

23HT – 1DV510 Technical Information and Communication

Introduction to Information Visualization: Theory and Tools

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Based on material by
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Outline

- Motivation for Information Visualization and Visual Analytics
- Foundations of InfoVis and VA
- Visualization Tools
- Programming Toolkits/Libraries
- Tips and Tricks for Data Visualization
- Further Resources and Links



Motivation for Information Visualization and Visual Analytics



Motivation for Visualization

- In which words is the letter “q” used in the following passage?

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

- What if we displayed the text in the following way:

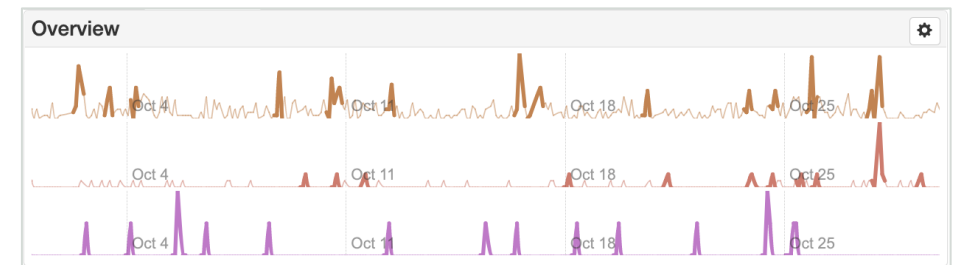
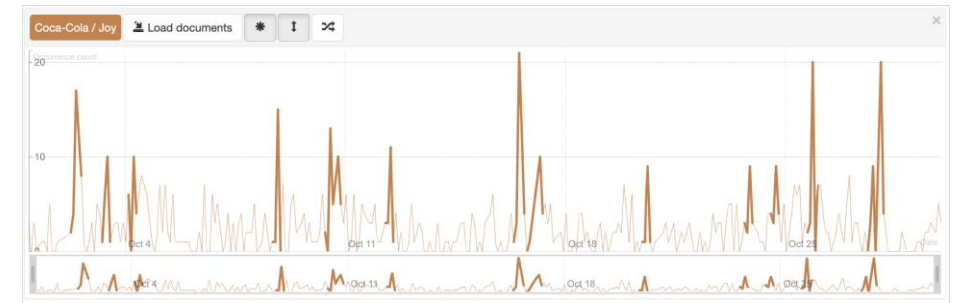
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.



Motivation for Visualization (cont.)

- The previous example \Rightarrow preattentive processing capability of human visual system
- **A picture is worth a thousand words**
- For most human beings, it is easier and faster to understand visualized data rather than raw data
 - E.g., spreadsheet rows, relational records, log entries, ...
- In certain cases, the data is practically impossible to understand otherwise due to scale, complexity, or other factors
 - Statistical summaries or computational results might be not enough on their own! (more in the next slide...)
- “In the information age, a person’s ability to read and make data visualizations is nearly as important as being able to read and write text” (Börner et al., 2016)

```
▼ {Joy: Array(327), Disgust: Array(326), Anger: Array(327)}
  ► Anger: (327) [{...}, {...}, {...}, {...}, {...}, {...}, {...}, {...}, {
  ► Disgust: (326) [{...}, {...}, {...}, {...}, {...}, {...}, {...}, {...}, {
  ▼ Joy: Array(327)
    ▼ [0 ... 99]
      ► 0: {timestamp: 1538420400000, value: 0}
      ► 1: {timestamp: 1538427600000, value: 1}
      ► 2: {timestamp: 1538463600000, value: 2}
      ► 3: {timestamp: 1538470800000, value: 4}
      ► 4: {timestamp: 1538478000000, value: 17}
      ► 5: {timestamp: 1538492400000, value: 8}
      ► 6: {timestamp: 1538499600000, value: 1}
```

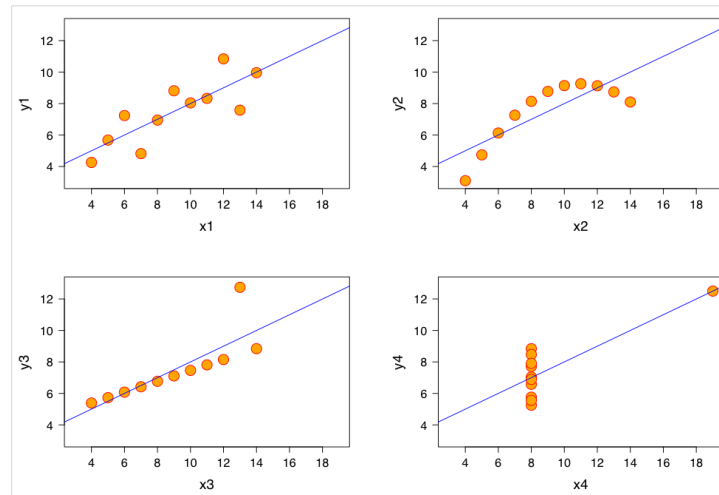


Motivation for Visualization (concl.)

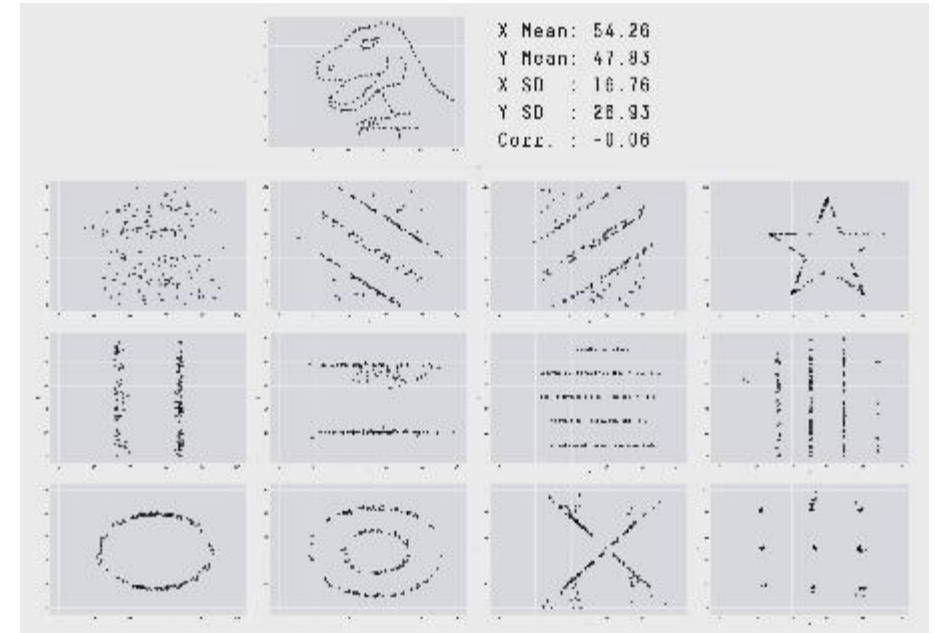
- Consider Anscombe's Quartet and Cairo's Datasaurus dataset...

Anscombe's Quartet: Raw Data

		I		II		III		IV	
	x	y	x	y	x	y	x	y	
	10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58	
	8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76	
	13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71	
	9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84	
	11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47	
	14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04	
	6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25	
	4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50	
	12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56	
	7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91	
	5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89	
mean	9.0	7.5	9.0	7.5	9.0	7.5	9.0	7.5	
var.	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75	
corr.		0.816		0.816		0.816		0.816	



[https://en.wikipedia.org/wiki/Anscombe%27s_quartet]

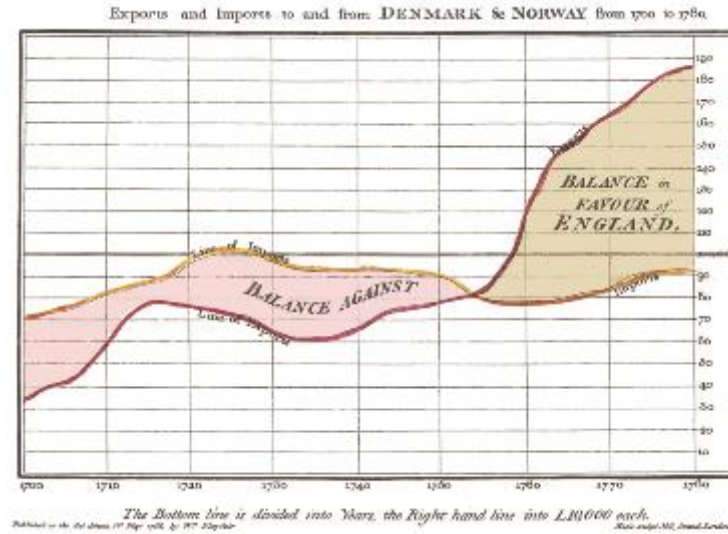


[Matejka and Fitzmaurice. 2017. Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing. In Proc. Of ACM CHI. <https://doi.org/10.1145/3025453.3025912> . Also see <https://www.autodesk.com/research/publications/same-stats-different-graphs>]

Historical Examples of Data Visualization

- Charts and diagrams used in mathematics, physics, statistics, etc.

- Example: William Playfair's trade balance chart (1786)



[https://commons.wikimedia.org/wiki/File:Playfair_TimeSeries-2.png]

- Maps

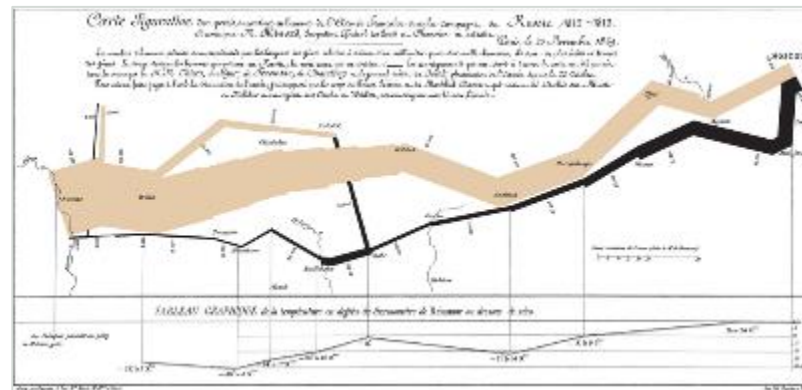
- Example: Ralph Hall's map of Virginia (1636)



[<https://www.loc.gov/item/96684632/>]

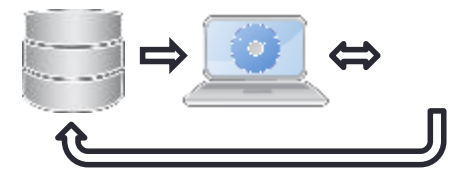
- Infographics

- Example: Charles Minard's novel chart of Napoleon's 1812 campaign (1869)



