Information Visualization
Marks & Channels, Rules of Thumb
Design Study Methodology

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Week 3, 18 Sep 2025

https://www.cs.ubc.ca/~tmm/courses/547-25

Plan for today

- 15 min: pitches details & project resources
- 20 min: Rules of Thumb
  - mini-lecture
- 10 min: Channels & Perception
  - mini-lecture
- 45 min: Marks Revisited
  - mini-lecture
- (break: 10 min)
- 70 min: Marks & Channels Practice
  - examples discussion
- if time: readings / Q&A discussion

Next week

- to read & discuss (async, before next class)
  - VAD book, Ch 7: Arrange Tables
  - VAD book, Ch 11: Manipulate View
  - paper: TACO: Visualizing Changes in Tables Over Time
- sync class: project pitches!
  - 4 min each
  - if already have full or partial team, can combine your times together
  - up to you: prerecord video OR present live, need slides either way
    - due on Canvas by 12pm (Thu Sep 25)
      - if prerecorded, videos and slides. if live: slides
    - video creation tips/resources https://www.cs.ubc.ca/~tmm/courses/547-25/video.html
  - near-realtime Q&A / discussion through dedicated Piazza thread

Pitches

- everybody must do one (solo or team)
  - also one from local company
- way to find teammates
  - convince them to work on yours, or you decide to work on theirs
  - even if your team is all set, situational awareness of what others doing
- schedule
  - pitches next week in class (Thu Sep 26)
  - must form teams week after that, by Fri Oct 3, noon
  - team pre-proposal meetings week after that, in class & OH slot (Thu Oct 9)
    - if no signoff: followup meetings only possible through Thu Oct 16 (not Fri Oct 17)
  - written proposals due Sun Oct 19, noon

Project resources: Datasets

- many choices!
  - Data Is Plural: weekly newsletter of interesting/quirky datasets by Jeremy Singer-Vine
    - browseable weekly lists
    - single master spreadsheet with everything
    - DVS Challenge: London Stage dataset
  - VAST Challenge
    - both data and tasks! (2003-2021)
    - multiple mini-challenges per year
  - Kaggle datasets
    - you'll need to think (hard) about tasks
  - many more on Resources page
    http://www.cs.ubc.ca/group/infovis/resources.shtml#data-repos

Project resources: Tools

- Tools: you're free to pick platform
  - align with current strengths? learn something new?
  - overview of the "big 4": D3, R/tidyverse, Python, Tableau
    https://www.cs.ubc.ca/~tmm/courses/547-25/tools/
  - consider covering your own strengths & goals in your pitch
- Smaller tools: also free to use
  - you pick project scope:
    - build skills by rolling your own?
    - do something bigger by building on existing toolkits/libraries?
  - many, many smaller building blocks
    - https://www.visualisingdata.com/resources/

Mini-Lecture: Rules of Thumb

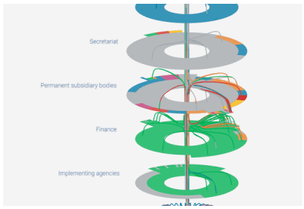
Rules of Thumb Summary

- No unjustified 3D
- No unjustified 2D
- Eyes beat memory
- Resolution over immersion
- Overview first, zoom and filter, details on demand
- Responsiveness is required
- Function first, form next

No Unjustified 3D

Multi-Layered Spinning 3D Radial Chord Donut

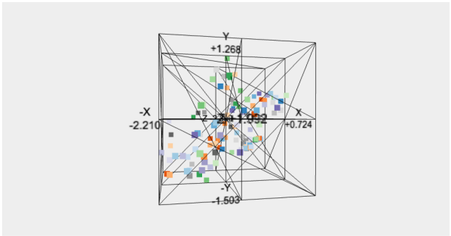
- critique



https://climateregimemap.net/hierarchical

Rotating 3D Scatterplot Cube

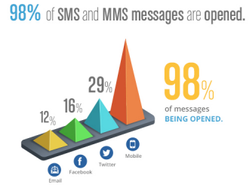
- critique



https://observablehq.com/@bumbeishvili/clx-porting-3d-scatter-plot-using-three-js

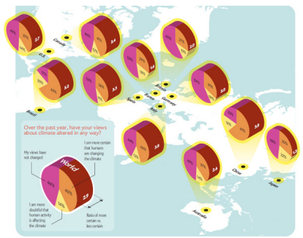
Messaging Pyramids

- critique



https://viz.wtf/post/150363881173/scheming-pyramids

Pie Chart Overlords



https://viz.wtf/post/136339952135/i-for-one-welcome-our-new-pie-chart-overlords

Eyes beat memory

- principle: external cognition vs. internal memory
  - easy to compare by moving eyes between side-by-side views
  - harder to compare visible item to memory of what you saw
- implications for animation
  - great for choreographed storytelling
  - great for transitions between two states
  - poor for many states with changes everywhere
    - consider small multiples instead

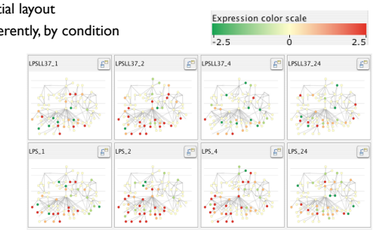
literal — abstract

animation — small multiples

show time with time — show time with space

Eyes beat memory example: Cerebral

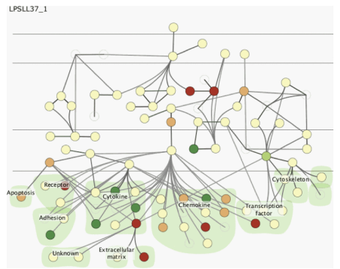
- small multiples: one graph instance per experimental condition
  - same spatial layout
  - color differently, by condition



[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.]

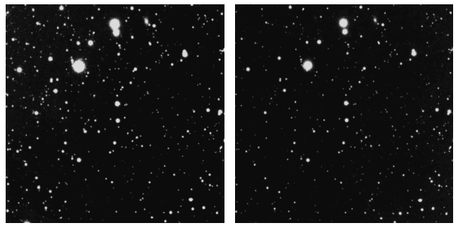
Why not animation?

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



Animation: Blink comparator

- just two contiguous frames is a special case: animation beats side by side
  - blink comparator used to discover Pluto



side by side

https://www.sightsize.com/the-blink-comparator/

Animation: Blink comparator

- just two contiguous frames is a special case: animation is great!
  - blink comparator used to discover Pluto

animated

https://www.sightsize.com/the-blink-comparator/

Change blindness

- if attention is directed elsewhere, even drastic changes not noticeable
  - remember door experiment?
- change blindness demos
  - mask in between images
    https://youtu.be/bh_9XFzbWV8

Function first, form next

- start with focus on functionality
  - possible to improve aesthetics later on, as refinement
  - if no expertise in-house, find good graphic designer to work with
  - aesthetics do matter: another level of function
    - visual hierarchy, alignment, flow
    - Gestalt principles in action
      - *(not covered in this class)*
- dangerous to start with aesthetics
  - usually impossible to add function retroactively

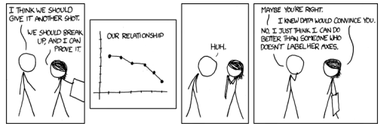
Form: Basic graphic design ideas

- proximity
  - do group related items together
  - avoid equal whitespace between unrelated
- alignment
  - do find/make strong line, stick to it
  - avoid automatic centering
- repetition
  - do unify by pushing existing consistencies
- contrast
  - if not identical, then very different
  - avoid not quite the same

- buy now and read cover to cover - very practical, worth your time, fast read!
  The Non-Designer's Design Book, 4th ed. Robin Williams, Peachpit Press, 2015.

