Practical Data Visualization

March 18, 2015

COMPSCI 216:
Everything Data

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WHY VISUALIZE?

Preserve complexity

Anscombe's Quartet

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

Preserve complexity

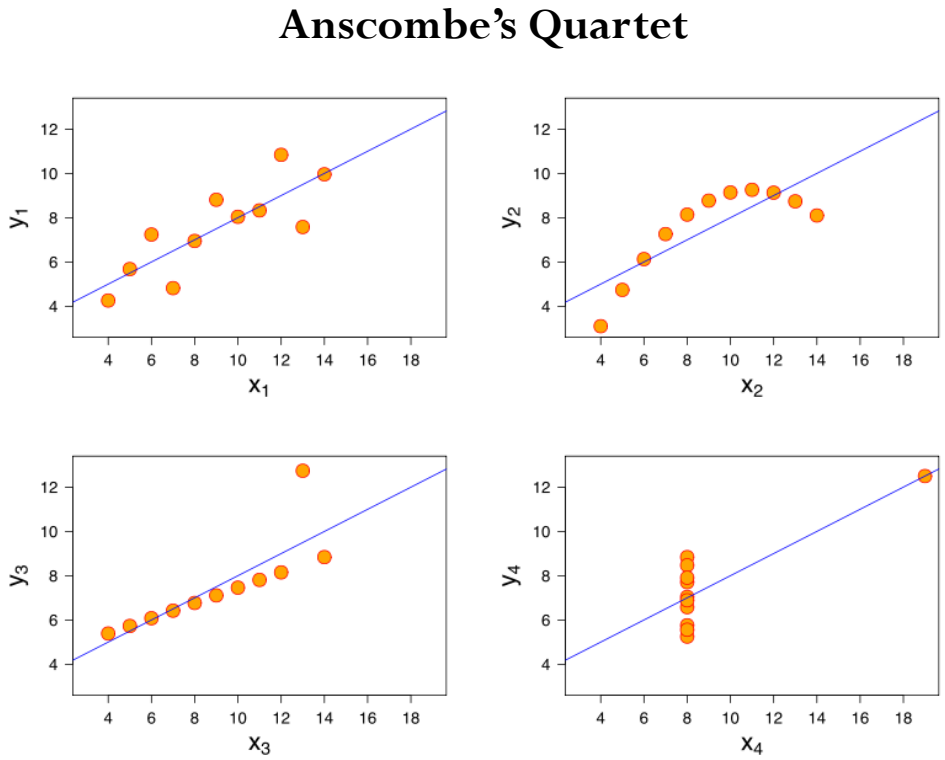
Anscombe's Quartet

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

Property	Value
Mean of x	9 (exact)
Variance of x	11 (exact)
Mean of y	7.50 (to 2 decimal places)
Variance of y	4.122 or 4.127 (to 3 decimal places)
Correlation between x and y	0.816 (to 3 decimal places)
Linear regression line	$y = 3.00 + 0.500x$ (to 2 and 3 decimal places, respectively)

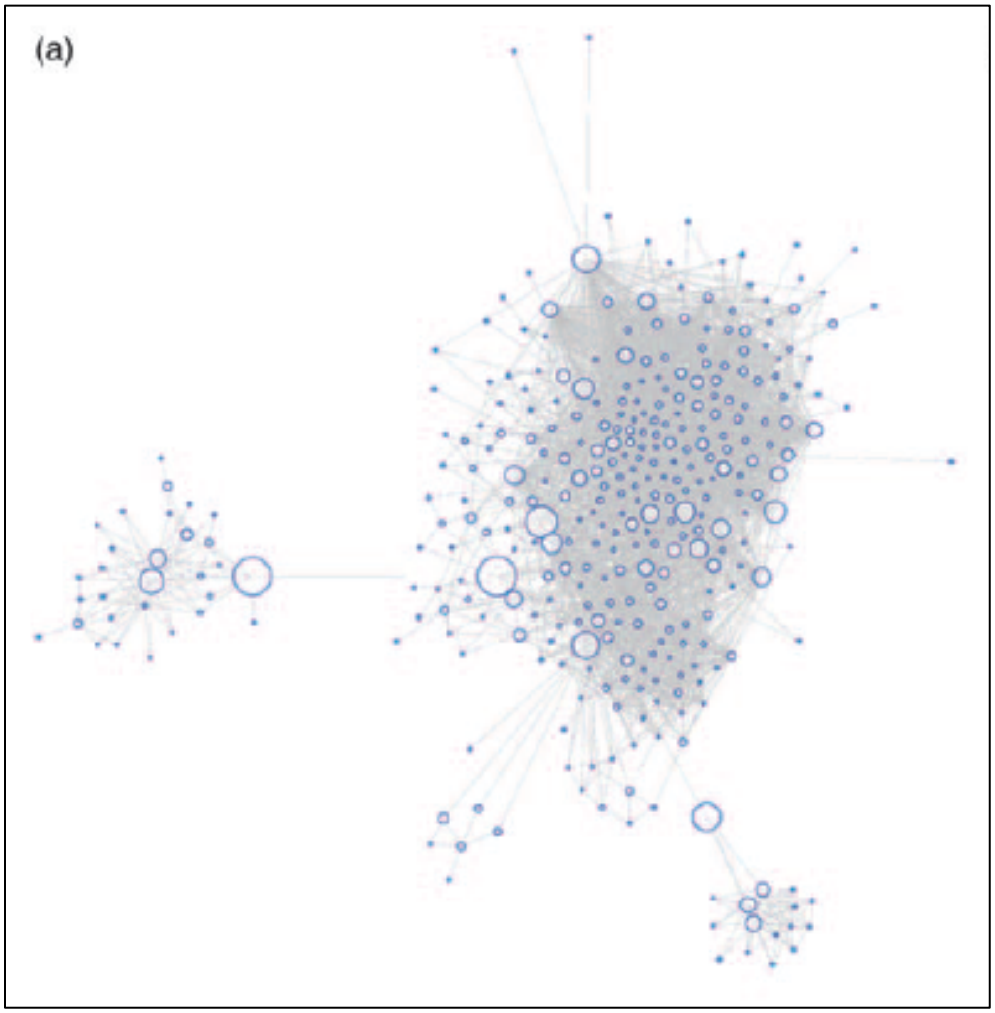
http://en.wikipedia.org/wiki/Anscombe%27s_quartet

Preserve complexity



http://en.wikipedia.org/wiki/Anscombe%27s_quartet

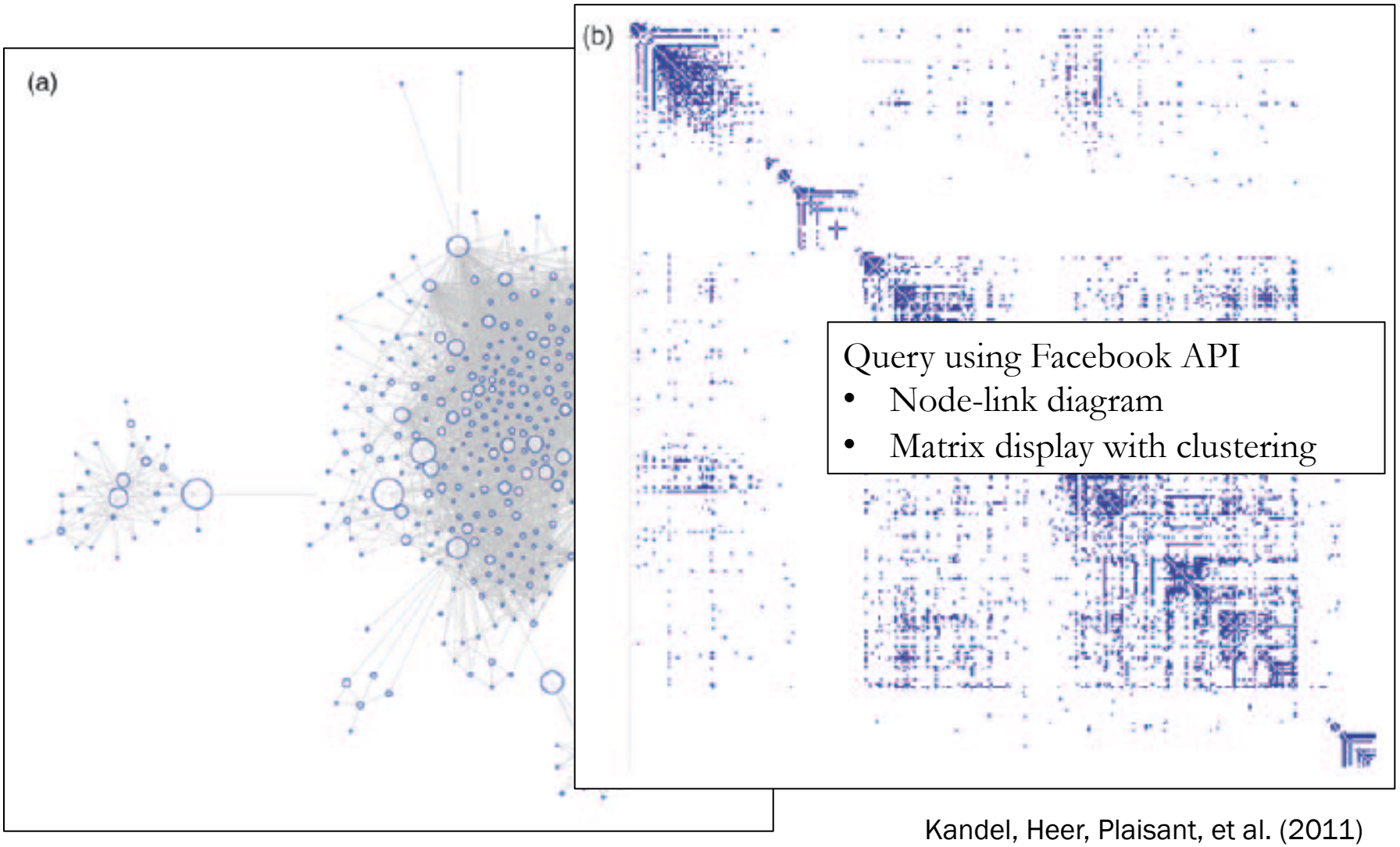
Evaluate data quality



Query using Facebook API
- Node-link diagram

Kandel, Heer, Plaisant, et al. (2011)
http://dx.doi.org/10.1177/1473871611415994

Evaluate data quality



Kandel, Heer, Plaisant, et al. (2011)
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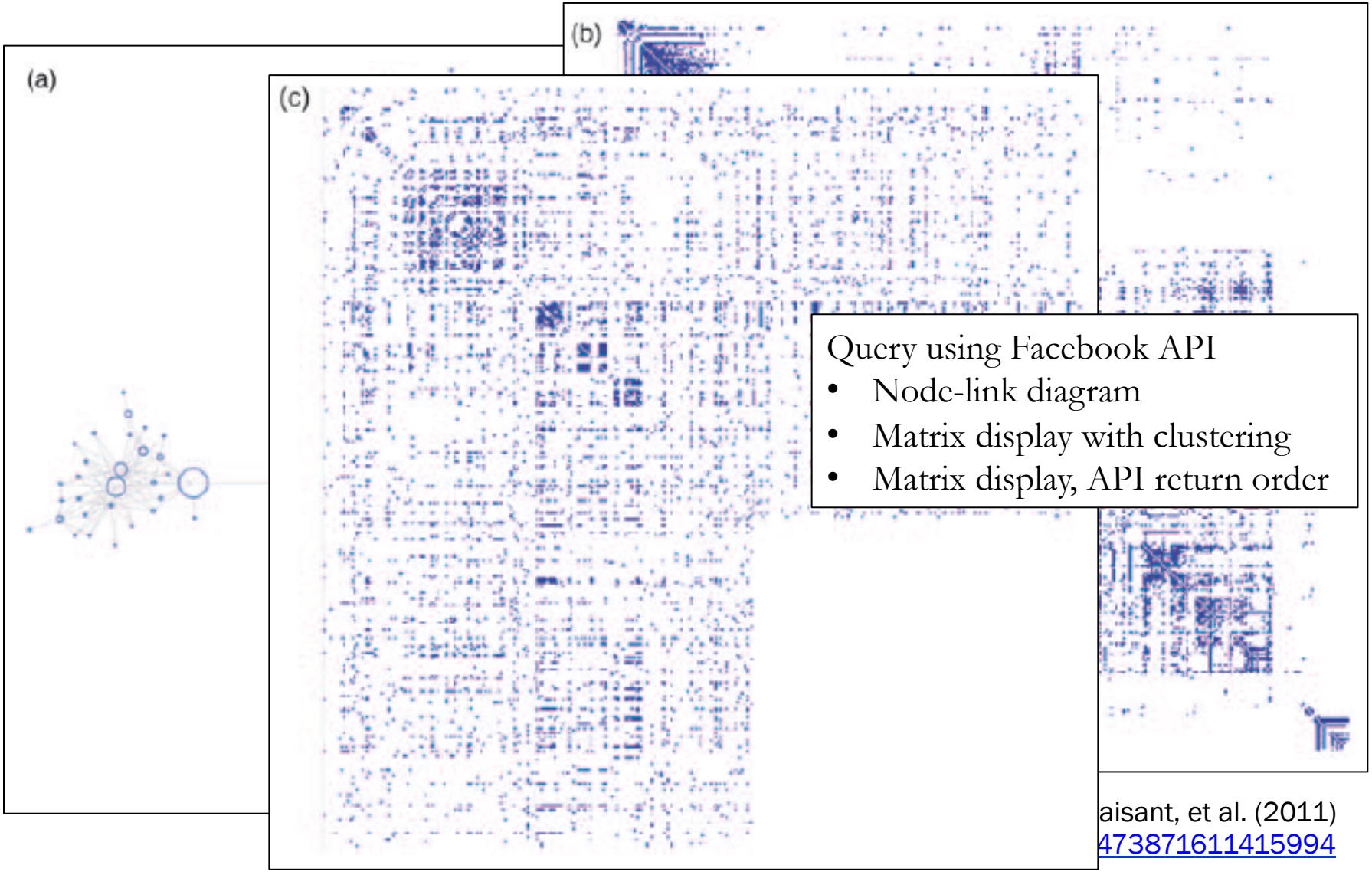
Evaluate data quality

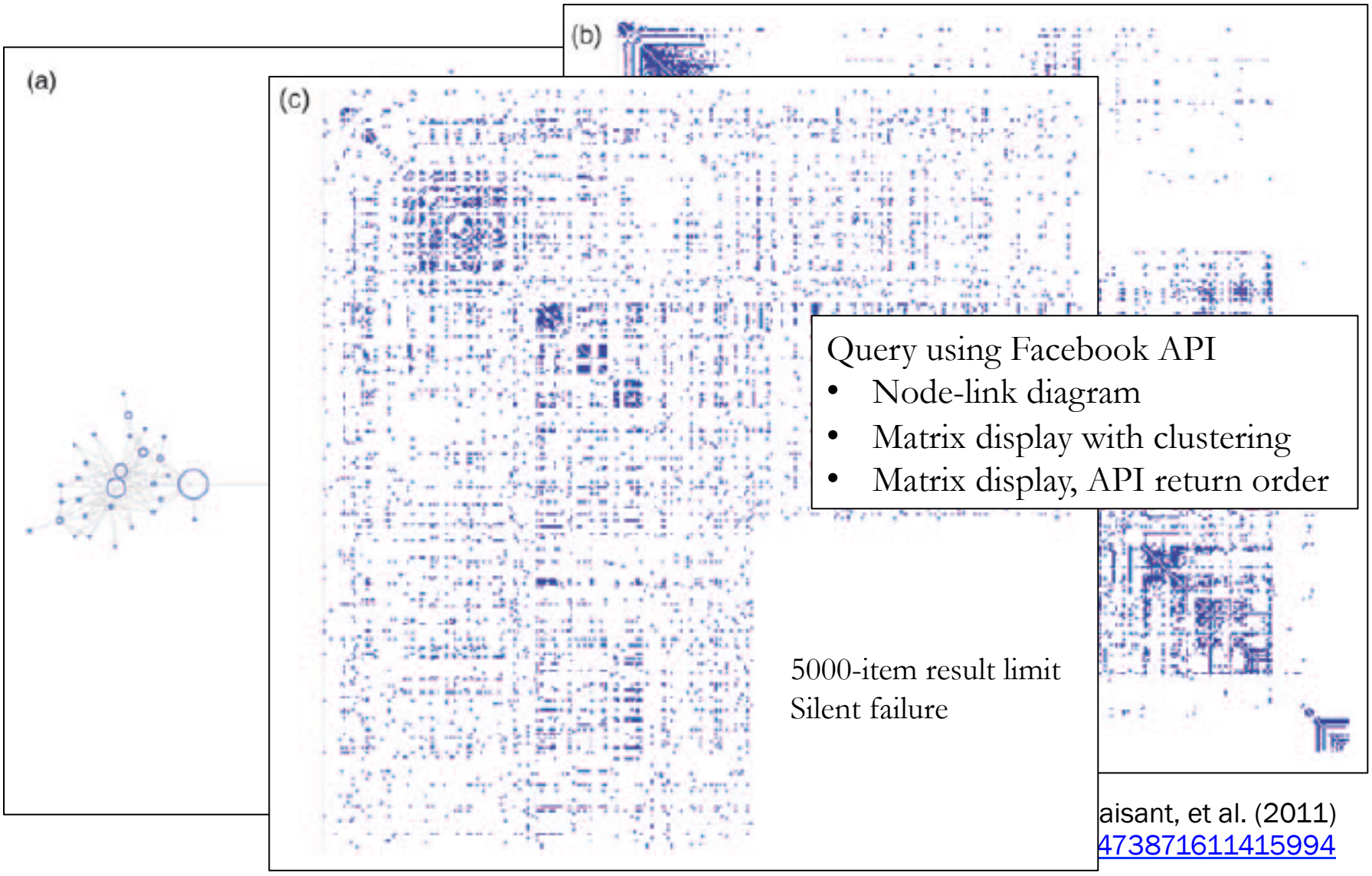


Query using Facebook API

- Node-link diagram
- Matrix display with clustering
- Matrix display, API return order

aisant, et al. (2011)
473871611415994

Evaluate data quality



aisant, et al. (2011)
473871611415994

Tell a story

Hans Rosling – The River of Myths
http://www.youtube.com/watch?v=Owll-dwh-bk
http://www.gapminder.org/

CREATING A VISUALIZATION

From Data to Graphic

- What data types are present in the data source?
  Categorical? Numerical? Relational?

Matching Data Types to Visual Elements

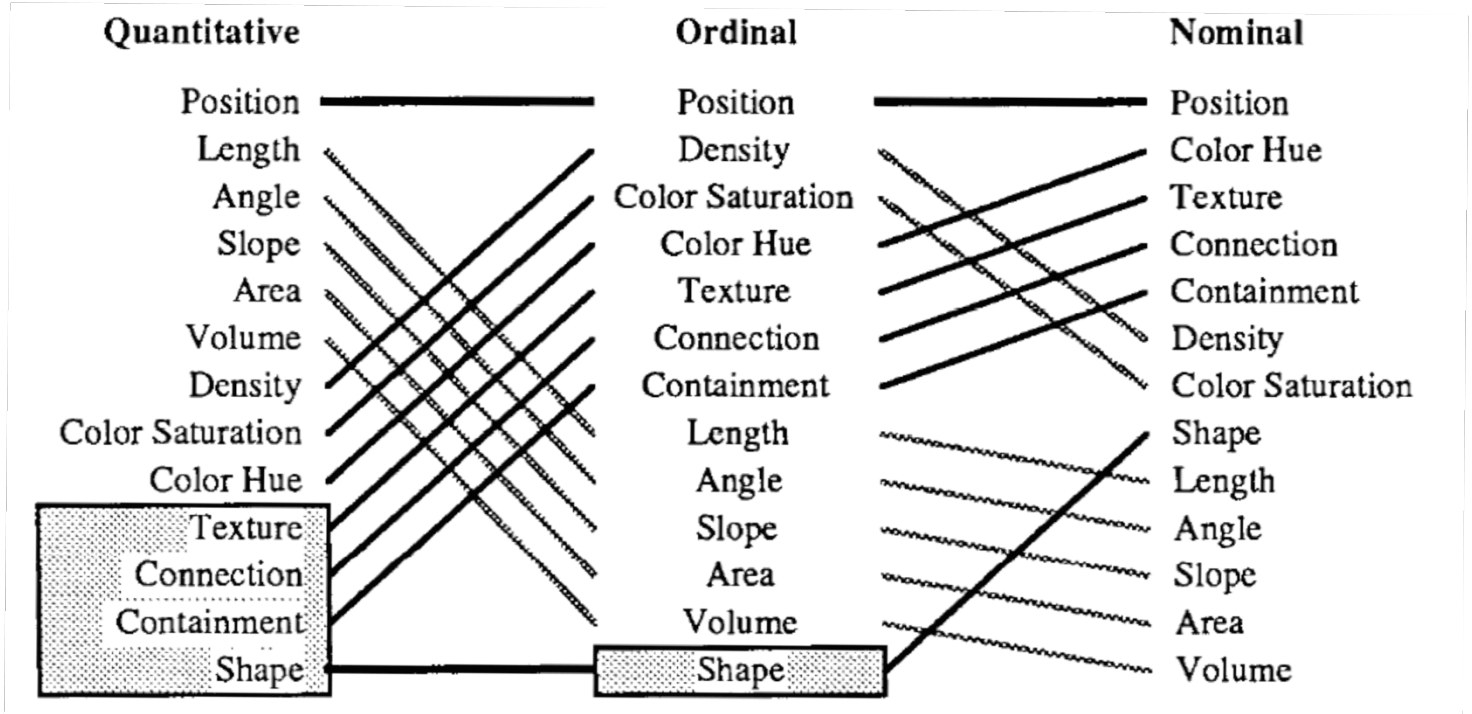


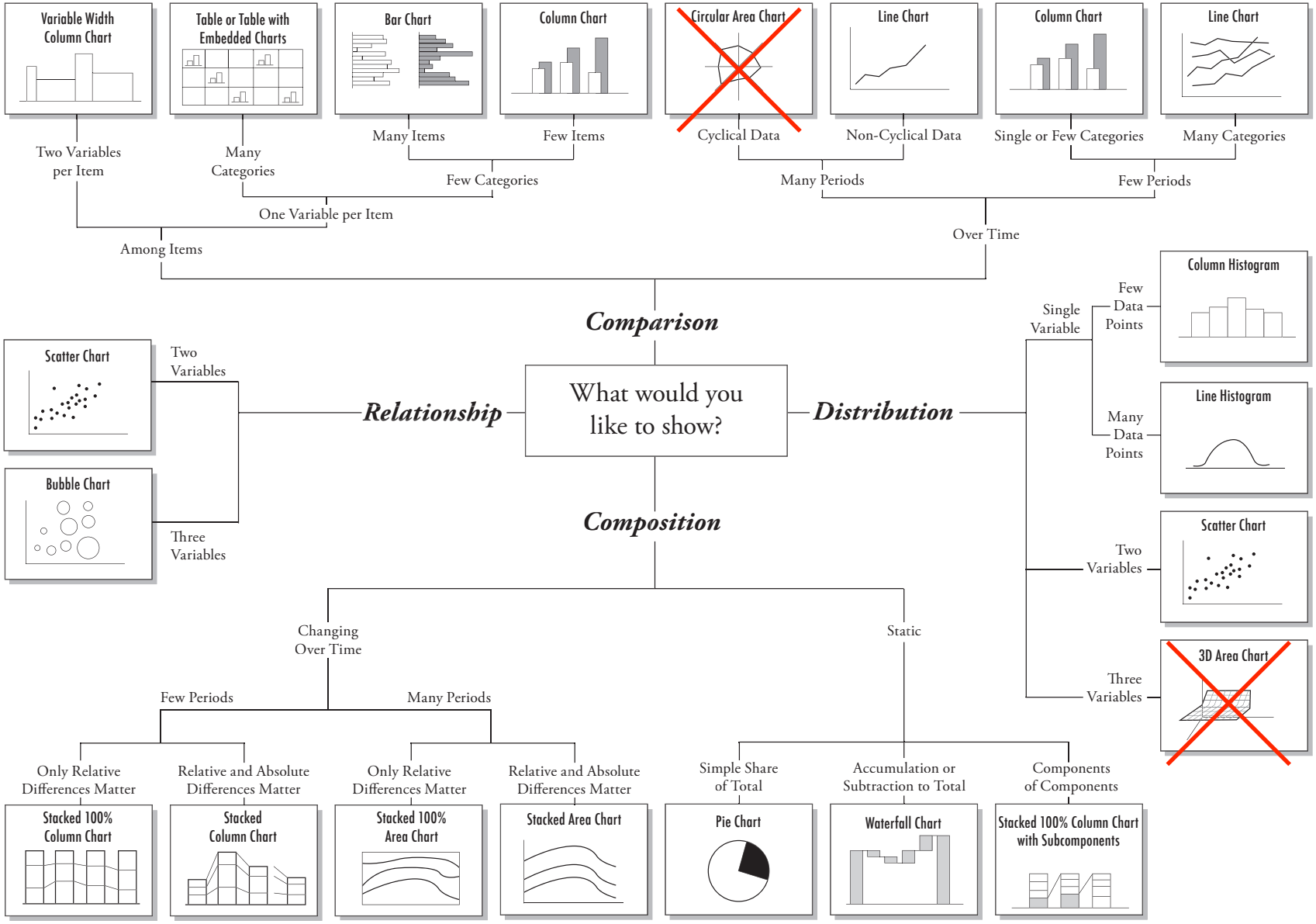
Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

Mackinlay, J. (1986). Automating the design of graphical presentations of relational information. *ACM Transactions on Graphics, 5*(2), 110-141. http://dx.doi.org.proxy.lib.duke.edu/10.1145/22949.22950

From Data to Graphic

- What data types are present in the data source?
- What type of analysis do you want to support?
  Are you looking for correlations? Distributions?

Chart Suggestions—A Thought-Starter



http://extremepresentation.typepad.com/blog/2006/09/choosing_a_good.html

From Data to Graphic

- What data types are present in the data source?
- What type of analysis do you want to support?
- What visualization type seems to be the best fit for the goal?

  Do you want the visualization to be accessible for a broad audience? Flashy and engaging? Convincing?

Position is everything.

@moritz_stefaner

Basic tips

- Rotated text is harder to read
- People are very good at reading x/y position, bar length
- People are not as good at reading angles, areas
- Avoid overlap by filtering, aggregating, leaving space

http://guides.library.duke.edu/topten

Color is difficult.

