Visualization Analysis & Design, In More Depth

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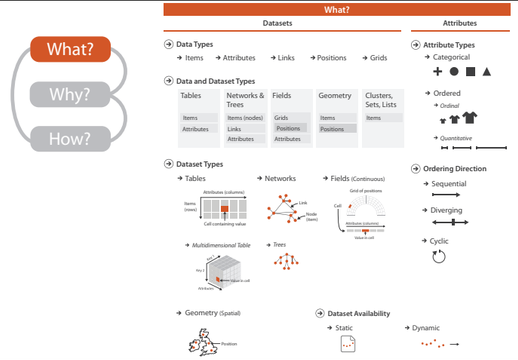
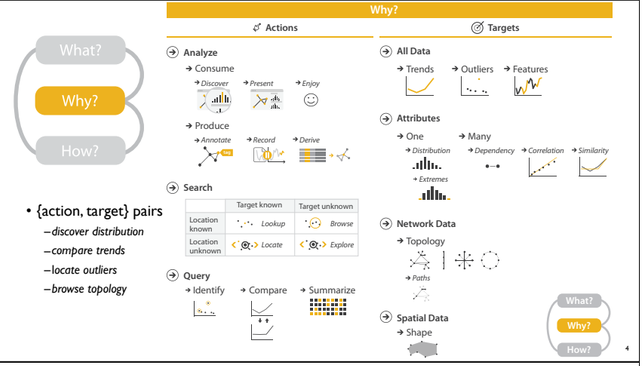
www.cs.ubc.ca/~tmm/talks.html#vad17can-aft @tamaramunzner

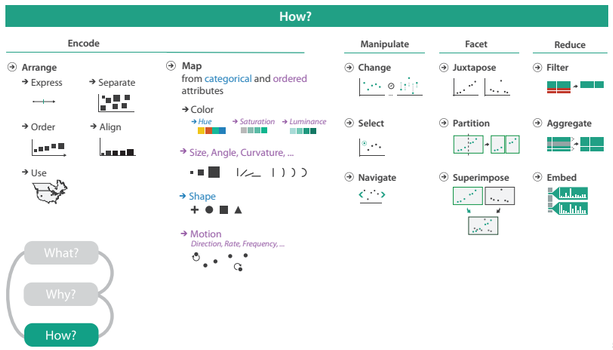
Outline

- Session 1 *10-11:30am*
  Data Visualization Pitfalls to Avoid
  - Introduction
  - Color
  - Space: 2D vs 3D
- Session 2 *12:30-3pm*
  Visualization Analysis & Design, In More Depth
  - Marks and Channels, Perception
  - Arrange Tables
  - Arrange Spatial Data
  - Arrange Networks
  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

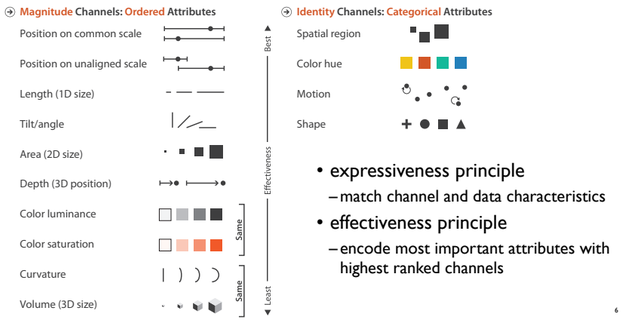




- {action, target} pairs
  - *discover distribution*
  - *compare trends*
  - *locate outliers*
  - *browse topology*

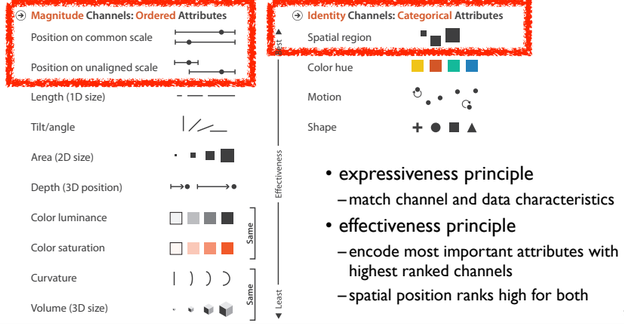


Channels: Rankings



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

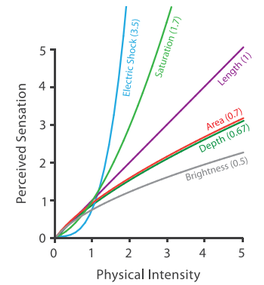
Channels: Expressiveness types and effectiveness rankings



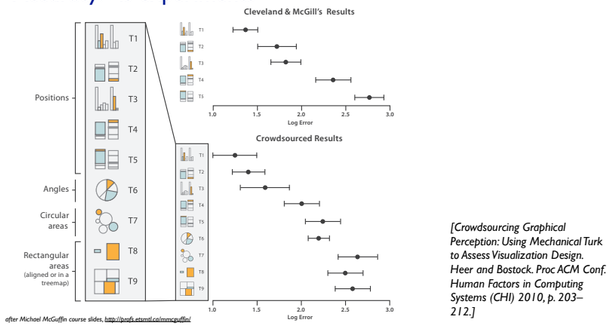
- expressiveness principle
  - match channel and data characteristics
- effectiveness principle
  - encode most important attributes with highest ranked channels
  - spatial position ranks high for both

Accuracy: Fundamental Theory

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



Accuracy: Vis experiments

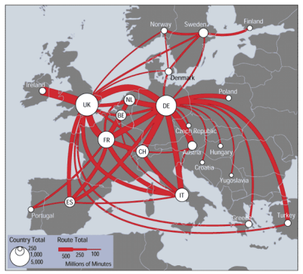


[Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

after Michael McGuffin course slides, http://profs.etsmtl.ca/mmcguffin/

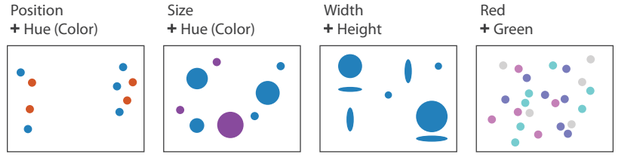
Discriminability: How many usable steps?