Best practices: Labelling

- make visualizations as self-documenting as possible
  - meaningful & useful title, labels, legends
    - axes and panes/subwindows should have labels
      - and axes should have good mix/max boundary tick marks
    - everything that's plotted should have a legend
      - and own header/labels if not redundant with main title
    - use reasonable numerical format
      - avoid scientific notation in most cases



[https://xkcd.com/833/]

Mini-Lecture: Perception

Popout

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

Popout

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  - how long does it take?

Popout

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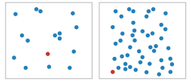
  - how long does it take?



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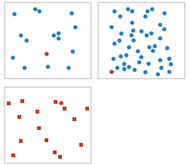

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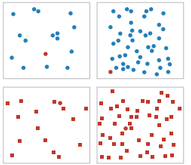

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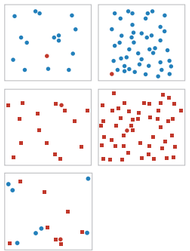

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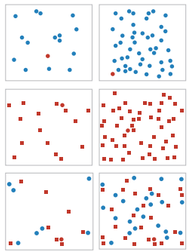
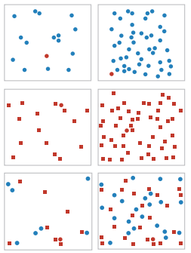
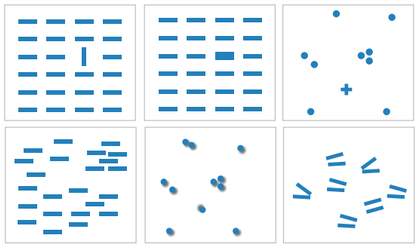


Popout

- 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

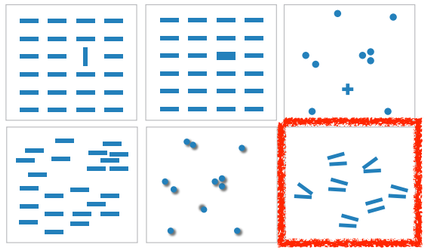


Popout



- 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

Factors affecting accuracy

- alignment
- distractors
- distance
- common scale

Relative vs. absolute judgements

- perceptual system mostly operates with relative judgements, not absolute

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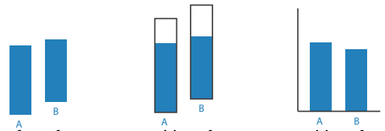
  - that's why accuracy increases with common frame/scale and alignment



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 vs. absolute judgements

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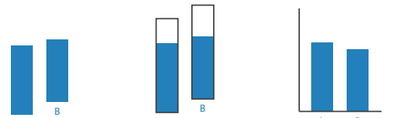
  - Weber's Law: ratio of increment to background is constant



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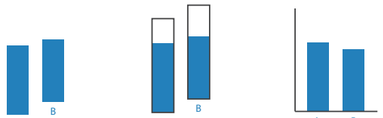
Relative vs. absolute judgements

- 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



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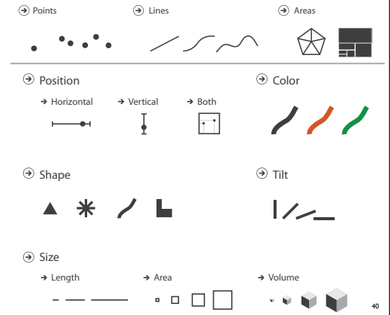
Mini-Lecture: Marks, Revisited

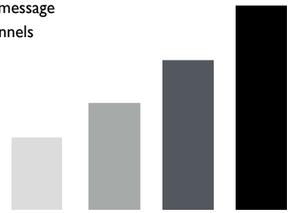
Marks and channels: original version

- marks
  - basic geometric elements
- channels
  - control appearance of marks



Redundant encoding

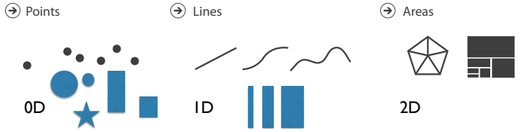
- multiple channels
  - sends stronger message
  - but uses up channels



Length and Luminance

Marks: Constrained vs encodable

- math view: geometric primitives have dimensions



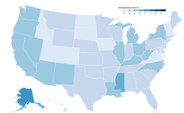
- constraint view: mark type constrains what else can be encoded
  - points: 0 constraints on size, can encode more attributes w/ size & shape
  - lines: 1 constraint on size (length), can still size code other way (width)
  - areas: 2 constraints on size (length/width), cannot size code or shape code

Constraints & Channel Availability

- consider marks and channels as imposing constraints
  - when does mark type constrain channel use?
  - when does using one channel constrain another channel?
- Channel Availability Model
  - Encoded: which channels directly used to encode attributes?
    - clear meaning
    - multiple channels can be directly used for redundant encoding
  - Free: which channels free to encode another attribute?
    - without changing usability of existing encoding
  - Unavailable: which channels unavailable / precluded / taken?
    - because of mark type or characteristics?
    - because of idiom/algorithm design specifics?
    - because other channels used?

Constraints

- geographic example: choropleth maps
- what can we do to California? could we encode additional data?
  - cannot shrink/grow (size channel)
  - cannot translate (position channel)
  - cannot rotate (orientation channel)
  - cannot reshape (symbol channel)
  - why not?
    - would lose meaning of that mark: boundary encodes meaning
    - also lose meaning for other occluded marks

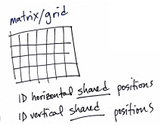


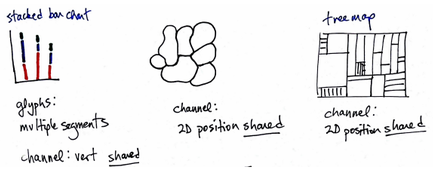
https://observablehq.com/@d3/us-state-choropleth

- constraints arise from shared boundaries between marks
  - can't independently change position, order, size, orientation, (symbol/shape)
  - could change all simultaneously, typically through algorithm

Shared boundary constraints

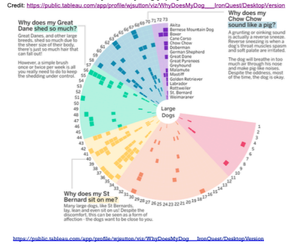
- marks that touch by design: shared boundary constraints
  - cannot change independently, moving one would affect the others
  - consider separately for each direction (horiz, vert) or intrinsically combined (2D)





Channel use: what does it mean?

- Does channel size encode attribute?
  - yes? sizes differ
    - according to dog name in alphabetical order
  - no! size differences not meaningful
    - just emerges from choice of layout, radial vs rectilinear
    - not a "real" attribute encoding
- Can we use size channel to encode another attribute?
  - no! not free
  - it's "taken" already, would change meaning
- Size channel is Unavailable



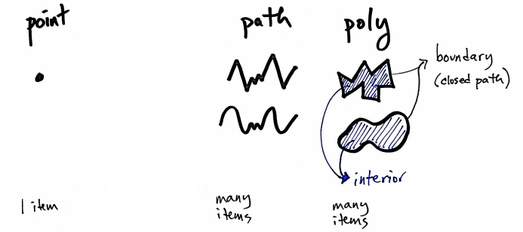
Marks revisited: for items

- basic geometric elements

- 3D volumes, not covered in this course

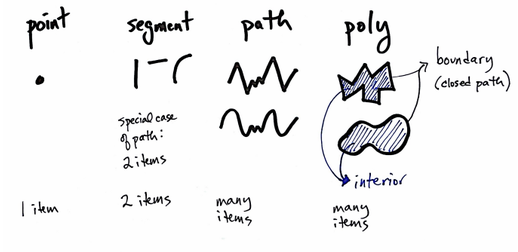
Marks revisited: for items

- basic geometric elements



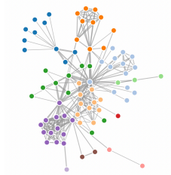
Marks revisited: for items

- basic geometric elements



Marks for links

Connection

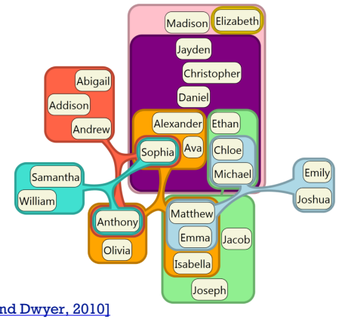


https://observablehq.com/@d3/force-directed-graph

Containment

vialab.science.uoit.ca/portfolio/bubblesets

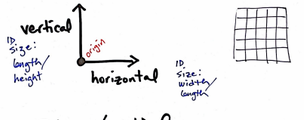
Containment can be nested



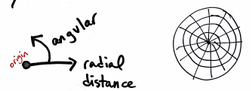
[Untangling Euler Diagrams, Riche and Dwyer, 2010]

