# Lectures 1&2:
# *Manipulate & Interact*

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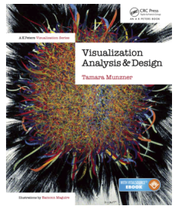



*DSCI 532, Data Visualization 2*
*Week 1, Jan 2 / Jan 4 2018*

www.cs.ubc.ca/~tmm/courses/mds-viz2-17

@tamaramunzner

## 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 represent all the data?

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

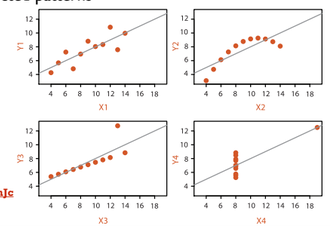
- summaries lose information, details matter
  - confirm expected and find unexpected patterns
  - assess validity of statistical model

**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






## 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.**

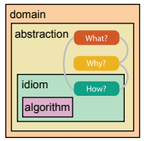
- computational limits
  - processing time
  - system memory
- human limits
  - human attention and memory
- display limits
  - pixels are precious resource, the most constrained resource
  - **information density**: ratio of space used to encode info vs unused whitespace
    - tradeoff between clutter and wasting space, find sweet spot between dense and sparse



## 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).*]



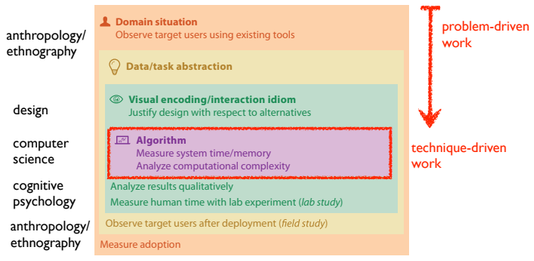
## Why is validation difficult?

- different ways to get it wrong at each level



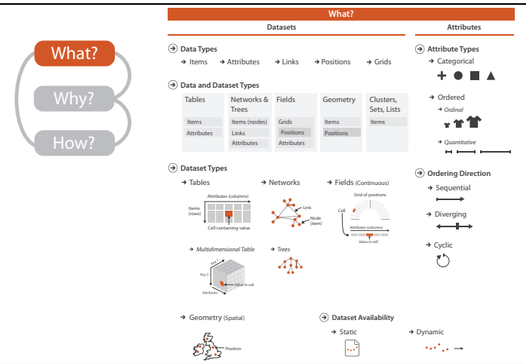

## Why is validation difficult?

- solution: use methods from different fields at each level




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

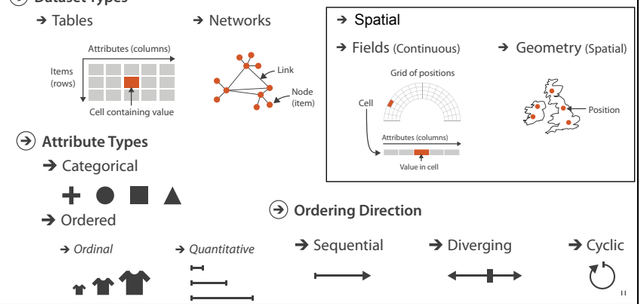






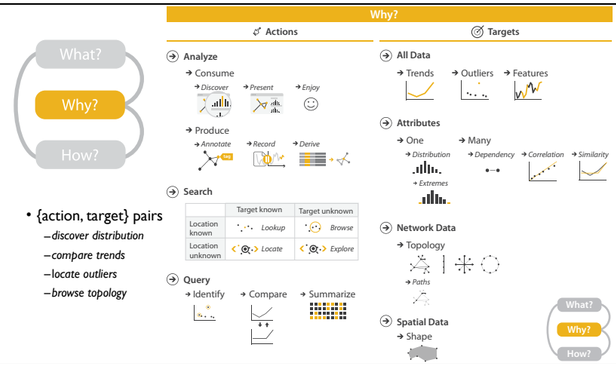

## Types: Datasets and data

- Dataset Types
  - Tables
  - Networks
  - Spatial
  - Fields (Continuous)
  - Geometry (Spatial)
- Attribute Types
  - Categorical
  - Ordered
    - Ordinal
    - Quantitative
- Ordering Direction
  - Sequential
  - Diverging
  - Cyclic






