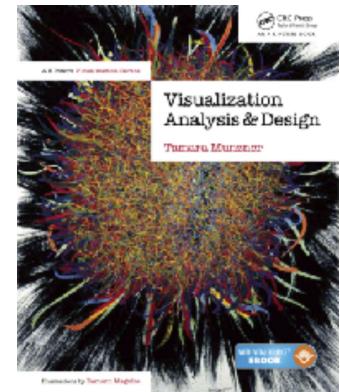


Visualization Analysis & Design



Analysis: Nested Model (Ch 4)

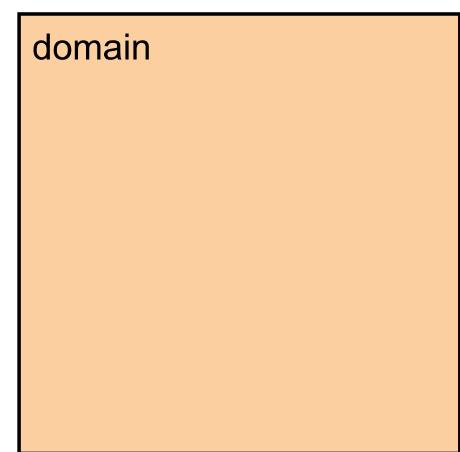
Tamara Munzner

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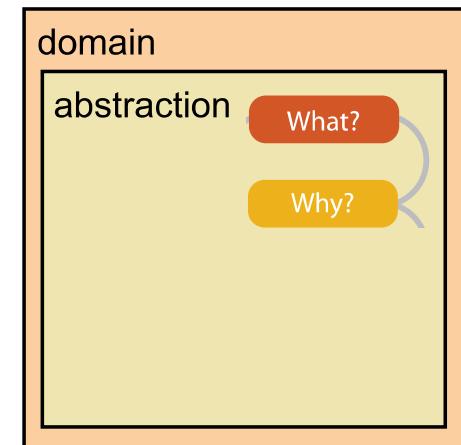
Analysis framework: Four levels, three questions

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



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

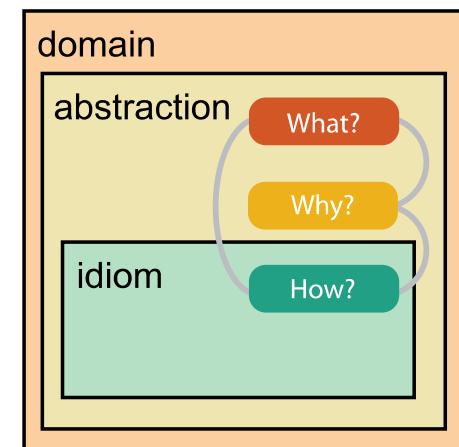


[A Multi-Level Typology of Abstract Visualization Tasks. Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]

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- *idiom*
 - **how** is it shown?
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 - **interaction** idiom: how to manipulate

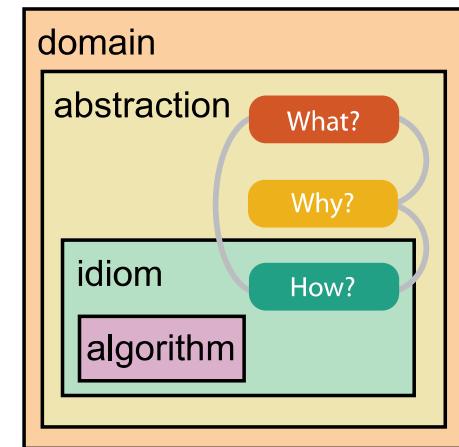


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- *algorithm*
 - efficient computation

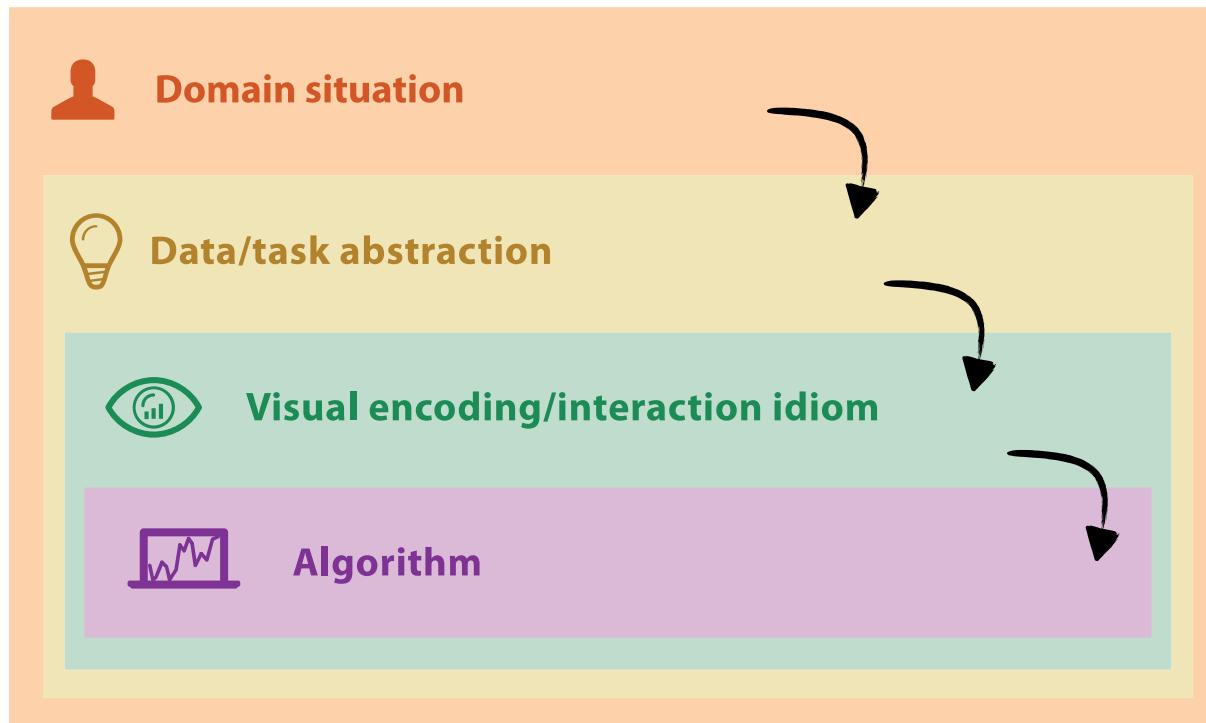


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Nested model

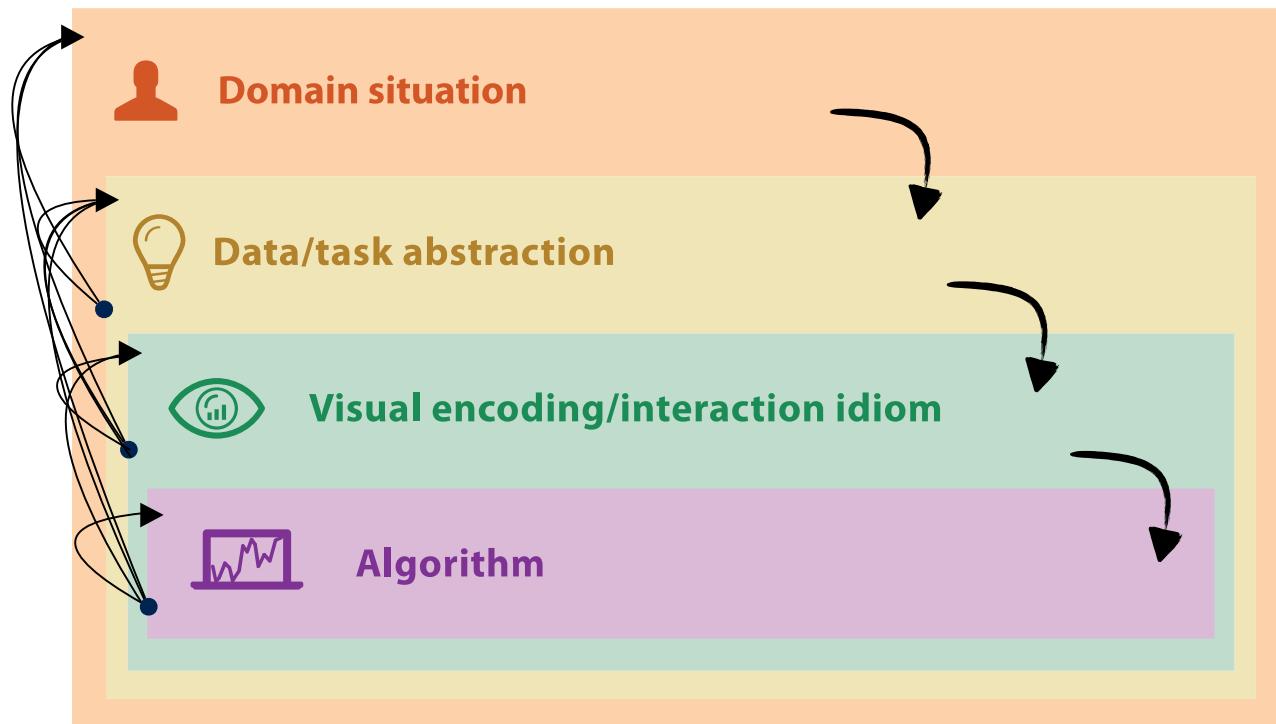
- downstream: cascading effects



[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

Domain situation

You misunderstood their needs

Data/task abstraction

You're showing them the wrong thing

Visual encoding/interaction idiom

The way you show it doesn't work

Algorithm

Your code is too slow

Why is validation difficult?

- solution: use methods from different fields at each level



Algorithm

Measure system time/memory

Analyze computational complexity

Why is validation difficult?

- solution: use methods from different fields at each level

computer
science



Algorithm

Measure system time/memory
Analyze computational complexity



technique-driven
work

Why is validation difficult?

- solution: use methods from different fields at each level

design

eye icon **Visual encoding/interaction idiom**
Justify design with respect to alternatives

computer
science

calculator icon **Algorithm**
Measure system time/memory
Analyze computational complexity

cognitive
psychology

analyze icon Analyze results qualitatively
Measure human time with lab experiment (*lab study*)

red arrow pointing right **technique-driven work**

Why is validation difficult?

