E6893 Big Data Analytics Lecture 6:

Big Data Visualization — I

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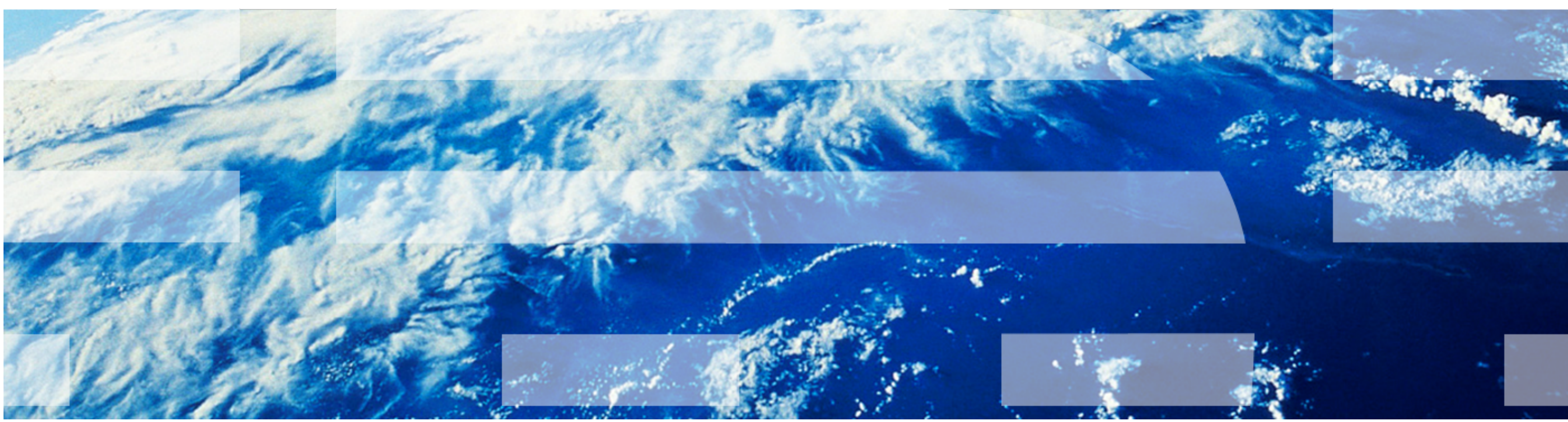


October 11th, 2024

Outline

Part I : Introduction
- What is visualization ?
- Why do we create visualisation ?
- Existing Visualisation Techniques

Part II : Big Data Visualization
- Challenges
- Techniques

Part III : How can we visualize big data
- Key techniques
- Open source tools
- Examples

Part IV : Visual Analysis of Big Data

Thanks to Dr. Nan Cao http://nancao.org

Part I : Introduction

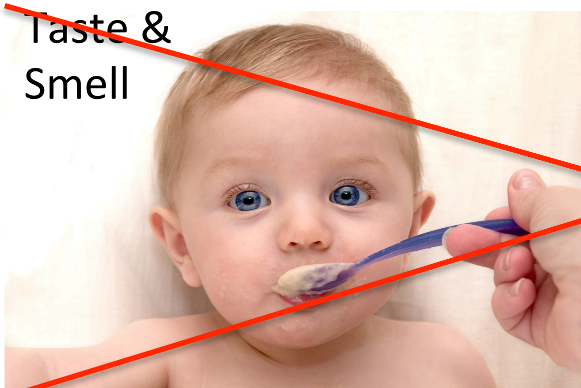
What is visualization?

How can we acquire information?

Do they effective ?

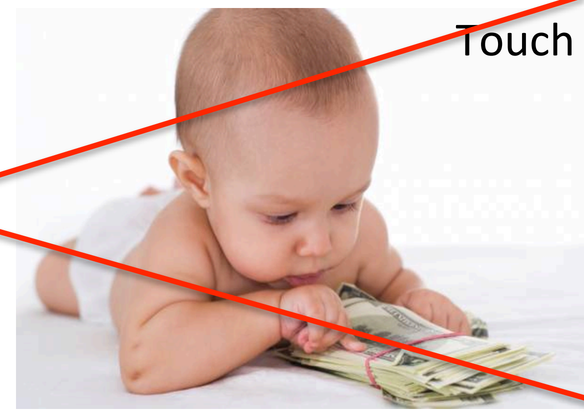
Chemical Signal

Taste &
Smell



Physical Signal

Touch



Bandwidth: ??? kb/s ??? kb/s

Can not be estimated by information theory

Do they effective ?

Sound Signal

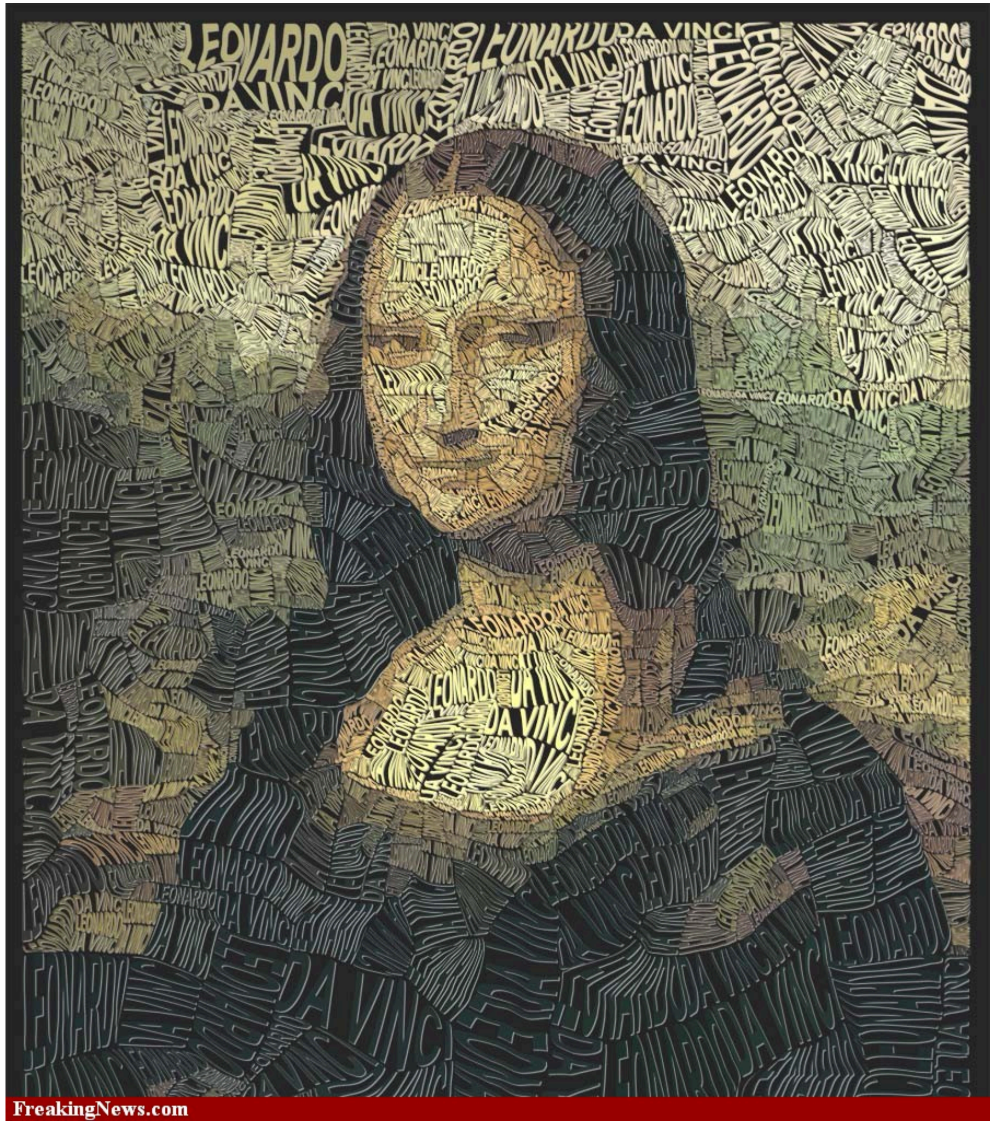
Electronic / Light Signal

Bandwidth: **about 0.1 KB / s**

> 100 MB/s

"Information Visualization, Perception for Design" 3rd Edition, by Colin Ware

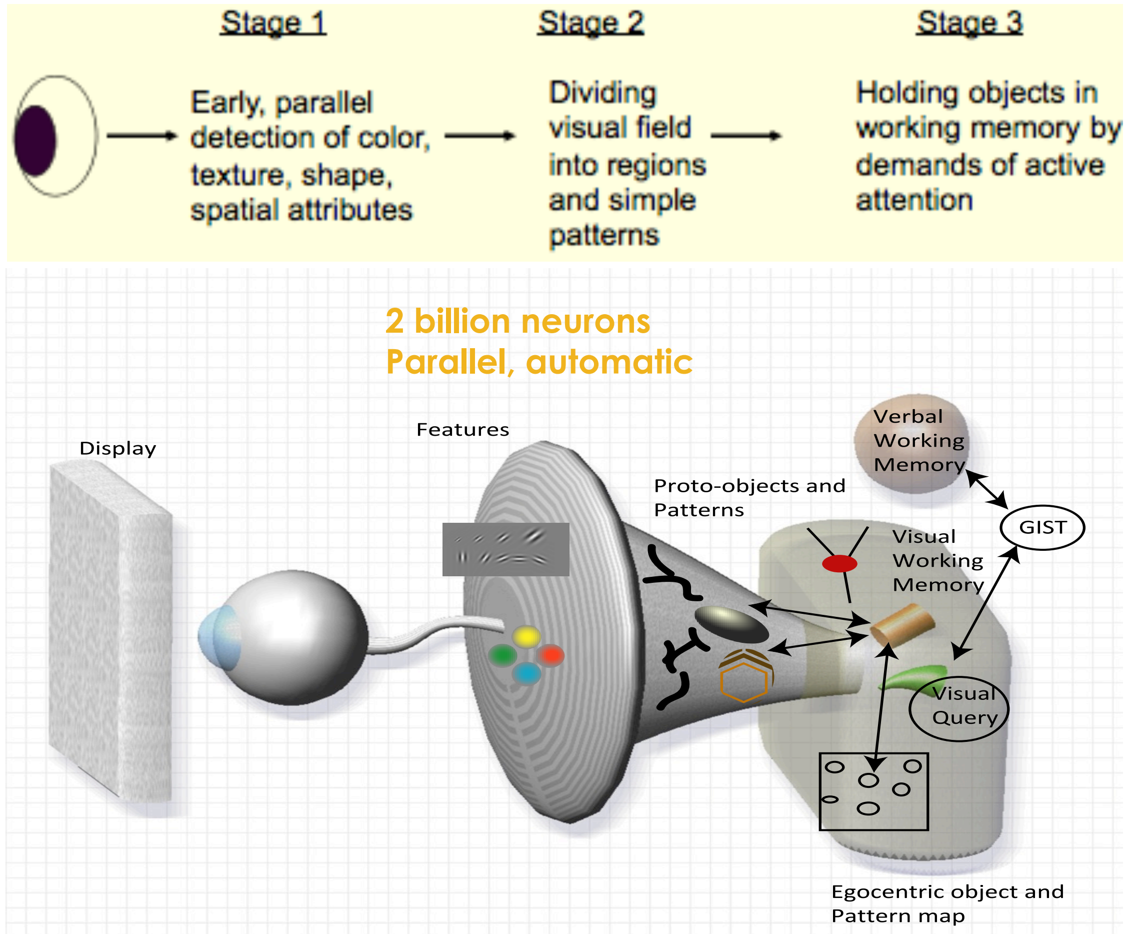
A picture worth 1000 Words



The Visual Thinking Pipeline

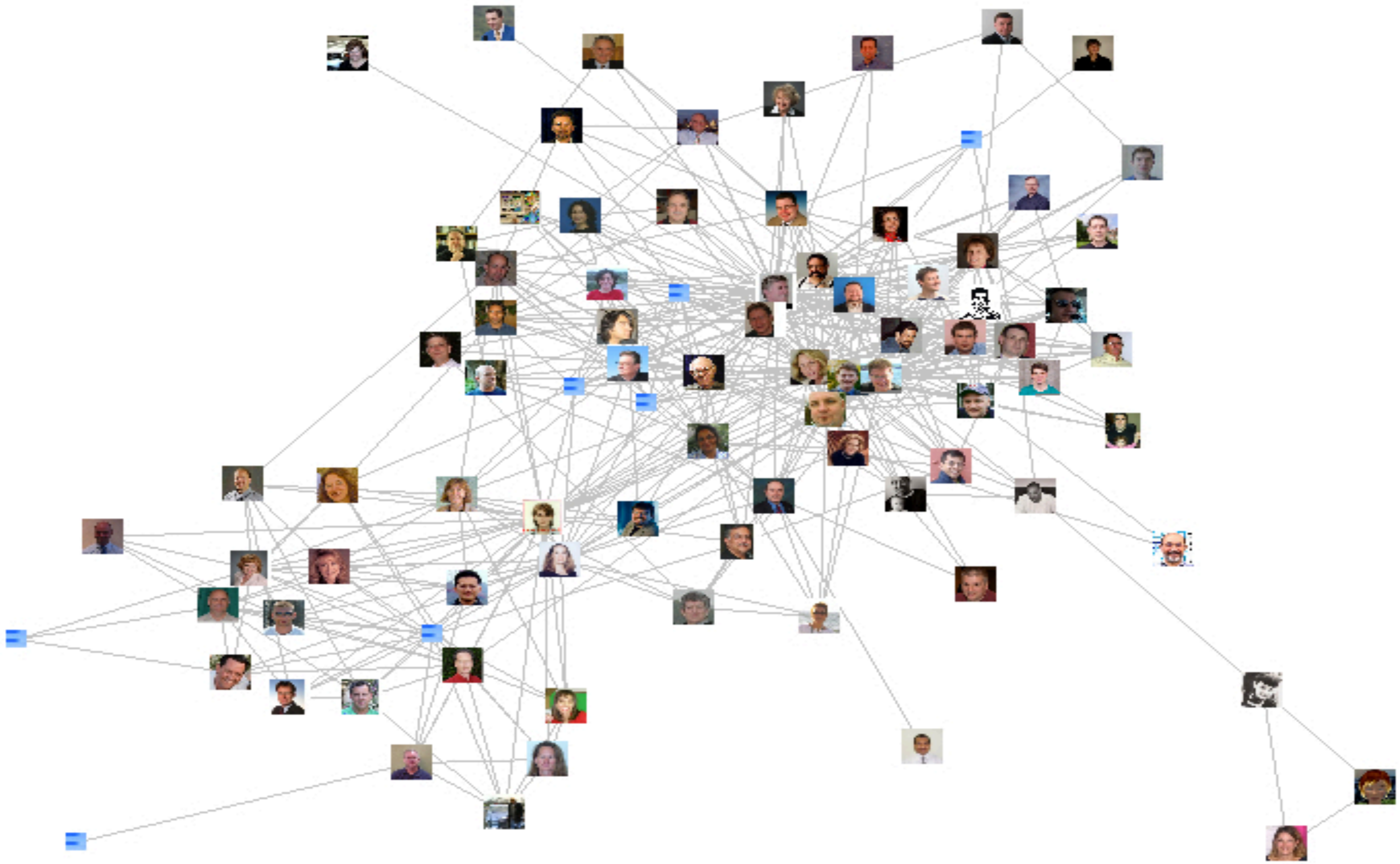
Parallel Processing to Extract Low-Level Visual Properties such as color, shape, etc

Sequential Goal-Oriented Processing



Example

Example

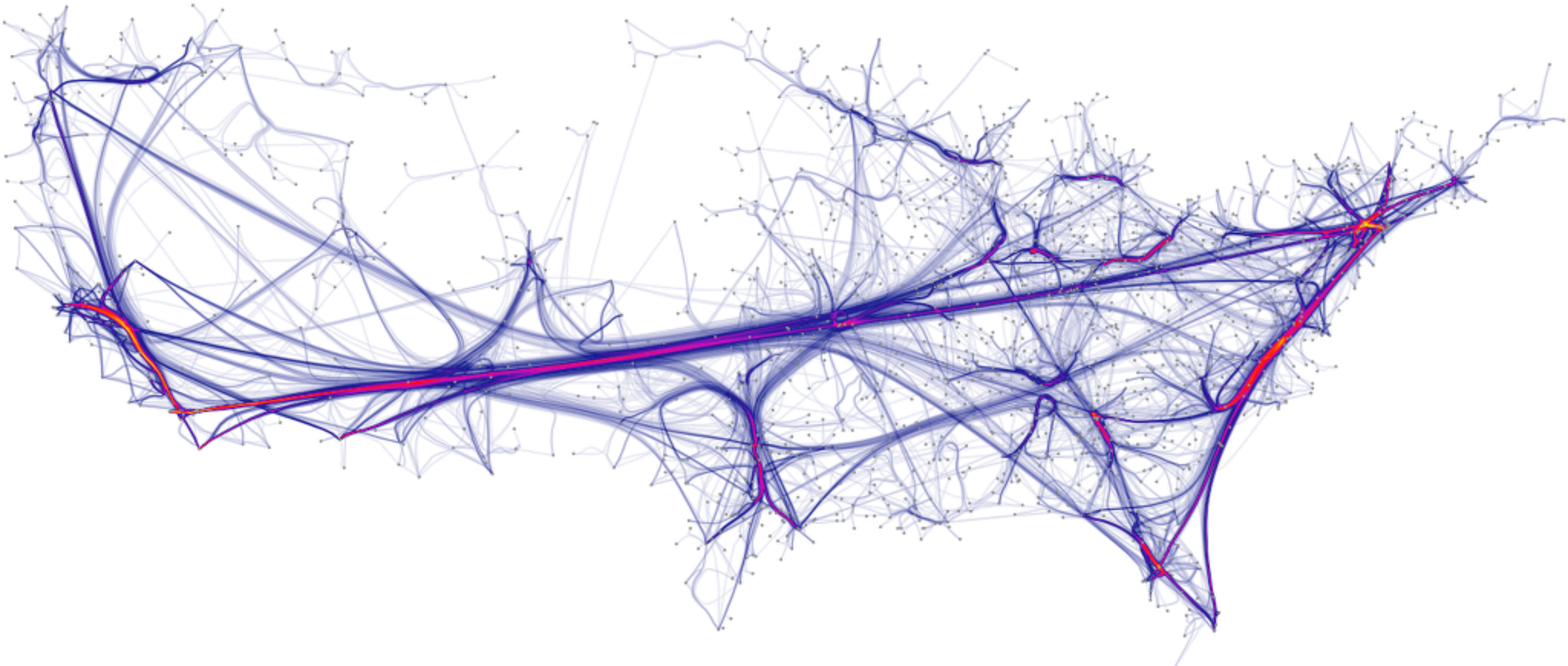


Ching-Yung Lin, **Nan Cao**, Shixia Liu, Spiros Papadimitriou, Jimeng Sun, and Xifeng Yan. SmallBlue: Social Network Analysis for Expertise Search and Collective Intelligence. ICDE 2009

Record of human activities to help find data patterns

Visualization is used for help reasoning and decision making

Summarization of Airlines in United States



Holten, Danny, and Jarke J. Van Wijk. "Force-Directed Edge Bundling for Graph Visualization." Computer Graphics Forum. Vol. 28. No. 3. Blackwell Publishing Ltd, 2009.

What is Information Visualization ?

"The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed."

-- Oxford English Dictionary

"... finding the artificial memory that best supports our natural means of perception.''

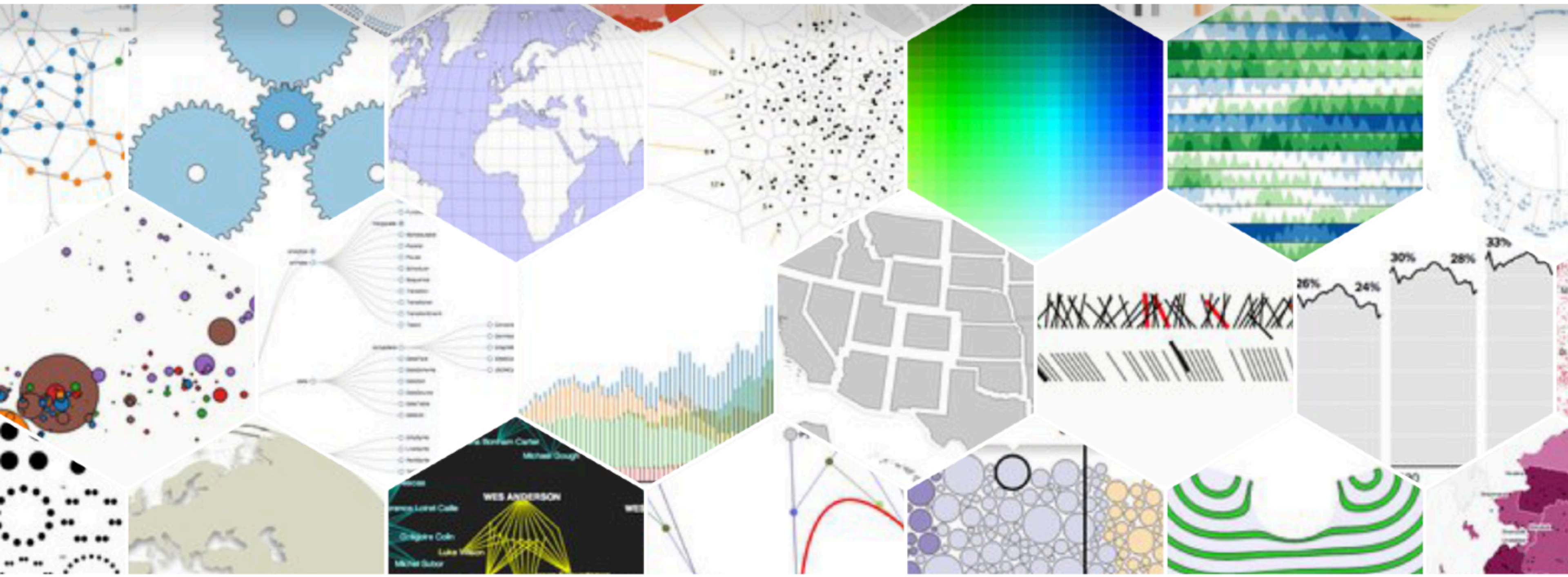
-- Bertin, 1983

The use of computer-supported, interactive, visual representations of abstract data to amplify cognition

-- Cart,Mackinlay, Shneiderman, 1999

http://d3js.org

Data-Driven Documents



Why do we create visualization?

