Graphics (Proc. 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.

Further reading, full Ch 3

- A Multi-Level Typology of Abstract Visualization Tasks.. Matthew Brehmer and Tamara Munzner. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 13) 19:12 (2013), 2376-2385.
- 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.

Visualization Analysis & Design

Analysis: Nested Model (Ch 4)



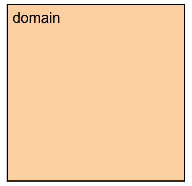
Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

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

Analysis framework: Four levels, three questions

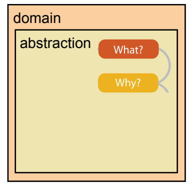
- *domain situation*
  - who are the target users?



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

Analysis framework: Four levels, three questions

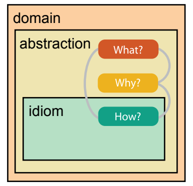
- *domain situation*
  - who are the target users?
- *abstraction*
  - translate from specifics of domain to vocabulary of vis
    - **what** is shown? **data** abstraction
    - **why** is the user looking at it? **task** abstraction



[A Multi-Level Typology of Abstract Visualization Tasks. Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Analysis framework: Four levels, three questions

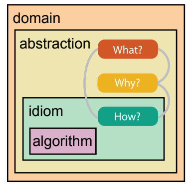
- *domain situation*
  - who are the target users?
- *abstraction*
  - translate from specifics of domain to vocabulary of vis
    - **what** is shown? **data** abstraction
    - **why** is the user looking at it? **task** abstraction
- *idiom*
  - **how** is it shown?
    - **visual encoding** idiom: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



[A Multi-Level Typology of Abstract Visualization Tasks. Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Analysis framework: Four levels, three questions

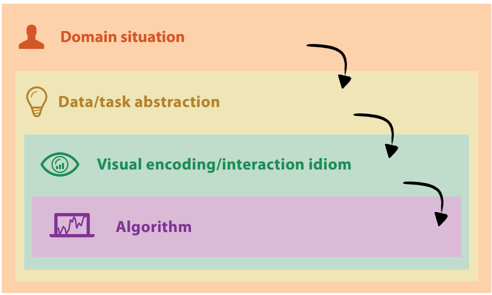
- *domain situation*
  - who are the target users?
- *abstraction*
  - translate from specifics of domain to vocabulary of vis
    - **what** is shown? **data** abstraction
    - **why** is the user looking at it? **task** abstraction
- *idiom*
  - **how** is it shown?
    - **visual encoding** idiom: 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).]
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Nested model

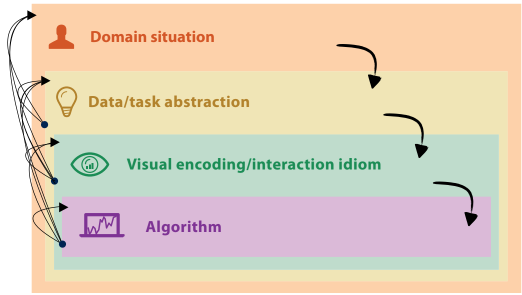
- downstream: cascading effects



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

Nested model

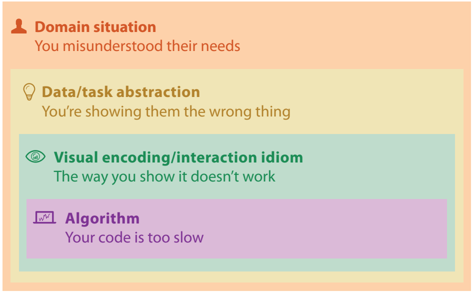
- downstream: cascading effects
- upstream: iterative refinement



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

Why is validation difficult?

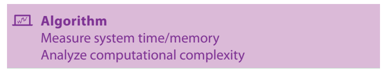
- different ways to get it wrong at each level



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

Why is validation difficult?

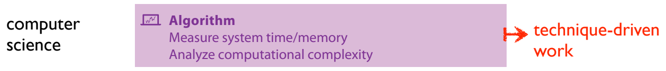
- solution: use methods from different fields at each level



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

Why is validation difficult?

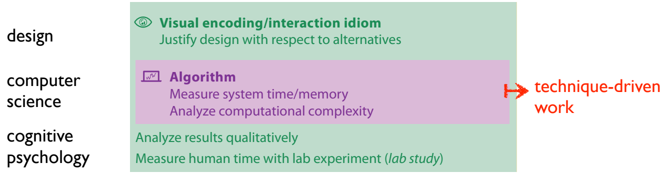
- solution: use methods from different fields at each level



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

Why is validation difficult?

