Visualization Analysis & Design

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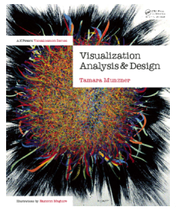
Visualization (vis) defined & motivated

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
  - doesn't know exactly what questions to ask in advance
  - longterm exploratory analysis
  - presentation of known results
  - stepping stone towards automation: refining, trustbuilding
- external representation: perception vs cognition
- intended task, measurable definitions of effectiveness



more at:
Visualization Analysis and Design, Chapter 1.
Munzner. AK Peters Visualization Series, CRC Press, 2014.

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 focus on tasks and effectiveness?

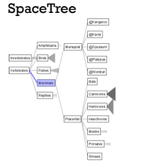
Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.

- tasks serve as constraint on design (as does data)
  - idioms do not serve all tasks equally!
  - challenge: recast tasks from domain-specific vocabulary to abstract forms
- most possibilities ineffective
  - validation is necessary, but tricky
  - 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

Why analyze?

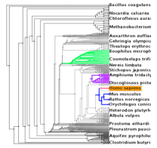
- imposes structure on huge design space
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new
  - most possibilities ineffective for particular task/data combination

SpaceTree

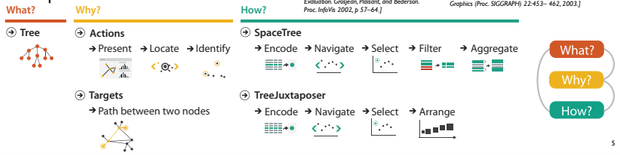


[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

TreeJuxtaposer



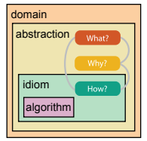
[TreeJuxtaposer: Scalable Tree Comparison Using Focus +Context With Guaranteed Visibility. ACM Trans. on Graphics (Proc. SIGGRAPH) 22:453– 462, 2003.]



Nested model: Four levels of vis design

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

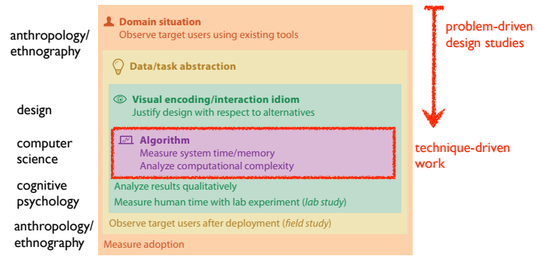


[A Multi-Level Typology of Abstract Visualization Tasks *Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).*]

Threats to validity differ at each level

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

Evaluate success at each level with methods from different fields



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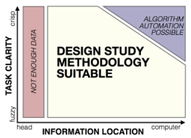

Design Study Methodology

Reflections from the Trenches and from the Stacks

Michael Sedlmair

Miriah Meyer

Tamara Munzner
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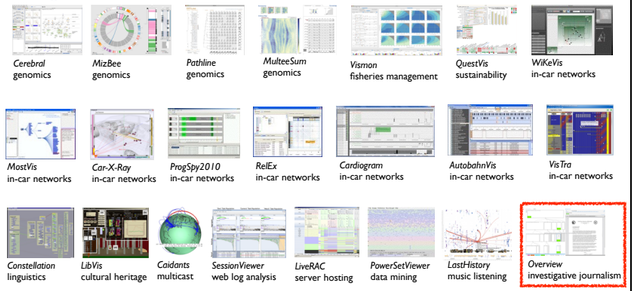
http://www.cs.ubc.ca/labs/imager/tr/2012/dsm/

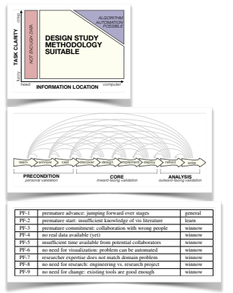
Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE Trans. Visualization and Computer Graphics 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