Position: Two possible coordinate systems

- Cartesian/rectilinear



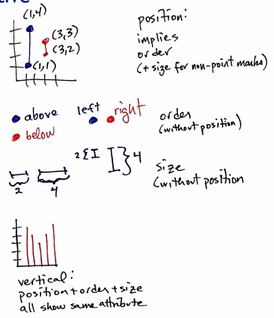
- Polar/radial



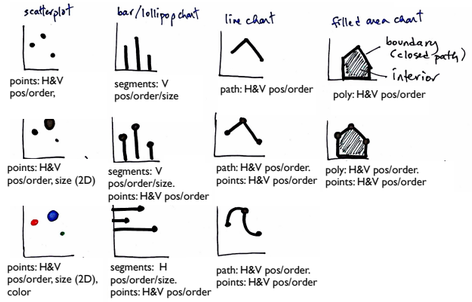
- mutually exclusive, can't use both at once

Position, order, size: Absolute vs relative

- position is absolute
  - position: absolute position that marks have in common within coordinate frame (Cartesian or polar)
- order and size are relative
  - order: relative locations
  - size: relative distances
  - can be used without absolute position
  - but follow position when that is used
    - always for order
    - with path/segment or poly types for size



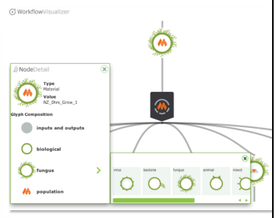
Visual encoding analysis, examples



Beyond simple marks: glyphs & levels

glyphs:
more than one mark for each item

levels:
hierarchical structure of marks: show info at multiple scales

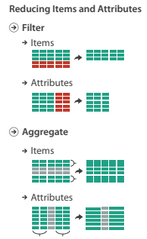


Maguire et al. Taxonomy-based Glyph Design – with a Case Study on Visualizing Workflows of Biological Experiments. TVCG 2012

Scope of analysis

- simplifying assumptions
  - at least one mark per item
  - single view
- later on
  - some items not represented by marks: aggregation and filtering
  - multiple views
    - beyond glyphs

one : many
mark : items
aggregation
filtering

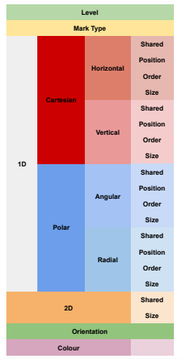


Break

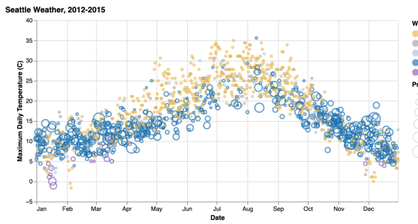
Marks & Channels Practice

Analyzing marks/channels

- mark level & type
- what is channel availability?
  - encoded (which attribute?)
  - free
  - unavailable
- are there shared boundaries?
  - separately in each dimension?
  - or combined in 2D?

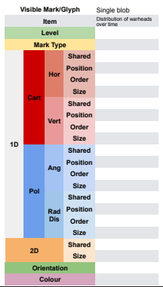


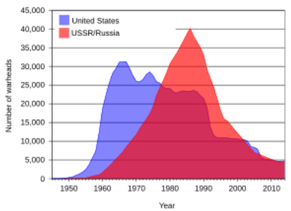
Analysis: Seattle Weather



https://vega.github.io/vega-lite/examples/interactive_seattle_weather.html

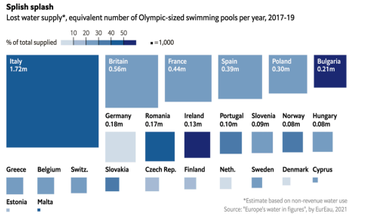
Analysis: Warheads





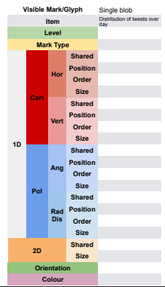
https://en.wikipedia.org/wiki/Area_chart#/media/File:US_and_USSR_nuclear_stockpiles.svg

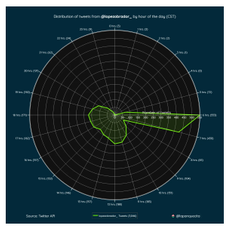
Analysis: Lost Water



https://www.economist.com/graphic-detail/2023/07/18/in-drought-stricken-europe-leaky-pipes-are-worsening-the-problem

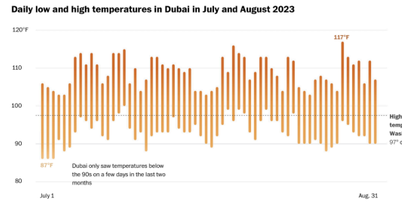
Analysis: Mexican President Tweets





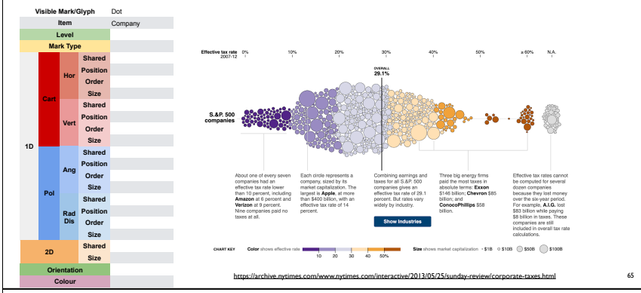
https://www.reddit.com/r/dataisbeautiful/comments/108bc46/oc_distribution_of_tweets_from_the_mexican/

Analysis: Dubai Temperatures



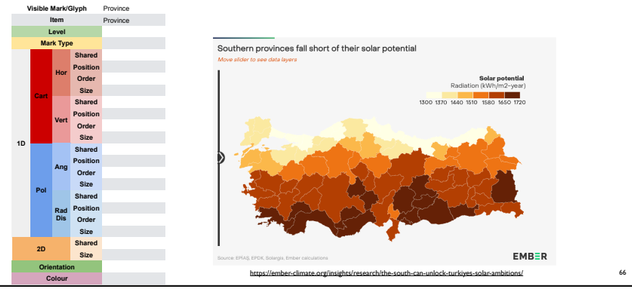
https://www.washingtonpost.com/world/2023/09/10/dubai-heat-staying-cool

Analysis: Tax Rates



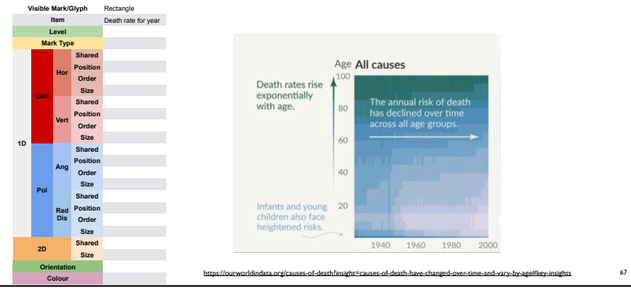
https://archive.nytimes.com/www.nytimes.com/interactive/2013/05/25/sunday-review/corporate-taxes.html