- must be sufficient for number of attribute levels to show
  - linewidth: few bins



[mappa.mundi.net/maps/maps_014/telegeography.html]

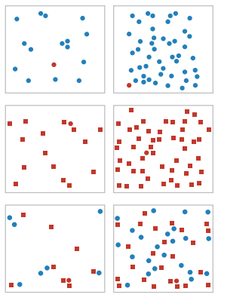
Separability vs. Integrality



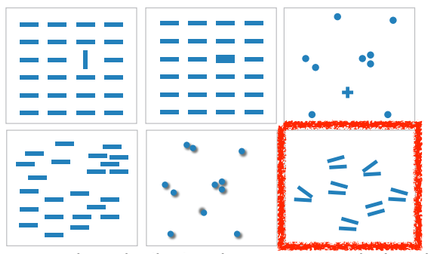
2 groups each | 2 groups each | 3 groups total: integral area | 4 groups total: integral hue

Popout

- find the red dot
  - how long does it take?
- parallel processing on many individual channels
  - speed independent of distractor count
  - speed depends on channel and amount of difference from distractors
- serial search for (almost all) combinations
  - speed depends on number of distractors



Popout

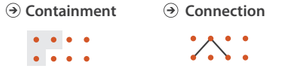


- many channels: tilt, size, shape, proximity, shadow direction, ...
- but not all! parallel line pairs do not pop out from tilted pairs

Grouping

- containment
- connection
- proximity
  - same spatial region
- similarity
  - same values as other categorical channels

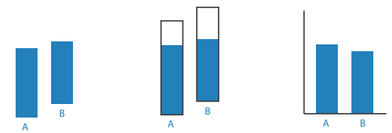
Marks as Links



Identity Channels: Categorical Attributes

Relative vs. absolute judgements

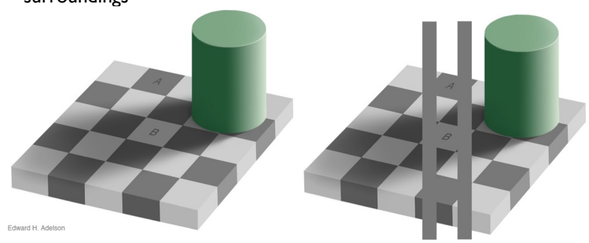
- perceptual system mostly operates with relative judgements, not absolute
  - that's why accuracy increases with common frame/scale and alignment
  - Weber's Law: ratio of increment to background is constant
    - filled rectangles differ in length by 1:9, difficult judgement
    - white rectangles differ in length by 1:2, easy judgement



after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Relative luminance judgements

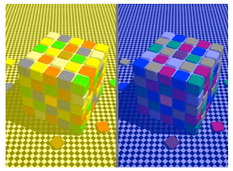
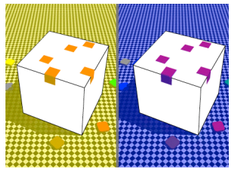
- perception of luminance is contextual based on contrast with surroundings



http://persci.mit.edu/gallery/checkershadow

Relative color judgements

- color constancy across broad range of illumination conditions

http://www.purveslab.net/seeforyourself/

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 5: Marks and Channels*
- *On the Theory of Scales of Measurement.* Stevens. Science 103:2684 (1946), 677–680.
- Psychophysics: Introduction to its Perceptual, Neural, and Social Prospects. Stevens. Wiley, 1975.
- *Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods.* Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.
- *Perception in Vision.* Healey. http://www.csc.ncsu.edu/faculty/healey/PP
- Visual Thinking for Design. Ware. Morgan Kaufmann, 2008.
- Information Visualization: Perception for Design, 3rd edition. Ware. Morgan Kaufmann /Academic Press, 2004.

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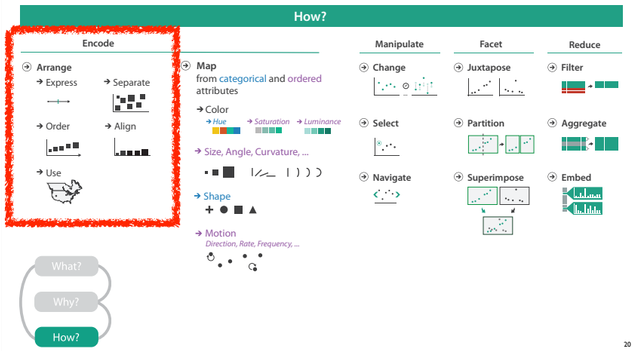
http://www.cs.ubc.ca/~tmm/talks.html#vad17can-aft @tamaramunzner



Encode tables: Arrange space

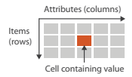
Encode

- Arrange
  - Express
  - Separate
  - Order
  - Align

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...

→ Tables



→ *Multidimensional Table*

Express Values → *1 Key List* → *2 Keys Matrix* → *3 Keys Volume* → *Many Keys Recursive Subdivision*

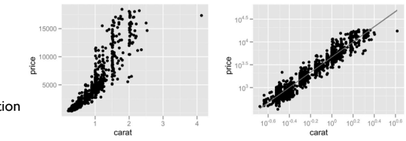
0 Keys

Express Values → *1 Key List* → *2 Keys Matrix* → *3 Keys Volume* → *Many Keys Recursive Subdivision*

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

Express Values



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

Some keys

Express Values → *1 Key List* → *2 Keys Matrix* → *3 Keys Volume* → *Many Keys Recursive Subdivision*

Some keys: Categorical regions

→ Separate → Order → Align

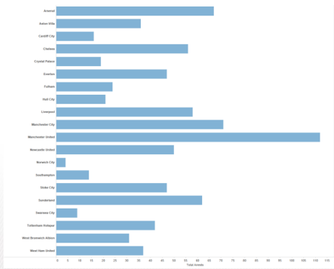
- **regions**: contiguous bounded areas distinct from each other
  - using space to ***separate*** (proximity)
  - following expressiveness principle for categorical attributes
- use ordered attribute to ***order*** and ***align*** regions

1 Key List → *2 Keys Matrix* → *3 Keys Volume* → *Many Keys Recursive Subdivision*

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

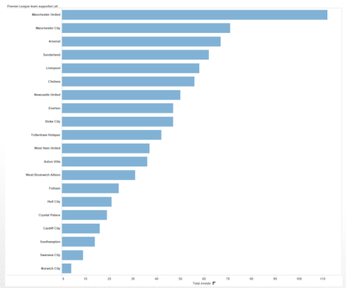
Separated and Aligned but not Ordered



LIMITATION: Hard to know rank. What's the 4th most? The 7th?

[Slide courtesy of Ben Jones]

Separated, Aligned and Ordered



[Slide courtesy of Ben Jones]

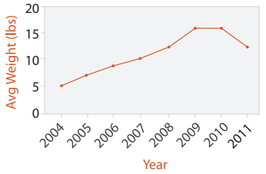
Separated but not Ordered or Aligned

LIMITATION: Hard to make comparisons

[Slide courtesy of Ben Jones]

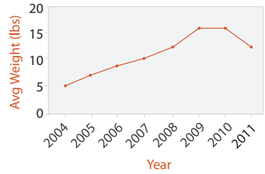
Idiom: **line chart**

- 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



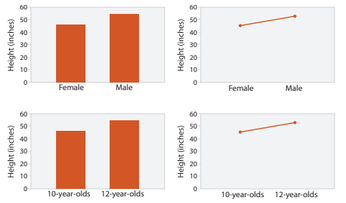
Idiom: **line chart / dot plot**

- 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
  - scalability
    - hundreds of key levels, hundreds of value levels



Choosing bar vs line charts

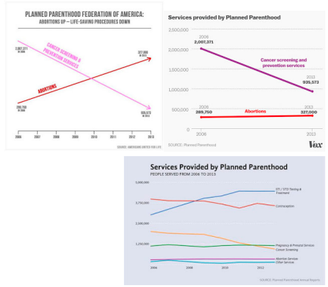
- depends on type of key attrib
  - –bar charts if categorical
  - –line charts if ordered
- do not use line charts for categorical key attribs
  - –violates expressiveness principle
    - implication of trend so strong that it overrides semantics!
      - – "The more male a person is, the taller he/she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



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

Chart axes

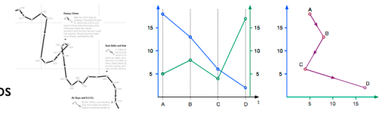
- labelled axis is critical
- avoid cropping y-axis
  - –include 0 at bottom left
  - –or slope misleads
- dual axes controversial
  - –acceptable if commensurate
  - –beware, very easy to mislead!

