Ch 7: Arrange Tables

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CPSC 547, Information Visualization
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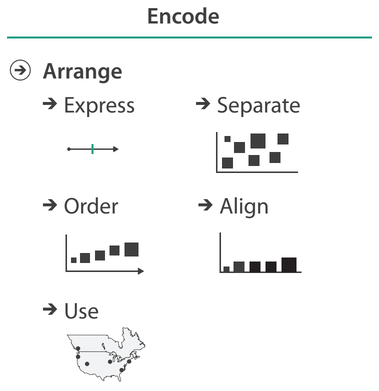
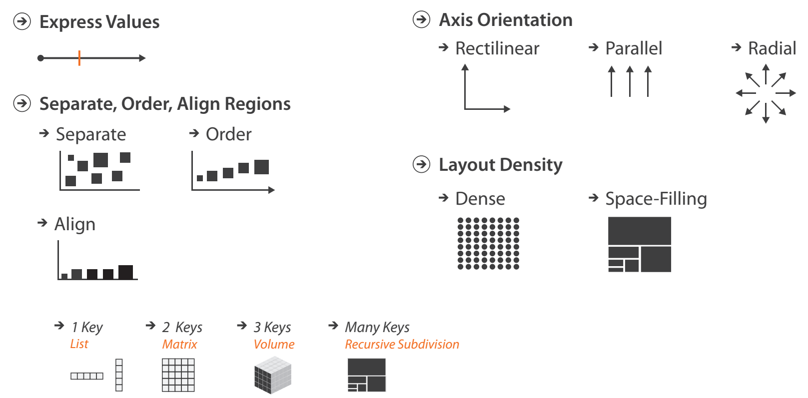
http://www.cs.ubc.ca/~tmm/courses/547-17

VAD Ch 7: Arrange Tables

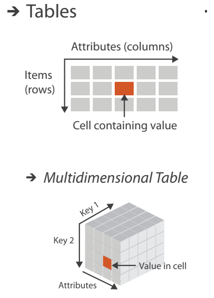


Arrange tables



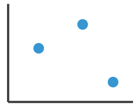
Keys and values

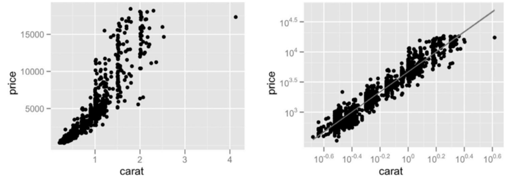
- key
  - independent attribute
  - used as unique index to look up items
  - simple tables: 1 key
  - multidimensional tables: multiple keys
- value
  - dependent attribute, value of cell
- classify arrangements by key count
  - 0, 1, 2, many...



Idiom: **scatterplot**

- *express* values
  - quantitative attributes
- no keys, only values
  - data
    - 2 quant attribs
  - mark: points
  - channels
    - horiz + vert position
  - tasks
    - find trends, outliers, distribution, correlation, clusters
  - scalability
    - hundreds of items





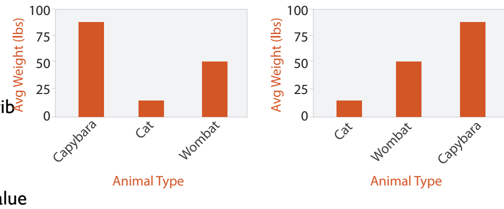
[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Some keys: Categorical regions

- **regions**: contiguous bounded areas distinct from each other
  - using space to ***separate*** (proximity)
  - following expressiveness principle for categorical attributes
- use ordered attribute to ***order*** and ***align*** regions

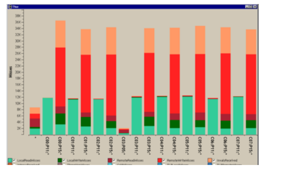
Idiom: **bar chart**

- one key, one value
  - data
    - 1 categ attrib, 1 quant attrib
  - mark: lines
  - channels
    - length to express quant value
    - spatial regions: one per mark
      - separated horizontally, aligned vertically
      - ordered by quant attrib
        - » by label (alphabetical), by length attrib (data-driven)
  - task
    - compare, lookup values
  - scalability
    - dozens to hundreds of levels for key attrib



Idiom: **stacked bar chart**

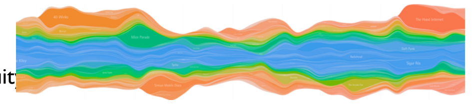
- one more key
  - data
    - 2 categ attrib, 1 quant attrib
  - mark: vertical stack of line marks
    - **glyph**: composite object, internal structure from multiple marks
  - channels
    - length and color hue
    - spatial regions: one per glyph
      - aligned: full glyph, lowest bar component
      - unaligned: other bar components
  - task
    - part-to-whole relationship
  - scalability
    - several to one dozen levels for stacked attrib



[Using Visualization to Understand the Behavior of Computer Systems. Bosch. Ph.D. thesis, Stanford Computer Science, 2001.]