@moritz_stefaner

Basic tips

For categorical variables:

- People have trouble differentiating between more than 5-7 hues (colors)

For numerical variables:

- People have trouble differentiating between more than 5-7 shades
- Rainbow color gradients are very problematic

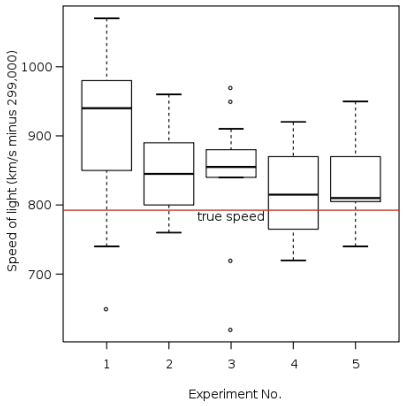
For highest contrast, only use color to highlight

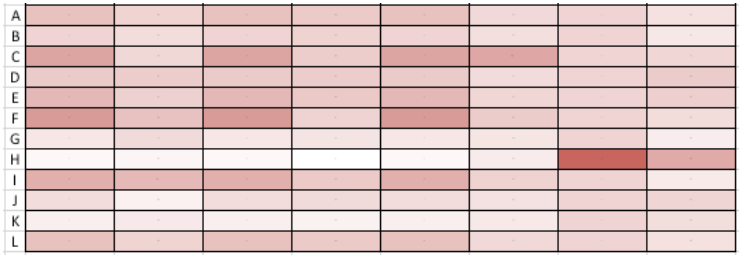
http://guides.library.duke.edu/topten

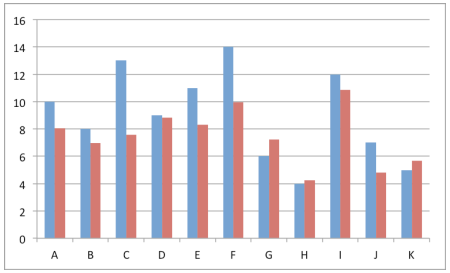
VISUALIZATION TYPES

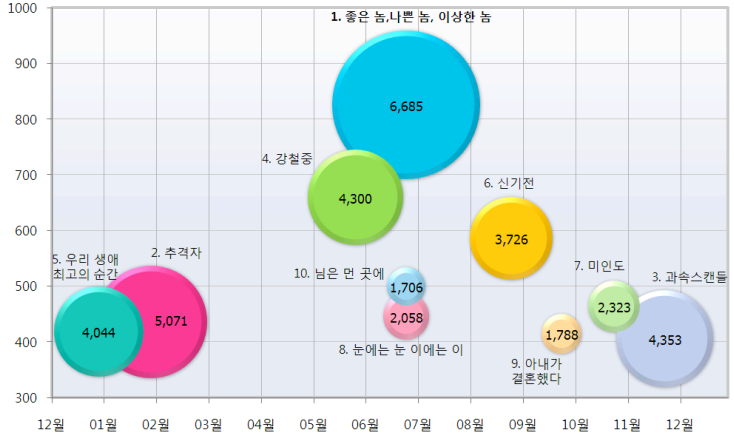
http://guides.library.duke.edu/vis_types

Showing Values

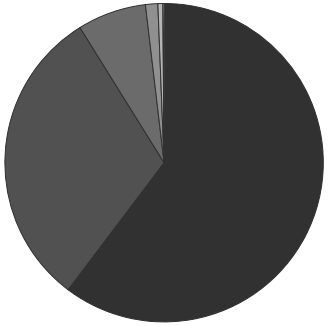


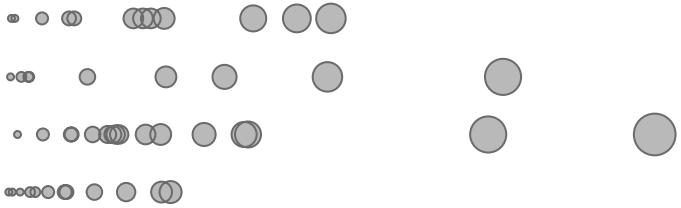




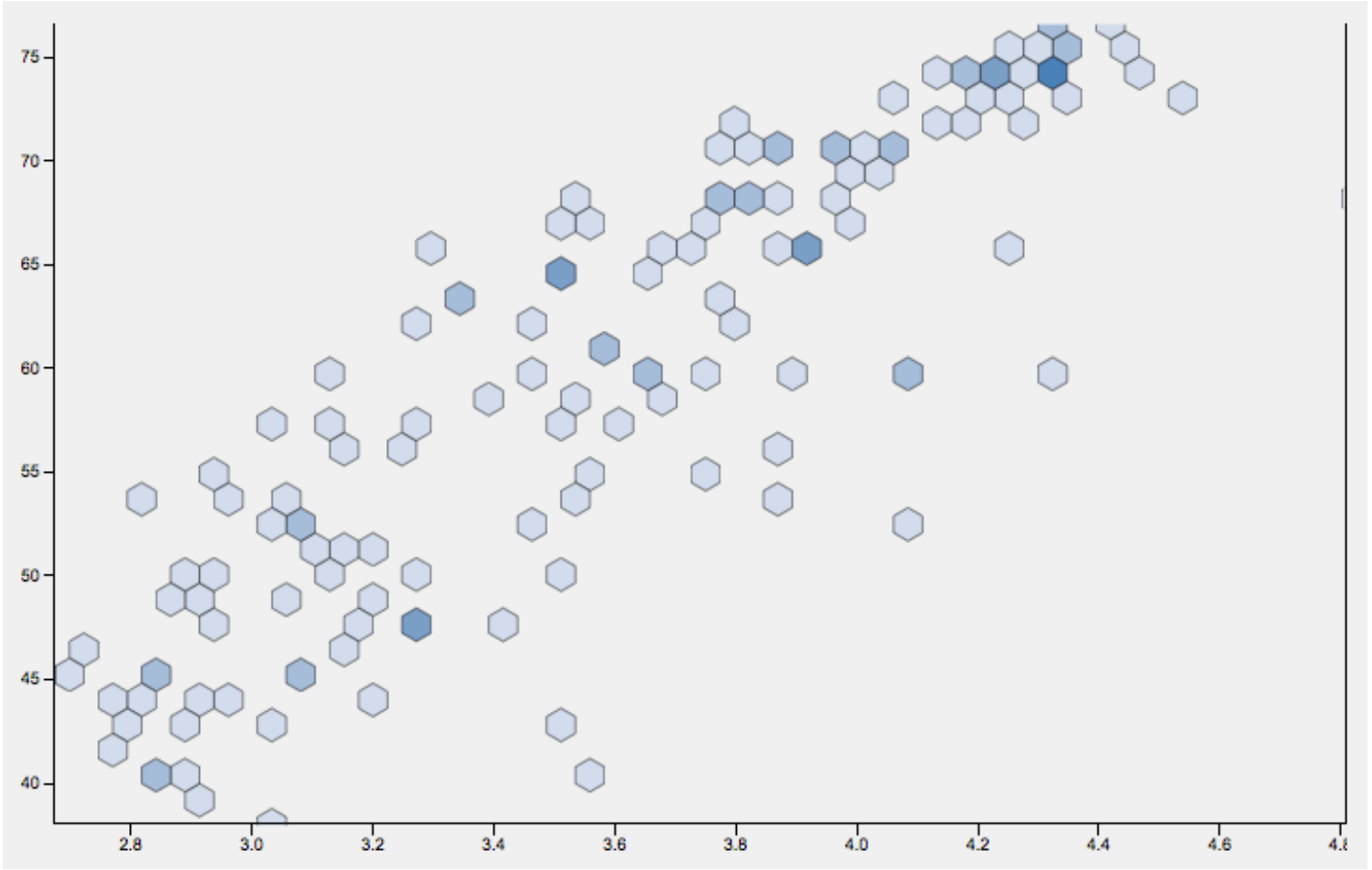


Basic charts and graphs



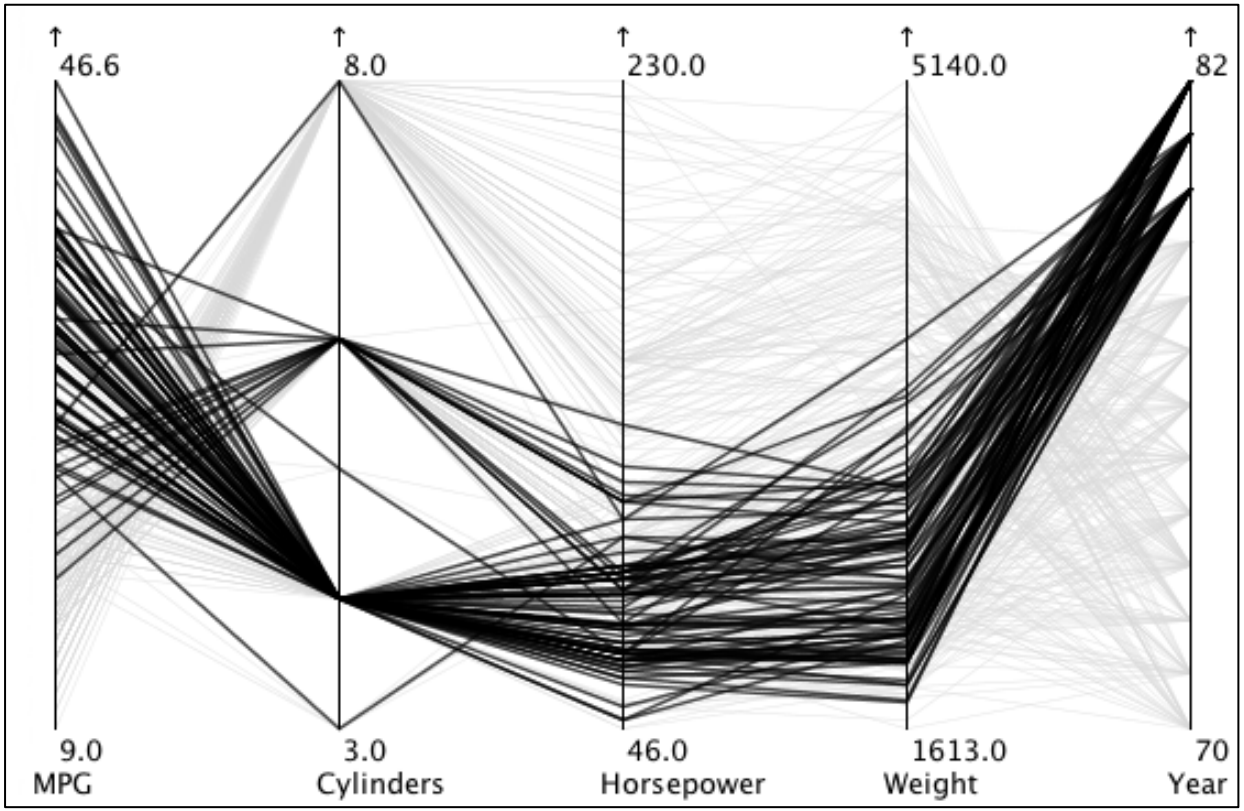


Binned Scatterplot



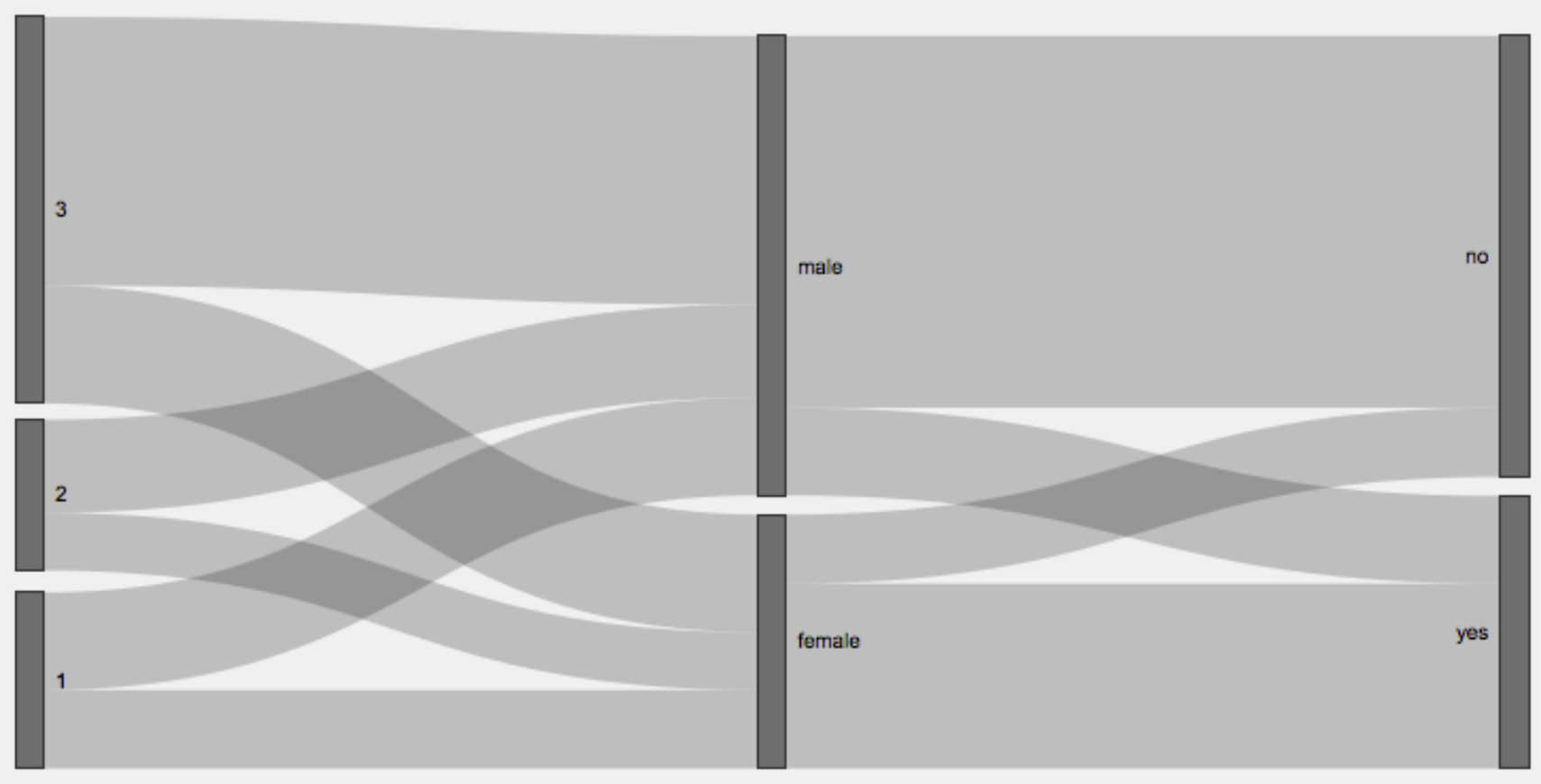
http://raw.densitydesign.org/

Parallel Coordinates



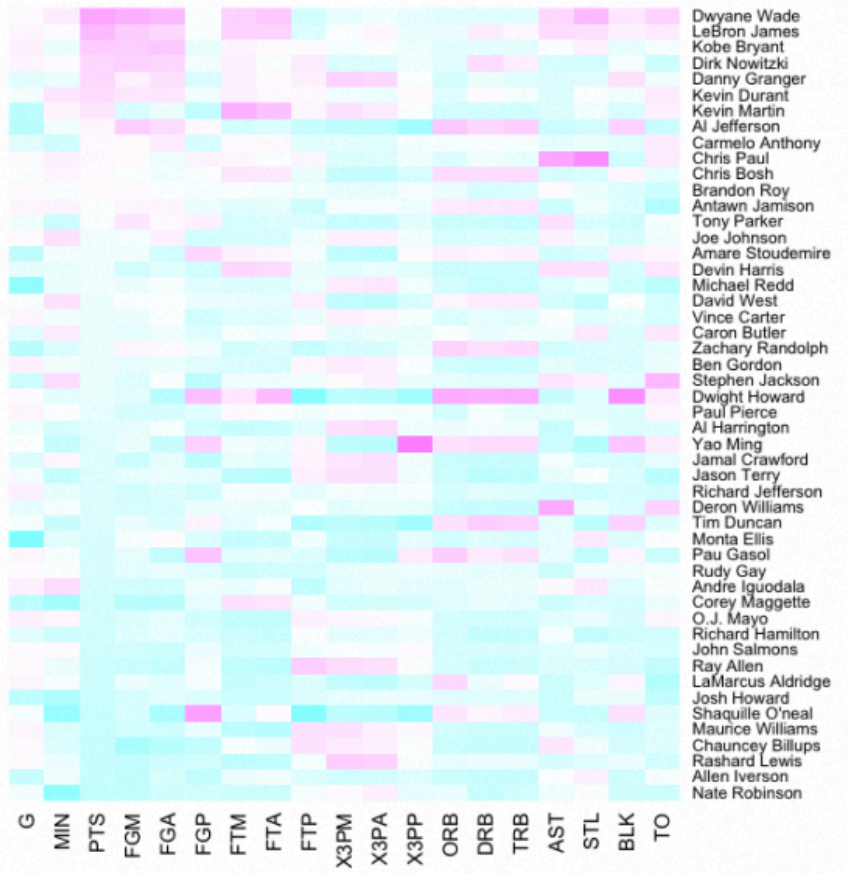
http://eagereyes.org/techniques/parallel-coordinates

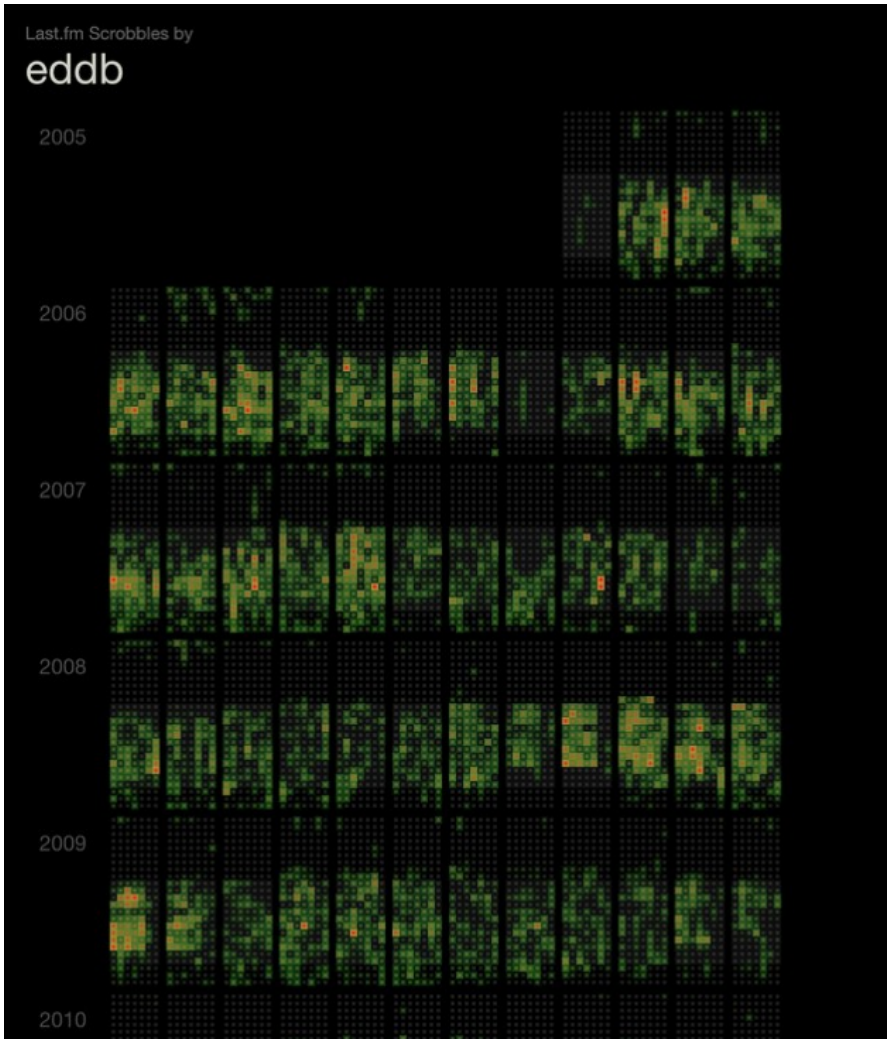
Sankey/Alluvial Diagram



http://raw.densitydesign.org/

Heat Maps



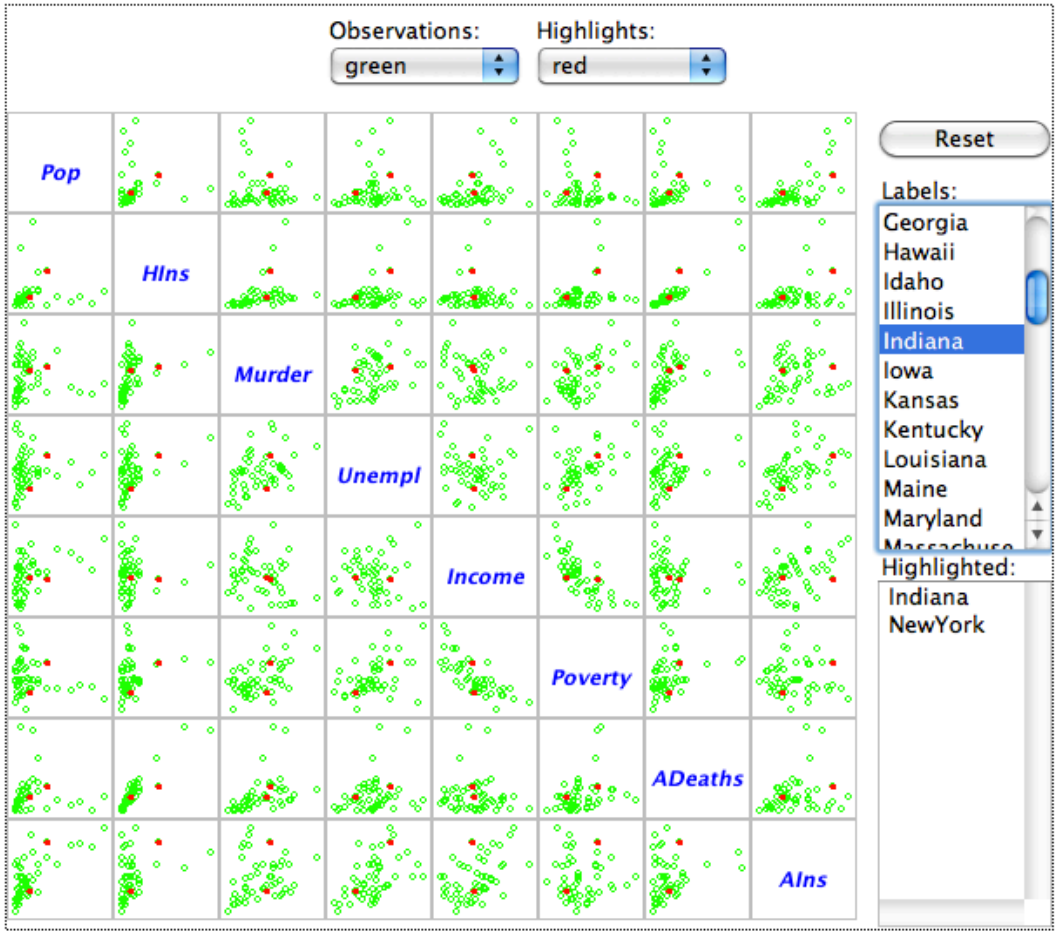


http://flowingdata.com/2010/01/21/how-to-make-a-heatmap-a-quick-and-easy-solution/

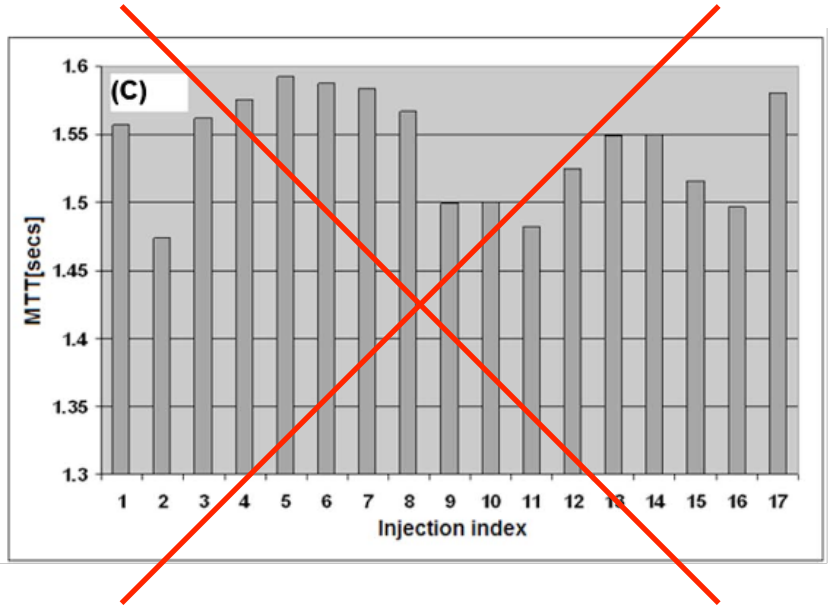
http://flowingdata.com/2011/09/13/last-fm-scrobbles-as-calendar-heat-map/

Pairs Plots

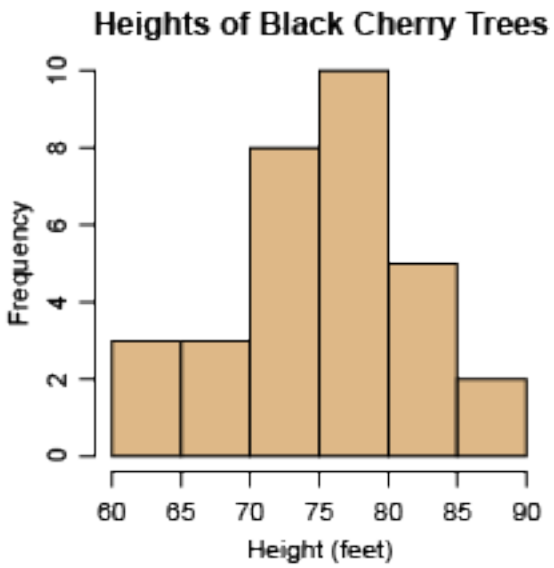
Dynamic Pairs Plot: http://www.stat.sc.edu/~west/bradley/census.html