Analysis: Turkish Solar



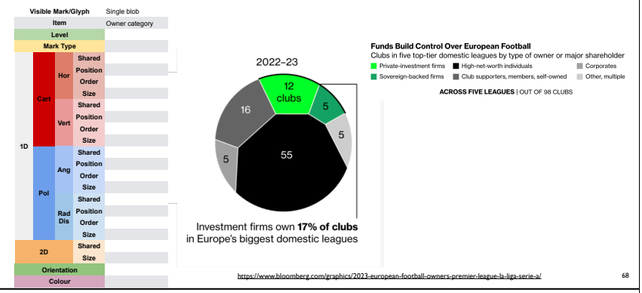
https://ember-climate.org/insights/research/the-south-can-unlock-turkiyes-solar-ambitions/

Analysis: Death Causes



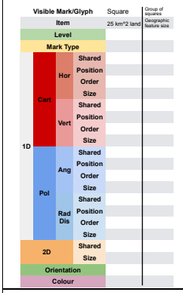
https://ourworldindata.org/causes-of-death?insight=causes-of-death-have-changed-over-time-and-vary-by-age#key-insights

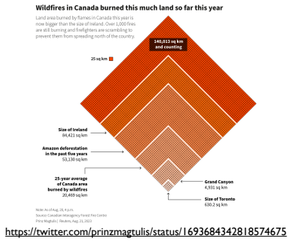
Analysis: Football Club Owners



https://www.bloomberg.com/graphics/2023-european-football-owners-premier-league-la-liga-serie-a/

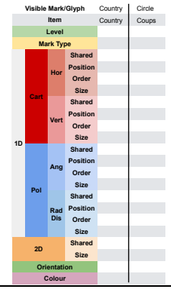
Analysis: Canada Wildfires (Multiscale)

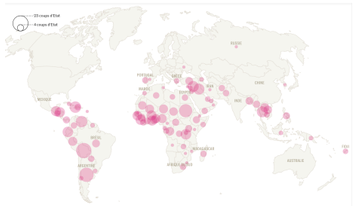




https://twitter.com/prinzmagtulis/status/1693684342818574675

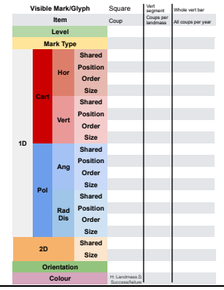
Analysis: Coups d'Etat (Map)

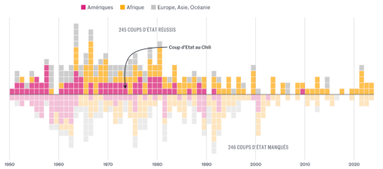




https://www.lemonde.fr/les-decodeurs/article/2023/09/11/depuis-1950-pres-de-cinq-cents-coups-d-etat-tentes-ou-reussis-surtout-en-amerique-latine-et-en-afrique_6188906_4355770.html

Analysis: Coups d'Etat (Multiscale)





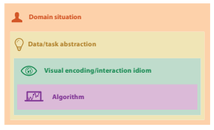
https://www.lemonde.fr/les-decodeurs/article/2023/09/11/depuis-1950-pres-de-cinq-cents-coups-d-etat-tentes-ou-reussis-surtout-en-amerique-latine-et-en-afrique_6188906_4355770.html

Q&A/Backup Slides

Marks and Channels

Visual encoding

- how to systematically analyze idiom structure?



Visual encoding

- how to systematically analyze idiom structure?

Visual encoding

- how to systematically analyze idiom structure?

- marks & channels
  - –marks: represent items or links
  - –channels: change appearance of marks based on attributes

Marks for items

- basic geometric elements

- 3D mark: volume, rarely used

Marks for links

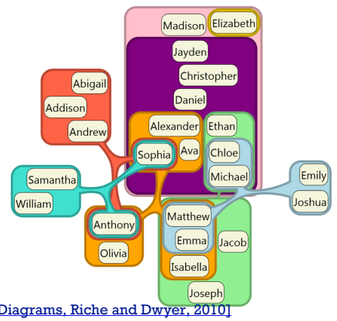
Containment

vialab.science.uoit.ca/portfolio/bubblesets

Connection

https://observablehq.com/@d3/force-directed-graph

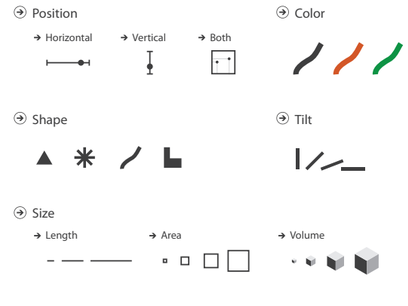
Containment can be nested



[Untangling Euler Diagrams, Riche and Dwyer, 2010]

Channels

- control appearance of marks
  - –proportional to or based on attributes
- many names
  - –**visual channels**
  - –visual variables
  - –retinal channels
  - –visual dimensions
  - –...

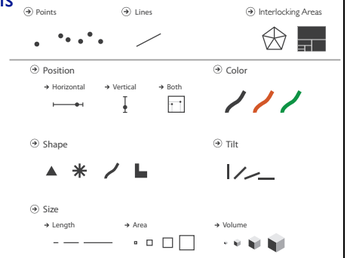


Definitions: Marks and channels

- marks
  - geometric primitives

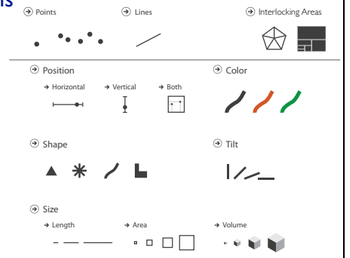
Definitions: Marks and channels

- 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

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

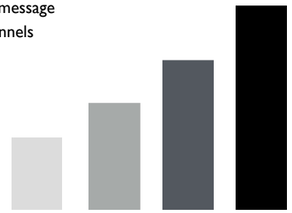
mark: point

mark: point

mark: point

Redundant encoding

- multiple channels
  - sends stronger message
  - but uses up channels



Length, Position, and Luminance

Marks as constraints

- math view: geometric primitives have dimensions

Marks as constraints

- math view: geometric primitives have dimensions

- constraint view: mark type constrains what else can be encoded
  - points: 0 constraints on size, can encode more attributes w/ size & shape
  - lines: 1 constraint on size (length), can still size code other way (width)
  - interlocking areas: 2 constraints on size (length/width), cannot size or shape code
    - interlocking: size, shape, position

Marks as constraints

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  - interlocking areas: 2 constraints on size (length/width), cannot size or shape code
    - interlocking: size, shape, position
- quick check: can you size-code another attribute
  - or is size/shape in use?

Scope of analysis

- simplifying assumptions: one mark per item, single view
- later on
  - multiple views
  - multiple marks in a region (glyph)
  - some items not represented by marks (aggregation and filtering)

When to use which channel?

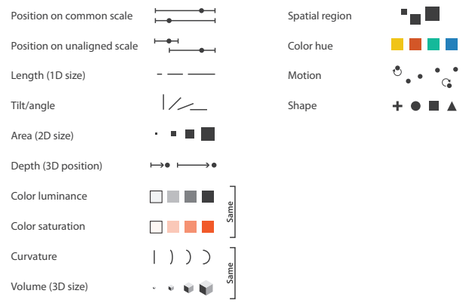
expressiveness

match channel type to data type

effectiveness

some channels are better than others

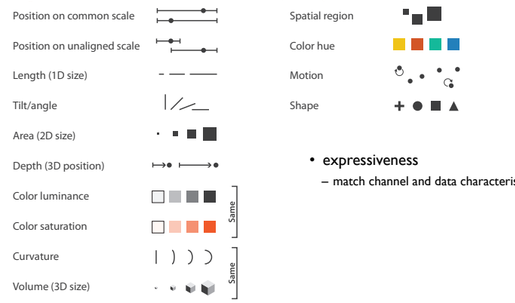
Channels: Rankings



Channels: Rankings

Magnitude Channels: Ordered Attributes

Identity Channels: Categorical Attributes



- expressiveness
  - match channel and data characteristics

Channels: Rankings

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

(Color luminance, Color saturation: Same; Curvature, Volume (3D size): Same)

Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

Attribute Types: Categorical; Ordered (Ordinal, Quantitative)

- expressiveness
  - match channel and data characteristics
  - magnitude for ordered
    - how much? which rank?
  - identity for categorical
    - what?