- solution: use methods from different fields at each level

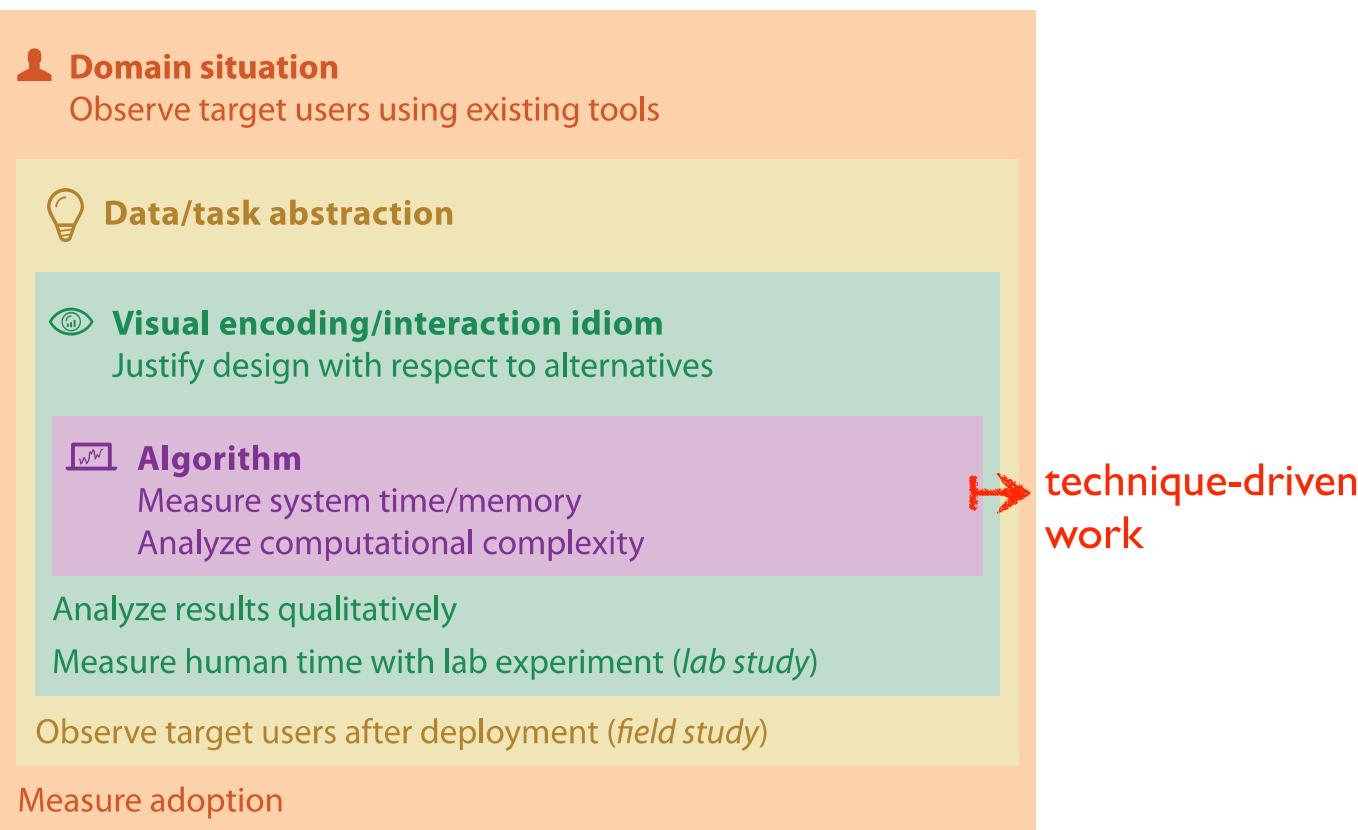
anthropology/
ethnography

design

computer
science

cognitive
psychology

anthropology/
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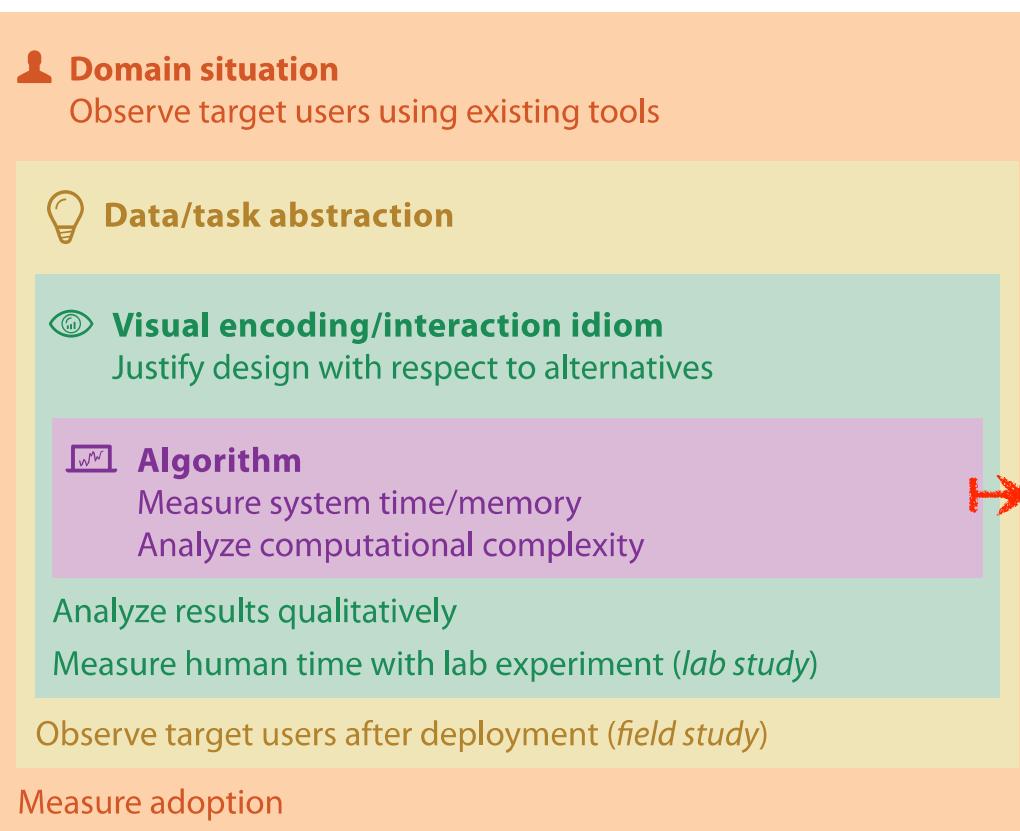
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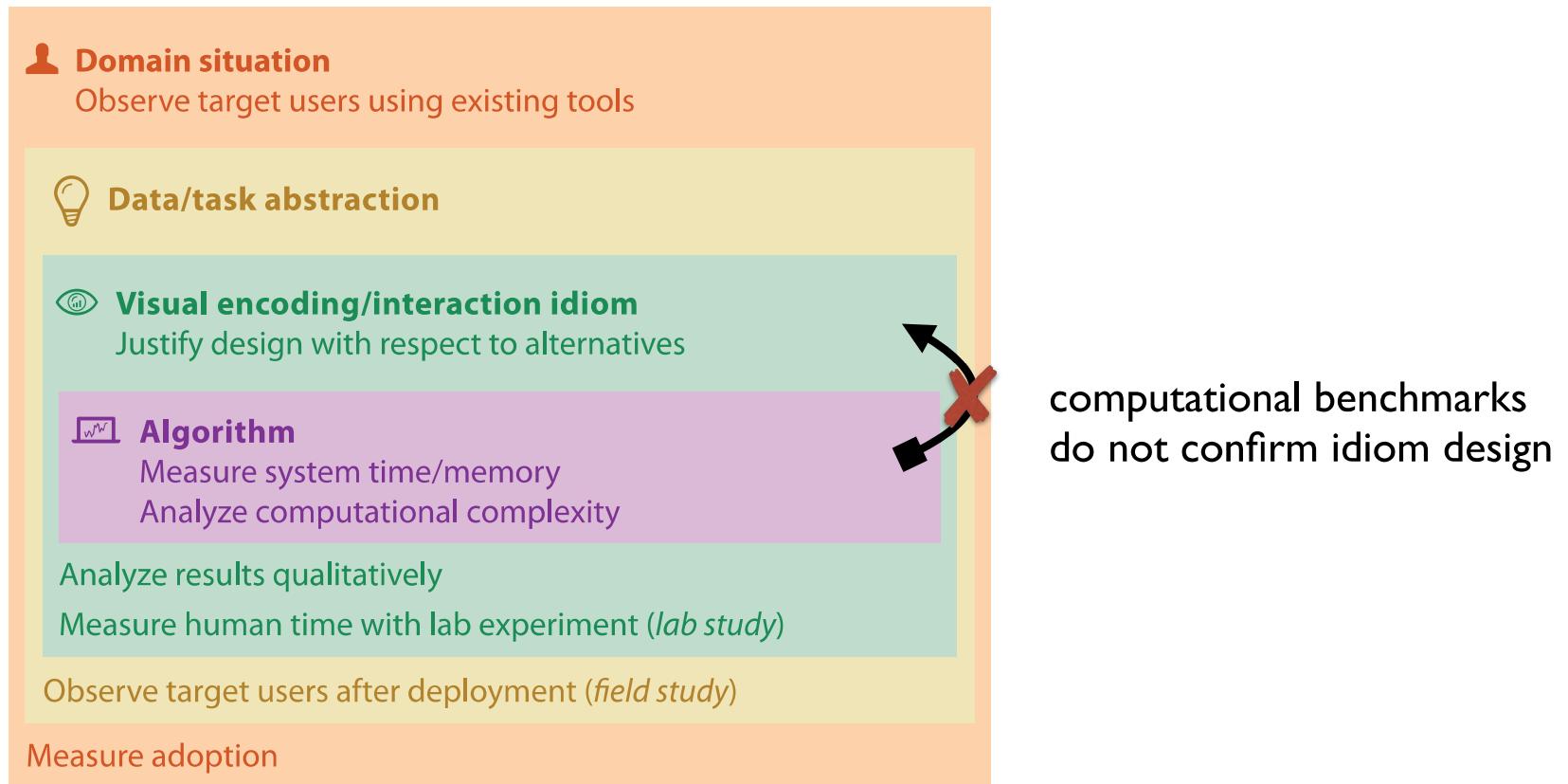
anthropology/
ethnography



problem-driven work
(design study)

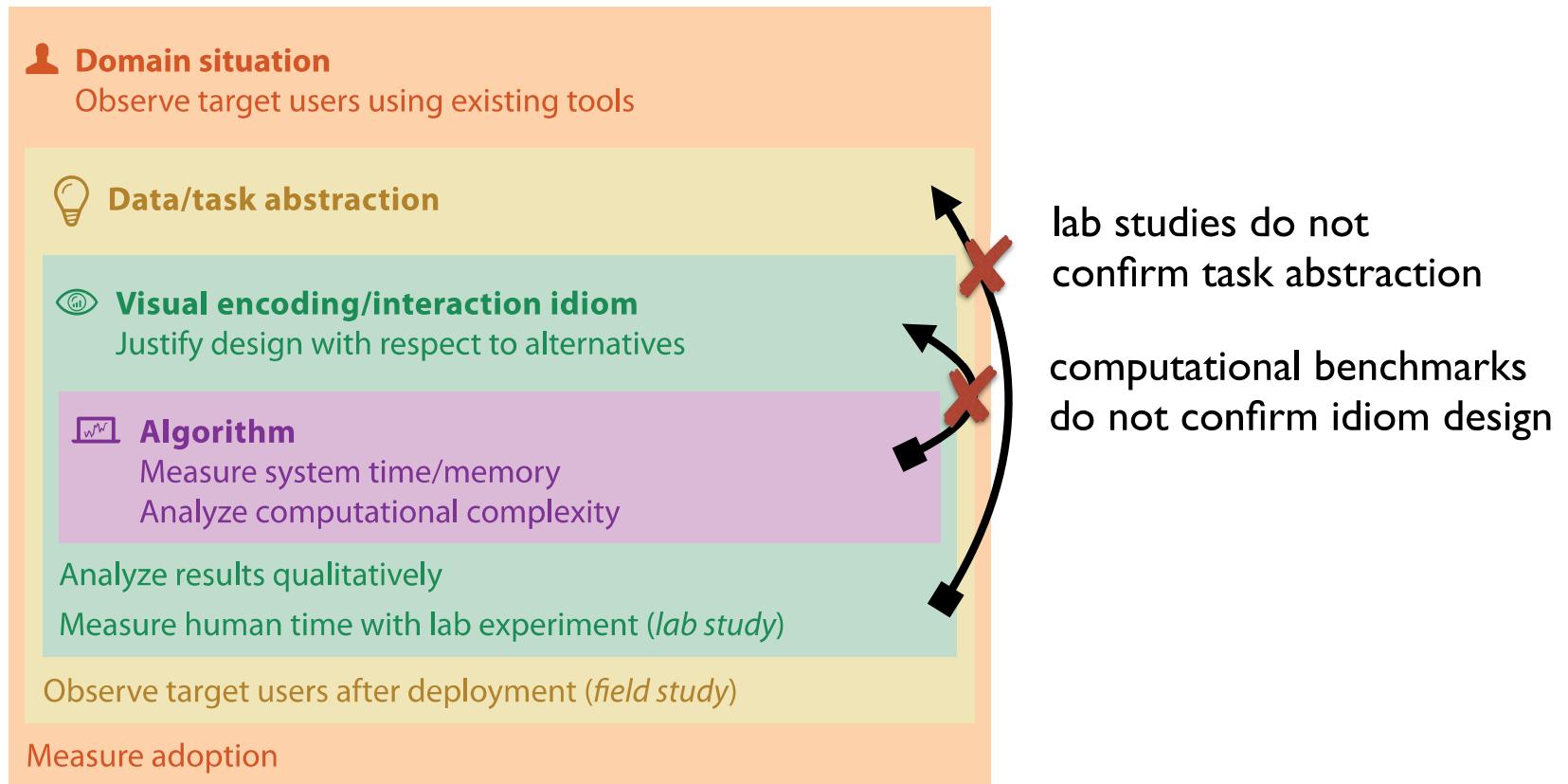
technique-driven
work

Avoid mismatches



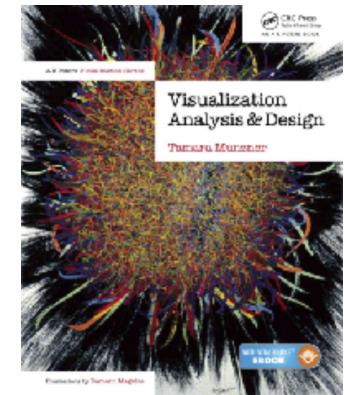
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Visualization Analysis & Design



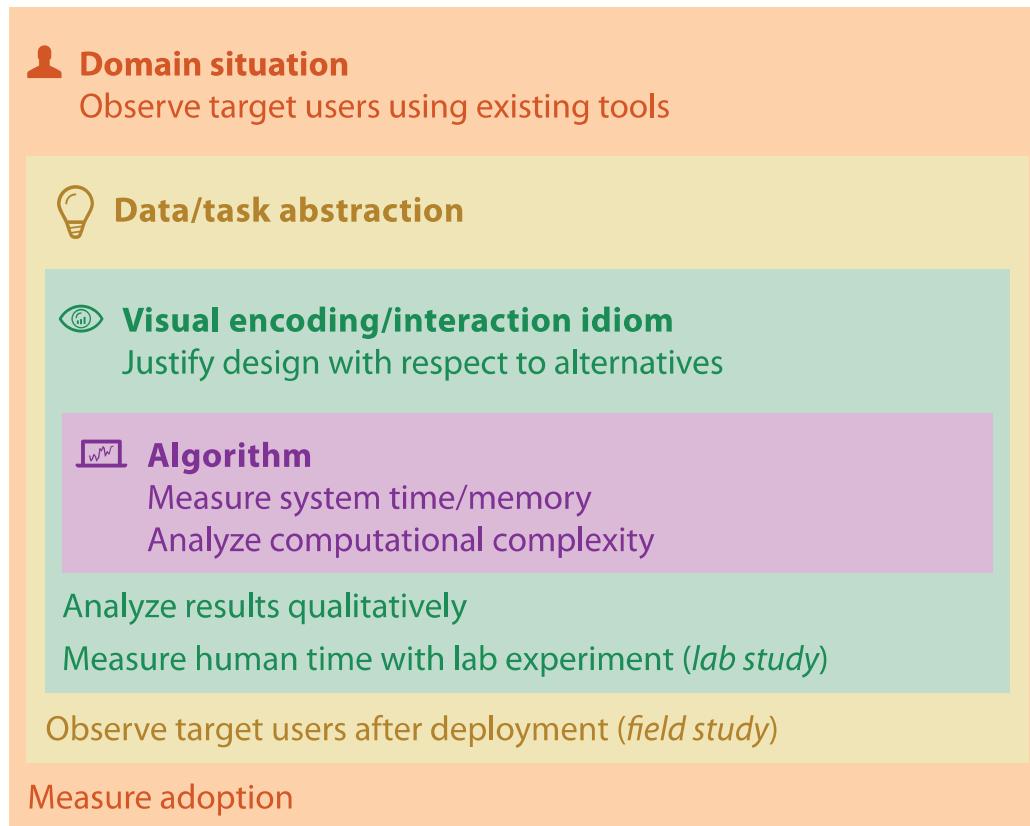
Analysis: Nested Model (Ch 4) II

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Analysis examples: Single paper includes only subset of methods



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MatrixExplorer. Henry and Fekete. InfoVis 2006.

observe and interview target users

justify encoding/interaction design

measure system time/memory

qualitative result image analysis

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Flow map layout. Phan et al. InfoVis 2005.