Showing Distributions

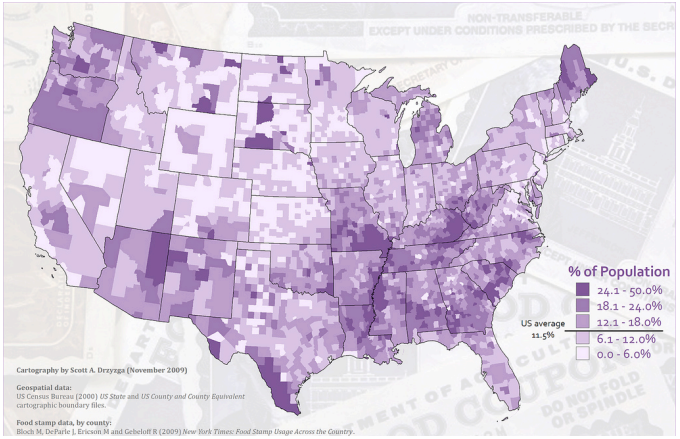


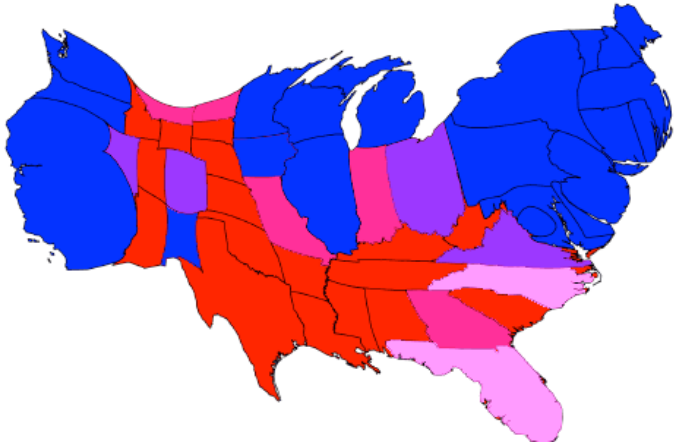
One-dimensional scatter plot



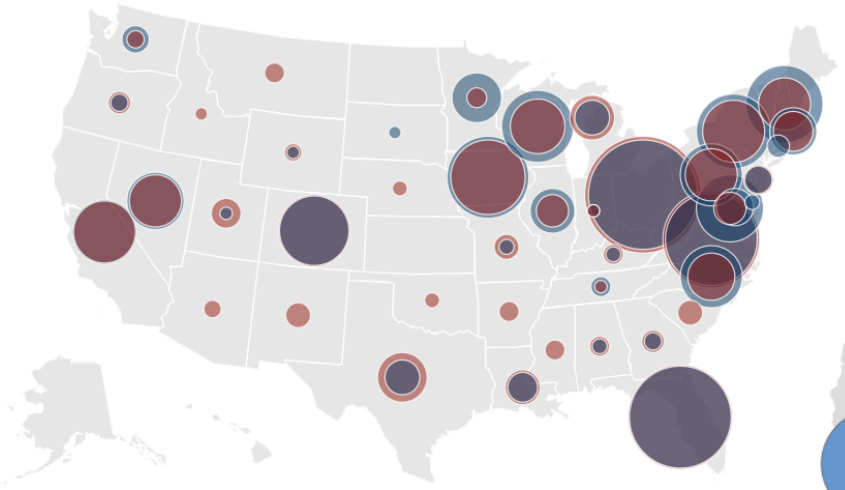
Histogram

Showing Space

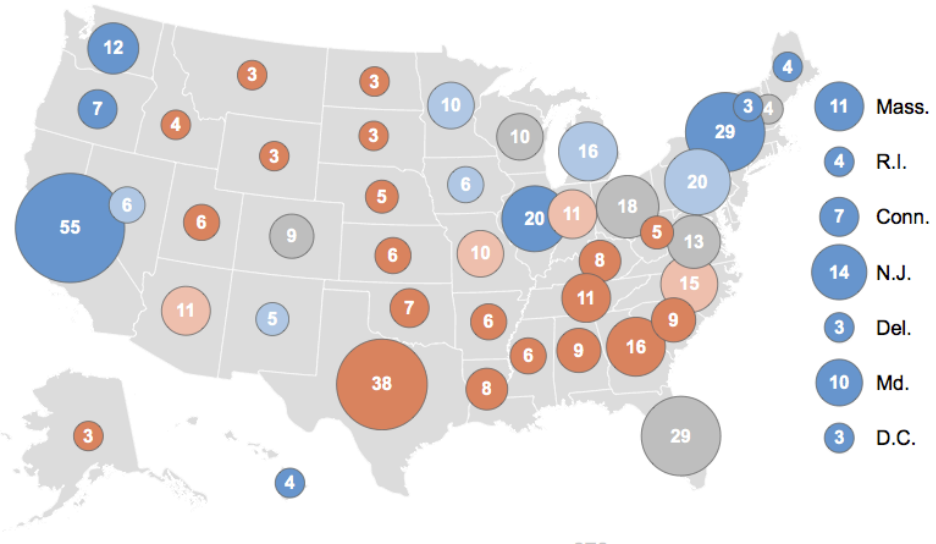




Proportional symbol



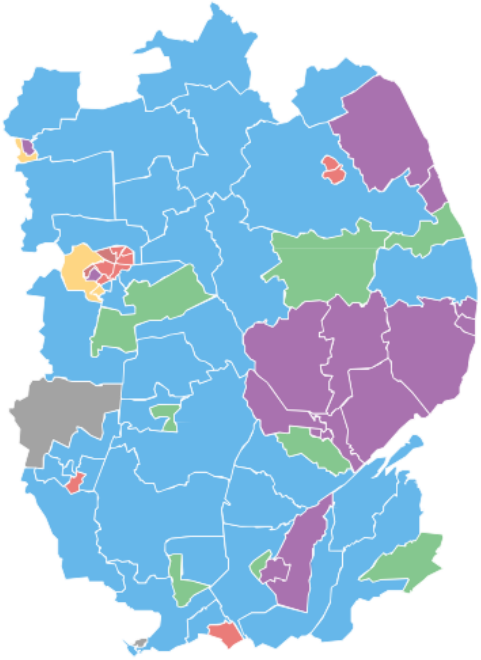
http://wapo.st/2012-campaignvisits



http://ti.me/RQaRH9

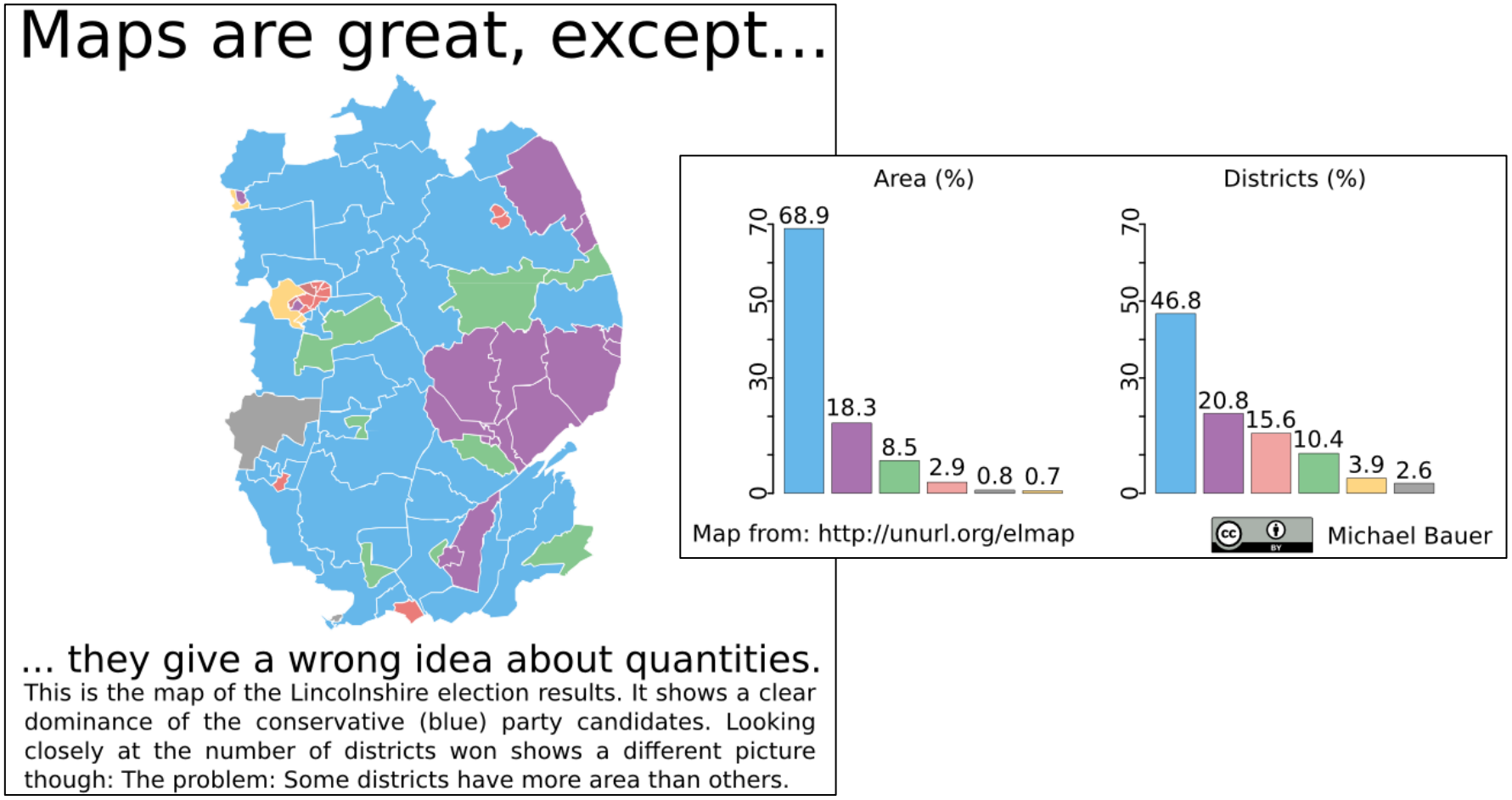
Proportional symbol

Choropleth



https://twitter.com/mihi_tr/status/330261204083810304/photo/1

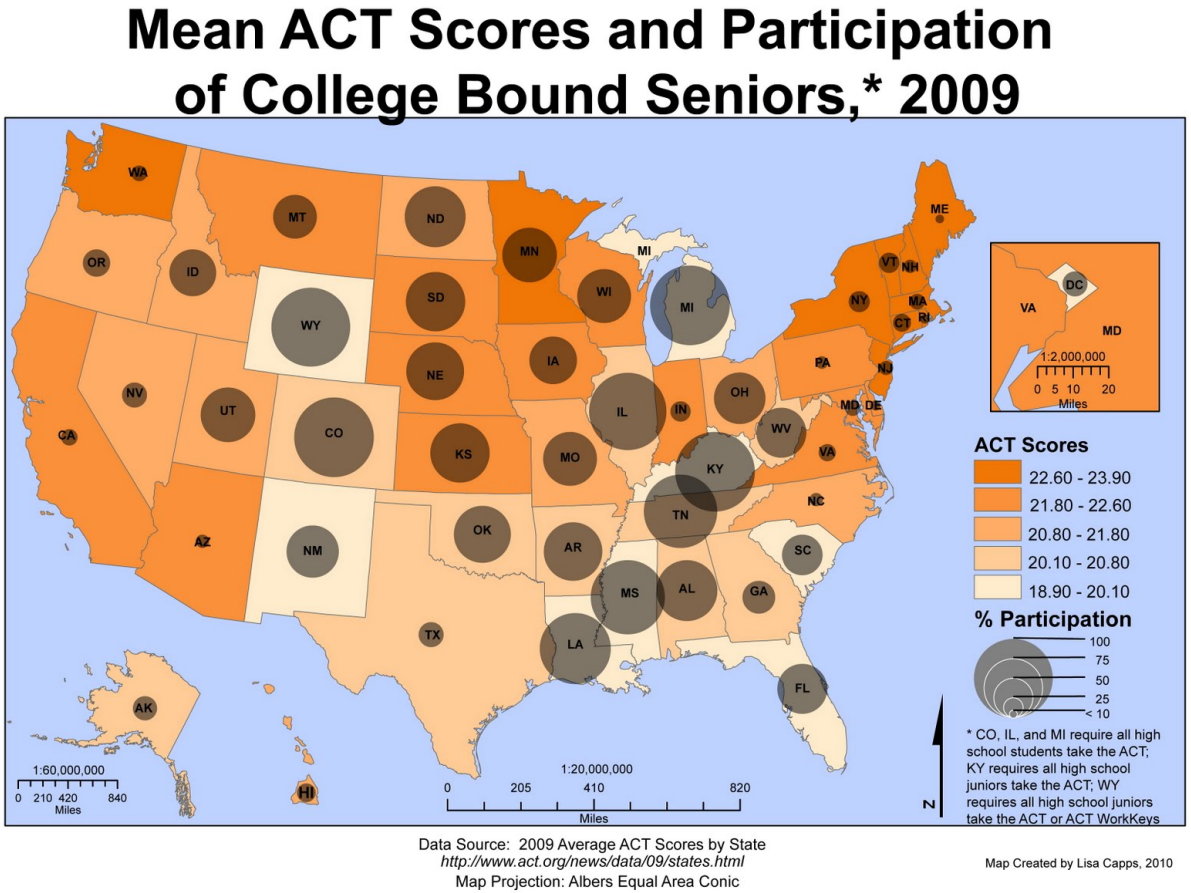
Choropleth



https://twitter.com/mihi_tr/status/330261204083810304/photo/1

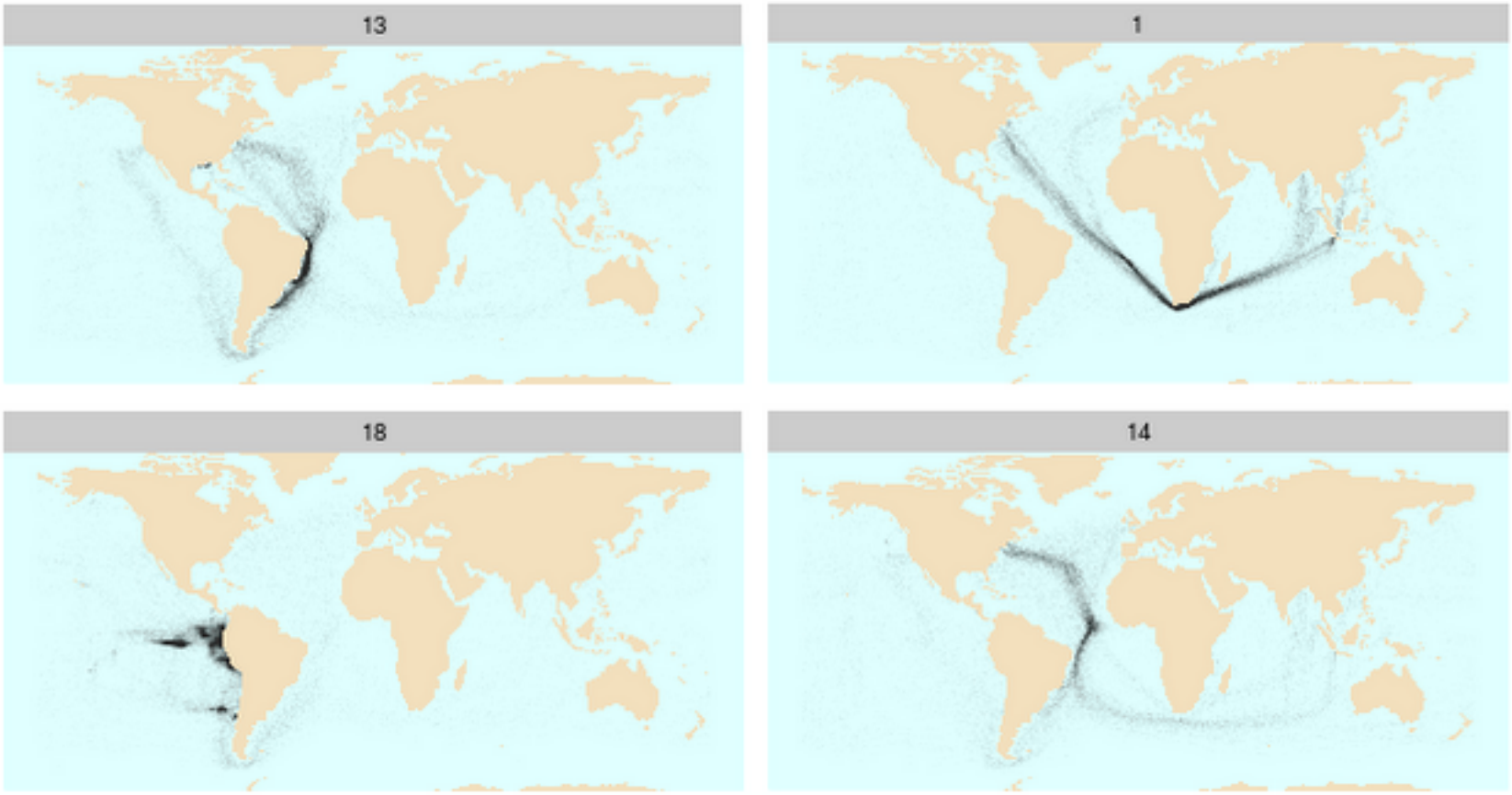
And don't make users do "visual math."

http://eagereyes.org/criticism/visual-math-wrong



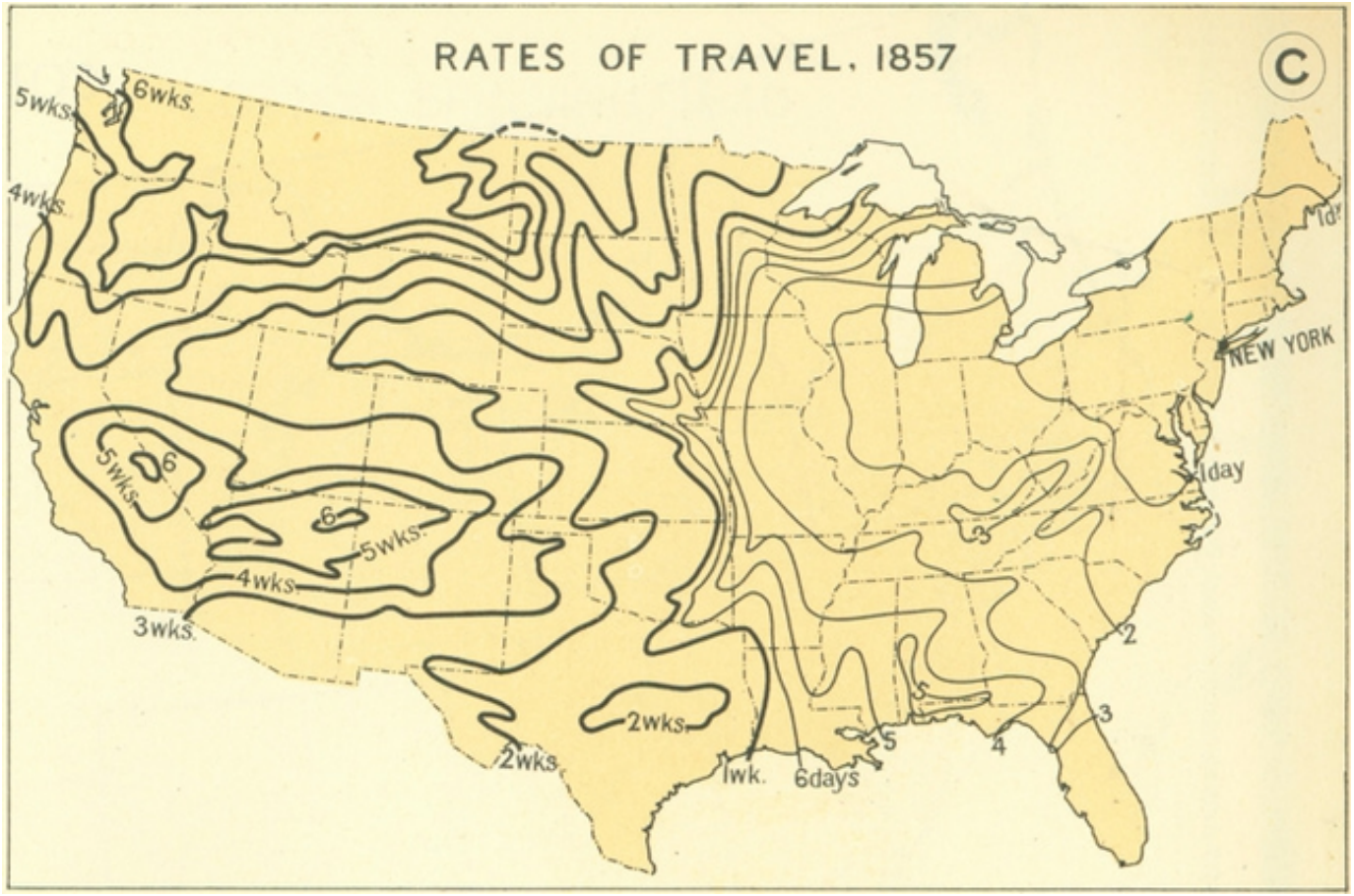
http://enb105-2012s-rw.blogspot.com/2012/02/lab-two-mapping-excercise.html

Common Routes Based on Ship Log Data



http://bit.ly/1i3PSQh

Atlas of the Historical Geography of the United States (1932)



http://bit.ly/1qv0Lvo

Possible tools for mapping

- ArcGIS
- QGIS
- Tableau Public
- CartoDB
- Google Fusion Tables
- Google Earth
- GeoCommons

- JavaScript
  - D3
    http://d3js.org/
  - Leaflet
    http://leafletjs.com/
  - Kartograph
    http://kartograph.org/
  - Polymaps
    http://polymaps.org/
  - Google Maps API
    https://developers.google.com/maps/documentation/javascript/

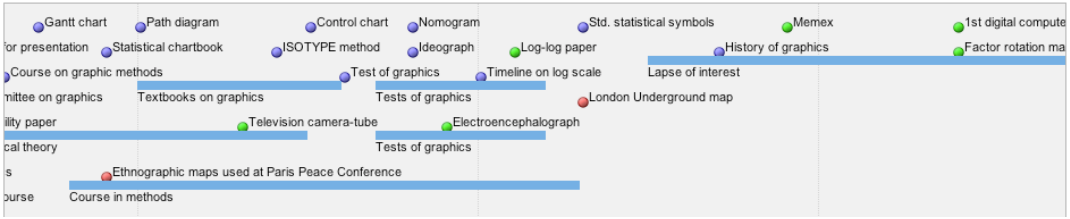
- Very basic:
  - Google Spreadsheets
  - BatchGeo
    http://batchgeo.com/
  - OpenHeatMap
    http://www.openheatmap.com/

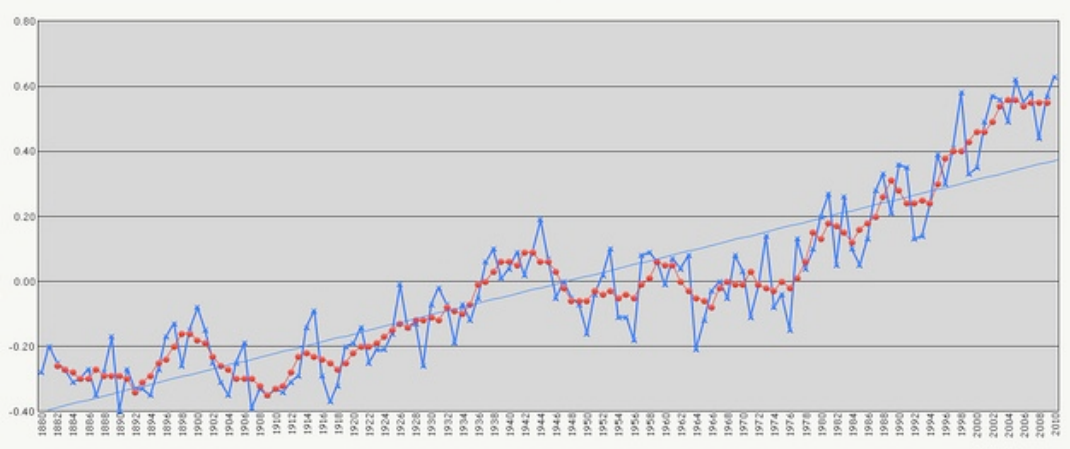
See also:
http://library.duke.edu/data/gis
https://github.com/veltman/learninglunches/tree/master/maps

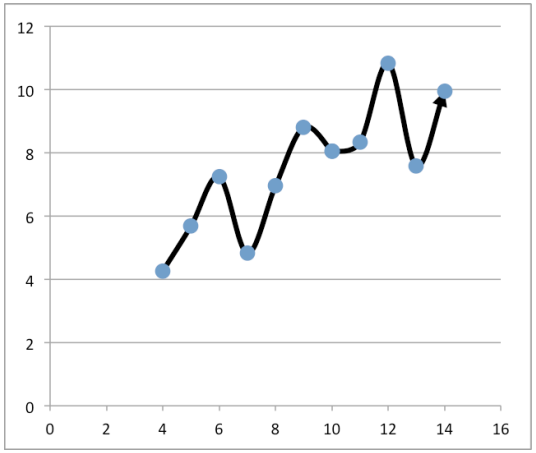
For congress data in Tableau

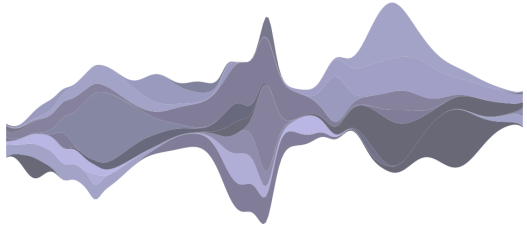
- http://www.tableau.com/public/blog/2012/10/congressional-districts-1696
- http://onlinehelp.tableau.com/current/pro/online/en-us/help.htm#maps_geographicroles.html

Showing Time

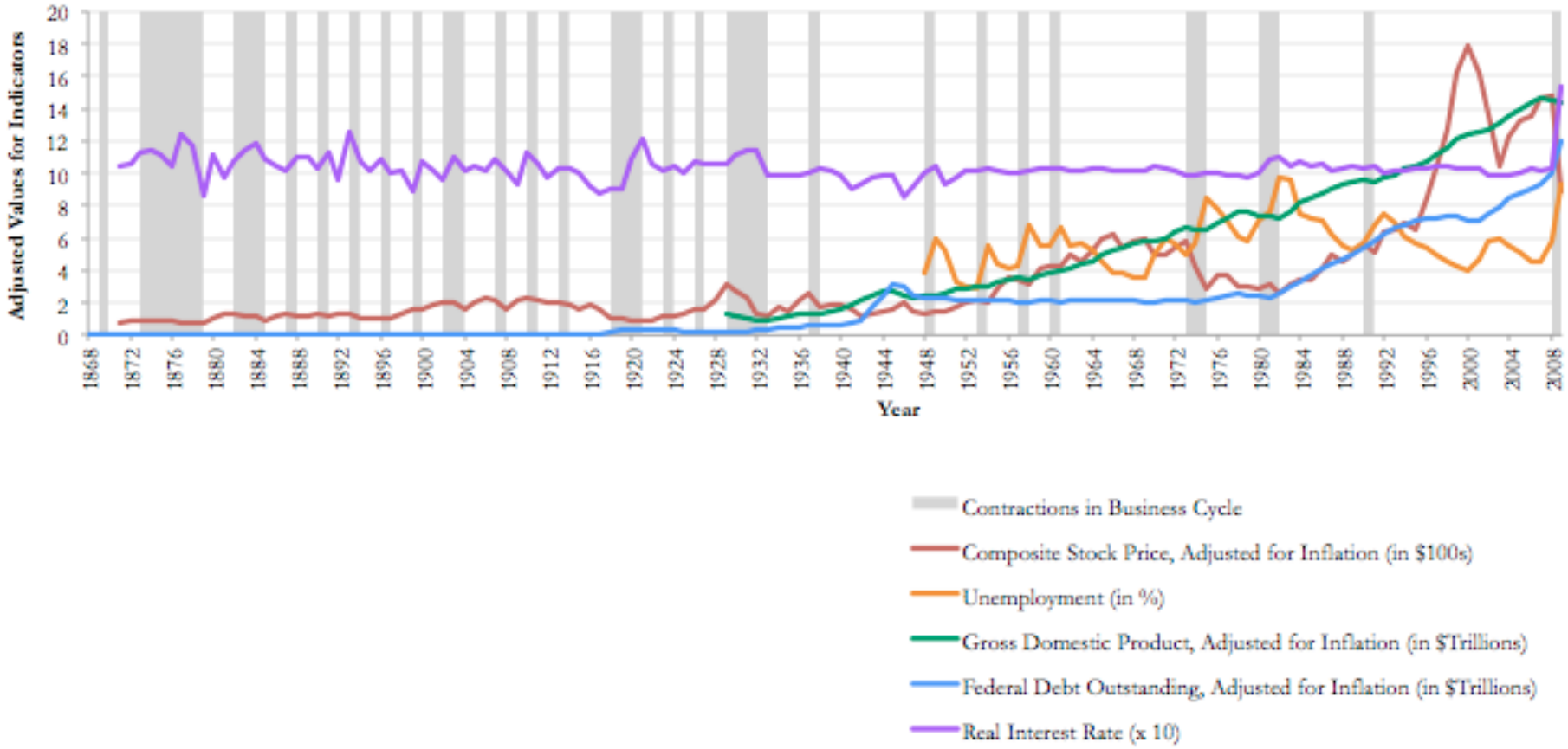






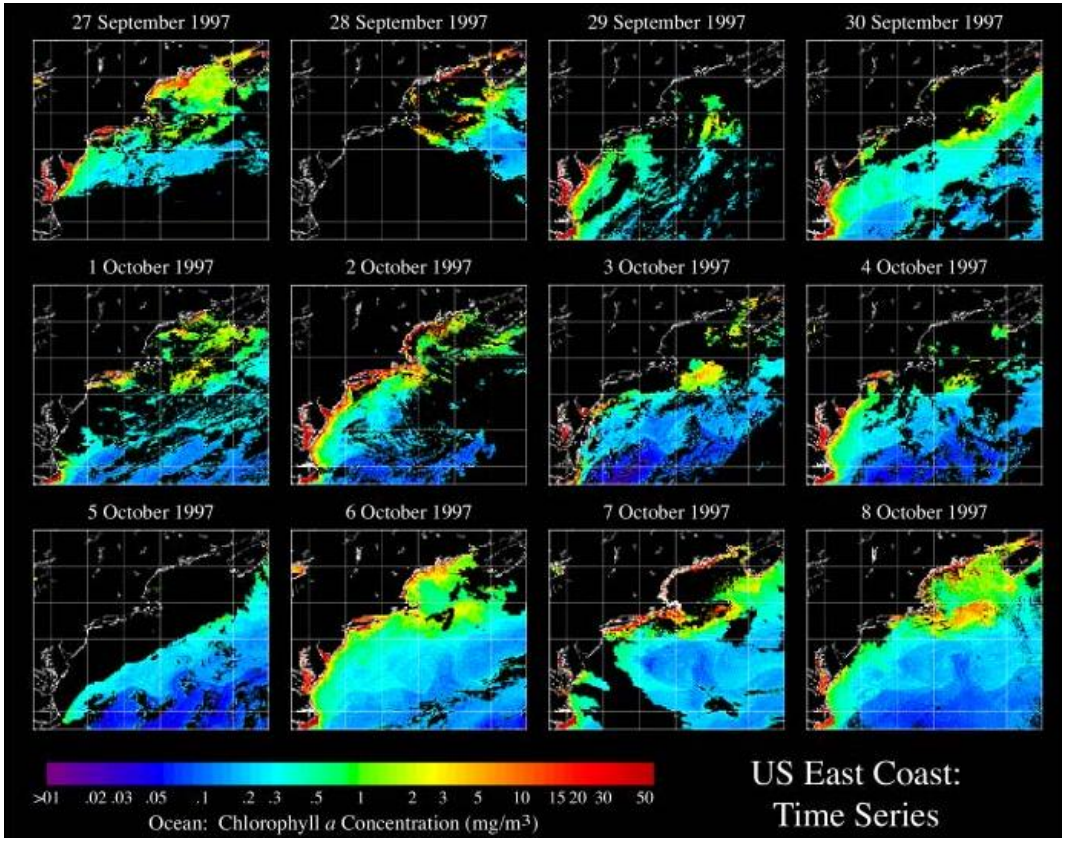


Economic indicators over time



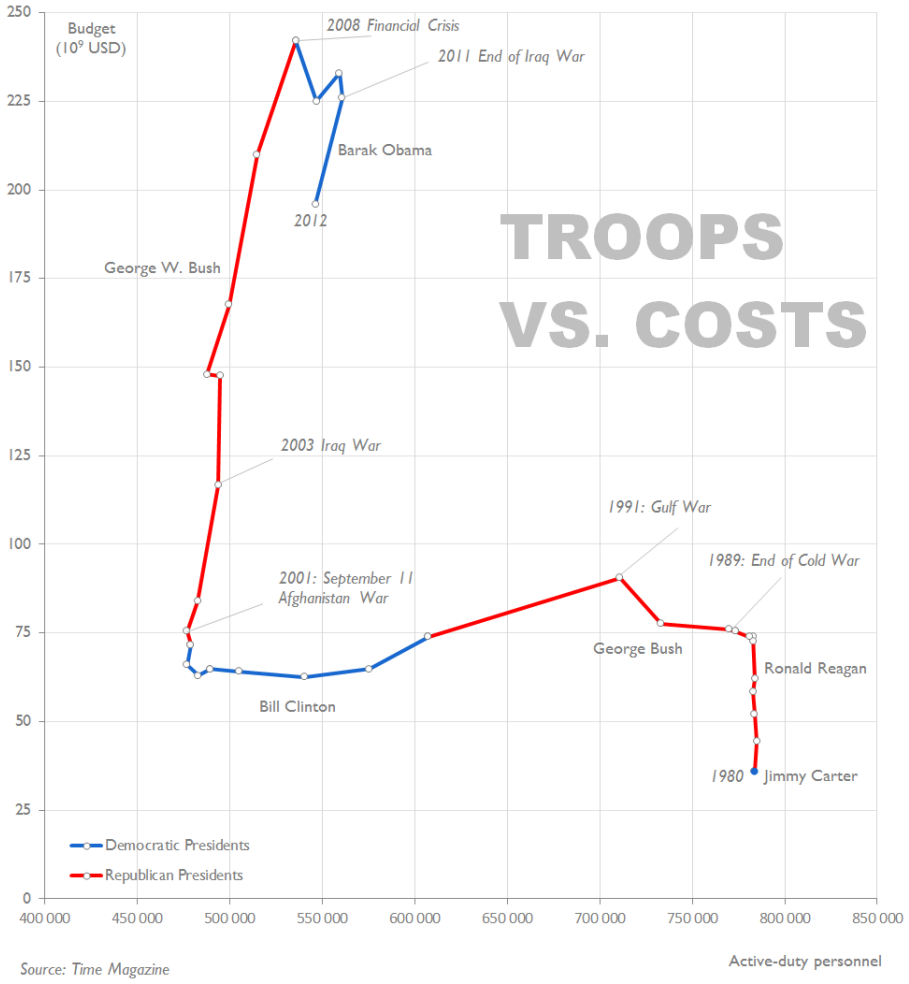
http://blogs.library.duke.edu/data/2012/11/12/adding-colored-regions-to-excel-charts/

Time series of 2D data set



http://seawifs.gsfc.nasa.gov/SEAWIFS/BACKGROUND/Gallery/time_series.jpg

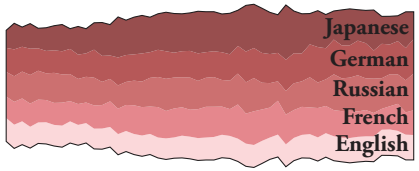
Connected Scatterplot



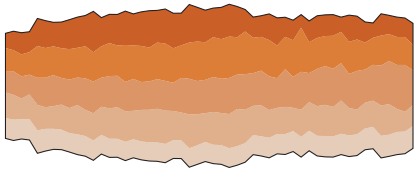
http://bit.ly/1AADeyq

Stream graphs

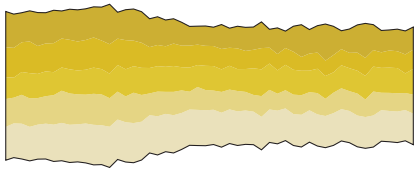
diseases of the circulatory system



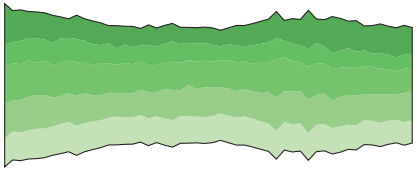
diseases of the digestive system



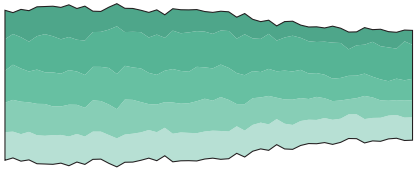
endocrine, nutritional and metabolic diseases



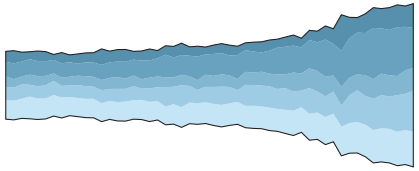
infectious and parasitic diseases



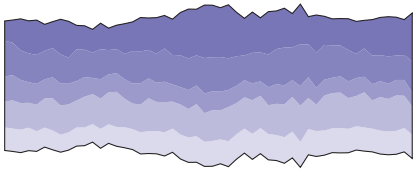
injury, poisoning and other external causes