## Why?




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



## Actions: Analyze, Query

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




## Derive

- 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*

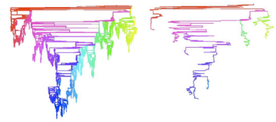
Derived Data

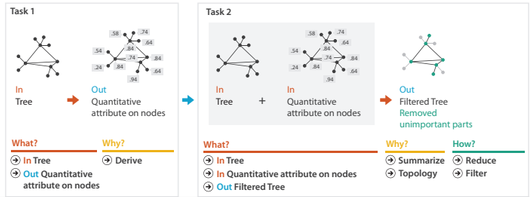


## Analysis example: Derive one attribute

- 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.]*

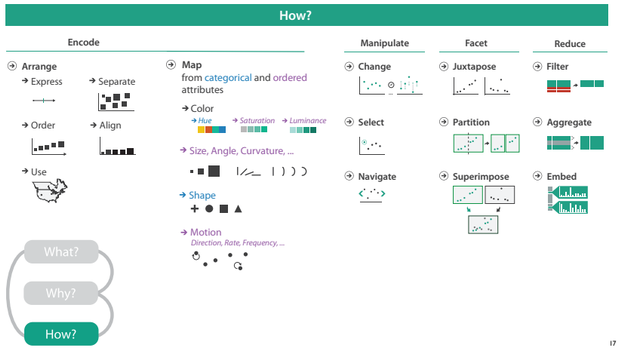







## Why: Targets

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

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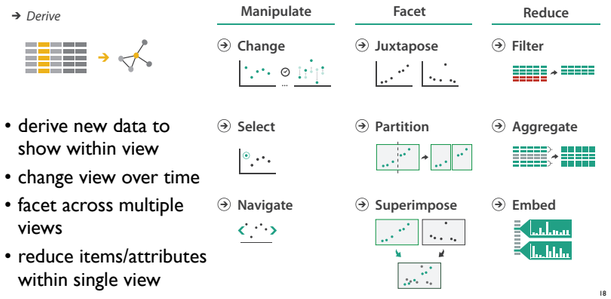
## How to handle complexity: 1 previous strategy + 3 more




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

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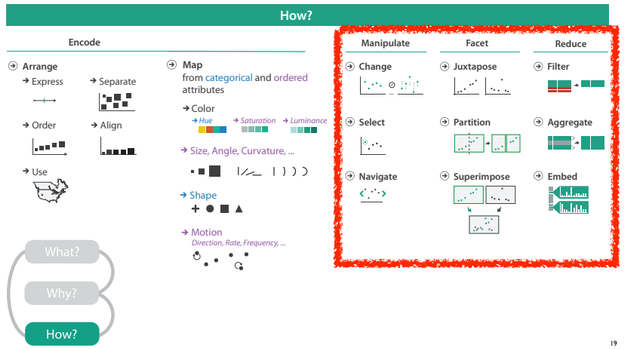


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## Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 1: What's Vis and Why Do It?*
  - *Chap 2: What: Data Abstraction*
  - *Chap 3: Why: Task Abstraction*
  - *Chap 4: Analysis: Four Levels for Validation*
- *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.
- Visualization of Time-Oriented Data. Aigner, Miksch, Schumann, and Tominski. Springer, 2011.

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# Manipulate / Interact

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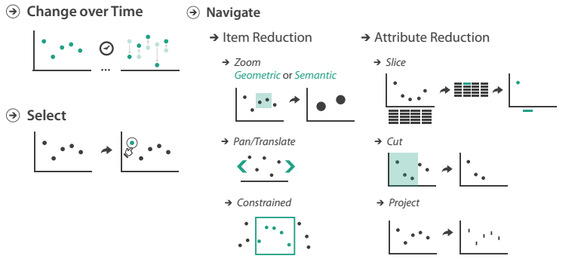
## Manipulate

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## Change over time

- change any of the other choices
  - encoding itself
  - parameters
  - arrange: rearrange, reorder
  - aggregation level, what is filtered...
  - interaction entails change

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## Idiom: **Re-encode** System: **Tableau**

*made using Tableau, http://tableausoftware.com*

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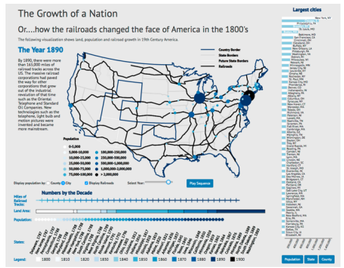
## Idiom: **Change parameters**

- widgets and controls
  - sliders, buttons, radio buttons, checkboxes, dropdowns/comboboxes
- pros
  - clear affordances, self-documenting (with labels)
- cons
  - uses screen space
- design choices
  - separated vs interleaved
    - controls & canvas