Channels: Rankings

Magnitude Channels: Ordered Attributes

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Effectiveness: Best ▲ ▼ Least

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

Channels: Rankings

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Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

Effectiveness: Best ▲ ▼ Least

- expressiveness
  - match channel and data characteristics
- effectiveness
  - channels differ in accuracy of perception
  - spatial position ranks high for both

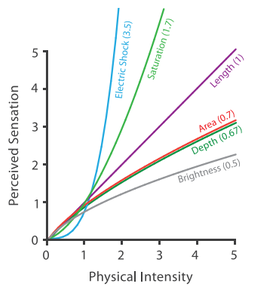
Channel effectiveness

- accuracy: how precisely can we tell the difference between encoded items?
- discriminability: how many unique steps can we perceive?
- separability: is our ability to use this channel affected by another one?
- popout: can things jump out using this channel?

Accuracy: Fundamental theory

- length is accurate: linear
- others magnified or compressed
  - exponent characterizes

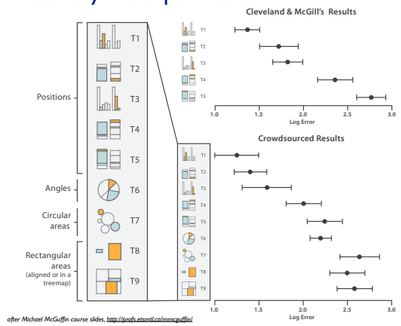
Steven's Psychophysical Power Law: $S = I^N$



S = sensation

I = intensity

Accuracy: Vis experiments

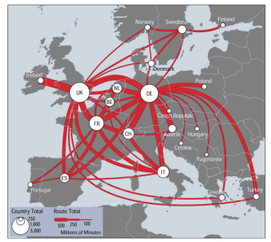


[Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

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

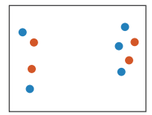
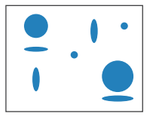
Discriminability: How many usable steps?

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



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

Separability vs. Integrality

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

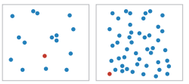
- find the red dot
  - how long does it take?

Popout

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

Popout

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



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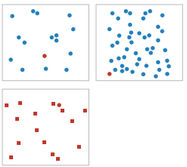

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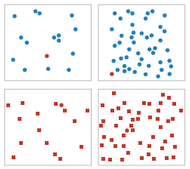

Popout

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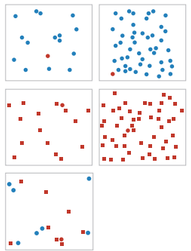

Popout

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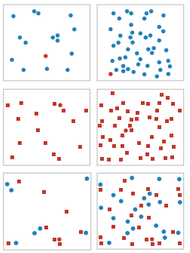
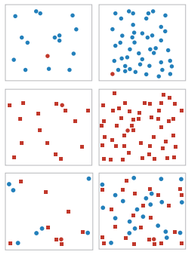
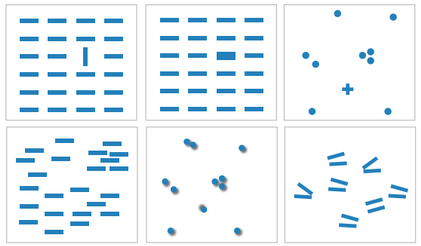


Popout

- 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

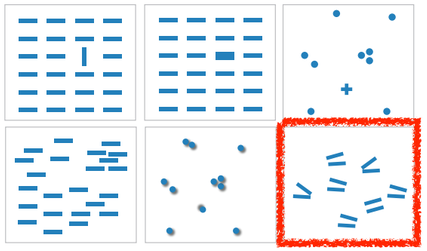


Popout



- 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

Factors affecting accuracy

- alignment
- distractors
- distance
- common scale

Relative vs. absolute judgements

- perceptual system mostly operates with relative judgements, not absolute

Relative vs. absolute judgements

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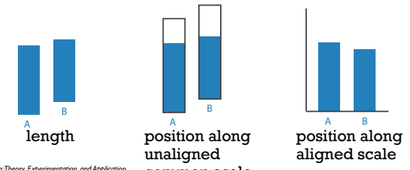

after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

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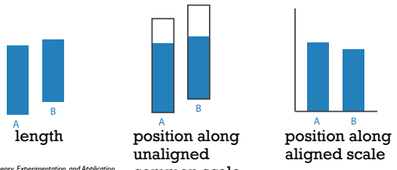

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Relative vs. absolute judgements

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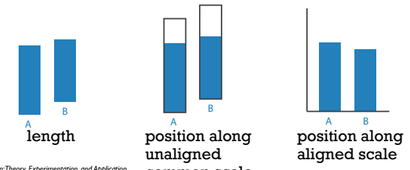
  - that's why accuracy increases with common frame/scale and alignment
  - Weber's Law: ratio of increment to background is constant
    - filled rectangles differ in length by 1:9, difficult judgement
    - white rectangles differ in length by 1:2, easy judgement



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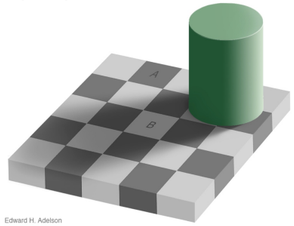
Relative luminance judgements

- perception of luminance is contextual based on contrast with surroundings



Edward H. Adelson

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

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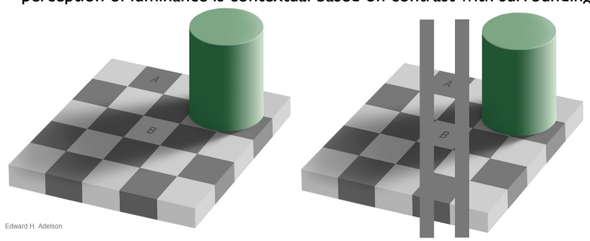

Edward H. Adelson

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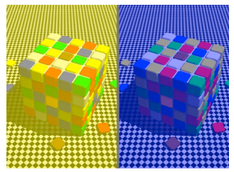
Relative color judgements

- color constancy across broad range of illumination conditions



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

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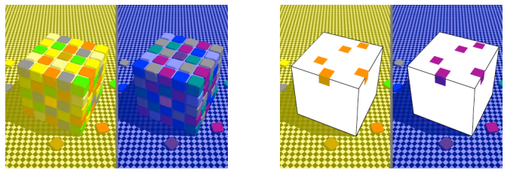
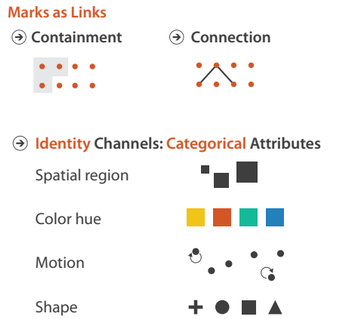


http://www.purveslab.net/seeforyourself/

Grouping

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

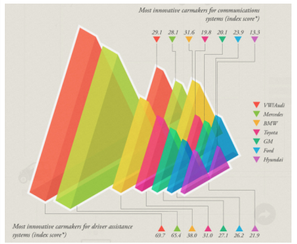


Rules of Thumb

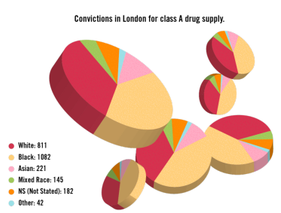
Rules of Thumb Summary

- No unjustified 3D
- No unjustified 2D
- Eyes beat memory
- Resolution over immersion
- Overview first, zoom and filter, details on demand
- Responsiveness is required
- Function first, form next