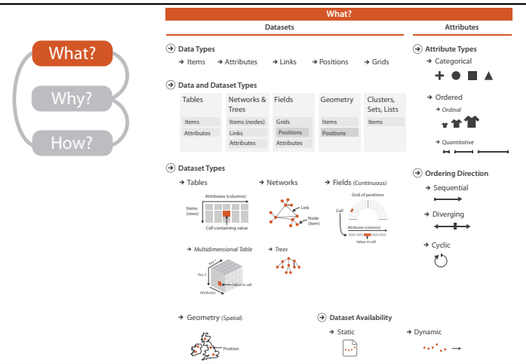
Design Studies: Lessons learned after 21 of them



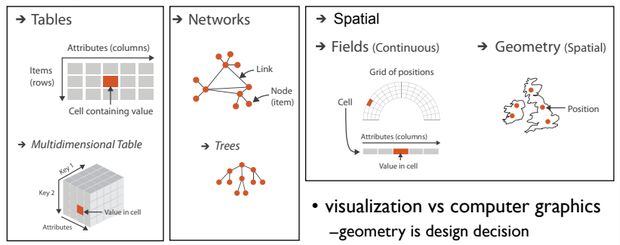
Methodology for Problem-Driven Work

- definitions
- 9-stage framework
- 32 pitfalls and how to avoid them



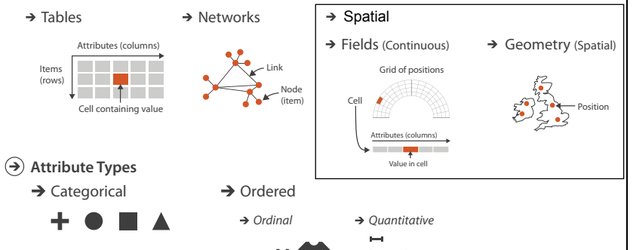


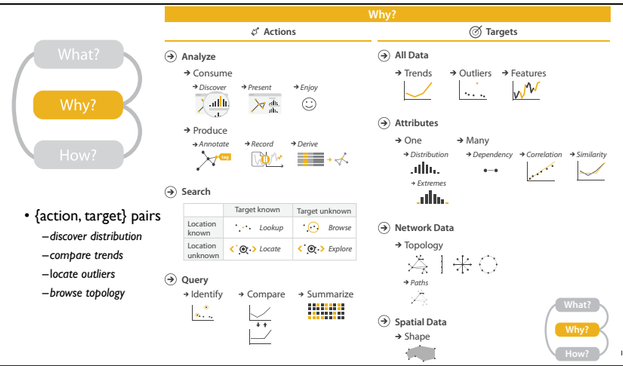
Three major datatypes



- visualization vs computer graphics
  - geometry is design decision

Types: Datasets and data

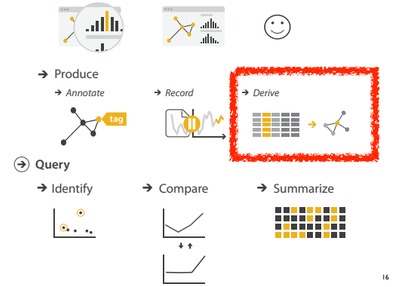




- {action, target} pairs
  - *discover distribution*
  - *compare trends*
  - *locate outliers*
  - *browse topology*