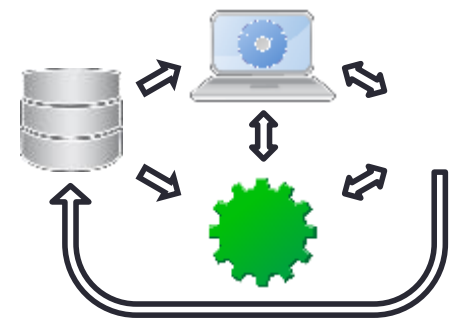
[<https://commons.wikimedia.org/wiki/File:Minard.png>]

Information Visualization



- Information visualization is “the use of computer-supported, *interactive, visual representations of abstract* data to amplify cognition” (Card et al., 1999)
 - “The purpose of visualization is insight, not pictures”
- Typically, the goal is to support either *exploratory data analysis* or *visual storytelling* (we ignore *artistic vis* here...)
 - Visualizations are designed for human users ⇒ evaluations with target audience (end-users) and collaborations with domain experts are encouraged
- Related disciplines and fields: Computer Graphics, Human-Computer Interaction, Data Science, ...
 - Related to—but different from—infographics and statistical graphics
- In practical terms, InfoVis approaches are typically implemented as software tools that address certain user tasks
 - “Overview first, zoom and filter, then details-on-demand” (Shneiderman, 1996)

Visual Analytics



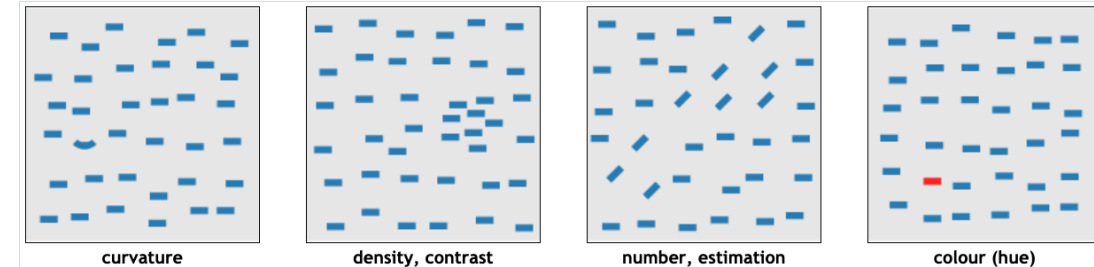
- Traditional InfoVis approaches focus on:
 1. Loading a certain dataset
 2. Applying a cleverly designed visual encoding
 3. Presenting this with an interactive visual interface, and
 4. Allowing the user to get insights through exploration
- However, such approaches generally neglect support for *computational* methods for data analysis
- Why not combine the best of both worlds?
- Visual analytics focuses on the interactions between the human analyst, the data, and both the computational and visual methods
- “Visual analytics is the science of *analytical reasoning* facilitated by *interactive visual interfaces*” (Thomas and Cook, 2005)

Foundations of InfoVis and VA



Perception and Cognition

- Preattentive processing
 - Visual features detected very rapidly and accurately
 - Can be disrupted when using several visual features/channels simultaneously ⇒ incl. motion/animation
- Change blindness
 - Issues with attention rather than eyesight/acuity
 - Changes to semantically important objects are detected faster than changes elsewhere
- Gestalt laws
 - Our minds tend to find patterns in what we see
 - E.g., closely positioned marks ⇒ perceived groups
 - Neighborhood, similarity, connectivity, symmetry, ...
- Optical illusions
 - E.g., perception of colors affected by the contrast



[<https://www.csc2.ncsu.edu/faculty/healey/PP/index.html>]

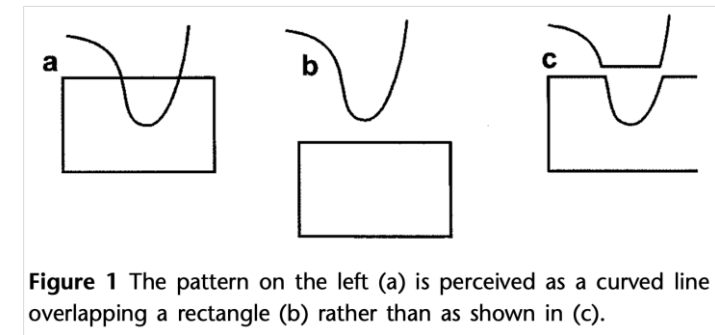


Figure 1 The pattern on the left (a) is perceived as a curved line overlapping a rectangle (b) rather than as shown in (c).

[Ware et al. 2002. Cognitive Measurements of Graph Aesthetics. Inf Vis 1(2). <https://doi.org/10.1057/palgrave.ivs.9500013>]



[https://en.wikipedia.org/wiki/Gestalt_psychology#Contributions]



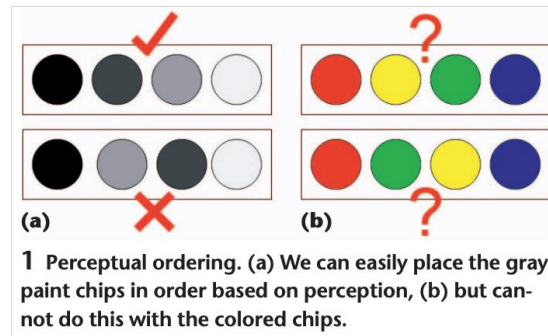
[https://commons.wikimedia.org/wiki/File:Chubb_Illusion.svg]

Perception and Cognition (cont.)

- Color science

- *Rainbow/Jet* color map is inefficient for many tasks (when value or order is important)
- Single hue or perceptually-uniform multi-hue color maps (e.g., *viridis* ⇒ blue–green–yellow) preferable for quantitative data
- Diverging color maps (e.g., blue–white–orange) for diverging data!
- For qualitative/categorical data, aim for ≤12 colors/hues, but better ≤7–8

- Very good resource with color maps for cartography and other data: ColorBrewer ⇒ <https://colorbrewer2.org/>
 - Includes colorblind-safe color maps
- Further color map examples ⇒ <https://www.kennethmoreland.com/color-maps/>



[Borland and Taylor II. 2007. Rainbow Color Map (Still) Considered Harmful. IEEE CG&A 27(2). <https://doi.org/10.1109/MCG.2007.323435>]

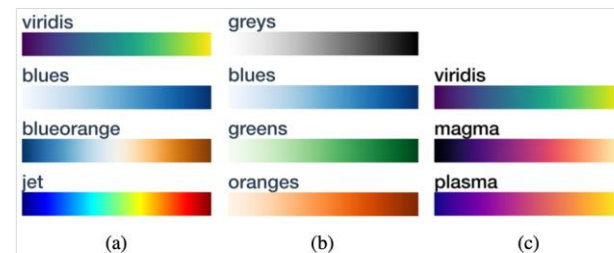
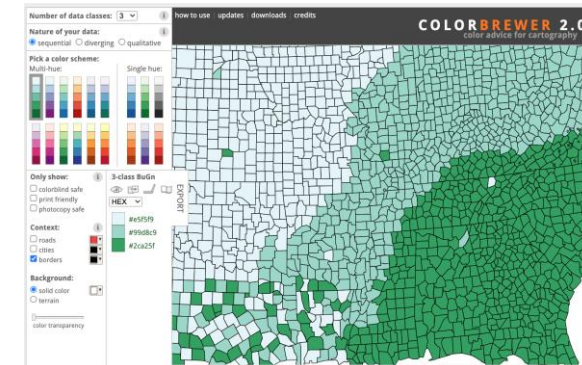


Figure 1: **Colormaps under study.** We evaluate four single-hue, three perceptually-uniform multi-hue, a diverging, and a rainbow colormap(s). We divide them into (a) assorted, (b) single-hue and (c) multi-hue groups, with two colormaps repeated across groups for replication.

[Liu and Heer. 2018. Somewhere Over the Rainbow: An Empirical Assessment of Quantitative Colormaps. In Proc. of ACM CHI. <https://doi.org/10.1145/3173574.3174172>]



[<https://colorbrewer2.org/>]

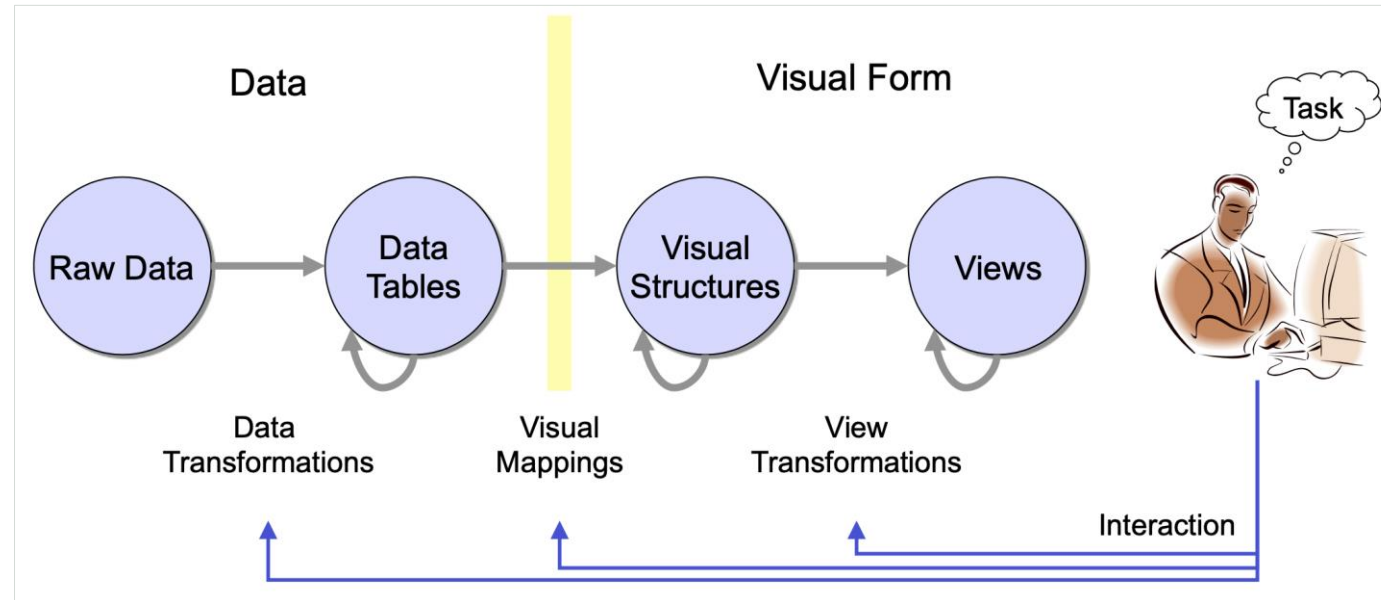


Fig. 1. The rainbow color map. Know thy enemy.