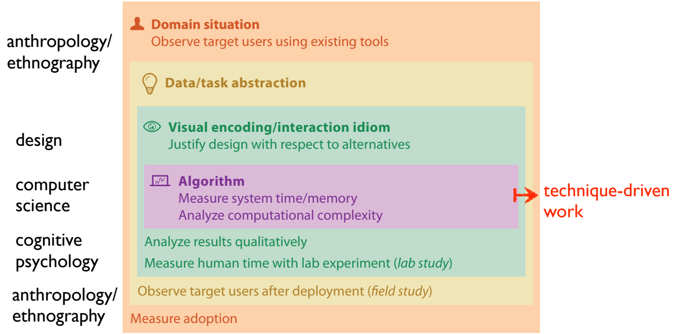
- solution: use methods from different fields at each level



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

Why is validation difficult?

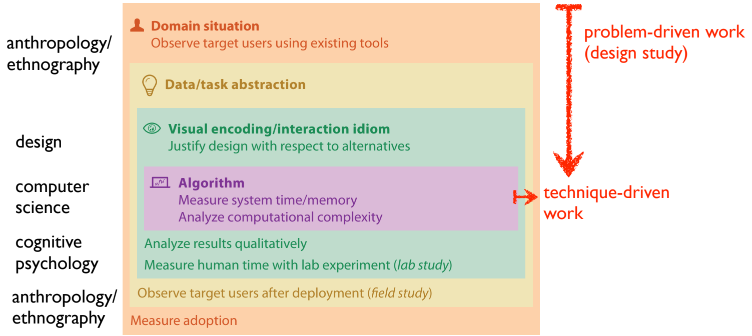
- solution: use methods from different fields at each level



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

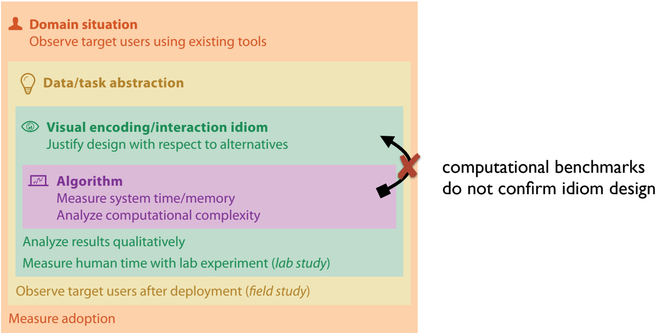
Why is validation difficult?

- solution: use methods from different fields at each level



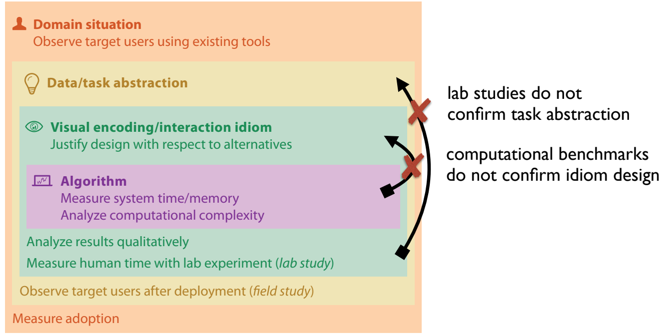
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Avoid mismatches



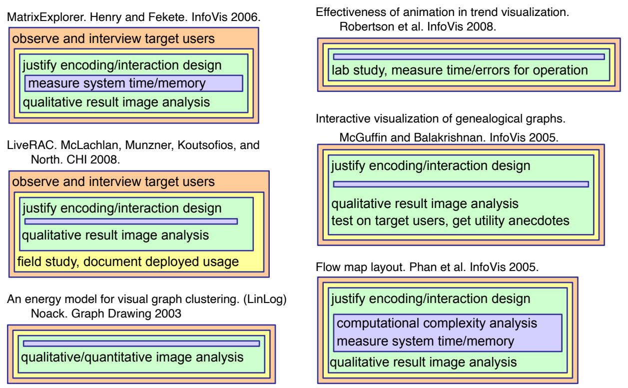
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Avoid mismatches



[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.

Usability

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.