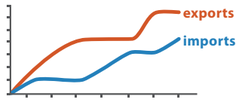
Actions: Analyze, Query

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

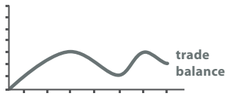


Derive: Crucial Design Choice

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



Original Data

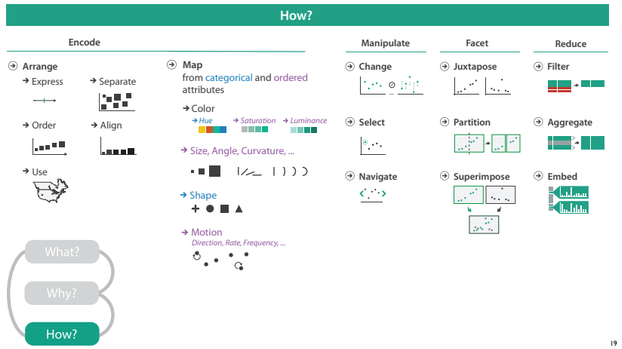


trade balance = exports – imports

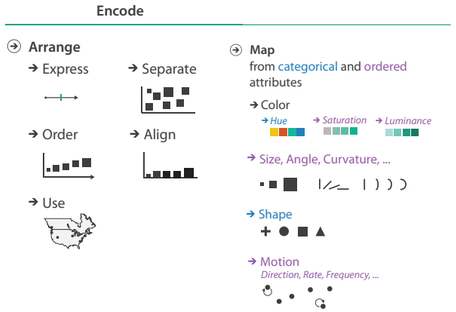
Derived Data

Targets

- **All Data**
  - Trends
  - Outliers
  - Features
- **Attributes**
  - One
  - Many
    - *Distribution*
    - *Extremes*
    - *Dependency*
    - *Correlation*
    - *Similarity*
- **Network Data**
  - Topology
  - *Paths*
- **Spatial Data**
  - Shape

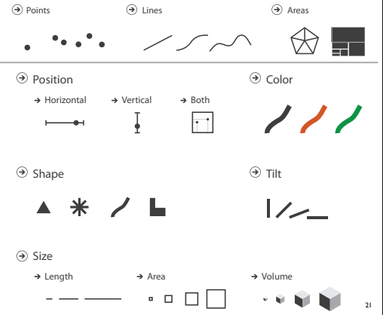


How to encode: Arrange space, map channels



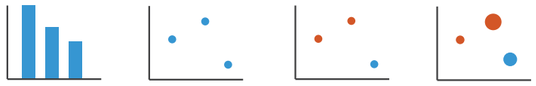
Definitions: Marks and channels

- marks
  - geometric primitives
- channels
  - control appearance of marks



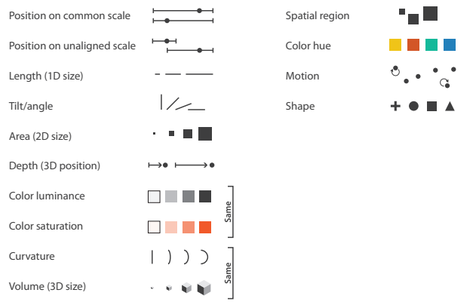
Encoding visually with marks and channels

- analyze idiom structure
  - as combination of marks and channels

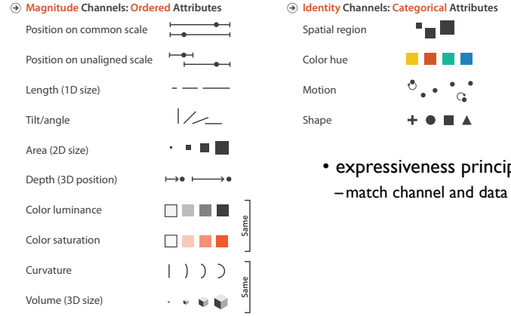


1:	2:	3:	4:
vertical position	vertical position horizontal position	vertical position horizontal position color hue	vertical position horizontal position color hue size (area)
mark: line	mark: point	mark: point	mark: point