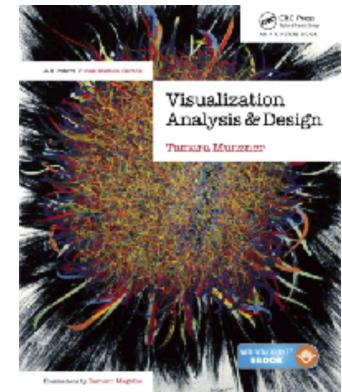
justify encoding/interaction design

computational complexity analysis

measure system time/memory

qualitative result image analysis

Visualization Analysis & Design



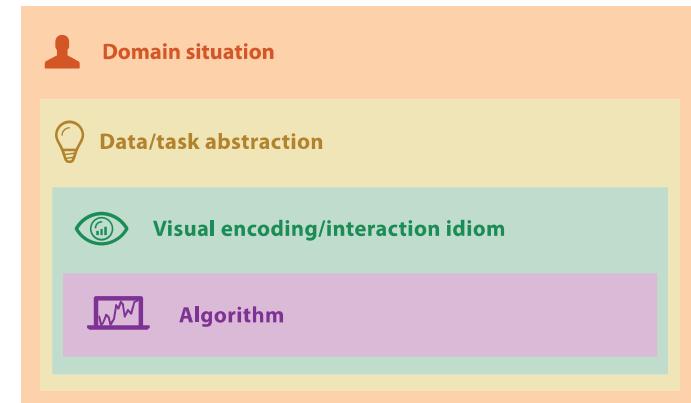
Task Abstraction (Ch 3)

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Department of Computer Science
University of British Columbia

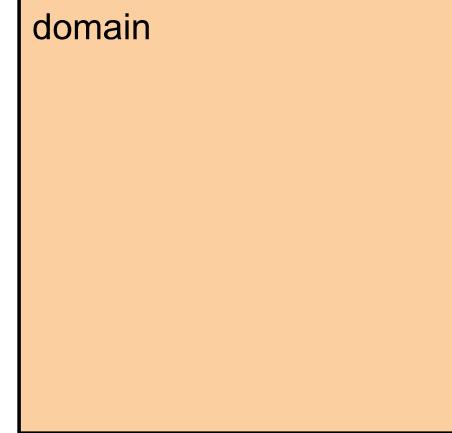
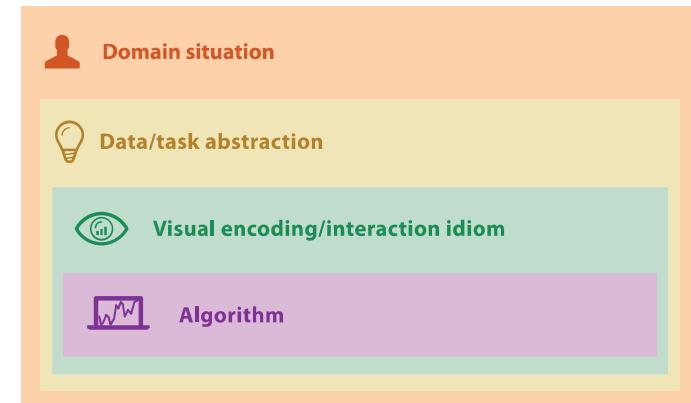
[@tamaramunzner](#)

From domain to abstraction



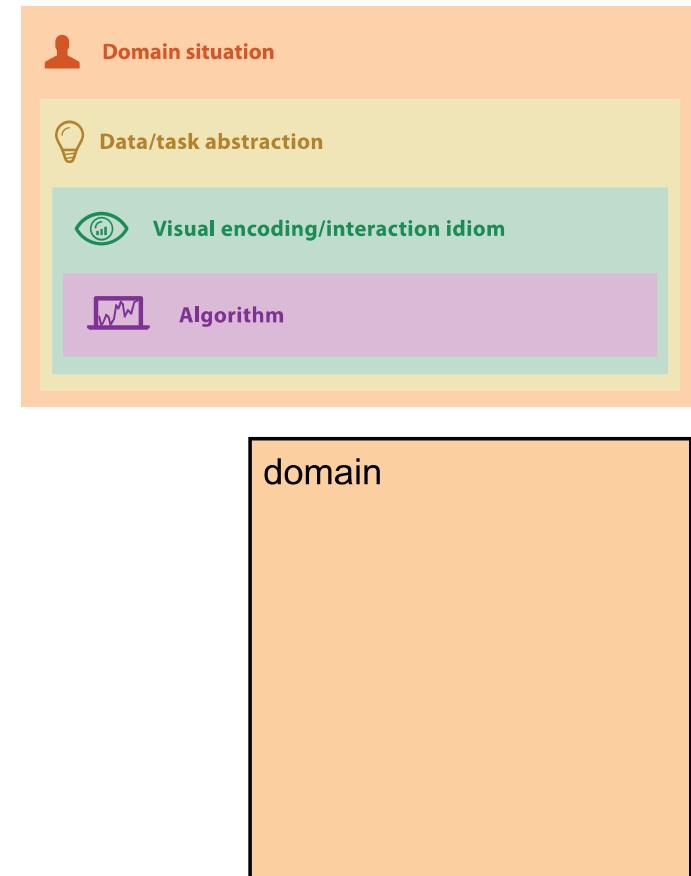
From domain to abstraction

- domain characterization:
details of application domain



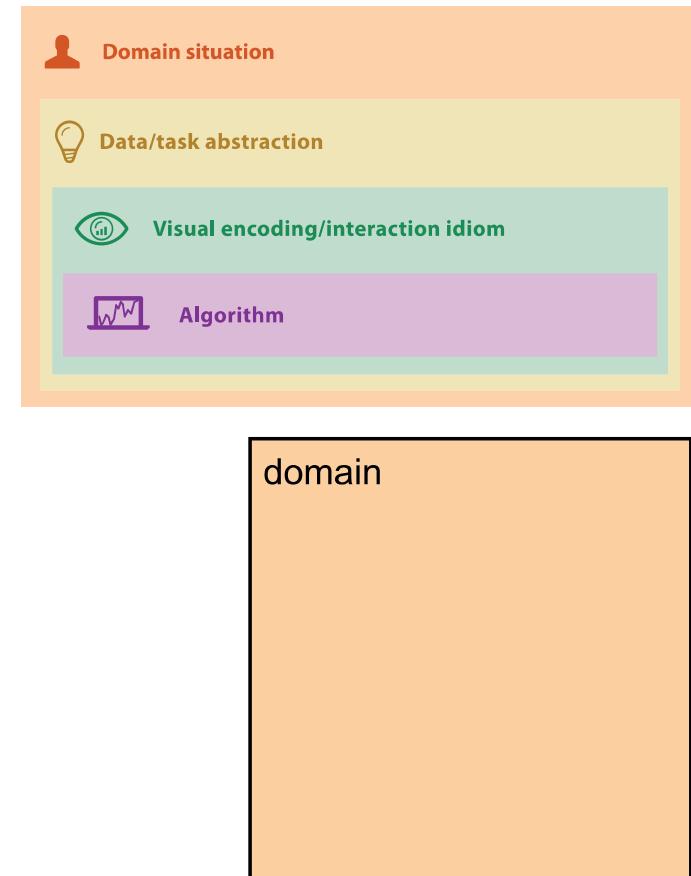
From domain to abstraction

- 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



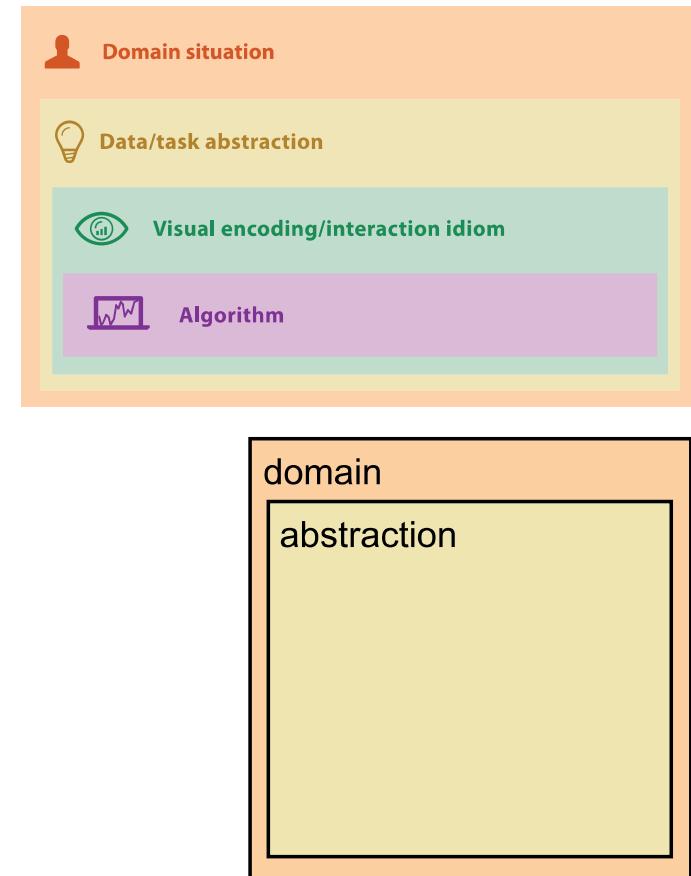
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 - break down into simpler abstract tasks



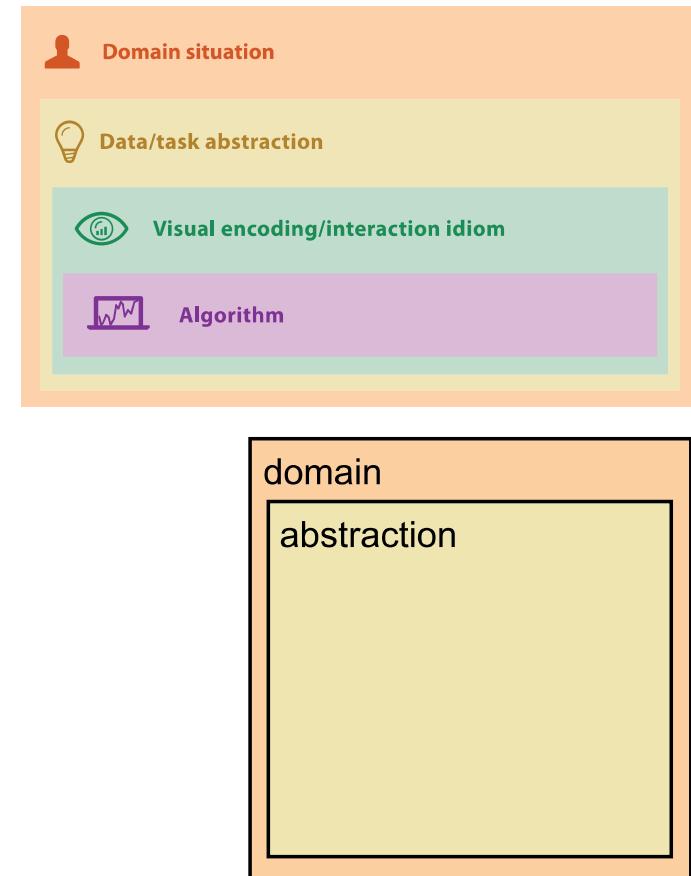
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 - break down into simpler abstract tasks
- abstraction: data & task
 - map *what* and *why* into generalized terms