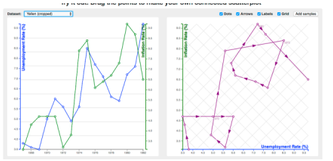


http://www.thefunctionalart.com/2015/10/if-you-see-bullshit-say-bullshit.html

Idiom: **connected scatterplots**

- scatterplot with line connection marks
  - –popular in journalism
  - –horiz + vert axes: value attribs
  - –line connection marks: temporal order
  - –alternative to dual-axis charts
    - horiz: time
    - vert: two value attribs
- empirical study
  - –engaging, but correlation unclear



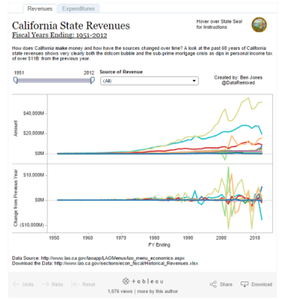


[The Connected Scatterplot for Presenting Paired Time Series. Haraz, Kosara and Franconeri. IEEE TVCG 22(9):2174-86, 2016.]

http://steveharoz.com/research/connected_scatterplot/

Idiom: **Indexed line charts**

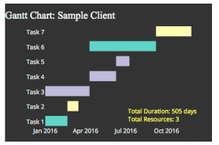
- data: 2 quant attires
  - – 1 key + 1 value
- derived data: new quant value attrib
  - –index
  - –plot instead of original value
- task: show change over time
  - –principle: normalized, not absolute
- scalability
  - –same as standard line chart



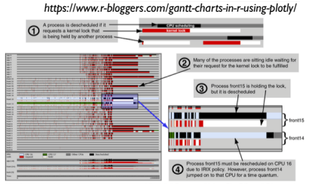
https://public.tableau.com/profile/ben.jones#!/vizhome/CAStateRevenues/Revenues

Idiom: **Gantt charts**

- one key, two (related) values
  - –data
    - 1 categ attrib, 2 quant attribs
  - –mark: line
    - length: duration
  - –channels
    - horiz position: start time (+end from duration)
  - –task
    - emphasize temporal overlaps, start/end dependencies between items
  - –scalability
    - dozens of key levels
    - hundreds of value levels



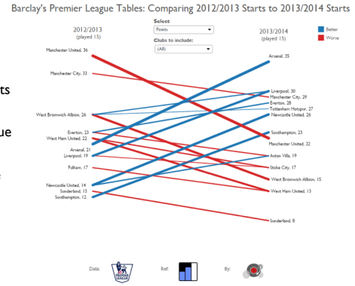
https://www.r-bloggers.com/gantt-charts-in-r-using-plotly/



[Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study. Bosch, Stolte, Stoll, Rosenblum, and Hanrahan. Proc. HPCA 2000.]

Idiom: **Slopegraphs**

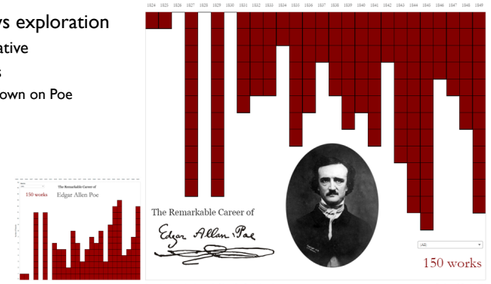
- two values
  - –data
    - 2 quant value attribs
  - –mark: point + line
    - line connecting mark between pts
  - –channels
    - 2 vertical pos: express attrib value
  - –task
    - emphasize changes in rank/value
  - –scalability
    - hundreds of value levels



https://public.tableau.com/profile/ben.jones#!/vizhome/Slopegraphs/Slopegraphs

Breaking conventions

- presentation vs exploration
  - –engaging/evocative
  - –inverted y axis
    - blood drips down on Poe



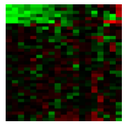
https://public.tableau.com/profile/ben.jones#!/vizhome/EdgarAllanPoeBoring/EdgarAllenPoeBoring

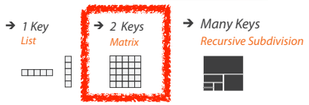
https://public.tableau.com/profile/ben.jones#!/vizhome/EdgarAllanPoeViz/EdgarAllanPoeViz

2 Keys

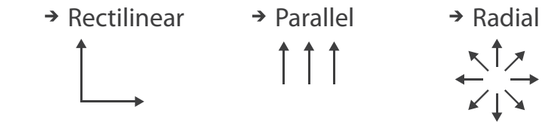
Idiom: **heatmap**

- 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



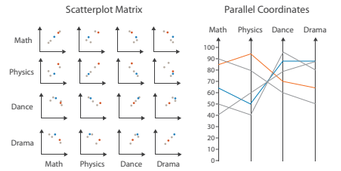


Axis Orientation



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



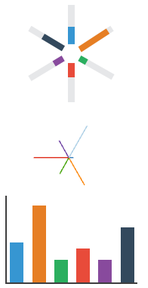
Table

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/]

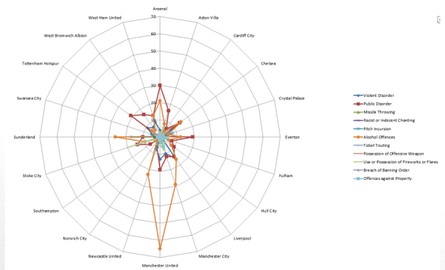
Idioms: **radial bar chart, star plot**

- 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.]