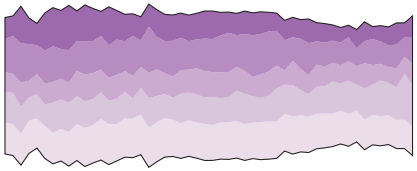
mental and behavioral disorders



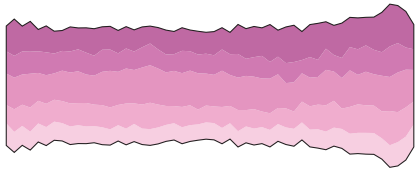
cancer (neoplasms)



pregnancy and childbirth

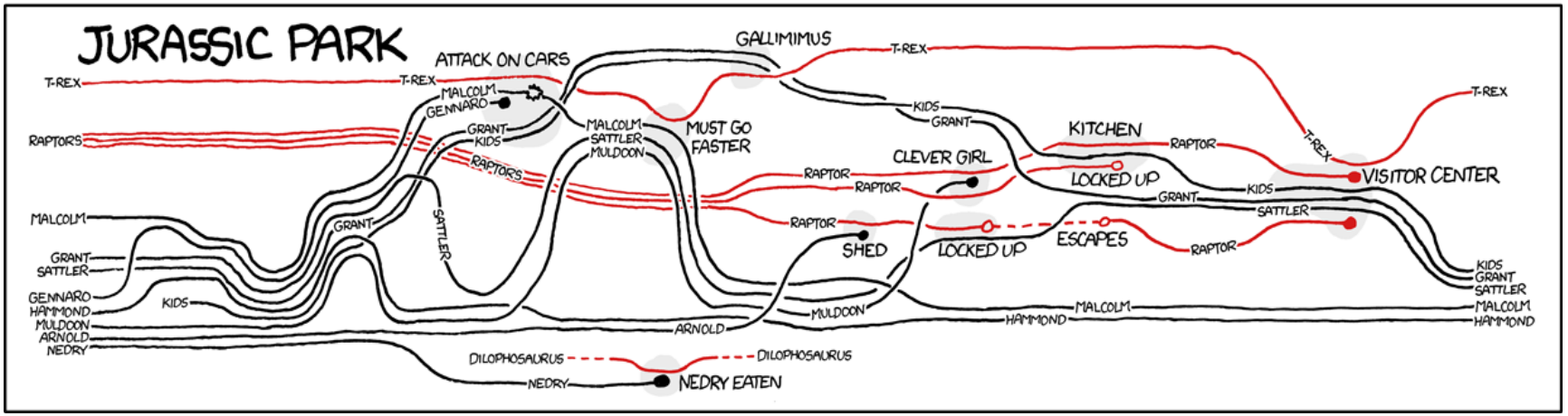


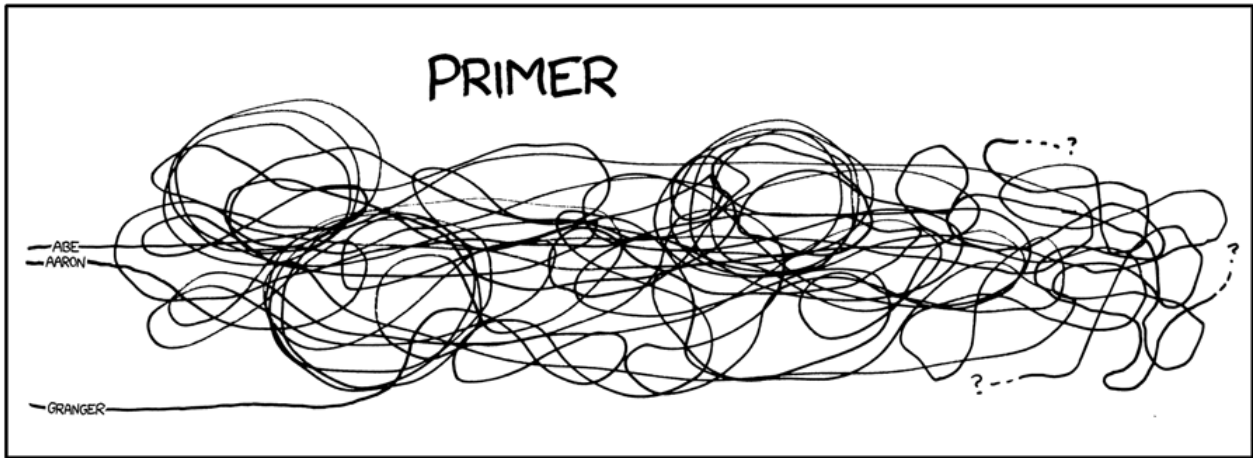
diseases of the respiratory system



http://bit.ly/pubmedvis

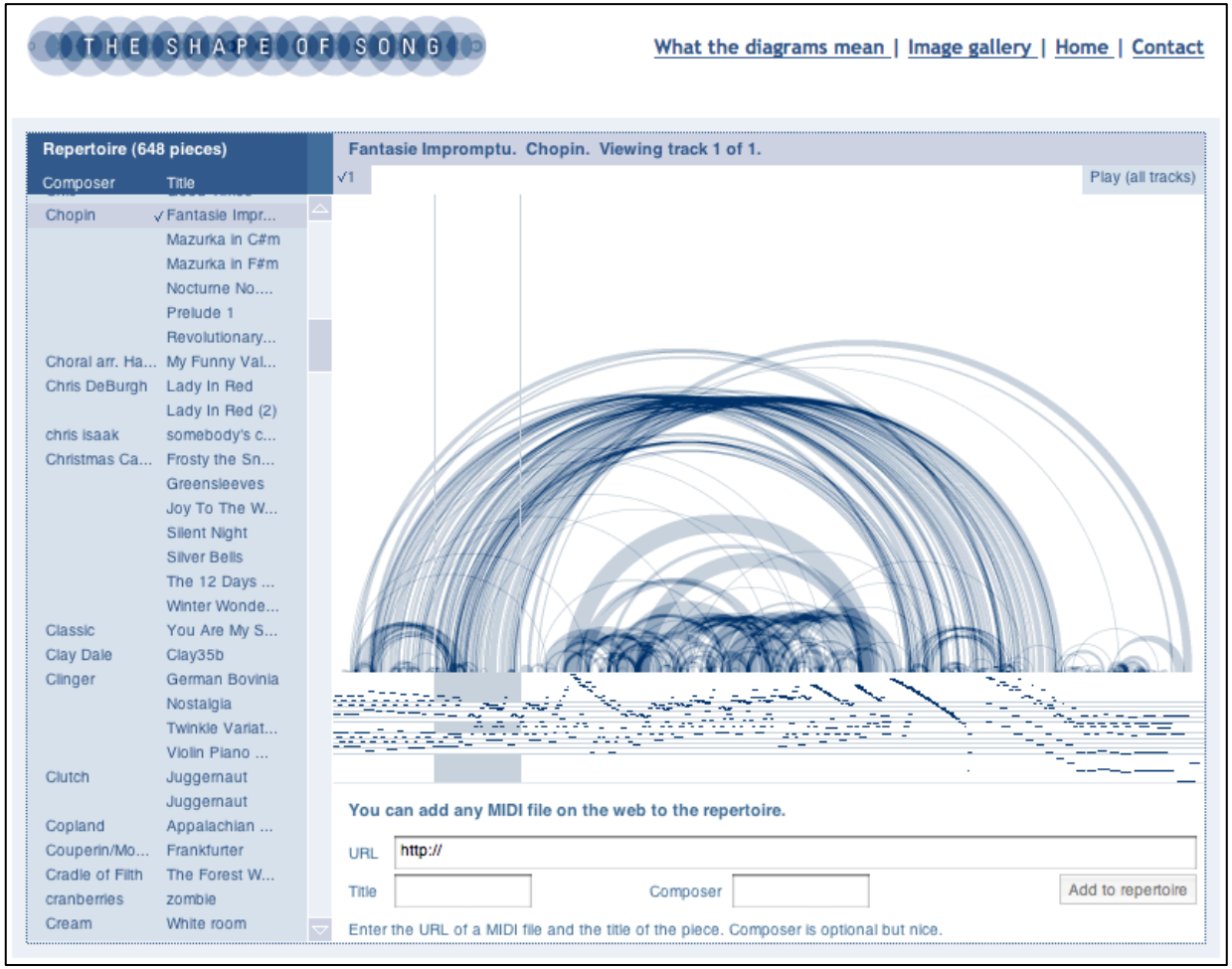
Storylines





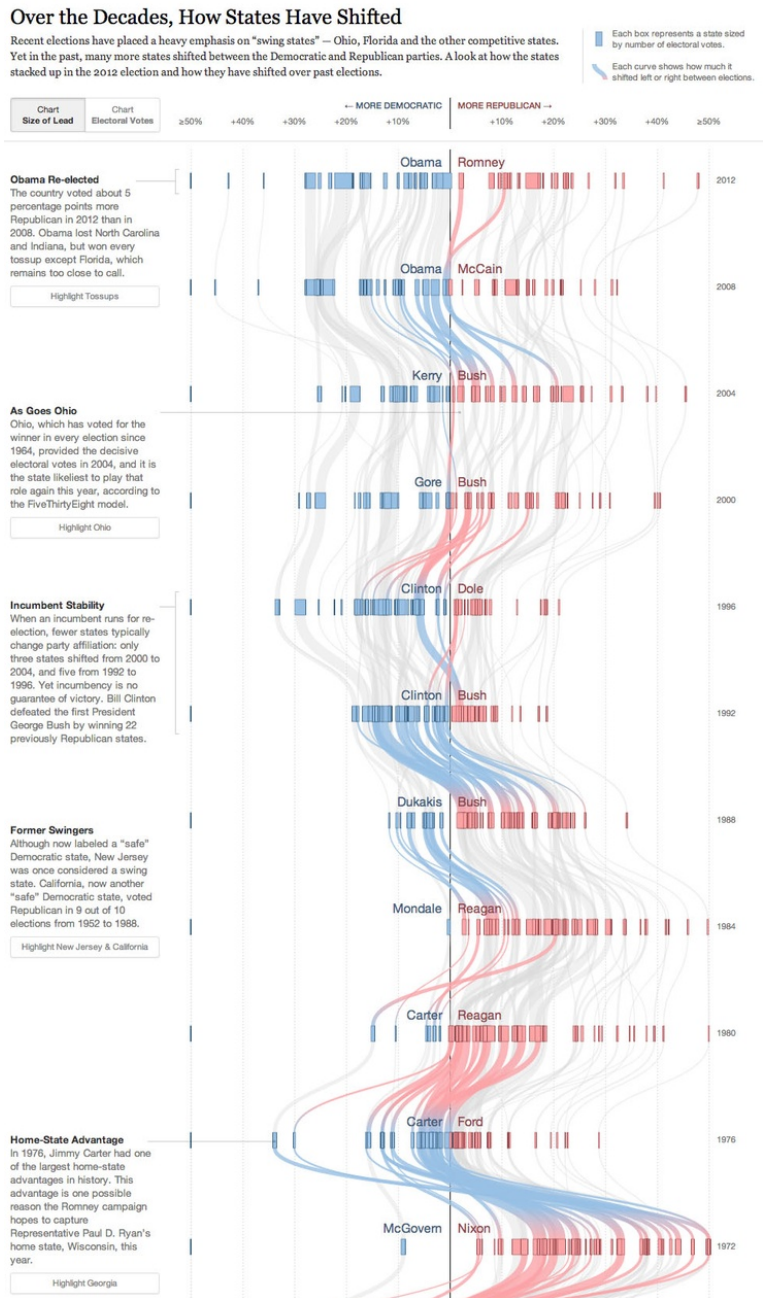
http://xkcd.com/657/

Shape of Song



http://www.turbulence.org/Works/song/mono.html

Over the Decades, How States Have Shifted

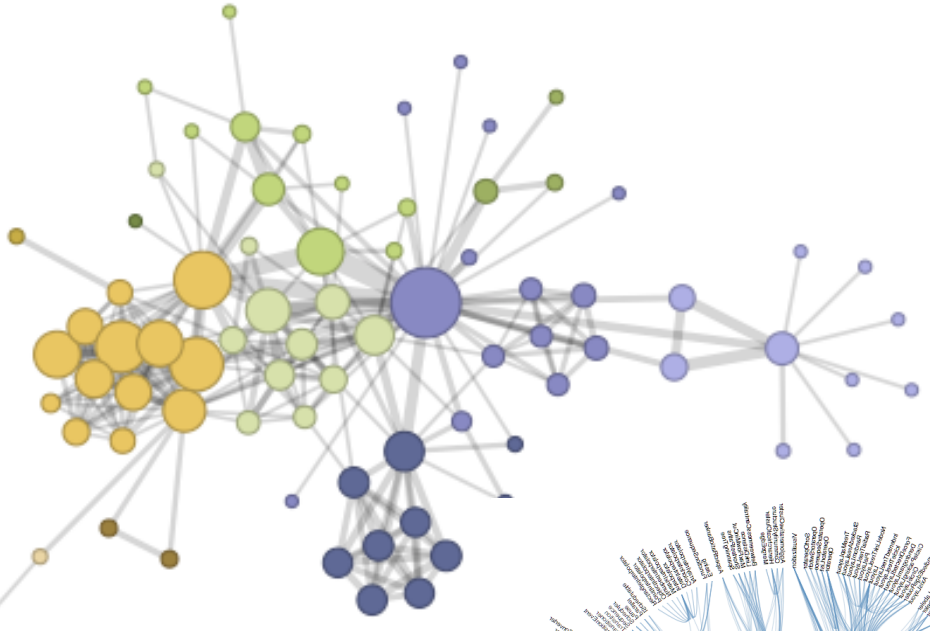


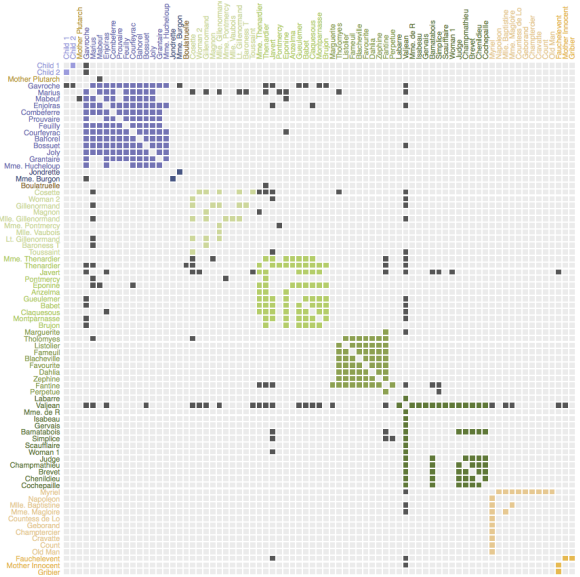
http://nyti.ms/Wr1dhZ

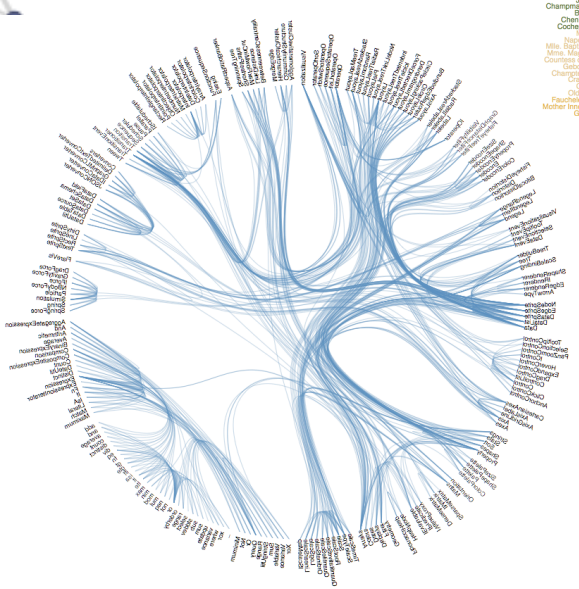
Possible tools for temporal vis.

- Basic charting tools
- Raw
  http://raw.densitydesign.org/
- TimelineJS
  http://timeline.knightlab.com/
- Simile Timeline
  http://simile.mit.edu/
- D3

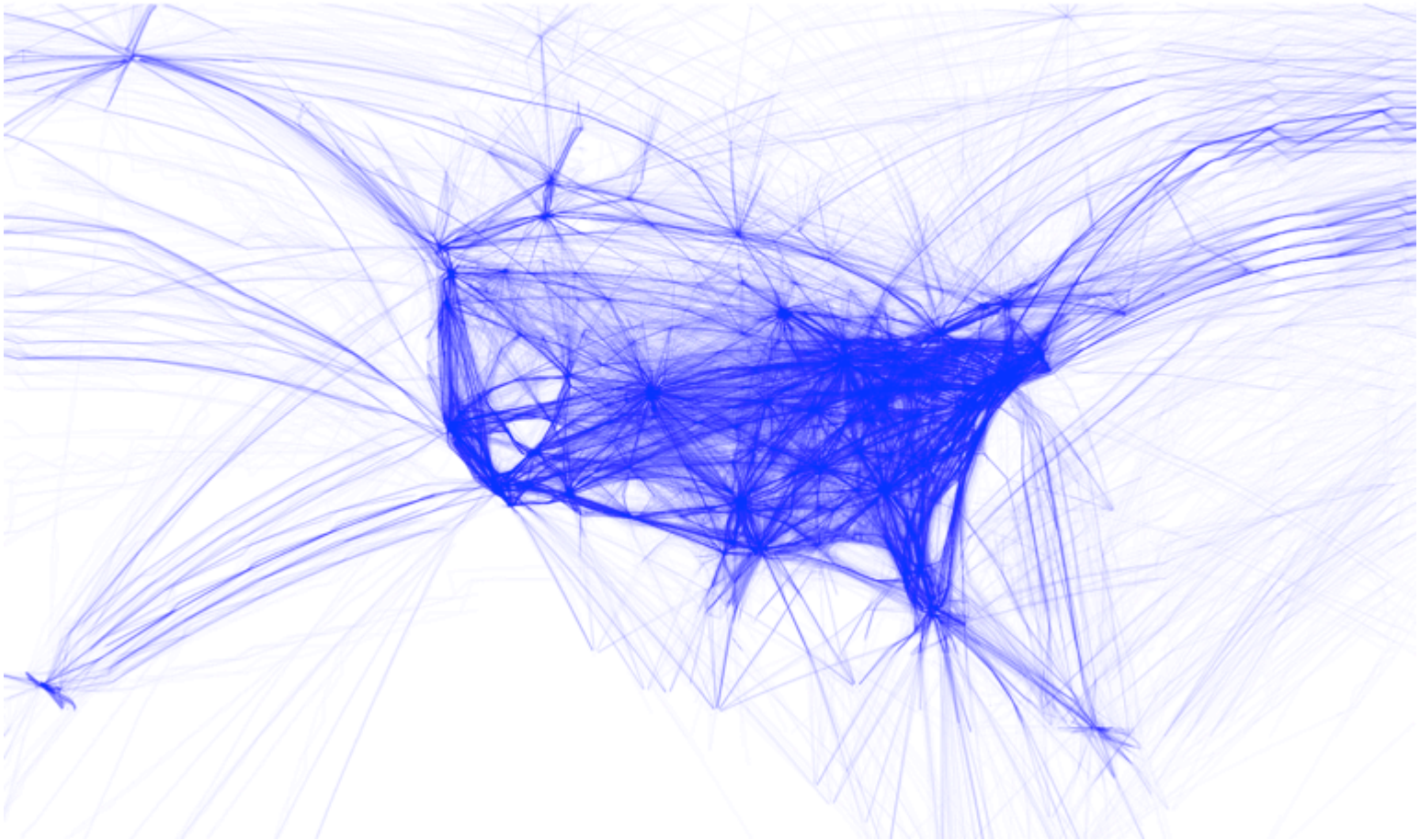
Showing Relationships





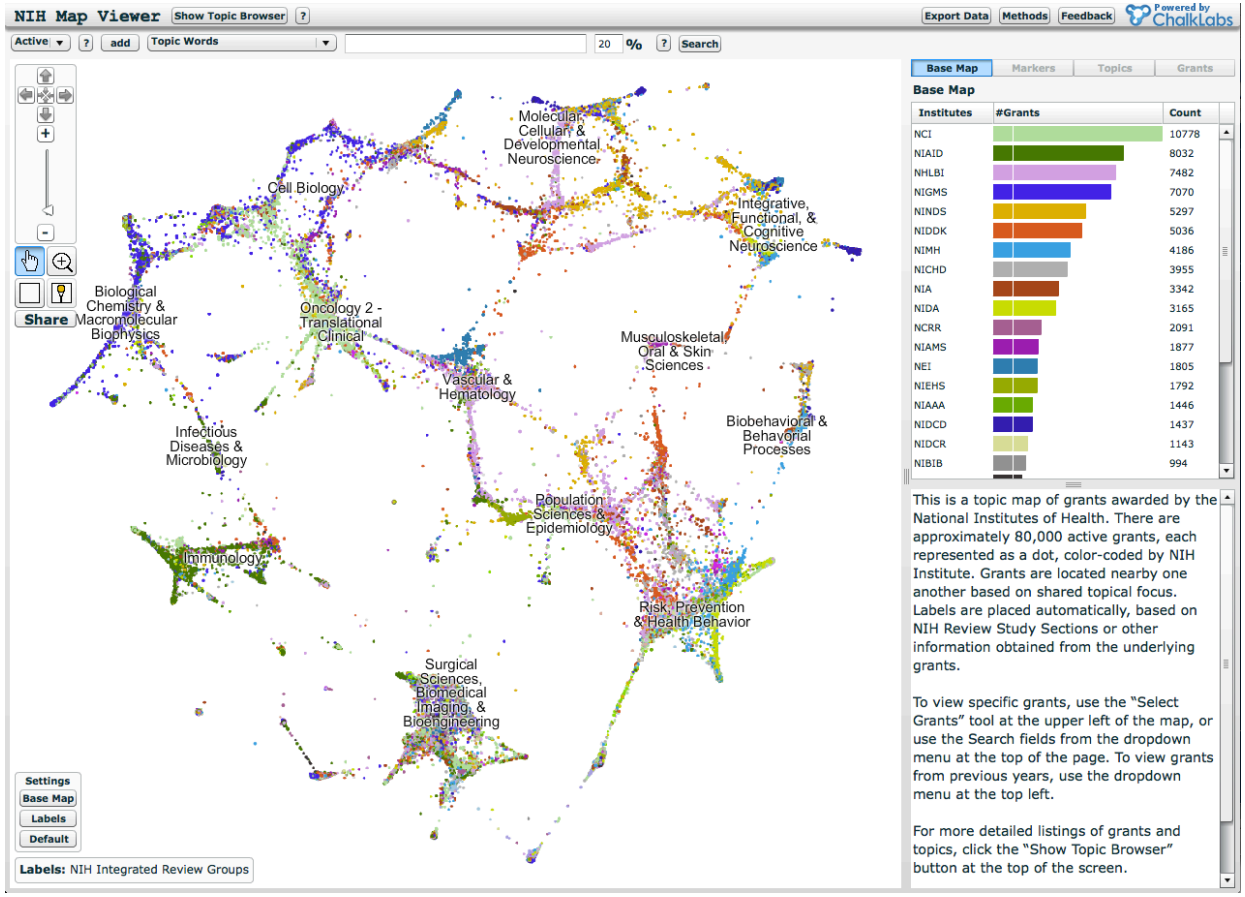


Edges



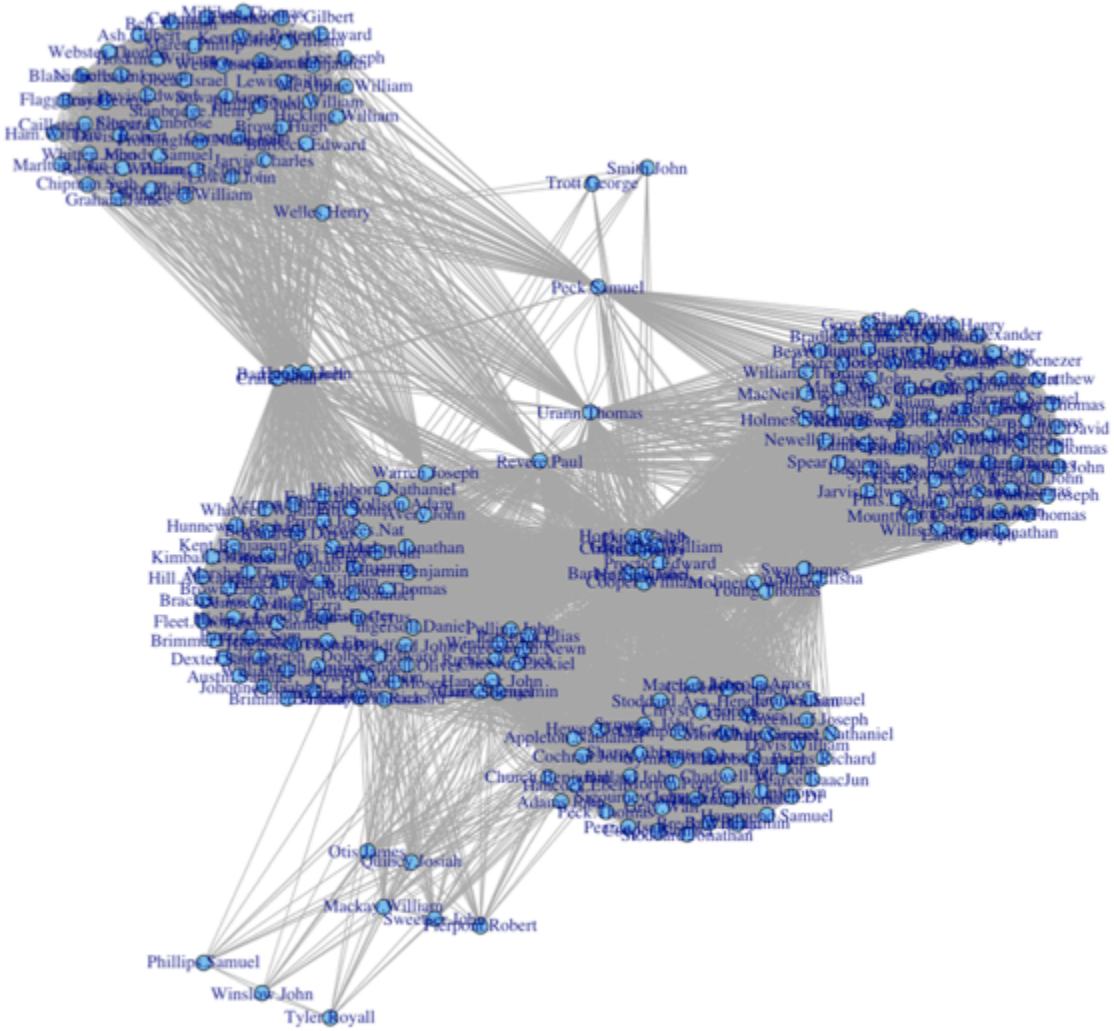
http://www.aaronkoblin.com/work/flightpatterns/

Nodes



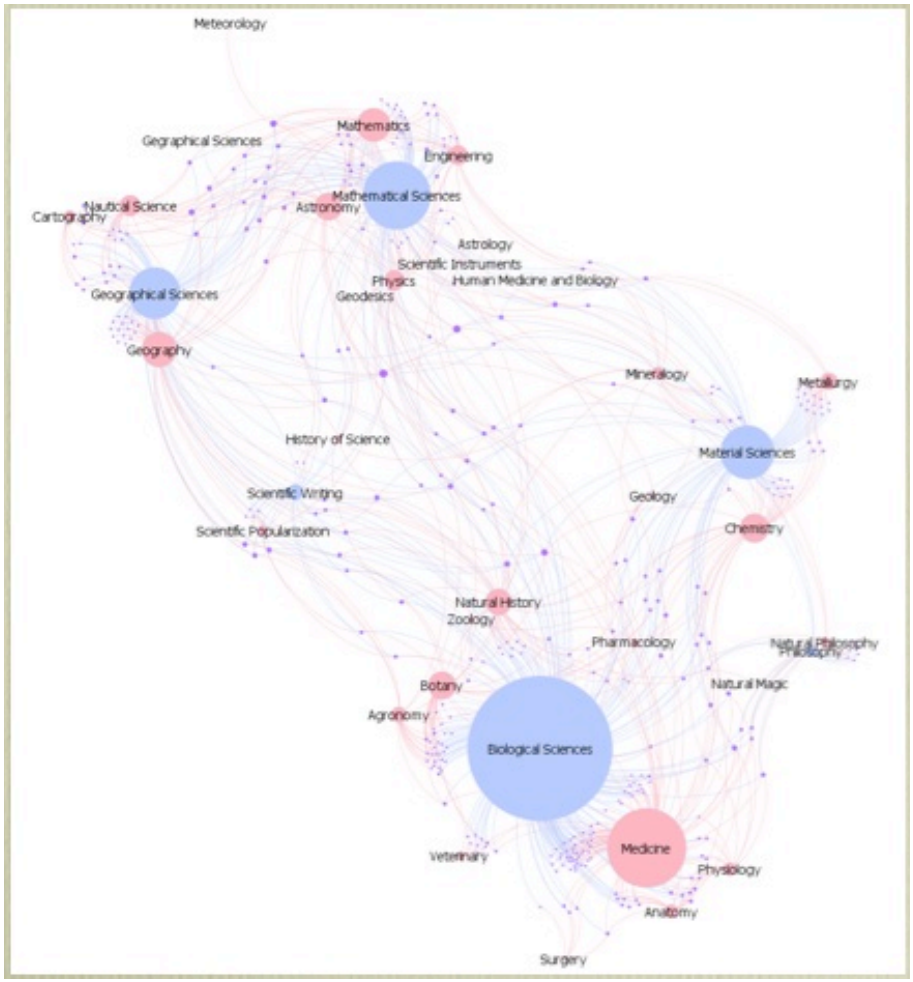
http://nihmaps.org/vids.php

Both



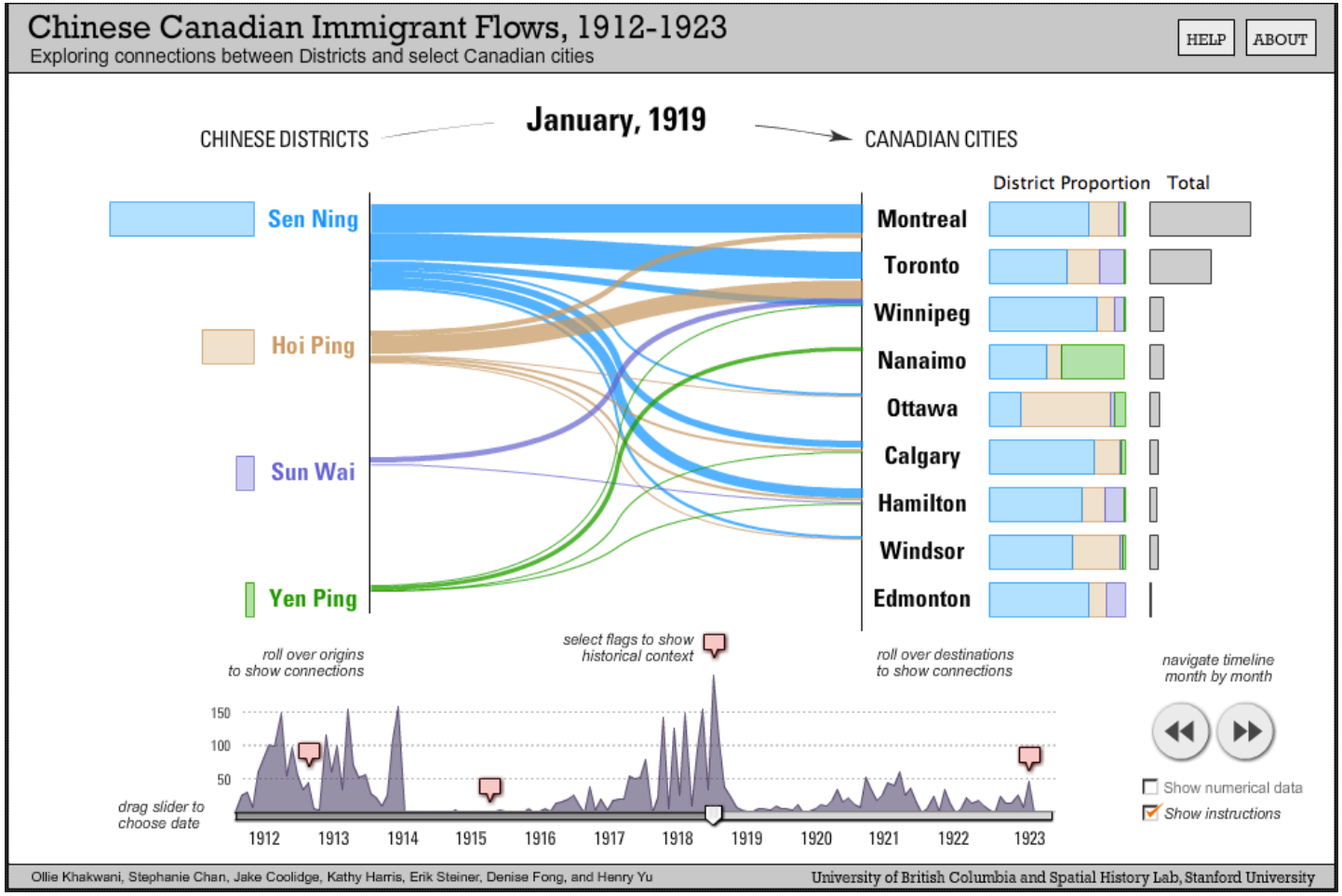
http://kieranhealy.org/blog/archives/2013/06/09/using-metadata-to-find-paul-revere/

