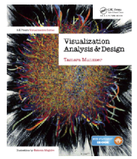
Visualization Analysis & Design
Half-Day Tutorial



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IEEE VIS 2020 Tutorial
October 2020, Salt Lake City UT (online)

http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

Visualization Analysis & Design, Half-Day Tutorial

- Session 1
  - Analysis: What, Why, How
  - Marks and Channels
  - Arrange Tables
  - Arrange Spatial Data
- Session 2
  - Arrange Networks and Trees
  - Map Color and Other Channels
  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

@tamaramunzner
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Defining visualization (vis)

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

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Why?...

Why have a human in the loop?

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Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

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

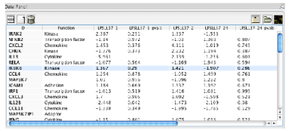
Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

- don't need vis when fully automatic solution exists and is trusted
- many analysis problems ill-specified
  - don't know exactly what questions to ask in advance
- possibilities
  - long-term use for end users (ex: exploratory analysis of scientific data)
  - presentation of known results (ex: New York Times Upshot)
  - stepping stone to assess requirements before developing models
  - help automatic solution developers refine & determine parameters
  - help end users of automatic solutions verify, build trust

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



[CerebralVisualizing Multiple Experimental Conditions on a Graph with Biological Context, Barsky, Munzner, Gardy, and Kincaid. IEEE TVCG (Proc. InfoVis) 14(6):1253-1260, 2008.]

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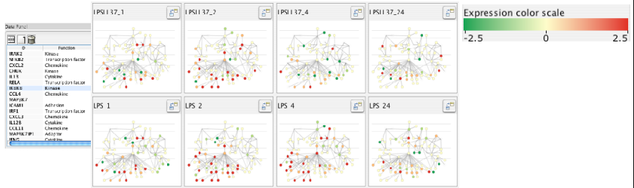

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Why represent all the data?

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

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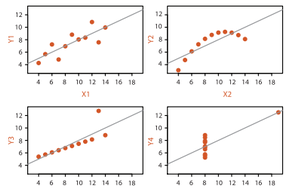

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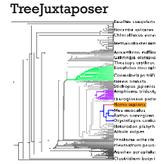
Why analyze?

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

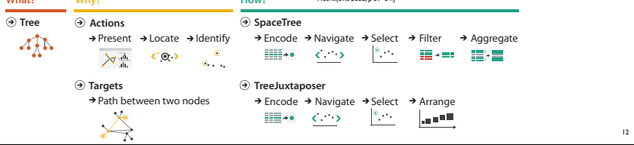
SpaceTree

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

TreeJuxtaposer



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



Analysis framework: Four levels, three questions

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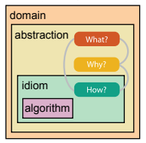
[A Nested Model of Visualization Design and Validation. *Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).*]



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

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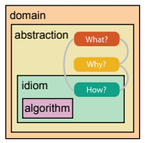

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    - **visual encoding** idiom: how to draw
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- *algorithm*
  - efficient computation

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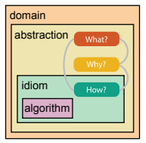

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Why is validation difficult?

- different ways to get it wrong at each level

Domain situation
You misunderstood their needs

Data/task abstraction
You're showing them the wrong thing

Visual encoding/interaction idiom
The way you show it doesn't work

Algorithm
Your code is too slow

Why is validation difficult?

- solution: use methods from different fields at each level

Domain situation
Observe target users using existing tools

Data/task abstraction

Visual encoding/interaction idiom
Justify design with respect to alternatives

Algorithm
Measure system time/memory
Analyze computational complexity

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

Observe target users after deployment (*field study*)

Measure adoption

Why is validation difficult?

- solution: use methods from different fields at each level

computer science

technique-driven work

Why is validation difficult?

- solution: use methods from different fields at each level

design

computer science

cognitive psychology

technique-driven work

Why is validation difficult?

- solution: use methods from different fields at each level

anthropology/ ethnography

design

computer science

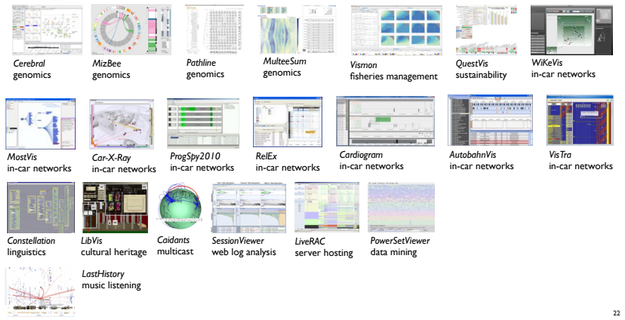
cognitive psychology

anthropology/ ethnography

problem-driven work (design study)

technique-driven work

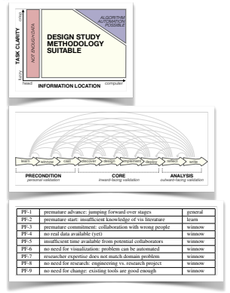
Design Studies: Lessons learned after 21 of them



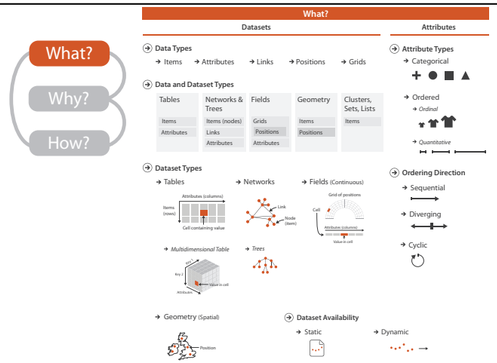
Design Study Methodology: Reflections from the Trenches and the Stacks

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

[Sedlmair, Meyer, Munzner. IEEE Trans. Visualization and Computer Graphics 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).]



PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
PF-5	insufficient time available from potential collaborators	winnow
PF-6	no need for visualization: problem can be automated	winnow
PF-7	researcher expertise does not match domain problem	winnow
PF-8	no need for research: engineering vs. research project	winnow
PF-9	no need for change: existing tools are good enough	winnow



Three major datatypes

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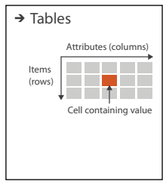
Dataset Types

→ Tables



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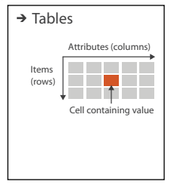
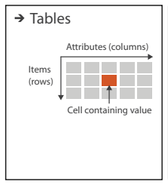


→ Networks

Three major datatypes

Dataset Types

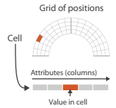
→ Tables



→ Networks

→ Spatial

→ Fields (Continuous)



→ Geometry (Spatial)

Three major datatypes

Dataset Types

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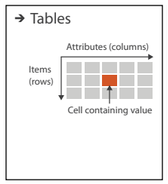

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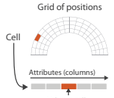


→ Geometry (Spatial)