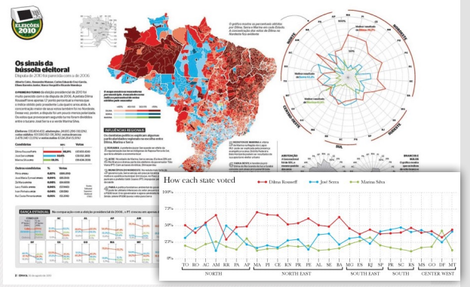
Radial Orientation: Radar Plots



LIMITATION: Not good when categories aren't cyclic

[Slide courtesy of Ben Jones]

"Radar graphs: Avoid them (99.9% of the time)"

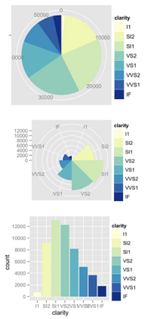


http://www.thefunctionalart.com/2012/11/radar-graphs-avoid-them-999-of-time.html

[Slide courtesy of Ben Jones]

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

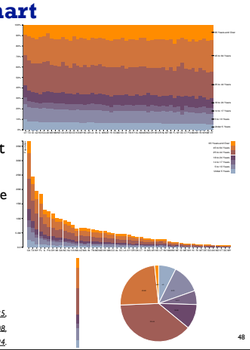
- pie chart
  - –area marks with angle channel
  - –accuracy: angle/area less accurate than line length
    - arclength also less accurate than line length
- polar area chart
  - –area marks with length channel
  - –more direct analog to bar charts
- data
  - – 1 categ key attrib, 1 quant value attrib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

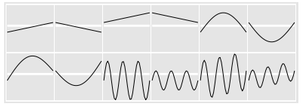
- task
  - –part-to-whole judgements
- normalized stacked bar chart
  - –stacked bar chart, normalized to full vert height
  - –single stacked bar equivalent to full pie
    - high information density: requires narrow rectangle
- pie chart
  - –information density: requires large circle



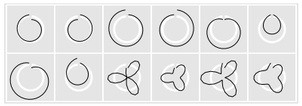
http://blocks.org/mbostock/3887235,
http://blocks.org/mbostock/3886208,
http://blocks.org/mbostock/3886394

Idiom: **glyphmaps**

- rectilinear good for linear vs nonlinear trends



- radial good for cyclic patterns



Axis Orientation → Rectilinear → Parallel → Radial

[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.]

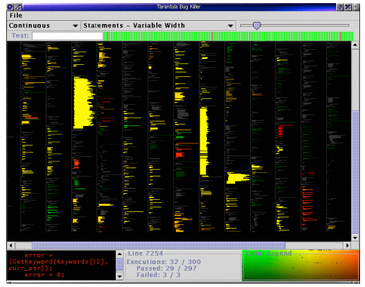
Axis Orientation → Rectilinear

→ Parallel

→ Radial

Layout Density → Dense

dense software overviews



[Visualization of test information to assist fault localization. Jones, Harrold, Stasko. Proc. ICSE 2002, p 467-477.]

Arrange tables

Express Values

Separate, Order, Align Regions

→ Separate

→ Order

→ Align

Axis Orientation → Rectilinear

→ Parallel

→ Radial

Layout Density → Dense

→ Space-Filling

→ *1 Key* *List*

→ *2 Keys* *Matrix*

→ *3 Keys* *Volume*

→ *Many Keys* *Recursive Subdivision*

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 7: Arrange Tables*
- Visualizing Data. Cleveland. Hobart Press, 1993.
- *A Brief History of Data Visualization.* Friendly. 2008. http://www.datavis.ca/milestones

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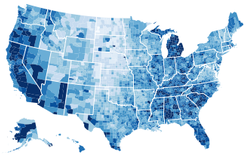
  - Arrange Spatial Data
  - Arrange Networks
  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

http://www.cs.ubc.ca/~tmm/talks.html#vad17can-aft @tamaramunzner

Idiom: **choropleth map**

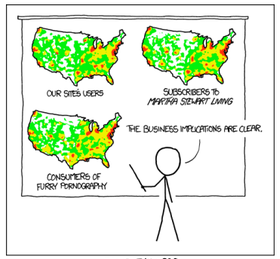
- *use* given spatial data
  - when central task is understanding spatial relationships
- data
  - geographic geometry
  - table with 1 quant attribute per region
- encoding
  - use given geometry for area mark boundaries
  - sequential segmented colormap *[more later]*



http://blocks.org/mbostock/4060606

Beware: Population maps trickiness!

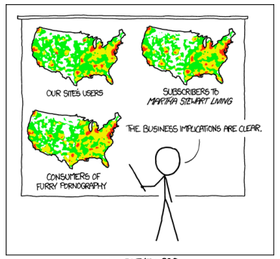
[https://xkcd.com/1138]



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

Population maps trickiness

- beware!
- absolute vs relative again
  - population density vs per capita
- investigate with Ben Jones Tableau Public demo
  - http://public.tableau.com/profile/ben.jones#!/vizhome/PopVsFin/PopVsFin
    Are Maps of Financial Variables just Population Maps?
    - yes, unless you look at per capita (relative) numbers

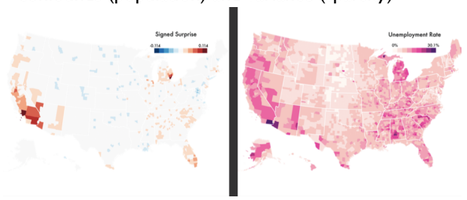


PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

[https://xkcd.com/1138]

Idiom: Bayesian surprise maps

- use models of expectations to highlight surprising values
- confounds (population) and variance (sparsity)



https://medium.com/@uwdata/surprise-maps-showing-the-unexpected-e92b67398865

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http://www.cs.ubc.ca/~tmm/talks.html#vad17can-aft @tamaramunzner

Arrange networks and trees

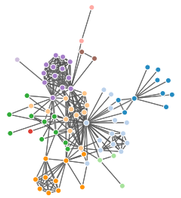
Node–Link Diagrams
Connection Marks
NETWORKS ✓ TREES ✓

Adjacency Matrix
Derived Table
NETWORKS ✓ TREES ✓

Enclosure
Containment Marks
NETWORKS ✗ TREES ✓

Idiom: **force-directed placement**

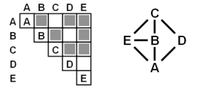
- visual encoding
  - link connection marks, node point marks
- considerations
  - spatial position: no meaning directly encoded
    - left free to minimize crossings
  - proximity semantics?
    - sometimes meaningful
    - sometimes arbitrary, artifact of layout algorithm
    - tension with length
      - long edges more visually salient than short
- tasks
  - explore topology; locate paths, clusters
- scalability
  - node/edge density E < 4N



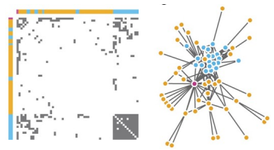
http://mbostock.github.com/d3/ex/force.html

Idiom: **adjacency matrix view**

- data: network
  - transform into same data/encoding as heatmap
- derived data: table from network
  - 1 quant attrib
    - weighted edge between nodes
  - 2 categ attribs: node list x 2
- visual encoding
  - cell shows presence/absence of edge
- scalability
  - 1K nodes, 1M edges



[NodeTrix: a Hybrid Visualization of Social Networks. Henry, Fekete, and McGuffin. IEEE TVCG (Proc. InfoVis) 13(6):1302-1309, 2007.]

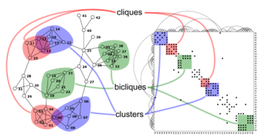


[Points of view: Networks. Gehlenborg and Wong. Nature Methods 9:115.]