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



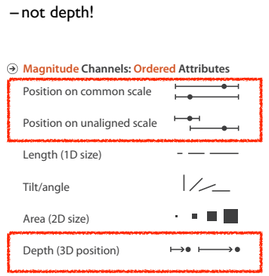
http://viz.wtf/post/137826497077/eye-popping-3d-triangles

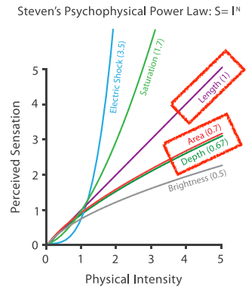


http://viz.wtf/post/139002022202/designer-drugs-ht-ducqn

Depth vs power of the plane

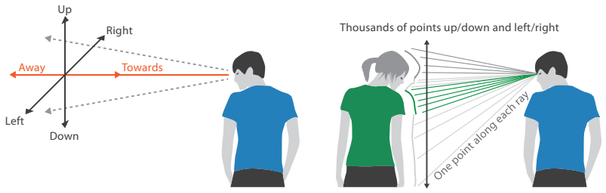
- high-ranked spatial position channels: **planar** spatial position
  - not depth!





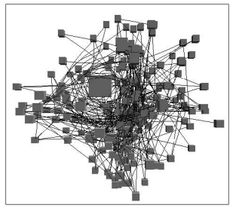
No unjustified 3D: Danger of depth

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



Occlusion hides information

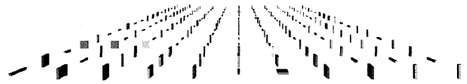
- occlusion
- interaction can resolve, but at cost of time and cognitive load



[Distortion Viewing Techniques for 3D Data. Carpendale et al. InfoVis 1996.]

Perspective distortion loses information

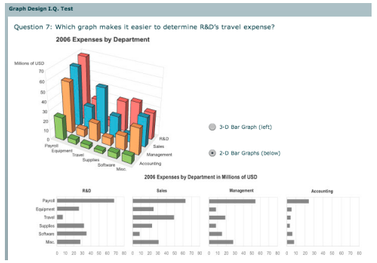
- perspective distortion
  - interferes with all size channel encodings
  - power of the plane is lost!



[Visualizing the Results of Multimedia Web Search Engines. Mukherjea, Hirata, and Hara. InfoVis 96]

3D vs 2D bar charts

- 3D bars very difficult to justify!
  - perspective distortion
  - occlusion
- faceting into 2D almost always better choice

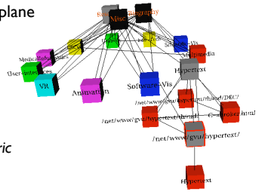


[http://perceptualedge.com/files/GraphDesignIQ.html]

Tilted text isn't legible

- text legibility
  - far worse when tilted from image plane
- further reading

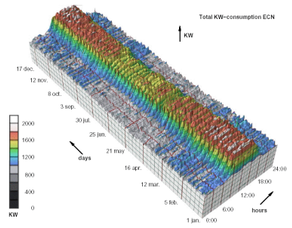
[Exploring and Reducing the Effects of Orientation on Text Readability in Volumetric Displays. Grossman et al. CHI 2007]



[Visualizing the World-Wide Web with the Navigational View Builder. Mukherjea and Foley. Computer Networks and ISDN Systems, 1995.]

No unjustified 3D example: Time-series data

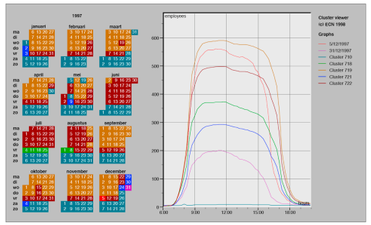
- extruded curves: detailed comparisons impossible



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

No unjustified 3D example: Transform for new data abstraction

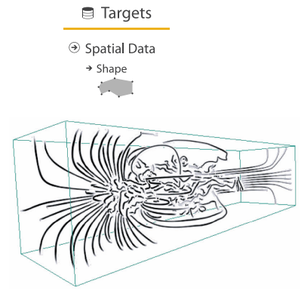
- derived data: cluster hierarchy
- juxtapose multiple views: calendar, superimposed 2D curves



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

Justified 3D: shape perception

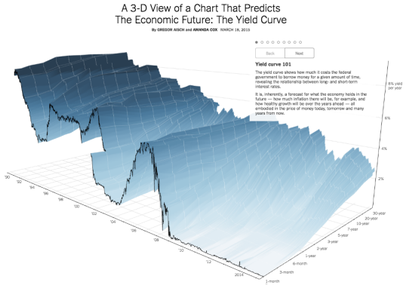
- benefits outweigh costs when task is shape perception for 3D spatial data
  - interactive navigation supports synthesis across many viewpoints



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

Justified 3D: Economic growth curve

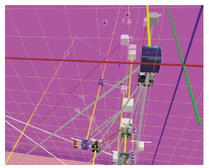
- constrained navigation steps through carefully designed viewpoints



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

No unjustified 3D

- 3D legitimate for true 3D spatial data
- 3D needs very careful justification for abstract data
  - enthusiasm in 1990s, but now skepticism
  - be especially careful with 3D for point clouds or networks



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

No unjustified 2D

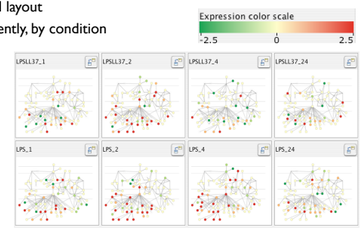
- consider whether network data requires 2D spatial layout
  - especially if reading text is central to task!
  - arranging as network means lower information density and harder label lookup compared to text lists
- benefits outweigh costs when topological structure/context important for task
  - be especially careful for search results, document collections, ontologies

Eyes beat memory

- principle: external cognition vs. internal memory
  - easy to compare by moving eyes between side-by-side views
  - harder to compare visible item to memory of what you saw
- implications for animation
  - great for choreographed storytelling
  - great for transitions between two states
  - poor for many states with changes everywhere
    - consider small multiples instead

Eyes beat memory example: Cerebral

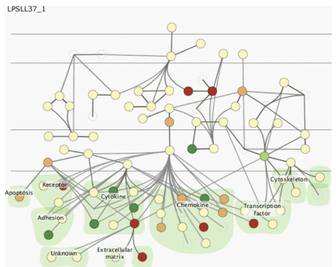
- small multiples: one graph instance per experimental condition
  - same spatial layout
  - color differently, by condition



[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.]

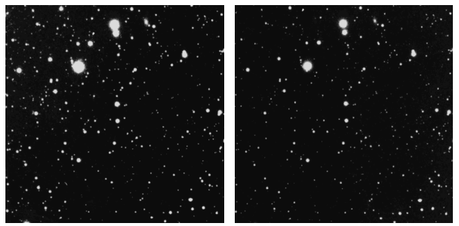
Why not animation?

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



Animation: Blink comparator

- just two contiguous frames is a special case: animation beats side by side
  - blink comparator used to discover Pluto



side by side

https://www.sightsize.com/the-blink-comparator/

Animation: Blink comparator

- just two contiguous frames is a special case: animation is great!
  - blink comparator used to discover Pluto

animated

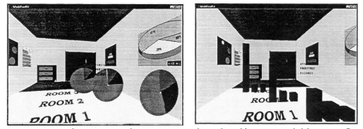
https://www.sightsize.com/the-blink-comparator/

Change blindness

- if attention is directed elsewhere, even drastic changes not noticeable
  - –remember door experiment?
- change blindness demos
  - –mask in between images
    https://youtu.be/bh_9XFzbWV8

Resolution beats immersion

- immersion typically not helpful for abstract data
  - –do not need sense of presence or stereoscopic 3D
  - –desktop also better for workflow integration
- resolution much more important: pixels are the scarcest resource
- virtual reality for abstract data difficult to justify thus far
  - but stay tuned with second wave, AR (augmented reality) has more promise



[Development of an information visualization tool using virtual reality. Kirner and Martins. Proc. Symp. Applied Computing 2000]

Overview first, zoom and filter, details on demand

- influential mantra from Shneiderman

[The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. Shneiderman. Proc. IEEE Visual Languages, pp. 336–343, 1996.]