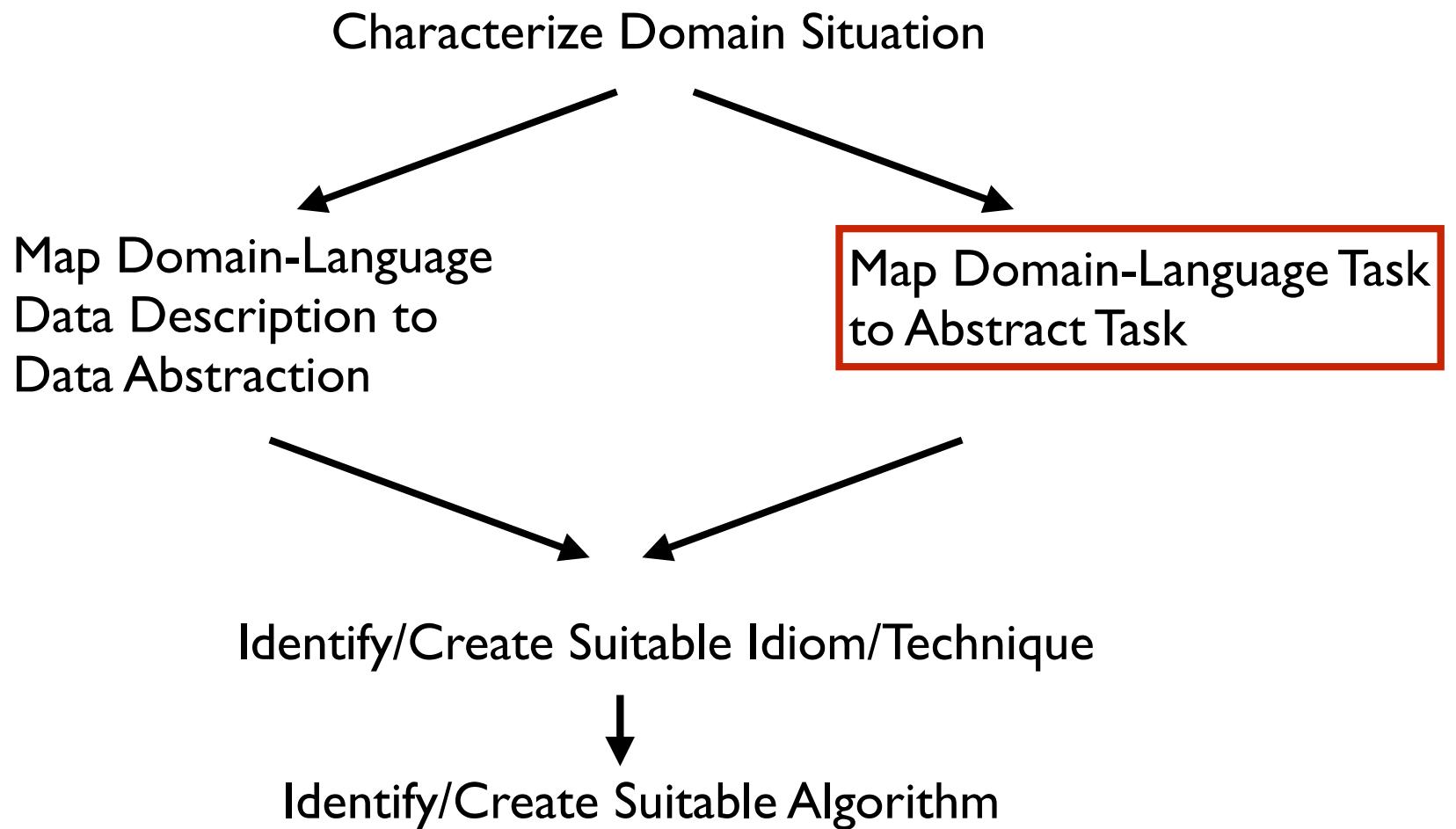


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- abstraction: data & task
 - map *what* and *why* into generalized terms
 - identify tasks that users wish to perform, or already do
 - find data types that will support those tasks
 - possibly transform /derive if need be



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

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

Actions: Analyze

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

→ Analyze

→ Consume

→ Discover



→ Present



→ Enjoy



→ Produce

→ Annotate



→ Record



→ Derive



Actions: Search

Actions: Search

- what does user know?
 - target, location

➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>

Actions: Search

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

➔ Search

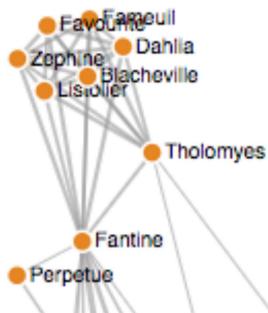
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Location unknown	 <i>Locate</i>	 <i>Explore</i>

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

➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
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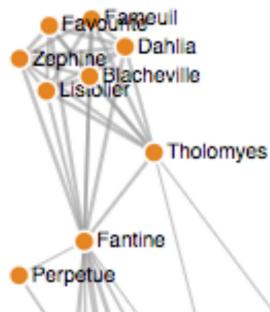
<https://bl.ocks.org/heybignick/3faf257bbbbc7743bb72310d03b86ee8>

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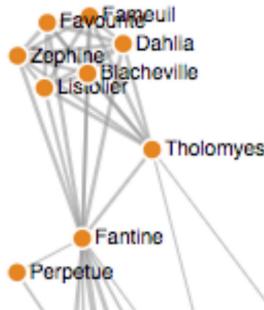
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Actions: Search

- 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

➔ Search

	Target known	Target unknown
Location known	 <i>Lookup</i>	 <i>Browse</i>
Location unknown	 <i>Locate</i>	 <i>Explore</i>



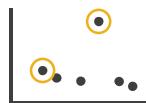
<https://bl.ocks.org/heybignick/3faf257bbbbc7743bb72310d03b86ee8>

Actions: Query

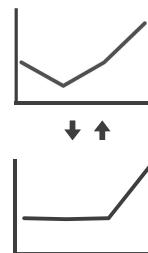
- how much of the data matters?
 - one: identify
 - some: compare
 - all: summarize