- visualization vs computer graphics
  - –geometry is design decision

Attribute types

Attribute Types

→ Categorical

→ Ordered

→ *Ordinal*

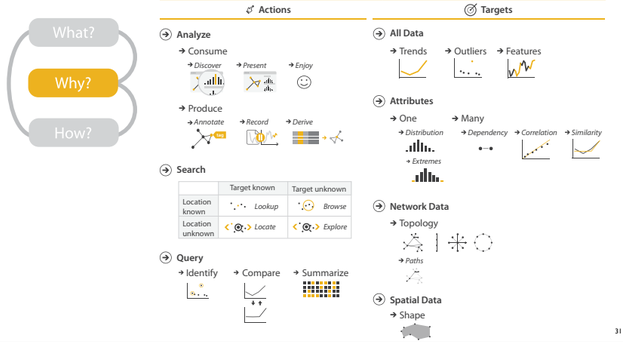
→ *Quantitative*

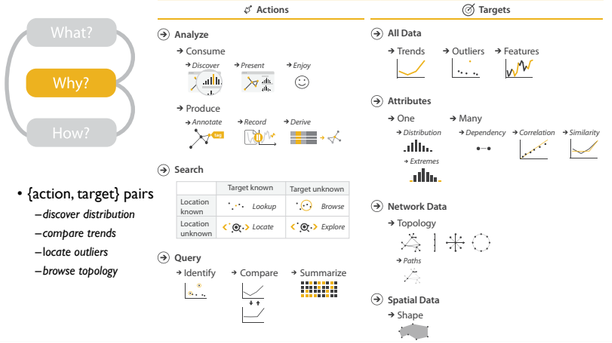
Ordering Direction

→ Sequential

→ Diverging

→ Cyclic

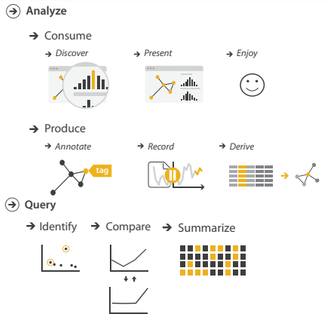




- {action, target} pairs
  - *–discover distribution*
  - *–compare trends*
  - *–locate outliers*
  - *–browse topology*

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)



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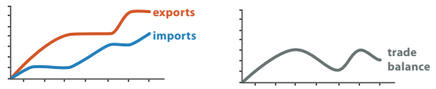
Derive

- don't necessarily 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

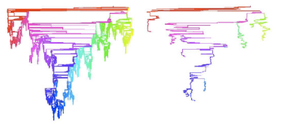
trade balance = exports – imports

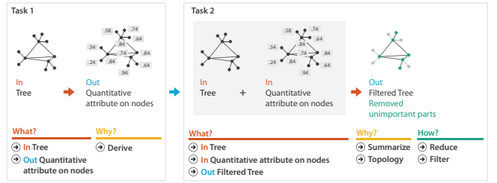
Derived Data

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

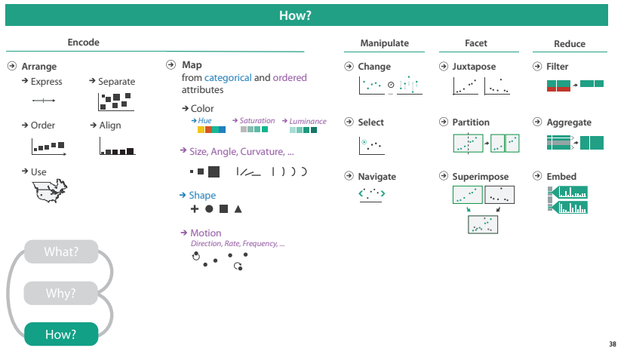
- One
  - Distribution
  - Extremes
- Many
  - Dependency
  - Correlation
  - Similarity

Network Data

- Topology
- Paths

Spatial Data

- Shape



Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, Nov 2014.
  - *Chap 1: What's Vis, and Why Do It?*
  - *Chap 2: What: Data Abstraction*
  - *Chap 3: Why: Task Abstraction*
- *A Multi-Level Typology of Abstract Visualization Tasks.* Brehmer and Munzner. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis) 19:12 (2013), 2376–2385.
- *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.
- *Rethinking Visualization: A High-Level Taxonomy.* Tory and Möller. Proc. IEEE InfoVis 2004, p 151–158.
- Visualization of Time-Oriented Data. Aigner, Miksch, Schumann, and Tominski. Springer, 2011.

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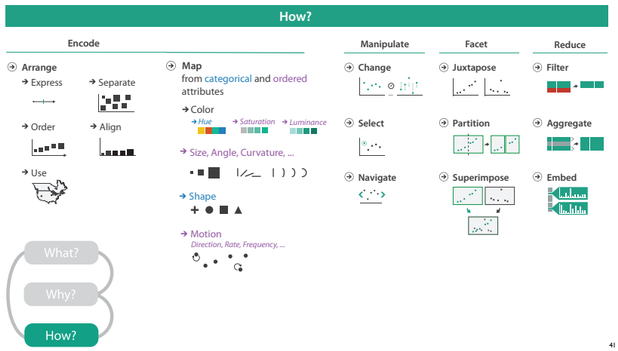

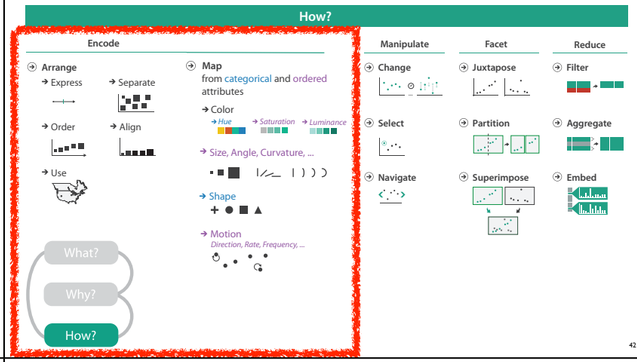

Visual encoding

- analyze idiom structure

Definitions: Marks and channels

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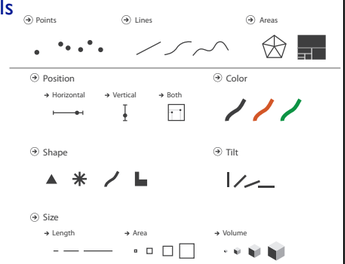
- marks
  - geometric primitives

Definitions: Marks and channels

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



Definitions: Marks and channels

- marks
  - geometric primitives
- channels
  - control appearance of marks
- channel properties differ
  - type & amount of information that can be conveyed to human perceptual system

Visual encoding

- analyze idiom structure as combination of marks and channels

1:
vertical position

mark: line

Visual encoding

- analyze idiom structure as combination of marks and channels

1:
vertical position

2:
vertical position
horizontal position

mark: line

mark: point

Visual encoding

- analyze idiom structure as combination of marks and channels

1:
vertical position

2:
vertical position
horizontal position

3:
vertical position
horizontal position
color hue

mark: line

mark: point

mark: point

Visual encoding

- analyze idiom structure as combination of marks and channels

1:
vertical position

2:
vertical position
horizontal position

3:
vertical position
horizontal position
color hue

4:
vertical position
horizontal position
color hue
size (area)