[Moreland. 2009. Diverging Color Maps for Scientific Visualization (Expanded). Also see https://doi.org/10.1007/978-3-642-10520-3_9]



InfoVis Reference Model



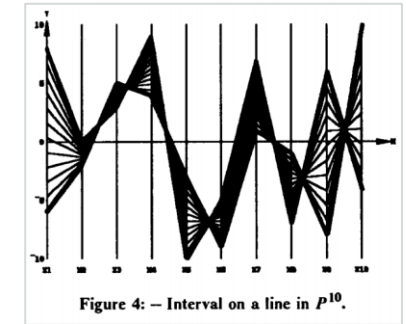
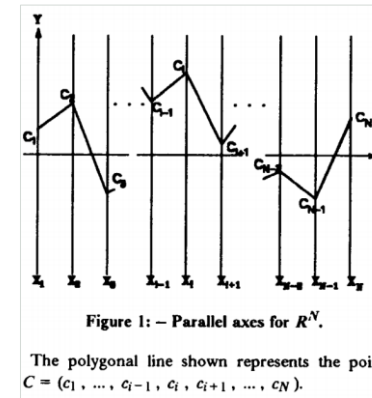
[Adapted from: Card et al. 1999. Readings in Information Visualization: Using Vision to Think.]

- Raw Data ⇒ various formats, missing cases, etc.
- Data Tables ⇒ structured representation + metadata about attributes/dimensions
- Visual Structures ⇒ spatial substrate (i.e., space and axes) + visual elements/*marks* (points, lines, ...) + graphical properties / *visual channels* (connection, color, animation, ...)
- Views ⇒ particular graphical parameters (zooming, clipping, ...)
- **Interaction is as important as the visual mapping!**

Visual Representations (cont.)

Typical strategies for multidimensional data:

- *Axis-based*:
 - *Scatter plot matrices (SPLOM)*
 - *Parallel coordinate plots (PCP)* \Rightarrow each data item represented with a *polyline* across N parallel axes
 - E.g., axis 1: age, axis 2: height, axis 3: weight...
 - *Star plots / radar charts / spider plots* \Rightarrow similar to PCPs, but the axes are radial
- *Glyph-based* \Rightarrow *stick figures*, *Chernoff faces*, custom glyphs...
- *Pixel-based* \Rightarrow miniscule (down to 1x1 px) representations, typically relying on color
- Furthermore, *dimensionality reduction*, etc.



[Inselberg and Dimsdale. 1990. Parallel Coordinates: A Tool for Visualizing Multi-dimensional Geometry. In Proc. of IEEE Visualization '90. <https://doi.org/10.1109/VISUAL.1990.146402>]

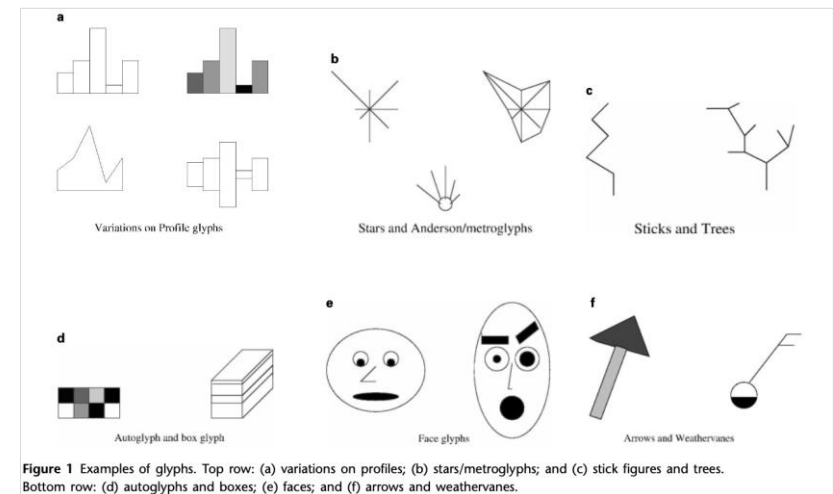


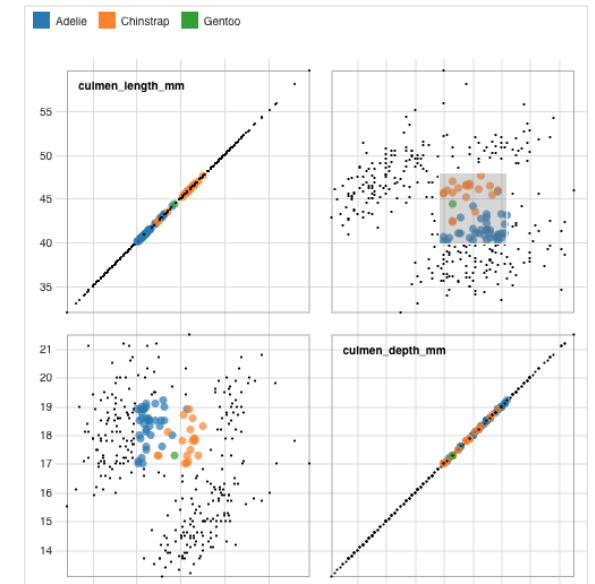
Figure 1 Examples of glyphs. Top row: (a) variations on profiles; (b) stars/metroglyphs; and (c) stick figures and trees. Bottom row: (d) autoglyphs and boxes; (e) faces; and (f) arrows and weather-vanes.

[Ward. 2002. A Taxonomy of Glyph Placement Strategies for Multidimensional Data Visualization. Inf.Vis. <https://doi.org/10.1057/PALGRAVE.IVS.9500025>]

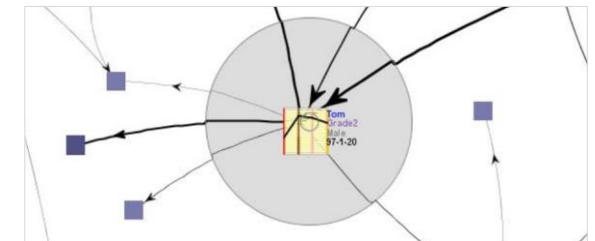
Interactions

Many interaction techniques proposed in InfoVis and HCI. Several “standard” and not-so-standard examples:

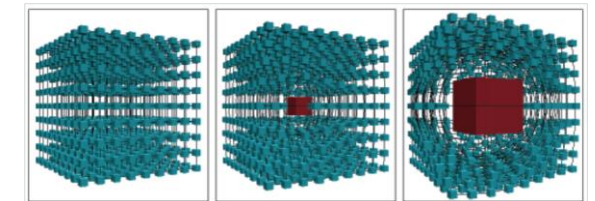
- *Brushing* ⇒ interactive selection (rectangular, lasso, etc.)
- *Linking* ⇒ interaction effects in one view (e.g., brushing) propagated to other views
 - Essential for coordinated multiple views!
- *Tooltips* ⇒ a straightforward way to provide details on demand
- *Magic lenses* ⇒ representation changes for areas under cursor
- *Overview + Detail* ⇒ outline/”minimap” + detailed view
- *Focus + Context* ⇒ nonlinear distortion, e.g., *fisheye view*
- ... and more!



[<https://observablehq.com/@d3/brushable-scatterplot-matrix>]



[Jusufi et al. 2010. The Network Lens: Interactive Exploration of Multivariate Networks Using Visual Filtering. In Proc. of IV '10. <https://doi.org/10.1109/IV.2010.15>]

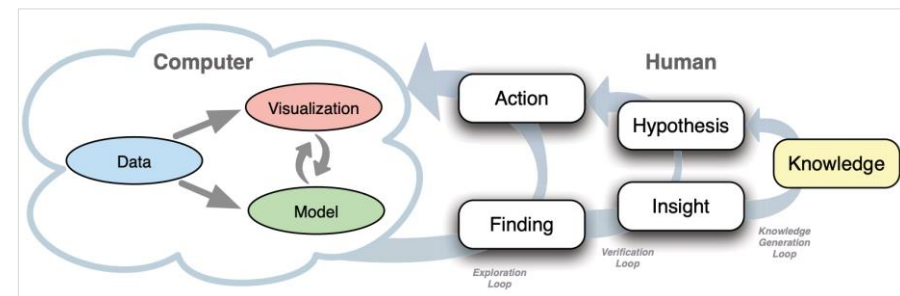


[Carpendale et al. 1997. Extending Distortion Viewing from 2D to 3D. IEEE CG&A 17(4). <https://doi.org/10.1109/38.595268>]

User Tasks and Workflows

- Back to the Visual Information Seeking Mantra (Shneiderman, 1996):
 - Overview
 - Zoom
 - Filter
 - Details-on-demand
 - Relate
 - History
 - Extract

- The Visual Analytics Mantra (Keim et al., 2008):
 - Analyse First
 - Show the Important
 - Zoom, Filter and Analyse Further
 - Details on Demand
- Knowledge Generation Model (Sacha et al., 2014)
- ... and further theoretical models for InfoVis and VA



[Shneiderman. 1996. The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. IEEE VL '96. <https://doi.org/10.1109/VL.1996.545307>]

[Sacha et al. 2014. Knowledge Generation Model for Visual Analytics. IEEE TVCG 20(12). <https://doi.org/10.1109/TVCG.2014.2346481>]

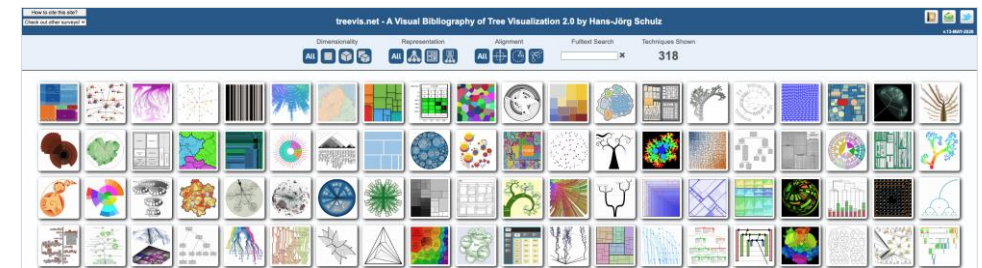


Visualization for Special Data Types

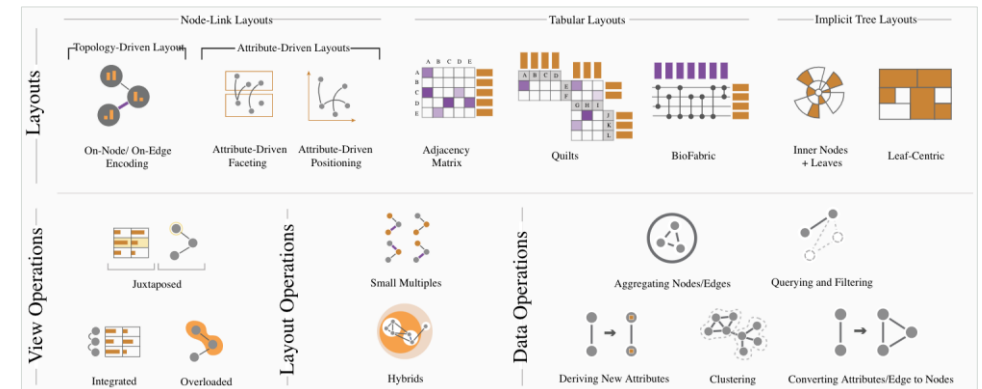
- Temporal data
 - Linear or cyclic time?
 - Timestamps or intervals?
 - Static or dynamic (\Rightarrow *animation*) representation?
- Tree data (\Rightarrow hierarchies)
 - *Node-link*, space-filling (\Rightarrow *treemaps*) repr., ...
- Graph/network data
 - More general and complex than tree data!
 - *Multivariate* networks, *dynamic* graphs, ...
- Geospatial data
- Text data
- ...