Channels

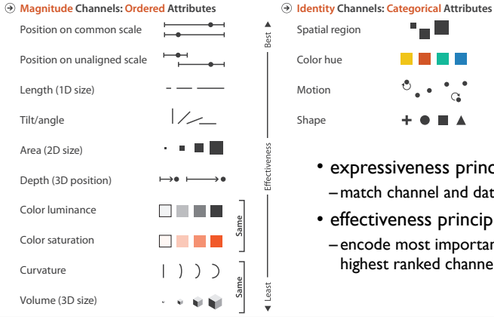


Channels: Matching Types



- expressiveness principle
  - match channel and data characteristics

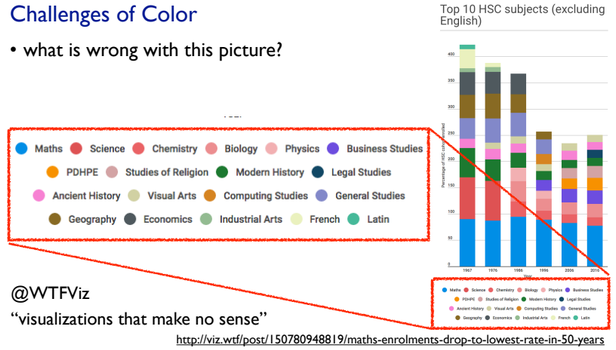
Channels: Rankings



- expressiveness principle
  - match channel and data characteristics
- effectiveness principle
  - encode most important attributes with highest ranked channels

Challenges of Color

- what is wrong with this picture?

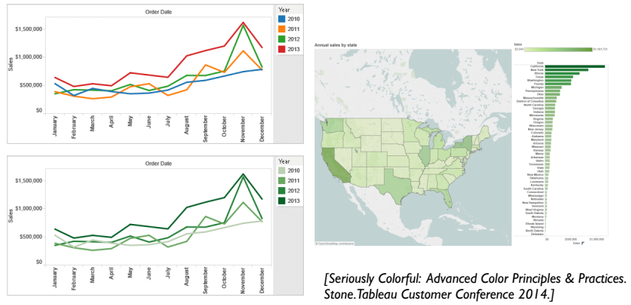


@WTFViz

"visualizations that make no sense"

http://viz.wtf/post/150780948819/maths-enrolments-drop-to-lowest-rate-in-50-years

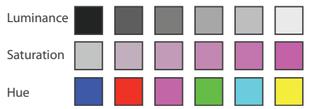
Categorical vs ordered color



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Decomposing color

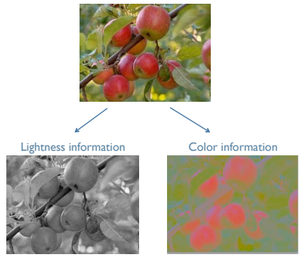
- first rule of color: do not talk about color!
  - color is confusing if treated as monolithic
- decompose into three channels
  - ordered can show magnitude
    - luminance
    - saturation
  - categorical can show identity
    - hue



- channels have different properties
  - what they convey directly to perceptual system
  - how much they can convey: how many discriminable bins can we use?

Luminance

- need luminance for edge detection
  - fine-grained detail only visible through luminance contrast
  - legible text requires luminance contrast!
- intrinsic perceptual ordering

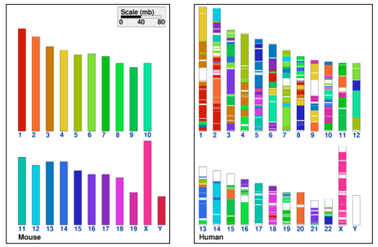


[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

Categorical color: limited number of discriminable bins

- human perception built on relative comparisons
  - great if color contiguous
  - surprisingly bad for absolute comparisons
- noncontiguous small regions of color
  - fewer bins than you want
  - rule of thumb: 6-12 bins, including background and highlights

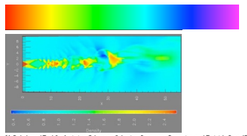
– so what can we do instead?



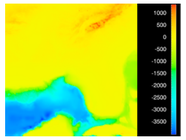
[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]

Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - fine-grained structure visible and nameable



[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]



[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. http://www.research.ibm.com/people/l/lloydt/color/color.HTM]

[Transfer Functions in Direct Volume Rendering: Design, Interface, Interaction. Kindlmann. SIGGRAPH 2002 Course Notes]

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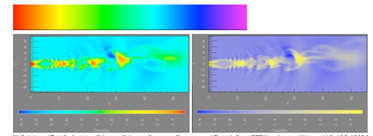
- alternatives
  - large-scale structure: fewer hues



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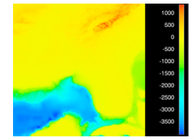