With color and size coding



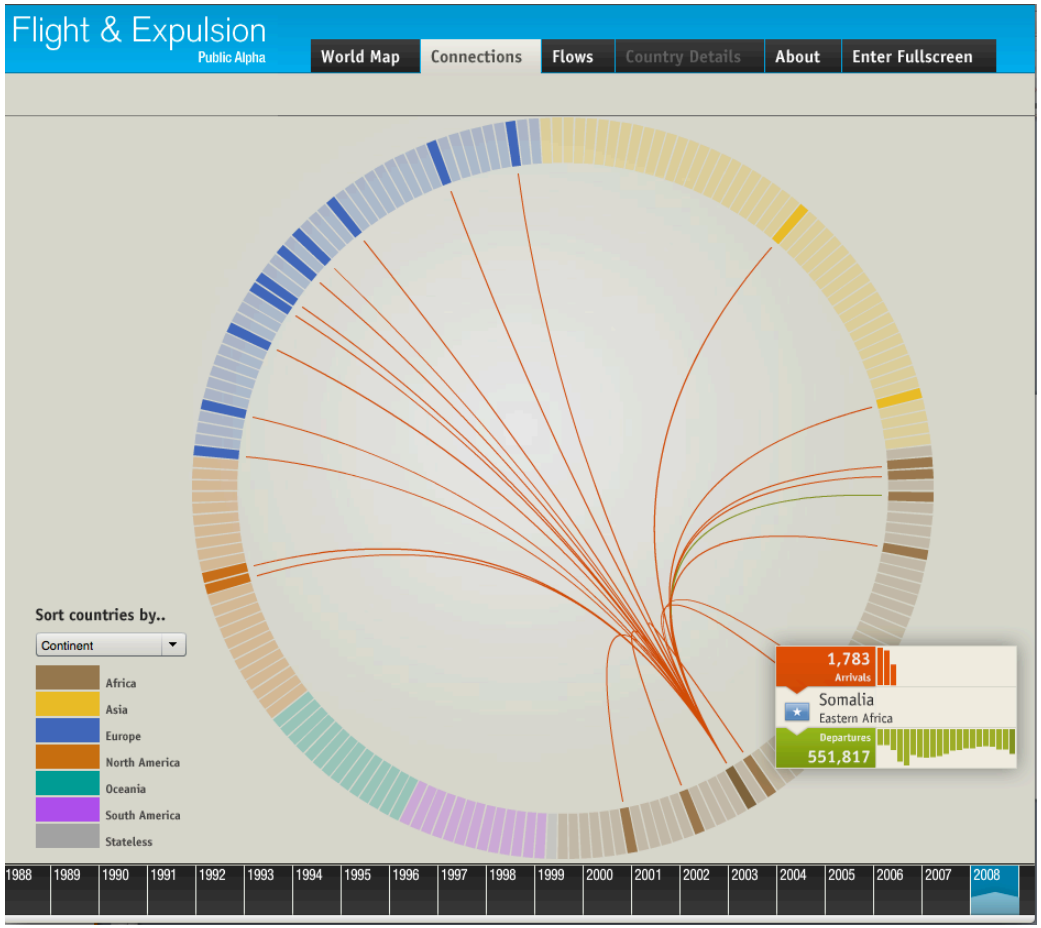
http://republicofletters.stanford.edu/casestudies/spanishempire.html

Bipartite graph, alluvial diagram



http://stanford.io/1hCYwkd

Circular layout/chord diagram



http://www.niceone.org/lab/refugees/

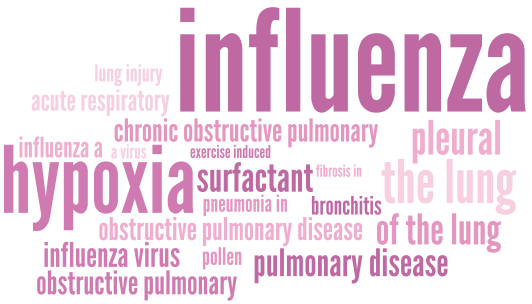
Tube Map

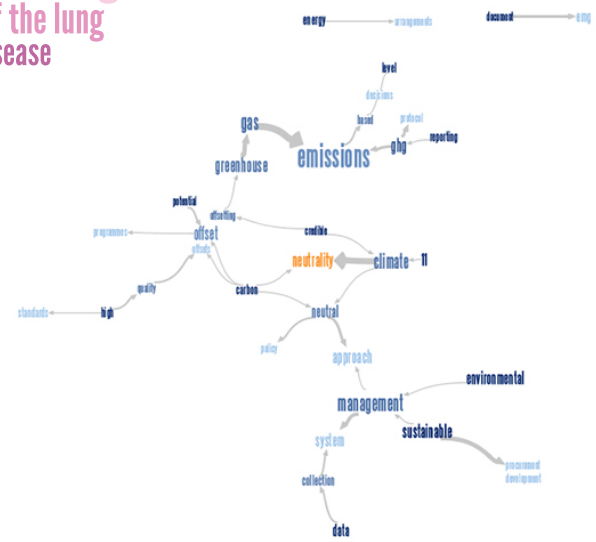
http://diagrams.org/images/png/large/f00022.html

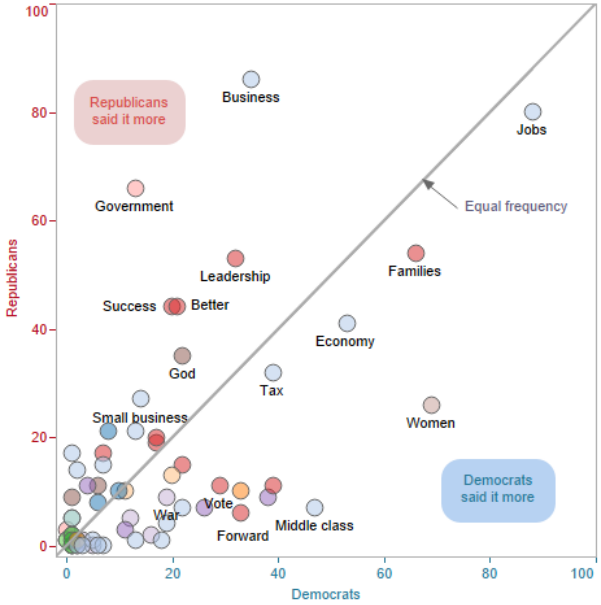
Possible tools for network vis.

- D3
- Gephi
  http://gephi.org/
- NodeXL
  http://nodexl.codeplex.com/
- Pajek
  http://vlado.fmf.uni-lj.si/pub/networks/pajek/
- Cytoscape
- Network Workbench/Sci²
  http://nwb.cns.iu.edu/,
  https://sci2.cns.iu.edu/
- VOSviewer
  http://www.vosviewer.com/
- UCINET
  https://sites.google.com/site/ucinetsoftware/home
- GUESS
  http://graphexploration.cond.org/
- R
- SigmaJS
  http://sigmajs.org/
- Circos
  http://circos.ca/

Showing Text







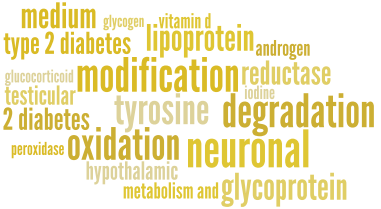
http://guides.library.duke.edu/text_vis

Word cloud

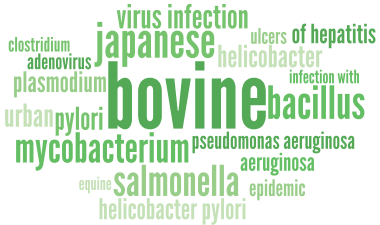
diseases of the circulatory system

diseases of the digestive system

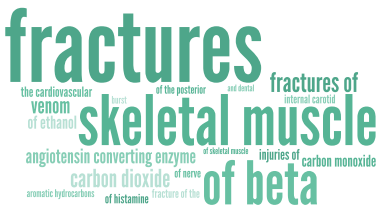
endocrine, nutritional and metabolic diseases



infectious and parasitic diseases

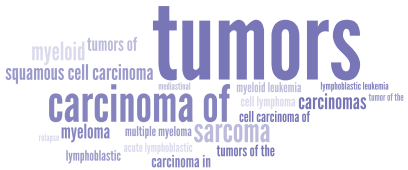


injury, poisoning and other external causes



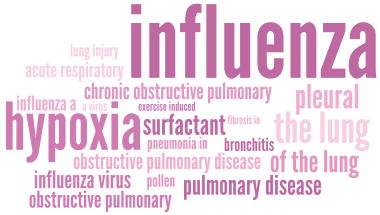
mental and behavioral disorders

cancer (neoplasms)

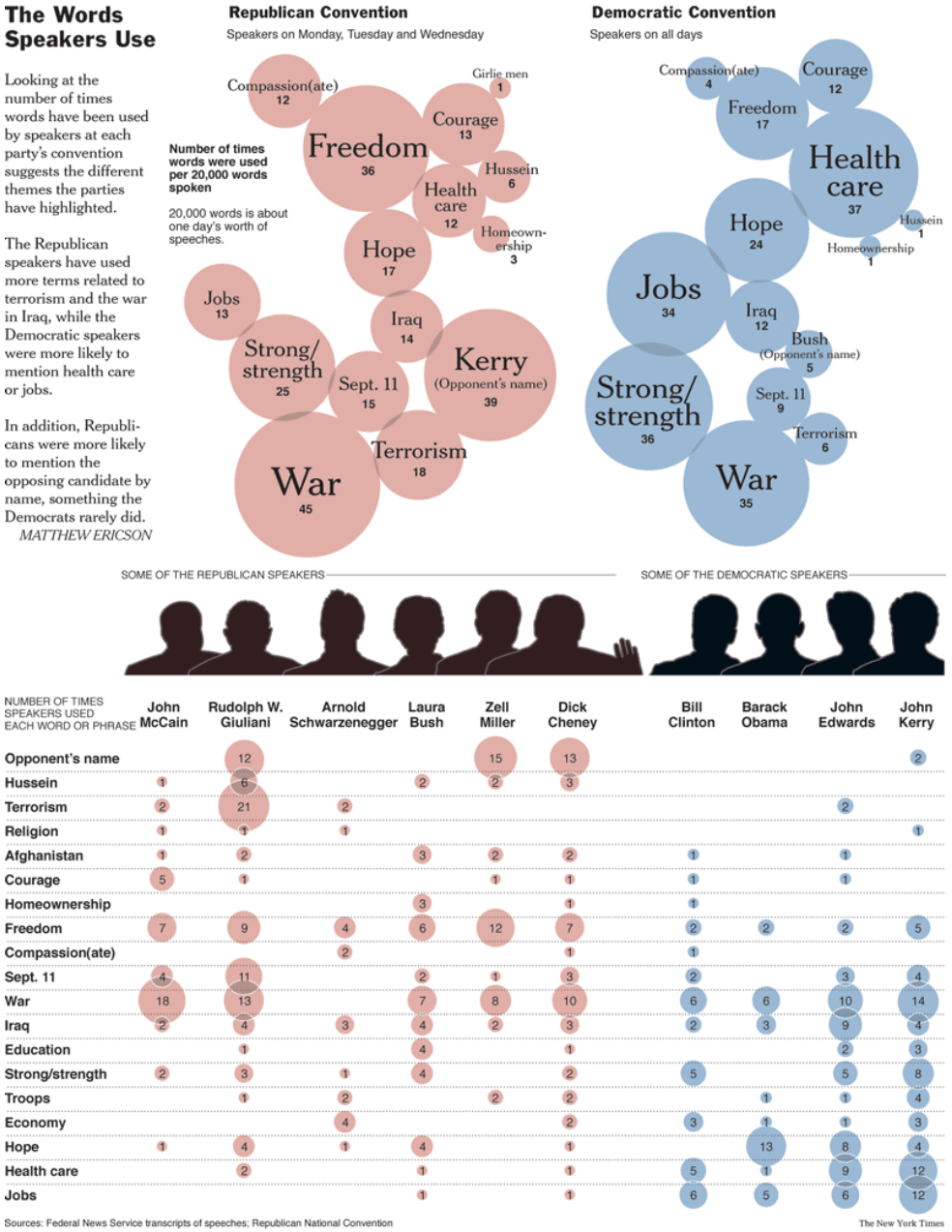


pregnancy and childbirth

diseases of the respiratory system

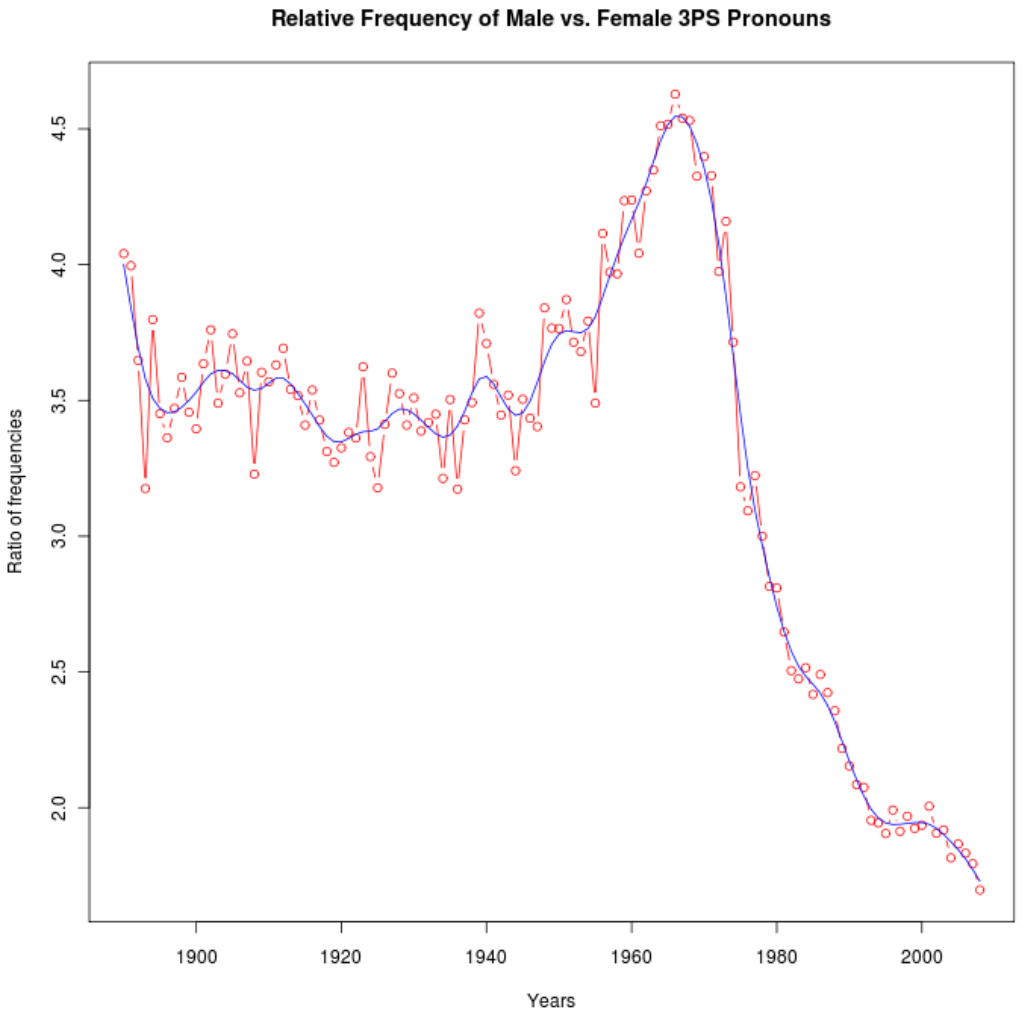


Bubble Plot



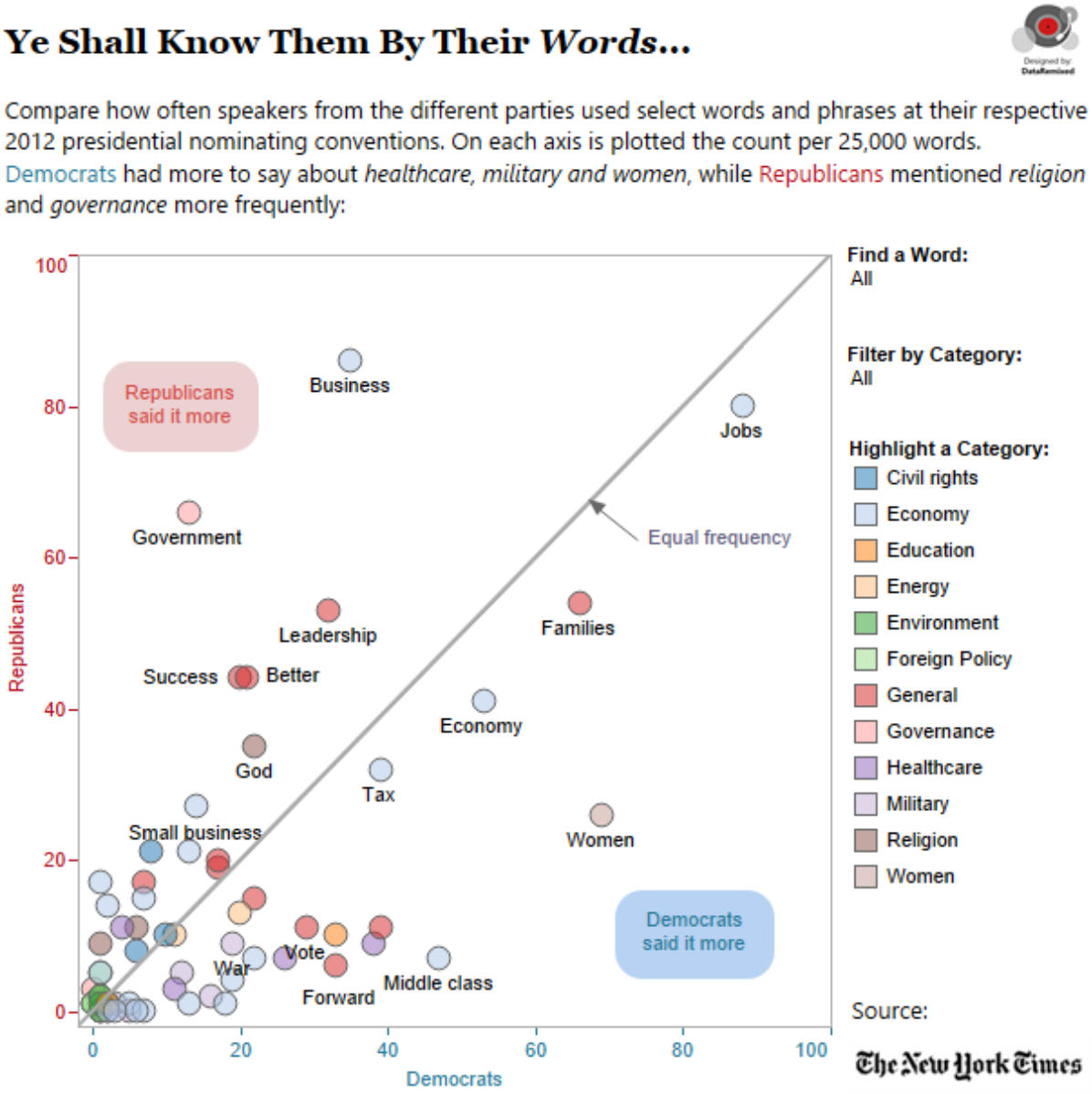
http://www.nytimes.com/interactive/2008/09/04/us/politics/20080905_WORDS_GRAPHIC.html

Frequencies over time



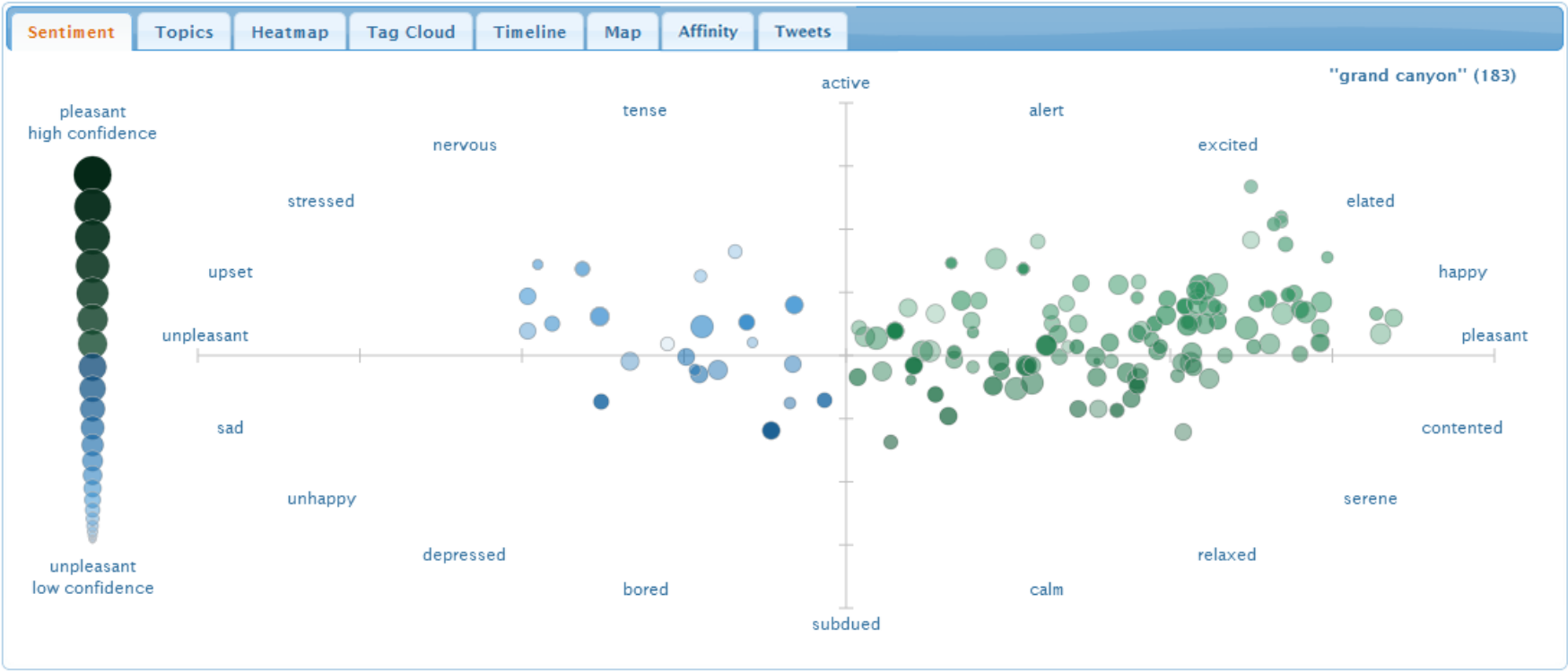
http://languagelog.ldc.upenn.edu/nll/?p=4126

Scatter Plot



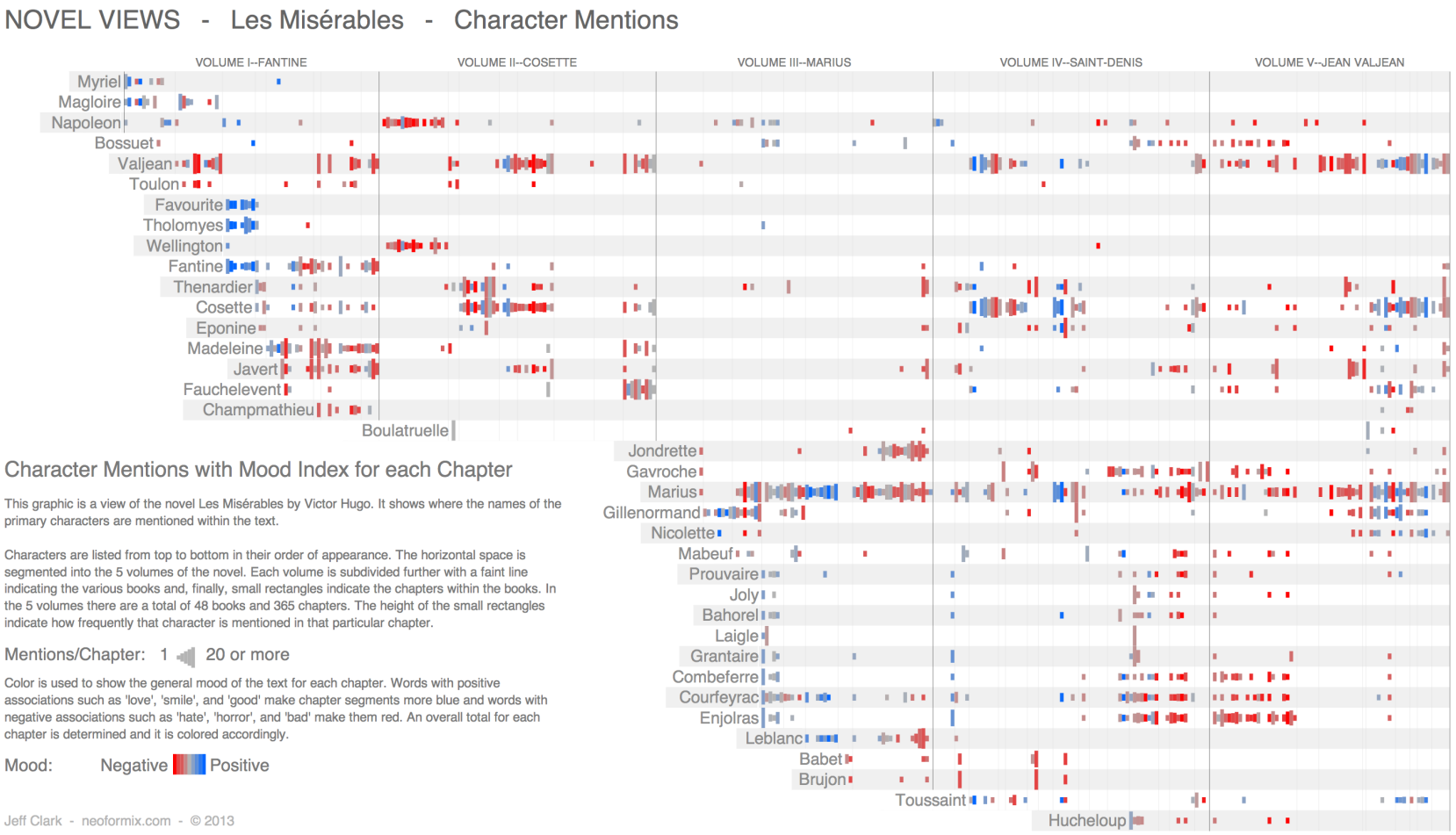
http://tabsoft.co/1ByN2br

Sentiment analysis



http://www.csc.ncsu.edu/faculty/healey/tweet_viz/

Sentiment analysis



http://neoformix.com/2013/NovelViews.html

Word Tree

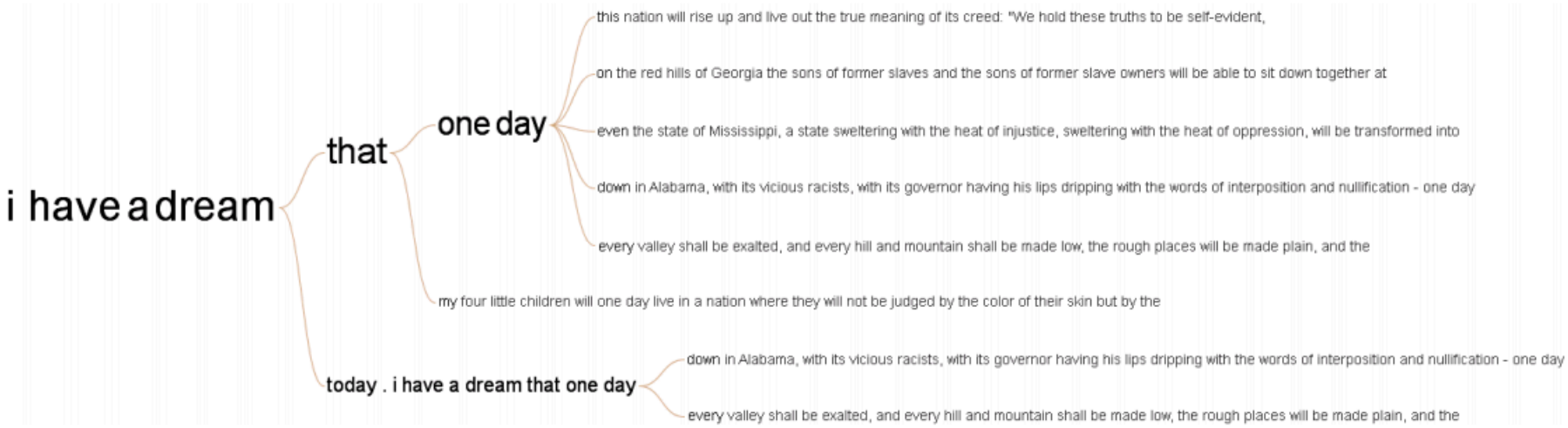
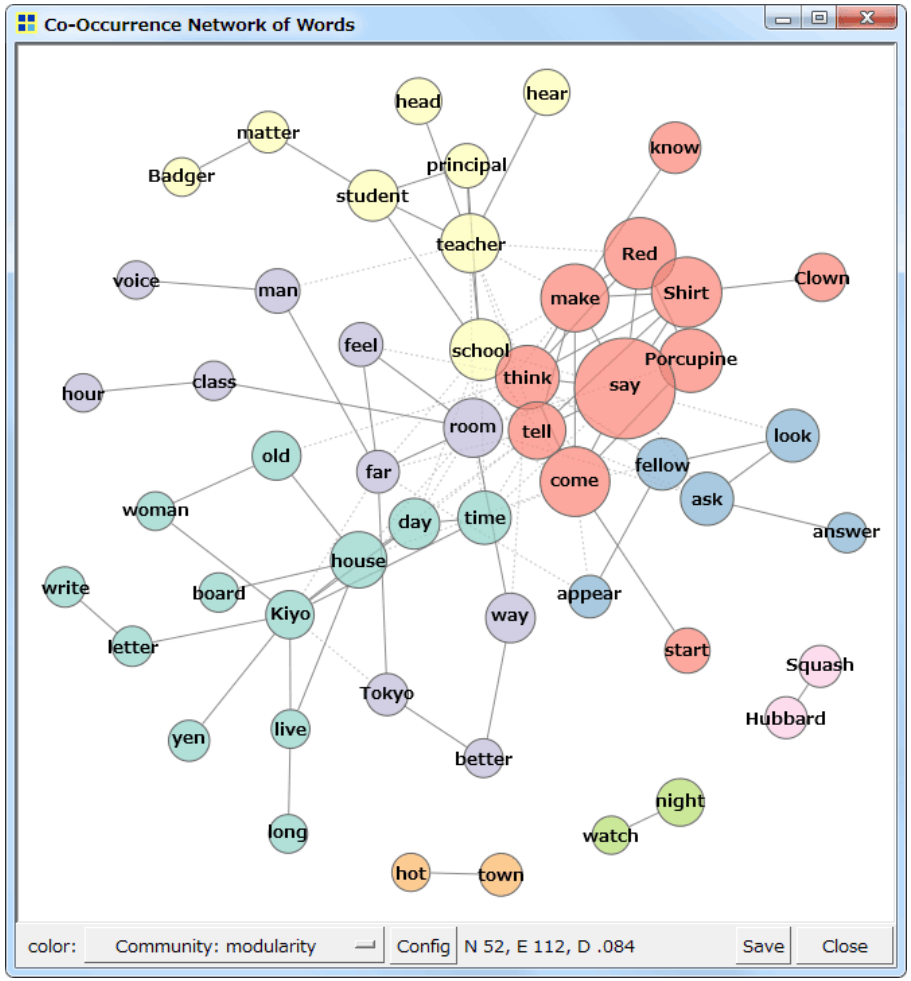


Fig 10: Word Tree showing all occurrences of “I have a dream” in Martin Luther King’s historical speech.

