ICMC USP SÃO CARLOS

Instituto de Ciências Matemáticas e de Computação

| Universidade de São Paulo |

# SCC 252 – COMPUTATIONAL VISUALIZATION

## Introduction: Data Visualization in the context of Data Science and Big Data

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2018-2



## Outline

- About...
- Data Science
- Big Data for productivity
- Visualization
- Visualization Techniques
- Looking Forward

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# What does it take?

- Algorithms
- Statistics – essential
  - Alone will not do the job
- Mining – essential
  - Will not do the whole job, even with statistics
- Visualization – exploratory situations and user centric decision
- Certain skills – from complex reasoning to complete programming to innovative and daring goals. But mostly: Undestand the data

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# Qualification - keywords

- Ex: Coursera (https://www.coursera.org/)
  - Data Science set of courses by Johns Hopkings U.
  - 9 courses.
    - Intro(concepts + infra – version control and R IDE)
    - R Programming
    - Data collecting, cleaning and sharing
    - Exploratory data analysis – visualization and such
      - Buzz words – visual analytics
    - Statistical Inference
    - Regression Models
    - Reproducible Research
    - Practical Machine Learning
    - Data products – making results usable

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## Big Data
### is this a real thing?

YES it is !


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## Some numbers

- Big Data: Growing 40X to $32.4 billion by 2017
- 4300% increase in data by 2020
- Internet of Things growth 1-b to 26-billion units by 2020
- 2014: Increase of 125% in companies with data driven projects.
- 69% of unstructured data never makes it to decision making.

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# Some more numbers

- In 2020: 7B people, 30Billion Devices, 44 Zettabytes of Data
- How advantageous:

Potential Productivity Gains - the power of 1%

| | Segment | Savings | 15 yr. Value |
|---|---|---|---|
| Aviation | Commercial | 1% fuel | $30B |
| Power | Gas fired generation | 1% fuel | $66B |
| Healthcare | System wide | 1% reduced inefficiency | $63B |
| Rail | Freight | 1% reduced inefficiency | $27B |
| Oil & gas | Exploration & development | 1% reduction in CAPEX | $90B |

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# Applications (Data Analytics – large scale)

- Cities: Transportation/Integration, Crime Prevention, Citizen Information, Currency, Energy, Utilities, Waste, Parking, Hospitality

(Open Data)

- Health: Health Manager, Cost Optimization, Death prevention
- Internet-of-things: Customer, Devices, Sensors, Robots. Ex. Environment monitoring sensors, factories, phones, energy.
- Aerospace & flying: Reports: structural changes ($$$) and customer needs (on-time flights & changes in bagage handling: 80 million US)
- Commerce: marketing wrong, social network analytics
- Agriculture:
- Government: Costs, Well being, Logistics, Tax,

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# How big – just a sample
## From IoT

46 million smart meters in the U.S alone
1.1 billion data points (.5TB) per day

A single consumer packaged good manufacturing machine generates 13B data samples per day

A large offshore field produces 0.75TB of data weekly
A large refinery generates 1TB of raw data per day

10TB of data for every 30 minutes of flight
With >25,000 flights per day, petabytes daily

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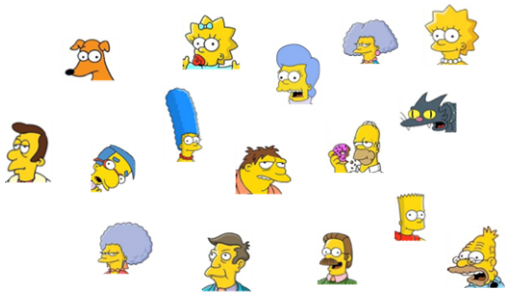
# Visualization Problem

- People trying to make sense of data

´messy´ data



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# Data is...

- Far too complex... (many dimensions, many types)
- Far too big... (´easy´ to collect)
- Far too varied... (images, videos, documents, news, networks)
- Never ending... (data streams)
- Much redundancy...
- Many relationships...
- Pieces missing...

- Studying natural & artificial systems and phenomena implies in handling lots of data...