[<http://browser.timeviz.net>]



[<https://treevis.net>]



[<https://vdl.sci.utah.edu/mvvnv/>]

Domain Applications

- Biological Data Visualization (BioVis)
- Visualization for Humanities and Social Sciences
- Visualization for (X)AI/ML
 - One of the challenges: increasing *trustworthiness* of the ML process using Vis
- Software Visualization (SoftVis)
- Personal and Casual Visualization
- Sports Data Visualization
- Visualization for Emergency Management
- ...

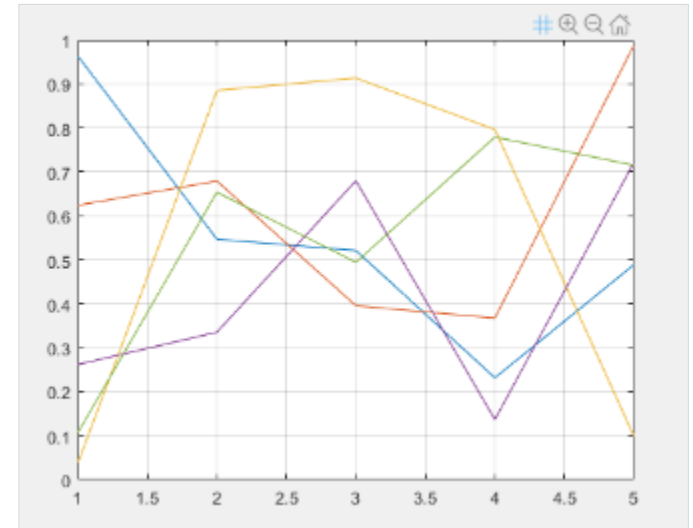


Visualization Tools



Visualization in Popular Software

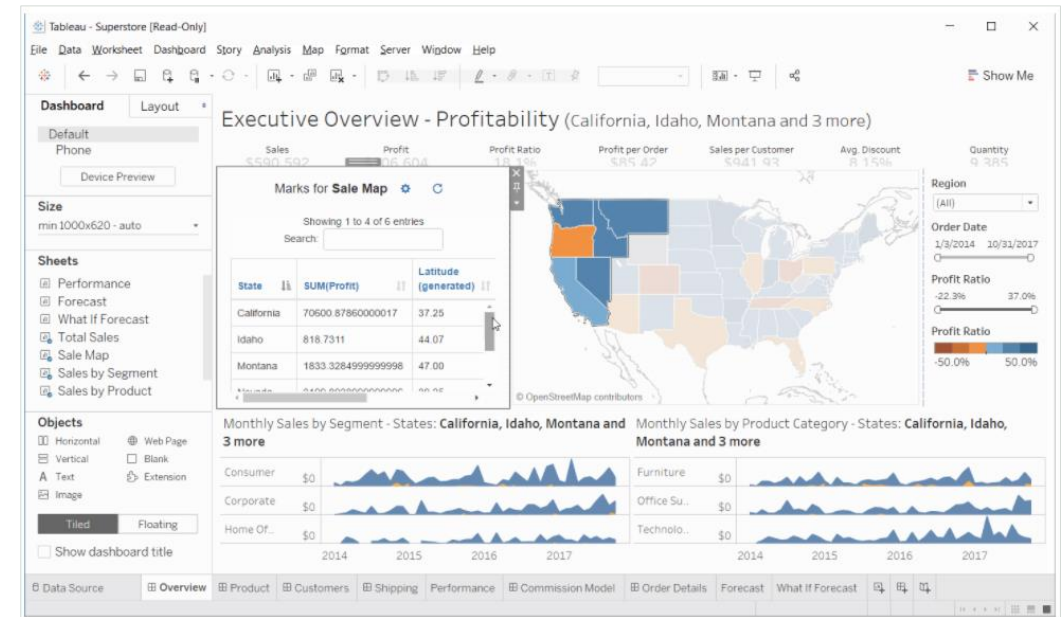
- Spreadsheet editors (Excel, etc.) ⇒ support for “standard” representations (line plots, bar charts...) and very limited support for interactivity
- Computing environments (Matlab, Octave, Scilab...) ⇒ typically support for “standard” representations with a strong focus on numerical data, and limited support for interactions
- Graphical editors and charting tools (MS Visio, Inkscape, Draw.io...) ⇒ creating static figures for a given data set (i.e., closer to infographics than InfoVis)
- To summarize, visualizations produced with such tools are often used for illustrative purposes or for non-interactive investigation (static figures)
- Next, we discuss some publicly available tools with a stronger focus on visualization and interaction



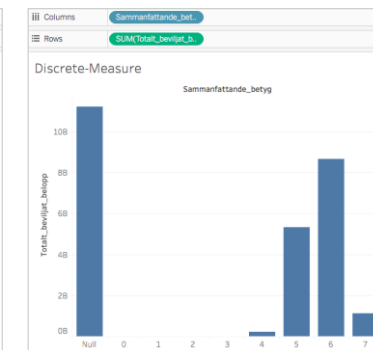
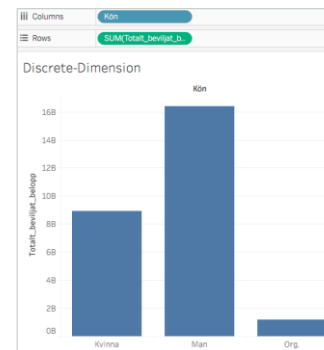
[https://se.mathworks.com/help/releases/R2019a/matlab/creating_plots/control-axes-interactions.html]

General-Purpose Visualization Tools

- **Tableau** ⇒ <https://tableau.com/academic/>
 - Supports numerous “standard” representations (and some not-so-standard) as well as standard interactions + *dashboards*
 - *Suggests* suitable representations for the data
 - Create one or several *sheets* with visualizations by drag’n’dropping data fields to the view area
 - Possible to create interactive *dashboards* and *stories* based on sheets
 - Quite flexible with regard to “messing” with the data (changing the representation type, adjusting the colors and ranges, etc.)
 - Treating an attribute as *discrete* vs *continuous*, *dimension* (qualitative, categorical...) vs *measure* (numerical, aggregated...), etc.



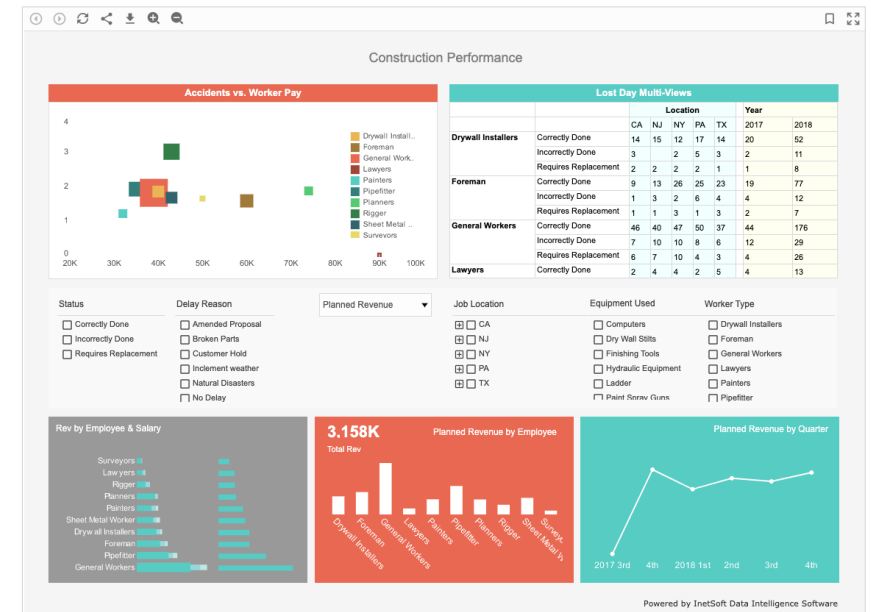
[https://help.tableau.com/current/pro/desktop/en-us/dashboard_extensions.htm]



General-Purpose Visualization Tools (cont.)

- **Visualize Free** ⇒ <https://visualizefree.com/>

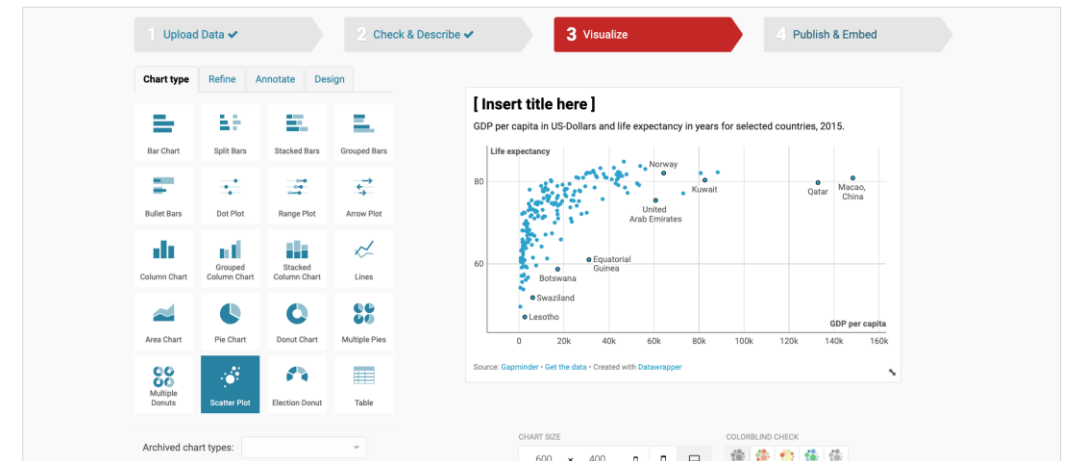
- Online general-purpose dashboard vis tool
- Workflow and interface quite similar to Tableau
- Available for free (the company also provides commercial tools) with good documentation and support; **limitation**: data set size up to 5 MB
- Supports several coordinated views
- Possible to share the resulting dashboard while keeping it private



[<https://www.visualizefree.com/#works>]

- **DataWrapper** ⇒ <https://datawrapper.de/>

- Online visualization authoring tool with support for basic interactivity and live data integration
- A single chart only (no multiple views...)