Counting the number of 3s in the following Text:

1235693234870452973467
0378937043679709102539

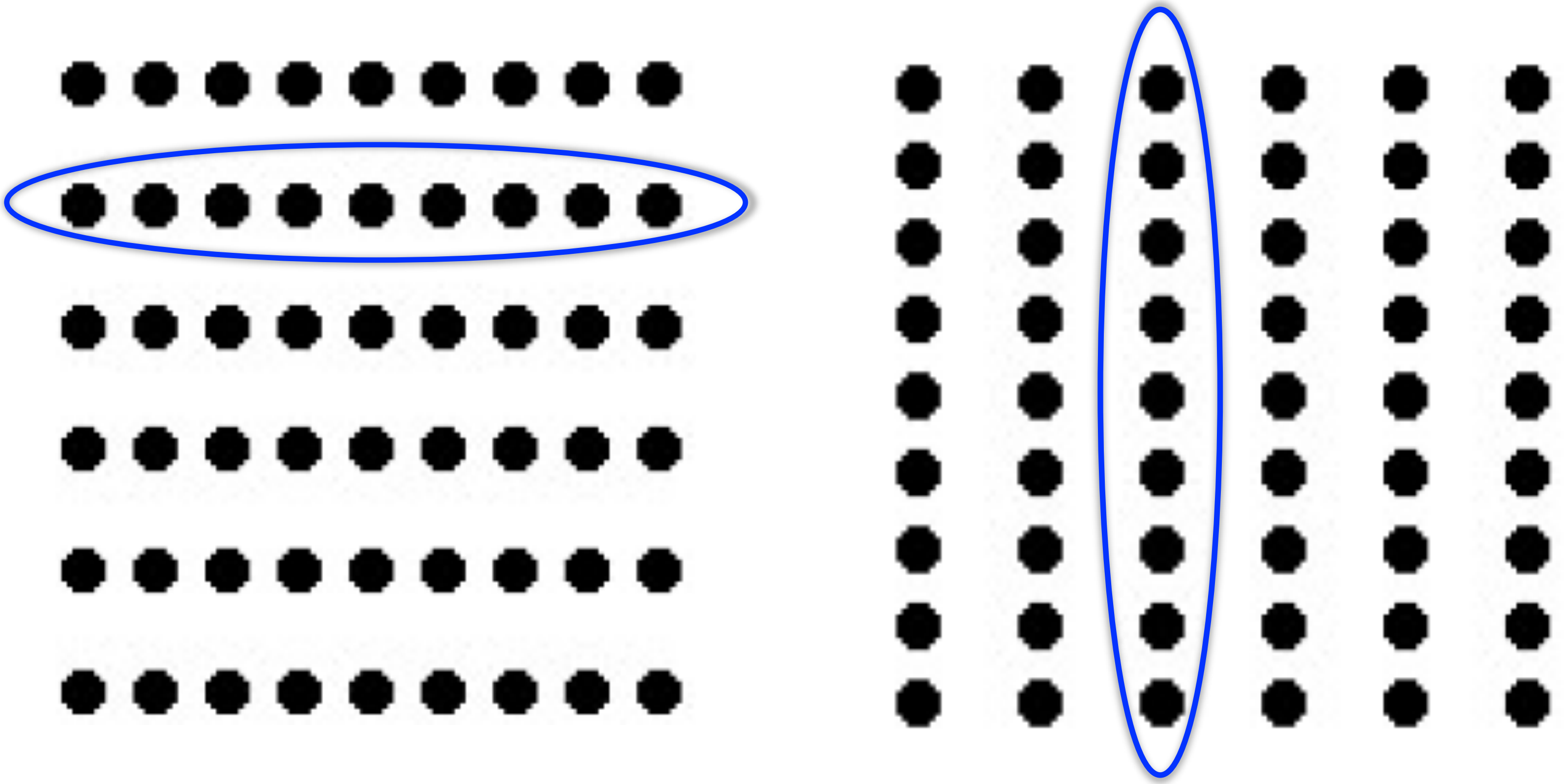
Find Patterns

Counting the number of 3s in the following Text:

12356932348704529734670378937043679709102539

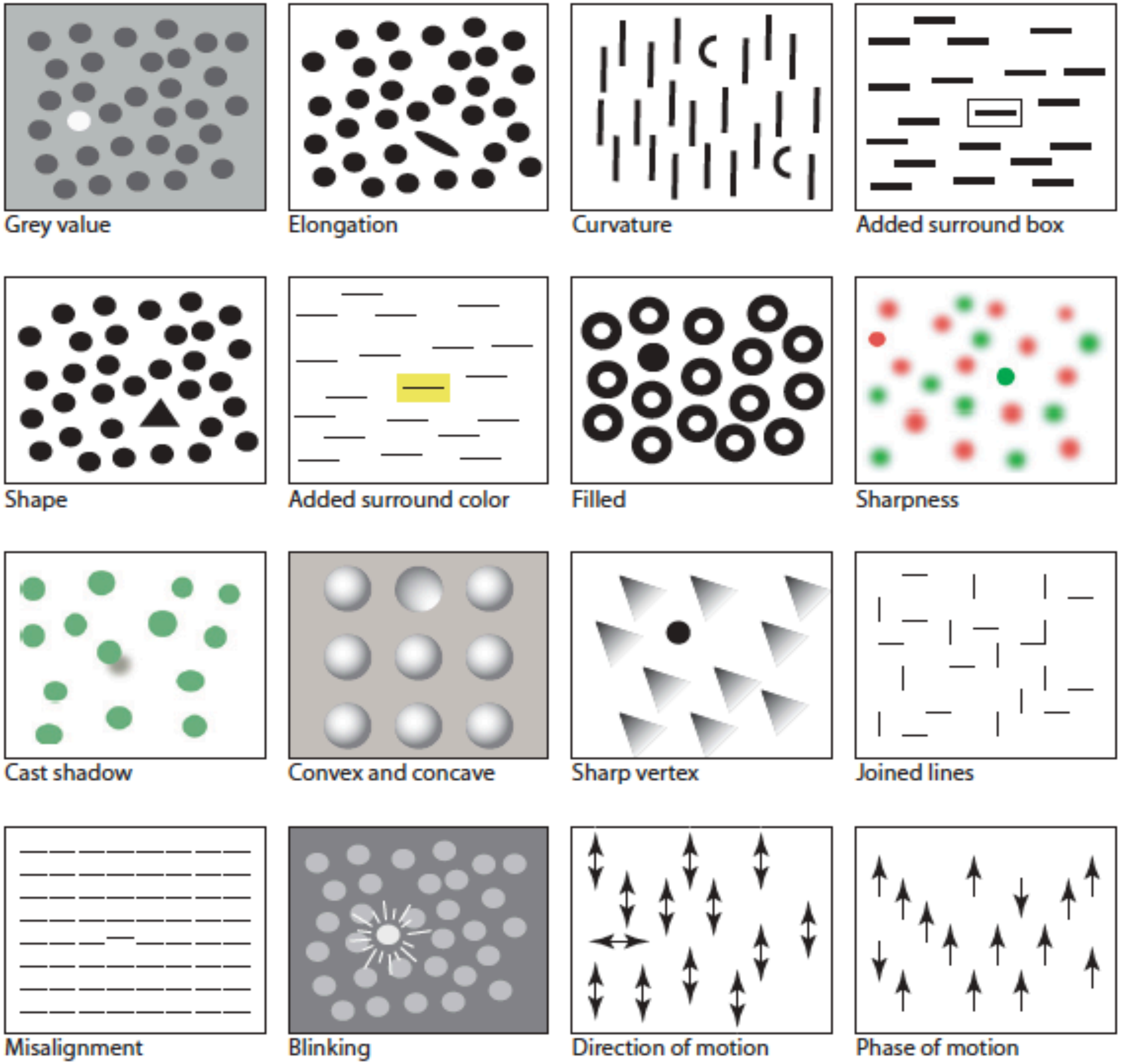
Find Patterns

Can you identify the groups of dots in the following figures ?



Law of Proximity
we tend to group elements that are closest to each other

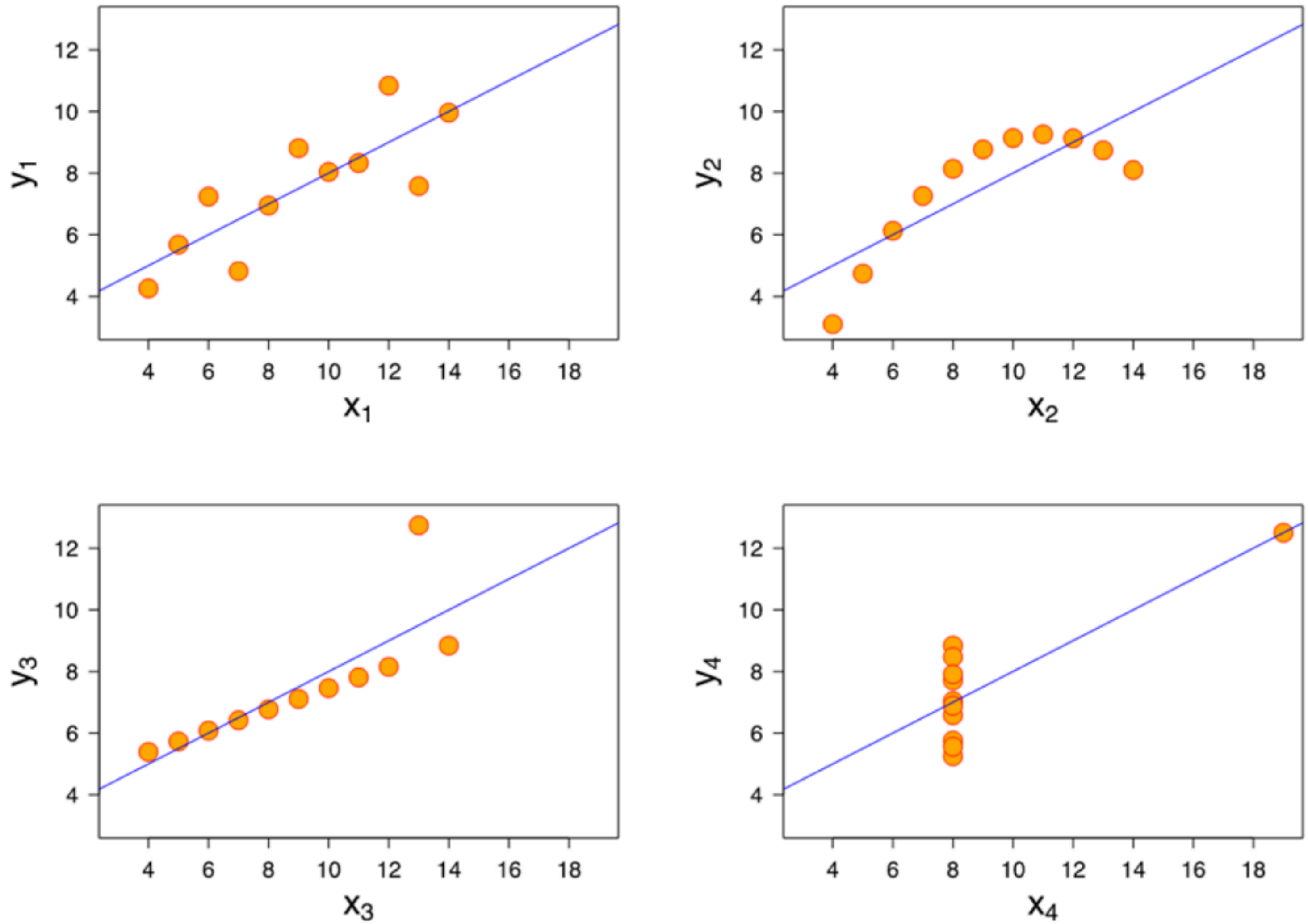
Find Patterns: Pre-Attentive Visual Channels



Why do we create Visualization?

	Set A		Set B		Set C		Set D	
	X	Y	X	Y	X	Y	X	Y
0	10	8.04	10	9.14	10	7.46	8	6.58
1	8	6.95	8	8.14	8	6.77	8	5.76
2	13	7.58	13	8.74	13	12.74	8	7.71
3	9	8.81	9	8.77	9	7.11	8	8.84
4	11	8.33	11	9.26	11	7.81	8	8.47
5	14	9.96	14	8.10	14	8.84	8	7.04
6	6	7.24	6	6.13	6	6.08	8	5.25
7	4	4.26	4	3.10	4	5.39	19	12.50
8	12	10.84	12	9.13	12	8.15	8	5.56
9	7	4.82	7	7.26	7	6.42	8	7.91
10	5	5.68	5	4.74	5	5.73	8	6.89
mean	9.00	7.50	9.00	7.50	9.00	7.50	9.00	7.50
std	3.32	2.03	3.32	2.03	3.32	2.03	3.32	2.03
corr	0.82		0.82		0.82		0.82	
lin. reg.	$y = 3.00 + 0.500x$		$y = 3.00 + 0.500x$		$y = 3.00 + 0.500x$		$y = 3.00 + 0.500x$	

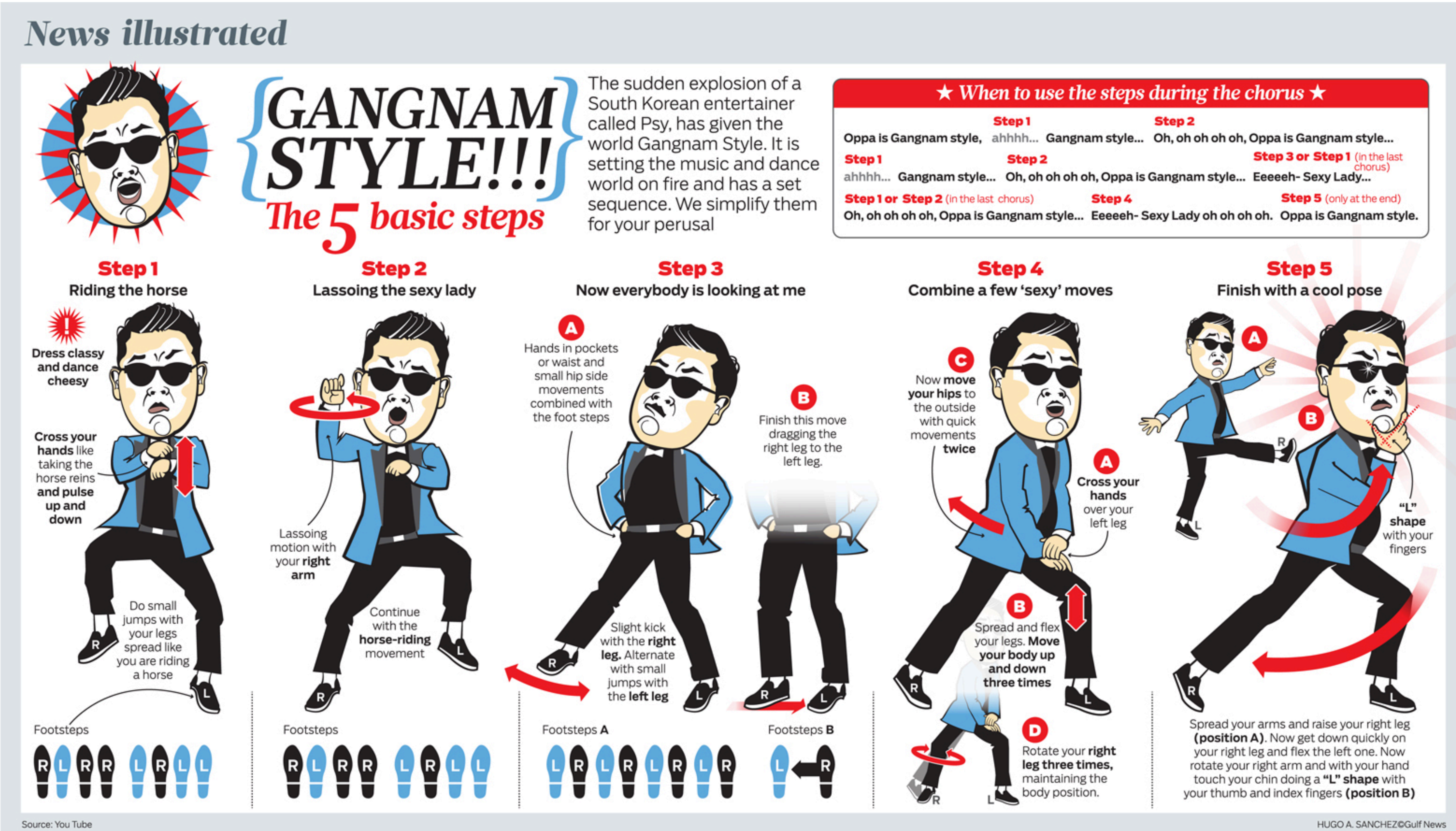
Seeing data in context



Why do we create visualization ?

Columbia University

A picture is worth a thousand words



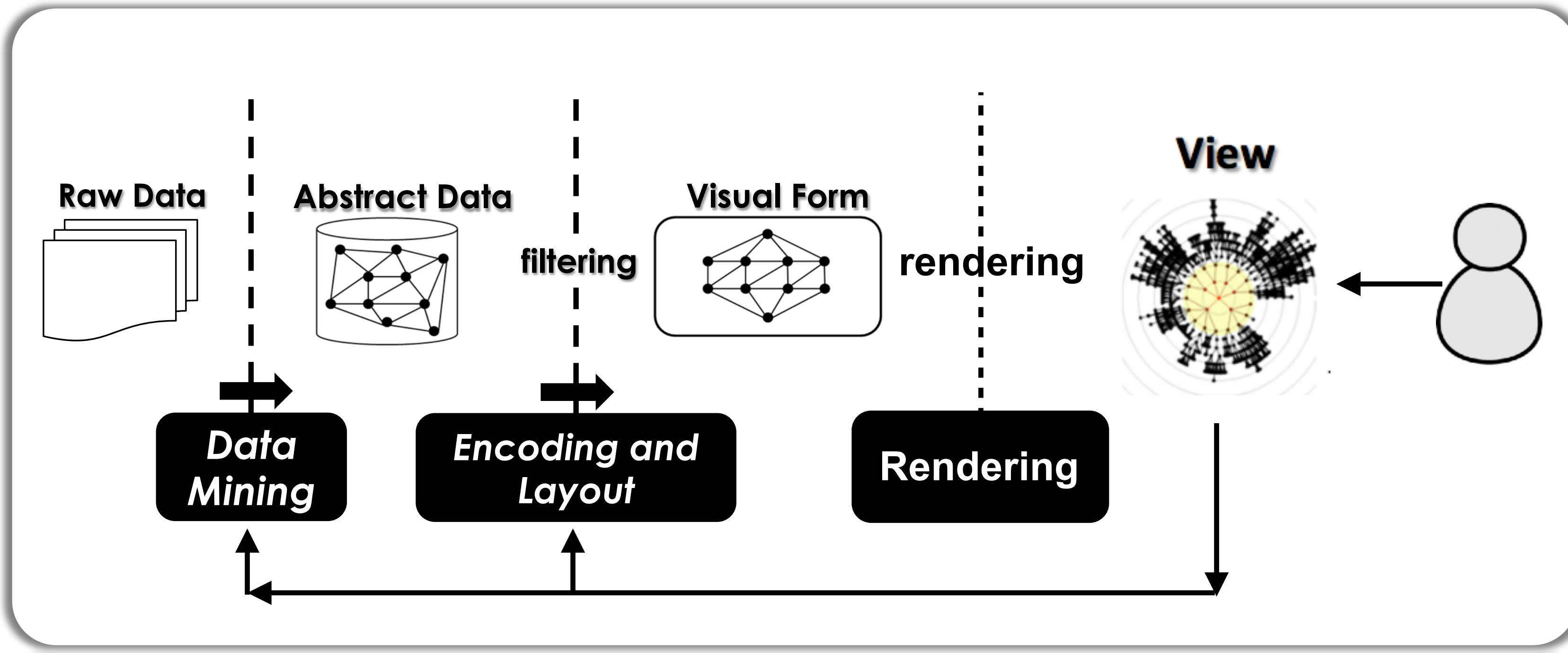
A better communication method

Some other reasons

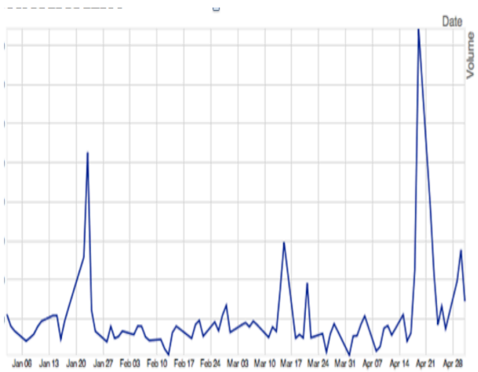
See data in context
Find patterns
Telling a story
Attract attentions
Communicate information with others
Summarization and interpretation
Graphical calculation
Expend memory
Inspire people