- overview = summary
  - –microcosm of full vis design problem

Rule of thumb: **Responsiveness is required**

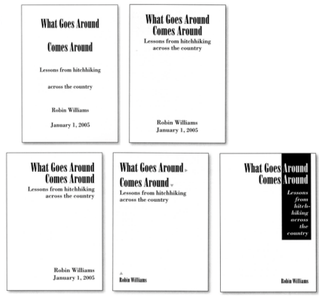
- *visual feedback: three rough categories*
  - *0.1 seconds: perceptual processing*
    - subsecond response for mouseover highlighting - ballistic motion
  - *1 second: immediate response*
    - fast response after mouseclick, button press - Fitts' Law limits on motor control
  - *10 seconds: brief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

Function first, form next

- start with focus on functionality
  - –possible to improve aesthetics later on, as refinement
  - –if no expertise in-house, find good graphic designer to work with
  - –aesthetics do matter: another level of function
    - –visual hierarchy, alignment, flow
    - –Gestalt principles in action
      - –*(not covered in this class)*
- dangerous to start with aesthetics
  - –usually impossible to add function retroactively

Form: Basic graphic design ideas

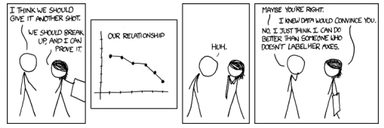
- proximity
  - – do group related items together
  - – avoid equal whitespace between unrelated
- alignment
  - – do find/make strong line, stick to it
  - – avoid automatic centering
- repetition
  - – do unify by pushing existing consistencies
- contrast
  - – if not identical, then very different
  - – avoid not quite the same



- buy now and read cover to cover - very practical, worth your time, fast read!
  The Non-Designer's Design Book, 4th ed. Robin Williams, Peachpit Press, 2015.

Best practices: Labelling

- make visualizations as self-documenting as possible
  - –meaningful & useful title, labels, legends
    - axes and panes/subwindows should have labels
      - –and axes should have good mix/max boundary tick marks
    - everything that's plotted should have a legend
      - –and own header/labels if not redundant with main title
    - use reasonable numerical format
      - –avoid scientific notation in most cases



[https://xkcd.com/833/]

Rules of Thumb Summary

- No unjustified 3D
  - –Power of the plane
  - –Disparity of depth
  - –Occlusion hides information
  - –Perspective distortion dangers
  - –Tilted text isn't legible
- No unjustified 2D
- Eyes beat memory
- Resolution over immersion
- Overview first, zoom and filter, details on demand
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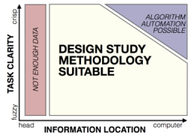
Design Study Methodology



Michael Sedlmair

Miriah Meyer

Design Study Methodology

Reflections from the Trenches and from the Stacks

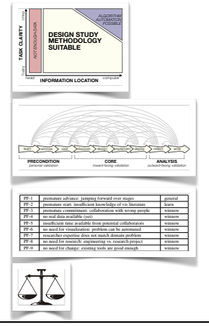
http://www.cs.ubc.ca/labs/imager/tr/2012/dsm/

Tamara Munzner
@tamaramunzner

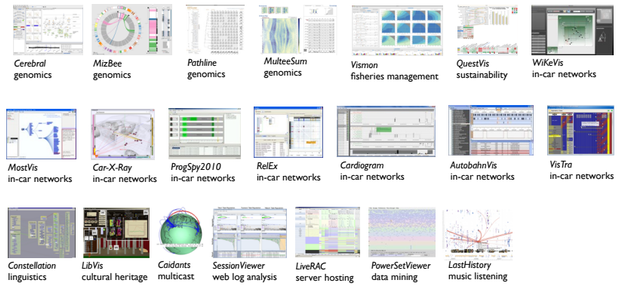
Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE Trans. Visualization and Computer Graphics 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

Methodology for problem-driven work

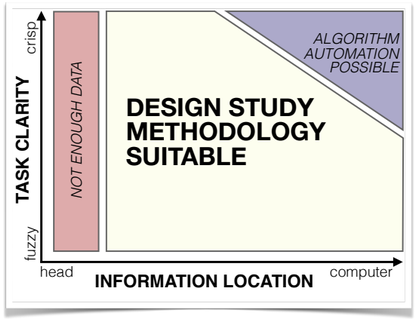
- definitions
- 9-stage framework
- 32 pitfalls & how to avoid them
- comparison to related methodologies



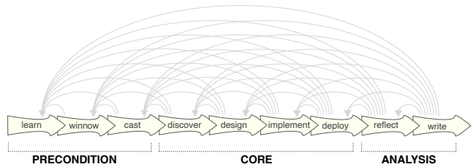
Lessons learned from the trenches: 21 between us



Design study methodology: definitions

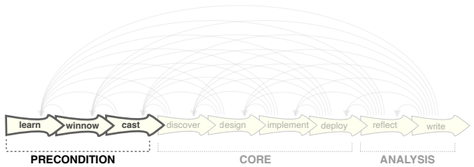


9 stage framework



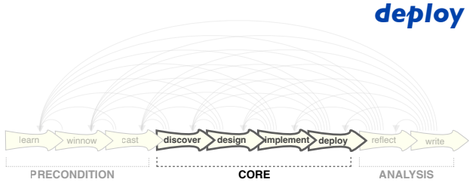
9-stage framework

learn winnow cast



9-stage framework

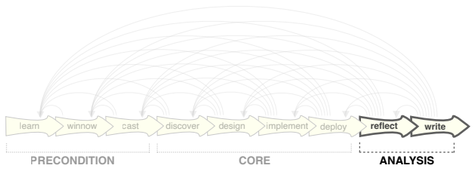
discover design implement deploy



9-stage framework

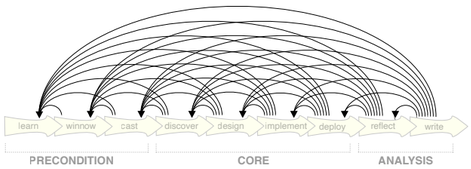
reflect
write

- guidelines: confirm, refine, reject, propose



9-stage framework

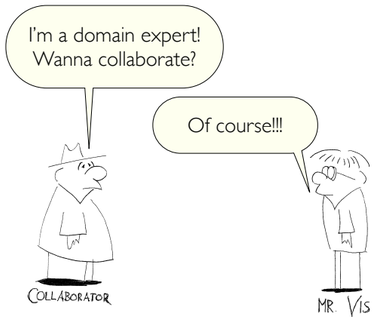
iterative



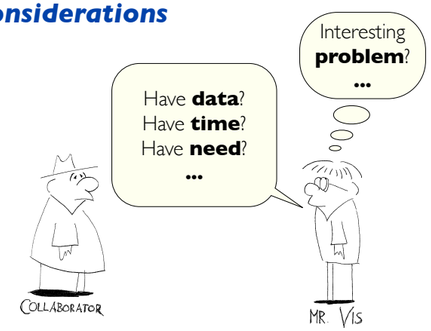
Design study methodology: 32 pitfalls

- and how to avoid them

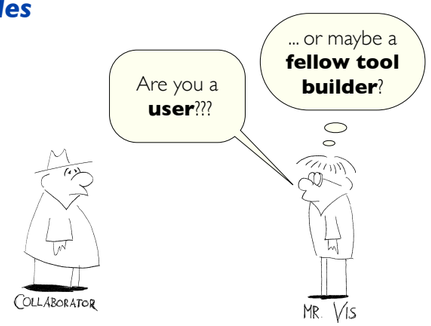
PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
PF-5	insufficient time available from potential collaborators	winnow
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