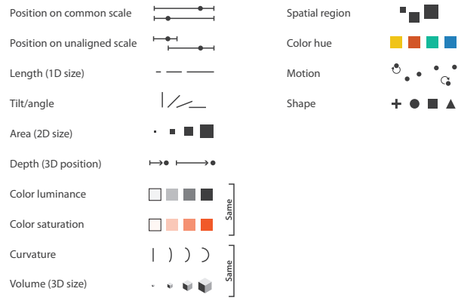
mark: line

mark: point

mark: point

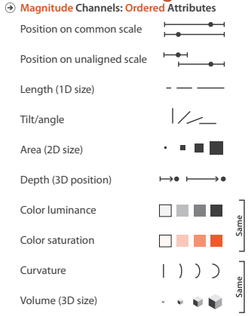
mark: point

Channels: Rankings

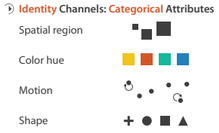


Channels: Rankings

Magnitude Channels: Ordered Attributes



Identity Channels: Categorical Attributes



- expressiveness
  - match channel and data characteristics

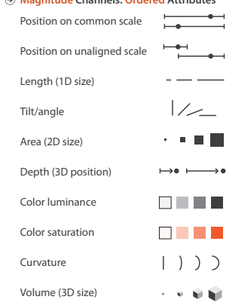
Attribute Types

→ Categorical

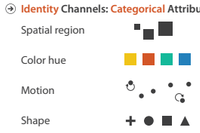
→ Ordered

Channels: Rankings

Magnitude Channels: Ordered Attributes

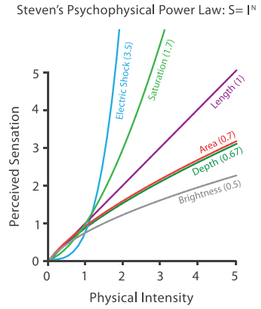


Identity Channels: Categorical Attributes

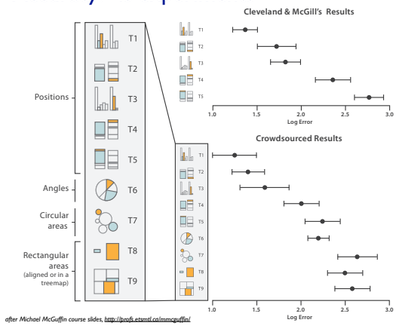


- expressiveness
  - match channel and data characteristics
- effectiveness
  - channels differ in accuracy of perception

Accuracy: Fundamental Theory



Accuracy: Vis experiments

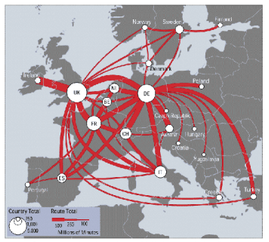


after Michael McGuffin course slides, http://profs.etsmtl.ca/mmcguffin/

[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.]

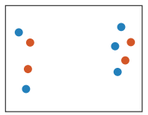
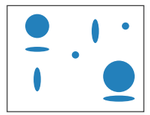
Discriminability: How many usable steps?

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



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

Separability vs. Integrality

Position + Hue (Color)	Size + Hue (Color)	Width + Height	Red + Green
			
Fully separable	Some interference	Some/significant interference	Major interference
2 groups each	2 groups each	3 groups total: integral area	4 groups total: integral hue

Popout

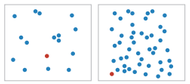
- find the red dot
  - how long does it take?

Popout

- find the red dot
  - how long does it take?

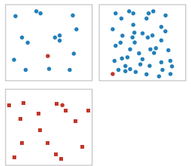
Popout

- find the red dot
  - how long does it take?



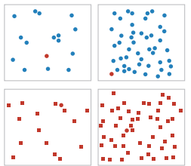
Popout

- find the red dot
  - how long does it take?



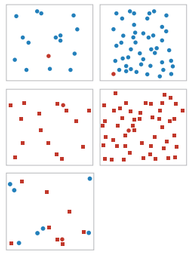
Popout

- find the red dot
  - how long does it take?



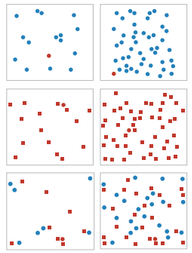
Popout

- find the red dot
  - how long does it take?



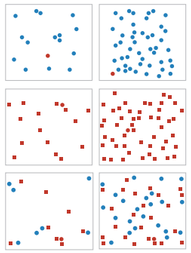
Popout

- find the red dot
  - how long does it take?

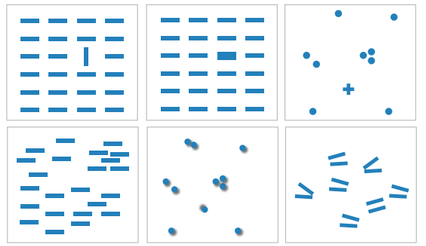


Popout

- 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

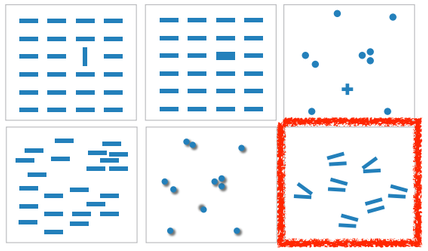


Popout



- many channels
  - tilt, size, shape, proximity, shadow direction, ...

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

→ Containment → Connection

→ Identity Channels: Categorical Attributes

Spatial region

Color hue

Motion

Shape

Further reading

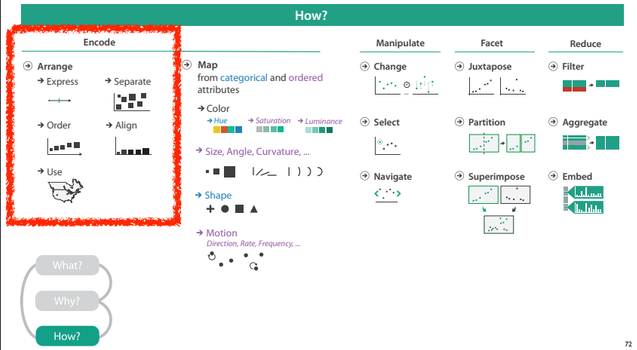
- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, Nov 2014.
  - *Chap 5: Marks and Channels*
- *On the Theory of Scales of Measurement.* Stevens. Science 103:2684 (1946), 677–680.
- Psychophysics: Introduction to its Perceptual, Neural, and Social Prospects. Stevens. 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.

Visualization Analysis & Design, Half-Day Tutorial

- Session 1
  - Analysis: What, Why, How
  - Marks and Channels
  - Arrange Tables
  - Arrange Spatial Data
- Session 2
  - Arrange Networks and Trees
  - Map Color and Other Channels
  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

@tamaramunzner

http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20



Arrange tables

→ Express Values

→ Separate, Order, Align Regions

→ Separate → Order

→ Align

→ Axis Orientation

→ Rectilinear → Parallel → Radial

→ Layout Density

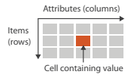
→ Dense → Space-Filling

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

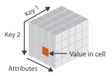
Keys and values

- 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*

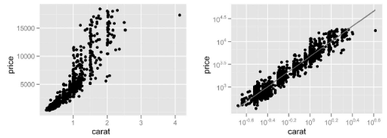


→ Express Values → 1 Key *List* → 2 Keys *Matrix*

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.]