Connection vs. adjacency comparison

- adjacency matrix strengths
  - predictability, scalability, supports reordering
  - some topology tasks trainable
- node-link diagram strengths
  - topology understanding, path tracing
  - intuitive, no training needed
- empirical study
  - node-link best for small networks
  - matrix best for large networks
    - if tasks don't involve topological structure!

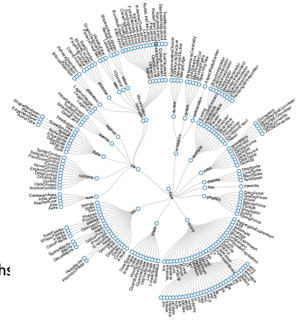
[On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis. Ghoniem, Fekete, and Castagliola. Information Visualization 4:2 (2005), 114–135.]



http://www.michaelmcguffin.com/courses/vis/patternsInAdjacencyMatrix.png

Idiom: **radial node-link tree**

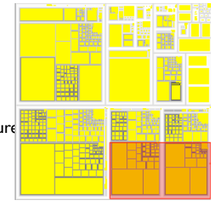
- data
  - tree
- encoding
  - link connection marks
  - point node marks
  - radial axis orientation
    - angular proximity: siblings
    - distance from center: depth in tree
- tasks
  - understanding topology, following paths
- scalability
  - 1K - 10K nodes



http://mbostock.github.com/d3/ex/tree.html

Idiom: **treemap**

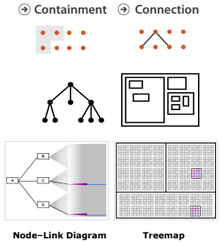
- data
  - tree
  - 1 quant attrib at leaf nodes
- encoding
  - area containment marks for hierarchical structure
  - rectilinear orientation
  - size encodes quant attrib
- tasks
  - query attribute at leaf nodes
- scalability
  - 1M leaf nodes



http://tulip.labri.fr/Documentation/3_7/userHandbook/html/ch06.html

Link marks: Connection and containment

- marks as links (vs. nodes)
  - common case in network drawing
  - 1D case: connection
    - ex: all node-link diagrams
    - emphasizes topology, path tracing
    - networks and trees
  - 2D case: containment
    - ex: all treemap variants
    - emphasizes attribute values at leaves (size coding)
    - only trees



[Elastic Hierarchies: Combining Treemaps and Node-Link Diagrams. Dong, McGuffin, and Chignell. Proc. InfoVis 2005, p. 57-64.]

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 9: Arrange Networks and Trees*
- Visual Analysis of Large Graphs: State-of-the-Art and Future Research Challenges. von Landesberger et al. Computer Graphics Forum 30:6 (2011), 1719–1749.
- Simple Algorithms for Network Visualization: A Tutorial. McGuffin. Tsinghua Science and Technology (Special Issue on Visualization and Computer Graphics) 17:4 (2012), 383–398.
- Drawing on Physical Analogies. Brandes. In Drawing Graphs: Methods and Models, LNCS Tutorial, 2025, edited by M. Kaufmann and D. Wagner, LNCS Tutorial, 2025, pp. 71–86. Springer-Verlag, 2001.
- http://www.treevis.net Treevis.net: A Tree Visualization Reference. Schulz. IEEE Computer Graphics and Applications 31:6 (2011), 11–15.
- Perceptual Guidelines for Creating Rectangular Treemaps. Kong, Heer, and Agrawala. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis) 16:6 (2010), 990–998.

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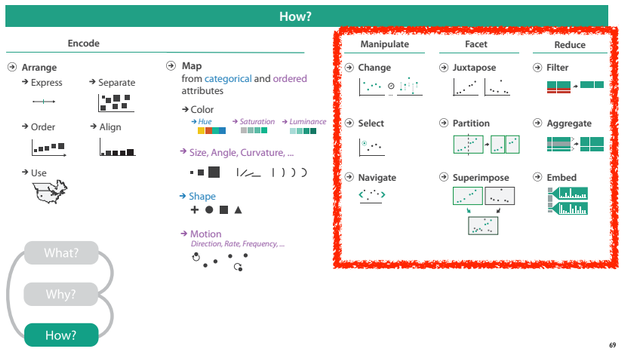
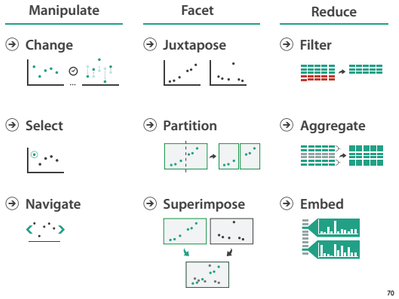
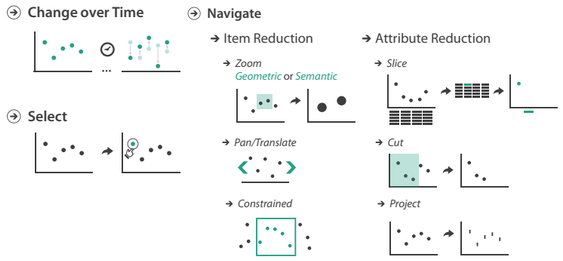


How to handle complexity: 1 previous strategy + 3 more

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



Manipulate



Change over time

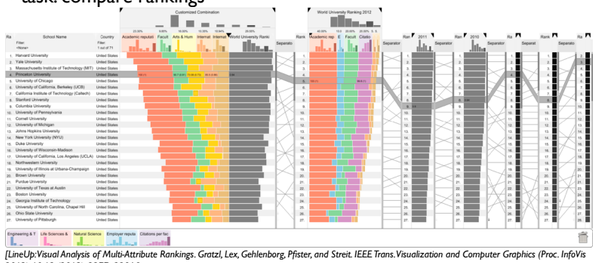
- change any of the other choices
  - encoding itself
  - parameters
  - arrange: rearrange, reorder
  - aggregation level, what is filtered...
  - interaction entails change

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

made using Tableau, http://tableausoftware.com

Idiom: **Reorder** System: **LineUp**

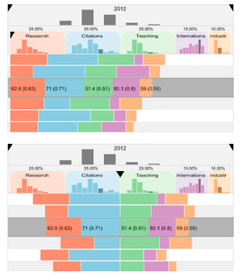
- data: tables with many attributes
- task: compare rankings



[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.]

Idiom: **Realign** System: **LineUp**

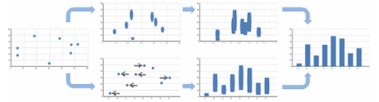
- stacked bars
  - easy to compare
    - first segment
    - total bar
- align to different segment
  - supports flexible comparison



[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.]