Idiom: **streamgraph**

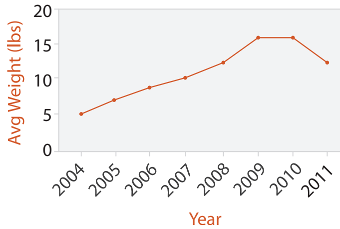
- generalized stacked graph
  - emphasizing horizontal continuity
    - vs vertical items
  - data
    - 1 categ key attrib (artist)
    - 1 ordered key attrib (time)
    - 1 quant value attrib (counts)
  - derived data
    - geometry: layers, where height encodes counts
    - 1 quant attrib (layer ordering)
  - scalability
    - hundreds of time keys
    - dozens to hundreds of artist keys
      - more than stacked bars, since most layers don't extend across whole chart



[Stacked Graphs Geometry & Aesthetics. Byron and Wattenberg. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14(6): 1245–1252, (2008).]

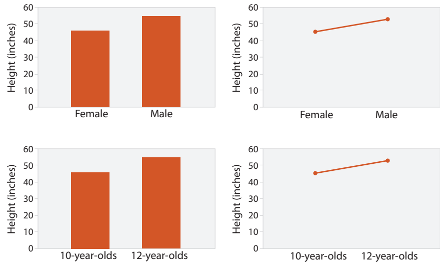
Idiom: **line chart**

- one key, one value
  - data
    - 2 quant attribs
  - mark: points
    - line connection marks between them
  - channels
    - aligned lengths to express quant value
    - separated and ordered by key attrib into horizontal regions
  - task
    - find trend
      - connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next



Choosing bar vs line charts

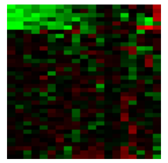
- depends on type of key attrib
  - bar charts if categorical
  - line charts if ordered
- do not use line charts for categorical key attribs
  - violates expressiveness principle
    - implication of trend so strong that it overrides semantics!
      - "The more male a person is, the taller he/she is"

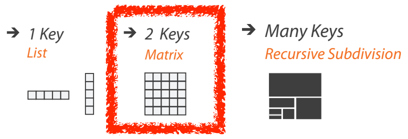


after [Bars and Lines: A Study of Graphic Communication. Zacks and Tversky. Memory and Cognition 27:6 (1999), 1073–1079.]

Idiom: **heatmap**

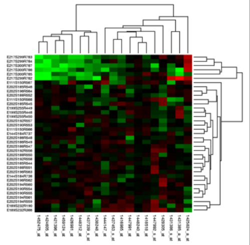
- two keys, one value
  - data
    - 2 categ attribs (gene, experimental condition)
    - 1 quant attrib (expression levels)
  - marks: area
    - separate and align in 2D matrix
      - indexed by 2 categorical attributes
  - channels
    - color by quant attrib
      - (ordered diverging colormap)
  - task
    - find clusters, outliers
  - scalability
    - 1M items, 100s of categ levels, ~10 quant attrib levels

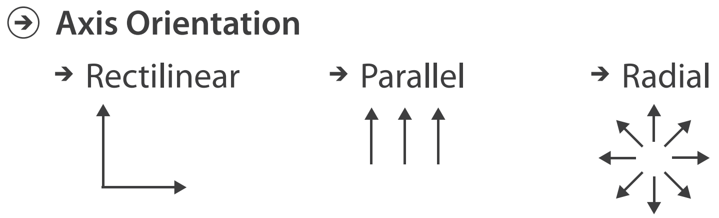




Idiom: **cluster heatmap**

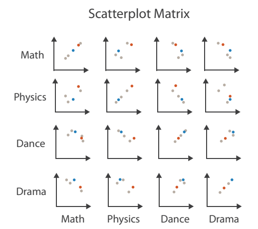
- in addition
  - derived data
    - 2 cluster hierarchies
  - dendrogram
    - parent-child relationships in tree with connection line marks
    - leaves aligned so interior branch heights easy to compare
  - heatmap
    - marks (re-)ordered by cluster hierarchy traversal