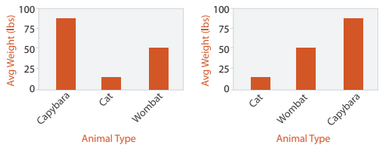
Some keys: Categorical regions

- 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

→ Separate → Order → Align

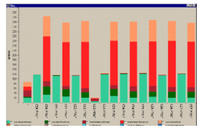
Idiom: **bar chart**

- 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**

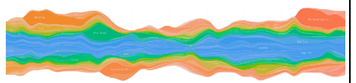
- one more key
  - data
    - 2 categ attrib, 1 quant attrib
  - mark: vertical stack of line marks
    - ***glyph***: composite object, internal structure from multiple marks
  - channels
    - length and color hue
    - spatial regions: one per glyph
      - aligned: full glyph, lowest bar component
      - 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**

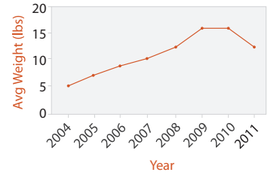
- generalized stacked graph
  - emphasizing horizontal continuity
    - vs vertical items
  - data
    - 1 categ key attrib (artist)
    - 1 ordered key attrib (time)
    - 1 quant value attrib (counts)
  - derived data
    - geometry: layers, where height encodes counts
    - 1 quant attrib (layer ordering)
  - scalability
    - hundreds of time keys
    - dozens to hundreds of artist keys
      - more than stacked bars: 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).]

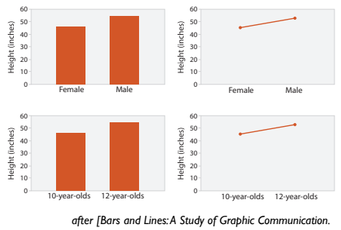
Idiom: **line chart / dot plot**

- 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



Choosing bar vs line charts

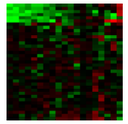
- depends on type of key attrib
  - bar charts if categorical
  - line charts if ordered
- do not use line charts for categorical key attribs
  - violates expressiveness principle
    - implication of trend so strong that it overrides semantics!
      - "The more male a person is, the taller he/she is"

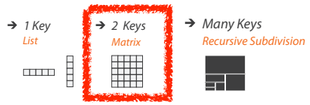


after [Bars and Lines: A Study of Graphic Communication. Zacks and Tversky. Memory and Cognition 27:6 (1999), 1073–1079.]

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
    - 1K categorical levels, 1M items; ~10 quantitative attribute levels



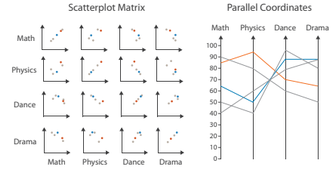


Axis Orientation

- Rectilinear
- Parallel
- Radial

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



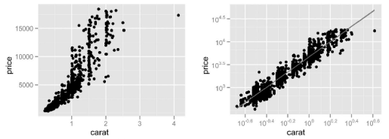
Table

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

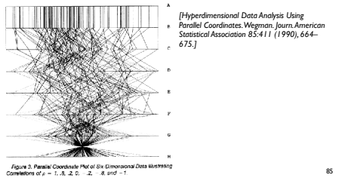
after [Visualization Course Figures. McGuffin, 2014. http://www.michaelmcguffin.com/courses/vis/]

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



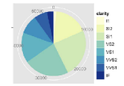
[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

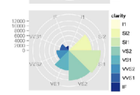


[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. Journ. American Statistical Association 85:411 (1990), 664–675.]

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

- pie chart
  - area marks with angle channel
  - accuracy: angle/area much 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

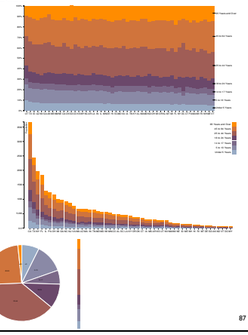




[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Idioms: **normalized stacked bar chart**

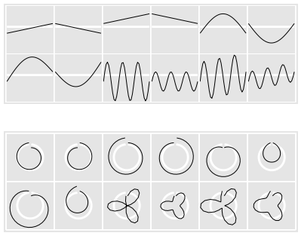
- task
  - part-to-whole judgements
- normalized stacked bar chart
  - stacked bar chart, normalized to full vert height
  - single stacked bar equivalent to full pie
    - high information density: requires narrow rectangle
- pie chart
  - information density: requires large circle



http://bl.ocks.org/mbostock/1887235
http://bl.ocks.org/mbostock/1886208
http://bl.ocks.org/mbostock/1886394

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, Hoffmann, 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

Further reading

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

Visualization Analysis & Design, Half-Day Tutorial

- Session 1
  - Analysis: What, Why, How
  - Marks and Channels
  - Arrange Tables
  - Arrange Spatial Data
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  - Map Color and Other Channels
  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

@tamaramunzner

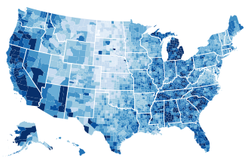
http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

Arrange spatial data

Use Given
- Geometry
  - *Geographic*
  - *Other Derived*
- Spatial Fields
  - *Scalar Fields (one value per cell)*
    - *Isocontours*
    - *Direct Volume Rendering*
  - *Vector and Tensor Fields (many values per cell)*
    - *Flow Glyphs (local)*
    - *Geometric (sparse seeds)*
    - *Textures (dense seeds)*
    - *Features (globally derived)*

Idiom: **choropleth map**

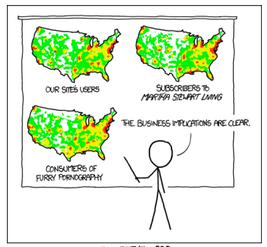
- use given spatial data
  - when central task is understanding spatial relationships
- data
  - geographic geometry
  - table with 1 quant attribute per region
- encoding
  - use given geometry for area mark boundaries
  - sequential segmented colormap [more later]



http://bl.ocks.org/mbostock/4060606

Beware: Population maps trickiness!