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- problems
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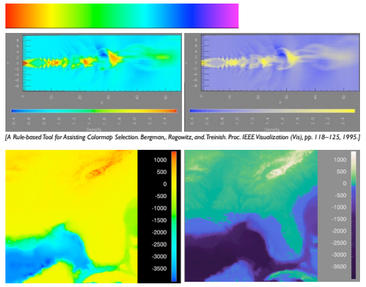
- alternatives
  - –large-scale structure: fewer hues
  - –fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]



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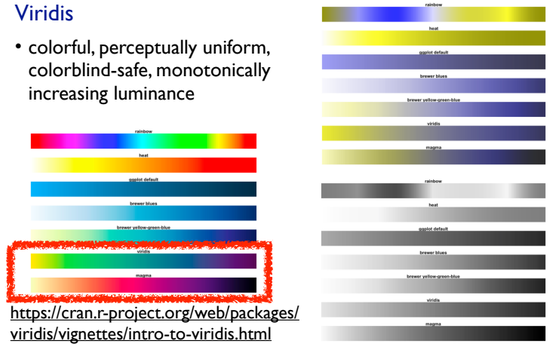
Viridis

- colorful, perceptually uniform, colorblind-safe, monotonically increasing luminance



https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html

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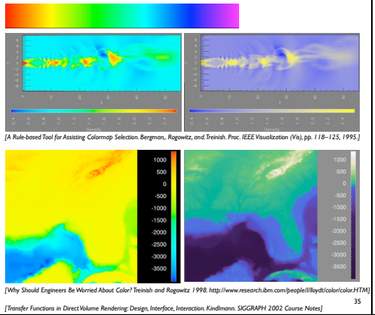
  - –segmented rainbows for binned or categorical



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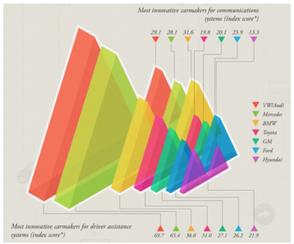
Visual encoding: 2D vs 3D

- 2D good, 3D better?
  - –not so fast…

http://amberleyromo.com/images/Bookcover/Animal-Farm.png

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

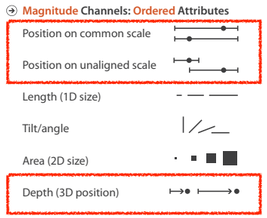


http://viz.wtf/post/137826497077/eye-popping-3d-triangles

http://viz.wtf/post/139002022202/designer-drugs-ht-ducqn

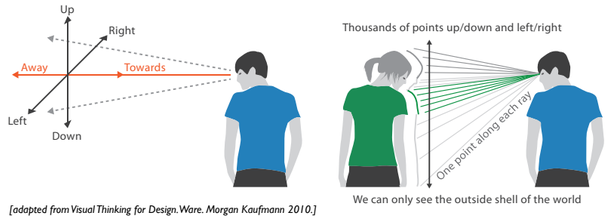
Depth vs power of the plane

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



Life in 3D?…

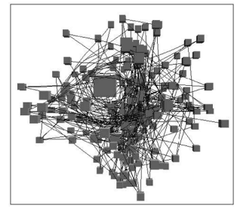
- we don't really live in 3D: we see in 2.05D
  - –acquire more info on image plane quickly from eye movements
  - –acquire more info for depth slower, from head/body motion



[adapted from Visual Thinking for Design. Ware. Morgan Kaufmann 2010.]

Occlusion hides information

- occlusion
- interaction complexity



[Distortion Viewing Techniques for 3D Data. Carpendale et al. InfoVis1996.]

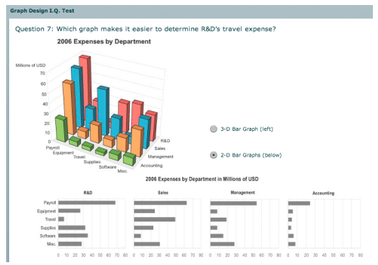
Perspective distortion loses information

- 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

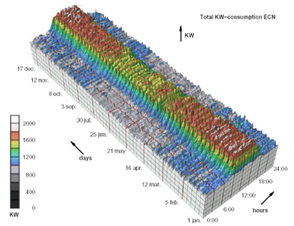
- 3D bars never a good idea!