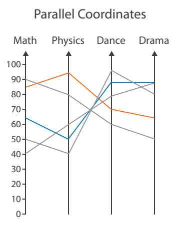




Idioms: **scatterplot matrix, parallel coordinates**

- scatterplot matrix (SPLOM)
  - rectilinear axes, point mark
  - all possible pairs of axes
  - scalability
    - one dozen attribs
    - dozens to hundreds of items
- parallel coordinates
  - parallel axes, jagged line representing item
  - rectilinear axes, item as point
    - axis ordering is major challenge
  - scalability
    - dozens of attribs
    - hundreds of items





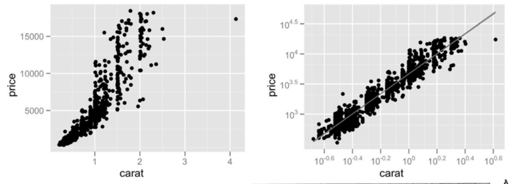
Table

Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

after [Visualization Course Figures. McGuffin, 2014. http://www.michaelmcguffin.com/courses/vis/]

Task: Correlation

- scatterplot matrix
  - positive correlation
    - diagonal low-to-high
  - negative correlation
    - diagonal high-to-low
  - uncorrelated
- parallel coordinates
  - positive correlation
    - parallel line segments
  - negative correlation
    - all segments cross at halfway point
  - uncorrelated
    - scattered crossings



[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

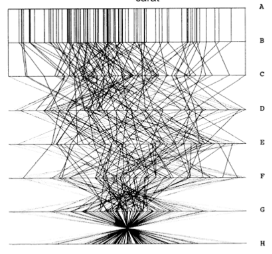
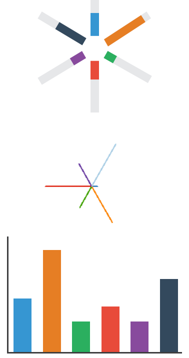


Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of $\rho = 1, .8, .2, 0, -.2, -.8$, and -1.

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. Journ. American Statistical Association 85:411 (1990), 664–675.]

Idioms: **radial bar chart, star plot**

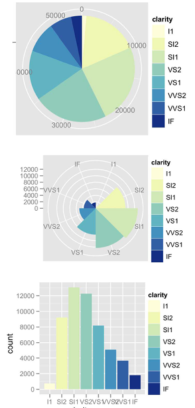
- radial bar chart
  - –radial axes meet at central ring, line mark
- star plot
  - –radial axes, meet at central point, line mark
- bar chart
  - –rectilinear axes, aligned vertically
- accuracy
  - –length unaligned with radial
    - less accurate than aligned with rectilinear



[Vismon: Facilitating Risk Assessment and Decision Making In Fisheries Management. Booshehrian, Möller, Peterman, and Munzner. Technical Report TR 2011-04, Simon Fraser University, School of Computing Science, 2011.]

Idioms: **pie chart, polar area chart**

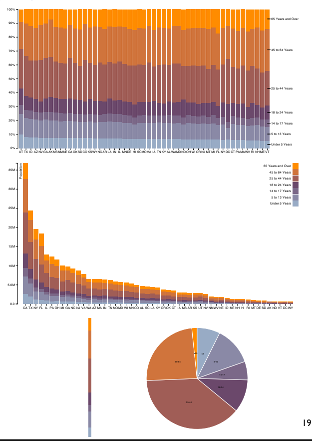
- pie chart
  - –area marks with angle channel
  - –accuracy: angle/area much less accurate than line length
- polar area chart
  - –area marks with length channel
  - –more direct analog to bar charts
- data
  - –1 categ key attrib, 1 quant value attrib
- task
  - –part-to-whole judgements



[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Idioms: **normalized stacked bar chart**

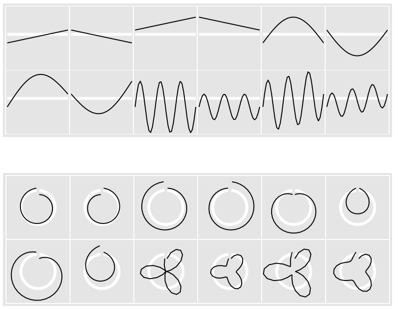
- task
  - –part-to-whole judgements
- normalized stacked bar chart
  - –stacked bar chart, normalized to full vert height
  - –single stacked bar equivalent to full pie
    - high information density: requires narrow rectangle
- pie chart
  - –information density: requires large circle



http://bl.ocks.org/mbostock/3887235,
http://bl.ocks.org/mbostock/3886208,
http://bl.ocks.org/mbostock/3886394.