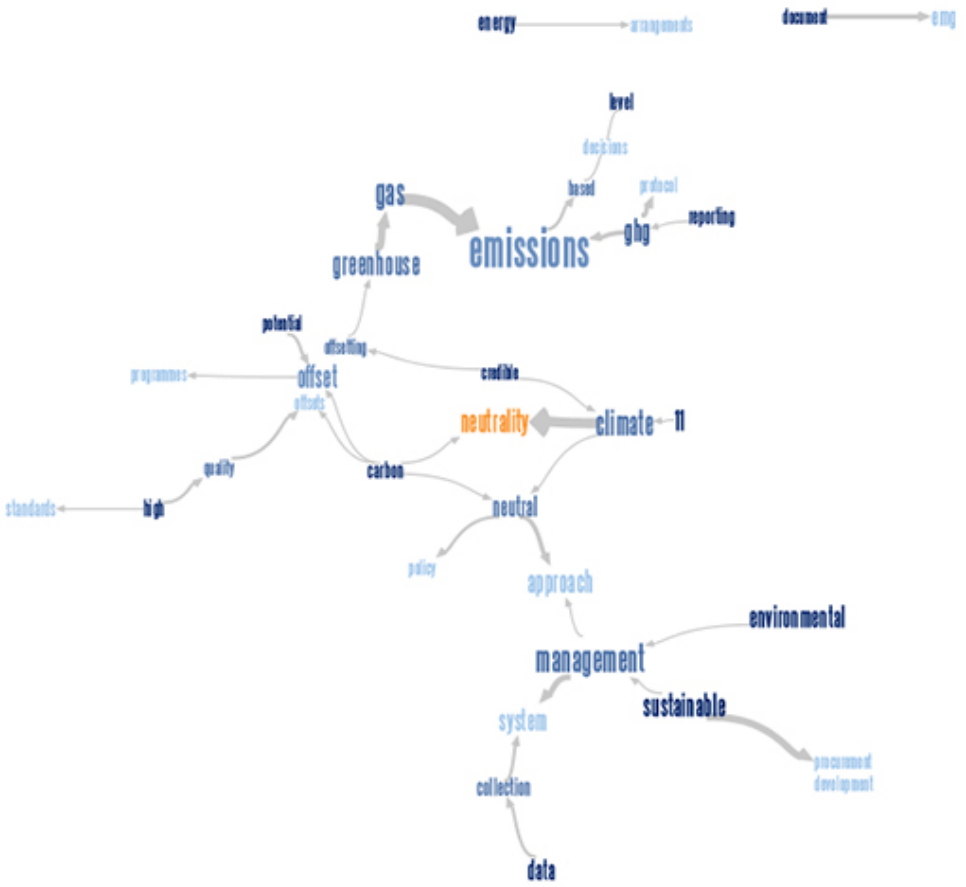
http://hint.fm/projects/wordtree/

Word co-occurrence network



http://en.wikipedia.org/wiki/Co-occurrence_networks

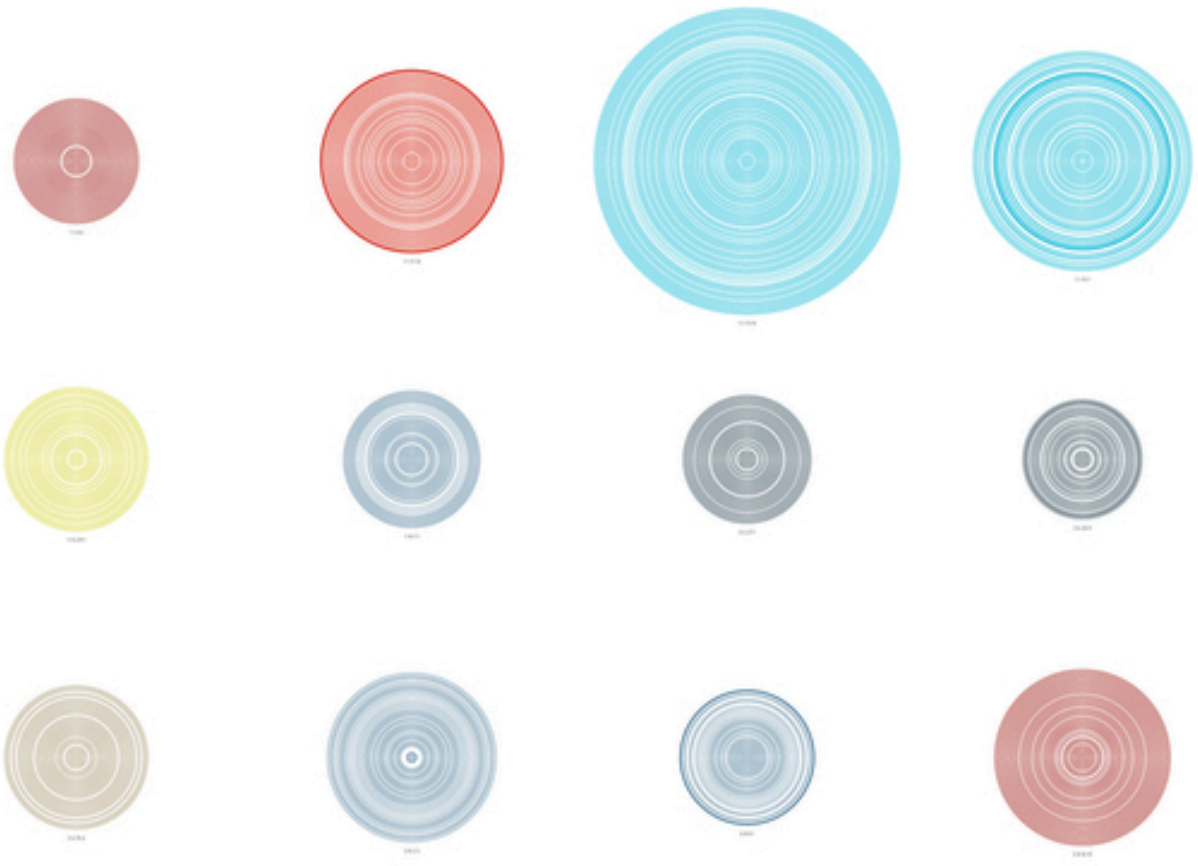
Phrasenet



http://www-01.ibm.com/software/analytics/many-eyes/

Rhythm Textures

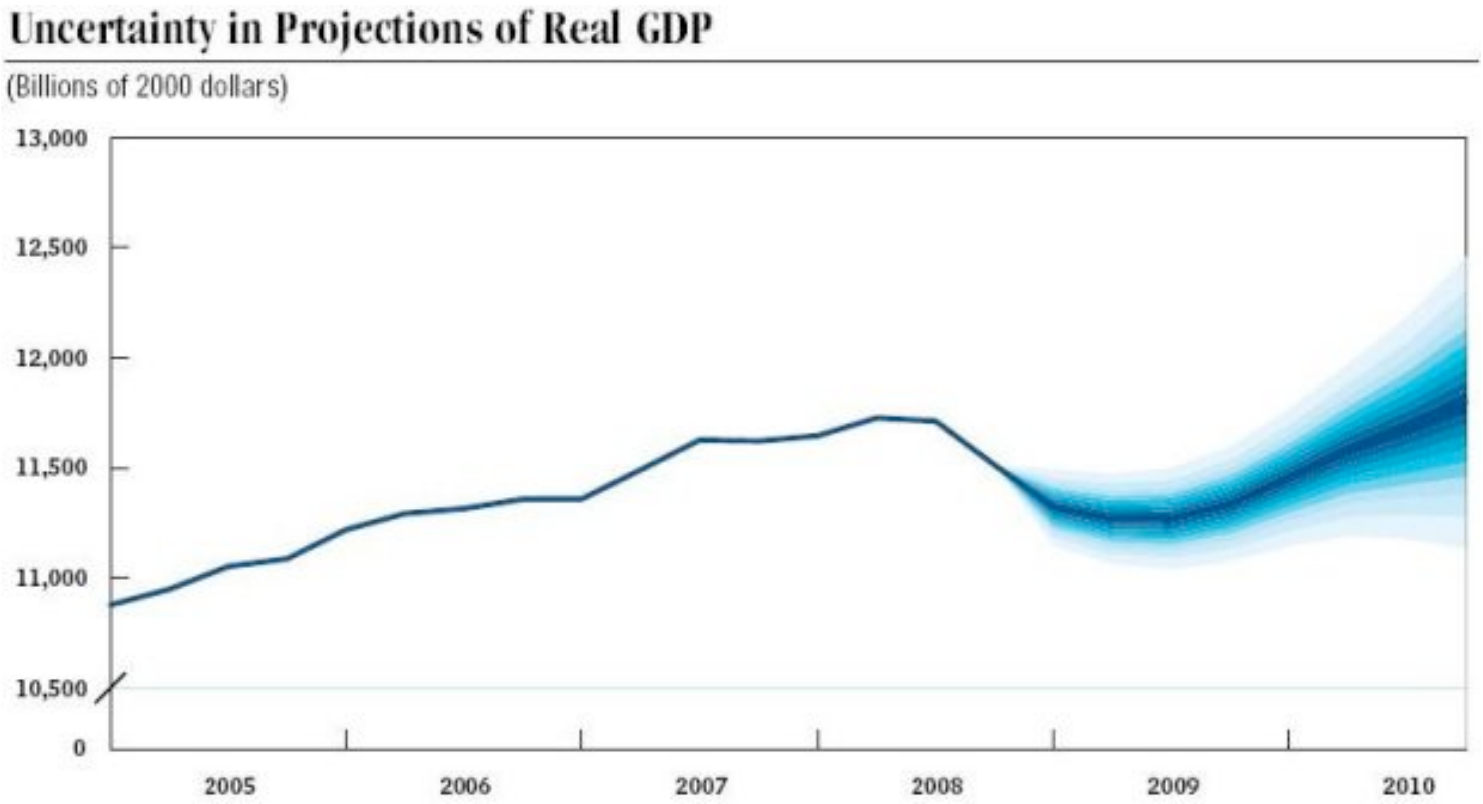
Exploring ways of visually representing sentences by using their punctuation to create circular diagrams. Each word is represented by a line, and the thickness of the lines (and the space between the lines) radiating outwards from the center point provides a record of the pauses and empasis created by the punctuation.



http://itsbeenreal.co.uk/index.php?/wwwords/rhythm-textures/

VISUALIZING UNCERTAINTY

Projections



http://peltiertech.com/WordPress/excel-fan-chart-showing-uncertainty-in-projections/

Missing data

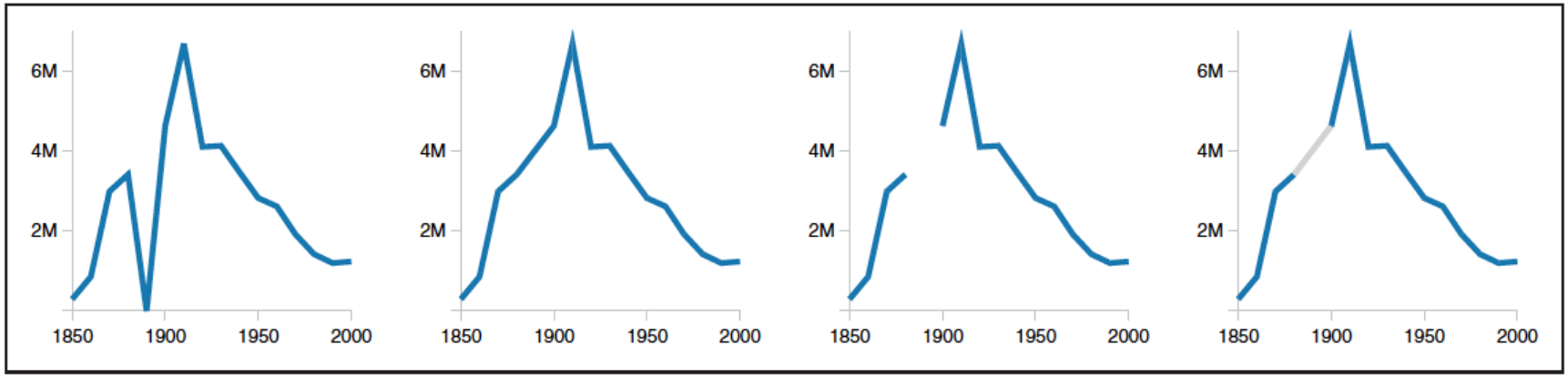
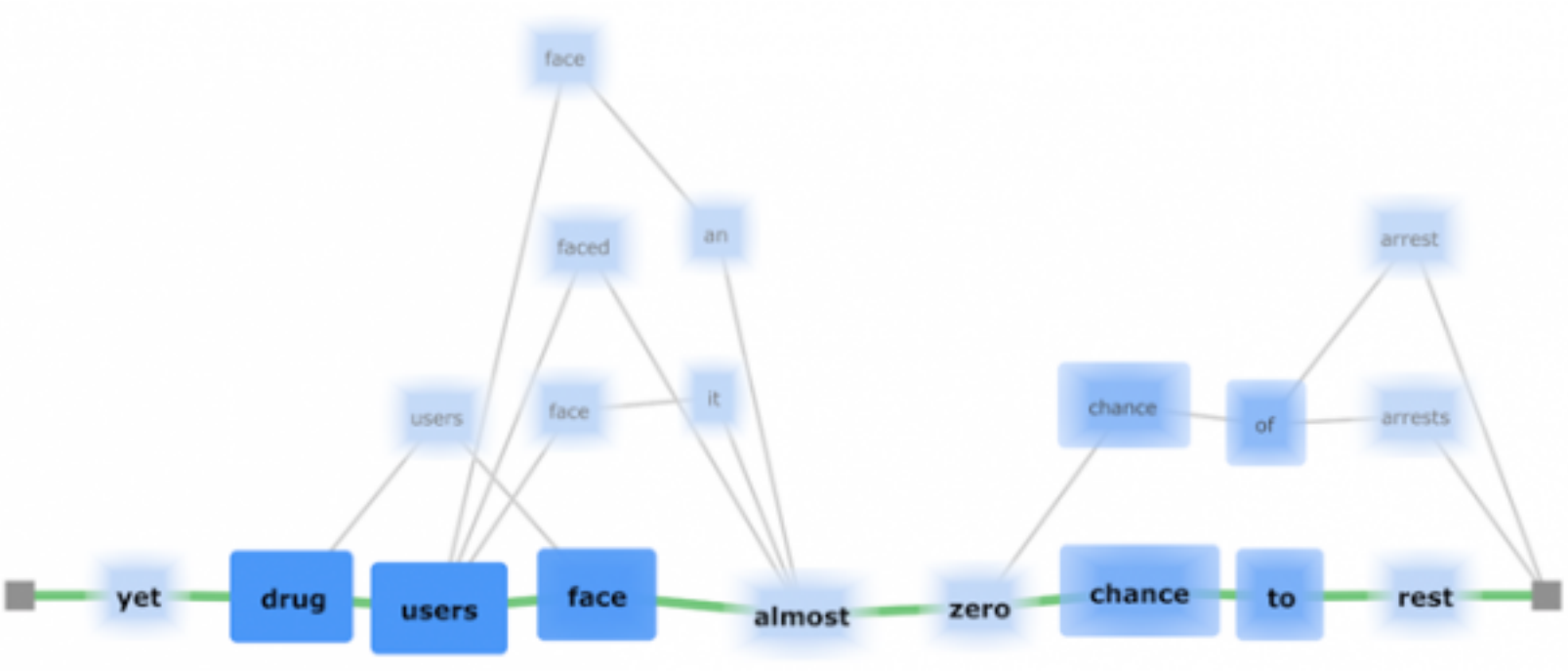


Figure 4. Alternative representations of missing data in a line chart. The data are U.S. census counts of people working as 'Farm Laborers'; values from 1890 are missing due to records being burned in a fire. (a) Missing data is treated as a zero value. (b) Missing data is ignored, resulting in a line segment that interpolates the missing value. (c) Missing data is omitted from the chart. (d) Missing data is explicitly interpolated and rendered in gray.

http://ivi.sagepub.com/content/10/4/271

Alternative solutions



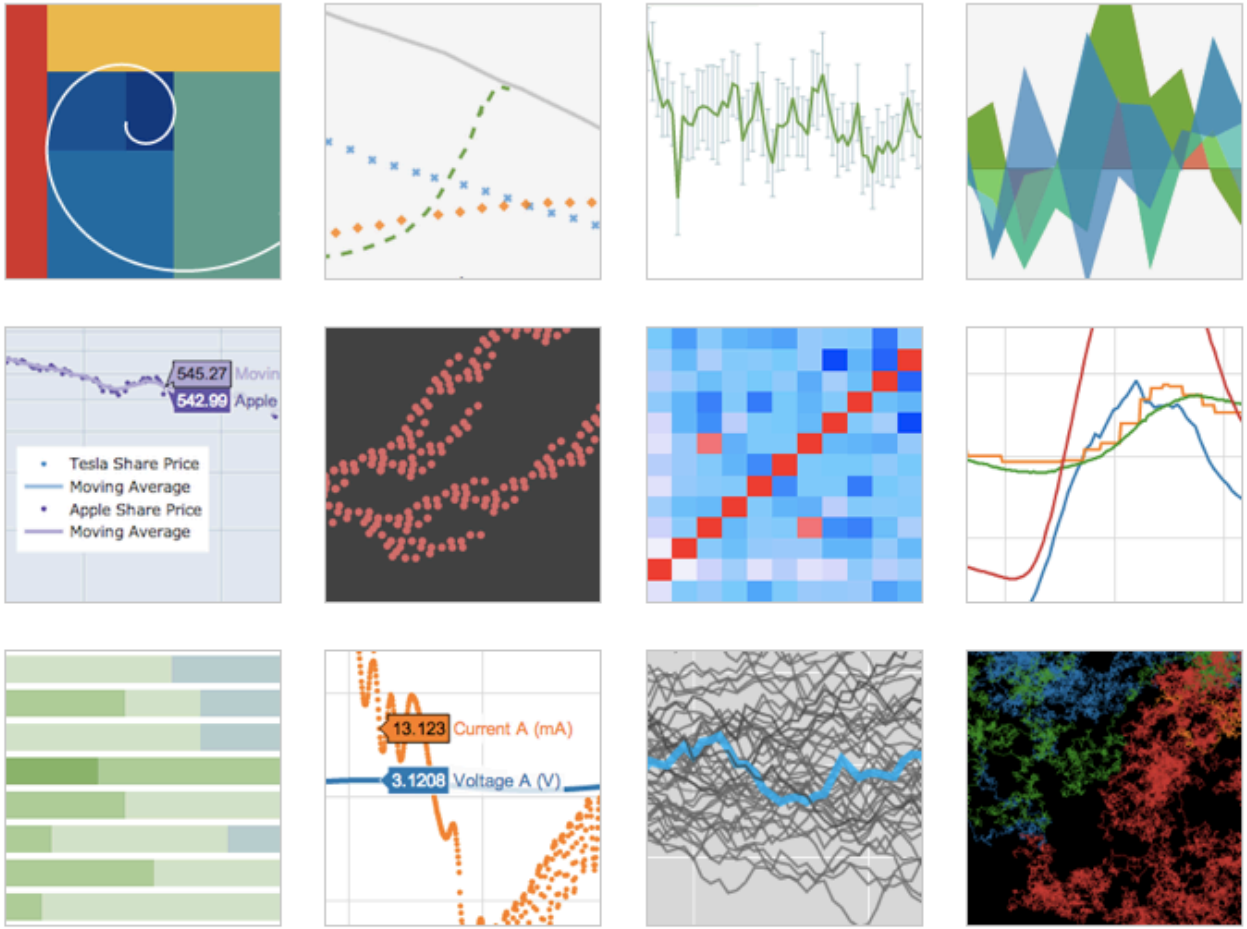
http://vialab.science.uoit.ca/portfolio/lattice-uncertainty-visualization-understanding-machine-translation-and-speech-recognition

Take-away

Uncertainty is blue.

Tools that Don't Need Installation

Plot.ly



https://plot.ly/

Plot.ly

- Browser based (or Excel add-in)
- Makes wide variety of chart types
- Allows for python, MATLAB, R, etc. syntax
- Makes charts that are hosted/shareable

https://plot.ly/

Example: Bubble chart

Click the column headers to choose x and y columns to graph. Then choose a "Size By" column to make the size of each point proportional to the row in this column. The optional "Text" column adds hover or floating text to each point.

OPTIONS

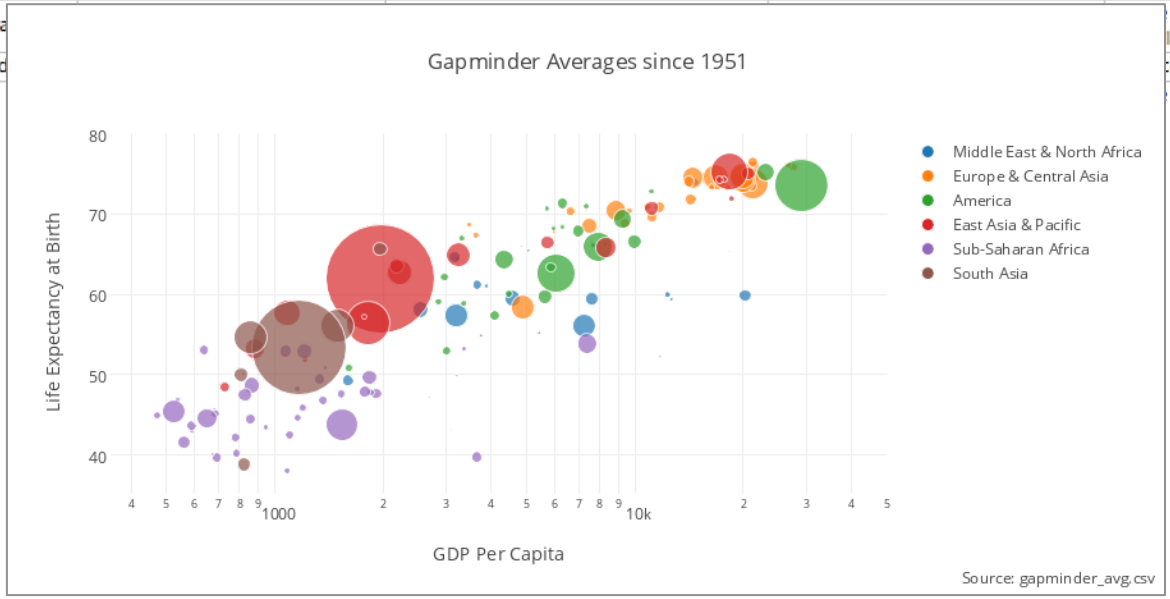
Group By

Size By

Text

Bubble chart

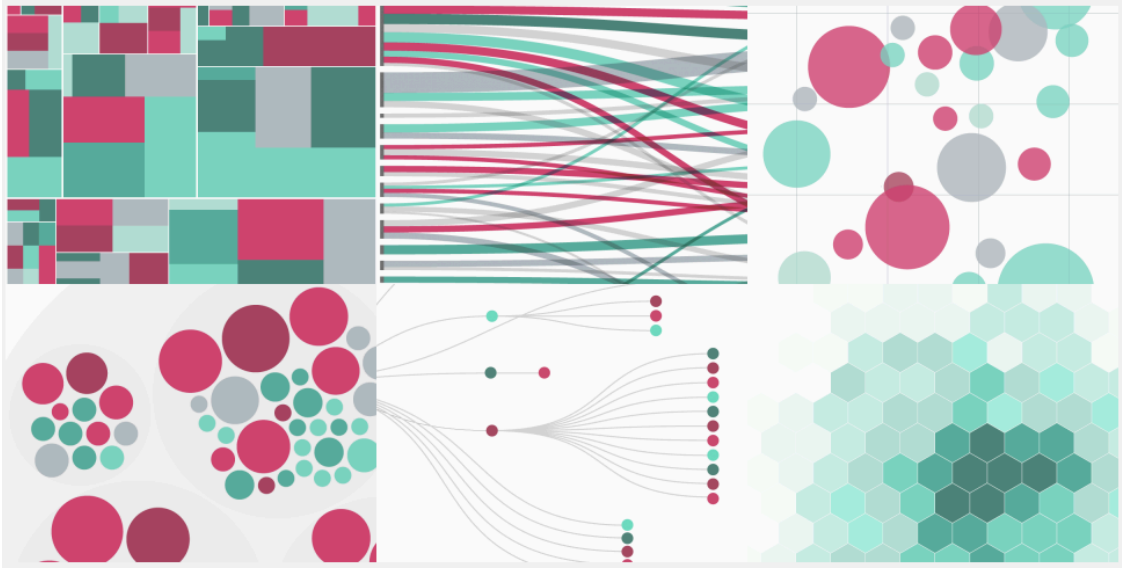
	Country	Average GDP per capita	Average Life expectancy at birth	Average Total population	Region
x	choose as x	choose as x	choose as x	choose as x	choose as x
y	choose as y	choose as y	choose as y	choose as y	choose as y
G	choose as G	choose as G	choose as G	choose as G	choose as G
S	choose as S	choose as S	choose as S	choose as S	choose as S
T	choose as T	choose as T	choose as T	choose as T	choose as T
1	Kuwait	64256.41951	68.35385246	1313738.049	Middle East & North Africa
2	Luxembourg	36286.24377	72.92478689	375718.3115	Europe & Central Asia
3	United States	28990.59574	73.5852623	235012383.7	America
4	Switzerland	27652.04918	75.87004918	6366298.164	Europe & Central Asia
5	Norwa				& Asia
6	Canad				ca
7					&



Raw

Has visualizations to show:

- Numbers
- Relationships
- Hierarchies



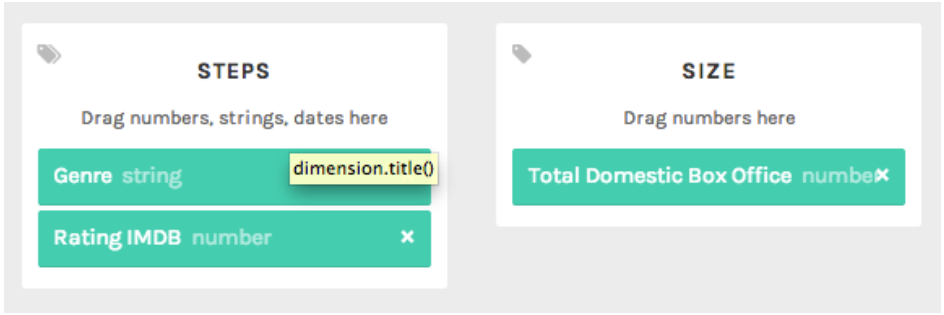
http://raw.densitydesign.org/

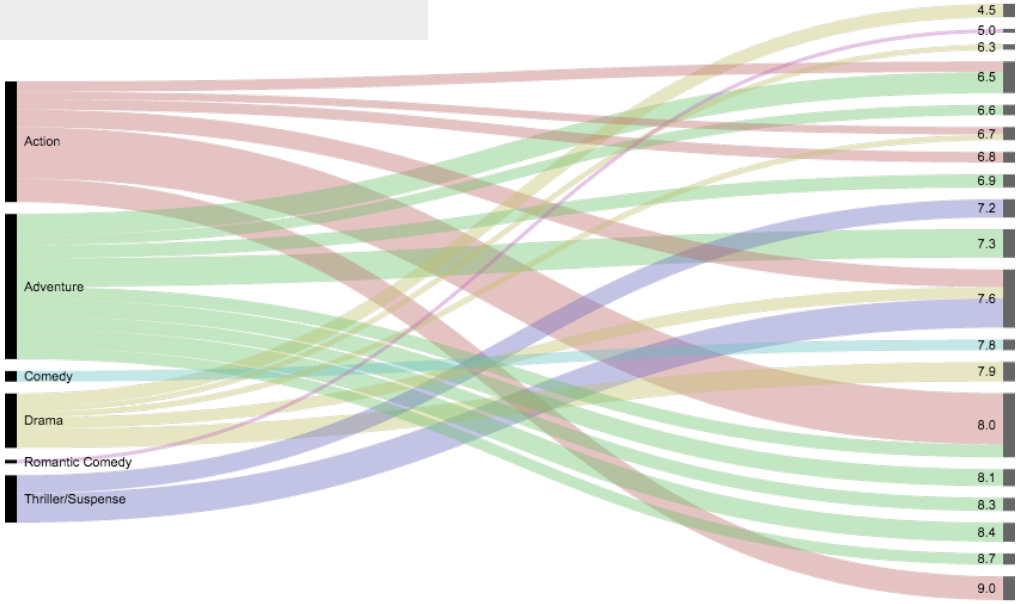
Raw

- Paste in a data table (.csv, .tsv, copied from Excel)
- Select chart type
- Drag column headers to different chart attributes
- Save out image or SVG code

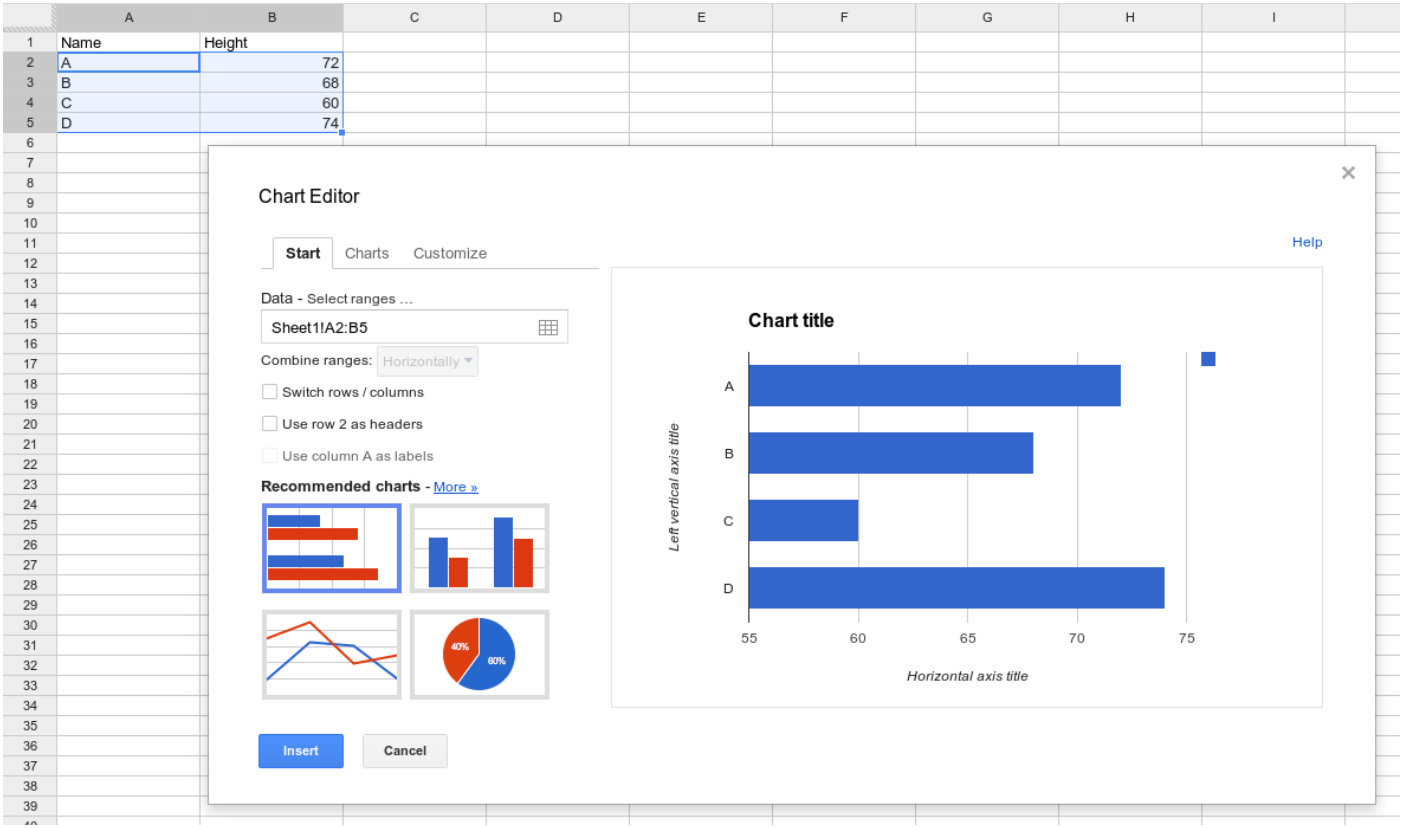
http://raw.densitydesign.org/

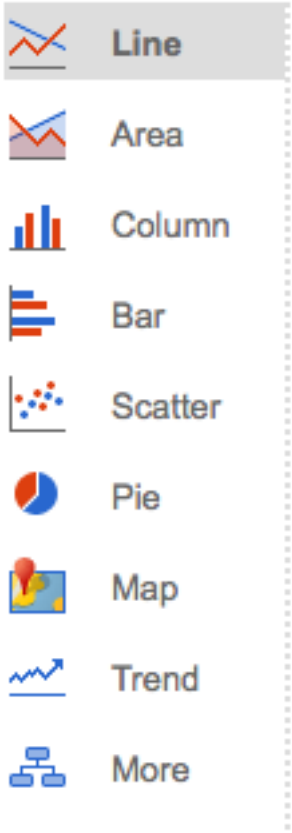
Example: Alluvial Diagram





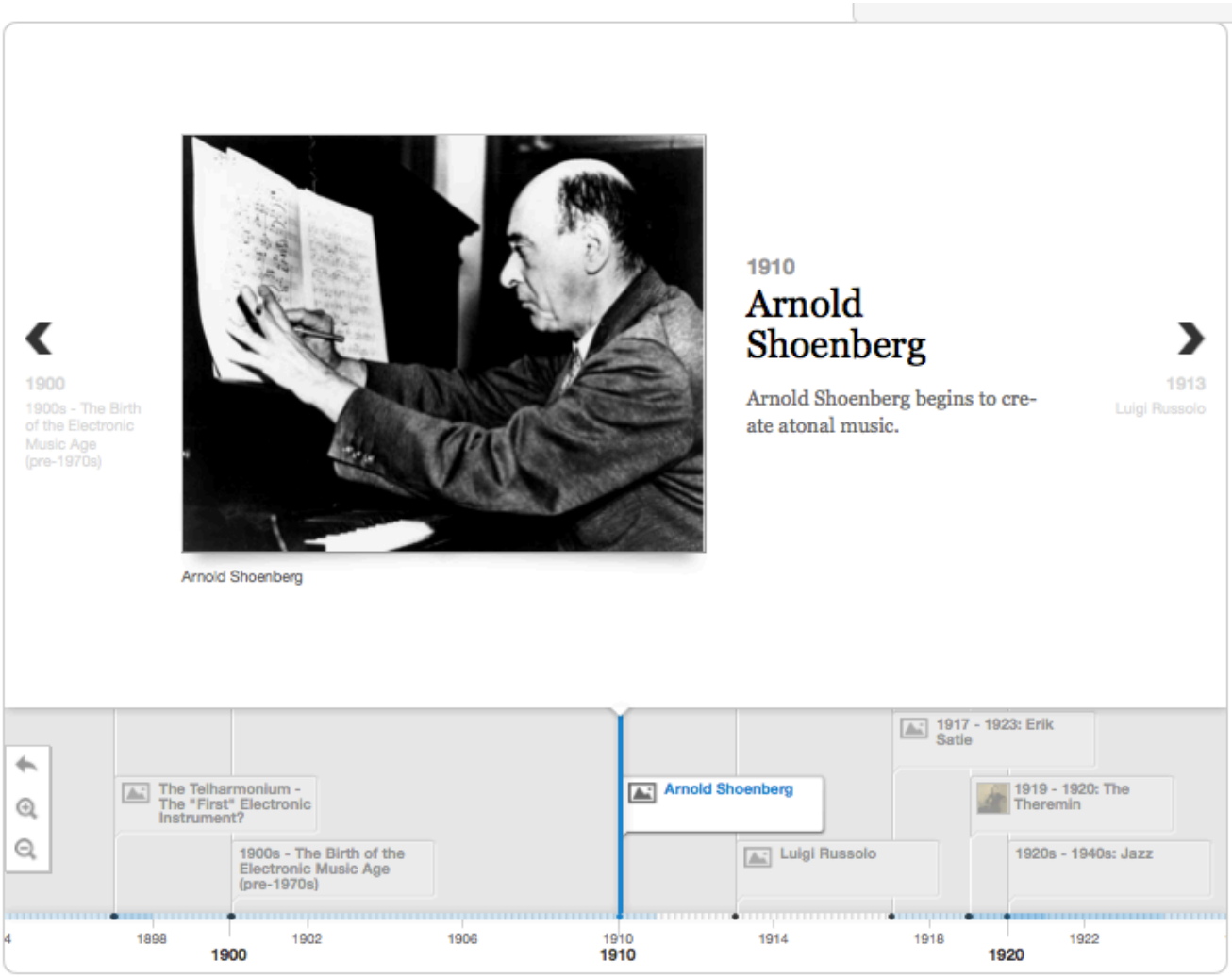
Google Spreadsheets





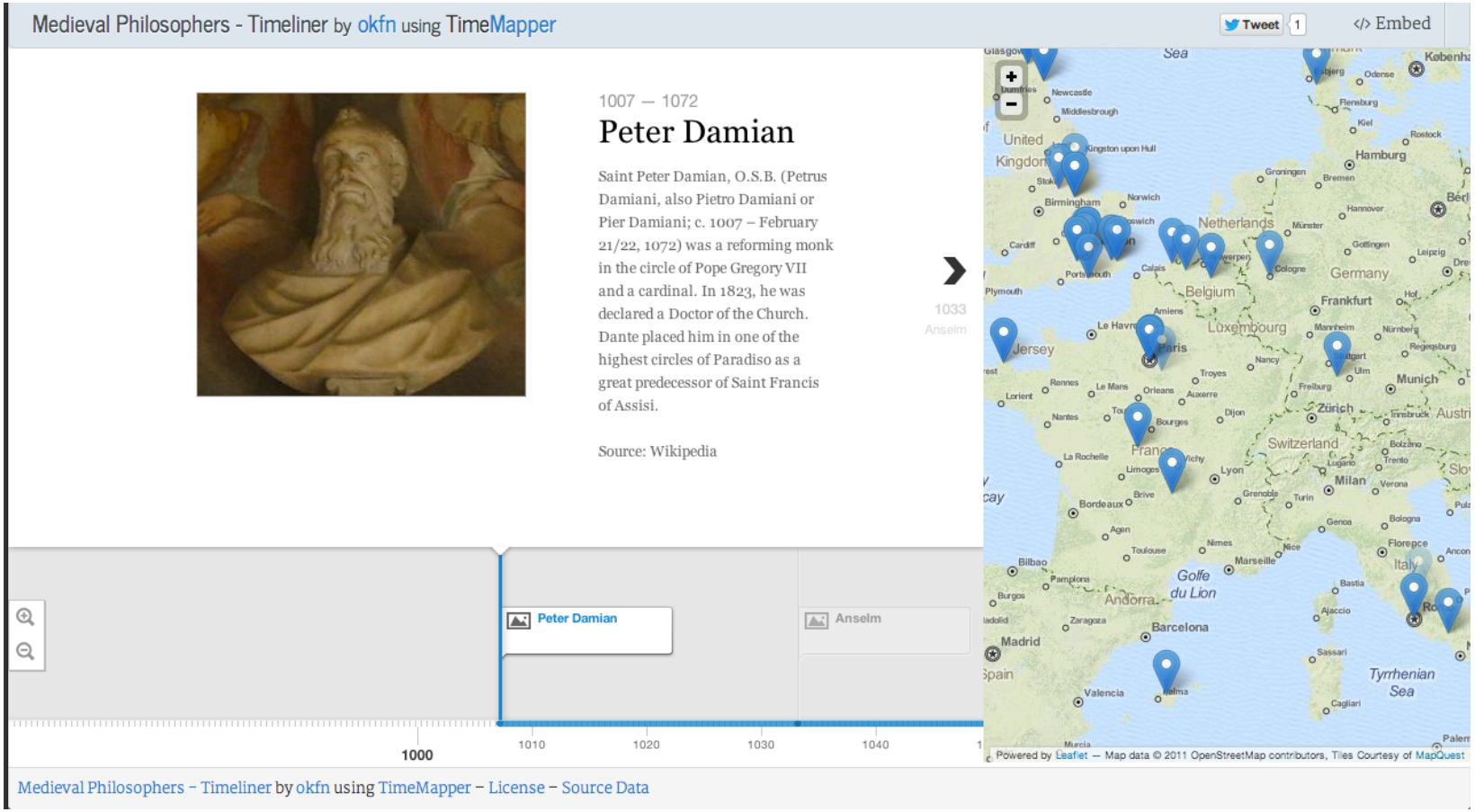
https://drive.google.com/

TimelineJS



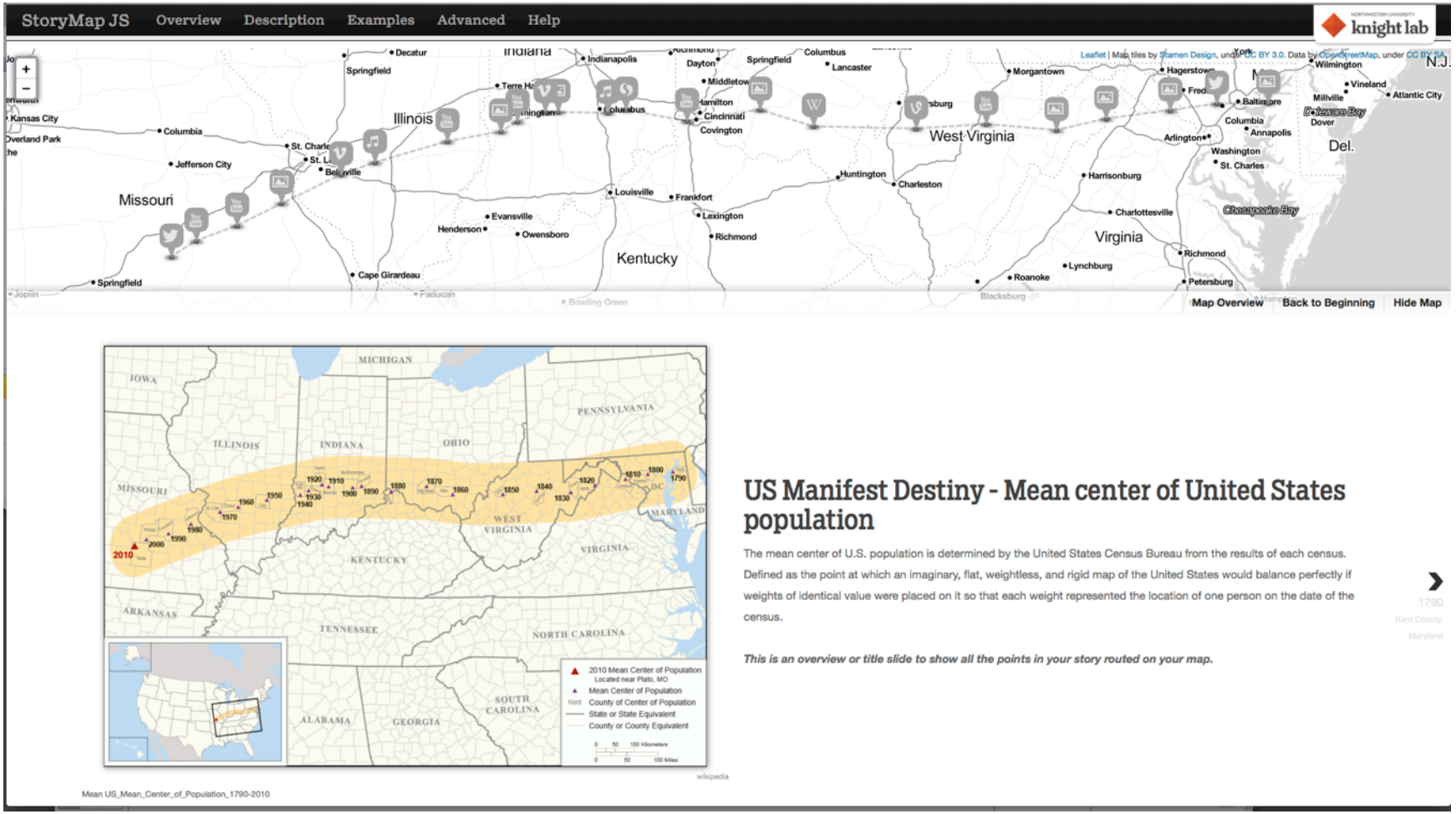
http://timeline.knightlab.com/

Timeliner



http://timemapper.okfnlabs.org/

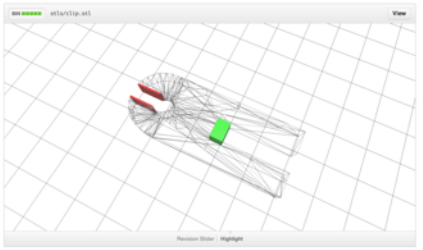
StoryMapJS

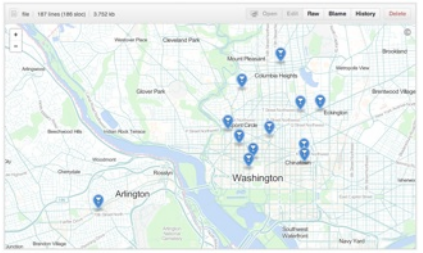


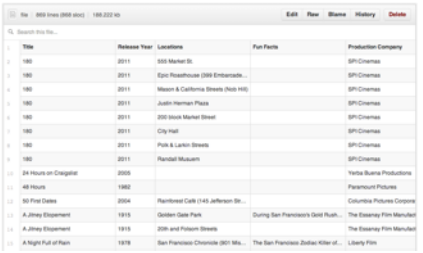
http://storymap.knightlab.com/

Also, GitHub auto-rendering

- 3D Files
  https://help.github.com/articles/3d-file-viewer
- GeoJSON/TopoJSON
  https://help.github.com/articles/mapping-geojson-files-on-github
- CSV/TSV
  https://help.github.com/articles/rendering-csv-and-tsv-data

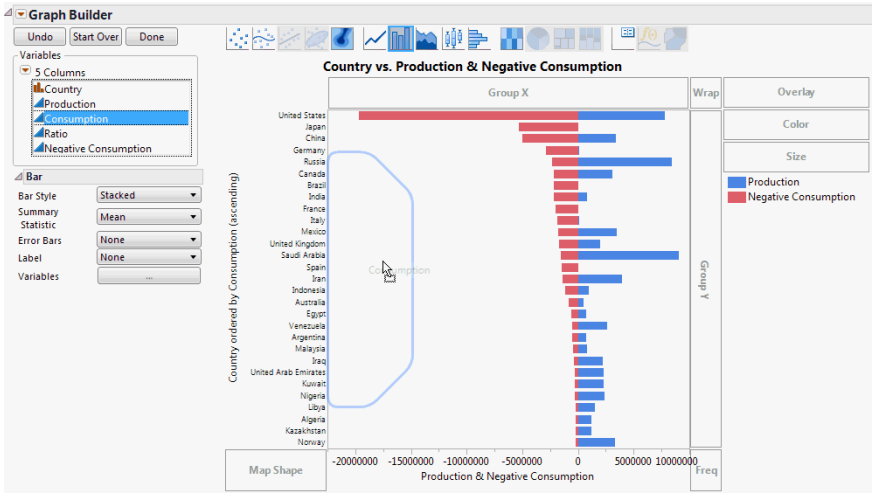


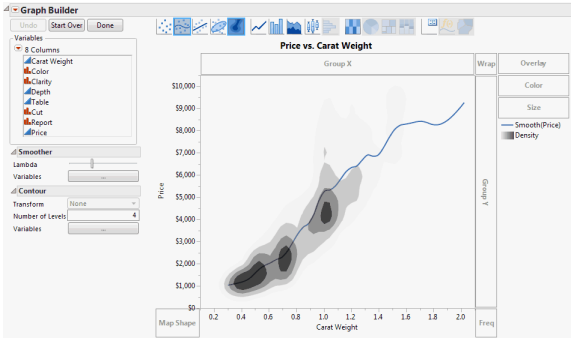


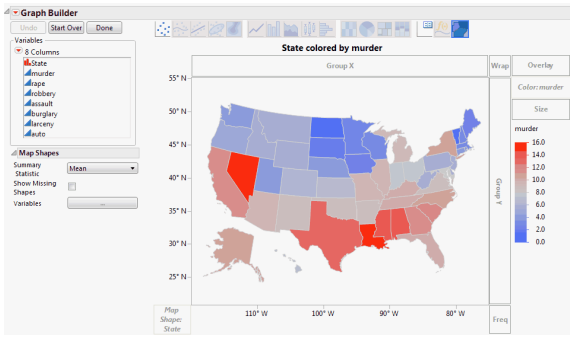


Software Applications

JMP Pro







https://oit.duke.edu/comp-print/software/license/detail.php?id=4

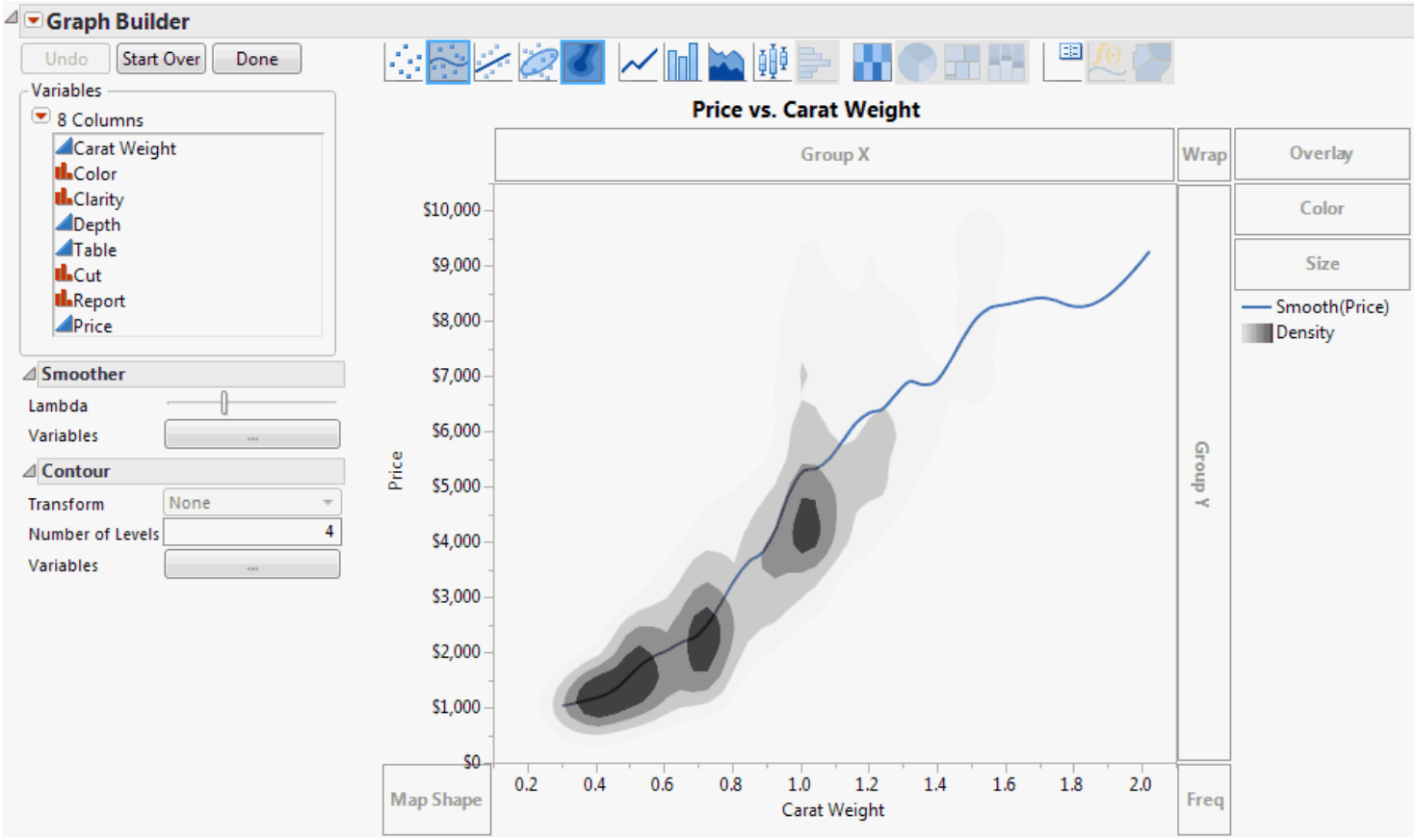
http://www.jmp.com/support/help/Essential_Graphing.shtml

JMP: Essential Graphing

- Overlay Plots
- Scatterplot 3D
- Contour Plots
- Bubble Plots
- Parallel Plots
- Cell Plots
- Treemaps
- Scatterplot Matrix
- Ternary Plots
- Summary Charts
- Create Maps

http://www.jmp.com/support/help/Essential_Graphing.shtml

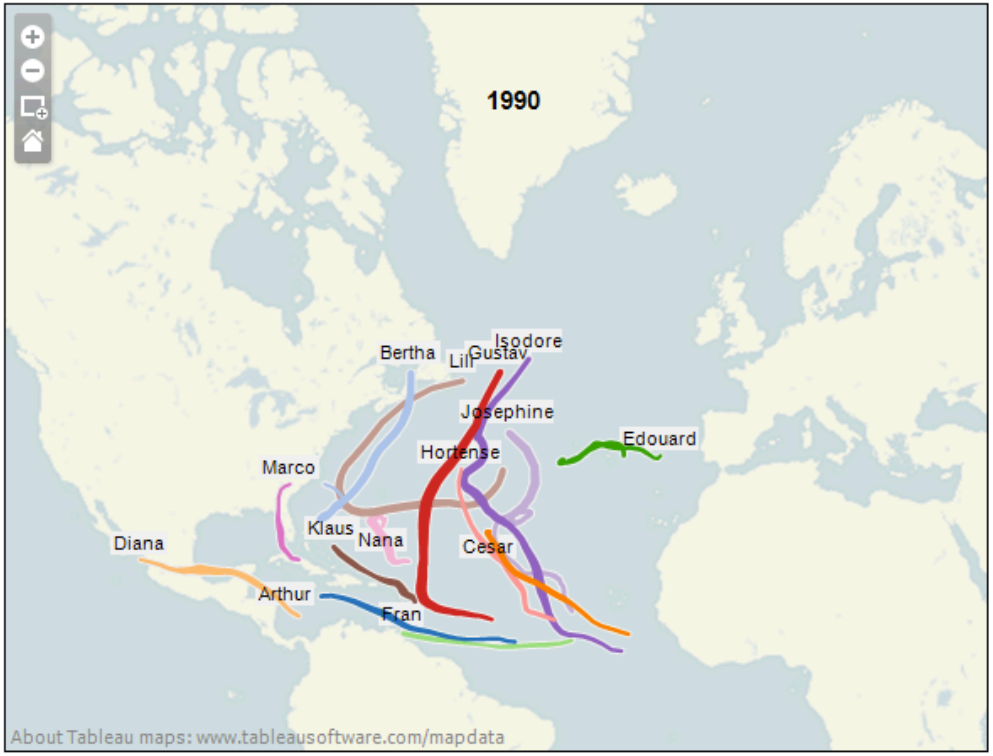
Example: Contour Plot

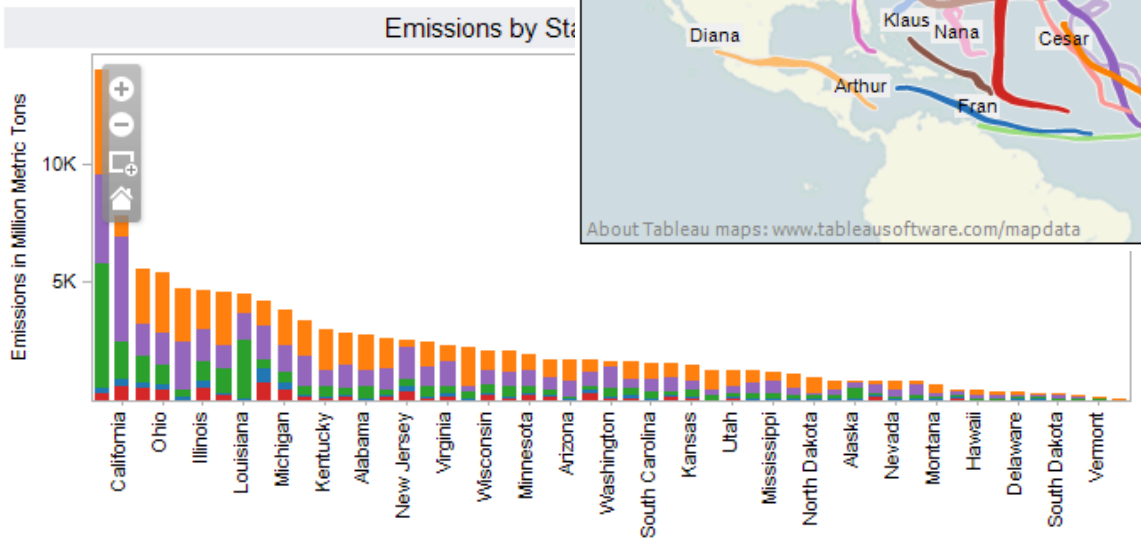


JMP Pro

- Statistical software
- Drag-and-drop chart builder
- Good charting options, including a basic map
- Can save code for all charts
  (good for reproducibility)
- Can save vector graphics from charts
  (good for print publications and graphic design work)

Tableau





http://guides.library.duke.edu/tableau

What can Tableau make?