Existing Visualisation Techniques

Visualization & Visual Analysis Reference Model



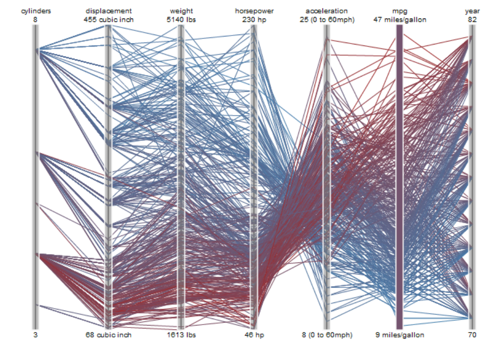
Taxonomy by data types



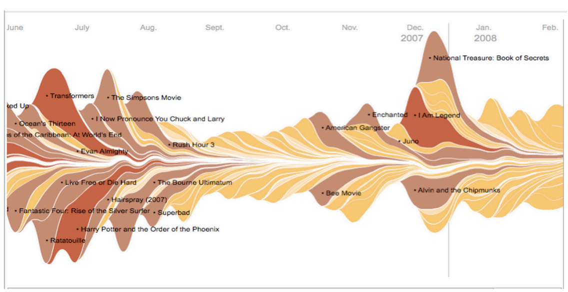
1D

2D

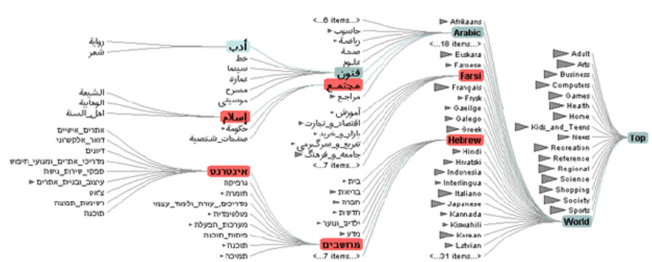
3D



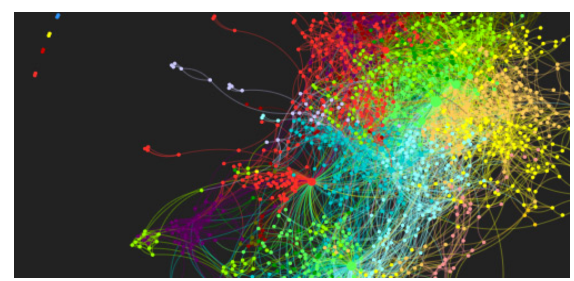
Multi-D



Temporal

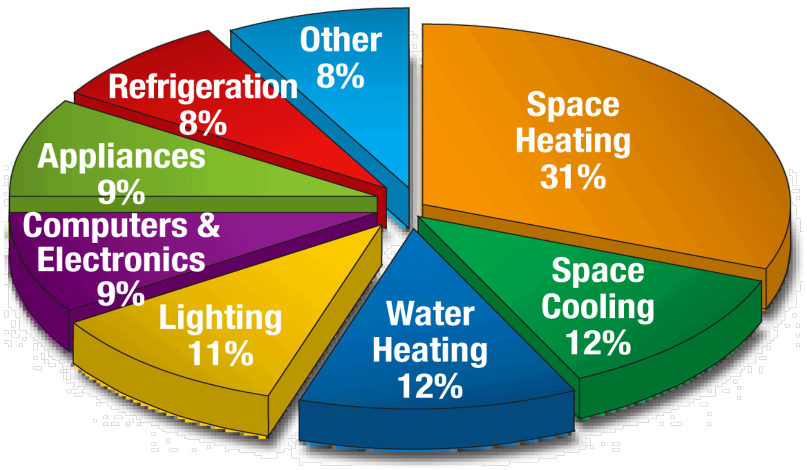


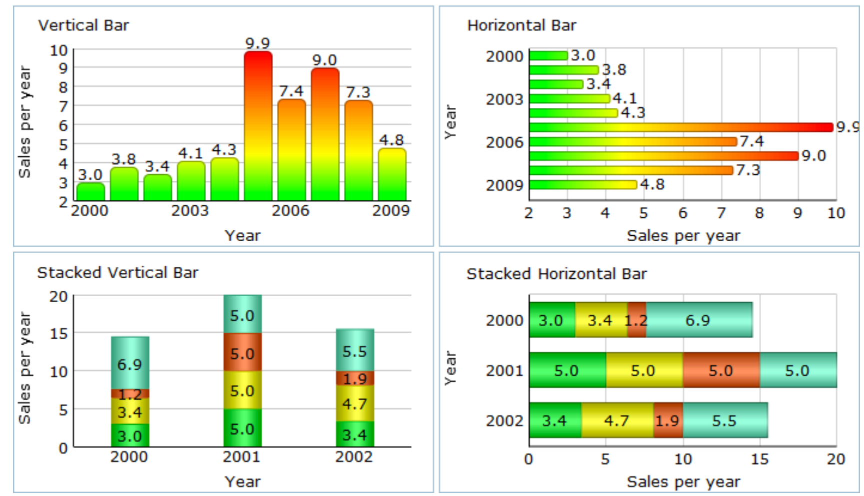
Tree

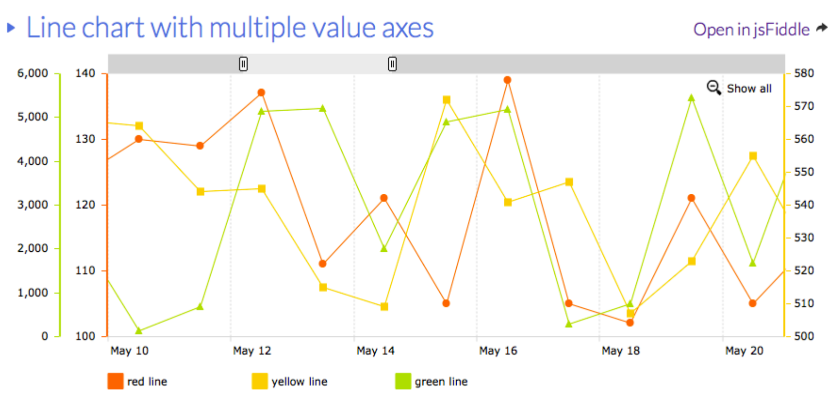


Graph

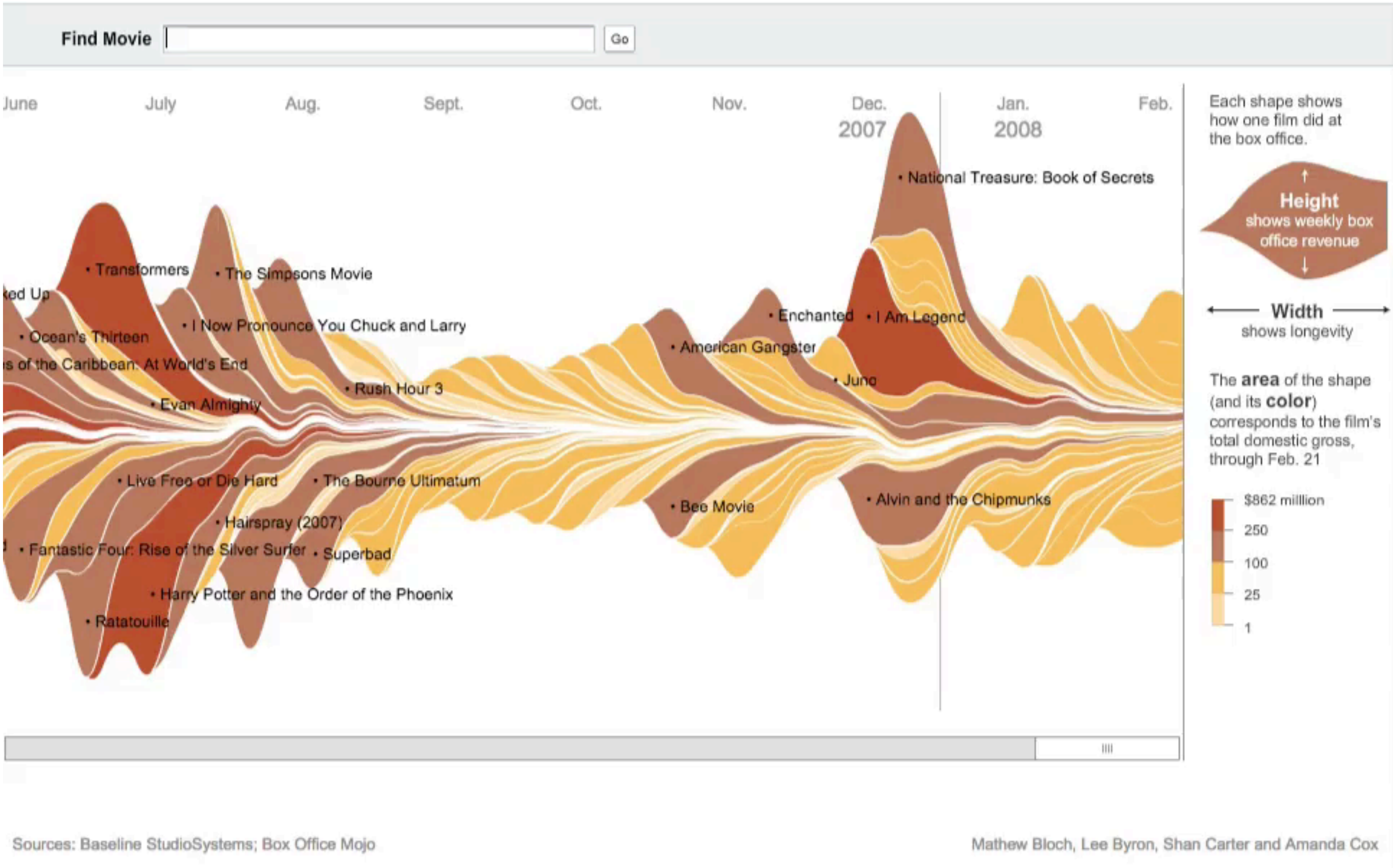
Examples: Visualizing 1D Numerical Data







Example : Visualizing 1D Ordinal Data

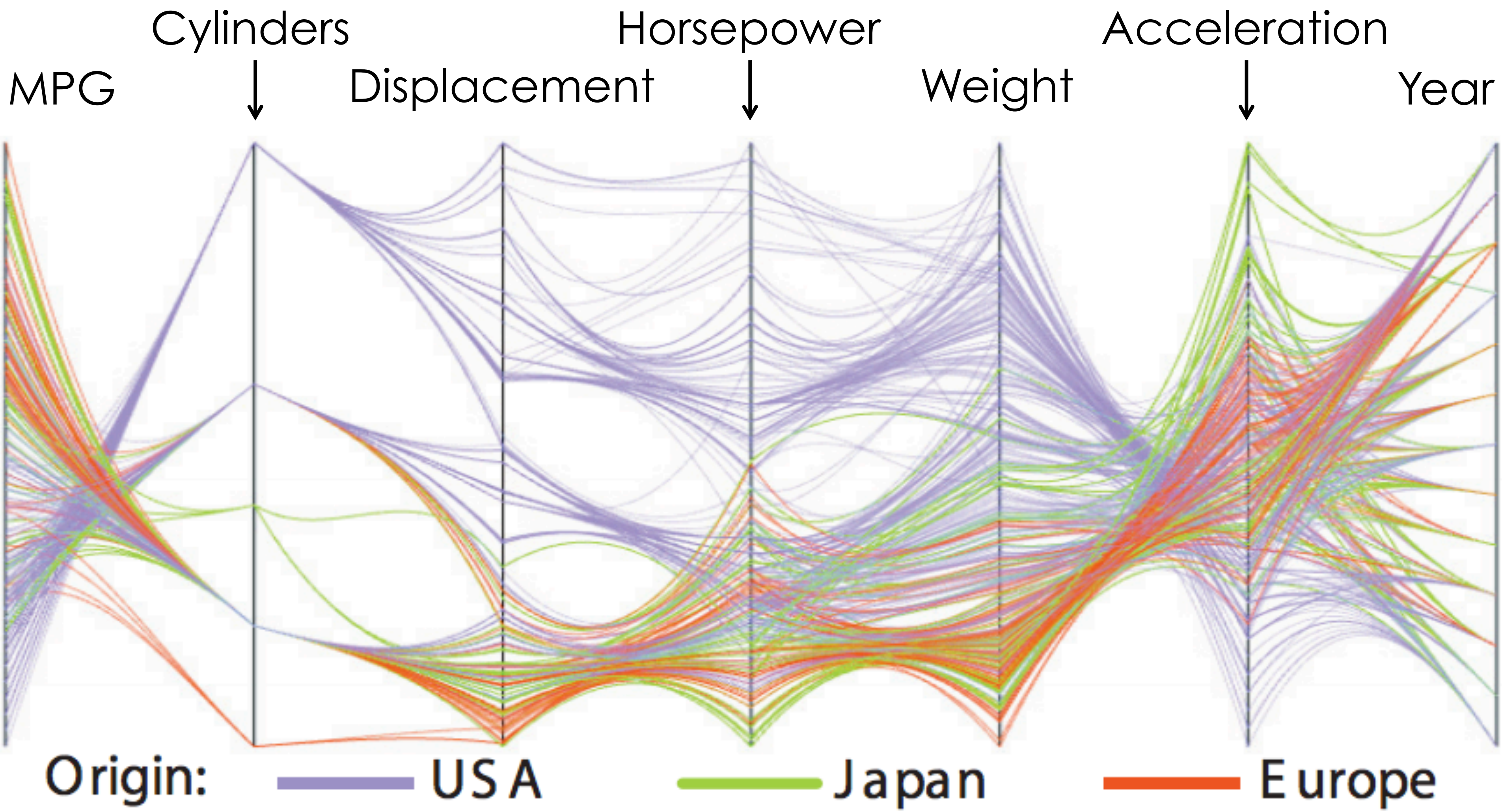


http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html

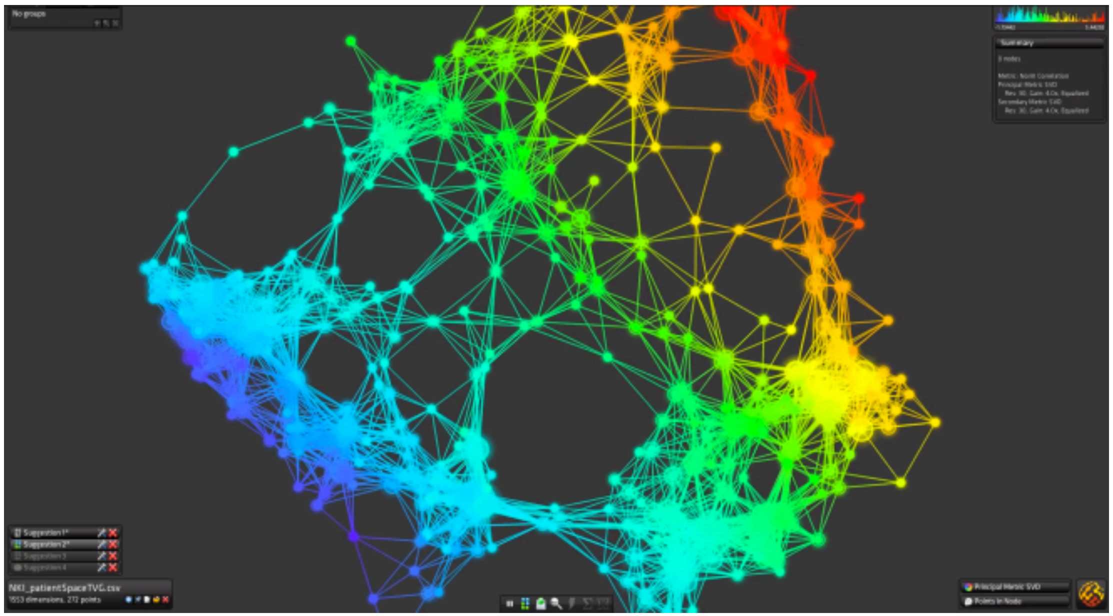
Examples: 2D Data

Size of each Cell: Stock Market Value
Color: Stock Change

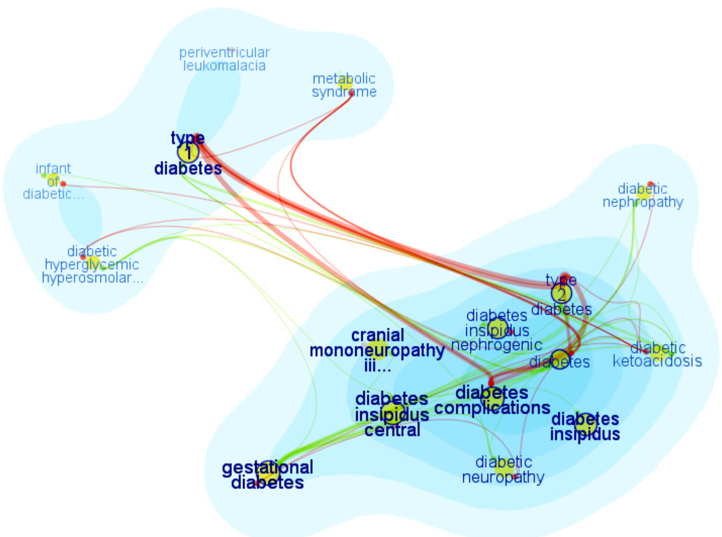
Example：Multi-Dimensional Data

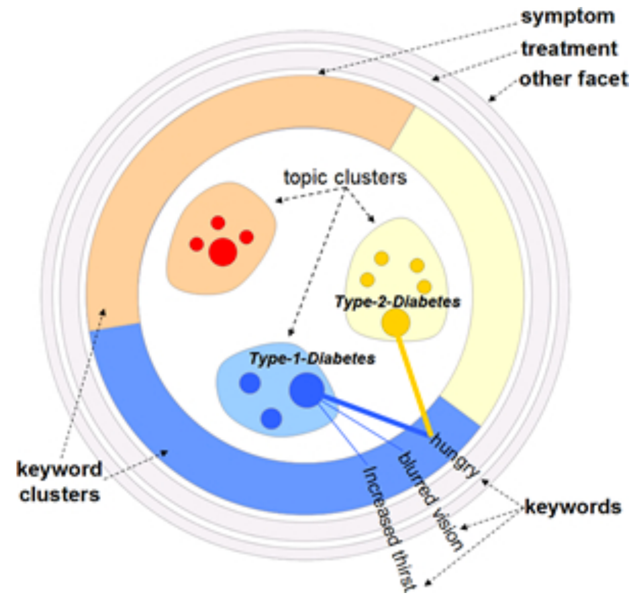


Examples: Visualizing Structured Data

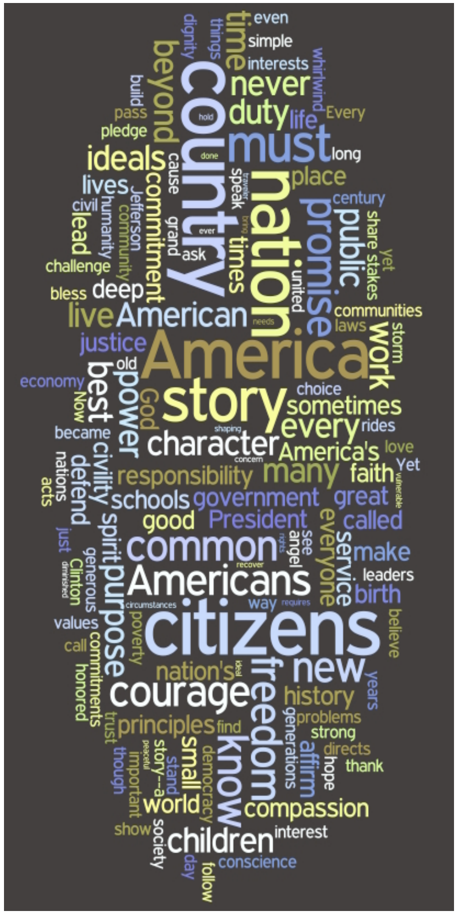


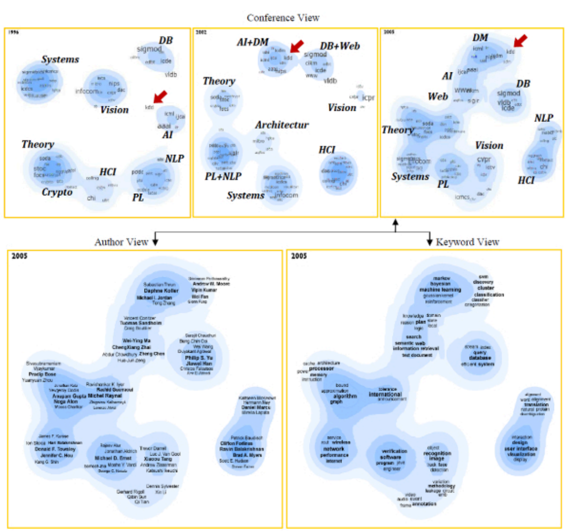
Examples: Visualizing Unstructured Data

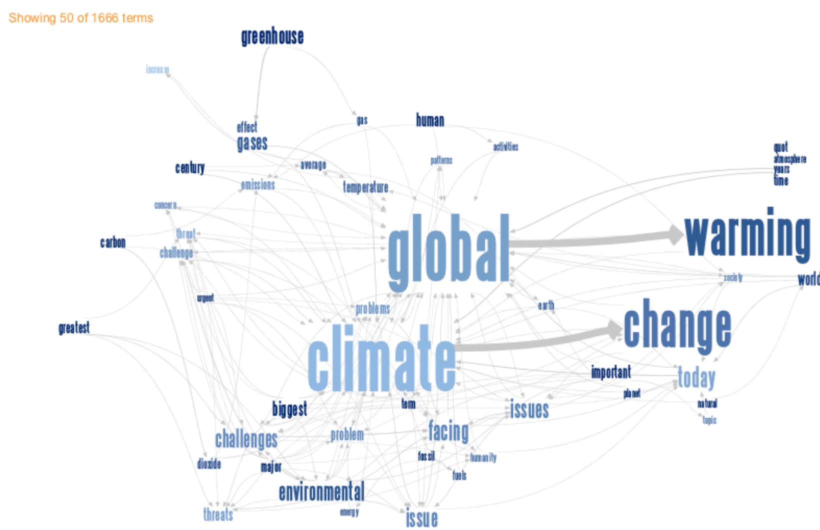




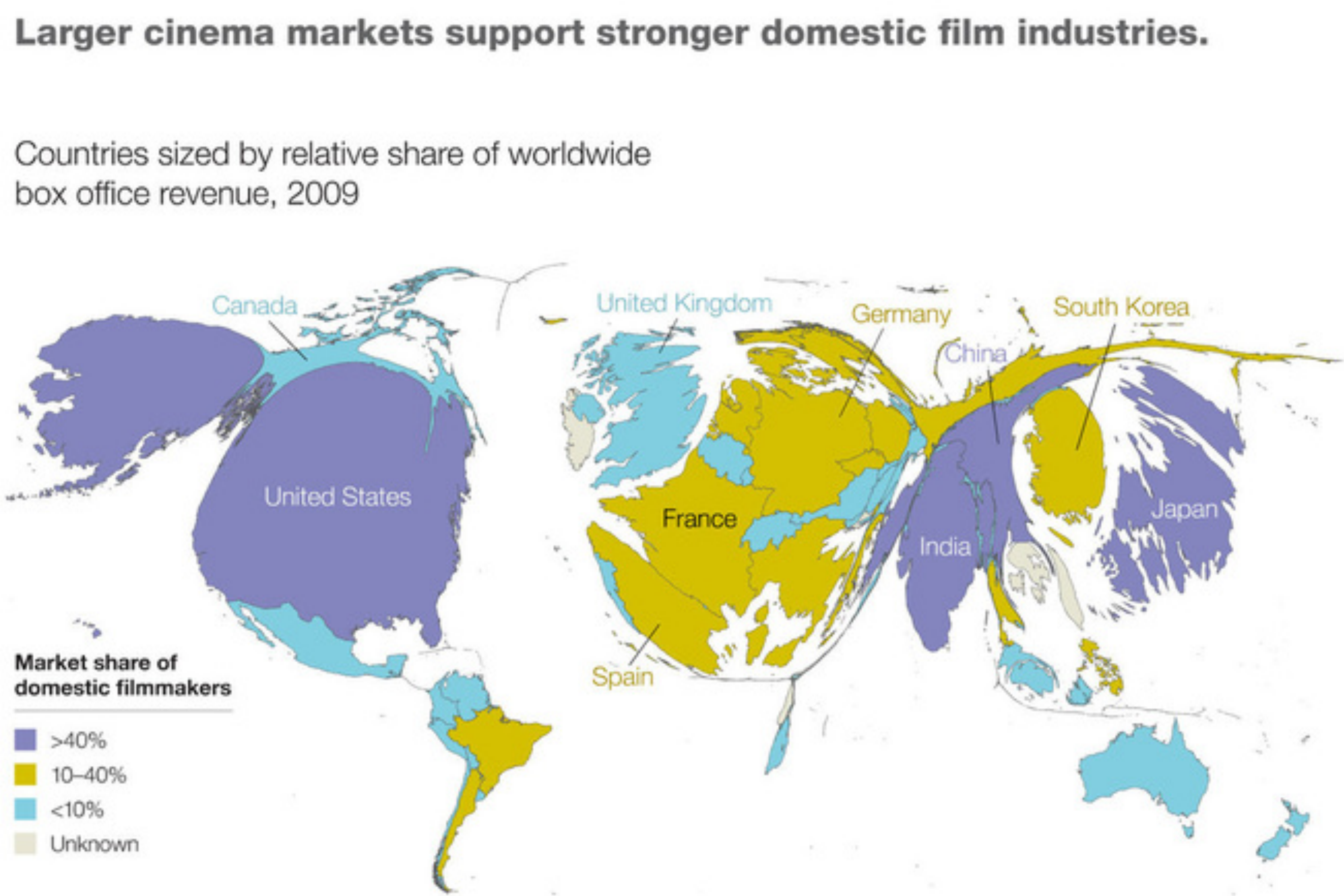
Visualization of Text Documents



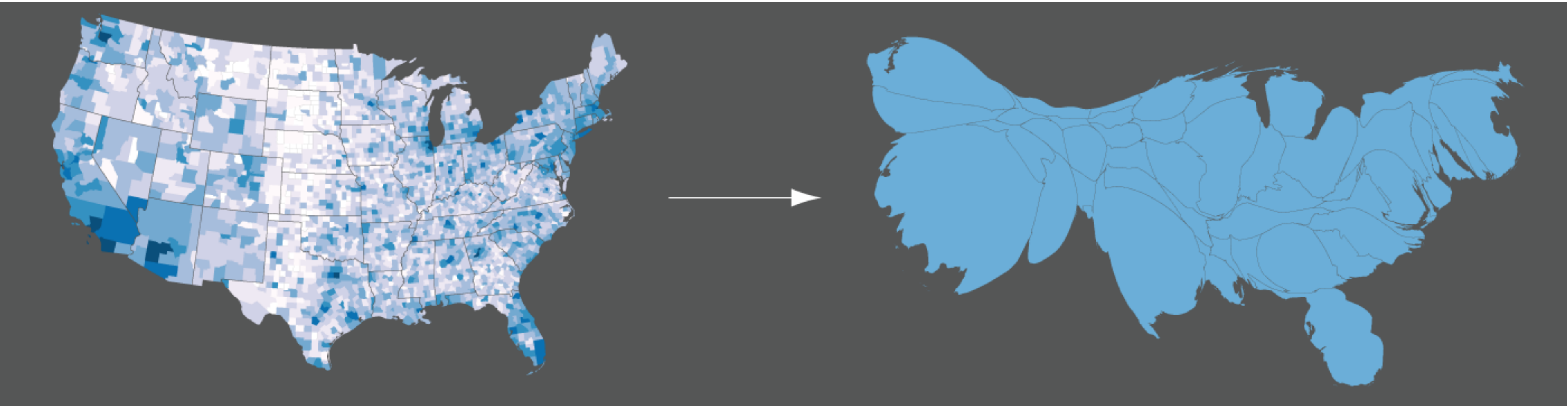


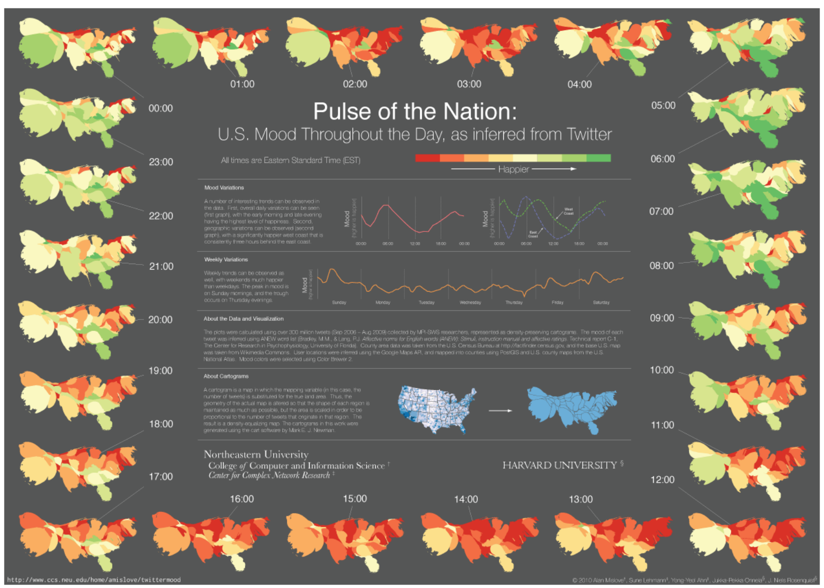


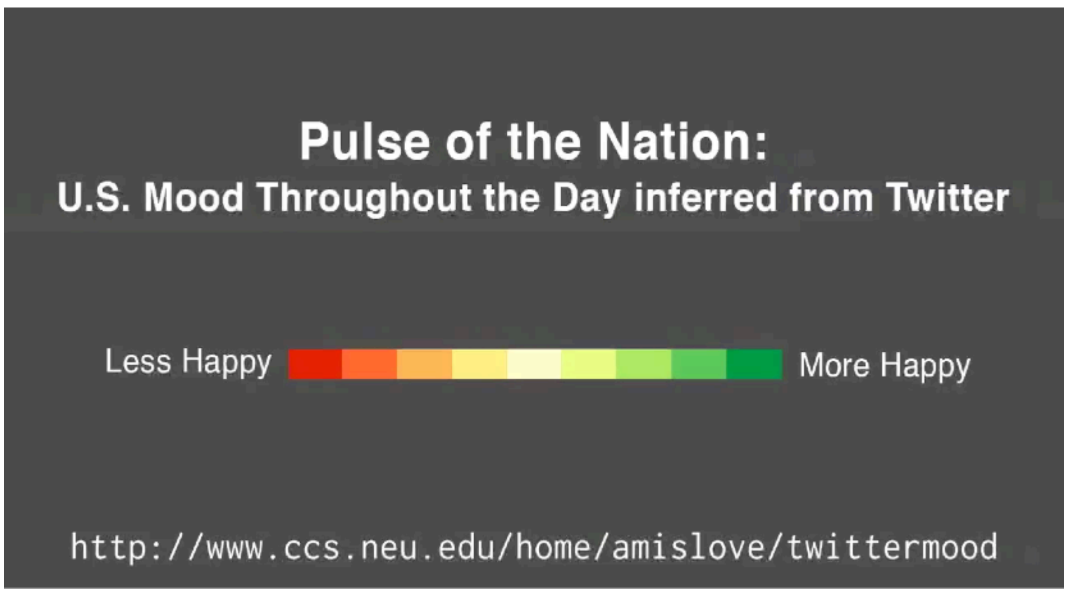
Examples: Geospatial



Examples: Visualizing Spatial Temporal Data







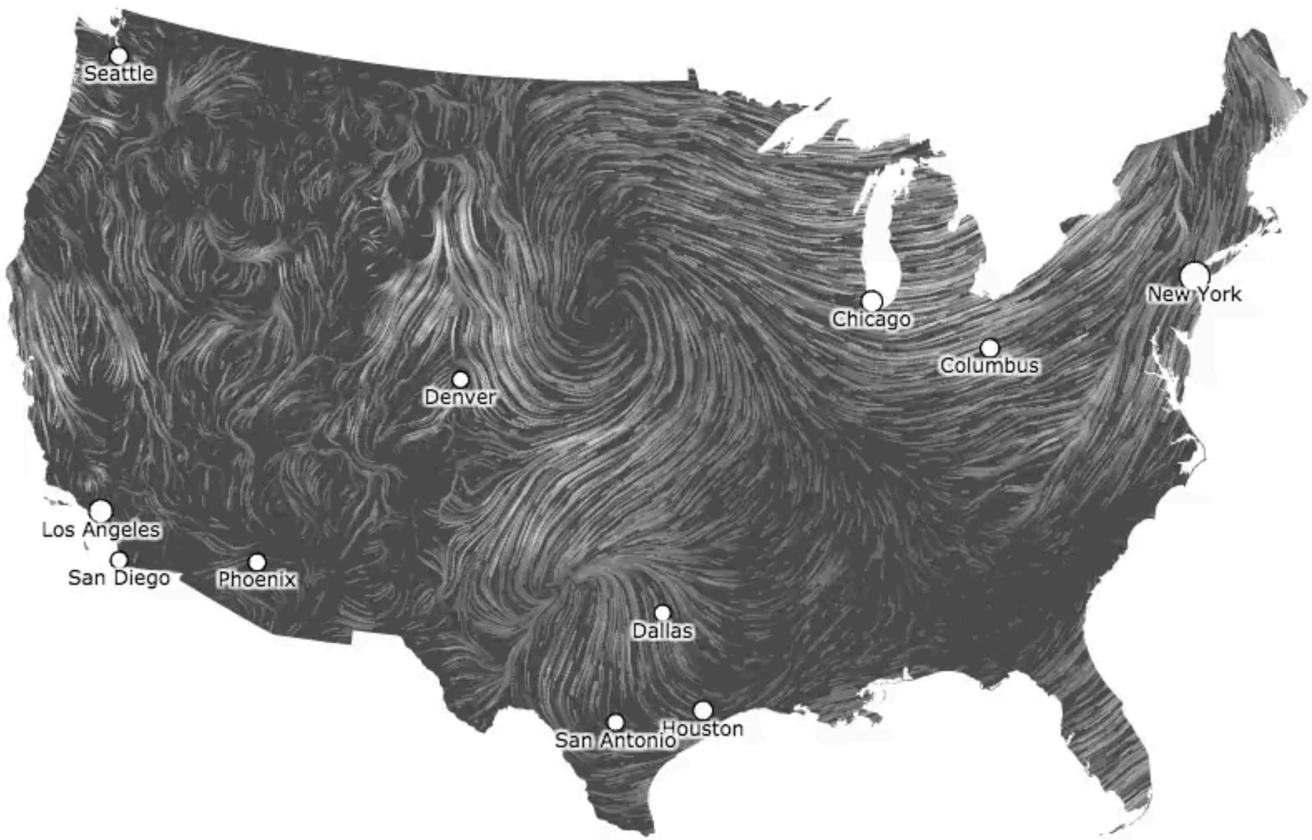