Idiom: **glyphmaps**

- rectilinear good for linear vs nonlinear trends
- radial good for cyclic patterns

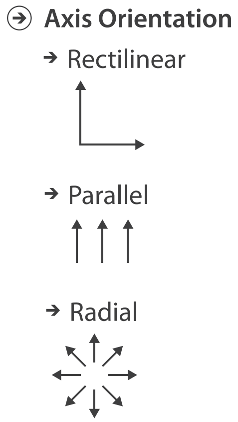


[Glyph-maps for Visually Exploring Temporal Patterns in Climate Data and Models. Wickham, Hofmann, Wickham, and Cook. Environmetrics 23:5 (2012), 382–393.]

Orientation limitations

- rectilinear: scalability wrt #axes
  - 2 axes best
  - 3 problematic
    - –more in afternoon
  - 4+ impossible
- parallel: unfamiliarity, training time
- radial: perceptual limits
  - –angles lower precision than lengths
  - –asymmetry between angle and length
    - can be exploited!

[Uncovering Strengths and Weaknesses of Radial Visualizations - an Empirical Approach. Diehl, Beck and Burch. IEEE TVCG (Proc. InfoVis) 16(6):935–942, 2010.]



Further reading

- Visualization Analysis and Design. Munzner. AK Peters / CRC Press, Oct 2014.
  - –*Chap 7: Arrange Tables*
- Visualizing Data. Cleveland. Hobart Press, 1993.

Paper: D3

- paper types
  - –design studies
  - –technique/algorithm
  - –evaluation
  - –model/taxonomy
  - **–system**

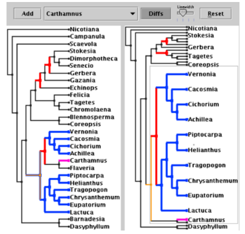
[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

Toolkits

- imperative: how
  - –low-level rendering: Processing, OpenGL
  - –parametrized visual objects: prefuse
    - also flare: prefuse for Flash
- declarative: what
  - –Protoviz, D3, ggplot2
  - –separation of specification from execution
- considerations
  - –expressiveness
    - can I build it?
  - –efficiency
    - how long will it take?
  - –accessibility
    - do I know how?

WebGL/OpenGL

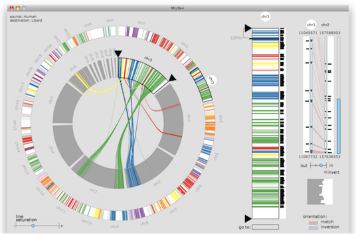
- graphics library
  - –pros
    - power and flexibility, complete control for graphics
    - hardware acceleration
    - many language bindings: C, C++, Java (w/ JOGL)
  - –cons
    - big learning curve if you don't know already
    - no vis support, must roll your own everything
  - –example app: TreeJuxtaposer (OpenGL)



[Fig 5. Munzner et al. TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Proc SIGGRAPH 2003, pp 453-462.]

Processing

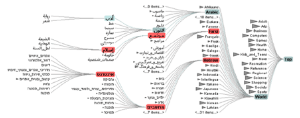
- layer on top of Java/OpenGL
- visualization esp. for artists/designers
- pros
  - –great sandbox for rapid prototyping
  - –huge user community, great documentation
- cons
  - –poor widget library support
- example app: MizBee



[Fig 1. Meyer et al. MizBee: A Multiscale Synteny Browser. Proc. InfoVis 2009.]

prefuse

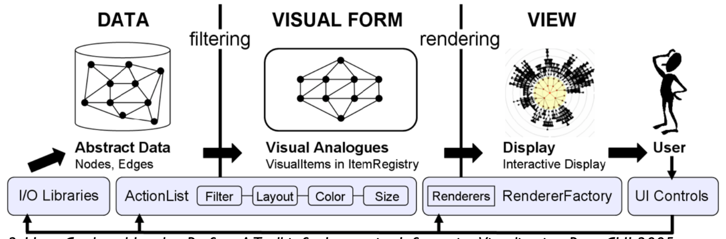
- infovis toolkit, in Java
- fine-grained building blocks for tailored visualizations
- pros
  - –heavily used (previously)
  - –very powerful abstractions
  - –quickly implement most techniques covered so far
- cons
  - –no longer active
  - –nontrivial learning curve
- example app: DOITrees Revisited



[DOITrees Revisited: Scalable, Space-Constrained Visualization of Hierarchical Data. Heer and Card. Proc. Advanced Visual Interfaces (AVI), pp. 421–424, 2004.]