*[Growth of a Nation](http://laurenwood.github.io/)*

*slide inspired by: Alexander Lex, Utah*

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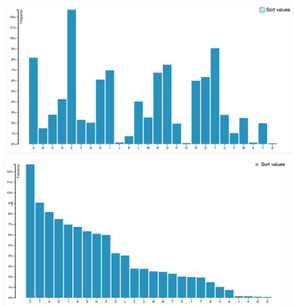
## Idiom: **Change order/arrangement**

- what: simple table
- how: data-driven reordering
- why: find extreme values, trends




*[Sortable Bar Chart](https://bl.ocks.org/mbostock/3885705)*

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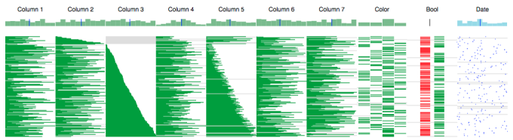
## Idiom: **Reorder** System: **DataStripes**

- what: table with many attributes
- how: data-driven reordering by selecting column
- why: find correlations between attributes




*[http://carlmanaster.github.io/datastripes/]*

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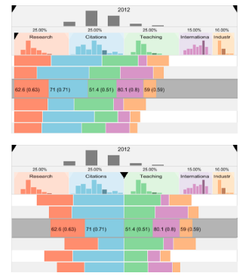
## Idiom: **Change alignment** System: **LineUp**

- stacked bars
  - easy to compare
    - first segment
    - total bar
- align to different segment
  - supports flexible comparison




*[LineUp: Visual Analysis of Multi-Attribute Rankings. Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286.]*

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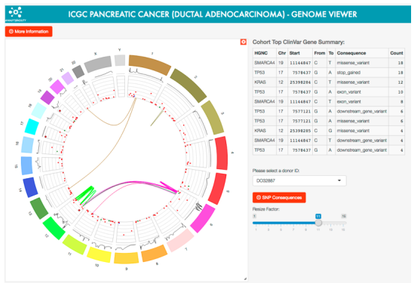
## Shiny example

- APGI genome browser
  - tooling: R/Shiny
  - interactivity
    - tooltip detail on demand on hover
    - expand/contract chromosomes
    - expand/contract control panes




https://gallery.shinyapps.io/genome_browser/

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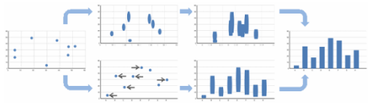
## Idiom: **Animated transitions**

- smooth interpolation from one state to another
  - alternative to jump cuts, supports item tracking
    - best case for animation
  - staging to reduce cognitive load
- example: animated transitions in statistical data graphics



video: vimeo.com/19278444

*[Animated Transitions in Statistical Data Graphics. Heer and Robertson. IEEE TVCG (Proc InfoVis 2007) 13(6):1240-1247, 2007]*

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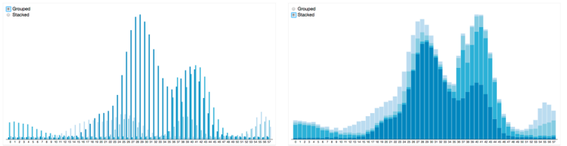
## Idiom: **Animated transitions - visual encoding change**

- smooth transition from one state to another
  - alternative to jump cuts, supports item tracking
    - best case for animation
  - staging to reduce cognitive load




*[Stacked to Grouped Bars](http://bl.ocks.org/mbostock/3943967)*

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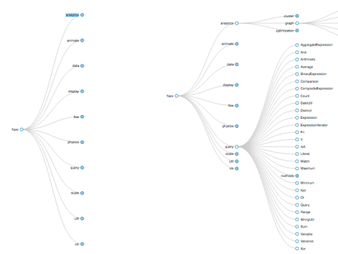
## Idiom: **Animated transition - tree detail**

- animated transition
  - network drilldown/rollup



[Collapsible Tree](https://bl.ocks.org/mbostock/4339083)

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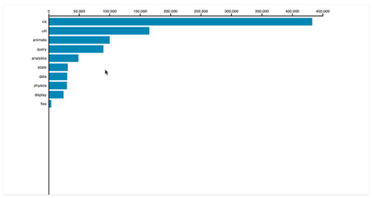
## Idiom: **Animated transition - bar detail**

- example: hierarchical bar chart
  - add detail during transition to new level of detail



[Hierarchical Bar Chart](https://bl.ocks.org/mbostock/1283663)



## Interaction technology

- what do you design for?
  - mouse & keyboard on desktop?
    - large screens, hover, multiple clicks
  - touch interaction on mobile?
    - small screens, no hover, just tap
  - gestures from video / sensors?
    - ergonomic reality vs movie bombast
  - eye tracking?