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

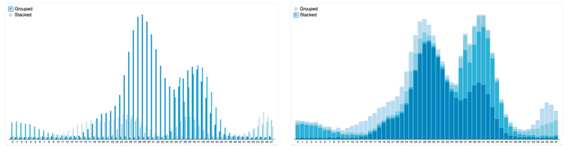


video: vimeo.com/19278444

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

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

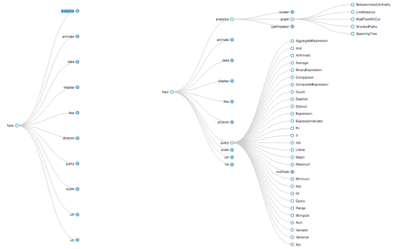
- smooth transition from one state to another
  - alternative to jump cuts, supports item tracking
    - best case for animation
  - staging to reduce cognitive load



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

Idiom: **Animated transition - tree detail**

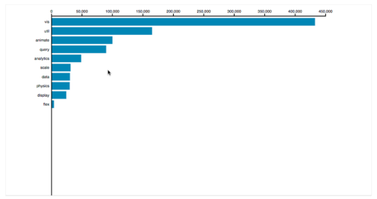
- animated transition
  - network drilldown/rollup



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

Idiom: **Animated transition - bar detail**

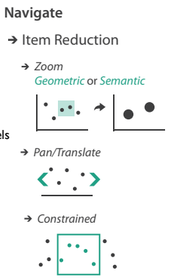
- example: hierarchical bar chart
  - add detail during transition to new level of detail



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

Navigate: Changing item visibility

- change viewpoint
  - changes which items are visible within view
  - camera metaphor
    - zoom
      - geometric zoom: familiar semantics
      - semantic zoom: adapt object representation based on available pixels
        - » dramatic change, or more subtle one
    - pan/translate
    - rotate
      - especially in 3D
  - constrained navigation
    - often with animated transitions
    - often based on selection set



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.

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  - Marks and Channels, Perception
  - Arrange Tables
  - Arrange Spatial Data
  - Arrange Networks
  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

http://www.cs.ubc.ca/~tmm/talks.html#vad17can-aft @tamaramunzner

Facet

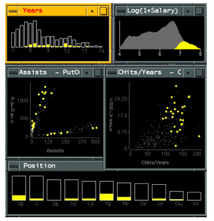
- Juxtapose
- Partition
- Superimpose

Juxtapose and coordinate views

- Share Encoding: Same/Different
  - *Linked Highlighting*
- Share Data: All/Subset/None
- Share Navigation

Idiom: **Linked highlighting** System: **EDV**

- see how regions contiguous in one view are distributed within another
  - powerful and pervasive interaction idiom
- encoding: different
  - ***multiform***
- data: all shared



[Visual Exploration of Large Structured Datasets. Wills. Proc. New Techniques and Trends in Statistics (NTTS), pp. 237–246. IOS Press, 1995.]

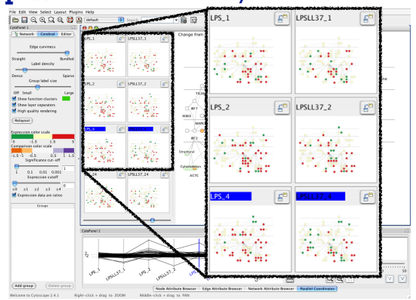
Idiom: **bird's-eye maps** System: **Google Maps**

- encoding: same
- data: subset shared
- navigation: shared
  - bidirectional linking
- differences
  - viewpoint
  - (size)
- ***overview-detail***

[A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1–31.]

Idiom: **Small multiples** System: **Cerebral**

- encoding: same
- data: none shared
  - different attributes for node colors
  - (same network layout)
- navigation: shared



[Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14:6 (2008), 1253–1260.]

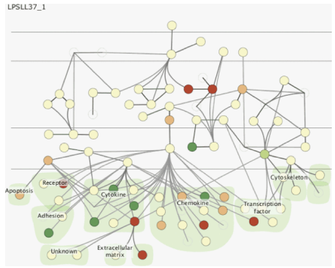
Coordinate views: Design choice interaction

Encoding	Data: All	Data: Subset	Data: None
Same	Redundant	Overview/Detail	Small Multiples
Different	Multiform	Multiform, Overview/Detail	No Linkage

- why juxtapose views?
  - benefits: eyes vs memory
    - lower cognitive load to move eyes between 2 views than remembering previous state with single changing view
  - costs: display area, 2 views side by side each have only half the area of one view

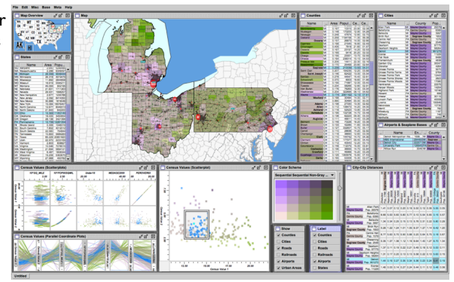
Why not animation?

- disparate frames and regions: comparison difficult
  - vs contiguous frames
  - vs small region
  - vs coherent motion of group
- safe special case
  - animated transitions



System: **Improvise**

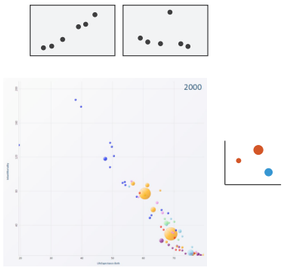
- investigate power of multiple views
  - pushing limits on view count, interaction complexity
  - how many is ok?
    - open research question
  - reorderable lists
    - easy lookup
    - useful when linked to other encodings



[Building Highly-Coordinated Visualizations In Improvise. Weaver. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 159–166, 2004.]

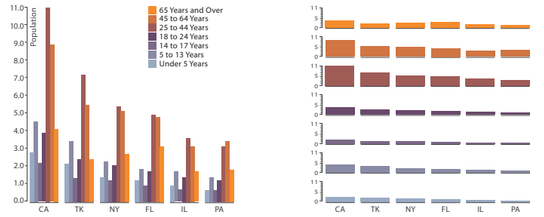
Partition into views

- how to divide data between views → Partition into Side-by-Side Views
  - split into regions by attributes
  - encodes association between items using spatial proximity
  - order of splits has major implications for what patterns are visible
- no strict dividing line
  - ***view:*** *big/detailed*
    - contiguous region in which visually encoded data is shown on the display
  - ***glyph:*** *small/iconic*
    - object with internal structure that arises from multiple marks



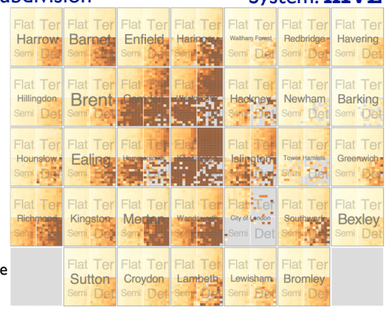
Partitioning: List alignment

- single bar chart with grouped bars
  - split by state into regions
    - complex glyph within each region showing all ages
  - compare: easy within state, hard across ages
- small-multiple bar charts
  - split by age into regions
    - one chart per region
  - compare: easy within age, harder across states



Partitioning: Recursive subdivision System: **HIVE**

- split by neighborhood
- then by type
- then time
  - years as rows
  - months as columns
- color by price
- neighborhood patterns
  - where it's expensive
  - where you pay much more for detached type