- consider when to normalize by population density
- general issue
  - absolute counts vs relative/normalized data

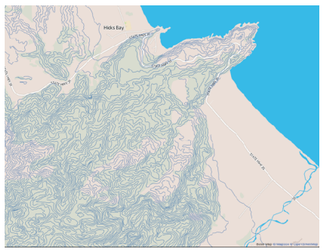


PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

[https://xkcd.com/1138]

Idiom: **topographic map**

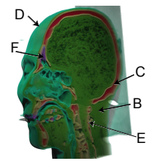
- data
  - geographic geometry
  - scalar spatial field
    - 1 quant attribute per grid cell
- derived data
  - isoline geometry
    - isocontours computed for specific levels of scalar values



Land Information New Zealand Data Service

Idioms: **isosurfaces, direct volume rendering**

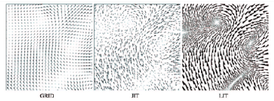
- data
  - scalar spatial field
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships
- isosurface
  - derived data: isocontours computed for specific levels of scalar values
- direct volume rendering
  - transfer function maps scalar values to color, opacity
    - no derived geometry



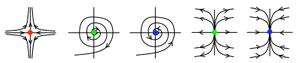
[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]
[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Vector and tensor fields

- data
  - many attribs per cell
- idiom families
  - flow glyphs
    - purely local
  - geometric flow
    - derived data from tracing particle trajectories
    - sparse set of seed points
  - texture flow
    - derived data, dense seeds
  - feature flow
    - global computation to detect features
      - encoded with one of methods above



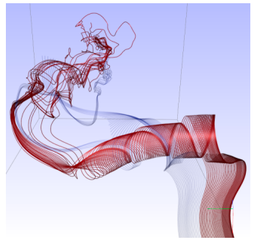
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

Idiom: **similarity-clustered streamlines**

- data
  - 3D vector field
- derived data (from field)
  - streamlines: trajectory particle will follow
- derived data (per streamline)
  - curvature, torsion, tortuosity
  - signature: complex weighted combination
  - compute cluster hierarchy across all signatures
  - encode: color and opacity by cluster
- tasks
  - find features, query shape
- scalability
  - millions of samples, hundreds of streamlines



[Similarity Measures for Enhancing Interactive Streamline Seeding. McLoughlin, Jones, Laramee, Malki, Masters, and Hansen. IEEE Trans. Visualization and Computer Graphics 19:8 (2013), 1342–1353.]

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 8: Arrange Spatial Data*
- How Maps Work: Representation, Visualization, and Design. MacEachren. Guilford Press, 1995.
- Overview of visualization. Schroeder and. Martin. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 3–39. Elsevier, 2005.
- Real-Time Volume Graphics. Engel, Hadwiger, Kniss, Reza-Salama, and Weiskopf. AK Peters, 2006.
- Overview of flow visualization. Weiskopf and Erlebacher. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 261–278. Elsevier, 2005.

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  - Reduce: Filter, Aggregate

@tamaramunzner

http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

Arrange networks and trees

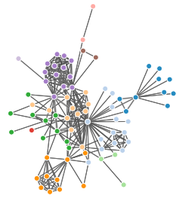
Node–Link Diagrams
Connection Marks
NETWORKS ✓ TREES ✓

Adjacency Matrix
Derived Table
NETWORKS ✓ TREES ✓

Enclosure
Containment Marks
NETWORKS ✗ TREES ✓

Idiom: **force-directed placement**

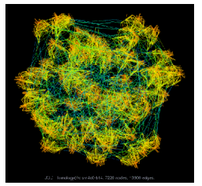
- visual encoding: node-link diagram
  - link connection marks, node point marks
- algorithm: energy minimization
  - analogy: nodes repel, links draw together like springs
  - optimization problem: minimize crossings
- spatial position: no meaning directly encoded
  - sometimes proximity meaningful
  - sometimes proximity arbitrary, artifact of layout algorithm
- tasks
  - explore topology; locate paths, clusters
- scalability
  - node/edge density E < 4N



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

Idiom: **sfdp** (multi-level force-directed placement)

- data
  - original: network
  - derived: cluster hierarchy atop it
- considerations
  - better algorithm for same encoding technique
    - same: fundamental use of space
    - hierarchy used for algorithm speed/quality but not shown explicitly
- scalability
  - nodes, edges: 1K-10K
  - hairball problem still hits eventually

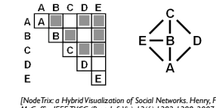


[Efficient and high quality force-directed graph drawing. Hu. The Mathematica Journal 10:37–71, 2005.]

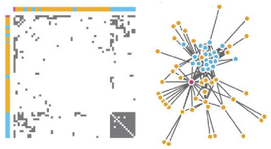
http://www.research.att.com/yifanhu/GALLERY/GRAPHS/index.html

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



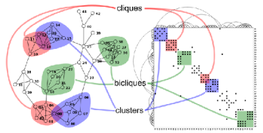
[NodeTrix: a Hybrid Visualization of Social Networks. Henry, Fekete, and McGuffin. IEEE TVCG (Proc. InfoVis) 13(6):1302-1309, 2007.]



[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!

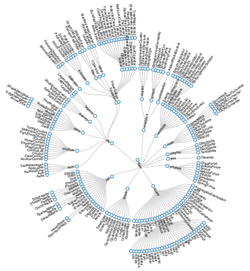


http://www.michaelmcguffin.com/courses/vis/patternsInAdjacencyMatrix.png

[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.]

Idiom: **radial node-link tree**

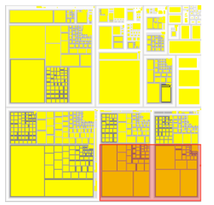
- data
  - tree
- encoding
  - link connection marks
  - point node marks
  - radial axis orientation
    - angular proximity: siblings
    - distance from center: depth in tree
- tasks
  - understanding topology, following paths
- scalability
  - 1K - 10K nodes



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

Idiom: **treemap**

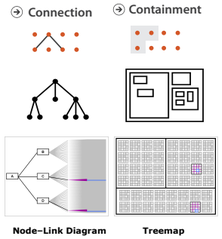
- data
  - tree
  - 1 quant attrib at leaf nodes
- encoding
  - area containment marks for hierarchical structure
  - rectilinear orientation
  - size encodes quant attrib
- tasks
  - query attribute at leaf nodes
- scalability
  - 1M leaf nodes



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, Nov 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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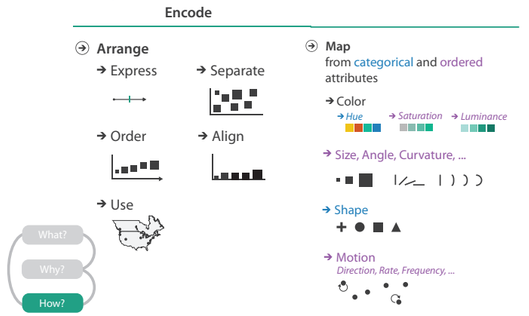
@tamaramunzner

http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

Idiom design choices: First half

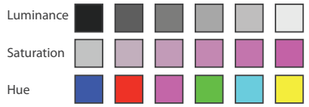


Decomposing color

- first rule of color: do not talk about color!
  - color is confusing if treated as monolithic

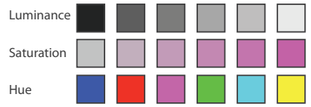
Decomposing color

- first rule of color: do not talk about color!
  - color is confusing if treated as monolithic
- decompose into three channels



Decomposing color

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



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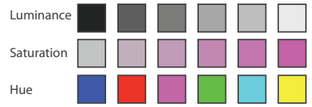
  - categorical can show identity
    - hue
- perceptual colorspace, in contrast to three channels of RGB



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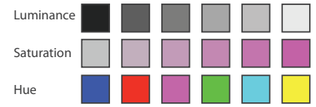
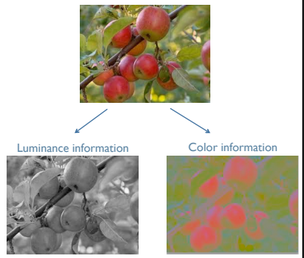


Luminance

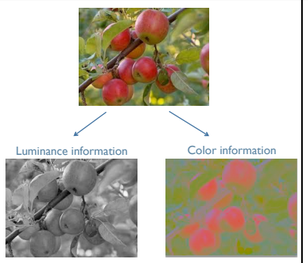
- need luminance for edge detection
  - fine-grained detail only visible through luminance contrast
  - legible text requires luminance contrast!