Data visualization and the news - Gregor Aisch (37 min)
vimeo.com/182590214

I Hate Tom Cruise - Alex Kauffmann (5 min)
www.youtube.com/watch?v=QXLfT9sFcbc

*slide inspired by: Alexander Lex, Utah*



## Selection

- selection: basic operation for most interaction
- design choices
  - how many selection types?
    - interaction modalities
      - click/tap (heavyweight) vs hover (lightweight but not available on most touchscreens)
      - multiple click types (shift-click, option-click, …)
      - proximity beyond click/hover (touching vs nearby vs distant)
    - application semantics
      - adding to selection set vs replacing selection
      - can selection be null?
        - ex: toggle so nothing selected if click on background
      - primary vs secondary (ex: source/target nodes in network)
      - group membership (add/delete items, name group, …)




## Highlighting

- highlight: change visual encoding for selection targets
  - visual feedback closely tied to but separable from selection (interaction)
- design choices: typical visual channels
  - change item color
    - but hides existing color coding
  - add outline mark
  - change size (ex: increase outline mark linewidth)
  - change shape (ex: from solid to dashed line for link mark)
- unusual channels: motion
  - motion: usually avoid for single view
    - with multiple views, could justify to draw attention to other views




## Tooltips

- popup information for selection
  - hover or click
  - can provide useful additional detail on demand
  - beware: does not support overview!
    - always consider if there's a way to visually encode directly to provide overview
    - "If you make a rollover or tooltip, assume nobody will see it. If it's important, make it explicit."
      - Gregor Aisch, NYTimes

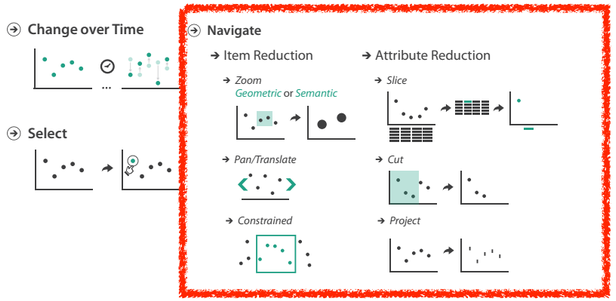


## Rule of thumb: **Responsiveness is required**

- *visual feedback: three rough categories*
  - *0.1 seconds: perceptual processing*
    - subsecond response for mouseover highlighting - ballistic motion
  - *1 second: immediate response*
    - fast response after mouseclick, button press - Fitts' Law limits on motor control
  - *10 seconds: brief tasks*
    - bounded response after dialog box - mental model of heavyweight operation (file load)
- scalability considerations
  - highlight selection without complete redraw of view (graphics frontbuffer)
  - show hourglass for multi-second operations (check for cancel/undo)
  - show progress bar for long operations (process in background thread)
  - rendering speed when item count is large (guaranteed frame rate)



## Manipulate






## Navigate: Changing viewpoint/visibility

- change viewpoint
  - changes which items are visible within view
- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways




## Idiom: **Scrollytelling**

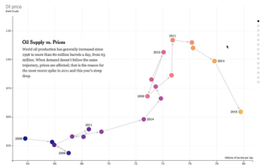
- how: navigate page by scrolling (panning down)
- pros:
  - familiar & intuitive, from standard web browsing
  - linear (only up & down) vs possible overload of click-based interface choices
- cons:
  - full-screen mode may lack affordances
  - scrolljacking, no direct access
  - unexpected behaviour
  - continuous control for discrete steps


https://eagereyes.org/blog/2016/the-scrollytelling-scourge
[How to Scroll, Bostock](https://bost.ocks.org/mike/scroll/)

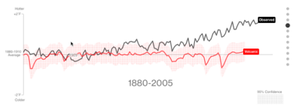
*slide inspired by: Alexander Lex, Utah*



## Scrollytelling examples




https://www.nytimes.com/interactive/2015/09/30/business/how-the-us-and-opec-drive-oil-prices.html?_r=1