[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

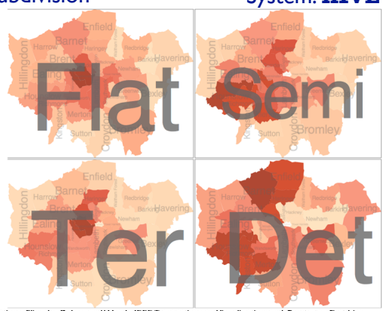
Partitioning: Recursive subdivision System: **HIVE**

- switch order of splits
  - type then neighborhood
- switch color
  - by price variation
- type patterns
  - within specific type, which neighborhoods inconsistent

[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

Partitioning: Recursive subdivision System: **HIVE**

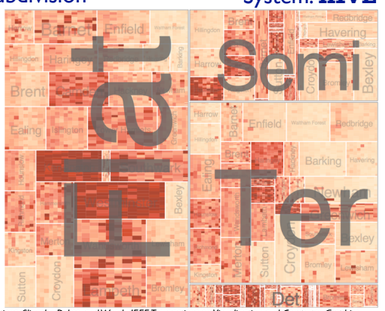
- different encoding for second-level regions
  - choropleth maps



[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

Partitioning: Recursive subdivision System: **HIVE**

- size regions by sale counts
  - not uniformly
- result: treemap



[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

Superimpose layers

- *layer*: set of objects spread out over region
  - –each set is visually distinguishable group
  - –extent: whole view
- design choices
  - –how many layers, how to distinguish?
    - encode with different, nonoverlapping channels
    - two layers achieveable, three with careful design
  - –small static set, or dynamic from many possible?

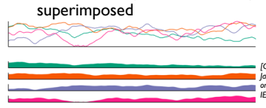
Static visual layering

- foreground layer: roads
  - –hue, size distinguishing main from minor
  - –high luminance contrast from background
- background layer: regions
  - –desaturated colors for water, parks, land areas
- user can selectively focus attention
- "get it right in black and white"
  - –check luminance contrast with greyscale view

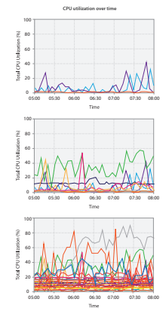
[Get it right in black and white. Stone. 2010. http://www.stonesc.com/wordpress/2010/03/get-it-right-in-black-and-white]

Superimposing limits

- few layers, but many lines
  - –up to a few dozen
  - –but not hundreds
- superimpose vs juxtapose: empirical study
  - –superimposed for local, multiple for global
  - –tasks
    - local: maximum, global: slope, discrimination
  - –same screen space for all multiples vs single superimposed

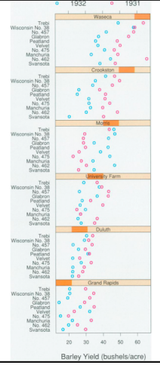


[Graphical Perception of Multiple Time Series. Javed, McDonnel, and Elmqvist. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE InfoVis 2010) 16:6 (2010), 927–934.]



Idiom: **Trellis plots**

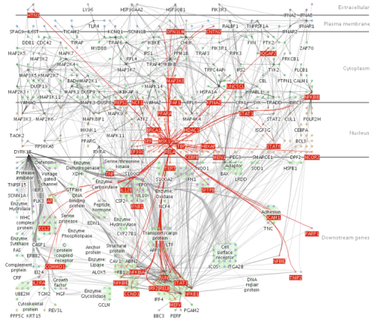
- superimpose within same frame
  - –color code by year



Dynamic visual layering

System: **Cerebral**

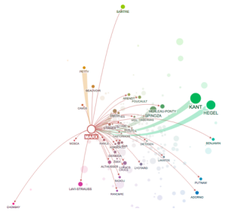
- interactive, from selection
  - –lightweight: click
  - –very lightweight: hover
- ex: 1-hop neighbors



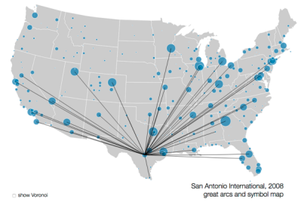
[Cerebral: a Cytoscape plugin for layout of and interaction with biological networks using subcellular localization annotation. Barsky, Gardy, Hancock, and Munzner. Bioinformatics 23:8 (2007), 1040–1042.]

Dynamic visual layering

- one-hop neighbour highlighting demos: click vs hover



http://mariandoerk.de/edgemaps/demo/



http://mbostock.github.io/d3/talk/20111116/airports.html

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - –*Chap 12: Facet Into Multiple Views*
- *A Review of Overview+Detail, Zooming, and Focus+Context Interfaces.* Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1–31.
- *A Guide to Visual Multi-Level Interface Design From Synthesis of Empirical Study Evidence.* Lam and Munzner. Synthesis Lectures on Visualization Series, Morgan Claypool, 2010.
- *Zooming versus multiple window interfaces: Cognitive costs of visual comparisons.* Plumlee and Ware. ACM Trans. on Computer-Human Interaction (ToCHI) 13:2 (2006), 179–209.
- *Exploring the Design Space of Composite Visualization.* Javed and Elmqvist. Proc. Pacific Visualization Symp. (PacificVis), pp. 1–9, 2012.
- *Visual Comparison for Information Visualization.* Gleicher, Albers, Walker, Jusufi, Hansen, and Roberts. Information Visualization 10:4 (2011), 289–309.
- *Guidelines for Using Multiple Views in Information Visualizations.* Baldonado, Woodruff, and Kuchinsky. In Proc. ACM Advanced Visual Interfaces (AVI), pp. 110–119, 2000.
- *Cross-Filtered Views for Multidimensional Visual Analysis.* Weaver. IEEE Trans. Visualization and Computer Graphics 16:2 (Proc. InfoVis 2010), 192–204, 2010.
- *Linked Data Views.* Wills. In Handbook of Data Visualization, Computational Statistics, edited by Unwin, Chen, and Härdle, pp. 216–241. Springer-Verlag, 2008.
- *Glyph-based Visualization: Foundations, Design Guidelines, Techniques and Applications.* Borgo, Kehrer, Chung, Maguire, Laramee, Hauser, Ward, and Chen. In Eurographics State of the Art Reports, pp. 39–63, 2013.