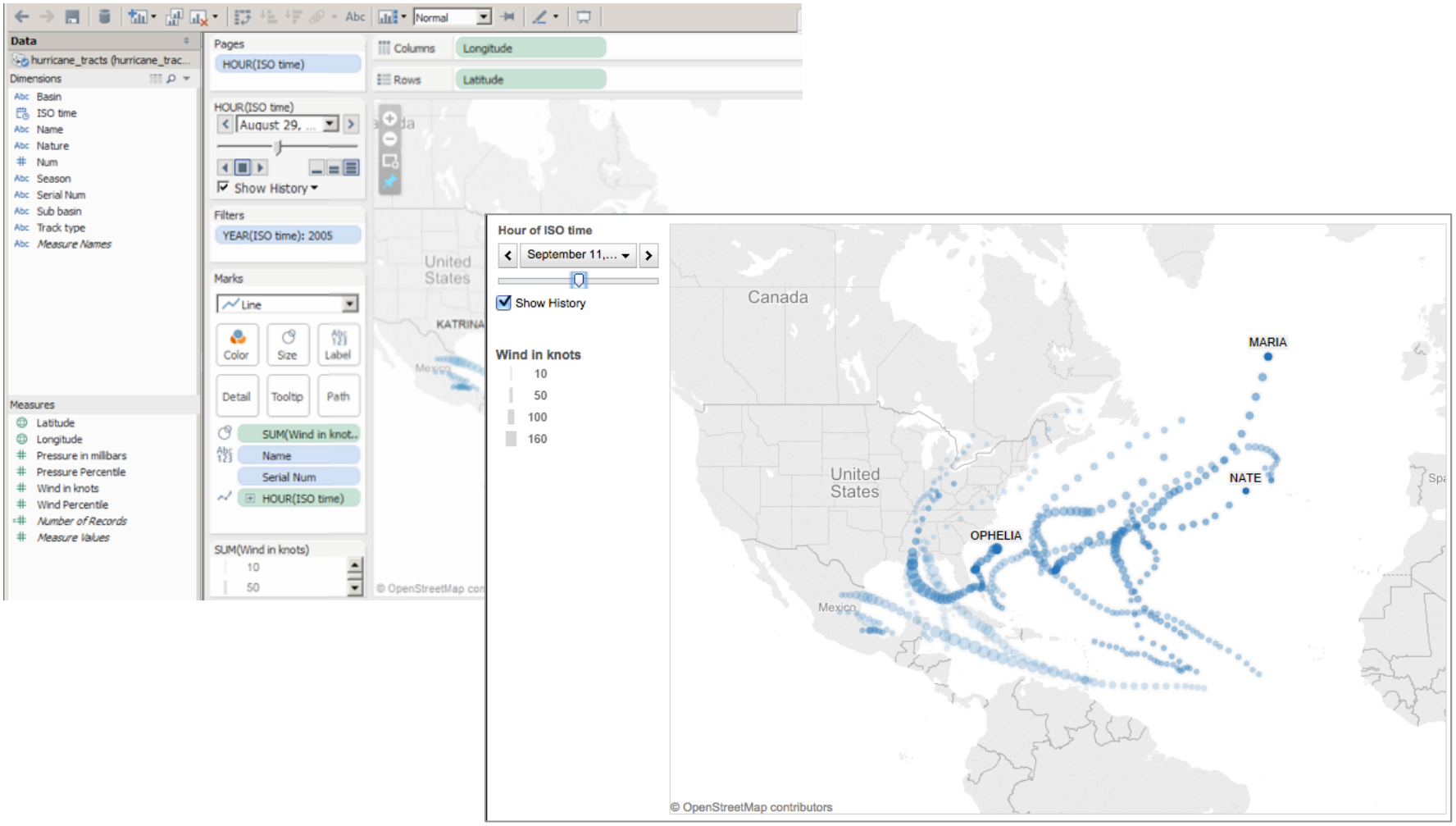
- Text tables
- Heat maps
  a grid representing variables by size and color
- Highlight tables
  a grid representing variables by text and color
- **Maps (symbol, filled)**
- Pie charts
- Horizontal bars
- Stacked bars
- Side-by-side bars
- **Treemap**
  a grid representing variables by size
- Circle views
- Side-by-side circles
- Lines/Area charts
- Lines/Area charts (discrete)
- Dual lines
- Dual combination
- Scatter plots
- **Histogram**
- **Box-and-whisker**
- **Gantt**
- **Bullet graphs**
- **Packed bubbles/ Word cloud**

Tableau Desktop

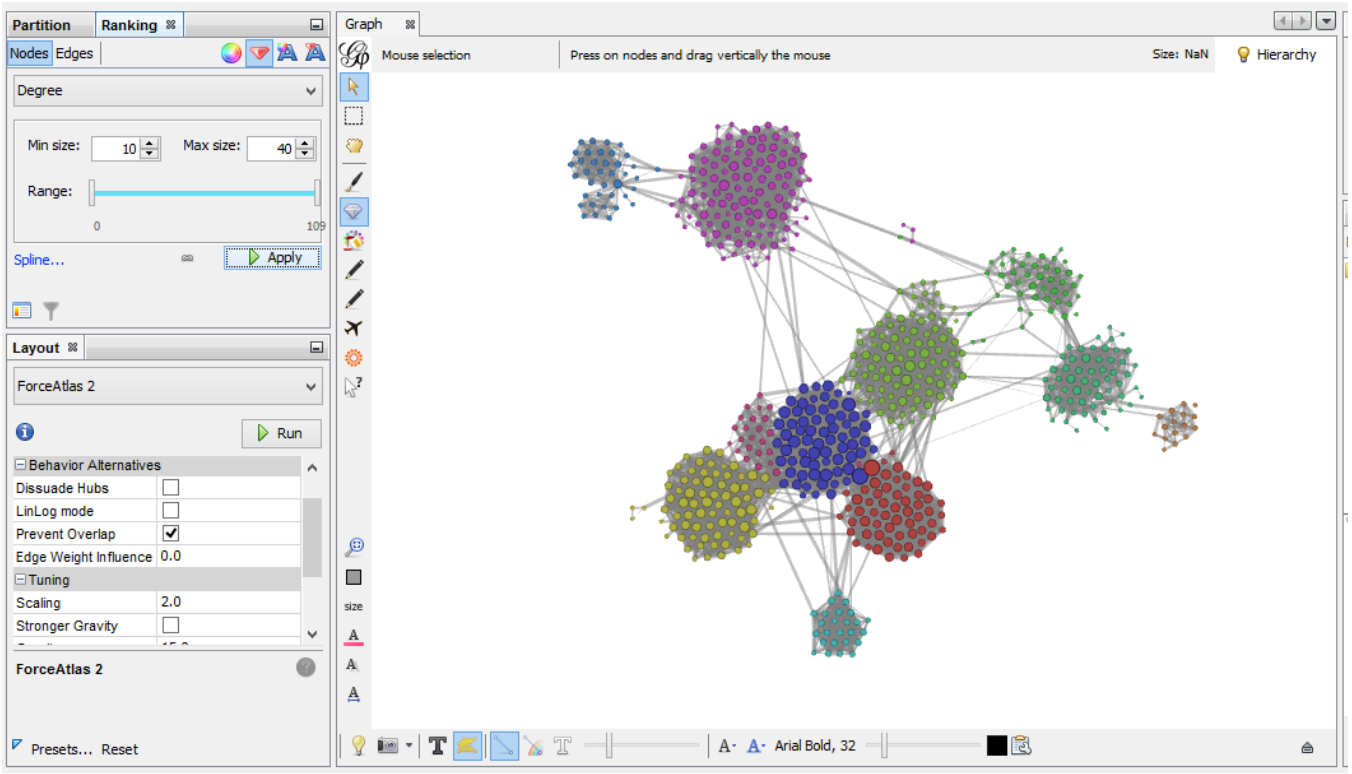
- Built specifically for visualization
- Can create interactive charts and dashboards
- Can post to the web
  (but make sure data are safe to share)
- Not great for print charts
  (basically have to take screenshots)

Free for students:
http://www.tableau.com/academic/students

Example: Animated Map



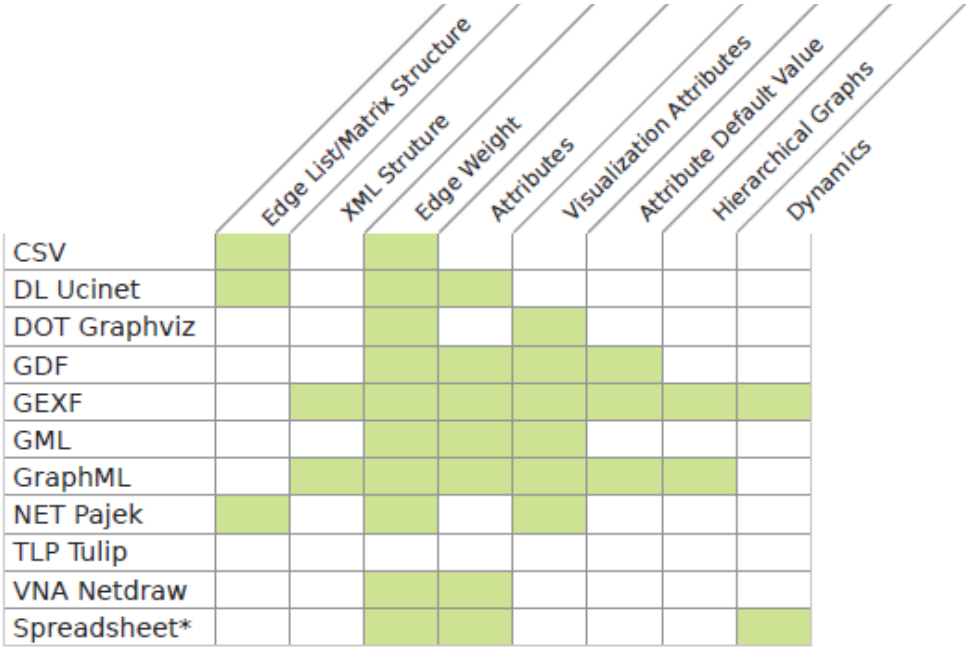
Gephi



http://bit.ly/gephi_workshop

Data formats

- Confusing number of choices
- GEXF supports many program features, but a pain to write by hand
- Spreadsheet is convenient and supports important features



	Edge List/Matrix Structure	XML Struture	Edge Weight	Attributes	Visualization Attributes	Attribute Default Value	Hierarchical Graphs	Dynamics
CSV	■		■					
DL Ucinet	■		■	■				
DOT Graphviz			■		■			
GDF			■	■	■	■		
GEXF		■	■	■	■	■	■	■
GML			■	■	■			
GraphML		■	■	■	■	■	■	
NET Pajek	■		■		■			
TLP Tulip								
VNA Netdraw			■	■				
Spreadsheet*			■	■				■

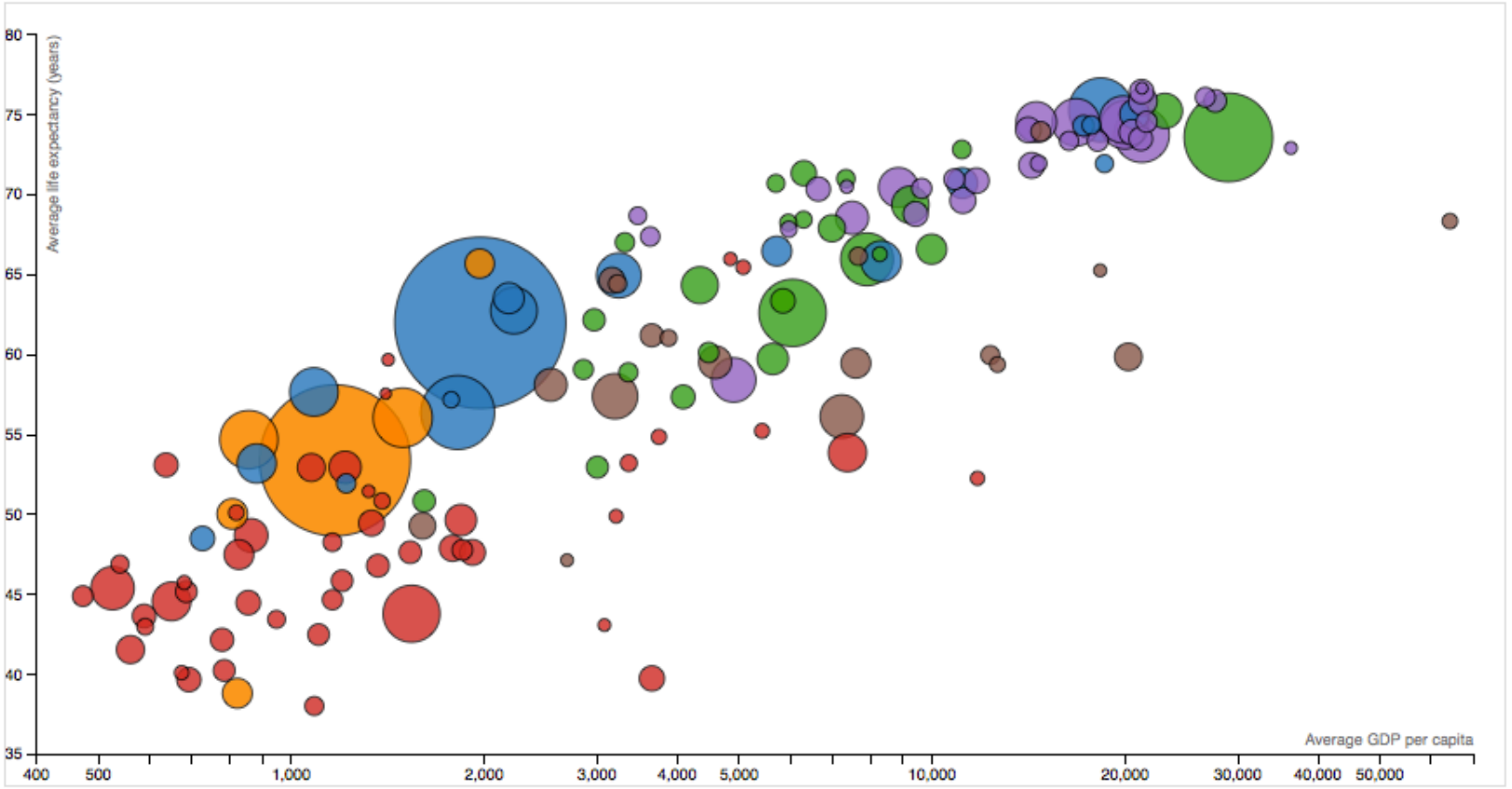
https://gephi.org/users/supported-graph-formats/

In addition to network visualization, Gephi can calculate:

- Degree (when directed, in-degree and out-degree)
- Diameter
  - Betweenness Centrality
  - Closeness Centrality
  - Eccentricity
- Density
- Clustering/Modularity

ADVANCED TOOLS

D3.js



http://d3js.org

http://bl.ocks.org/dukevis/8782982

About D3

- JavaScript library
- Fairly low level; building with rectangles and circles and lines, instead of pre-made chart structures*
- Basic functioning makes it easy to join HTML elements with data points

*D3 Middleware

Basic line/area chart:

- xCharts ~10 lines?
  http://tenxer.github.io/xcharts/
- Rickshaw (specifically for time series) ~16 lines
  http://code.shutterstock.com/rickshaw/
- NVD3 ~31 lines
  http://nvd3.org/
- Vega ~57 lines
  http://trifacta.github.io/vega/

http://chimera.labs.oreilly.com/books/1230000000345/ch02.html#_tools_built_with_d3

*D3 Middleware, cont'd.

- DC (http://dc-js.github.io/dc.js/)
  good for dashboards (includes Crossfilter)
- D3plus (http://d3plus.org/)
  good for tool tips and info panels
- Dimplejs (http://dimplejs.org/)
  good for annotations, very pretty

D3 Resources

- Interactive Data Visualization for the Web
  http://chimera.labs.oreilly.com/books/1230000000345
- Tutorial and Cheat Sheet, c. 2012
  www.jeromecukier.net/blog/2012/10/15/d3-tutorial-at-visweek-2012/
- D3 Tips and Tricks
  https://leanpub.com/D3-Tips-and-Tricks/read

When to use D3

- Need for customized chart types (http://bl.ocks.org/mbostock)
- Want to use JavaScript
- Have only a low number of data points or elements (SVG vs. HTML5 Canvas)
- Want to have it on your résumé

D3 workshop tomorrow!

Visualization in d3

Thursday, March 19, 7-9pm

Edge Workshop Room (Bostock 1st Floor)

http://library.duke.edu/events/data/event.do?id=6817&occur=15231

(Workshop is full, but if there are no-shows you could try to sneak in.)

Python

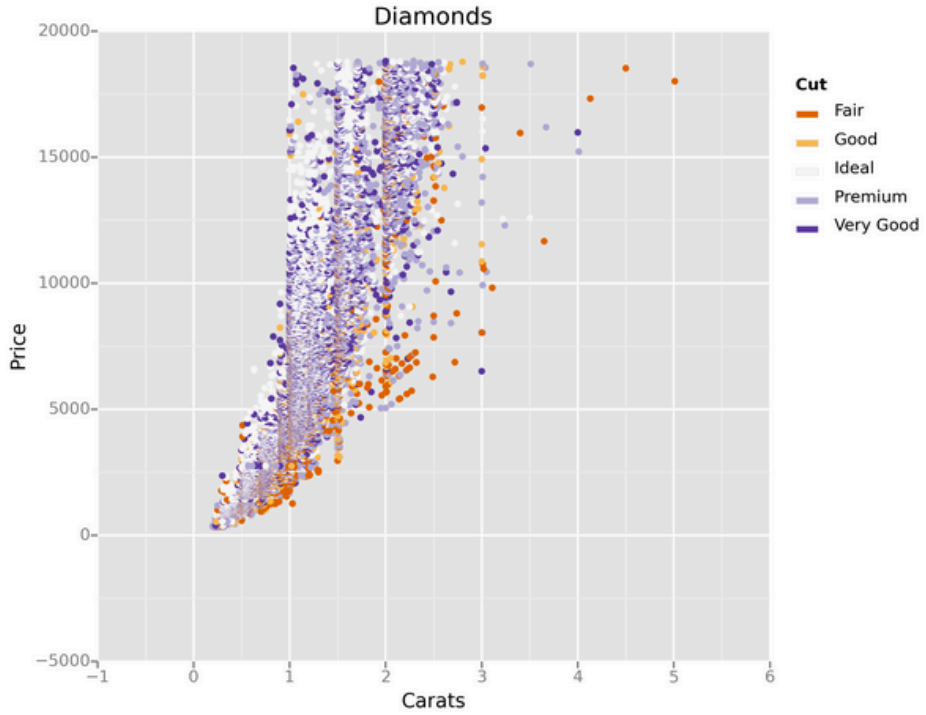
- Bokeh

  http://bokeh.pydata.org

  web visualizations with big datasets

Python

- ggplot2 for python
  http://ggplot.yhathq.com/
  includes good graphical principles

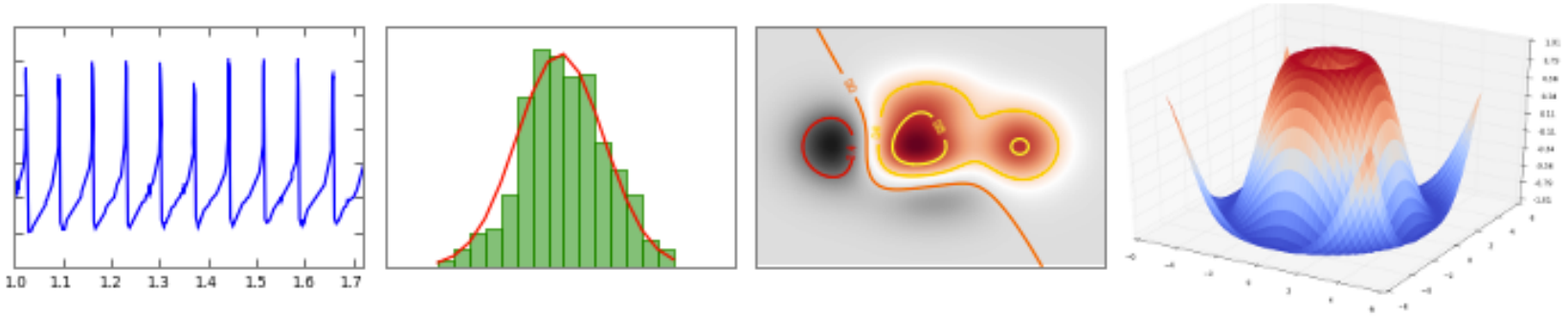


Python

- Anaconda

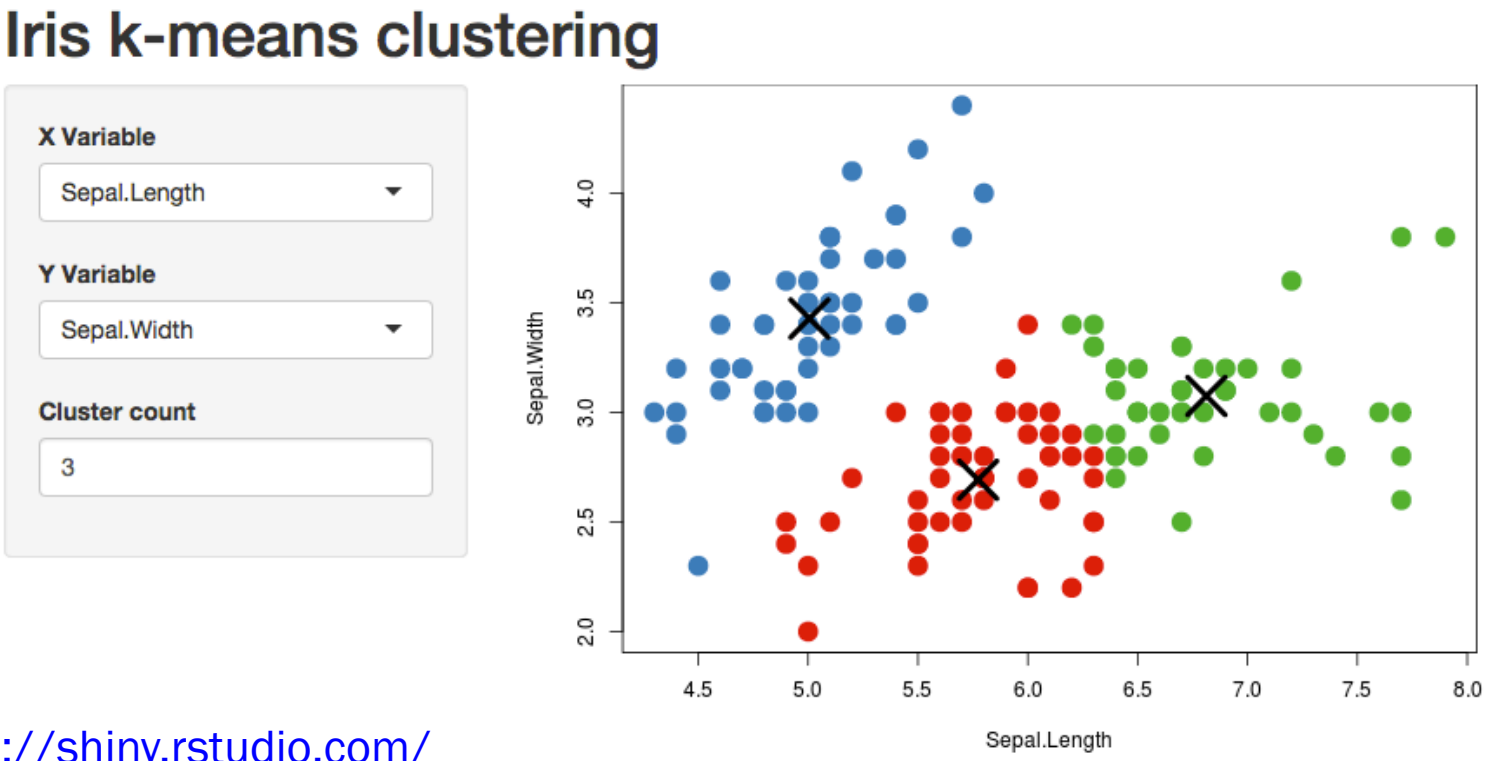
  https://store.continuum.io/cshop/anaconda/

  good for installing many data analysis packages, including matplotlib



http://matplotlib.org/

R Shiny



http://shiny.rstudio.com/

https://vm-manage.oit.duke.edu/

http://www.shinyapps.io/

ELK stack

http://www.elasticsearch.org/

ELK stack

- Elasticsearch

  “flexible and powerful open source, distributed, real-time search and analytics engine” · full-text search (lucene) plus fast queries and many built-in aggregations for large data (time-based and stats w/facets)

- Logstash

  “helps you take logs and other time based event data from any system and store it in a single place” · parse

- Kibana

  “Elasticsearch’s data visualization engine” · sharable dashborads for real-time, interactive visual exploration

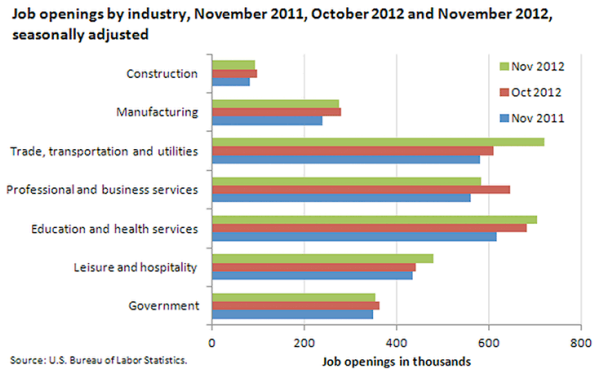
ELK stack

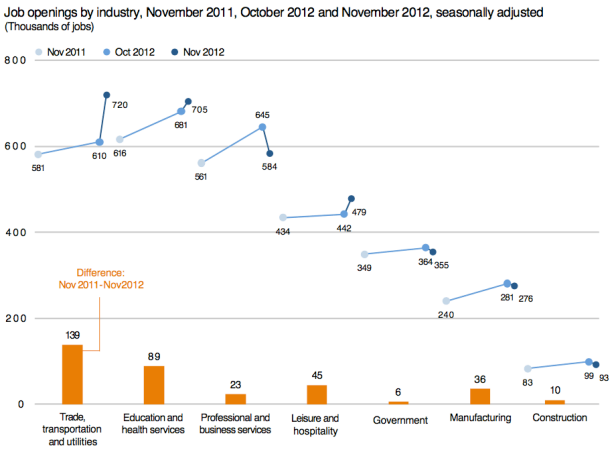
- Open source, but company builds APIs for all major languages
- Potential end-to-end solution for storage, plus monitoring by both developers and customers
- Geared towards large time-based, geo-spatial, and textual data
- Free for academic use
- Security product is pay only

More Tips

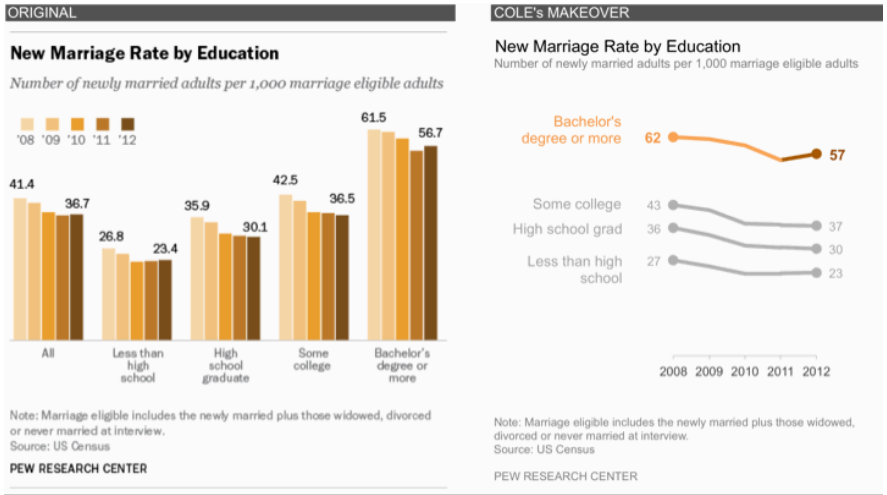
Good Chart Makeover Examples

The Why Axis chart remakes
http://thewhyaxis.info/remakes/





Storytelling With Data visual makeovers:
http://www.storytellingwithdata.com/search/label/Visual%20Makeover



On the web

- Bad examples:
  WTF Viz, http://wtfviz.net/
- Good examples:
  Thumbs Up Viz, http://thumbsupviz.com/
- Ask for help:
  Help Me Viz, http://helpmeviz.com/

More on Data Visualization

Visual communication:
http://guides.library.duke.edu/visualcomm

Data visualization:

http://guides.library.duke.edu/datavis/

Top 10 dos and don'ts for charts and graphs:
http://guides.library.duke.edu/topten

Getting Help

Data and Visualization Services

- Data collections, LibGuides, etc.
  http://library.duke.edu/data/
- Blog (tutorials, announcements, etc.)
  http://blogs.library.duke.edu/data/
- Walk-in consultations
  http://library.duke.edu/data/about/schedule
  (or by appointment – askdata@duke.edu)
- Data and Visualization Lab in the Edge
  http://library.duke.edu/data/about/lab
  (fast hardware, diverse software)
- Additional workshops
  http://library.duke.edu/data/news/
  (listserv – dvs-announce@duke.edu)

QUESTIONS? SUGGESTIONS?

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http://twitter.com/duke_vis