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

Luminance

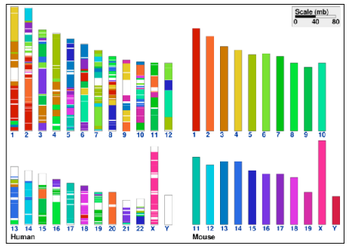
- need luminance for edge detection
  - fine-grained detail only visible through luminance contrast
  - legible text requires luminance contrast!
- HLS better than RGB for encoding but beware
  - L lightness ≠ L* luminance



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

Categorical color: Discriminability constraints

- noncontiguous small regions of color: only 6-12 bins



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

Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear

Ordered color: Rainbow is poor default

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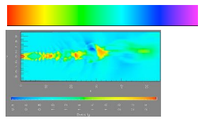
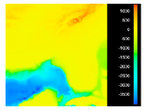
Ordered color: Rainbow is poor default

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



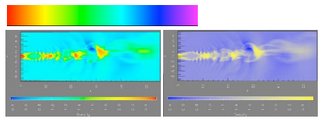
[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]



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

Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - fine-grained structure visible and nameable
- alternatives
  - large-scale structure: fewer hues



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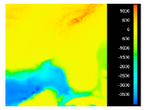

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- problems
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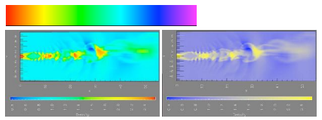
- benefits
  - fine-grained structure visible and nameable
- alternatives
  - large-scale structure: fewer hues
  - fine structure: multiple hues with monotonically increasing luminance [eg viridis]



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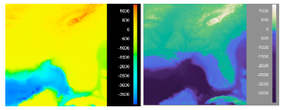

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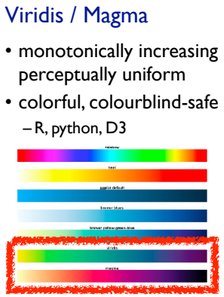
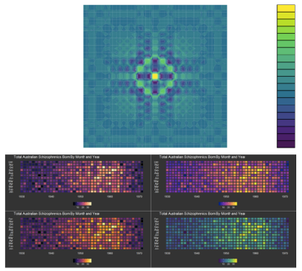
Viridis / Magma

- monotonically increasing luminance, perceptually uniform
- colorful, colourblind-safe
  - R, python, D3

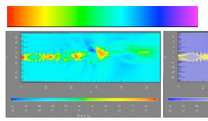




https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html

Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - fine-grained structure visible and nameable
- alternatives
  - large-scale structure: fewer hues
  - fine structure: multiple hues with monotonically increasing luminance [eg viridis]
  - categorical: segmented saturated rainbow is good!



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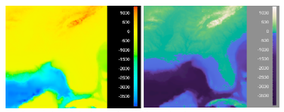
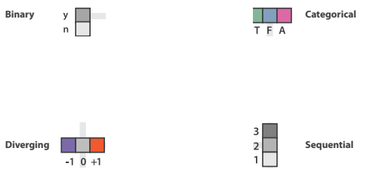


[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. http://www.research.ibm.com/people/l/lloydt/color/color.HTM]

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

Colormaps

- Categorical
- Ordered
  - Sequential
  - Diverging

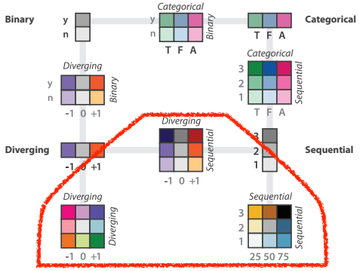


after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994. http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html]

Colormaps

- Categorical
- Ordered
  - Sequential
  - Diverging
- Bivariate

use with care if more than two levels (binary)!



after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994. http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html]

Colormaps

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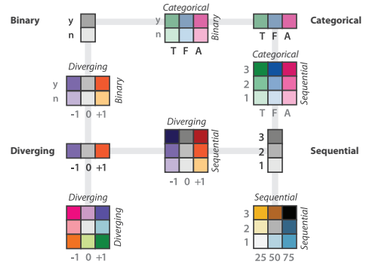

- color channel interactions
  - size heavily affects salience
    - small regions need high saturation
    - large need low saturation
  - saturation & luminance: 3-4 bins max
    - also not separable from transparency

after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994. http://www.personal.psu.edu/faculty/c/a/cab38/ColorSchi/Schemes.html]

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, Nov 2014.
  - *Chap 10: Map Color and Other Channels*
- ColorBrewer, Brewer.
  - http://www.colorbrewer2.org
- *Color In Information Display*. Stone. IEEE Vis Course Notes, 2006.
  - http://www.stonesc.com/Vis06
- A Field Guide to Digital Color. Stone. AK Peters, 2003.
- *Rainbow Color Map (Still) Considered Harmful.* Borland and Taylor. IEEE Computer Graphics and Applications 27:2 (2007), 14–17.
- Visual Thinking for Design. Ware. Morgan Kaufmann, 2008.
- Information Visualization: Perception for Design, 3rd edition. Ware. Morgan Kaufmann /Academic Press, 2004.
- http://www.r-bloggers.com/using-the-new-viridis-colormap-in-r-thanks-to-simon-garnier/

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  - Manipulate: Change, Select, Navigate
  - Facet: Juxtapose, Partition, Superimpose
  - Reduce: Filter, Aggregate

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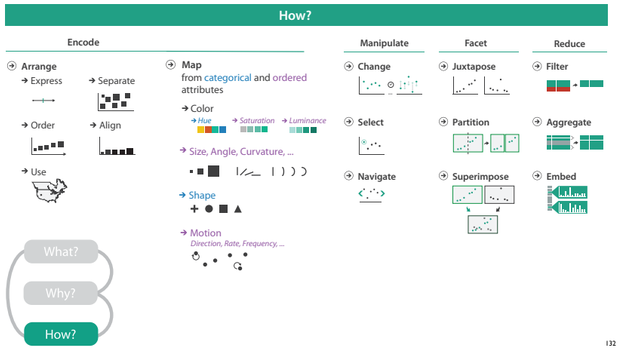
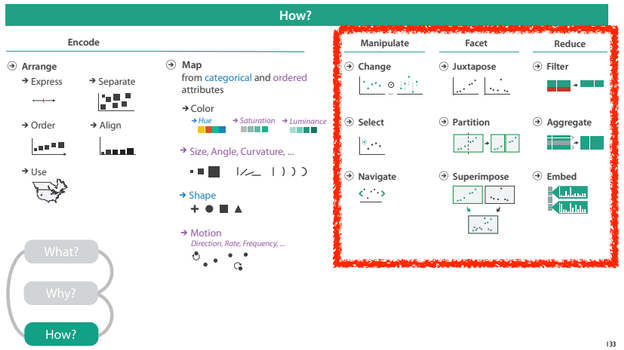
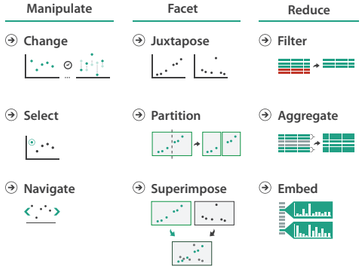
http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20