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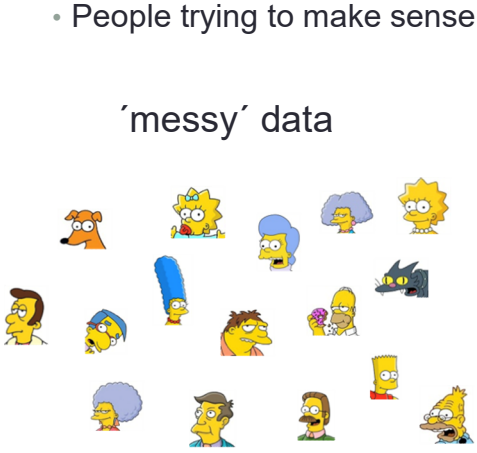
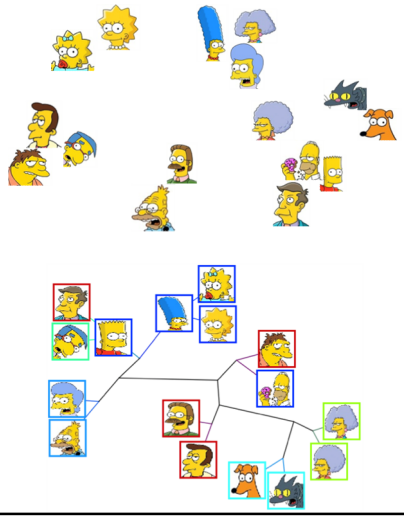
# What does your data tell???

- People trying to make sense of data

´messy´ data





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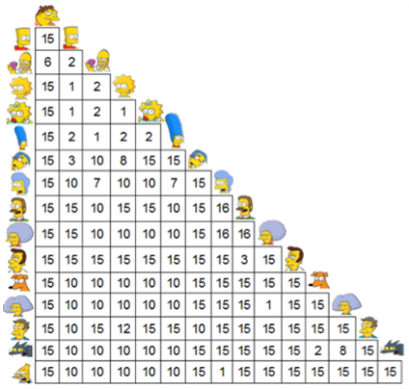
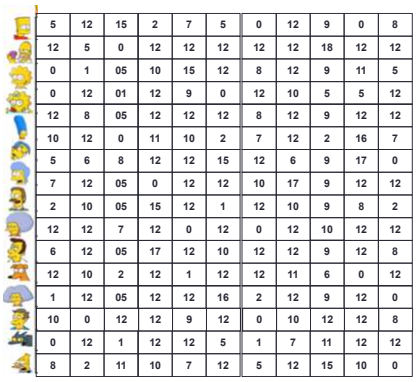
# Techniques

- Multidimensional visualization: data organization



pairwise distances

and/or



dimensional embedding (feature space)

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# Example: On studies on ecology and environment

- Collaborative work with biologists
- D.Sc. project: Visual exploration of feature spaces to support green algae taxonomic classification
- Classification based on features from images & other sources
- Time-varying images, feature extraction, representation and analysis

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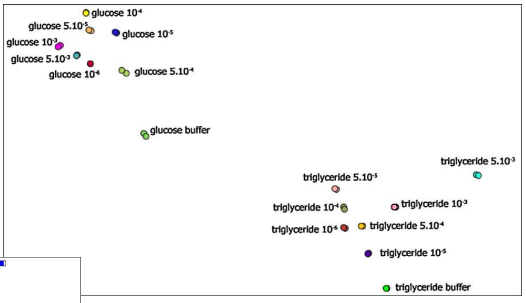
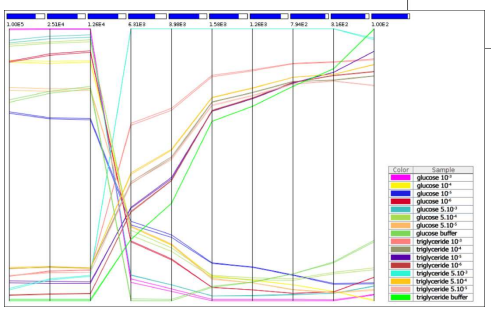
# Example: Data from nanotech sensors & biosensors

Collaborative work with physicists

finding good sensor configurations: segregation tasks on data



Moraes et. al, Detection of glucose and triglycerides using information visualization methods to process impedance spectroscopy data, ***Sensors & Actuators B***, 2012

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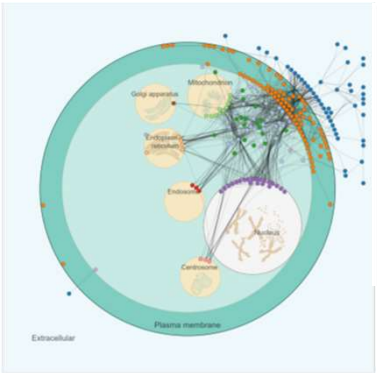
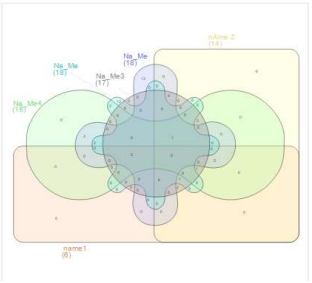
# Example: Proteomics and Cancer

- Masters/PhD project: Visual comparison of protein candidates.