Examples: Visualizing Spatial Temporal Data

Columbia University

wind map

Dec. 3, 2014
11:35 am EST
(time of forecast download)

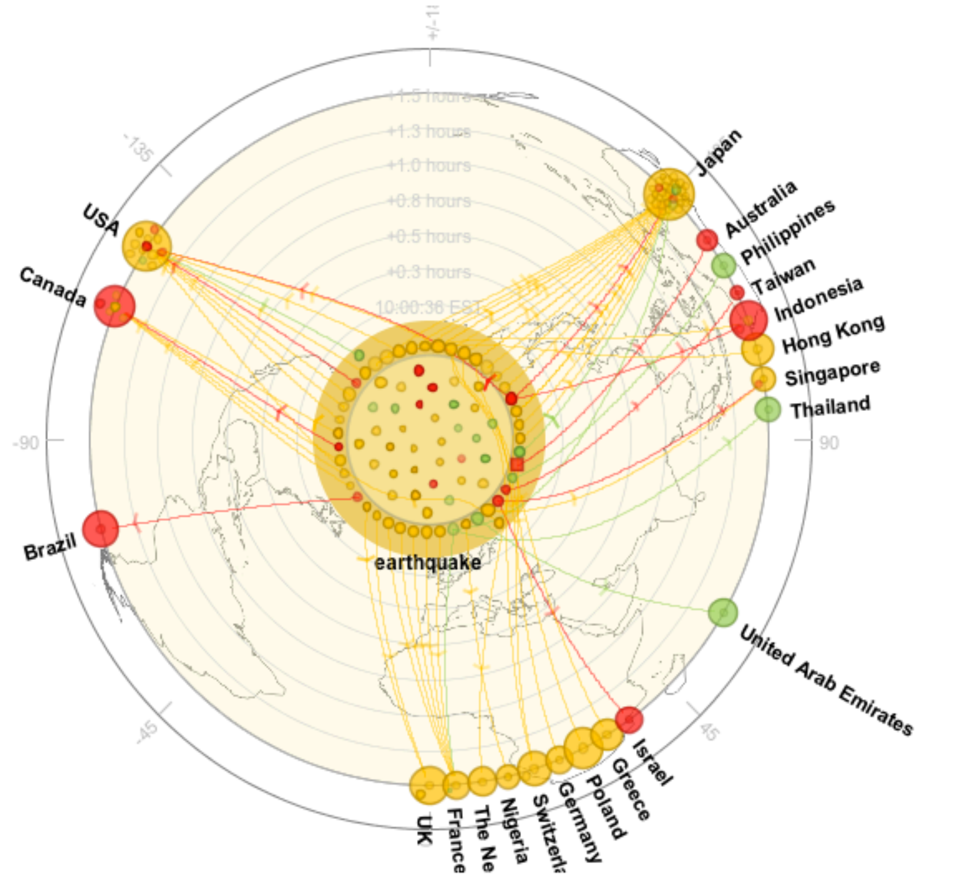
top speed: **31.5 mph**
average: **8.2 mph**



1 mph
3 mph
5 mph
10 mph
15 mph
30 mph

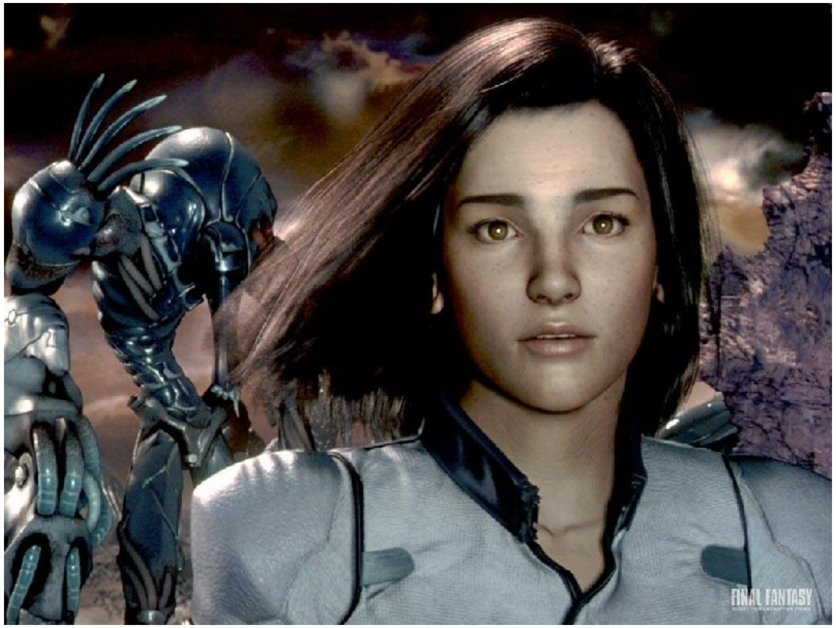
http://hint.fm/wind/

Visualization is not just a beautiful picture

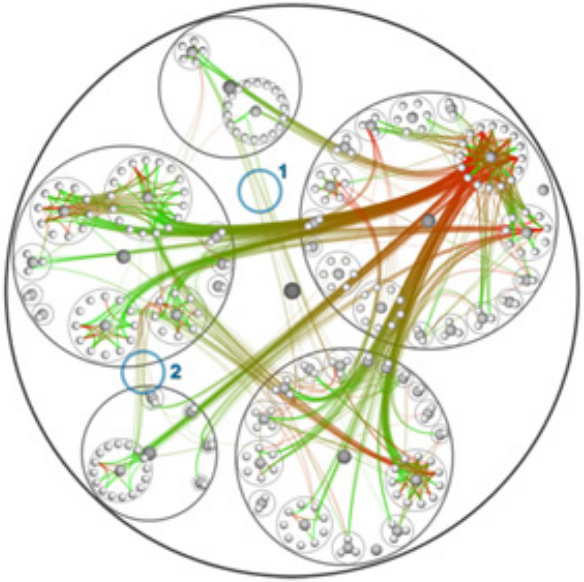


The purpose of visualization is to reveal the insight of the data

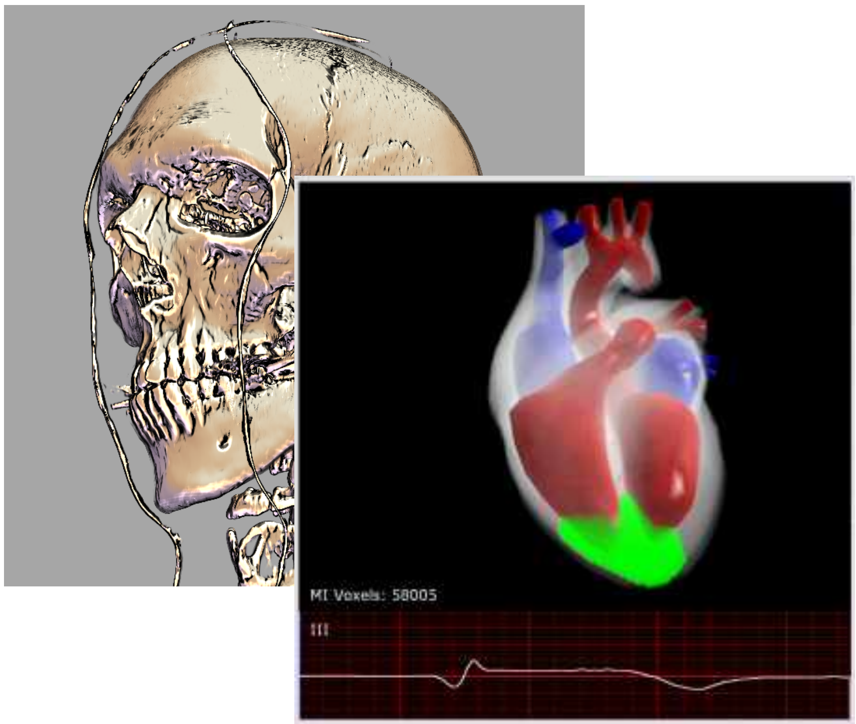
InfoVis vs Computer Graphics



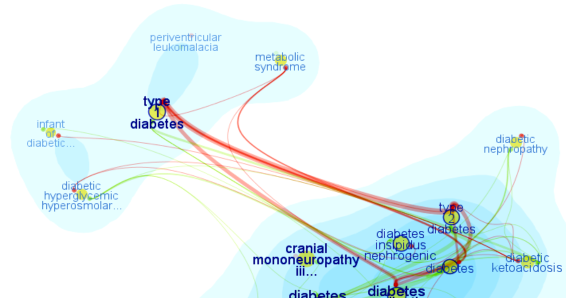
Realism

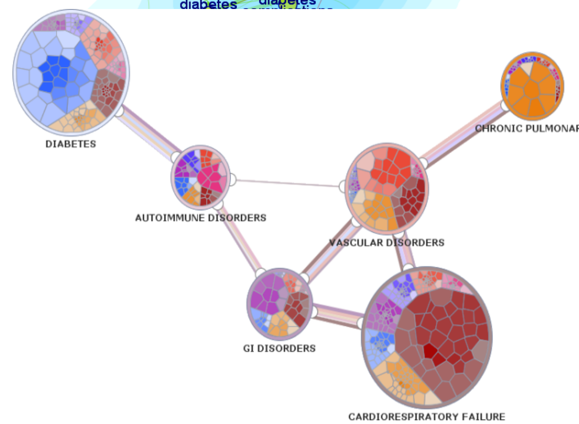


Information



Physical Data

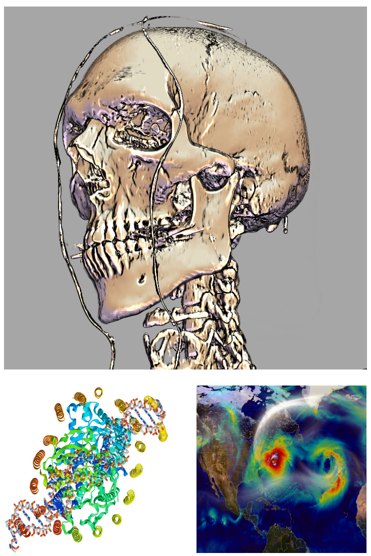




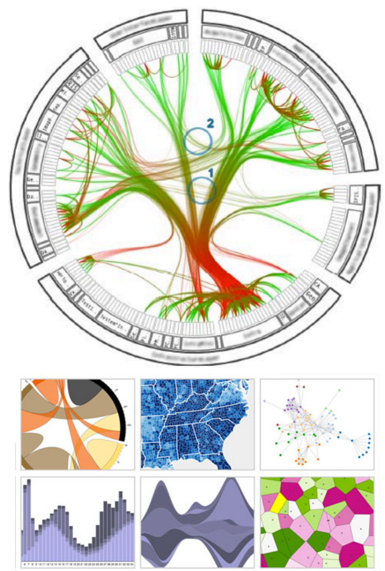
Artificial Data

Three Sub-areas

Scientific Visualization (SCIVIS)	Information Visualization (InfoVis)	Visual Analysis (VA)



Physical Data



Abstract Data

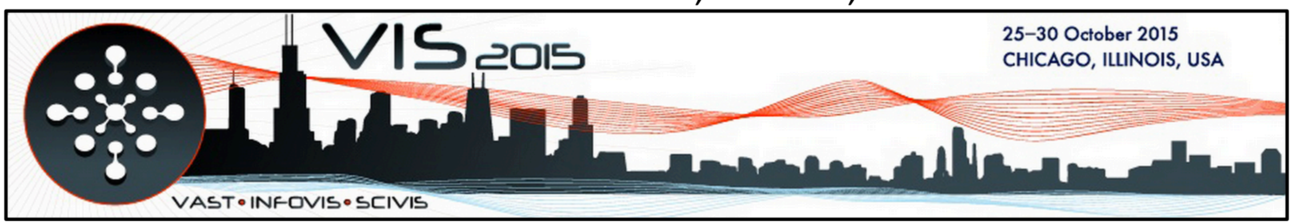
InfoVis
Data Mining
Machine Learning

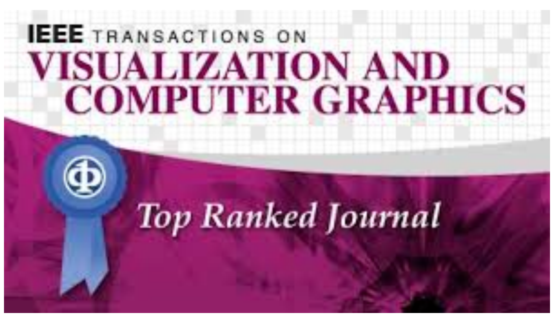
Traditional — Research Trend — Modern Technique

Major Conferences and Journals

Scientific Visualization (SCIVIS)	Information Visualization (InfoVis)	Visual Analysis (VA)

VisWeek: IEEE SCIVIS, INFOVIS, VAST





IEEE Transaction on Visualization and Computer Graphics

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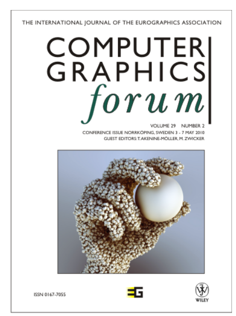