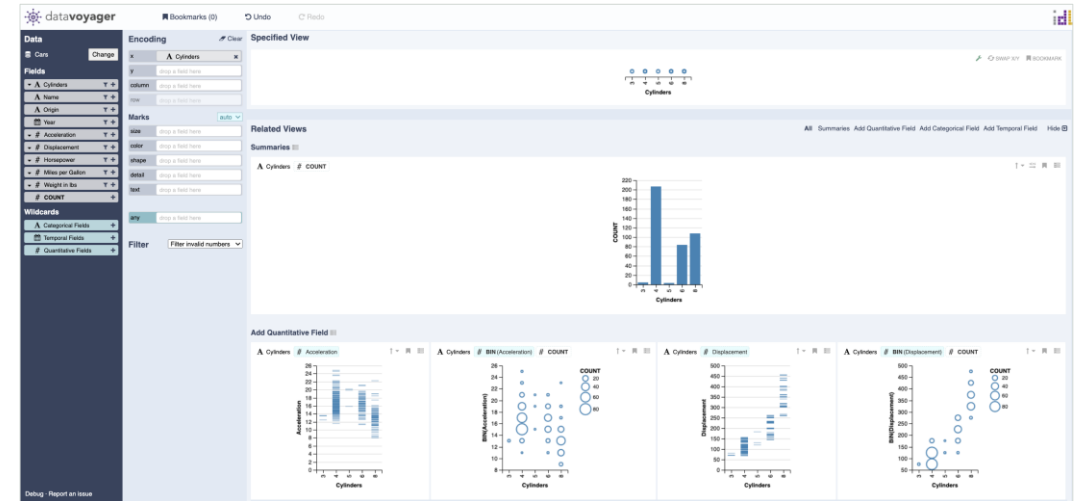
[<https://www.datawrapper.de/>]

General-Purpose Visualization Tools (cont.)

- **Voyager 2 (Data Voyager)** ⇒

<https://vega.github.io/voyager2/>

- Mixed-initiative system that blends manual and automated chart specification
- Wildcards let users specify multiple charts in parallel, while related views suggest visualizations relevant to the currently specified chart

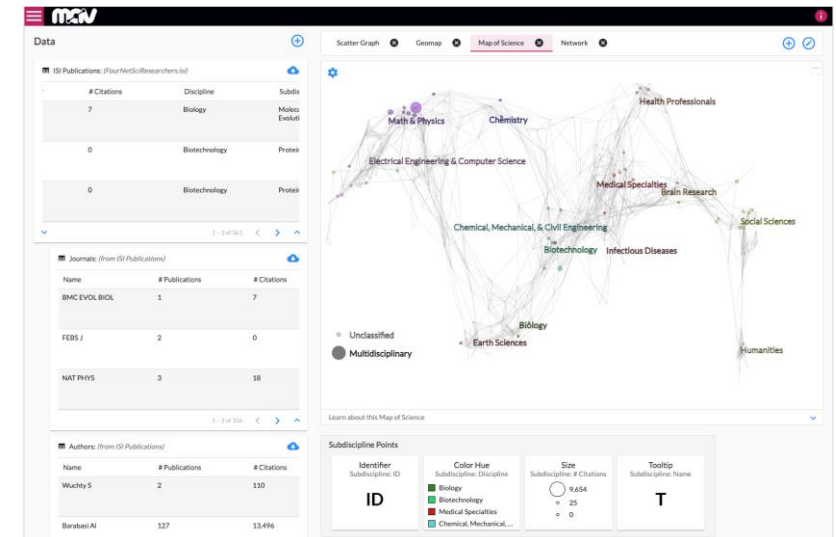


[<https://vega.github.io/voyager2/>]

- **Make-a-Vis** ⇒

<https://cns-iu.github.io/make-a-vis/>

- Support for several visual representations
- Multiple views, but not coordinated...



[<https://cns-iu.github.io/make-a-vis/?share=a21ae4ec86b3b58>]

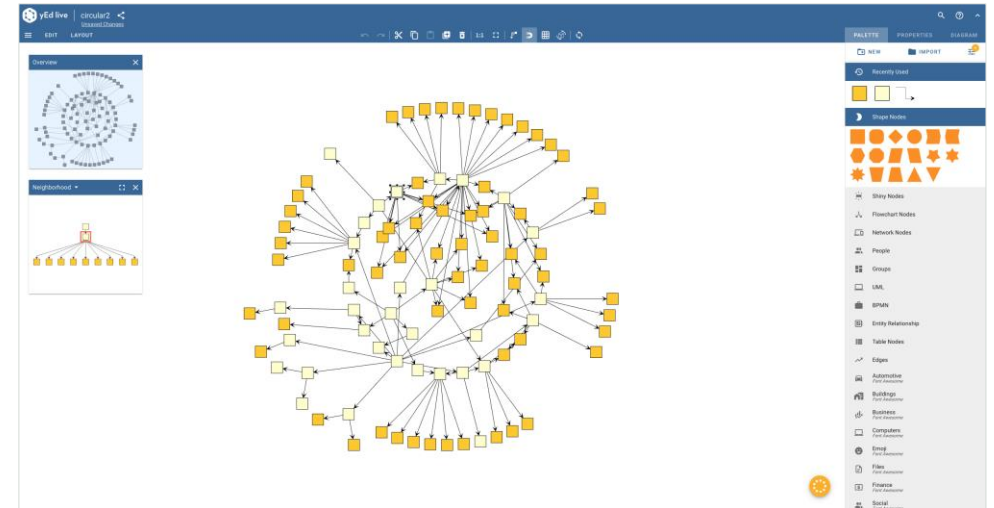


Visualization Tools for Special Data Types

- **yEd Live** ⇒

<https://www.yworks.com/yed-live/>

- Graph layout can be notoriously difficult! ⇒ yWorks are world-class experts in this
- yEd is based on arguably the best graph drawing library in the world (yFiles)



[<https://www.yworks.com/yed-live/>]

- **kepler.gl** ⇒ <https://kepler.gl/>

- Open source geospatial analysis tool for large-scale data
- Base map representation + additional layers (e.g., points, arc/edges, ...)

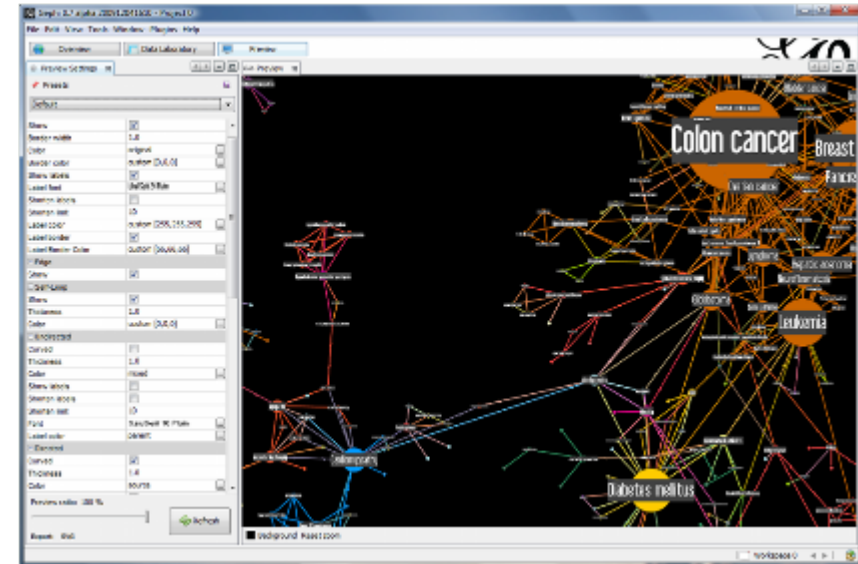


[<https://kepler.gl/demo/ukcommute>]



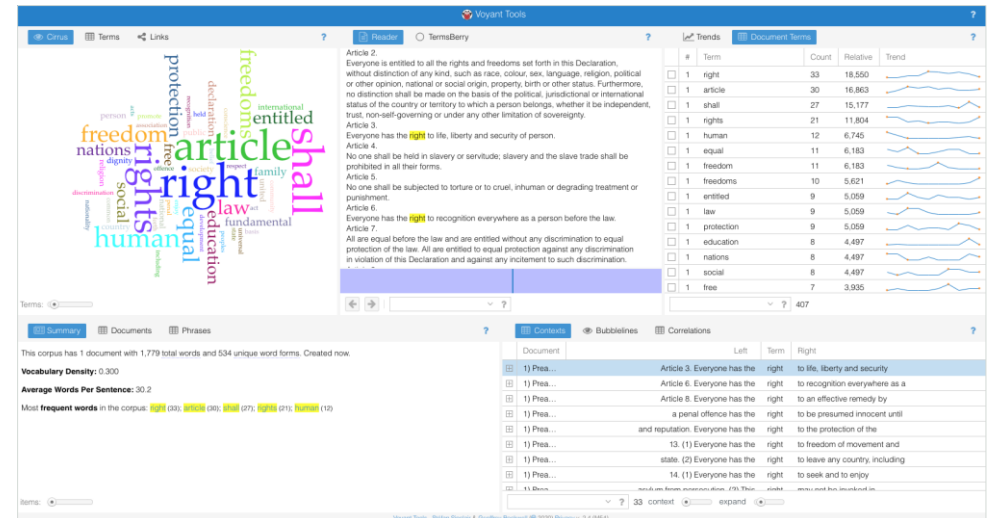
Visualization Tools for Special Data Types (cont.)

- **Gephi** ⇒ <https://gephi.org/>
 - Open source graph/network analysis and visualization tool with support for multiple layouts and customizations
 - Rather easy to use, good layout results, and useful analyses (centralities, connected components, ...)