➔ Query

➔ Identify



➔ Compare

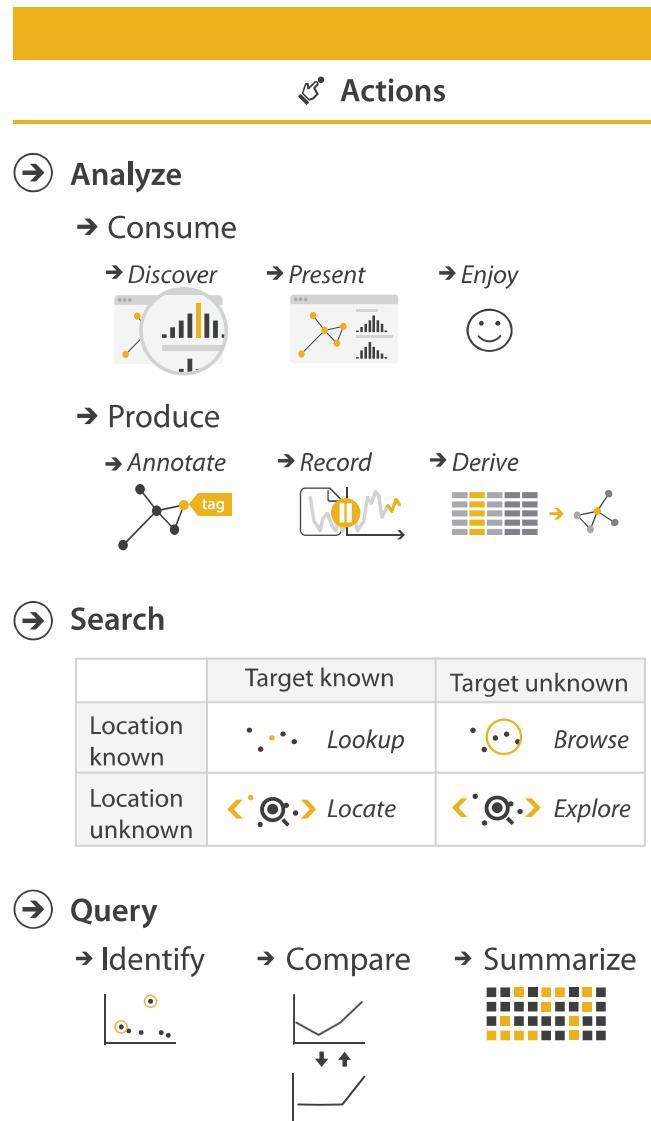


➔ Summarize



Actions

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



Task abstraction: Targets

Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



→ Features



Task abstraction: Targets

→ All Data

→ Trends → Outliers → Features



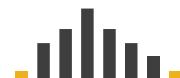
→ Attributes

→ One → Many

→ Distribution



→ Extremes



→ Dependency



→ Correlation



→ Similarity



Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



→ Features



→ Attributes

→ One



→ Many

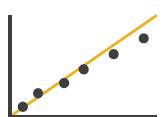
→ Distribution



→ Dependency



→ Correlation



→ Similarity

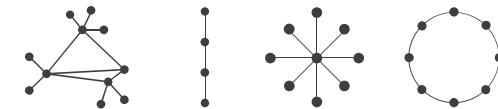


→ Extremes



→ Network Data

→ Topology



→ Paths



Task abstraction: Targets

→ All Data

→ Trends



→ Outliers



→ Features



→ Attributes

→ One

→ Distribution



→ Extremes



→ Many

→ Dependency



→ Correlation



→ Similarity



→ Network Data

→ Topology



→ Paths



→ Spatial Data

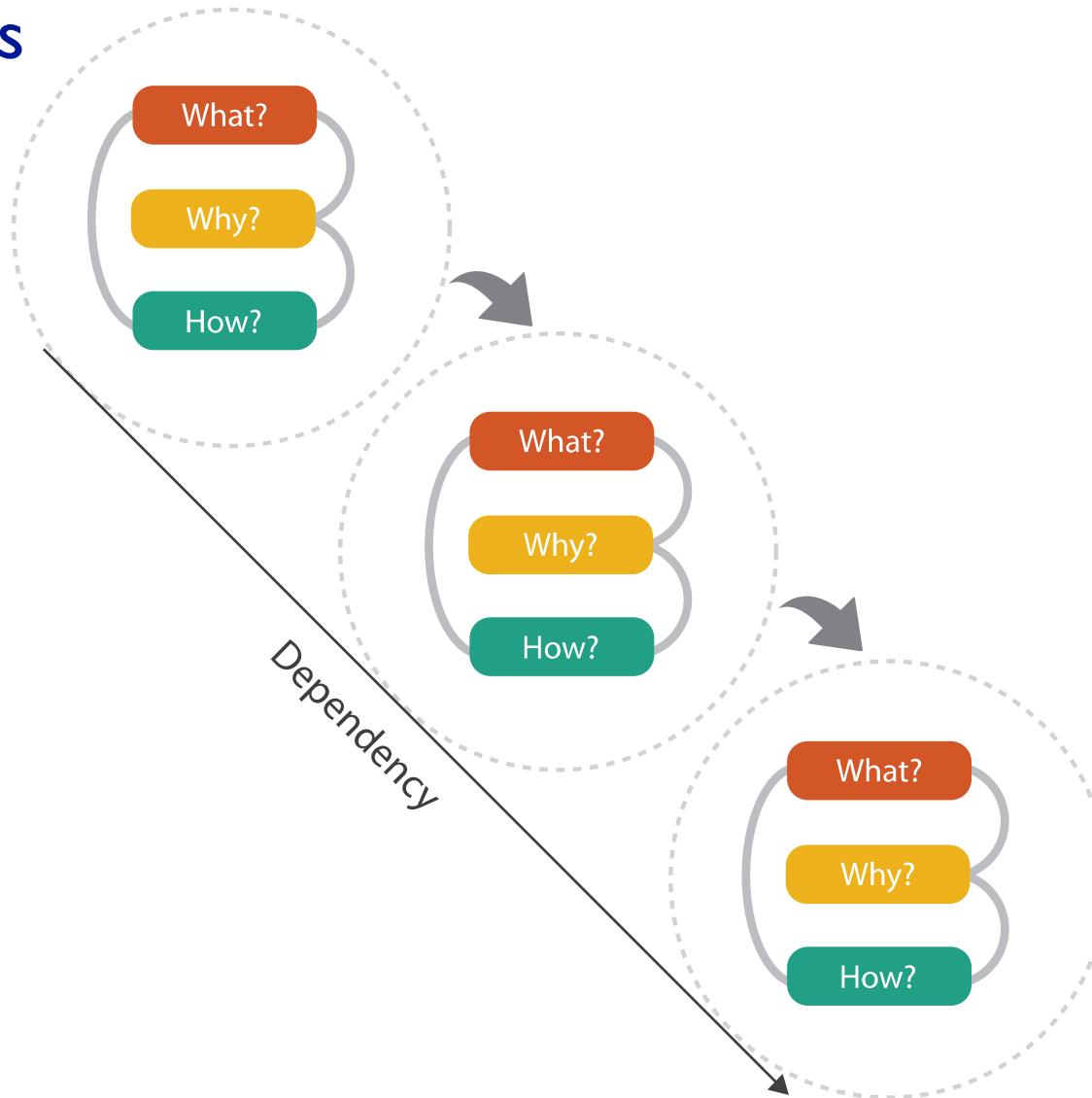
→ Shape

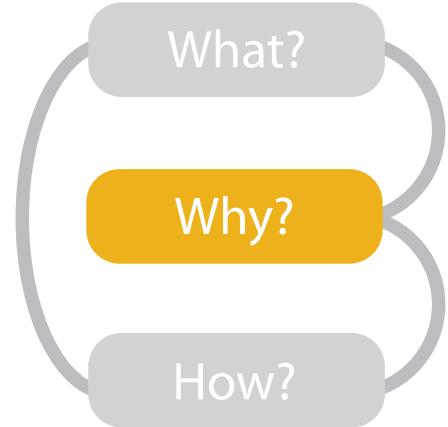


Abstraction

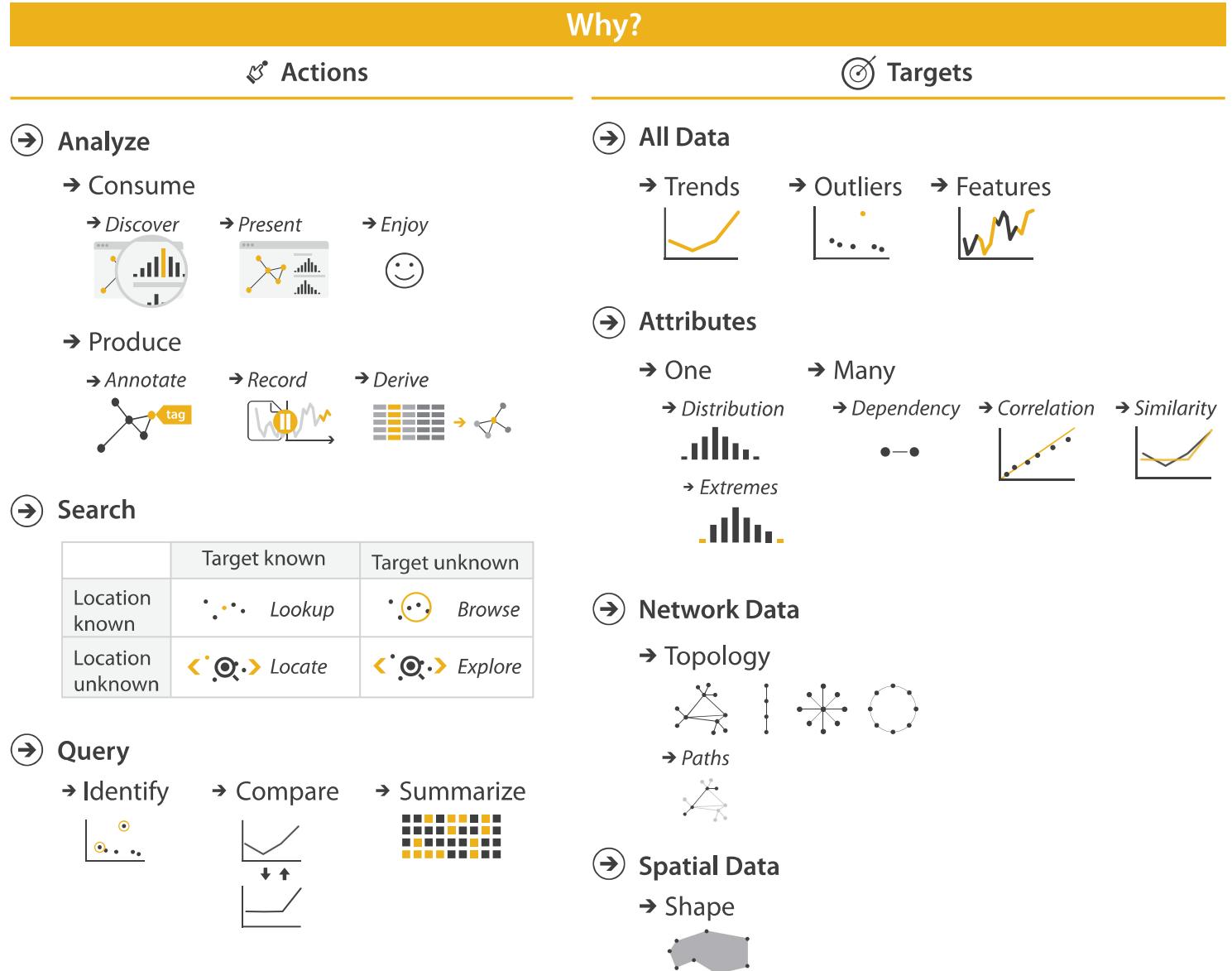
- these {action, target} pairs are good starting point for vocabulary
 - but sometimes you'll need more precision!
- rule of thumb
 - systematically remove all domain jargon
- interplay: task and data abstraction
 - need to use data abstraction within task abstraction
 - to specify your targets!
 - but 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

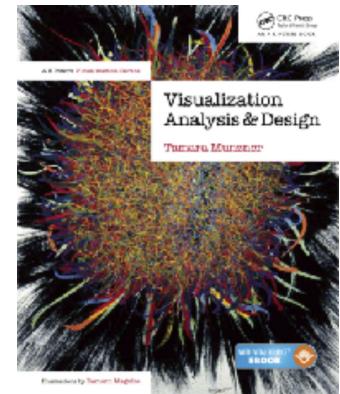




- {action, target} pairs
 - discover distribution
 - compare trends
 - locate outliers
 - browse topology



Visualization Analysis & Design



Rules of Thumb (Ch 6)

Tamara Munzner

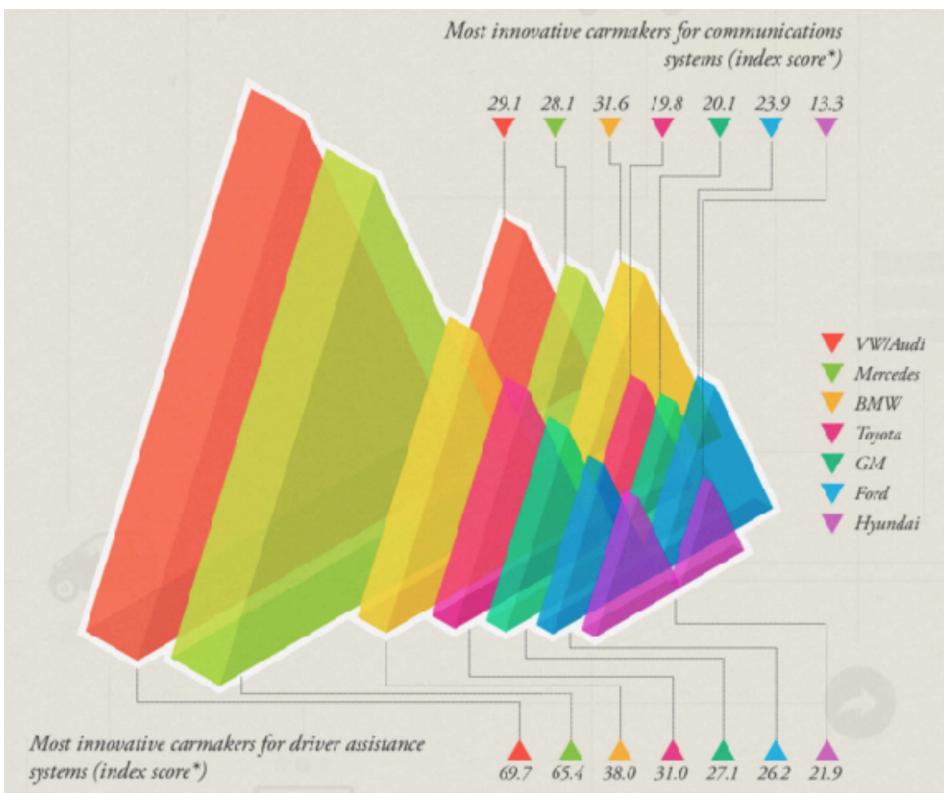
Department of Computer Science
University of British Columbia

[@tamaramunzner](#)

Rules of Thumb

- Guidelines and considerations, not absolute rules
 - when to use 3D? when to use 2D?
 - when to use eyes instead of memory?
 - when does immersion help?
 - when to use overviews?
 - how long is too long?
 - which comes first, form or function?

Unjustified 3D all too common, in the news and elsewhere



Convictions in London for class A drug supply.



<http://viz.wtf/post/137826497077/eye-popping-3d-triangles>

<http://viz.wtf/post/139002022202/designer-drugs-h-t-ducqn>

Depth vs power of the plane

- high-ranked spatial position channels: **planar** spatial position
 - not depth!

④ Magnitude Channels: Ordered Attributes

Position on common scale 

Position on unaligned scale 

Length (1D size) 

Tilt/angle 

Area (2D size) 

Depth (3D position) 

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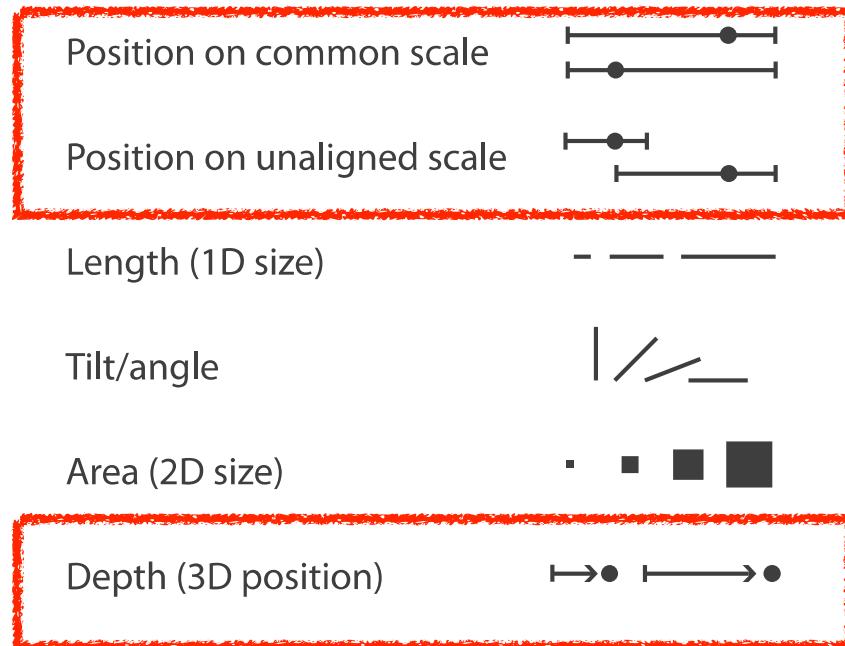
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Length (1D size)	
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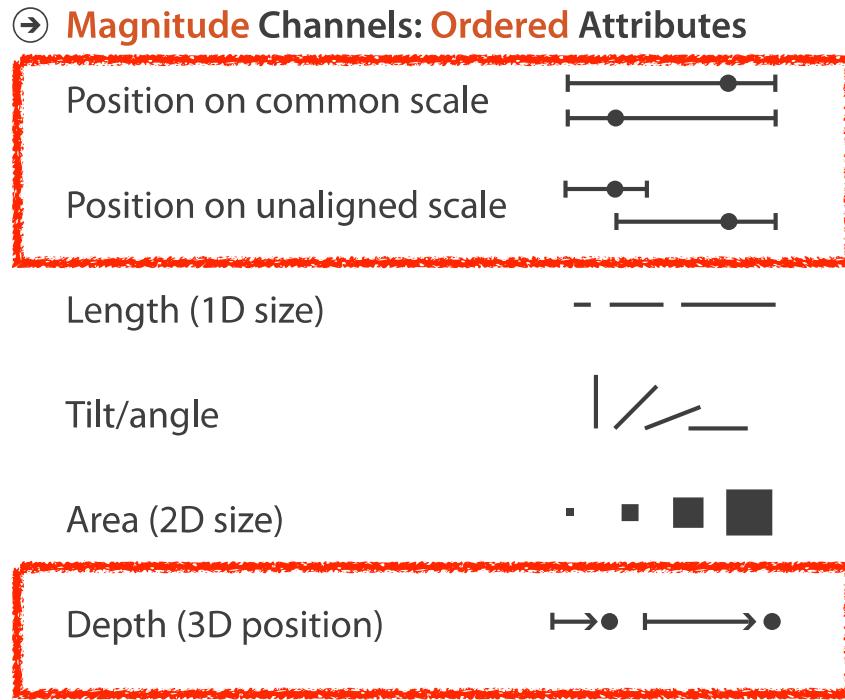
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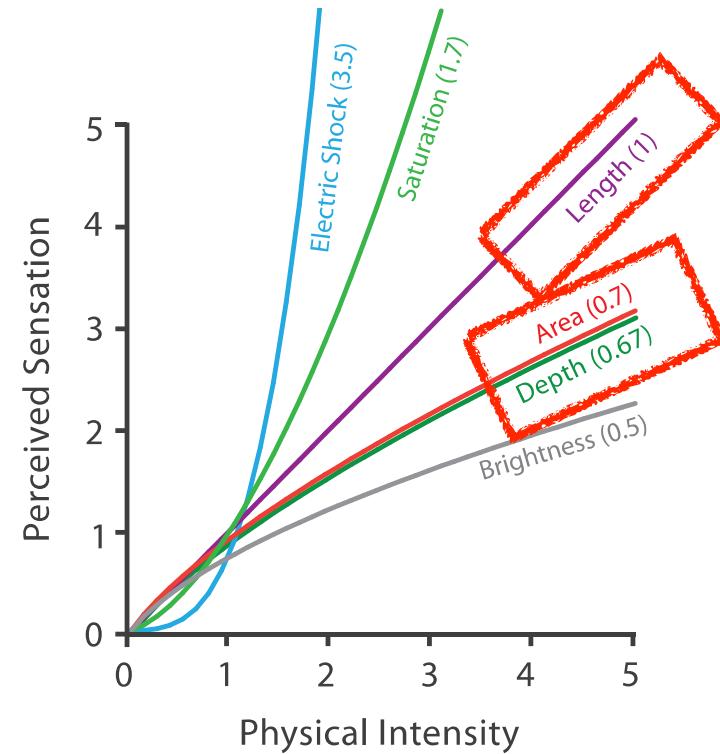


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 - not depth!