Heberle, H. ; Meirelles, G. V. ; Silva, F. R. ; Telles, G. P. ; MINGHIM, R. . InteractiVenn: a web-based tool for the analysis of sets through Venn diagrams. **BMC Bioinformatics**, v. 16, p. (169), 2015.

Kawahara, R., Meirelles, G., Heberle, H., Domingues, R., Granato, D., Yokoo, S., Canevarolo, R., Winck, F., Ribeiro, A. C., Brand~ao, T. B., Filgueiras, P., Cruz, K., Barbuto, J. A., Poppi, R., Minghim, R., Telles, G., Fonseca, F. P., Fox, J., Santos-Silva, A., Coletta, R., Sherman, N., and Leme, A. P. Integrative analysis to select cancer candidate biomarkers to targeted validation. **Oncotarget** 6, 41 (2015), 43635-43652.

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## Links to sources of data visualization tools and data

- HDR (ONU):
  - (data) http://hdr.undp.org/en/composite/GII
  - (vis) http://hdr.undp.org/en/data-explorer/
- D3:
  - https://d3js.org/
  - (gallery) https://github.com/mbostock/d3/wiki/Gallery/

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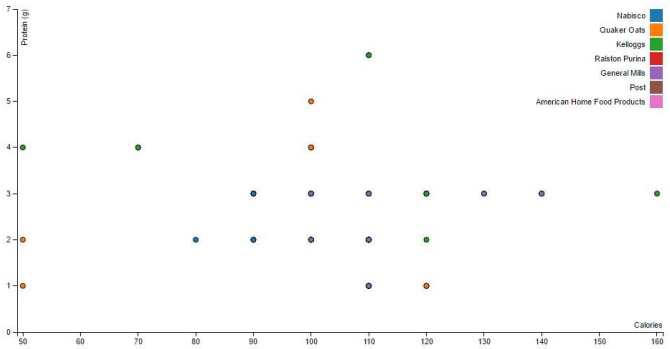
## Technique: Scatter Plot

- http://bl.ocks.org/weiglemc/6185069



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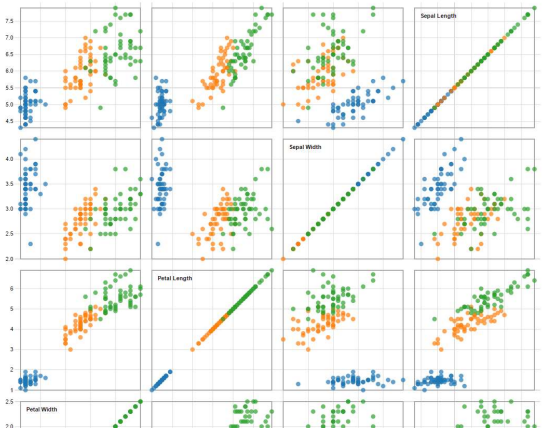
# Technique: Scatter Plot Matrix

- https://bl.ocks.org/mbostock/4063663

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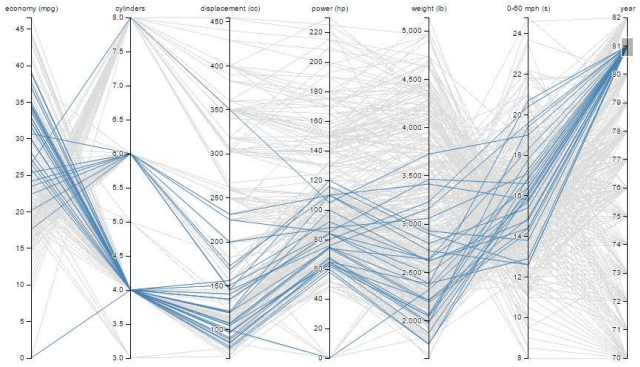
# Technique: Parallel Coordinates