[<https://gephi.org/>]

- **VoyantTools** ⇒ <https://voyant-tools.org/>
 - Web-based text analytics suite
 - Might be very useful for text analyses in (digital) humanities



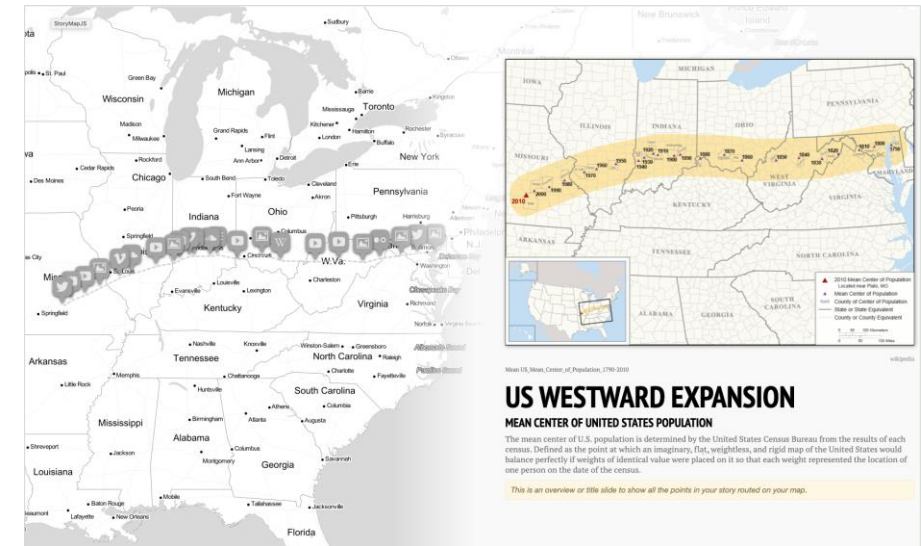
[<https://voyant-tools.org/>]

Visualization Tools for Special Data Types (concl.)

- **StoryMapJS** ⇒

<https://storymap.knightlab.com>

- Authoring tool for map-based storytelling
- Highlights the locations of a series of events, presented slide by slide



[<https://storymap.knightlab.com>]

- **TimelineJS** ⇒

<https://timeline.knightlab.com>

- Authoring tool for timeline-based storytelling
- Similar to StoryMapJS, but with a focus on the timeline



[<https://timeline.knightlab.com>]



Commercial Visual Analytic Platforms

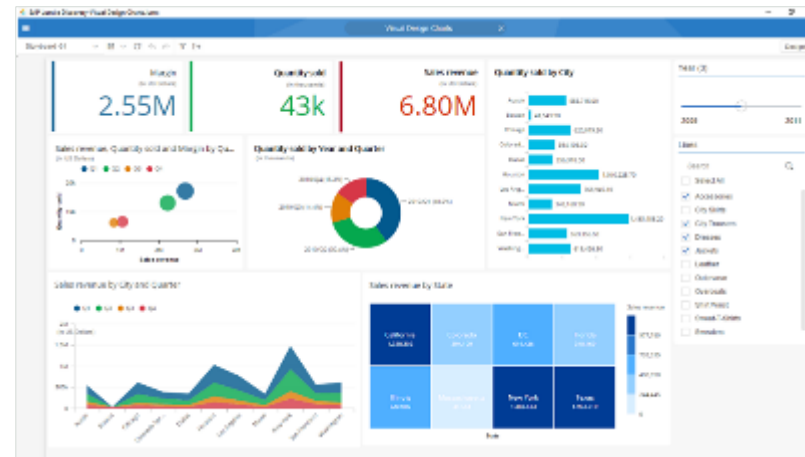
- Multiple vendors offering *business intelligence* (BI) analytics suites combining data management, visualization (⇒ typically dashboards with at least “standard” representations), and machine learning integration...

IBM Cognos Analytics



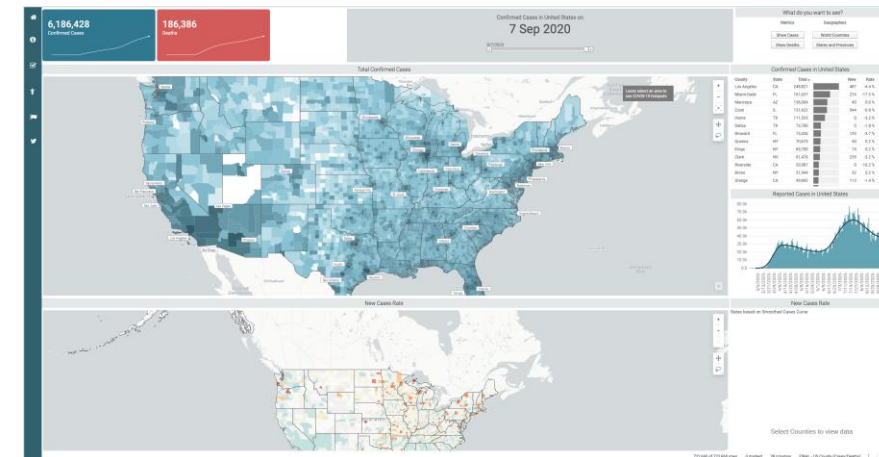
[<http://cognos-analytics-experience.mybluemix.net/>]

SAP Lumira



[<https://www.sap.com/products/lumira/capabilities.html>]

TIBCO Spotfire



[<https://www.tibco.com/node/204061>]

Programming Toolkits/Libraries



Visualization Tool Development

- By 2013, visualization tools were still mainly developed as desktop applications
- Since mid-2010s, the situation has changed due to multiple reasons ⇒ focus on web-based visualization for InfoVis and VA
- Special cases dealing with very large datasets are still developed as desktop applications
- Web-based tools pros and cons:
 - + Deployment and accessibility for the users
 - + Development process (incl. debugging)
 - + Additional technical perks (e.g., browser UI zooming, page text search...)
 - Support quirks for non-mainstream cases
 - Performance issues with larger data



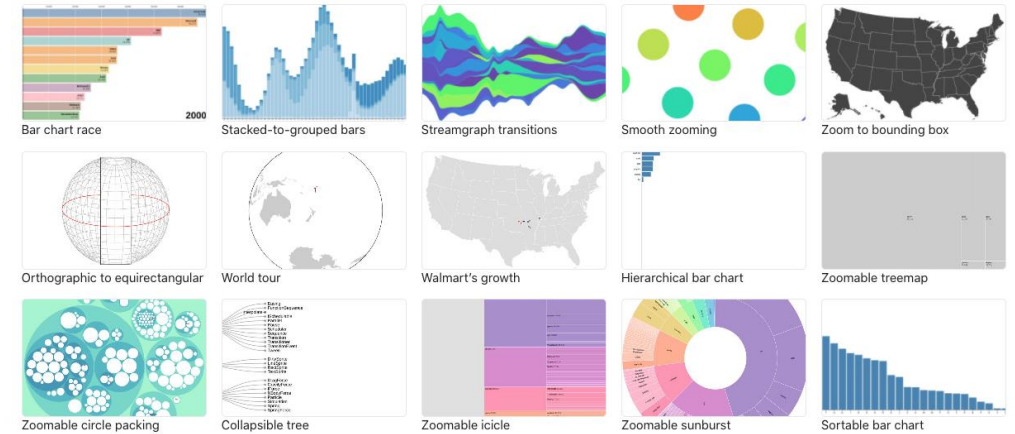


[<https://webvis-do.minik.us/assets/img/devtools/js-good-parts.jpeg>]

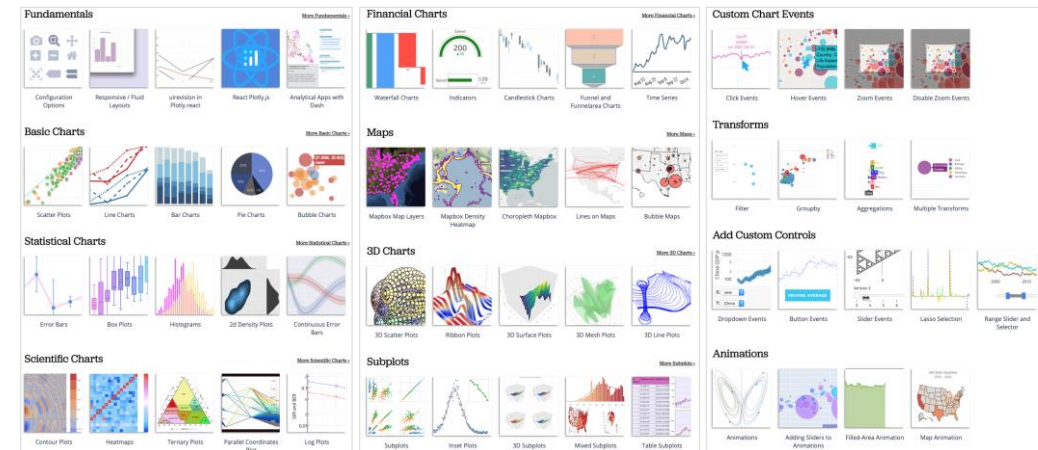


Programming Library Examples

- Extremely low level (i.e., basic graphics/drawing functions): **PixiJS**, **Three.js**
- **D3** ⇒ low-level JavaScript visualization library for web-based tools
 - Way to go when designing custom, novel visual representations from scratch! ⇒ Useful in **research**, but perhaps higher-level approaches recommended for practical use
 - Followed up with further higher-level declarative approaches (Vega, Vega-Lite, ...)
- **Plotly.js** ⇒ high-level charting library based on D3 and stack.gl
 - Supports over 40 representations, standard interactions, and support for customization



[<https://observablehq.com/@d3/gallery>]

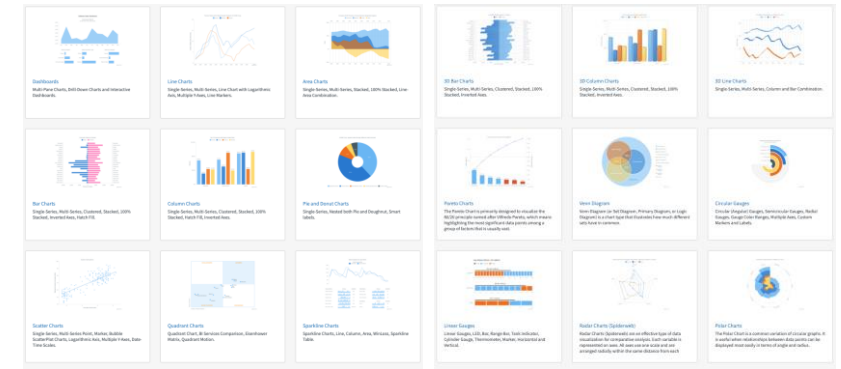


[<https://plotly.com/javascript/>]

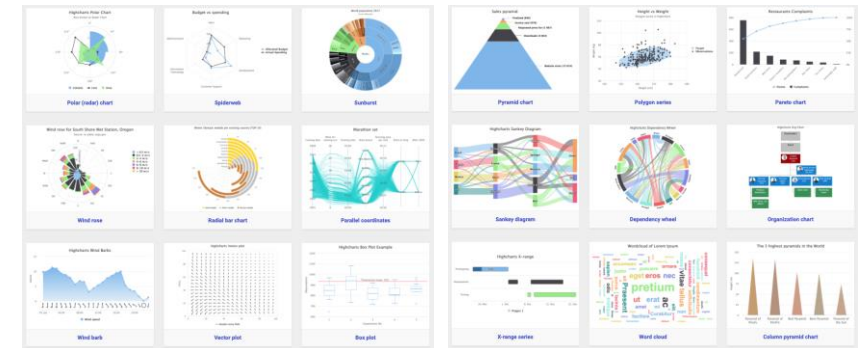


Programming Library Examples (cont.)