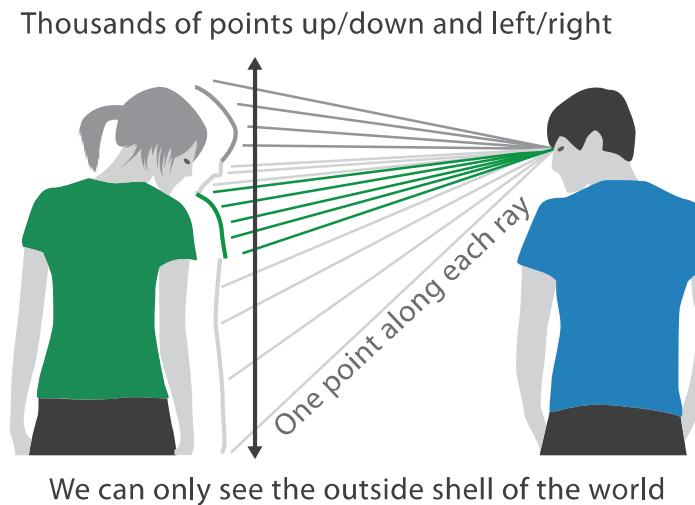
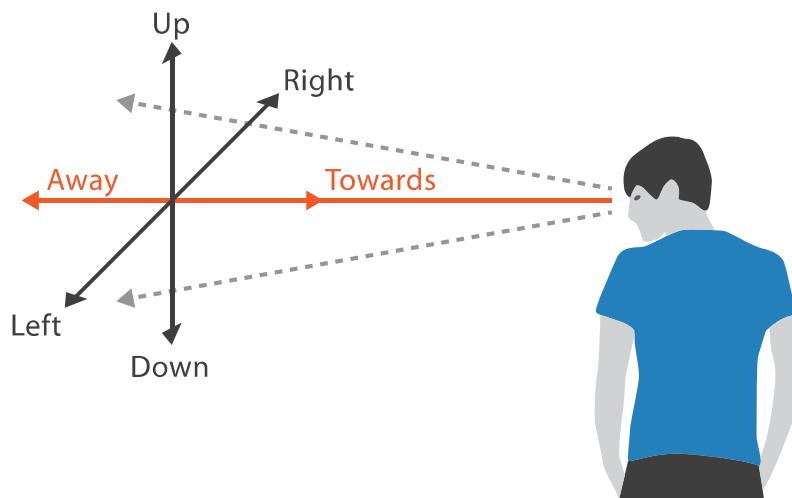


Steven's Psychophysical Power Law: $S = I^N$



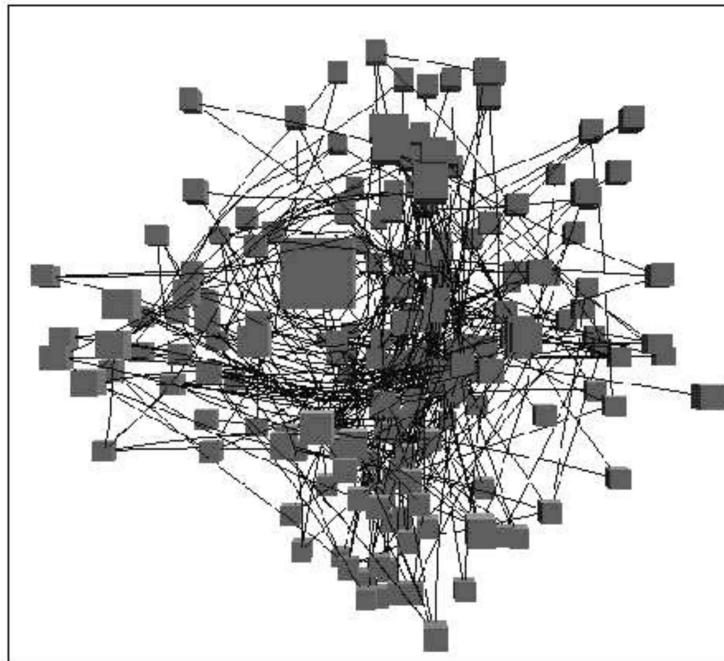
No unjustified 3D: Danger of depth

- we don't really live in 3D: we **see** in 2.05D
 - acquire more info on image plane quickly from eye movements
 - acquire more info for depth slower, from head/body motion



Occlusion hides information

- occlusion
- interaction can resolve, but at cost of time and cognitive load



[*Distortion Viewing Techniques for 3D Data. Carpendale et al. InfoVis 1996.*]

Perspective distortion loses information

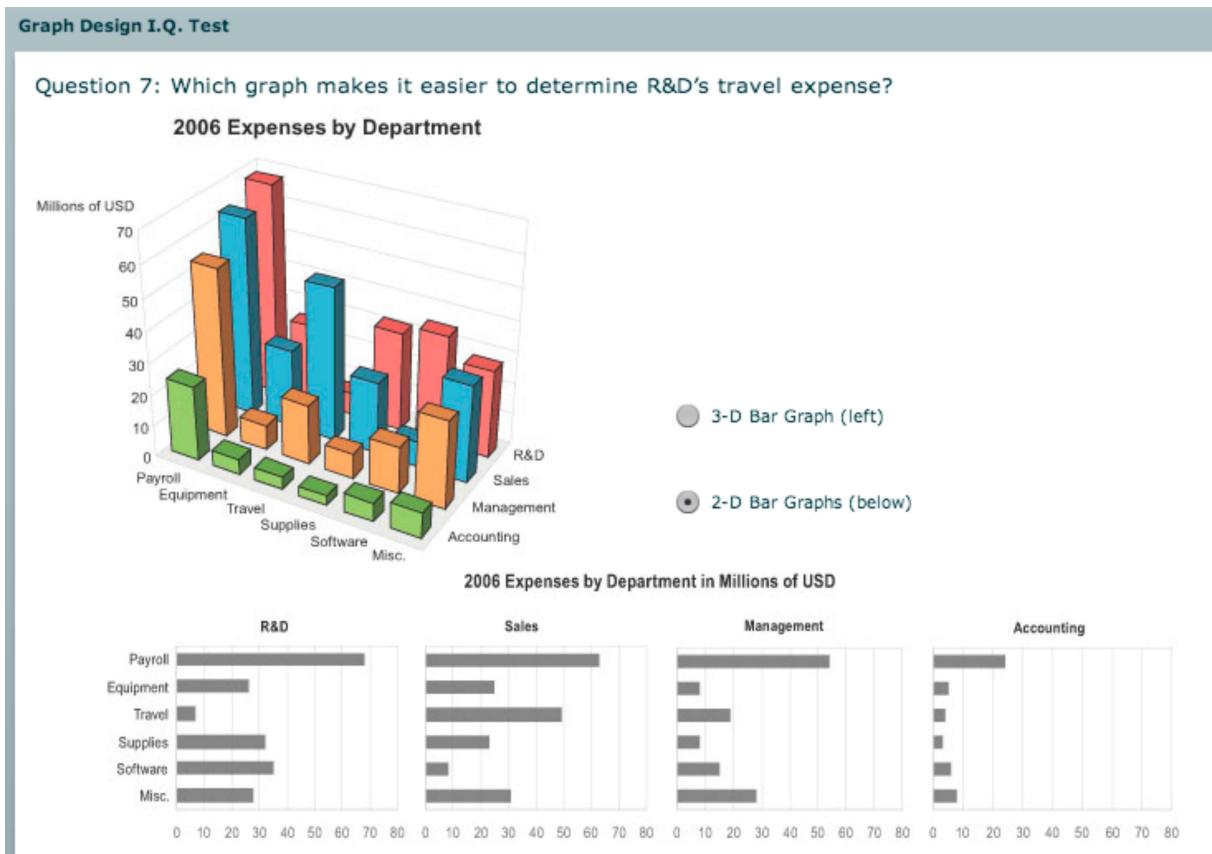
- perspective distortion
 - interferes with all size channel encodings
 - power of the plane is lost!



[Visualizing the Results of Multimedia Web Search Engines. Mukherjea, Hirata, and Hara. InfoVis 96]

3D vs 2D bar charts

- 3D bars:
very difficult to justify!
 - perspective distortion
 - occlusion
- faceting into 2D almost
always better choice



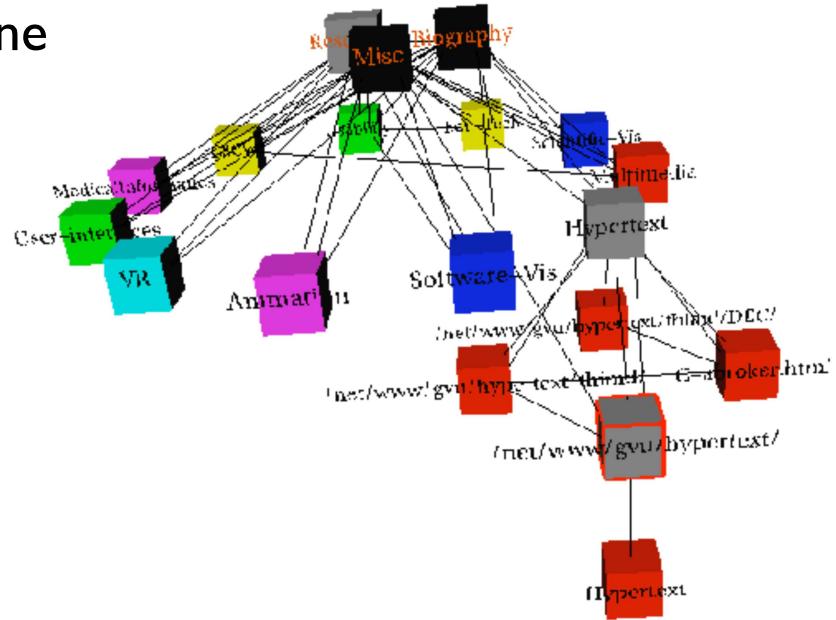
[<http://perceptualedge.com/files/GraphDesignIQ.html>]

Tilted text isn't legible

- text legibility
 - far worse when tilted from image plane

- further reading

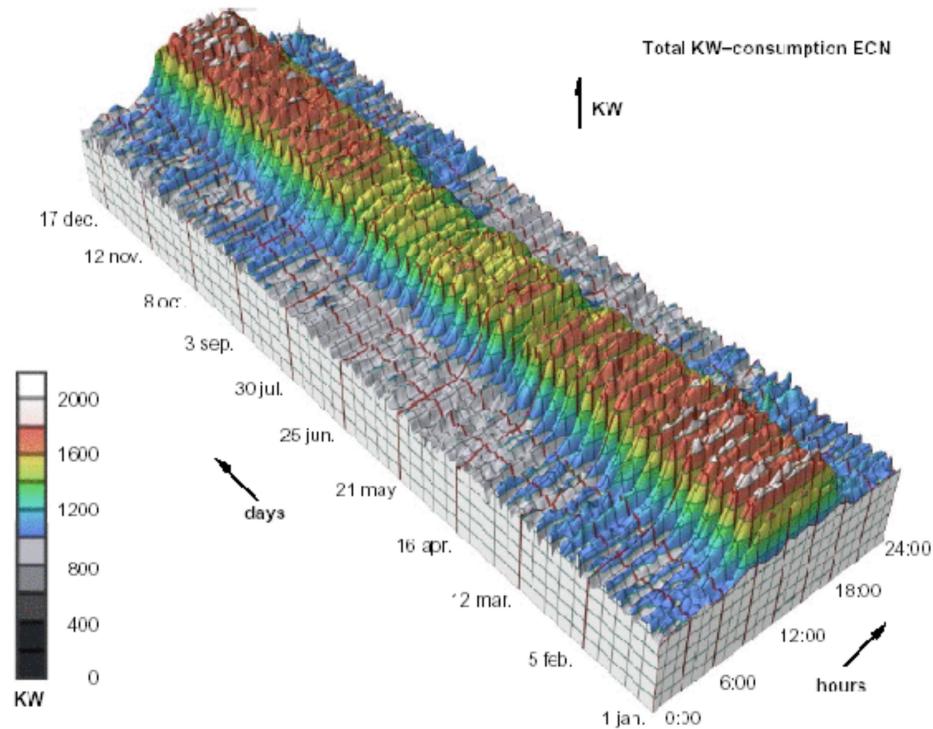
Exploring and Reducing the Effects of Orientation
on Text Readability in Volumetric Displays.
Grossman et al. CHI 2007



[Visualizing the World-Wide Web with the Navigational View Builder. Mukherjea and Foley. Computer Networks and ISDN Systems, 1995.]

No unjustified 3D example: Time-series data

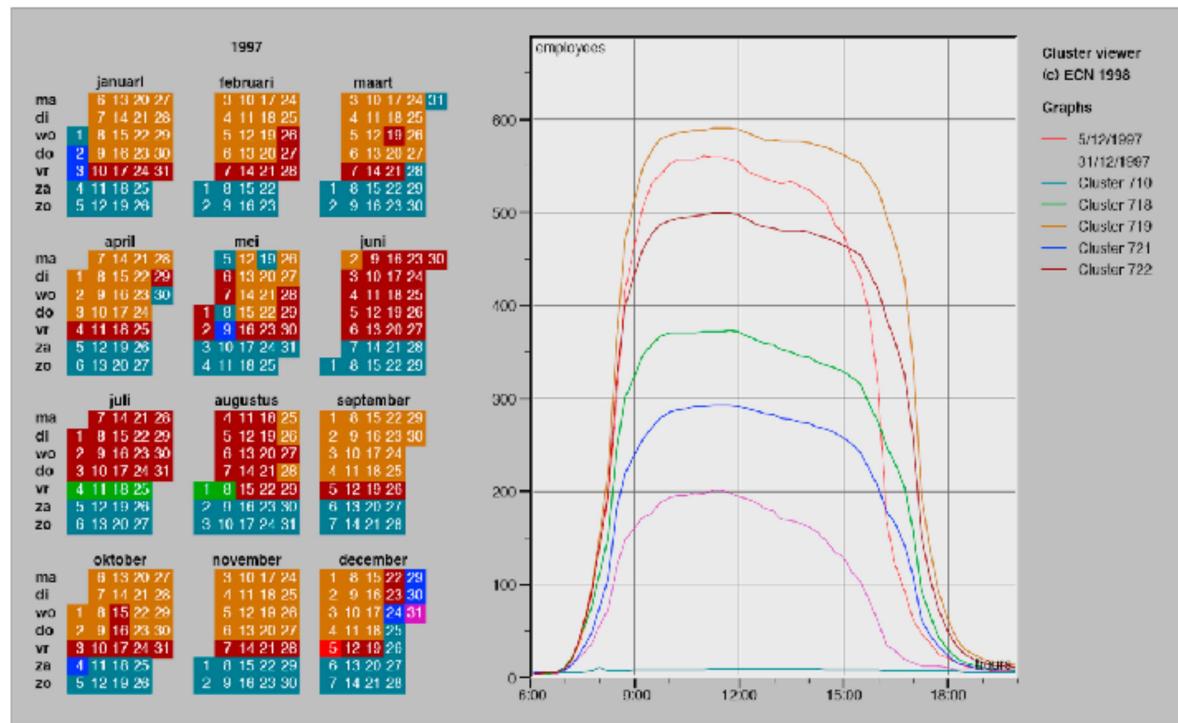
- extruded curves: detailed comparisons impossible



[Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc. InfoVis 99.]

No unjustified 3D example: Transform for new data abstraction

- derived data: cluster hierarchy
- juxtapose multiple views: calendar, superimposed 2D curves



[Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc. InfoVis 99.]