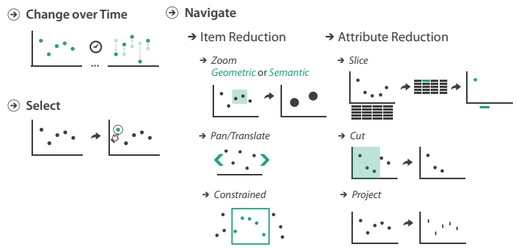


How to handle complexity: 1 previous strategy + 3 more

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

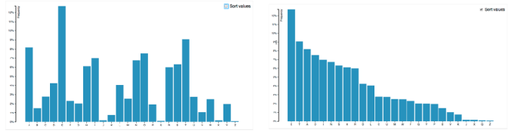


Manipulate



Idiom: **Change order/arrangement**

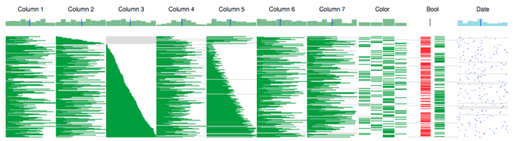
- what: simple table
- how: data-driven reordering
- why: find extreme values, trends



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

Idiom: **Change order** System: **DataStripes**

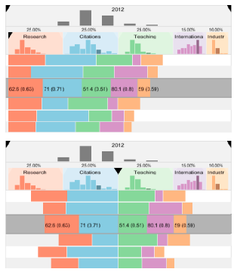
- what: table with many attributes
- how: data-data-driven reordering by selecting column
- why: find correlations between attributes



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

Idiom: **Change align** System: **LineUp**

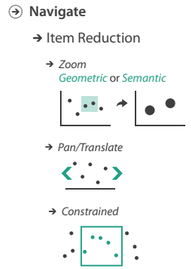
- stacked bars
  - easy to compare
    - first segment
    - total bar
- align to different segment
  - supports flexible comparison



[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.]

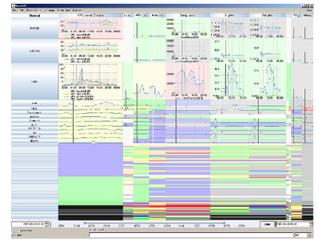
Navigate: Changing item visibility

- 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



Idiom: **Semantic zooming** System: **LiveRAC**

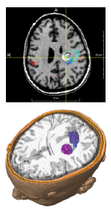
- visual encoding change
  - colored box
  - sparkline
  - simple line chart
  - full chart: axes and tickmarks

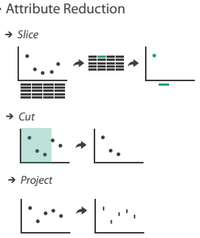


[LiveRAC - Interactive Visual Exploration of System Management Time-Series Data. McLachlan, Munzner, Koutsofios, and North. Proc. ACM Conf. Human Factors in Computing Systems (CHI), pp. 1483–1492, 2008.]

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
      - perspective
      - many others: Mercator, cabinet, ...





[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.]

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. InfoVis 07) 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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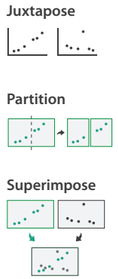
@tamaramunzner

http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

Facet



Juxtapose and coordinate views

→ Share Encoding: Same/Different

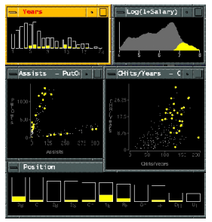
→ *Linked Highlighting*

→ 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:
  - different items: different condition keys, same gene keys
  - same attributes: expression values for node colors
  - (same network layout for nodes=genes)
- 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

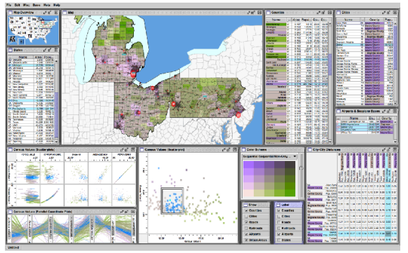
Coordinate views: Design choice interaction

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

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.]

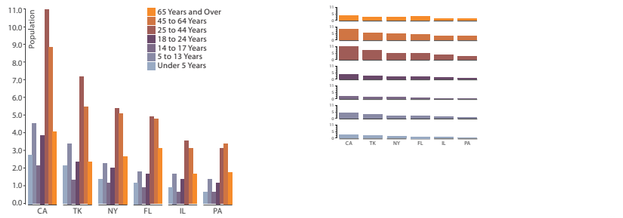
Partition into views

→ Partition into Side-by-Side Views

- how to divide data between views
  - split into regions by attributes
  - encodes association between items using spatial proximity
  - order of splits has major implications for what patterns are visible

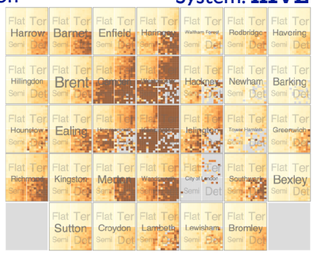
Partitioning: List alignment

- 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**

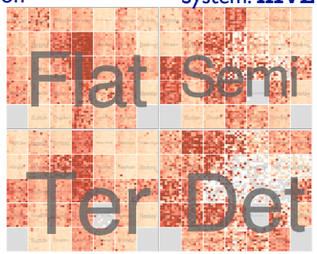
- split by neighborhood
- then by type
- then time
  - years as rows
  - months as columns
- color by price
- neighborhood patterns
  - where it's expensive
  - where you pay much more for detached type



[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**

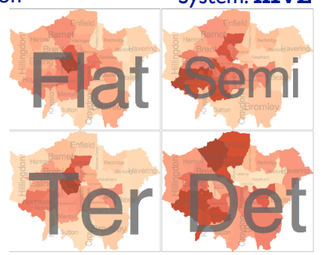
- switch order of splits
  - type then neighborhood
- switch color
  - by price variation
- type patterns
  - within specific type, which neighborhoods inconsistent



[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.]

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?

→ Superimpose Layers

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

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

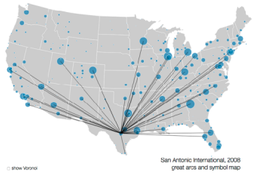
[Get it right in black and white. Stone. 2010. http://www.stonesc.com/wordpress/2010/03/get-it-right-in-black-and-white]

Idiom: **Trellis plots**

- superimpose within same frame
  - color code by year
- partitioning
  - split by site, rows are wheat varieties
- main-effects ordering
  - derive value of median for group, use to order
  - order rows within view by variety median
  - order views themselves by site median

Dynamic visual layering

- interactive based on selection
- one-hop neighbour highlighting demos: click vs hover (lightweight)



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 Visualization.* 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.