- **AnyChart** ⇒ high-level JS library
 - Support for >79 visual representations and various interactions
 - Requires a license for commercial use ⇒ educational and non-profit licenses exist (and the source code is publicly available), though
- **Highcharts** ⇒ high-level JS library
 - Support for multiple representations, interactions, and customization options
 - Free for non-commercial use
- **Google Charts** ⇒ high-level JS library
 - Straightforward API; easy to make use of Google Maps
 - Works well for its intended use cases, but customization options are somewhat limited



[<https://www.anychart.com/products/anychart/gallery/>]



[<https://www.highcharts.com/demo>]



[<https://developers.google.com/chart/interactive/docs/gallery>]

Programming Library Examples (concl.)

- **Bokeh**

- Python library ⇒ generates a web-based vis
- Supports multiple representations and interactions

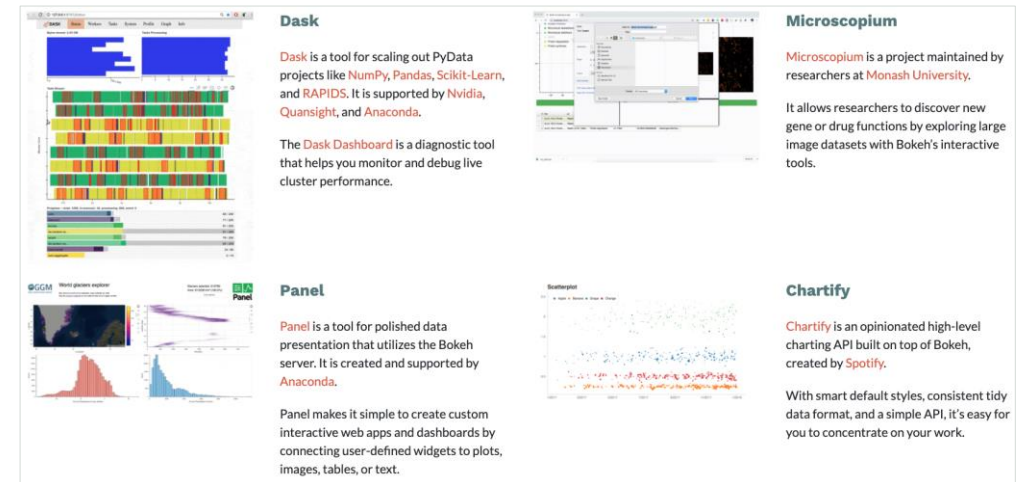
- **Plotly.py**

- Python; generates a web-based vis (⇒ a single chart) using Plotly.js

- **Dash**

- Python or R; generates a web-based dashboard using Plotly.js

- Further libraries available, e.g., for graph/network (**yFiles**, **Cytoscape.js**) or time series (**Rickshaw**) data...



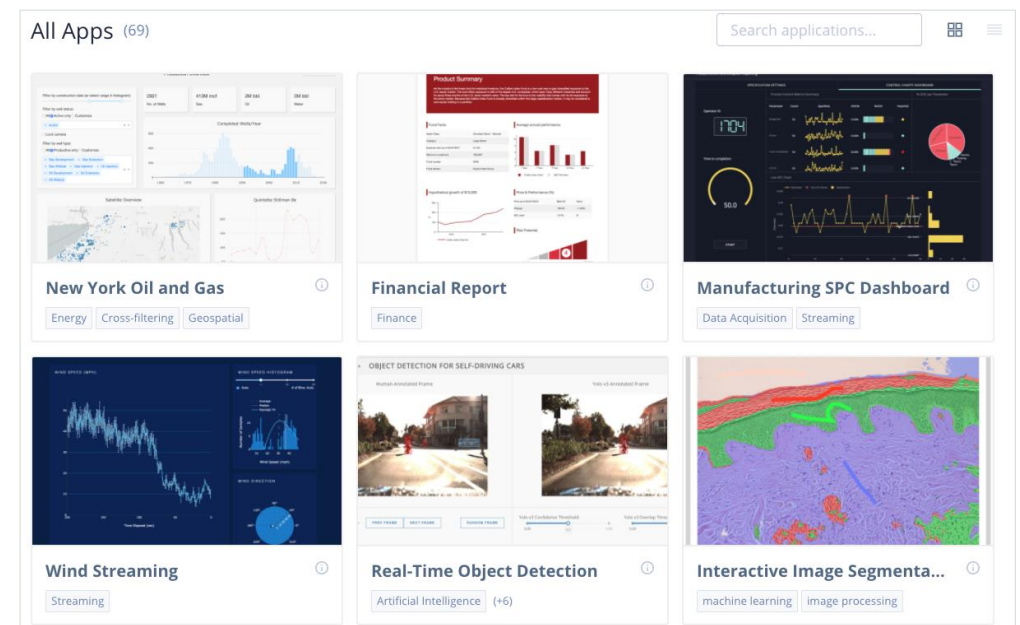
Dask
Dask is a tool for scaling out PyData projects like NumPy, Pandas, Scikit-Learn, and RAPIDS. It is supported by Nvidia, Quansight, and Anaconda.
The **Dask Dashboard** is a diagnostic tool that helps you monitor and debug live cluster performance.

Microscopium
Microscopium is a project maintained by researchers at Monash University.
It allows researchers to discover new gene or drug functions by exploring large image datasets with Bokeh's interactive tools.

Panel
Panel is a tool for polished data presentation that utilizes the Bokeh server. It is created and supported by Anaconda.
Panel makes it simple to create custom interactive web apps and dashboards by connecting user-defined widgets to plots, images, tables, or text.

Chartify
Chartify is an opinionated high-level charting API built on top of Bokeh, created by Spotify.
With smart default styles, consistent tidy data format, and a simple API, it's easy for you to concentrate on your work.

[<https://bokeh.org/>]



All Apps (69) Search applications...

New York Oil and Gas Energy Cross-filtering Geospatial

Financial Report Finance

Manufacturing SPC Dashboard Data Acquisition Streaming

Wind Streaming Streaming

Real-Time Object Detection Artificial Intelligence (+6)

Interactive Image Segmenta... machine learning image processing

[<https://dash-gallery.plotly.host/Portal/>]



Tips and Tricks for Data Visualization



Vis Design Process

Suggested workflow for a new, unfamiliar data set:

- Learn a bit about the data
- If possible, get a domain expert or a target audience representative!
- **Decide on the high-level tasks/goals to support**
- Decide on the concrete lower-level tasks to support
- Choose the visual representations and interactions
- Reflect and iterate, if necessary \Rightarrow usual for larger projects!
- Implement, evaluate, deploy...



Munzner's Nested Model

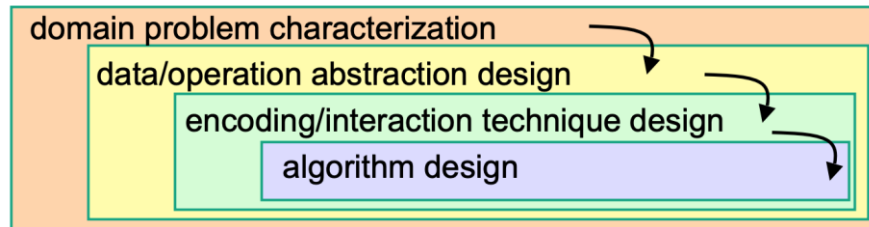


Fig. 1. Our model of visualization creation has four nested layers.

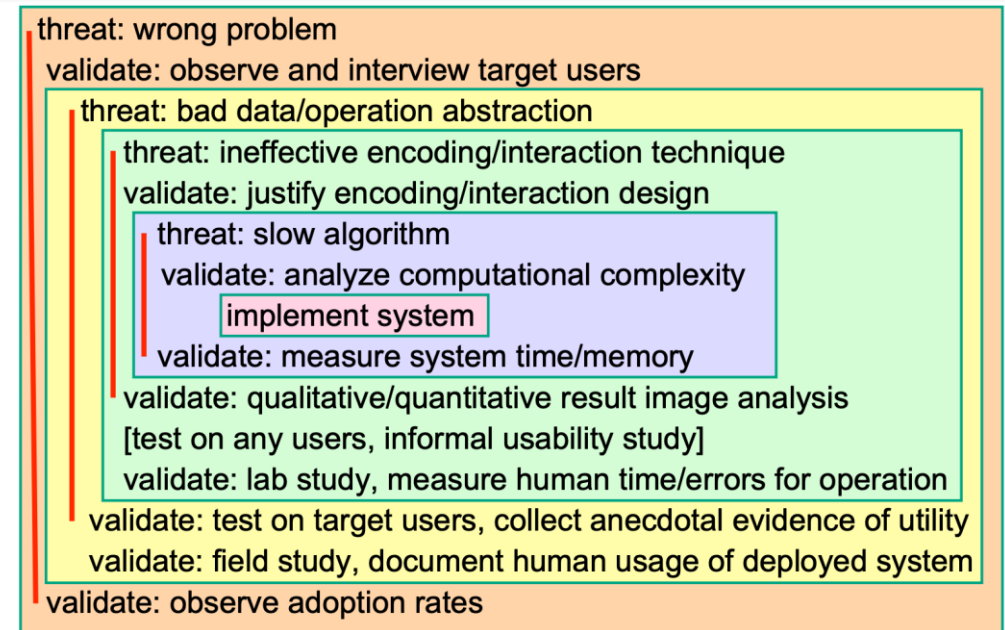


Fig. 2. Threats and validation in the nested model.