- https://bl.ocks.org/jasondavies/1341281
- http://mbostock.github.io/d3/talk/20111116/iris-parallel.html



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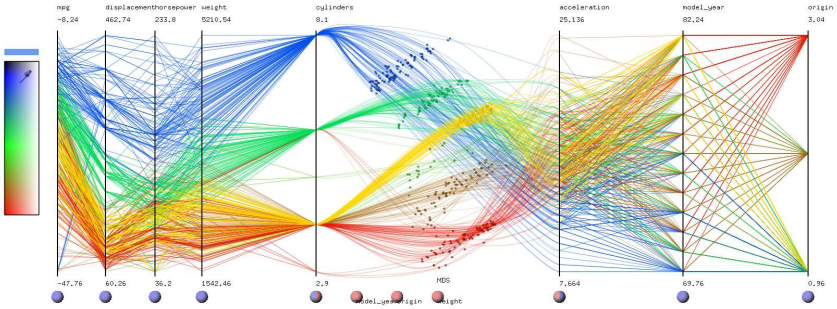
# Technique: Scattering Points in Parallel Coordinates




Project: http://vis.pku.edu.cn/wiki/project/hdvis

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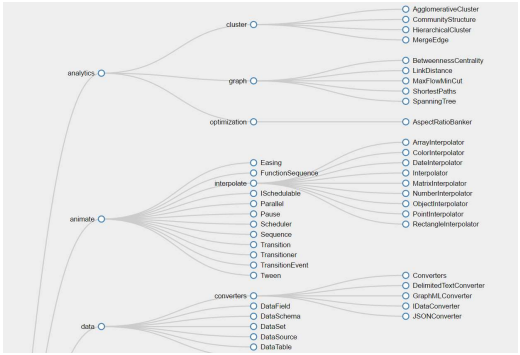
# Technique: Tree Visualization

- http://bl.ocks.org/robschmuecker/raw/7880033/
- Drag and Drop, Zoomable, Panning, Collapsible Tree with auto-sizing



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# Technique: Radial Reingold–Tilford Tree

- http://bl.ocks.org/mbostock/4063550/

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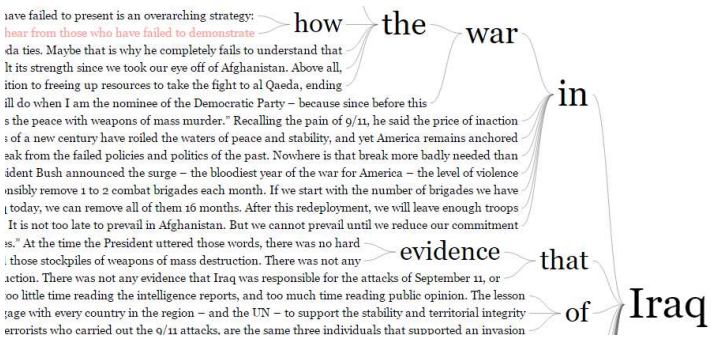
# Technique: Word Tree

- https://www.jasondavies.com/wordtree/?source=obama-war-speech.txt&prefix=Iraq&reverse=1



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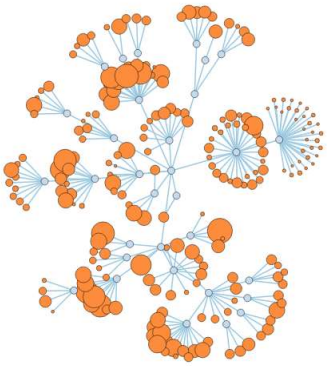
# Technique: Tree - Force Layout

- http://mbostock.github.io/d3/talk/20111116/force-collapsible.html



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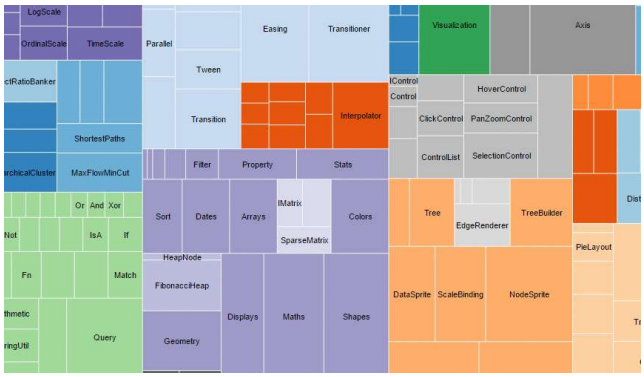
# Technique: Tree - TreeMap