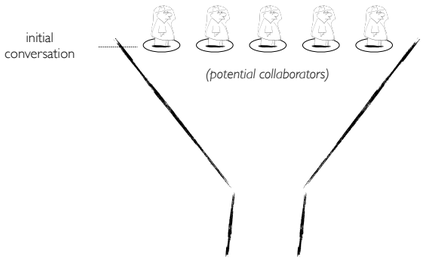
considerations



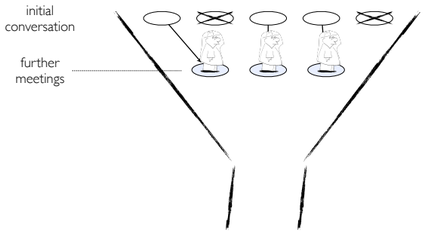
roles



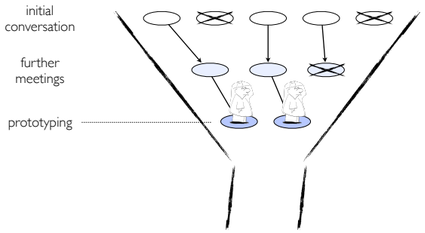
Collaborator winnowing



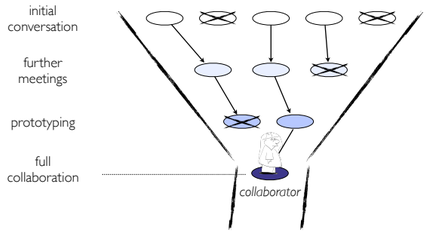
Collaborator winnowing



Collaborator winnowing



Collaborator winnowing



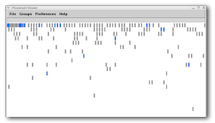
Collaborator winnowing

Talk with many, stay with few!

EXAMPLE FROM THE TRENCHES

Premature Collaboration!

PowerSet Viewer
2 years / 4 researchers



WikeVis
0.5 years / 2 researchers

EXAMPLE FROM THE TRENCHES

Premature Collaboration!

PowerSet Viewer
2 years / 4 researchers

WikeVis
0.5 years / 2 researchers

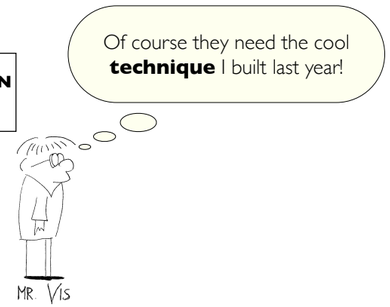
- Fellow tool builders
- Data promised

Design study methodology: 32 pitfalls

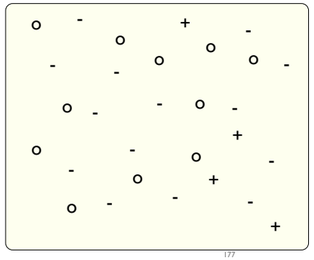
PF-10	no real/important/recurring task	winnow
PF-11	no rapport with collaborators	winnow
PF-12	not identifying front line analyst and gatekeeper before start	cast
PF-13	assuming every project will have the same role distribution	cast
PF-14	mistaking fellow tool builders for real end users	cast
PF-15	ignoring practices that currently work well	discover
PF-16	expecting *just talking* or *fly on wall* to work	discover
PF-17	experts focusing on visualization design vs. domain problem	discover
PF-18	learning their problems/language: too little / too much	discover
PF-19	abstraction: too little	design
PF-20	premature design commitment: consideration space too small	design

PITFALL

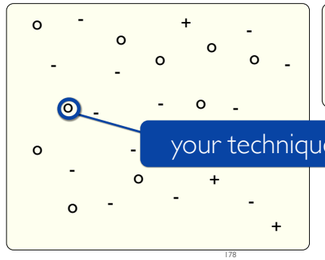
PREMATURE DESIGN COMMITMENT



METAPHOR
Design Space



METAPHOR
Design Space



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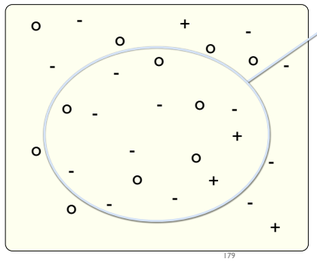
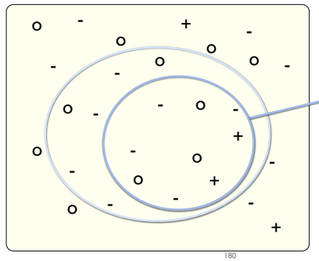
Design Space



METAPHOR
Design Space



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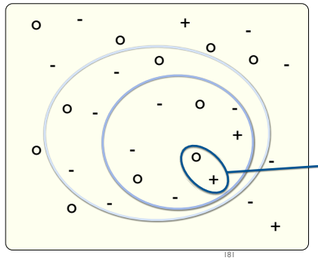
Design Space



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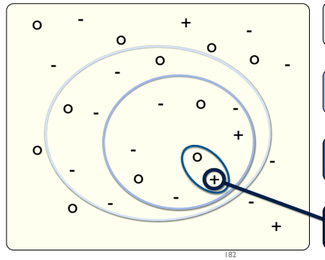
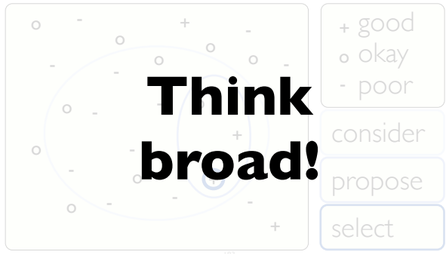
Design Space



METAPHOR
Design Space

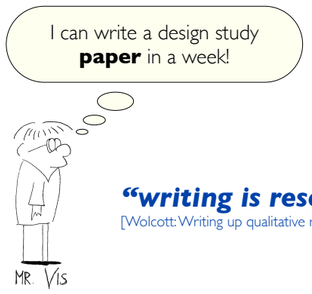


Design study methodology: 32 pitfalls

PF-21	mistaking technique-driven for problem-driven work	design
PF-22	nonrapid prototyping	implement
PF-23	usability: too little / too much	implement
PF-24	premature end: insufficient deploy time built into schedule	deploy
PF-25	usage study not case study: non-real task/data/user	deploy
PF-26	*liking* necessary but not sufficient for validation	deploy
PF-27	failing to improve guidelines: confirm, refine, reject, propose	reflect
PF-28	insufficient writing time built into schedule	write
PF-29	no technique contribution ≠ good design study	write
PF-30	too much domain background in paper	write
PF-31	story told chronologically vs. focus on final results	write
PF-32	premature end: win race vs. practice music for debut	write

PITFALL

PREMATURE PUBLISHING



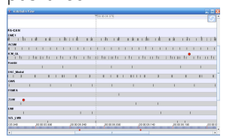
"writing is research"
[Wolcott: Writing up qualitative research, 2009]

METAPHOR
Horse Race vs. Music Debut

technique-driven | problem-driven

EXAMPLE FROM THE TRENCHES
Don't step on your own toes!

First design round published



AutobahnVis 1.0
[Sedlmair et al., Smart Graphics, 2009]

Subsequent work not stand-alone paper

AutobahnVis 2.0
[Sedlmair et al., Information Visualization 10(3), 2011]

Reflections from the stacks: Wholesale adoption inappropriate

- ethnography
  - rapid, goal-directed fieldwork
- grounded theory
  - not empty slate: vis background is key
- action research
  - aligned
    - intervention as goal
    - transferability not reproducibility
    - personal involvement is key
  - opposition
    - translation of participant concepts into visualization language
    - researcher lead not facilitate design
    - orthogonal to vis concerns: participants as writers, adversarial to status quo, postmodernity