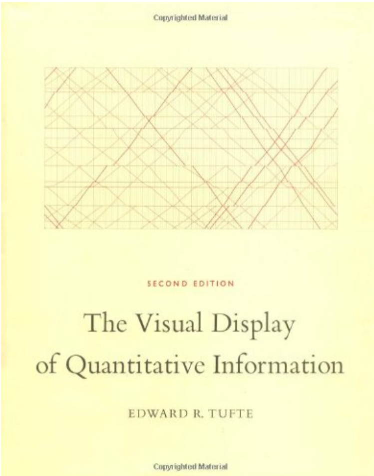
Computer Graphics Forum

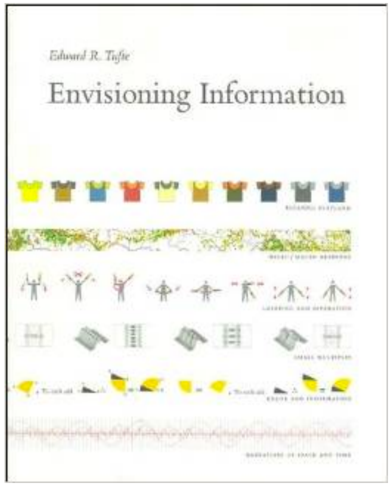
>

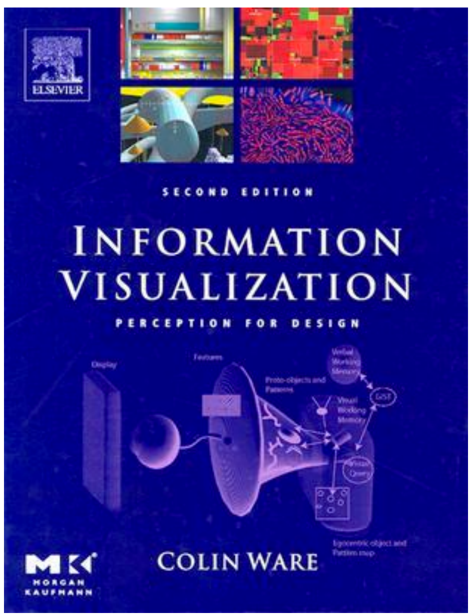
IEEE Computer Graphics and Application

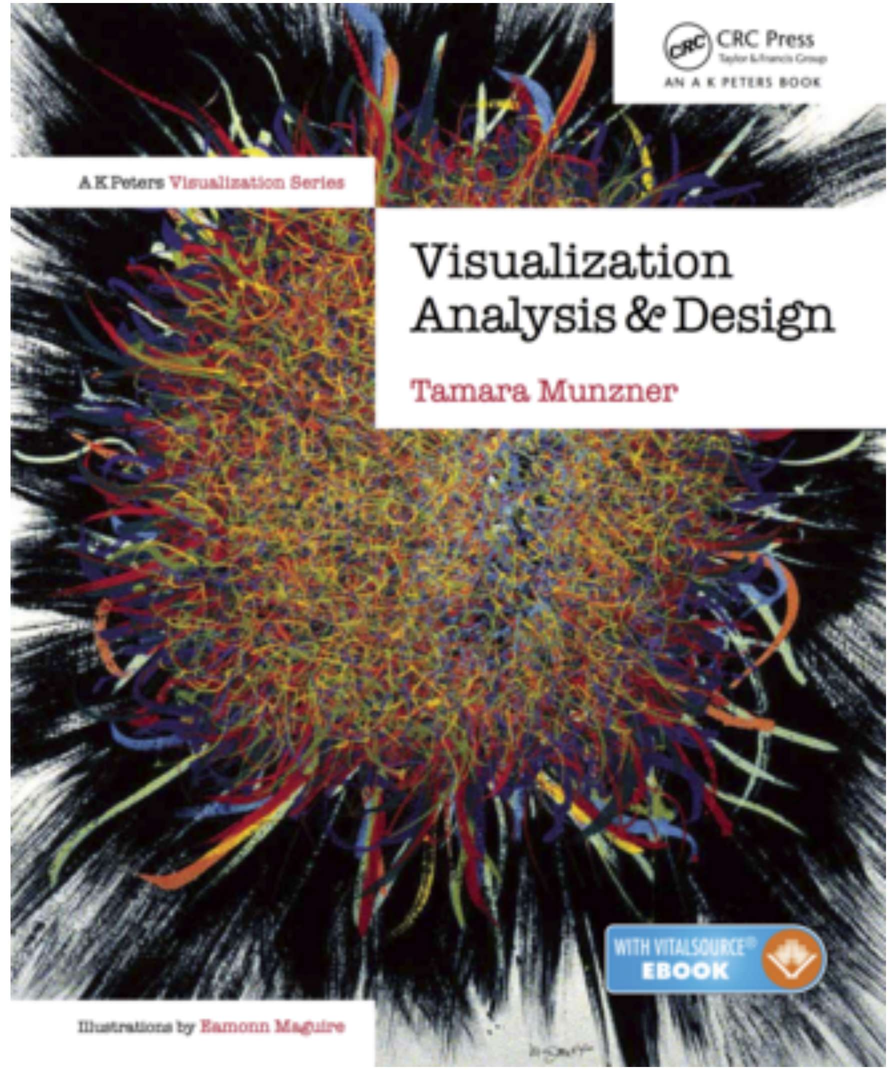
36

Recommended Books







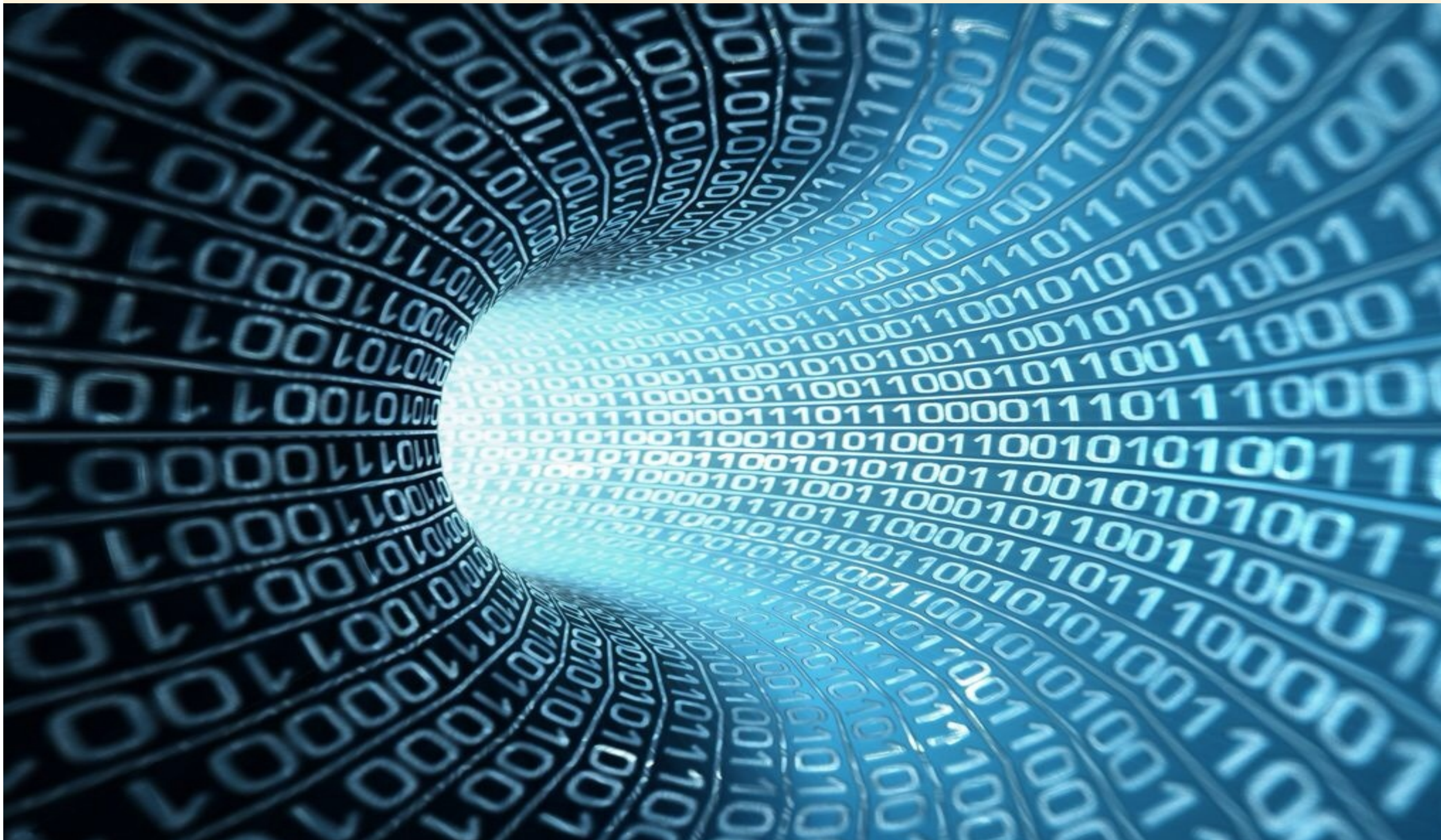


Recommend Must-Learn

- SVG
- D3.js
- Bootstrap
- (Of course — HTML, Javascript, and CSS)

Part II: Visualising Big Data

Are you ready to *Big Data?*



ty

340 million tweets a day!

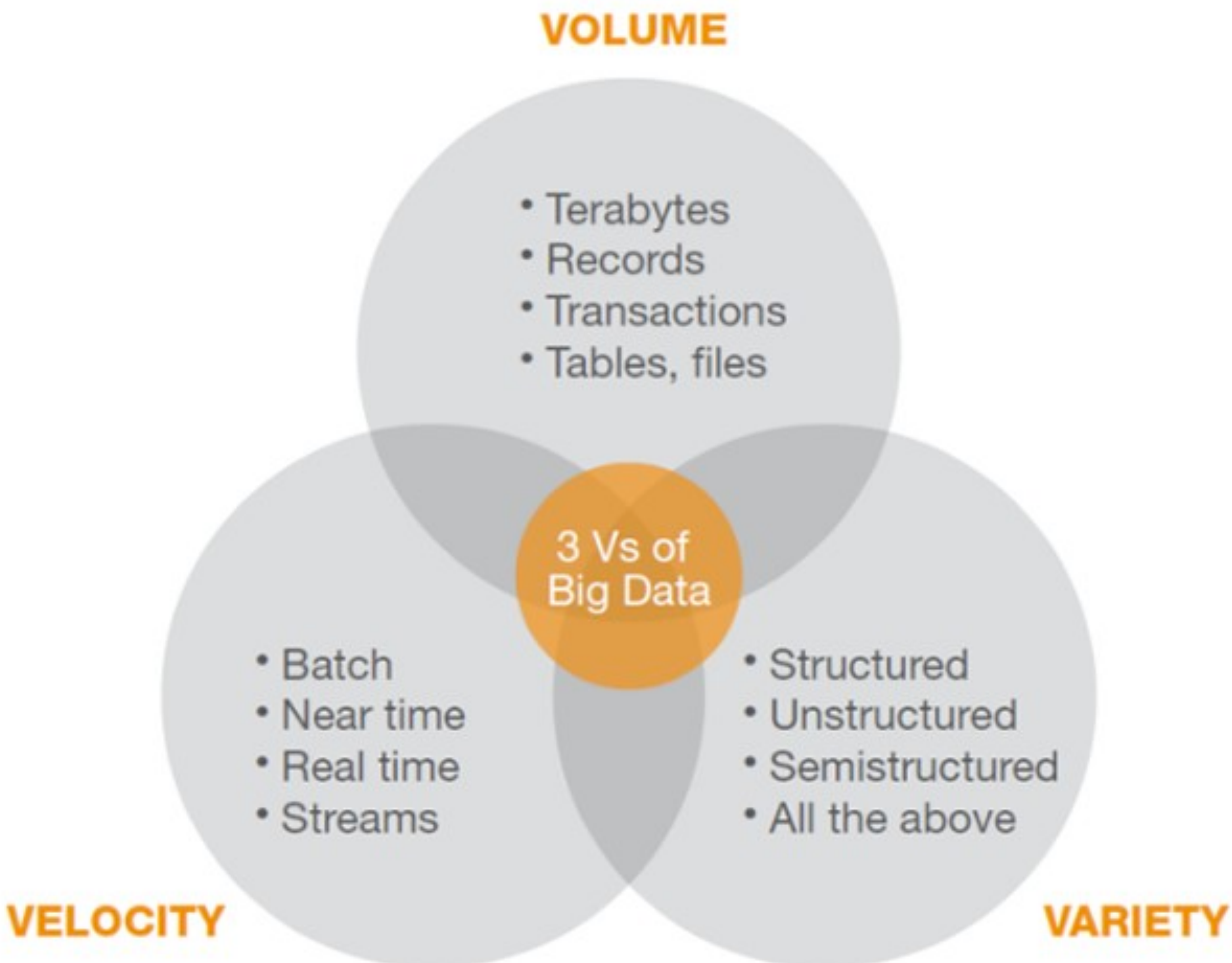
4 billion messages a day!

Information Overload

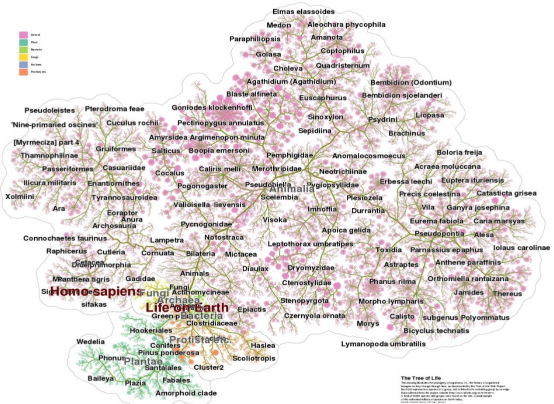
difficult caused by too much information

How can we acquire useful information from the overwhelming data

3Vs of Big Data

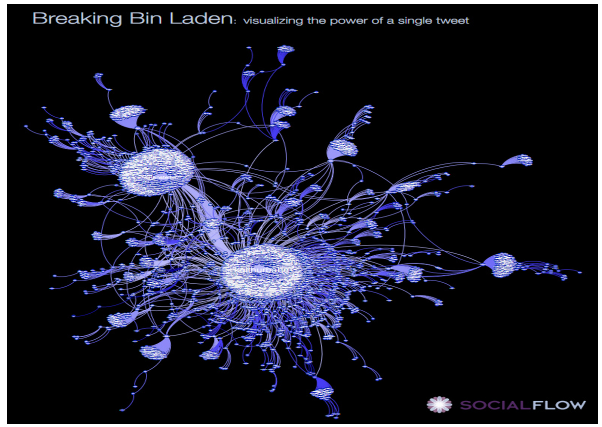


76425 species



Tree of Life by Dr. Yifan Hu

14.8 million tweets



The information diffusion graph of the death of Osama bin Laden by Gilad Lotan

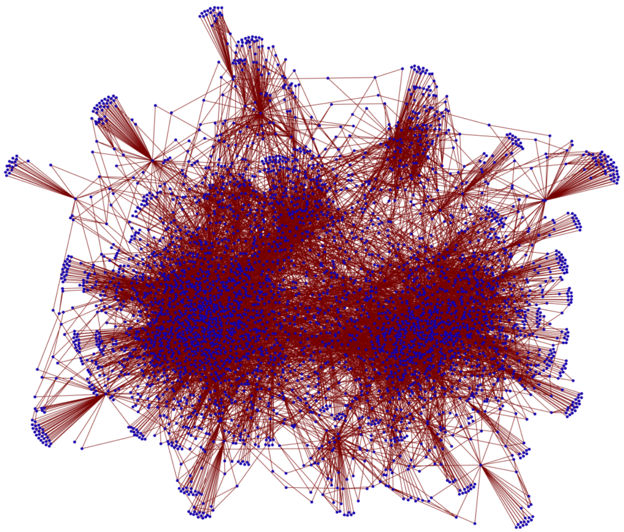
500 million users

Facebook friendship graph by Paul Butler

Challenging Task:

Squeezing millions and even billions of records into million pixels (1600 X 1200 = 2 million pixels)

Challenges



Visual clutter

How can we avoid visual clutters like overlaps and crossings?

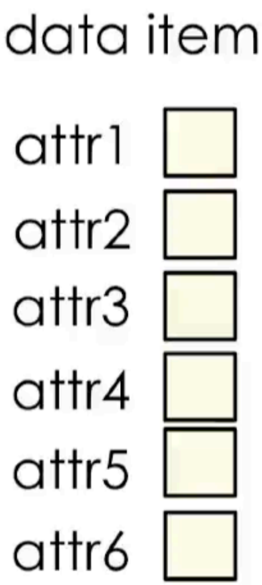
Performance issues

How can we render the huge datasets in real time with rich interactions?

Limited cognition

How can users understand the visual representation when the information is overwhelming?

Techniques (1) : Pixel Oriented Visualization



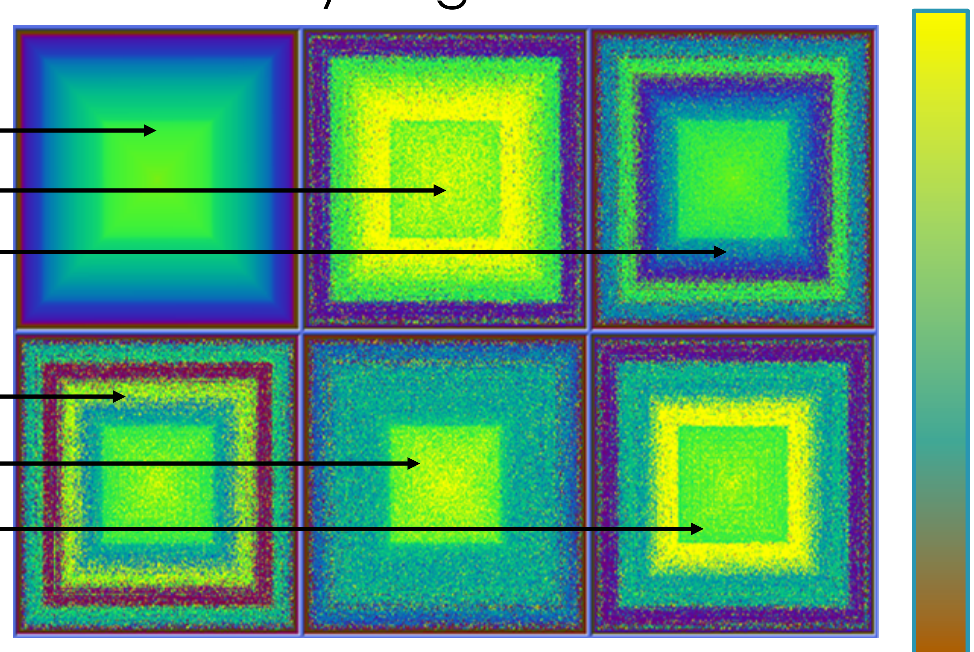
- A multidimensional data item contains 6 attributes

Technique(1) : Pixel Oriented Visualization

Database visualization (10,000 items, 6 dimensions)

Jan	Feb	Mar	Apr	May	Jun
-99.99	-99.99	315.7	317.45	317.5	317.26
315.62	316.38	316.71	317.72	318.29	318.16
316.43	316.97	317.58	319.02	320.03	319.59
316.93	317.7	318.54	319.48	320.58	319.77
317.94	318.56	319.68	320.63	321.01	320.55
318.74	319.08	319.86	321.39	322.24	321.47
319.57	-99.99	-99.99	-99.99	322.24	321.89
319.44	320.44	320.89	322.13	322.16	321.87
320.62	321.59	322.39	323.87	324.01	323.75
322.06	322.5	323.04	324.42	325	324.09
322.57	323.15	323.89	325.02	325.57	325.36
324	324.42	325.64	326.66	327.34	326.76
325.03	325.99	326.87	328.14	328.07	327.66
326.17	326.68	327.18	327.78	328.92	328.57
326.77	327.63	327.75	329.72	330.07	329.09
328.55	329.56	330.3	331.5	332.48	332.07
329.35	330.71	331.48	332.65	333.09	332.25
330.4	331.41	332.04	333.31	333.96	333.6
331.75	332.56	333.5	334.58	334.87	334.34
332.93	333.42	334.7	336.07	336.74	336.27
334.97	335.39	336.64	337.76	338.01	337.89
336.23	336.76	337.96	338.89	339.47	339.29
338.01	338.36	340.08	340.77	341.46	341.17
339.23	340.47	341.38	342.51	342.91	342.25
340.75	341.61	342.7	343.57	344.13	343.35
341.37	342.52	343.1	344.94	345.75	345.32
343.7	344.5	345.28	347.08	347.43	346.79
344.97	346	347.43	348.35	348.93	348.25
346.3	346.96	347.86	349.55	350.21	349.54
348.02	348.47	349.42	350.99	351.84	351.25
350.43	351.73	352.22	353.59	354.22	353.79
352.76	353.07	353.68	355.42	355.67	355.13
353.66	354.7	355.39	356.2	357.16	356.23
354.72	355.75	357.16	358.6	359.33	358.24
355.98	356.72	357.81	359.15	359.66	359.25
356.7	357.16	358.38	359.46	360.28	359.6
358.37	358.91	359.97	361.26	361.68	360.95
359.97	361	361.64	363.45	363.79	363.26
362.05	363.25	364.02	364.72	365.41	364.97
363.18	364	364.56	366.35	366.79	365.62
365.33	366.15	367.31	368.61	369.3	368.87
368.15	368.87	369.59	371.14	371	370.35
369.14	369.46	370.52	371.66	371.82	371.7
370.28	371.5	372.12	372.87	374.02	373.3
372.43	373.09	373.52	374.86	375.55	375.41
374.68	375.63	376.11	377.65	378.35	378.13
376.79	377.37	378.41	380.52	380.63	379.57
378.37	379.69	380.41	382.1	382.28	382.13
381.38	382.03	382.64	384.62	384.95	384.06
382.45	383.68	384.23	386.26	386.39	385.87
385.07	385.72	385.85	386.71	388.45	387.64