- http://mbostock.github.io/d3/talk/20111018/treemap.html



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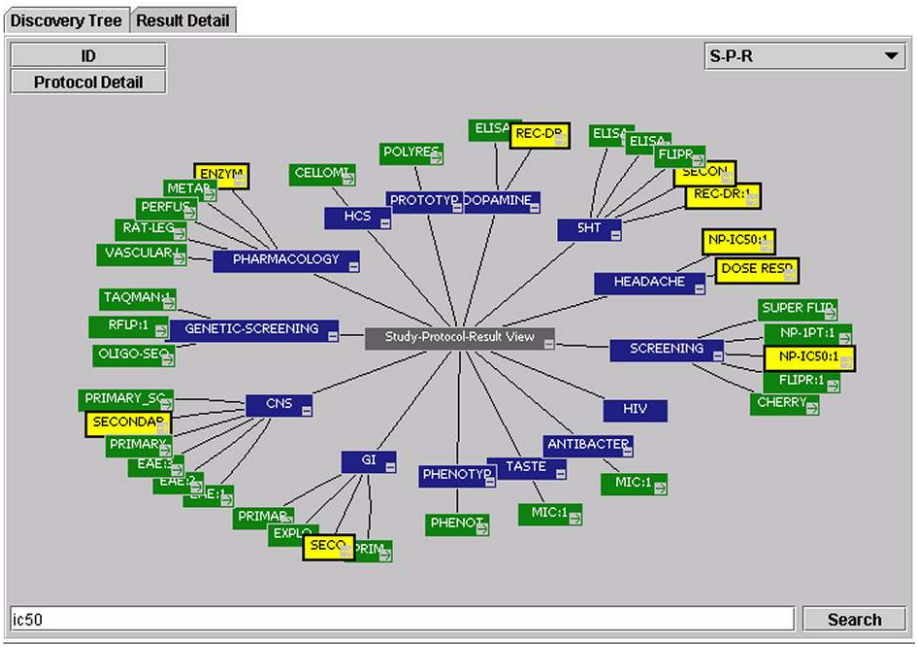


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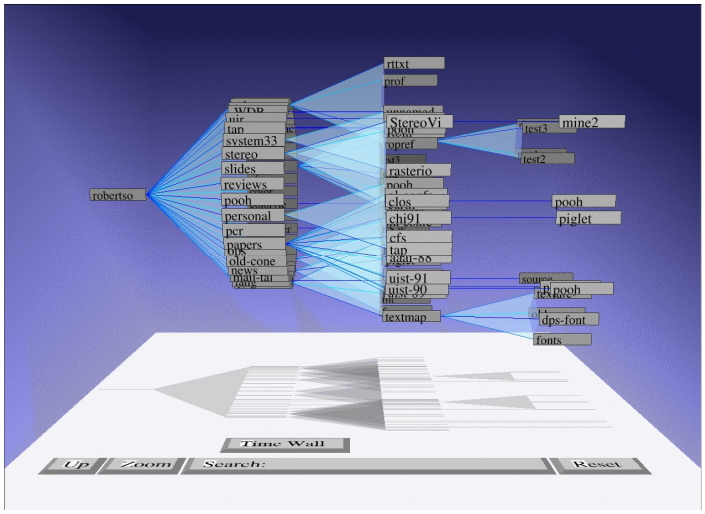
# Cone Tree




File system structure visualized as a cone tree

Animated 3D visualization of hierarchical data

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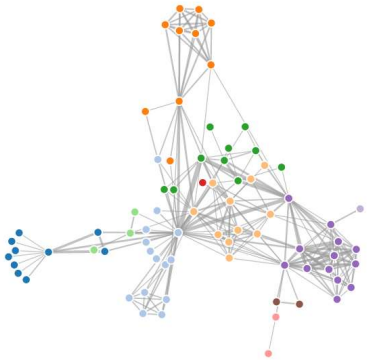
# Force-directed Graph Layout