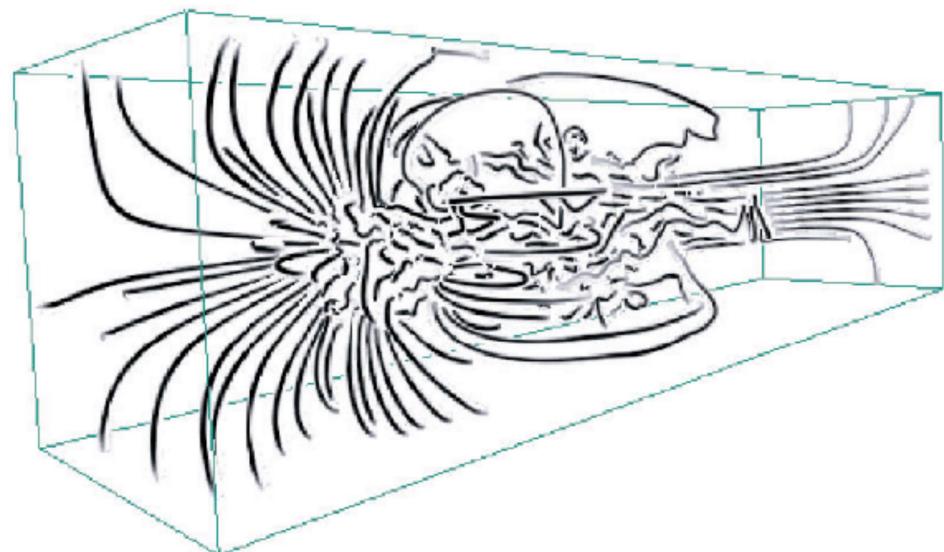
Justified 3D: shape perception

- benefits outweigh costs when task is shape perception for 3D spatial data
 - interactive navigation supports synthesis across many viewpoints

Targets

→ Spatial Data

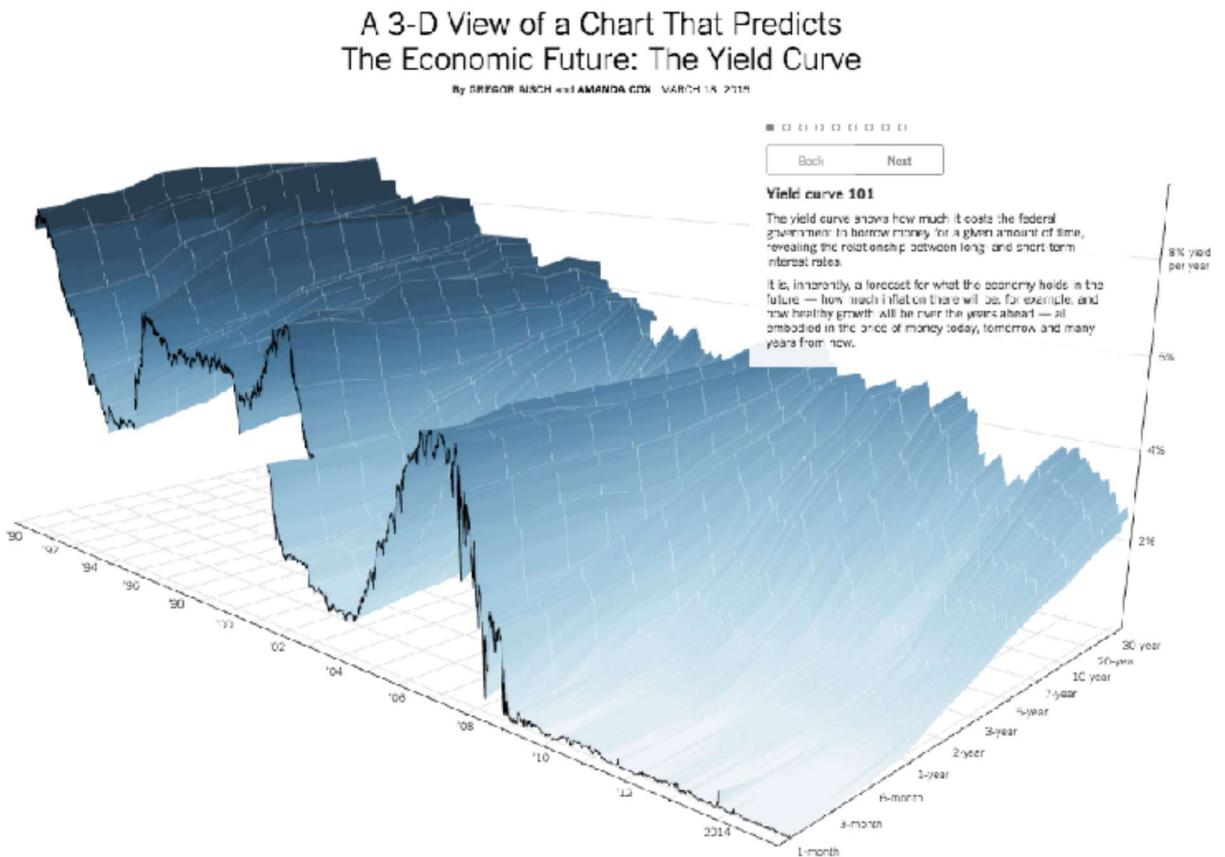
→ Shape



[Image-Based Streamline Generation and Rendering. Li and Shen.
IEEE Trans. Visualization and Computer Graphics (TVCG) 13:3 (2007), 630–640.]

Justified 3D: Economic growth curve

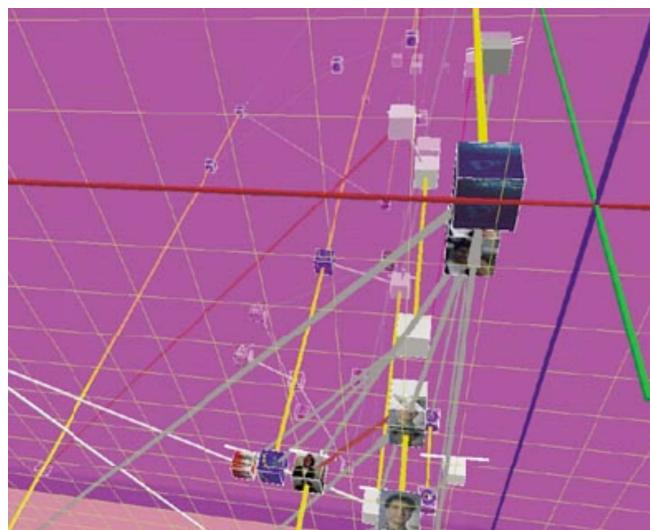
- constrained navigation steps through carefully designed viewpoints



<http://www.nytimes.com/interactive/2015/03/19/upshot/3d-yield-curve-economic-growth.html>

No unjustified 3D

- 3D legitimate for true 3D spatial data
- 3D needs very careful justification for abstract data
 - enthusiasm in 1990s, but now skepticism
 - be especially careful with 3D for point clouds or networks



[WEBPATH-a three dimensional Web history. Frecon and Smith. Proc. InfoVis 1999]

No unjustified 2D

- consider whether network data requires 2D spatial layout
 - especially if reading text is central to task!
 - arranging as network means lower information density and harder label lookup compared to text lists
- benefits outweigh costs when topological structure/context important for task
 - be especially careful for search results, document collections, ontologies



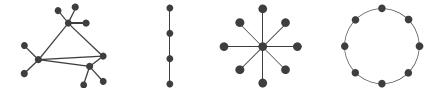
Targets



Network Data



Topology



→ Paths



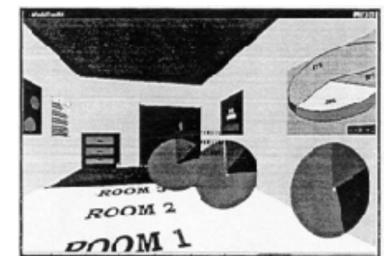
Eyes beat memory

- principle: external cognition vs. internal memory
 - easy to compare by moving eyes between side-by-side views
 - harder to compare visible item to memory of what you saw
- implications for animation
 - great for choreographed storytelling
 - great for transitions between two states
 - poor for many states with changes everywhere
 - consider small multiples instead

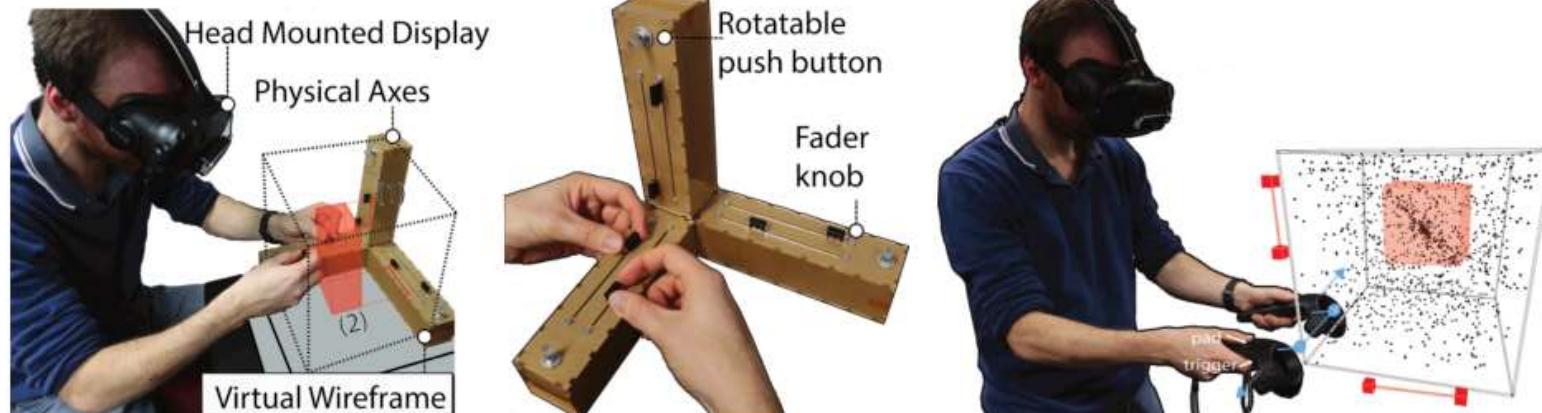


Resolution beats immersion

- immersion typically not helpful for abstract data
 - do not need sense of presence or stereoscopic 3D
 - desktop also better for workflow integration
- resolution much more important: pixels are the scarcest resource
- first wave: virtual reality for abstract data difficult to justify
- second wave: AR/MR (augmented/mixed reality) has more promise



[Development of an information visualization tool using virtual reality. Kirner and Martins. Proc. Symp. Applied Computing 2000]



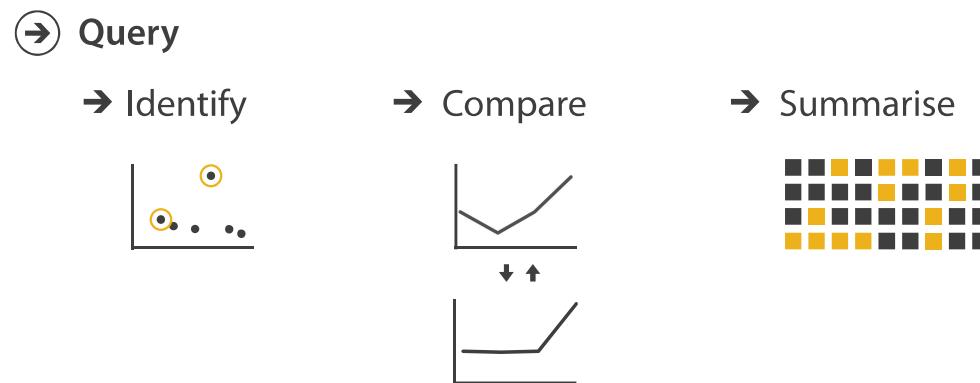
[A Design Space for Spatio-Data Coordination: Tangible Interaction Devices for Immersive Information Visualisation. Cordeil, Bach, Li, Elliott, and Dwyer. Proc. PacificVis 2017 Notes.]

Overview first, zoom and filter, details on demand

- influential mantra from Shneiderman

[*The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations.*
Shneiderman. Proc. IEEE Visual Languages, pp. 336–343, 1996.]