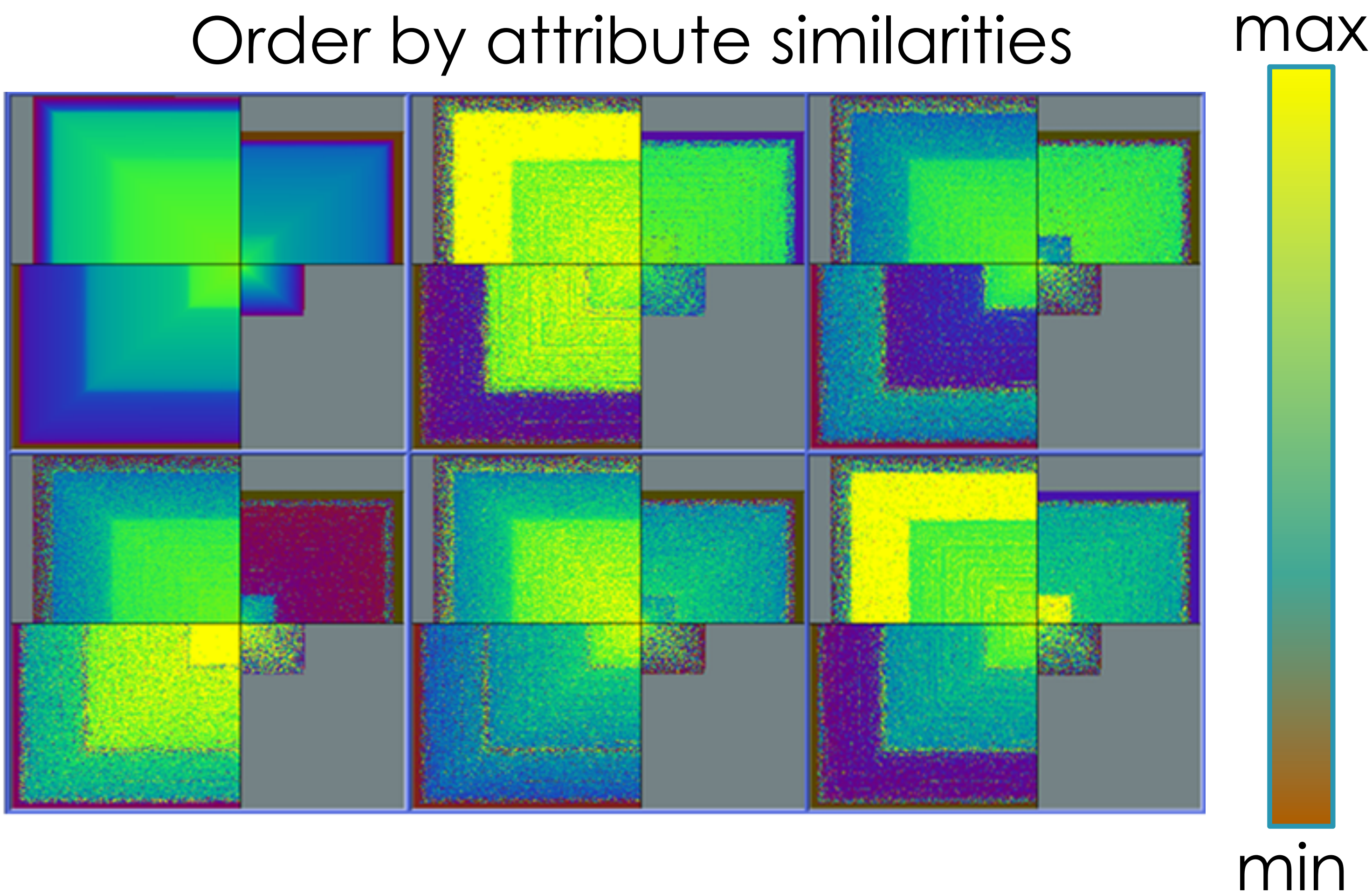
Order by degree of interests



(Keim & Kriegel, 1994; 1996)

Techniques (1): Pixel Oriented Visualization

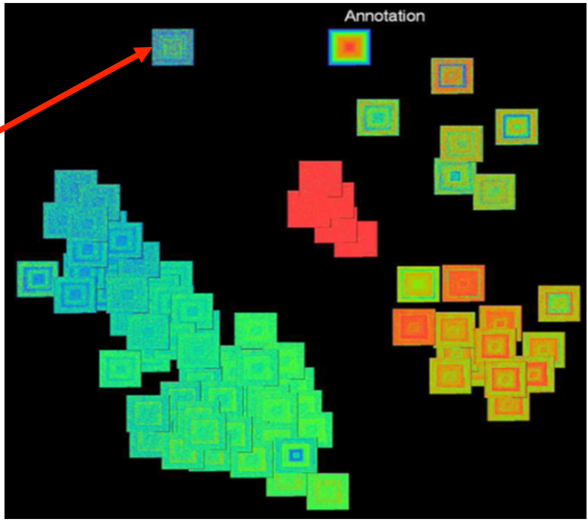
Database Visualization (10,000 items, 6 dimensions)



Different Ways for splitting the display region

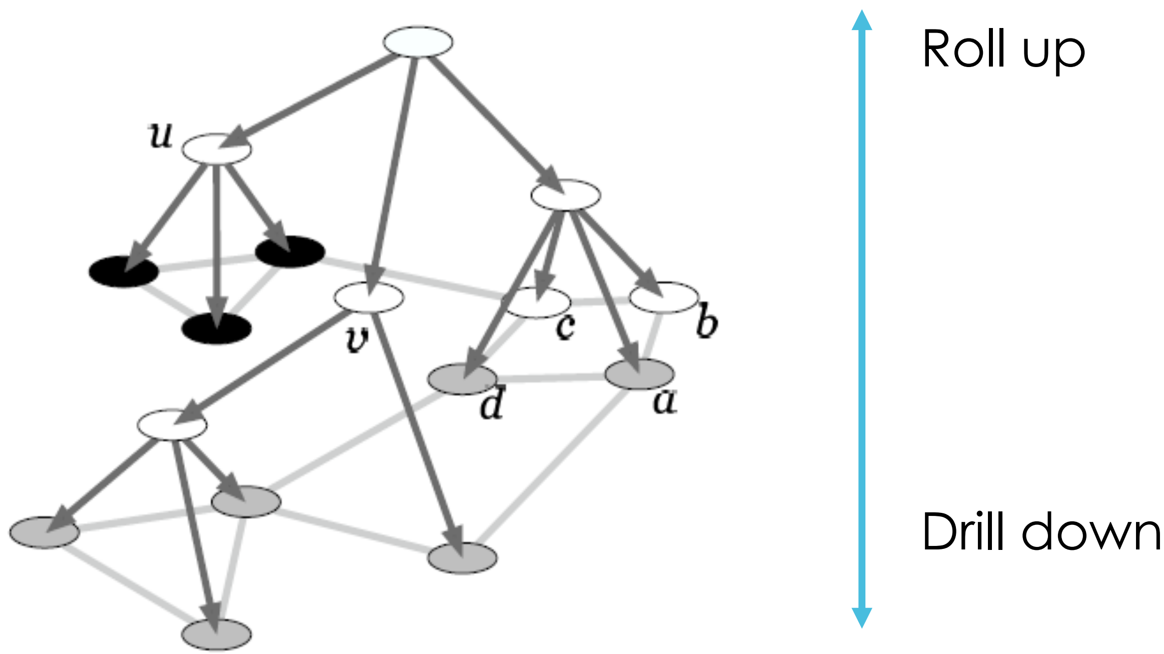
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
1958	-99.99	-99.99	315.7	317.45	317.5	317.26	315.86	314.93	313.2	312.44	313.33	314.6[illegible]	-99.99
1959	315.62	316.38	316.71	317.72	318.29	318.16	316.54	314.8	313.84	313.26	314.8	315.58	315.98
1960	316.43	316.97	317.58	319.02	320.03	319.59	318.18	315.91	314.16	313.84	315	316.19	316.91
1961	316.93	317.7	318.54	319.48	320.58	319.77	318.57	316.79	314.8	315.38	316.1	317.01	317.64
1962	317.94	318.56	319.68	320.63	321.01	320.55	319.58	317.4	316.25	315.42	316.69	317.7	318.45
1963	318.74	319.08	319.86	321.39	322.24	321.47	319.74	317.77	316.21	315.99	317.12	318.31	318.99
1964	319.57	-99.99	-99.99	-99.99	322.24	321.89	320.44	318.7	316.7	316.79	317.79	318.71	-99.99
1965	319.44	320.44	320.89	322.13	322.16	321.87	321.39	318.8	317.81	317.3	318.87	319.42	320.04
1966	320.62	321.59	322.39	323.87	324.01	323.75	322.39	320.37	318.64	318.1	319.79	321.08	321.38
1967	322.06	322.5	323.04	324.42	325	324.09	322.55	320.92	319.31	319.31	320.72	321.96	322.16
1968	322.57	323.15	323.89	325.02	325.57	325.36	324.14	322.03	320.41	320.25	321.31	322.84	323.05
1969	324	324.42	325.64	326.66	327.34	326.76	325.88	323.67	322.38	321.78	322.85	324.12	324.63
1970	325.03	325.99	326.87	328.14	328.07	327.66	326.35	324.69	323.1	323.16	323.98	325.13	325.68
1971	326.17	326.68	327.18	327.78	328.92	328.57	327.34	325.46	323.36	323.57	324.8	326.01	326.32
1972	326.77	327.63	327.75	329.72	330.07	329.09	328.05	326.32	324.93	325.06	326.5	327.55	327.45
1973	328.55	329.56	330.3	331.5	332.48	332.07	330.87	329.31	327.51	327.18	328.16	328.64	329.68
1974	329.35	330.71	331.48	332.65	333.09	332.25	331.18	329.4	327.43	327.37	328.46	329.57	330.25
1975	330.4	331.41	332.04	333.31	333.96	333.6	331.91	330.06	328.56	328.34	329.49	330.76	331.15
1976	331.75	332.56	333.5	334.58	334.87	334.34	333.05	330.94	329.3	328.94	330.31	331.68	332.15
1977	332.93	333.42	334.7	336.07	336.74	336.27	334.93	332.75	331.59	331.16	332.4	333.85	333.9
1978	334.97	335.39	336.64	337.76	338.01	337.89	336.54	334.68	332.76	332.55	333.92	334.95	335.51
1979	336.23	336.76	337.96	338.89	339.47	339.29	337.73	336.09	333.91	333.86	335.29	336.73	336.85
1980	338.01	338.36	340.08	340.77	341.46	341.17	339.56	337.6	335.88	336.02	337.1	338.21	338.69
1981	339.23	340.47	341.38	342.51	342.91	342.25	340.49	338.43	336.69	336.86	338.36	339.61	339.9[illegible]
1982	340.75	341.61	342.7	343.57	344.13	343.35	342.06	339.81	337.98	337.86	339.26	340.49	[illegible]1.13
1983	341.37	342.52	343.1	344.94	345.75	345.32	343.99	342.39	339.86	339.99	341.15	342.99	342.78
1984	343.7	344.5	345.28	347.08	347.43	346.79	345.4	343.28	341.07	341.35	342.98	344.22	344.42
1985	344.97	346	347.43	348.35	348.93	348.25	346.56	344.68	343.09	342.8	344.24	345.55	345.9
1986	346.3	346.96	347.86	349.55	350.21	349.54	347.94	345.9	344.85	344.17	345.66	346.9	347.15
1987	348.02	348.47	349.42	350.99	351.84	351.25	349.52	348.1	346.45	346.36	347.81	348.96	348.93
1988	350.43	351.73	352.22	353.59	354.22	353.79	352.38	350.43	348.72	348.88	350.07	351.34	351.48
1989	352.76	353.07	353.68	355.42	355.67	355.13	353.9	351.67	349.8	349.99	351.29	352.52	352.91
1990	353.66	354.7	355.39	356.2	357.16	356.23	354.82	352.91	350.96	351.18	352.83	354.21	354.19
1991	354.72	355.75	357.16	358.6	359.33	358.24	356.17	354.02	352.15	352.21	353.75	354.99	355.59
1992	355.98	356.72	357.81	359.15	359.66	359.25	357.02	355	353.01	353.31	354.16	355.4	356.37
1993	356.7	357.16	358.38	359.46	360.28	359.6	357.57	355.52	353.69	353.99	355.34	356.8	357.04
1994	358.37	358.91	359.97	361.26	361.68	360.95	359.55	357.48	355.84	355.99	357.58	359.04	358.89
1995	359.97	361	361.64	363.45	363.79	363.26	361.9	359.46	358.05	357.76	359.56	360.7	360.88
1996	362.05	363.25	364.02	364.72	365.41	364.97	363.65	361.48	359.45	359.6	360.76	362.33	362.64
1997	363.18	364	364.56	366.35	366.79	365.62	364.47	362.51	360.19	360.77	362.43	364.28	363.76
1998	365.33	366.15	367.31	368.61	369.3	368.87	367.64	365.77	363.9	364.23	365.46	366.97	366.63
1999	368.15	368.87	369.59	371.14	371	370.35	369.27	366.93	364.63	365.13	366.67	368.01	368.31
2000	369.14	369.46	370.52	371.66	371.82	371.7	370.12	368.12	366.62	366.73	368.29	369.53	369.48
2001	370.28	371.5	372.12	372.87	374.02	373.3	371.62	369.55	367.96	368.09	369.68	371.24	371.02
2002	372.43	373.09	373.52	374.86	375.55	375.41	374.02	371.49	370.7	370.25	372.08	373.78	373.1
2003	374.68	375.63	376.11	377.65	378.35	378.13	376.62	374.5	372.99	373.01	374.35	375.7	375.64
2004	376.79	377.37	378.41	380.52	380.63	379.57	377.79	375.86	374.07	374.24	375.86	377.47	377.38
2005	378.37	379.69	380.41	382.1	382.28	382.13	380.66	378.71	376.42	376.88	378.32	380.04	379.67
2006	381.38	382.03	382.64	384.62	384.95	384.06	382.29	380.47	378.67	379.06	380.14	381.74	381.84
2007	382.45	383.68	384.23	386.26	386.39	385.87	384.39	381.78	380.73	380.81	382.33	383.69	383.55
2008	385.07	385.72	385.85	386.71	388.45	387.64	386.1	383.95	382.91	382.73	383.96	385.0[illegible]	385.34

Values above represent monthly concentrations adjusted to represent 2400 hours on the 15th day of each month. Units are parts per million by volume (ppmv) expressed in the 2003A SIO manometric mole fraction scale. The "annual average" is the arithmetic mean of the twelve monthly values where no monthly values are missing.



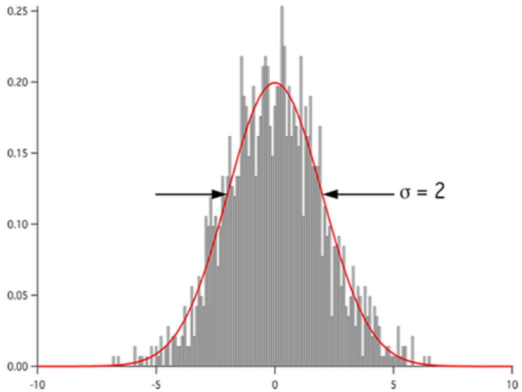
(Yang et al., 2006)

Columbia University

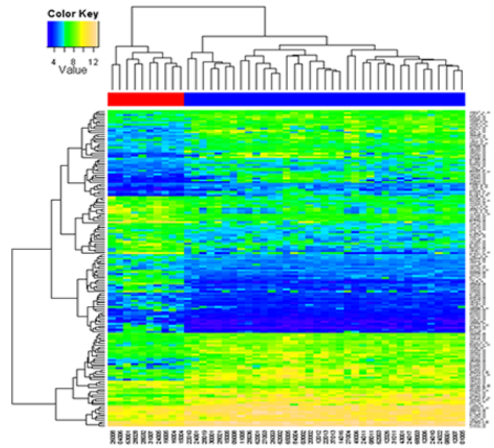


Building a tree for aggregating data items in either a bottom-up or top-down approach

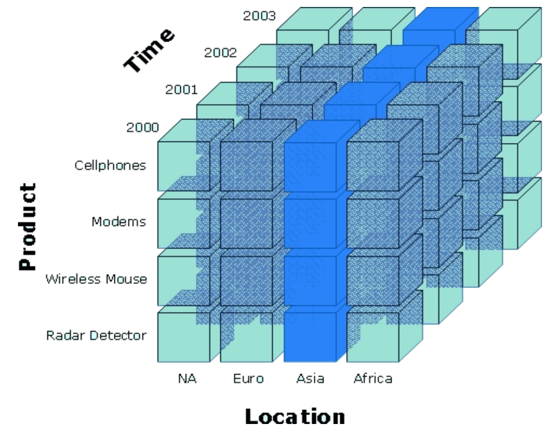
Technique (2) : Aggregation & LOD



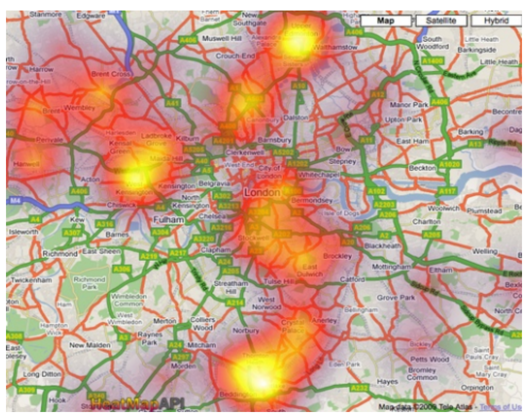
Histogram (Pearson, 1895)



Heatmap
(Wilkinson & Friendly, 2009)

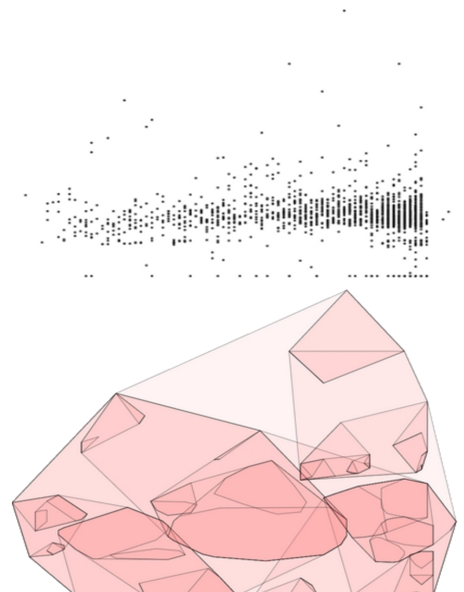


InfoCube
(Stolte et al., 2003)

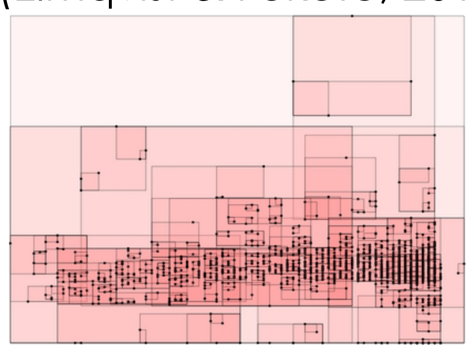


(Lin et al., 2010)

Scatter Plots

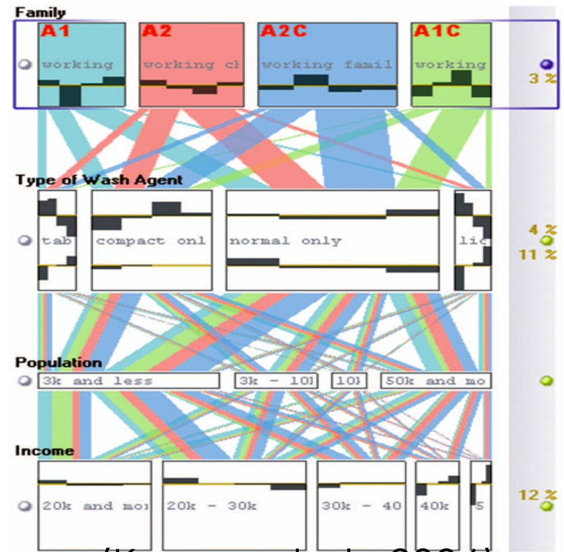


(Elmqvist & Fekete, 2010)

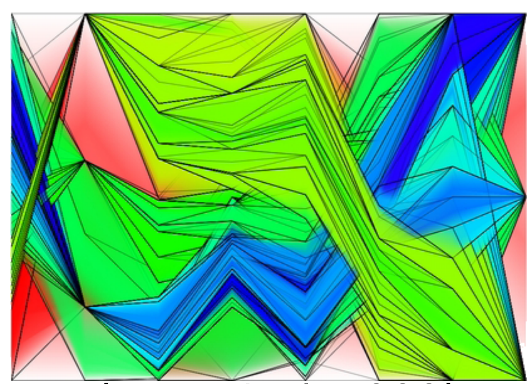


(Yang et al., 2003b)

Parallel Coordinates

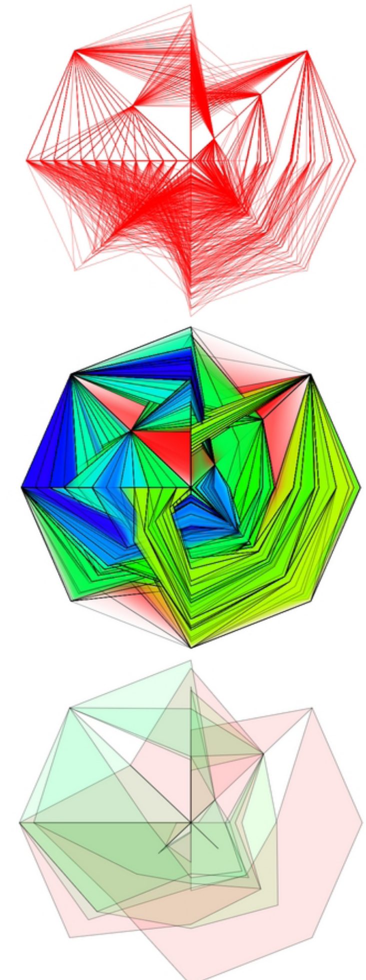


(Kosara et al., 2006)



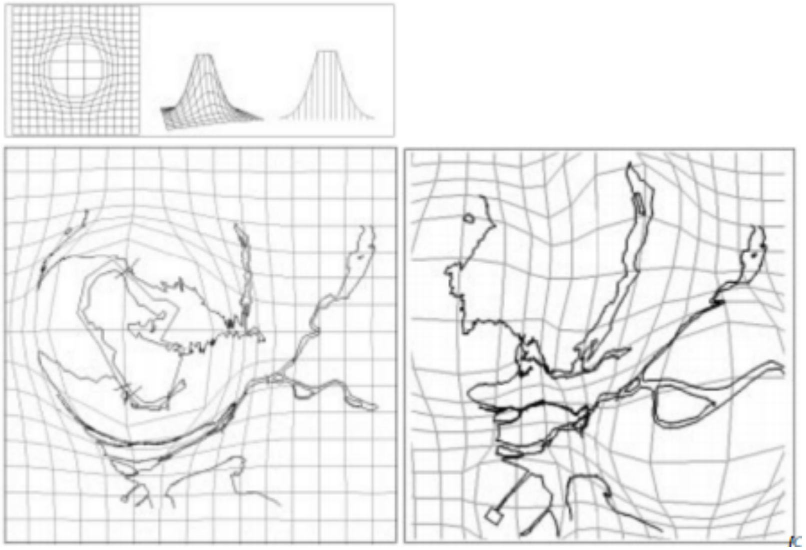
(Fua et al. 1999)