- http://bl.ocks.org/mbostock/4062045



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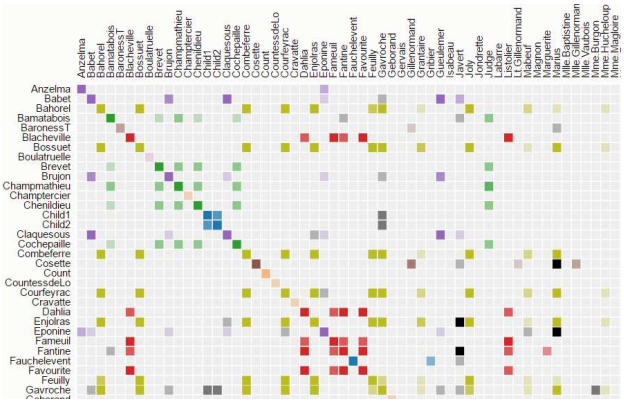
# Adjacency Matrix Graph Layout

- https://bost.ocks.org/mike/miserables/



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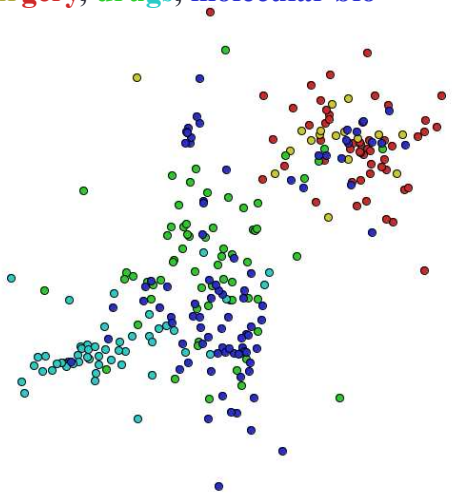
## Projection Techniques:
Mapping data set on the plane, allowing direct exploration

Ex: Patents **surgery**, **drugs**, **molecular bio**



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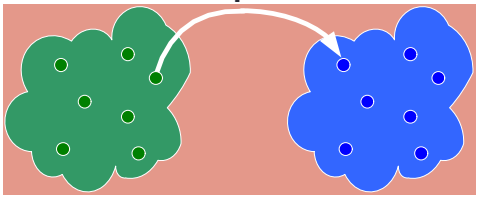
## Projection Techniques

$X \in R^m \quad f \quad Y \in R^{p=\{1,2,3\}}$



- $\delta$: $x_i, x_j \rightarrow R$, $x_i, x_j \in X$
- d: $y_i, y_j \rightarrow R$, $y_i, y_j \in Y$
- f: $X \rightarrow Y, |\delta(x_i,x_j) - d(f(x_i), f(x_j))| \approx 0, \forall x_i, x_j \in X$

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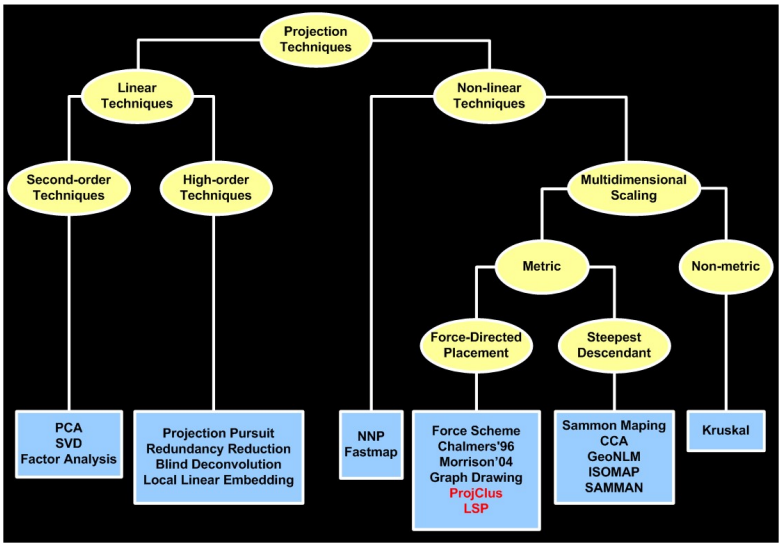


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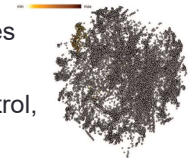
# Similarity based Techniques

- Projections
  - variations on MDS, dimension reduction, or other approaches
  - data mapped to low-dimensional visual space
  - preserving distances vs neighborhoods, global vs. local control, segregation



- fully interactive manipulation, dynamically adapting to user feedback
- massive data, sparse high-dimensional data. streaming data

- Tree-based
  - hierarchy of similarity relations
  - variations on tree layouts

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## Approach and Method

- Understand the data
- Understand the needs
- Exploratory – agree with user/customer/partner
- Find relevant information
- Know the available methods
- Work in pairs/groups.