- overview = summary
 - microcosm of full vis design problem



Rule of thumb: **Responsiveness is required**

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 - rendering speed when item count is large (guaranteed frame rate)

Function first, form next

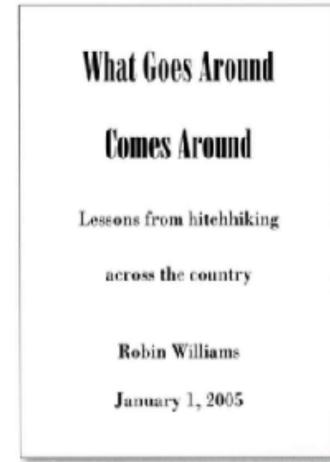
- dangerous to start with aesthetics
 - usually impossible to add function retroactively

Function first, form next

- dangerous to start with aesthetics
 - usually impossible to add function retroactively
- start with focus on functionality
 - possible to improve aesthetics later on, as refinement
 - if no expertise in-house, find good graphic designer to work with
 - aesthetics do matter! another level of function
 - visual hierarchy, alignment, flow
 - Gestalt principles in action

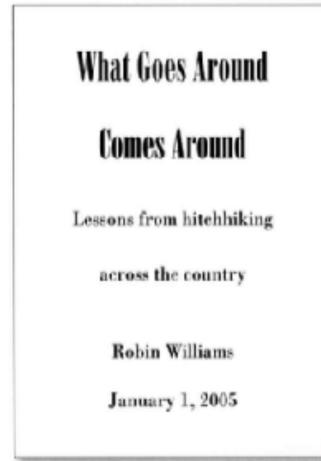
Form: Basic graphic design ideas

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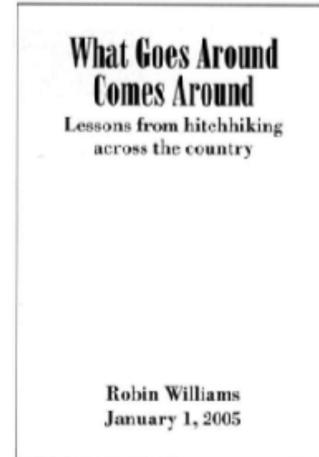
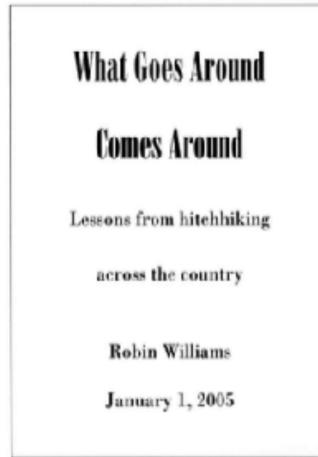
Form: Basic graphic design ideas

- proximity
 - do group related items together
 - avoid equal whitespace between unrelated



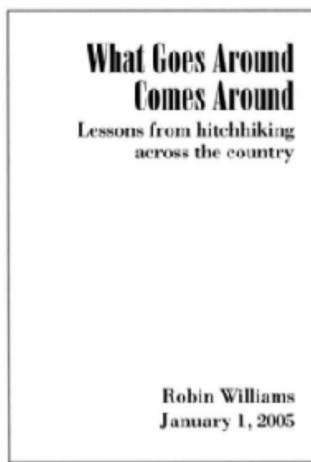
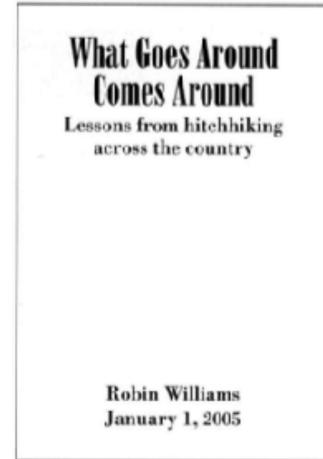
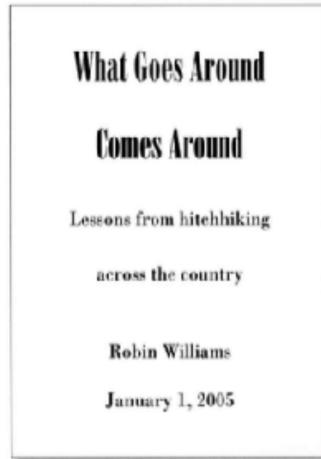
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 - do find/make strong line, stick to it
 - avoid automatic centering



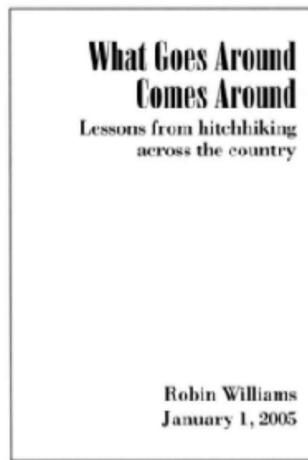
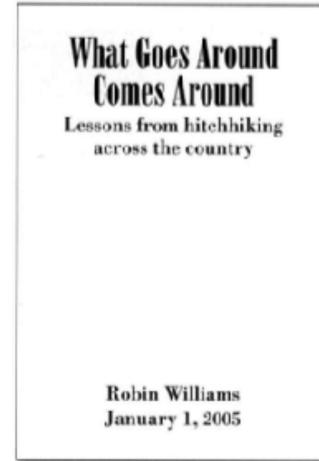
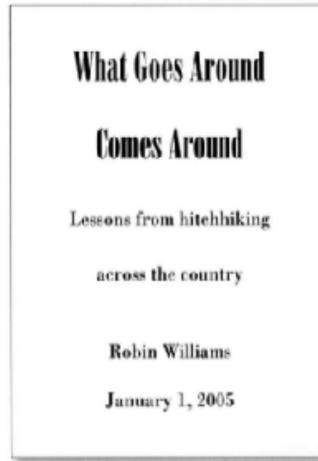
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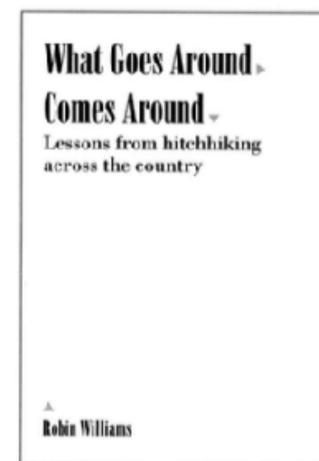
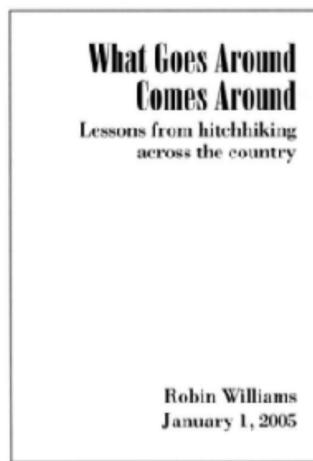
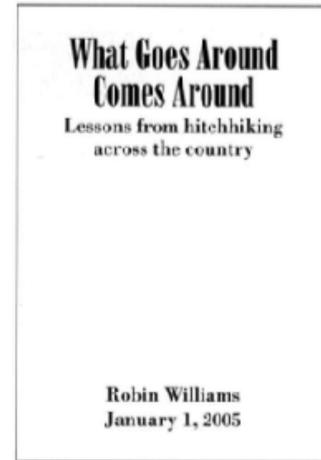
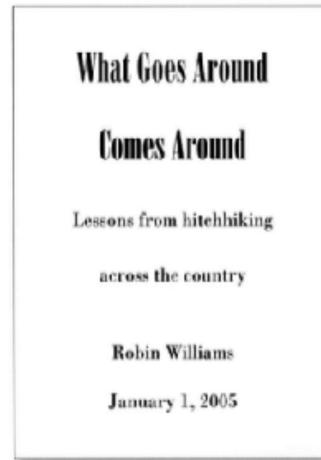
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- repetition
 - do unify by pushing existing consistencies



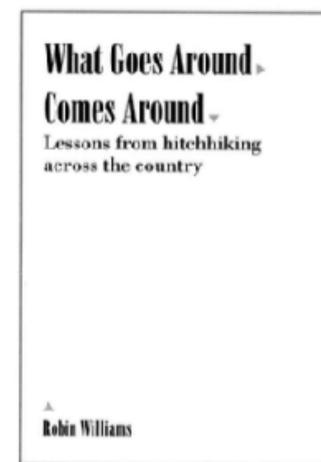
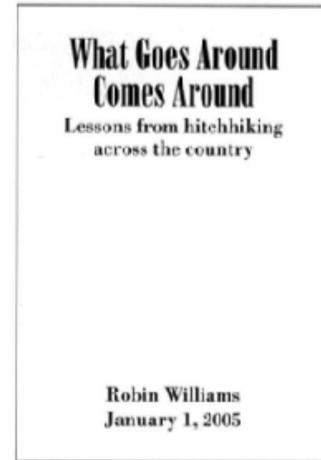
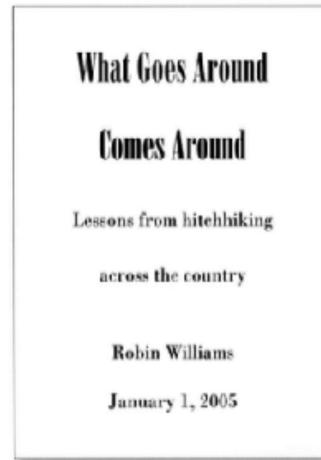
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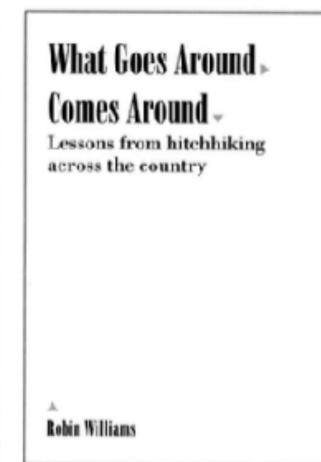
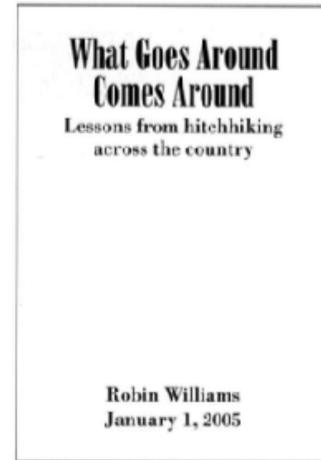
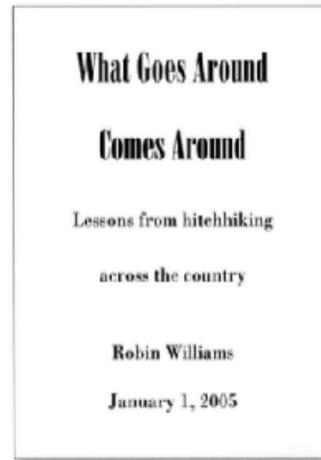
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- contrast
 - if not identical, then very different
 - avoid not quite the same



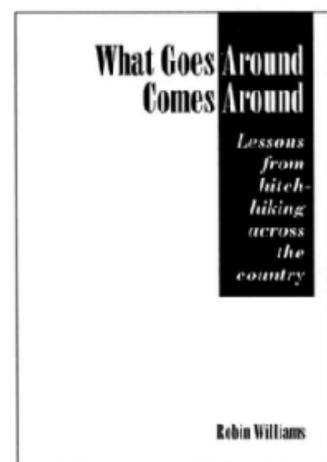
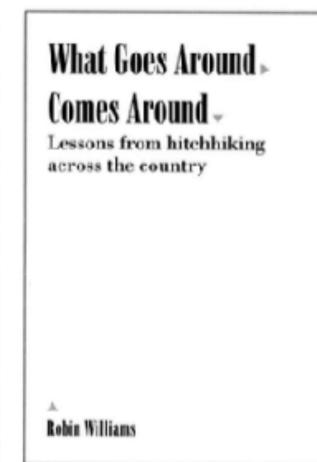
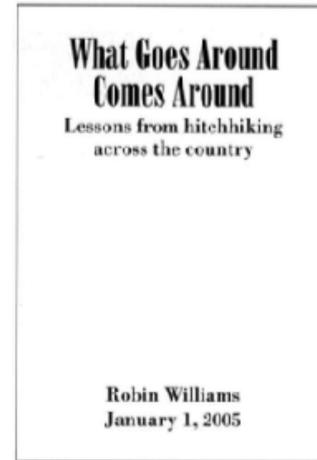
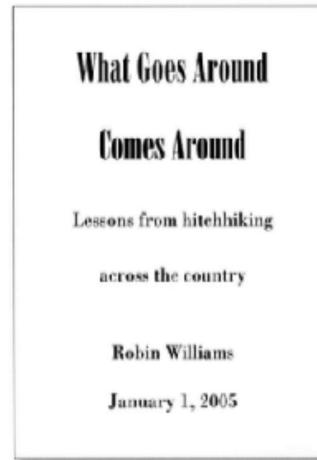
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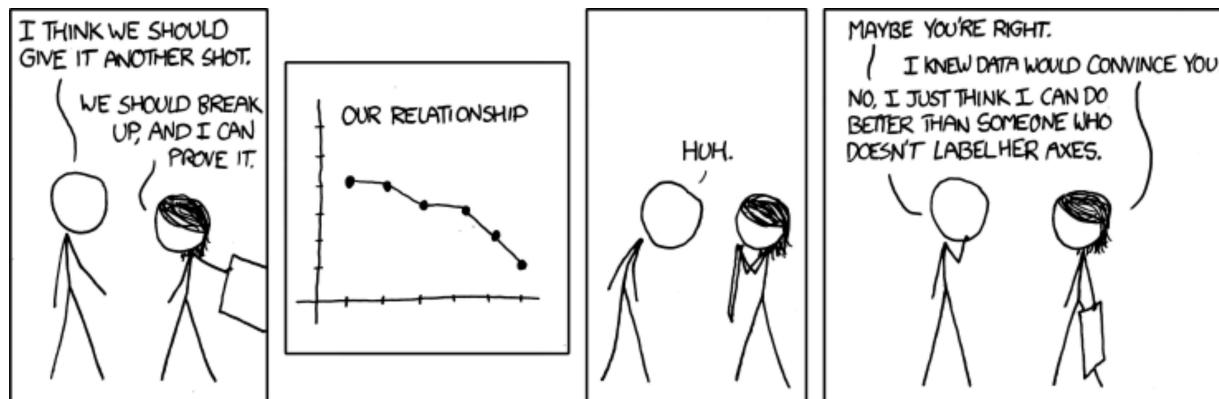
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- *The Non-Designer's Design Book, 4th ed. Robin Williams, Peachpit Press, 2015.*
 - fast read, very practical to work through whole thing



Best practices: Labelling

- make visualizations as self-documenting as possible
 - meaningful & useful title, labels, legends
 - axes and panes/subwindows should have labels
 - and axes should have good min/max boundary tick marks
 - everything that's plotted should have a legend
 - and own header/labels if not redundant with main title
 - use reasonable numerical format
 - avoid scientific notation in most cases



[<https://xkcd.com/833/>]

Rules of Thumb Summary

- No unjustified 3D
 - Power of the plane
 - Disparity of depth
 - Occlusion hides information
 - Perspective distortion dangers
 - Tilted text isn't legible
- No unjustified 2D
- Eyes beat memory
- Resolution over immersion
- Overview first, zoom and filter, details on demand
- Responsiveness is required
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How?