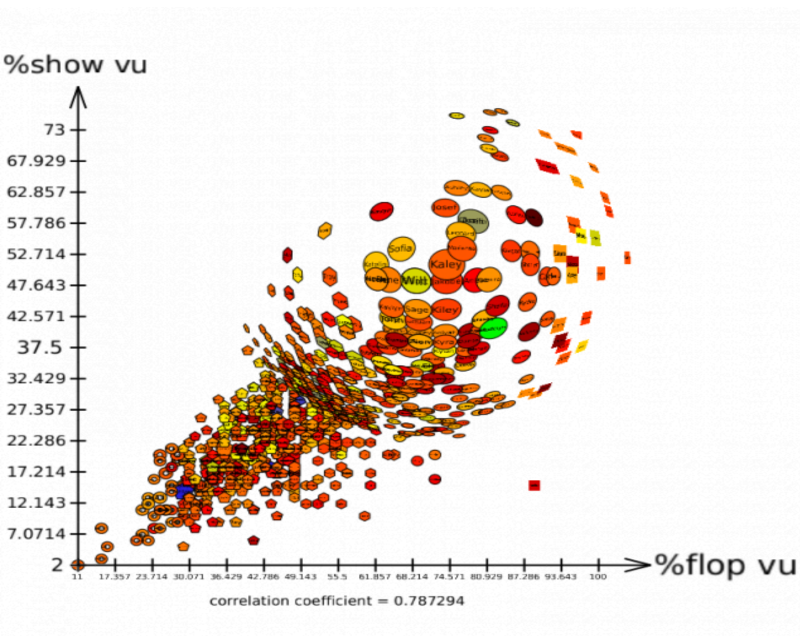
Star Plots

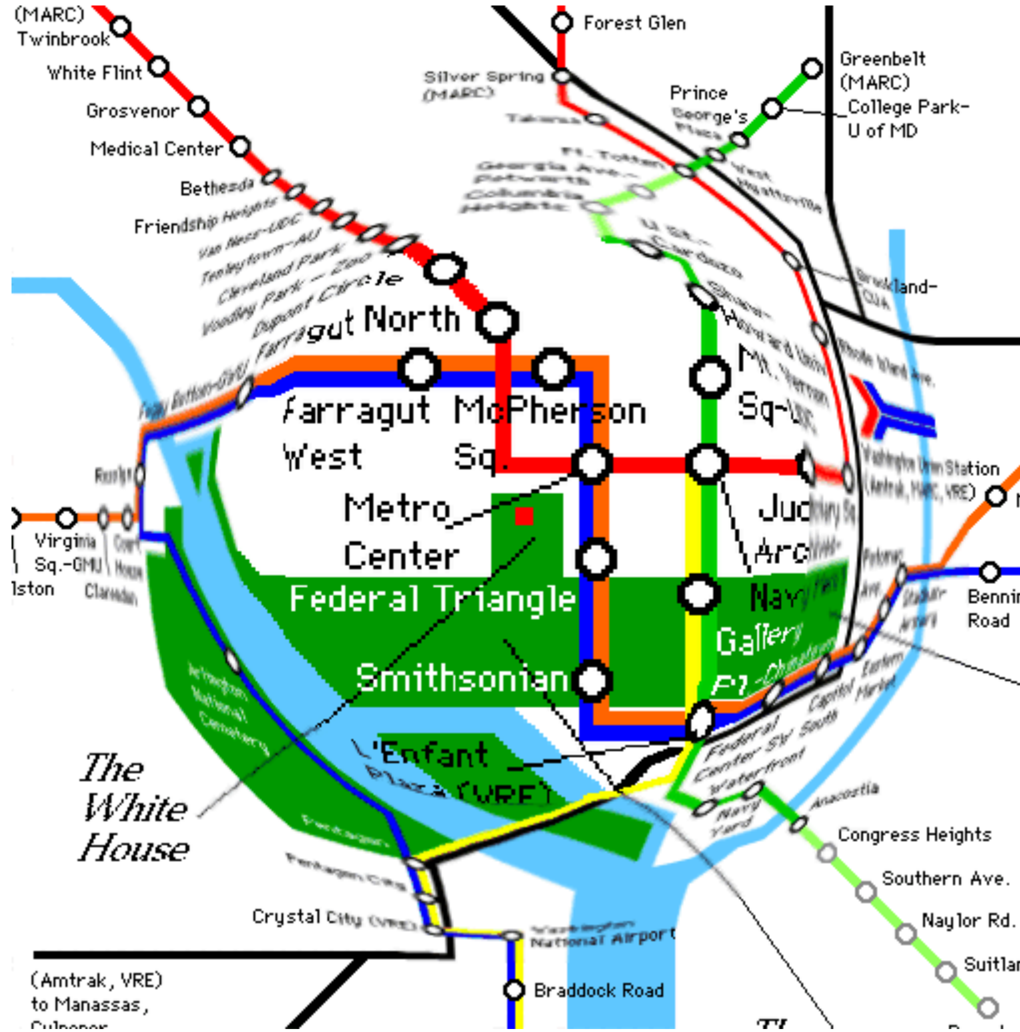


(Fua et al. 1999)