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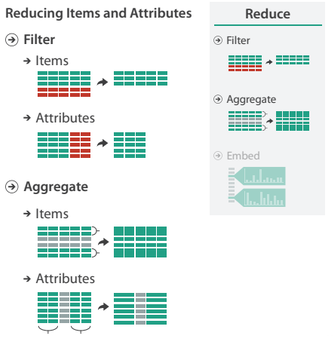
@tamaramunzner

http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

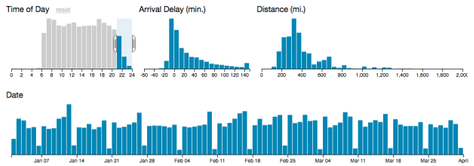
Reduce items and attributes

- 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: **cross filtering** System: **Crossfilter**

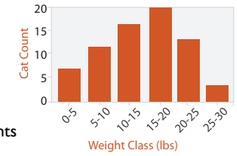
- item filtering
- coordinated views/controls combined
  - all scented histogram bisliders update when any ranges change



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

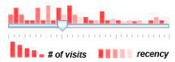
Idiom: **histogram**

- 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

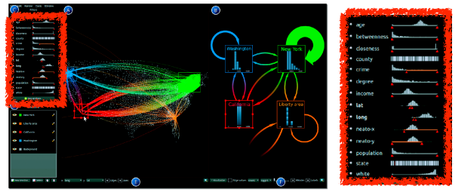


Idiom: **scented widgets**

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



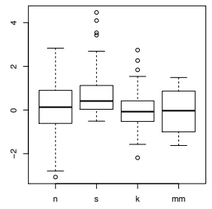
[Scented Widgets: Improving Navigation Cues with Embedded Visualizations. Willett, Heer, and Agrawala. IEEE TVCG (Proc. InfoVis 2007) 13:6 (2007), 1129–1136.]



[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).]

Idiom: **boxplot**

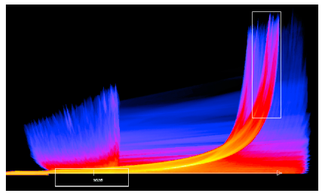
- static item aggregation
- task: find distribution
- data: table
- derived data
  - 5 quant attribs
    - median: central line
    - lower and upper quartile: boxes
    - lower upper fences: whiskers
      - values beyond which items are outliers
  - outliers beyond fence cutoffs explicitly shown



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

Idiom: **Continuous scatterplot**

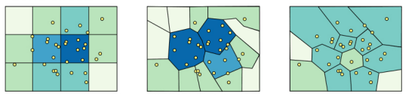
- static item aggregation
- data: table
- derived data: table
  - key attribs x,y for pixels
  - quant attrib: overplot density
- dense space-filling 2D matrix
- color: sequential categorical hue + ordered luminance colormap
- scalability
  - no limits on overplotting: millions of items



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

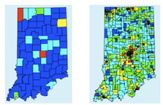
Spatial aggregation

- MAUP: Modifiable Areal Unit Problem
  - changing boundaries of cartographic regions can yield dramatically different results
  - zone effects



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

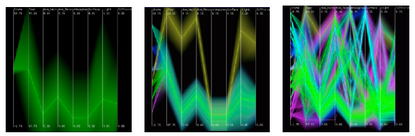
  - scale effects



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

Idiom: **Hierarchical parallel coordinates**

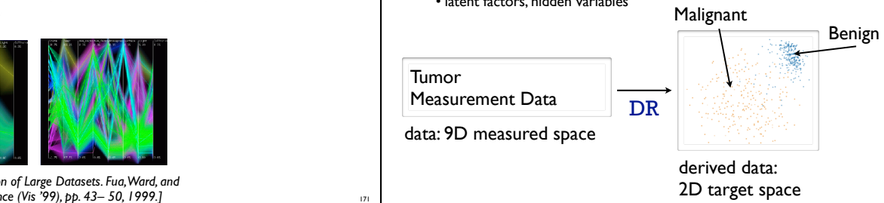
- dynamic item aggregation
- derived data: ***hierarchical clustering***
- encoding:
  - cluster band with variable transparency, line at mean, width by min/max values
  - color by proximity in hierarchy



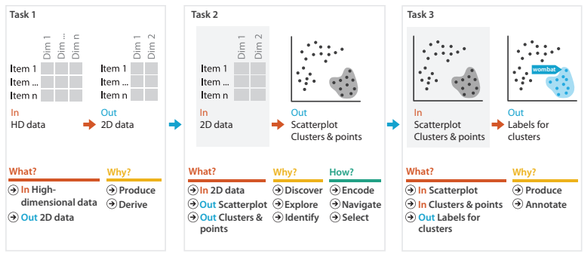
[Hierarchical Parallel Coordinates for Exploration of Large Datasets. Fua, Ward, and Rundensteiner. Proc. IEEE Visualization Conference (Vis '99), pp. 43– 50, 1999.]

Dimensionality reduction

- attribute aggregation
  - derive low-dimensional target space from high-dimensional measured space
  - use when you can't directly measure what you care about
    - true dimensionality of dataset conjectured to be smaller than dimensionality of measurements
    - latent factors, hidden variables



Idiom: **Dimensionality reduction for documents**

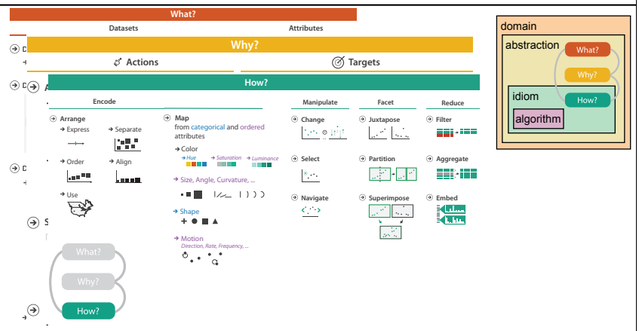


Further reading

- 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.

Not covered

- Rules of Thumb
  - No unjustified 3D
    - Power of the plane, dangers of depth
    - Occlusion hides information
    - Perspective distortion loses information
    - Tilted text isn't legible
  - No unjustified 2D
  - Eyes beat memory
  - Resolution over immersion
  - Overview first, zoom and filter, details on demand
  - Responsiveness is required
  - Function first, form next
- Embed: Focus+Context

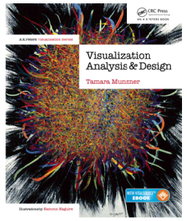


More information

- this tutorial
  http://www.cs.ubc.ca/~tmm/talks.html#halfdaycourse20

- book
  http://www.cs.ubc.ca/~tmm/vadbook
  - 20% promo code for book+ebook combo: HVN17
  - http://www.crcpress.com/product/isbn/9781466508910
  - illustration acknowledgement: Eamonn Maguire

- full courses, papers, videos, software, talks
  http://www.cs.ubc.ca/group/infovis
  http://www.cs.ubc.ca/~tmm



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

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