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## Challenges

- Sheer volume
- Data transformation/formatting/structuring
- Ownership of the data
- Different types
- Spurious correlations
- Inespecificity of  questions

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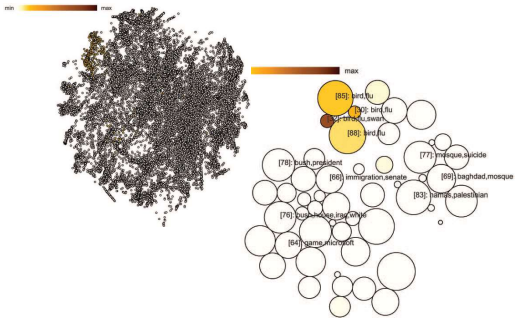
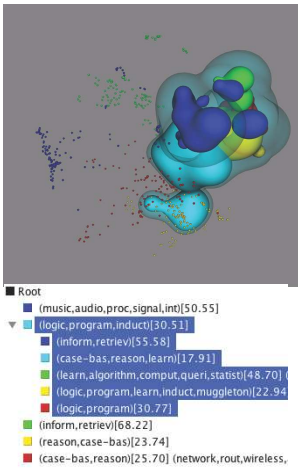
# Visualization examples: clutter




Paulovich and Minghim, HiPP: a novel hierarchical point placement strategy and its application to the exploration of document collections, ***IEEE Trans. Visualization & Computer Graphics***, *2008*




Poco; Etedmapour, Paulovich, Long, Rosenthal, Oliveira, Linsen, Minghim. A framework for exploring multidimensional data with 3D projections, ***Computer Graphics Forum***, Eurovis 2011.

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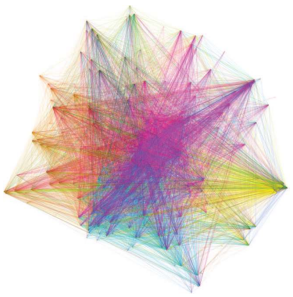
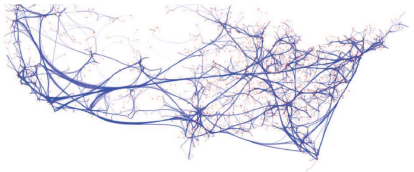
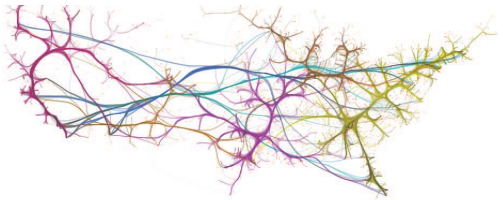
# Networks: even worse



Ersoy, Hurter, Paulovich, Cantareira, Telea, Skeleton-based edge bundling for graph visualization. ***IEEE Trans. Visualization and Computer Graphics,*** Infovis 2011





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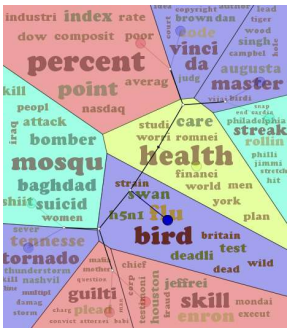
# More Data – Summarization

- Wordclouds
- Representative Images




Multi-level text




Multi-level images

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# Homework

- Explore HDR variables and indices (see slide 17 – links)
  - Mention 5 interesting patterns found, 3 expected, 2 somewhat surprising
  - How does Brazil relate with other countries with similar HDI, both in a positive and in a negative way?
  - How does Brazil relate directly (if at all) with countries in a different range of HDI?
- Choose 2 different visualizations programmed in D3 (see slide 17 – links)
  - Run each one of these with 2 different data sets of your choice.

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## Evaluation - Undergrad

- 2 visualization tasks – one presented in class and one report submitted – 3 students per task.
- 1 test (26/11)
- 1 programming project.

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## Evaluation - Grad

- 1 project (30 %)
- 2 paper discussions (15%)
- 1 seminar on a particular visualization subject (15%)
- 1 test (40%) - 26/11

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# VISUALIZATION, DATA SCIENCE AND BIG DATA

Rosane Minghim

THANK YOU!!!