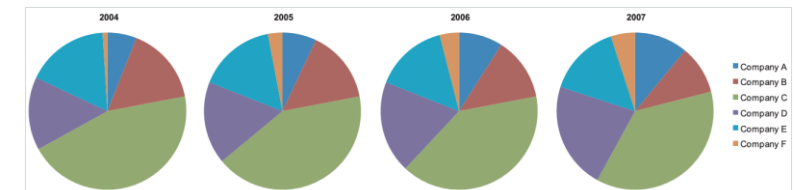
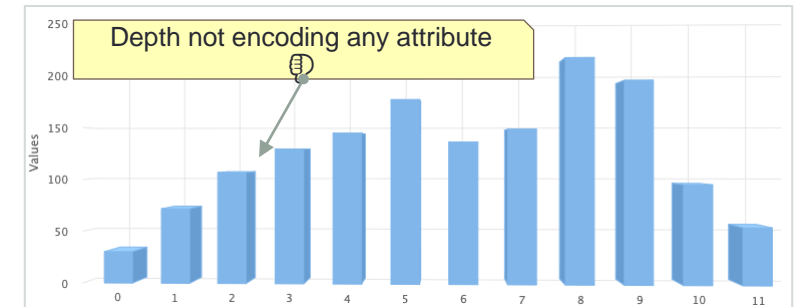
Practical Advice for Vis Design and Implementation

- My advice: start with simple representations and standard interactions
 - “Kill the frills and get to the point!” (Tufte, 1997)
- E.g., line plots (or area charts) for temporal data, scatter plots for 2D/3D projections, bar charts for comparison tasks, histograms for distributions, PCPs for nD numerical data, etc.
- A table or a text view (perhaps, also a radar chart or a glyph) with details
- Support for coordinated multiple views + Shneiderman’s mantra
- **Think about how all of them fit together and whether the workflow would make sense to the users and help address their tasks!**
 - Issues of *effectiveness* (“getting the job done”) and *efficiency* (completing tasks faster than alternative techniques) — but also specific conventions and users’ expectations...
- Also keep in mind the limitations of potential implementation tools

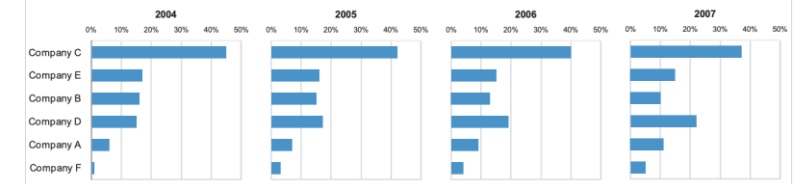


Practical Advice for Vis Design and Implementation (cont.)

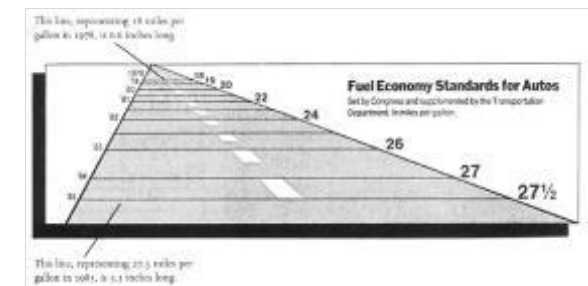
- Avoid 3D bar/pie charts!
 - Don't use 3D gratuitously without a good reason
- Also, bar charts are much better than pie charts 😊
- Be careful with the choice of colors (remember the perception issues) ⇒ e.g., consider <https://colorbrewer2.org/>
- Be careful with quantitative data encoding ⇒ e.g., use *area* of circles/dots rather than *radius* to encode numerical values
 - Tufte even calculated the “*lie factor*” by dividing (1) the size of displayed effect by (2) the size of effect in the underlying data (Tufte, 1991)



Try to follow the changes of these various companies and how they compare to one another through time. It is nearly impossible. Notice how easily you can do it, however, using the following display:



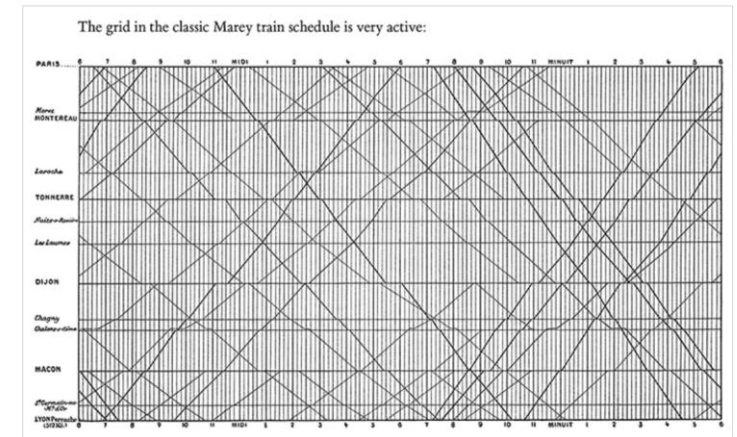
[Few. 2007. Save the Pies for Dessert. <https://www.perceptualedge.com/articles/08-21-07.pdf>]



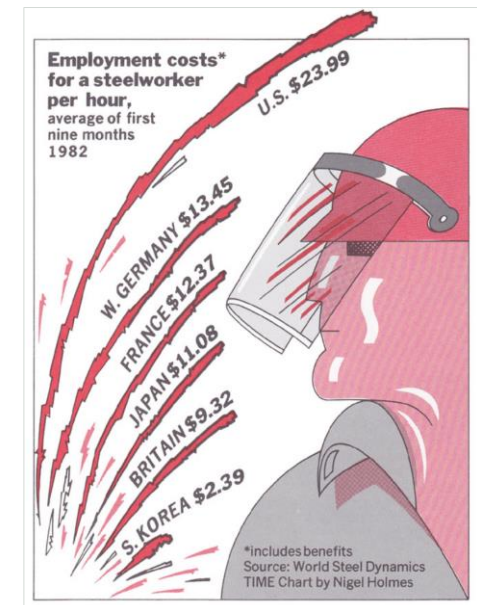
[Tufte. 1991. The Visual Display of Quantitative Information (2nd ed).]

Practical Advice for Vis Design and Implementation (concl.)

- Visual encoding should aim for *expressiveness* ⇒ representing *all* and *only* the information present in the data
 - I.e., it should not mislead users by hiding or “inventing” values, patterns, etc.
 - Remember the issues in the previous slide
- Typically try to avoid *chartjunk* ⇒ non-data and redundant data elements (Tufte, 1991)
 - Redundant representations, over-busy grid lines and excess ticks, unintentional moire effects...
 - In case of artistic decorations for infographics ⇒ **tasks** and **evaluation criteria** (e.g., attracting the readers’ attention, being entertaining...) different from InfoVis



[Tufte, 1991. The Visual Display of Quantitative Information (2nd ed).]



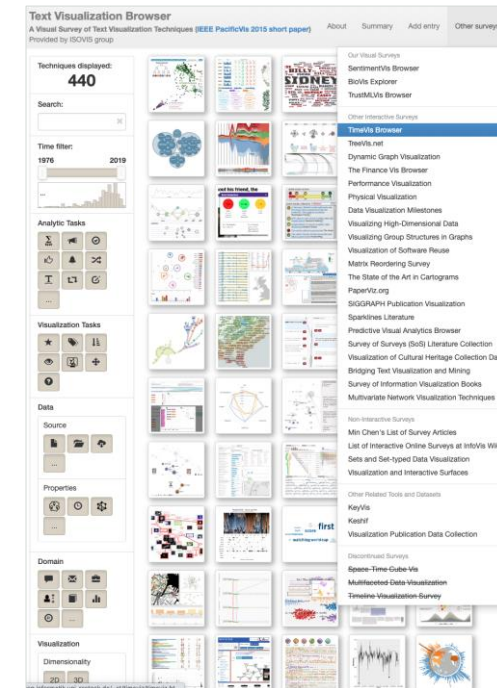
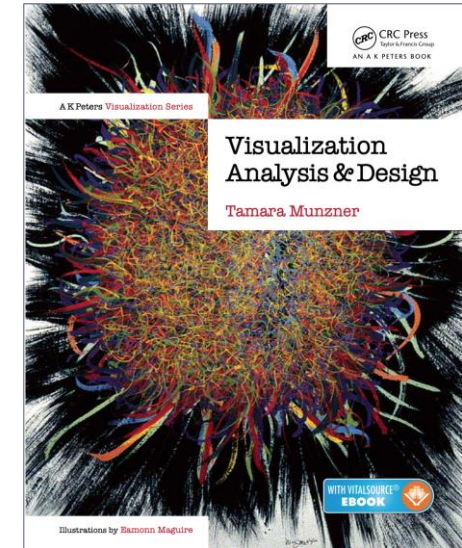
[Few, 2011. The Chartjunk Debate: A Close Examination of Recent Findings. https://perceptualedge.com/articles/visual_business_intelligence/the_chartjunk_debate.pdf]

Further Resources and Links



Selected Resources

- infovis-wiki.net
- **Visualization Analysis and Design** (Munzner, 2014)
 - <https://www.cs.ubc.ca/~tmm/vadbook/> ⇒ including video presentations
- **Data Visualization Literacy** (Börner, 2018)
 - https://youtu.be/N5wYoIR1K_4
- **Visualization as Lingua Franca in Machine Learning** (Viégas, 2018)
 - <https://youtu.be/xH19VRSOG7g>
- **Perception in Visualization** (Healey, 2012)
 - <https://www.csc2.ncsu.edu/faculty/healey/PP/index.html> ⇒ including interactive demos
- **Solving Problems with Visual Analytics** (Keim et al., 2010)
 - <https://www.vismaster.eu/book/> ⇒ free introductory book on Visual Analytics
- **Online Survey Browsers from the ISOVIS Group** ⇒ including links to other surveys!
 - <https://textvis.lnu.se> + <https://sentimentvis.lnu.se>
 - <https://trustmlvis.lnu.se>
 - <https://biovis.lnu.se>



Selected Resources (concl.)

- **Overview of Various Vis Tools in Keshif**
 - <https://gallery.keshif.me/VisTools>
- **Data Vis Tools, Revisited** (Rost, 2018)
 - <https://lisacharlottemuth.com/datavistools-revisited-talk>
- **Everything Except the Chart** (Baur & Stefaner, 2018)
⇒ Tutorial on web-based visualization
 - <https://webvis-do.minik.us>
- **D3 Examples Gallery**
 - <https://observablehq.com/@d3/gallery>
- **Data Viz Project** ⇒ Example gallery
 - <https://datavizproject.com/>
- **Chartopedia** ⇒ Example gallery from AnyChart
 - <https://www.anychart.com/chartopedia/usage-type/>
- **Reddit:** r/dataisbeautiful and r/dataisugly