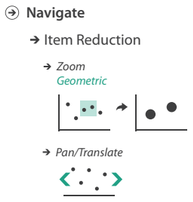

https://www.bloomberg.com/graphics/2015-whats-warming-the-world/

*slide inspired by: Alexander Lex, Utah*



## Navigate: Changing viewpoint/visibility

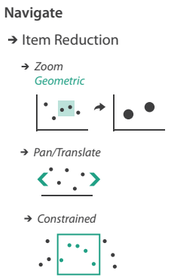
- change viewpoint
  - changes which items are visible within view
- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways
  - rotate/spin
    - typically in 3D
  - zoom in/out
    - enlarge/shrink world == move camera closer/further
    - geometric zoom: standard, like moving physical object






## Navigate: Unconstrained vs constrained

- unconstrained navigation
  - easy to implement for designer
  - hard to control for user
    - easy to overshoot/undershoot
- constrained navigation
  - typically uses animated transitions
  - trajectory automatically computed based on selection
    - just click; selection ends up framed nicely in final viewport






## Idiom: **Animated transition + constrained navigation**

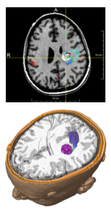
- example: geographic map
  - simple zoom, only viewport changes, shapes preserved

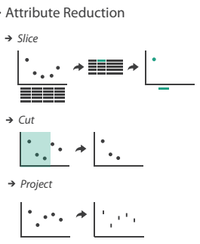

[Zoom to Bounding Box](https://bl.ocks.org/mbostock/4699541)



## Navigate: Reducing attributes

- continuation of camera metaphor
  - slice
    - show only items matching specific value for given attribute: slicing plane
    - axis aligned, or arbitrary alignment
  - cut
    - show only items on far slide of plane from camera
  - project
    - change mathematics of image creation
      - orthographic (eliminate 3rd dimension)
      - perspective (foreshortening captures limited 3D information)



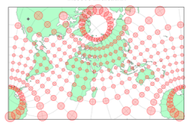



*[Interactive Visualization of Multimodal Volume Data for Neurosurgical Tumor Treatment. Rieder, Ritter, Raspe, and Peitgen. Computer Graphics Forum (Proc. EuroVis 2008) 27:3 (2008), 1055–1062.]*

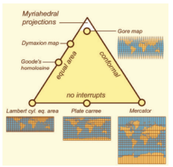


## Navigate: Cartographic projections

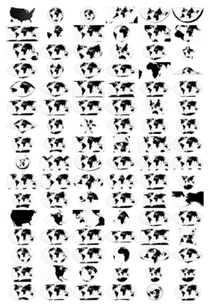
- project from 2D sphere surface to 2D plane
  - can only fully preserve 2 out of 3
    - angles: conformal
    - area: equal area
    - contiguity: no interruptions




https://www.jasondavies.com/maps/tissot/




https://www.win.tue.nl/~vanwijk/myriahedral/



*[Every Map Projection](https://bl.ocks.org/mbostock/29cddc0006f8b98eff12e60dd08f59a7)*



## Interaction benefits

- interaction pros
  - major advantage of computer-based vs paper-based visualization
  - flexible, powerful, intuitive
    - exploratory data analysis: change as you go during analysis process
    - fluid task switching: different visual encodings support different tasks
  - animated transitions provide excellent support
    - empirical evidence that animated transitions help people stay oriented

## Interaction limitations

- interaction has a time cost
  - sometimes minor, sometimes significant
  - degenerates to human-powered search in worst case
- remembering previous state imposes cognitive load
  - *rule of thumb: eyes over memory*
    - *hard to compare visible item to memory of what you saw*
    - ex: maintaining context/orientation when navigating
    - ex: tracking complex changes during animation
- controls may take screen real estate
  - or invisible functionality may be difficult to discover (lack of affordances)
- users may not interact as planned by designer
  - NYTimes logs show ~90% don't interact beyond scrollytelling - Aisch, 2016



## Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 11: Manipulate View*
- *Animated Transitions in Statistical Data Graphics*. Heer and Robertson. IEEE Trans. on Visualization and Computer Graphics (Proc. InfoVis07) 13:6 (2007), 1240–1247.
- *Selection: 524,288 Ways to Say "This is Interesting"*. Wills. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 54–61, 1996.
- *Smooth and efficient zooming and panning*. van Wijk and Nuij. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 15–22, 2003.
- *Starting Simple - adding value to static visualisation through simple interaction*. Dix and Ellis. Proc. Advanced Visual Interfaces (AVI), pp. 124–134, 1998.