Outline

- Session 1 *10-11:30am*
  Data Visualization Pitfalls to Avoid
  - – Introduction
  - – Color
  - – Space: 2D vs 3D
- Session 2 *12:30-3pm*
  Visualization Analysis & Design, In More Depth
  - – Marks and Channels, Perception
  - – Arrange Tables
  - – Arrange Spatial Data
  - – Arrange Networks
  - – Manipulate: Change, Select, Navigate
  - – Facet: Juxtapose, Partition, Superimpose
  - – Reduce: Filter, Aggregate

http://www.cs.ubc.ca/~tmm/talks.html#vad17can-aft

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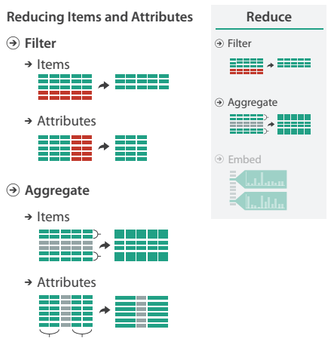
Reduce items and attributes

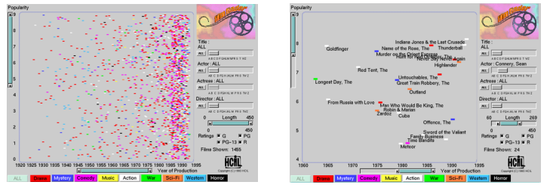
- reduce/increase: inverses
- filter
  - –pro: straightforward and intuitive
    - to understand and compute
  - –con: out of sight, out of mind
- aggregation
  - –pro: inform about whole set
  - –con: difficult to avoid losing signal
- not mutually exclusive
  - –combine filter, aggregate
  - –combine reduce, change, facet



Idiom: **dynamic filtering**

System: **FilmFinder**

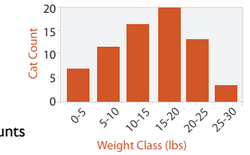
- item filtering
- browse through tightly coupled interaction
  - –alternative to queries that might return far too many or too few



[Visual information seeking: Tight coupling of dynamic query filters with starfield displays. Ahlberg and Shneiderman. Proc. ACM Conf. on Human Factors in Computing Systems (CHI), pp. 313–317, 1994.]

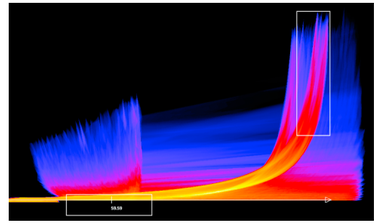
Idiom: **histogram**

- static item aggregation
- task: find distribution
- data: table
- derived data
  - –new table: keys are bins, values are counts
- bin size crucial
  - –pattern can change dramatically depending on discretization
  - –opportunity for interaction: control bin size on the fly



Continuous scatterplot

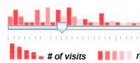
- static item aggregation
- data: table
- derived data: table
  - – key attribs x,y for pixels
  - – quant attrib: overplot density
- dense space-filling 2D matrix
- color: sequential categorical hue + ordered luminance colormap



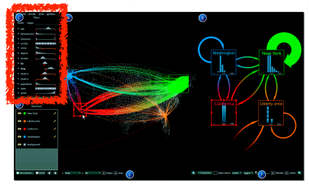
[Continuous Scatterplots. Bachthaler and Weiskopf. IEEE TVCG (Proc. Vis 08) 14:6 (2008), 1428–1435. 2008.]

Idiom: **scented widgets**

- augmented widgets show information scent
  - –cues to show whether value in drilling down further vs looking elsewhere
- concise use of space: histogram on slider

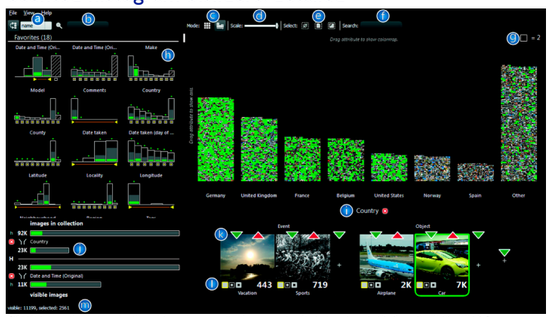


[Scented Widgets: Improving Navigation Cues with Embedded Visualizations. Willett, Heer, and Agrawala. IEEE TVCG (Proc. InfoVis 2007) 13:6 (2007), 1129–1136.]



[Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations. van den Elzen, van Wijk, IEEE TVCG 20(12): 2014 (Proc. InfoVis 2014).]

Scented histogram bisliders: detailed

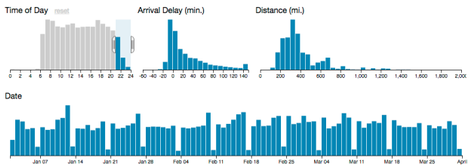


[ICLIC: Interactive categorization of large image collections. van der Corput and van Wijk. Proc. PacificVis 2016.]

Idiom: **cross filtering**

System: **Crossfilter**

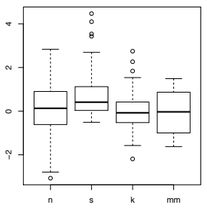
- item filtering
- coordinated views/controls combined
  - all scented histogram bisliders update when any ranges change



[http://square.github.io/crossfilter/]

Idiom: **boxplot**

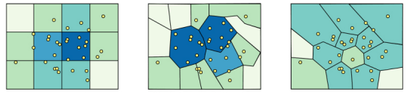
- static item aggregation
- task: find distribution
- data: table
- derived data
  - –5 quant attribs
    - median: central line
    - lower and upper quartile: boxes
    - lower upper fences: whiskers
      - – values beyond which items are outliers
  - –outliers beyond fence cutoffs explicitly shown



[40 years of boxplots. Wickham and Stryjewski. 2012. had.co.nz]

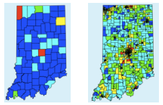
Spatial aggregation

- MAUP: Modifiable Areal Unit Problem
  - –gerrymandering (manipulating voting district boundaries) is only one example!
  - –zone effects



[http://www.e-education.psu.edu/geog486/l4_p7.html, Fig 4.cg.6]

  - –scale effects



https://blog.cartographica.com/blog/2011/5/19/the-modifiable-areal-unit-problem-in-gis.html

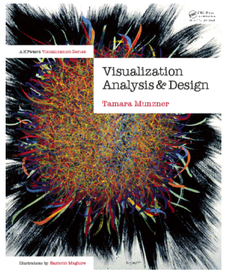
Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *–Chap 13: Reduce Items and Attributes*
- *Hierarchical Aggregation for Information Visualization: Overview, Techniques and Design Guidelines.* Elmqvist and Fekete. IEEE Transactions on Visualization and Computer Graphics 16:3 (2010), 439–454.
- *A Review of Overview+Detail, Zooming, and Focus+Context Interfaces*. Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1–31.
- *A Guide to Visual Multi-Level Interface Design From Synthesis of Empirical Study Evidence.* Lam and Munzner. Synthesis Lectures on Visualization Series, Morgan Claypool, 2010.

More Information

@tamaramunzner

- this talk
  http://www.cs.ubc.ca/~tmm/talks.html#vad17can-aft
- book page (including tutorial lecture slides)
  http://www.cs.ubc.ca/~tmm/vadbook
  - –20% promo code for book+ebook combo: HVN17
  - – http://www.crcpress.com/product/isbn/9781466508910
  - –illustrations: Eamonn Maguire
- papers, videos, software, talks, courses
  http://www.cs.ubc.ca/group/infovis
  http://www.cs.ubc.ca/~tmm



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