prefuse

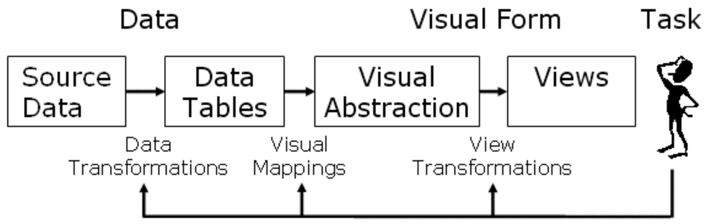
- separation: abstract data, visual form, view
  - –data: tables, networks
  - –visual form: layout, color, size, ...
  - –view: multiple renderers



[Fig 2. Heer, Card, and Landay. Prefuse: A Toolkit for Interactive Information Visualization. Proc. CHI 2005, 421-430]

InfoVis Reference Model

- conceptual model underneath design of prefuse and many other toolkits
- heavily influenced much of infovis (including nested model)
  - –aka infovis pipeline, data state model



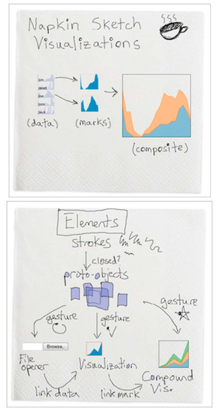
[Redrawn Fig 1.23. Card, Mackinlay, and Shneiderman. Readings in Information Visualization: Using Vision To Think, Chapter 1. Morgan Kaufmann, 1999.]

Declarative toolkits

- imperative tools/libraries
  - –say exactly **how** to do it
  - –familiar programming model
    - OpenGL, prefuse, ...
- declarative: other possibility
  - –just say **what** to do
  - –Protovis, D3

Protovis

- declarative infovis toolkit, in Javascript
  - –also later Java version
- marks with inherited properties
- pros
  - –runs in browser
  - –matches mark/channel mental model
  - –also much more: interaction, geospatial, trees,...
- cons
  - –not all kinds of operations supported
- example app: NapkinVis (2009 course project)



[Fig 1, 3. Chao. NapkinVis. http://www.cs.ubc.ca/~tmm/courses/533-09/projects.html#will]

Protovis Validation

- wide set of old/new app examples
  - –expressiveness, effectiveness, scalability
  - –accessibility
- analysis with cognitive dimensions of notation
  - –closeness of mapping, hidden dependencies
  - –role-expressiveness visibility, consistency
  - –viscosity, diffuseness, abstraction
  - –hard mental operations

[Cognitive dimensions of notations. Green (1989). In A. Sutcliffe and L. Macaulay (Eds.) People and Computers V. Cambridge, UK: Cambridge University Press, pp 443-460.]

D3

- declarative infovis toolkit, in Javascript
- Protovis meets Document Object Model
- pros
  - –seamless interoperability with Web
  - –explicit transforms of scene with dependency info
  - –massive user community, many thirdparty apps/libraries on top of it, lots of docs
- cons
  - –even more different from traditional programming model
- example apps: many

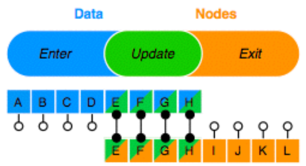
D3

- objectives
  - –compatibility
  - –debugging
  - –performance
- related work typology
  - –document transformers
  - –graphics libraries
  - –infovis systems
    - general note: all related work sections are a mini-taxonomy!

[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

D3 capabilities

- query-driven selection
  - –selection: filtered set of elements queries from the current doc
    - also partitioning/grouping!
  - –operators act on selections to modify content
    - instantaneous or via animated transitions with attribute/style interpolators
    - event handlers for interaction
- data binding to scenegraph elements
  - –data joins bind input data to elements
  - –enter, update, exit subselections
  - –sticky: available for subsequent re-selection
  - –sort, filter



[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

D3 Features

- document transformation as atomic operation
  - –scene changes vs representation of scenes themselves
- immediate property evaluation semantics
  - –avoid confusing consequences of delayed evaluation

- validation
  - –performance benchmarks
    - page loads, frame rate
  - –accessibility
    - everybody has voted with their feet by now!

Next Time

- to read
  - –VAD Ch. 8: Arrange Spatial Data
  - –<u>Radial Sets: Interactive Visual Analysis of Large Overlapping Sets</u>.
    Bilal Alsallakh, Wolfgang Aigner, Silvia Miksch, and Helwig Hauser.
    IEEE Transactions on Visualization and Computer Graphics (Proc InfoVis 2013), 19(12):2496-2505, 2013.
    - paper type: technique