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

No unjustified 3D example: Time-series data

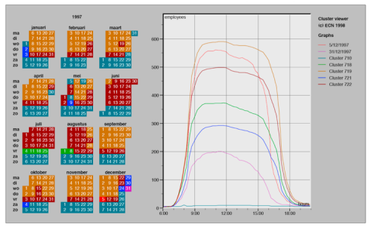
- extruded curves: detailed comparisons impossible



[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

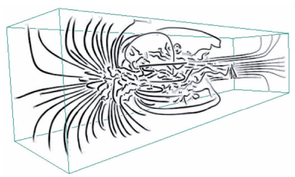
- derived data: cluster hierarchy
- juxtapose multiple views: calendar, superimposed 2D curves



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

Justified 3D: shape perception

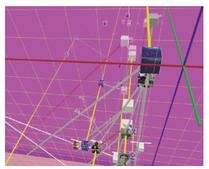
- benefits outweigh costs when task is shape perception for 3D spatial data
  - –interactive navigation supports synthesis across many viewpoints



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

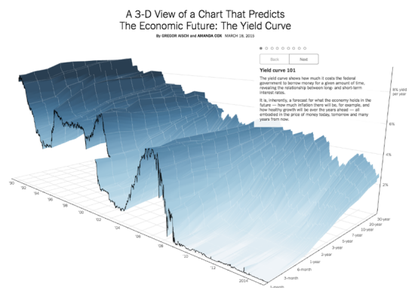
No unjustified 3D

- 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



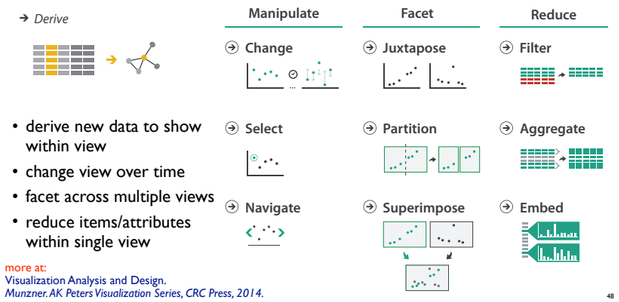
[WEBPATH-a three dimensional Web history. Frecon and Smith. Proc. InfoVis 1999]

Justified 3D: Economic growth curve



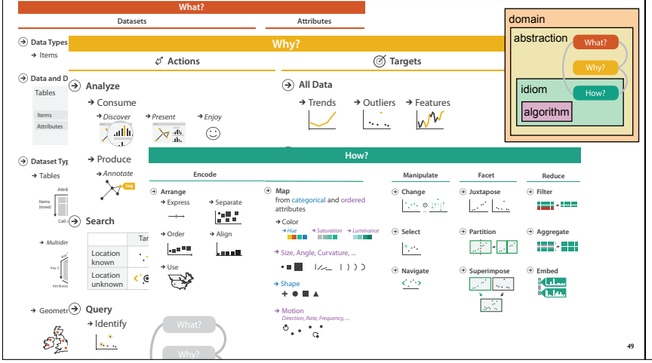
http://www.nytimes.com/interactive/2015/03/19/upshot/3d-yield-curve-economic-growth.html

Four strategies to handle complexity



- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

more at:
Visualization Analysis and Design.
Munzner. AK Peters Visualization Series, CRC Press, 2014.



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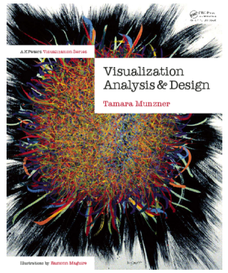

Visualization Analysis and Design.
Munzner. A K Peters Visualization Series, CRC Press, Visualization Series, 2014.