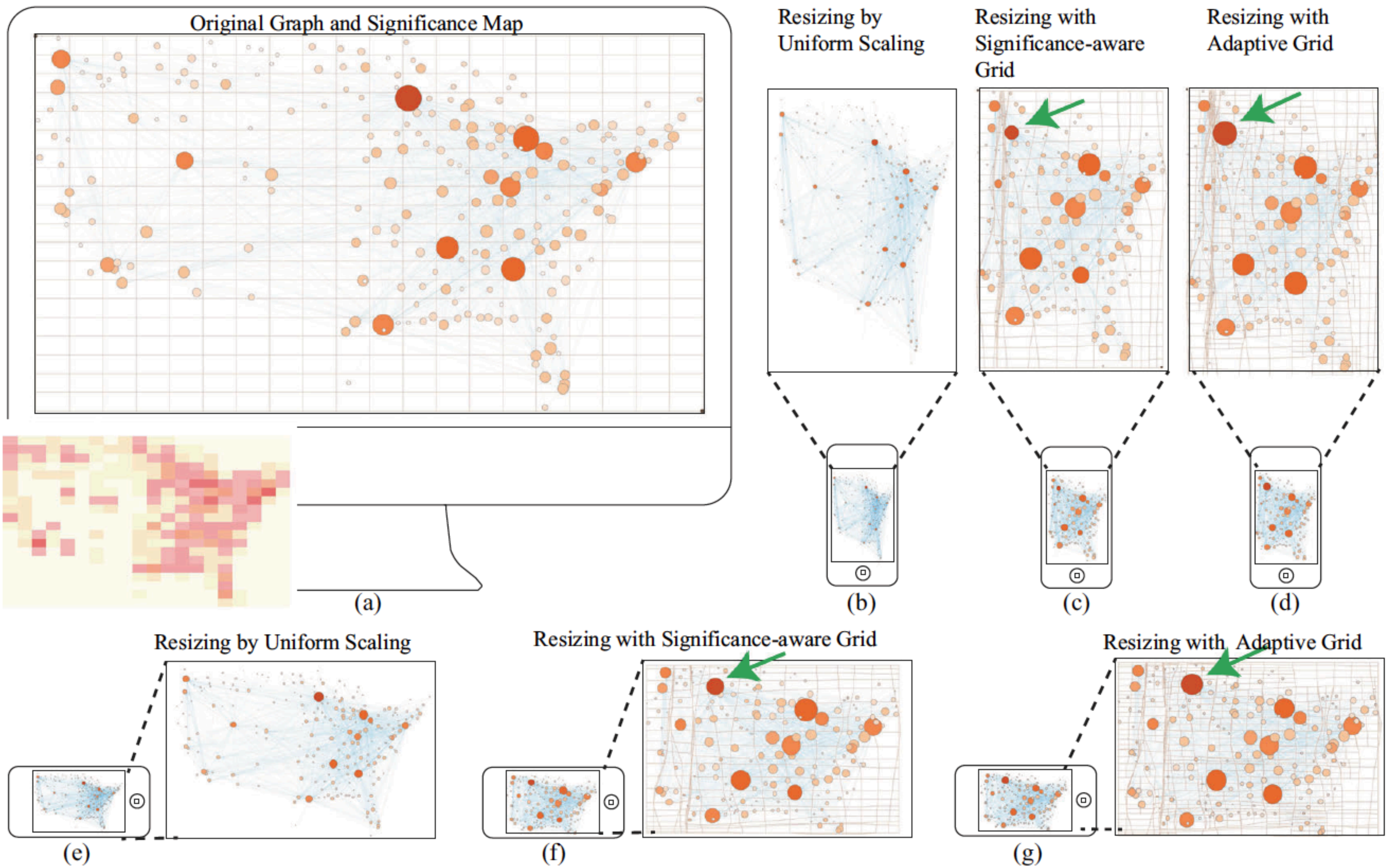
Technique (3) : Distortion



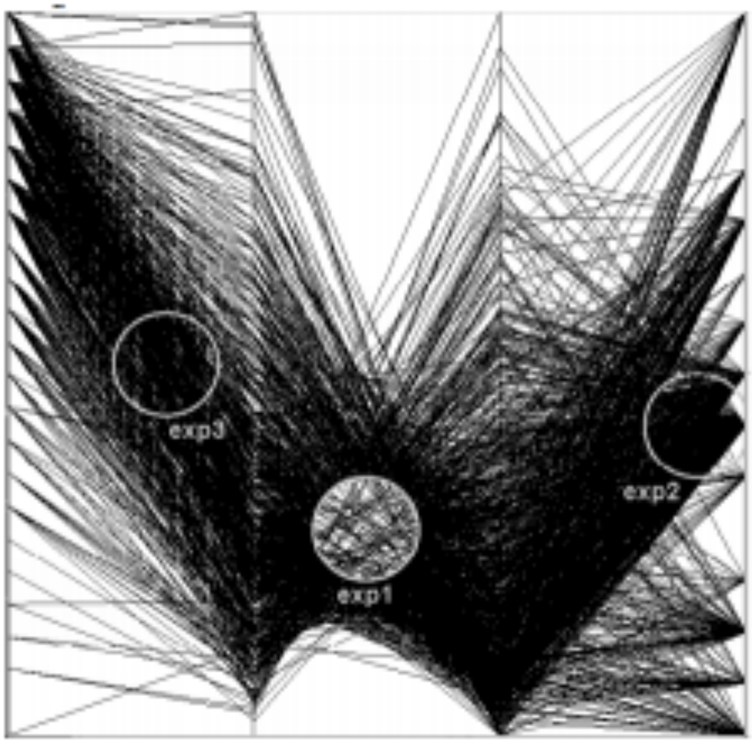




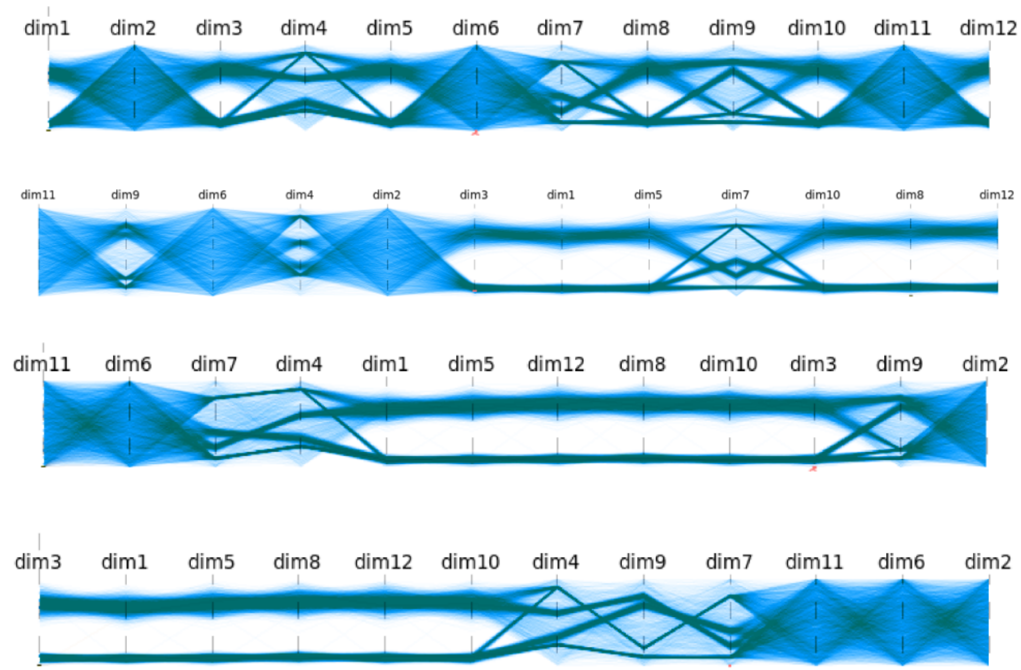
Techniques (3) : Distortion



Technique (4) : Clutter Reduction

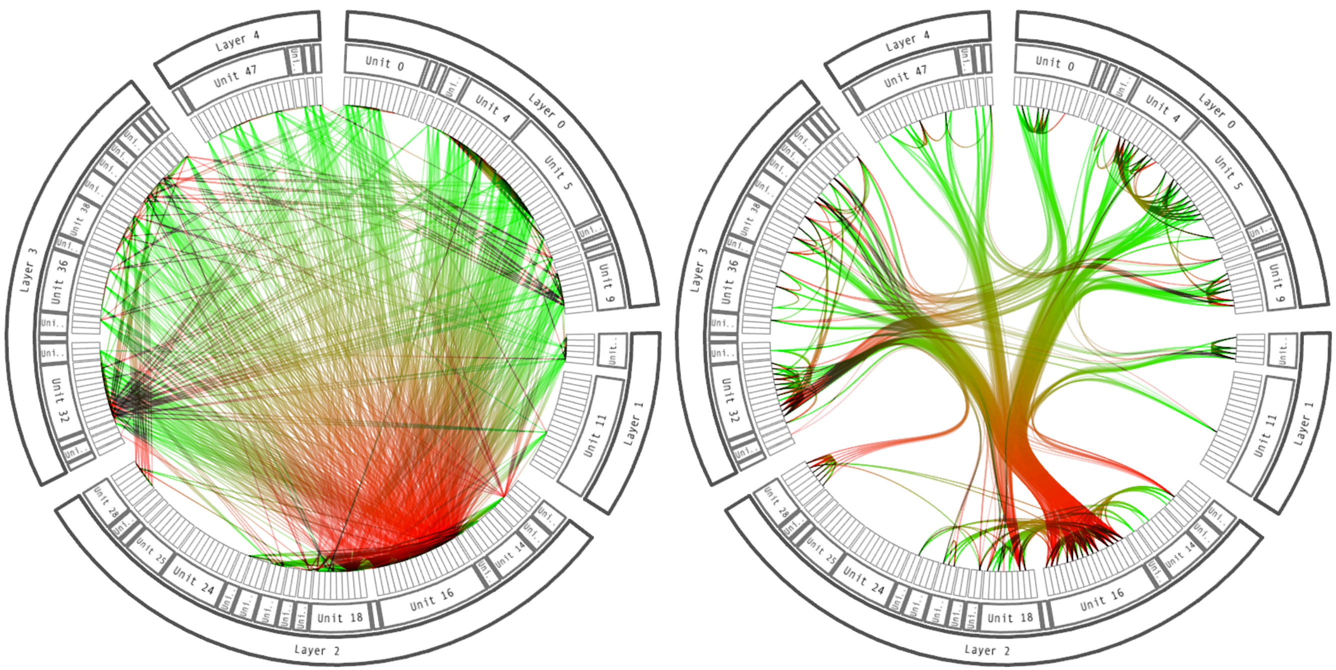


Sampling

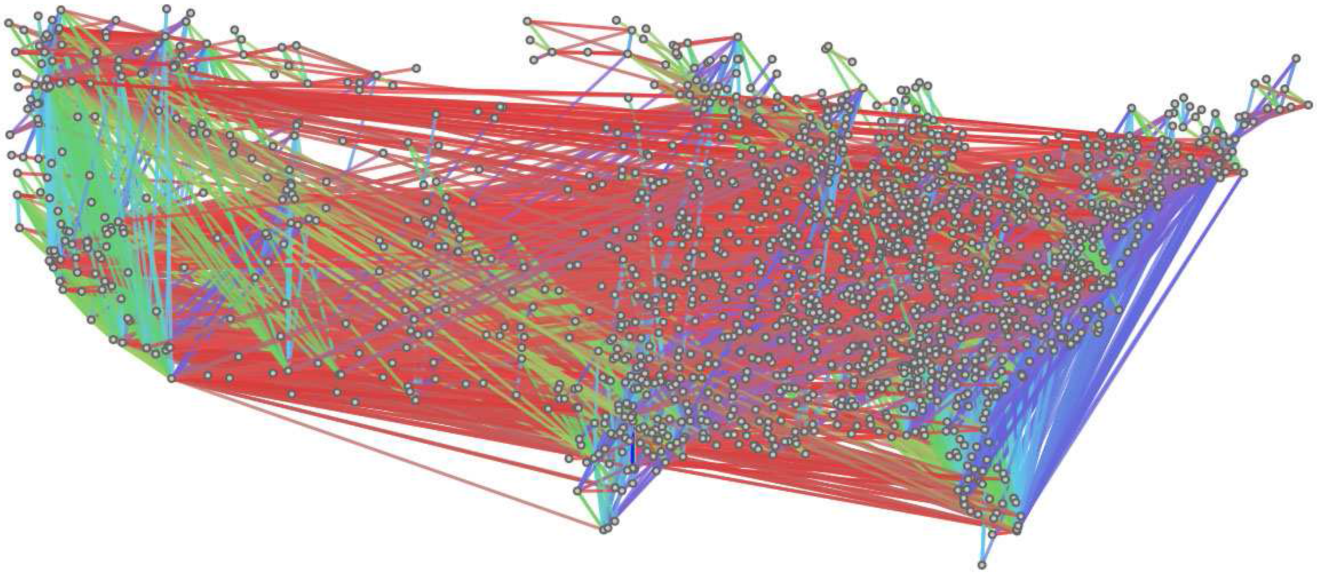


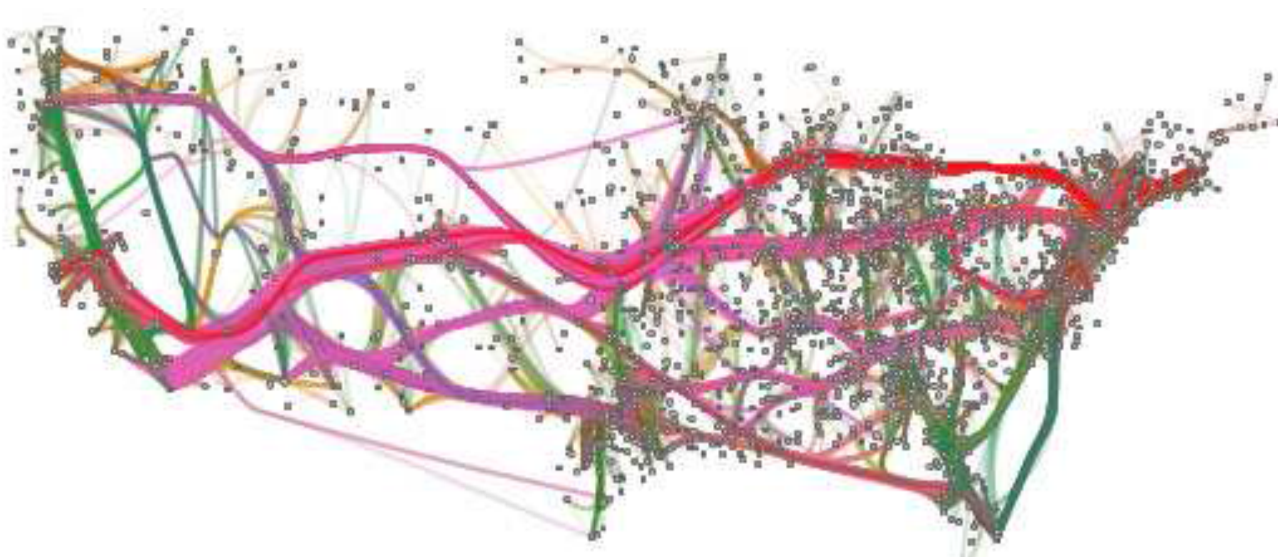
Reordering

Edge Bundling

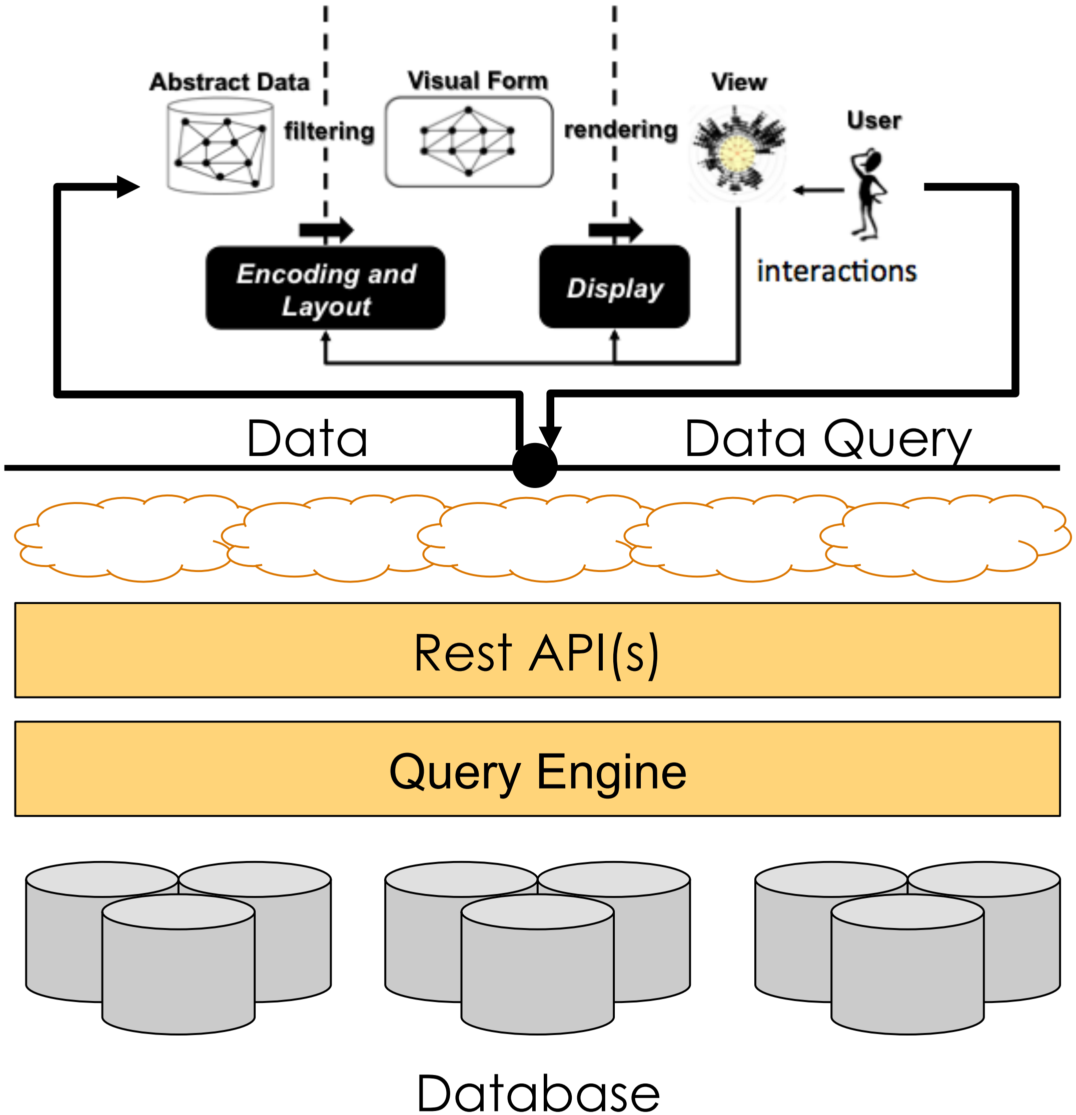


Technique (4): Clutter Reduction

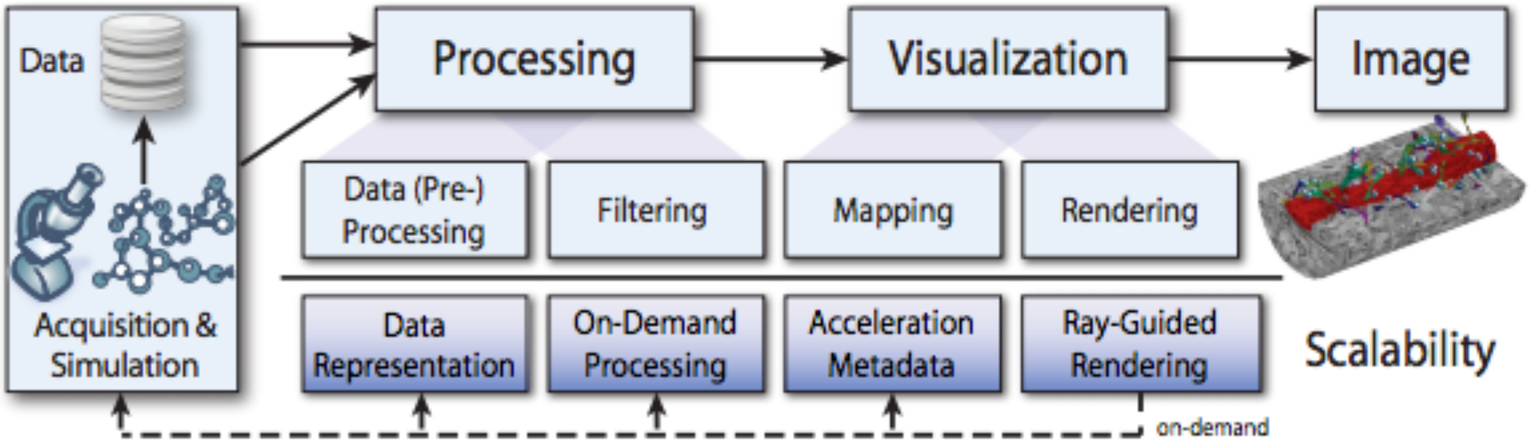




Technique (4): Query based Visualization



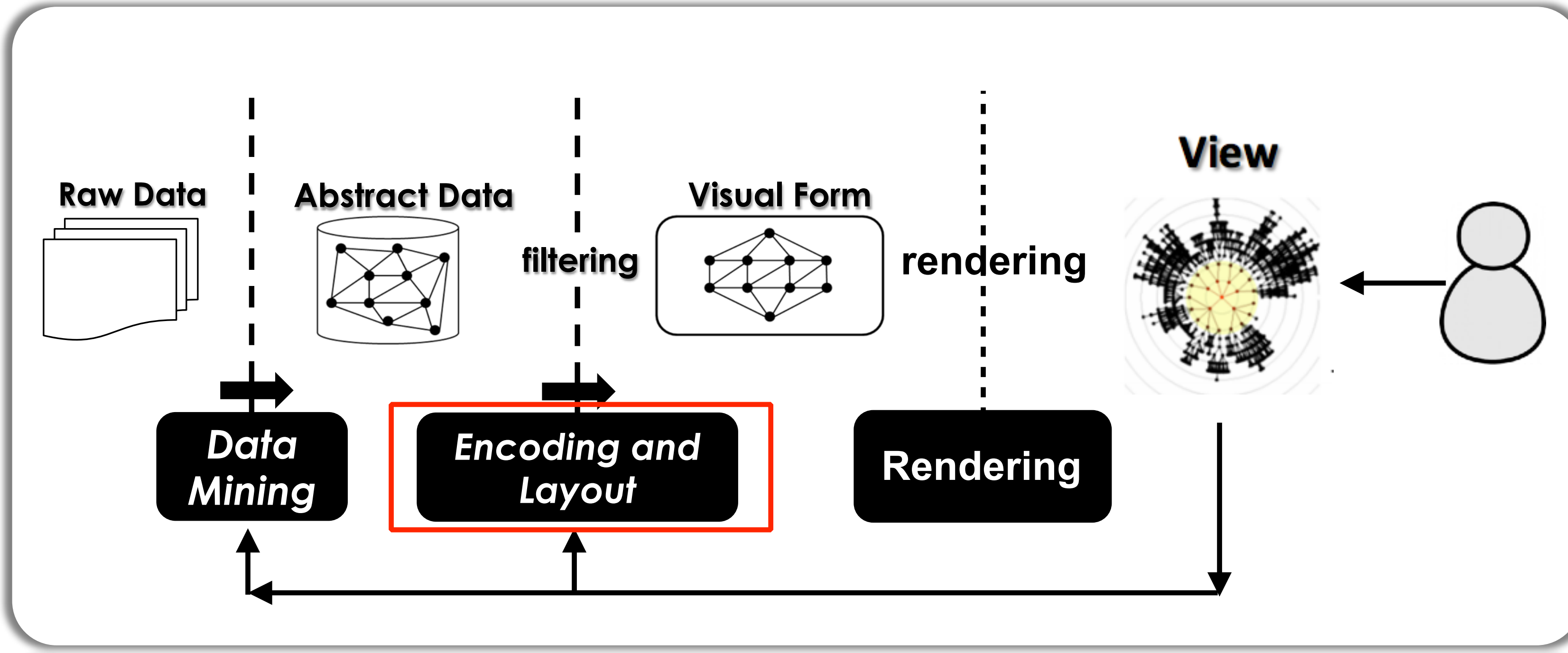
Technique (5): Parallel Computing via GPU or GUGPU



A Survey of GPU-Based Large-Scale Volume Visualization, EuroVis, 2014

Part III :
How can we visualize big data ?

Visualization & Visual Analysis Reference Model

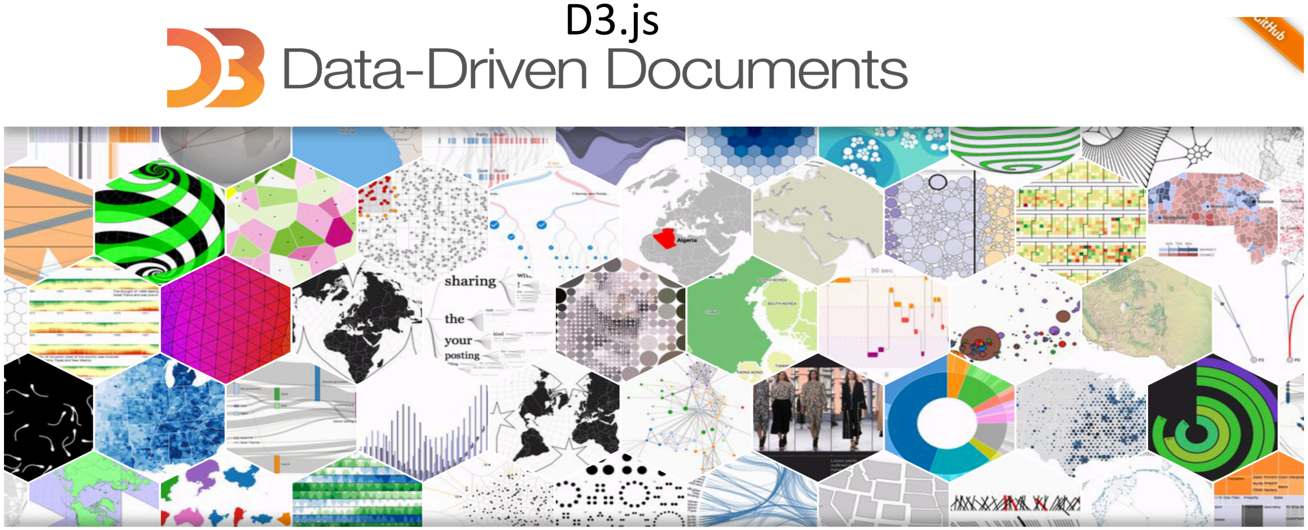


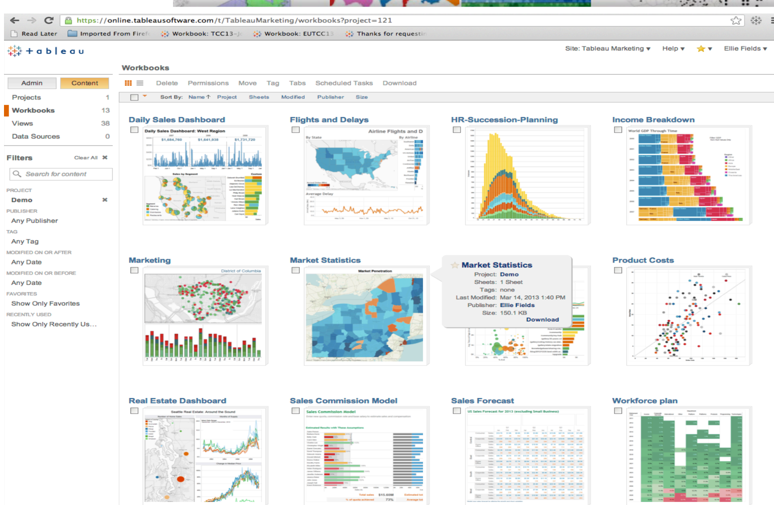
Encoding : Visual Design

Technique : Layout Algorithm

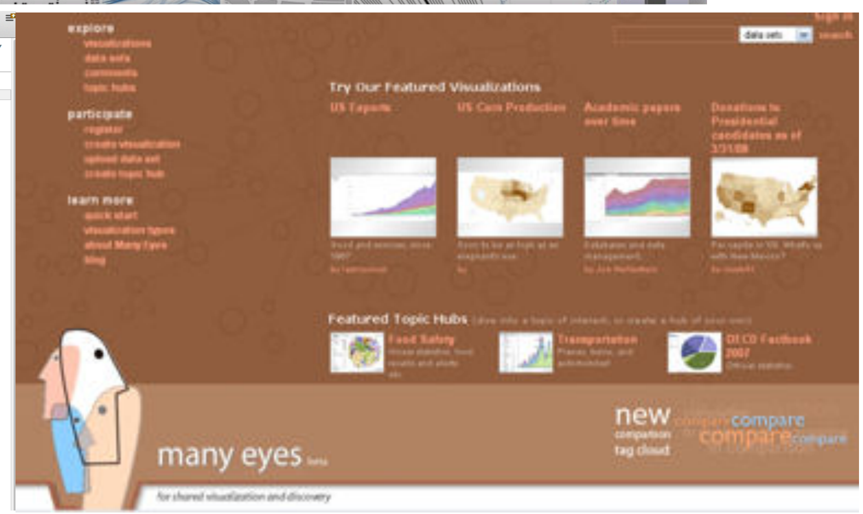
Using existing tools are easy

D3.js





Tableau



ManyEyes

Python:

iGraph : http://igraph.org/redirect.html
Networkx : https://networkx.github.io/

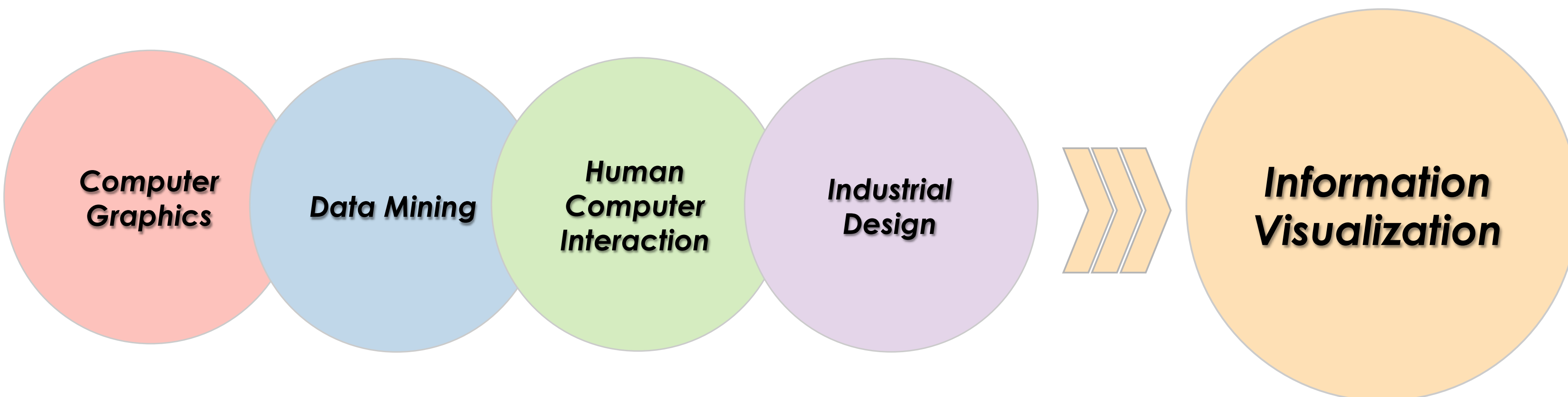
JavaScript:

D3.js (2D, SVG): http://d3js.org/
Tree.js (3D, WebGL): http://threejs.org/

Java:

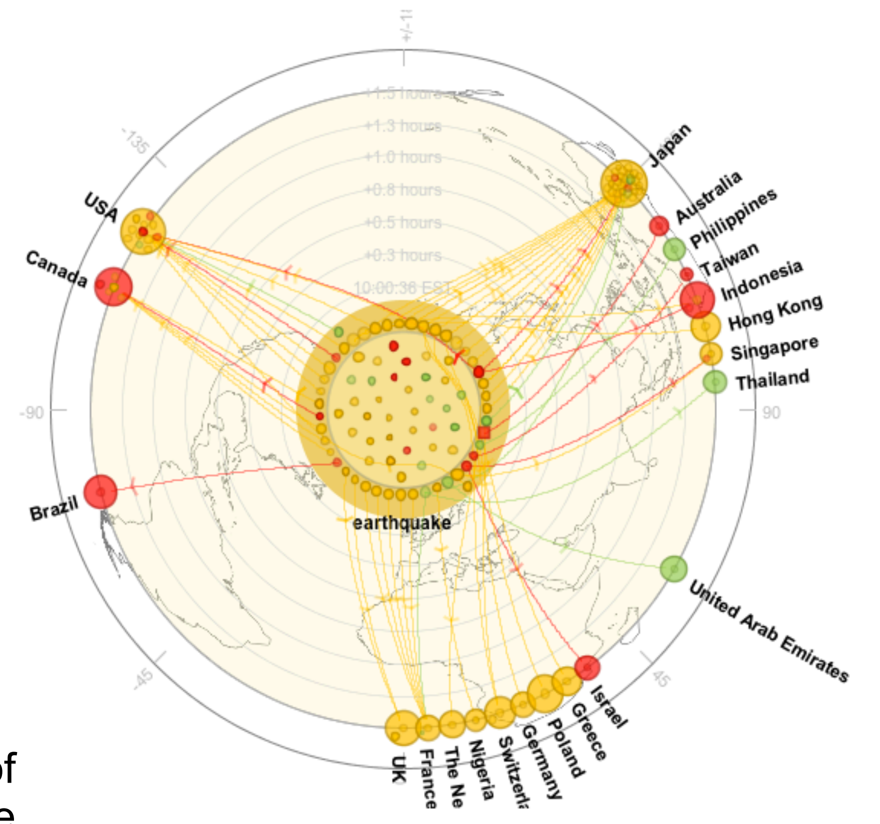
prefuse: http://prefuse.org/
InofVis Toolkit: http://ivtk.sourceforge.net/

Developing new ones require knowledge from different areas



Columbia University

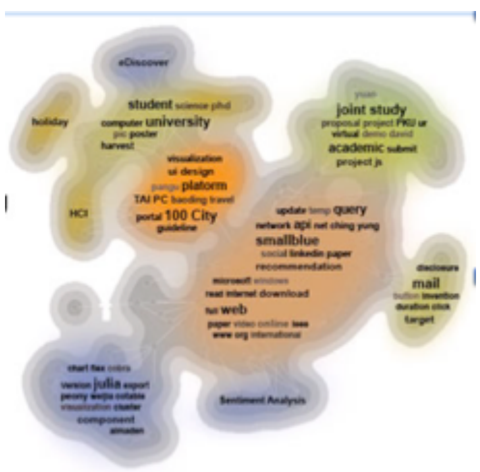
Example 1:
Visualising Streaming Data



Whisper: Tracing the Spatiotemporal Process of
Information Diffusion in Real Time
IEEE InfoVis 2012

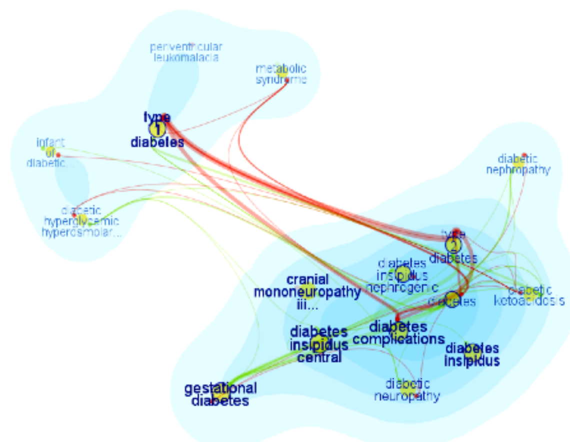
COLUMBIA UNIVERSITY

Example 2: Visualizing Large Text Corpus



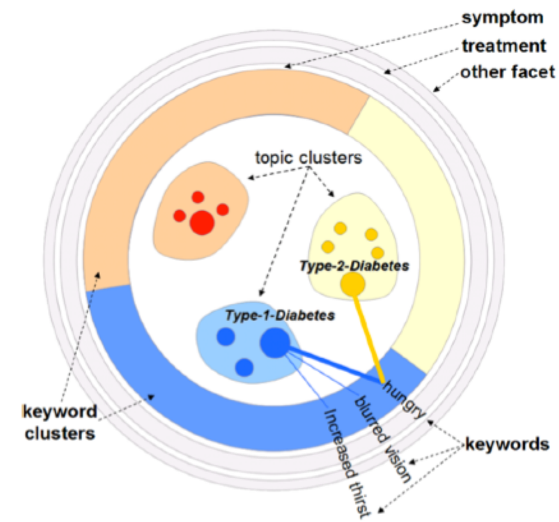
ContexTour
SDM 2010

Visualizing Heterogeneous Clusters



FacetAtlas
TVCG (InfoVis 2010)

Visualizing Multi-relational Clusters



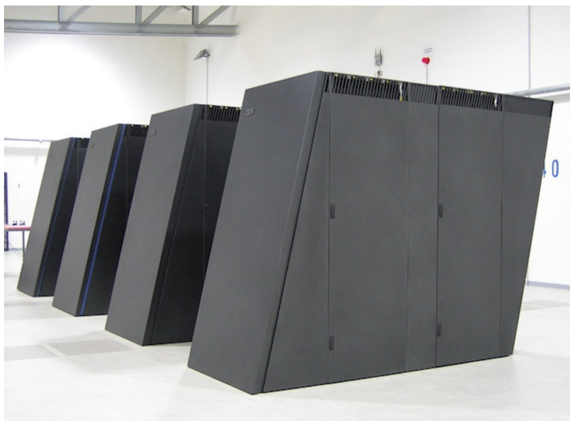
SolarMap
ICDM 2011

Cluster Interpretation

Part IV :
Visual Analysis of Big Data

Visual Analysis v.s. Data Mining

Computational Power

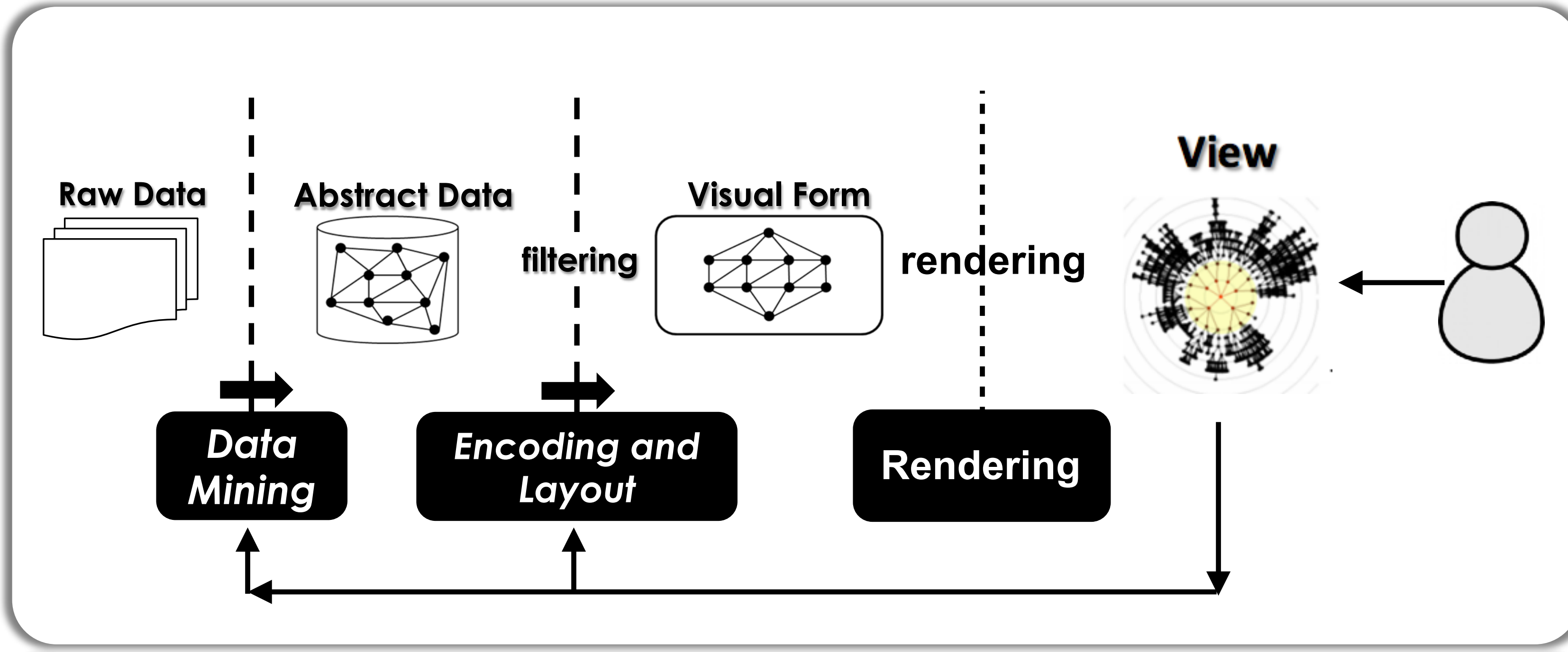


Human Intellegence

+

Data Mining

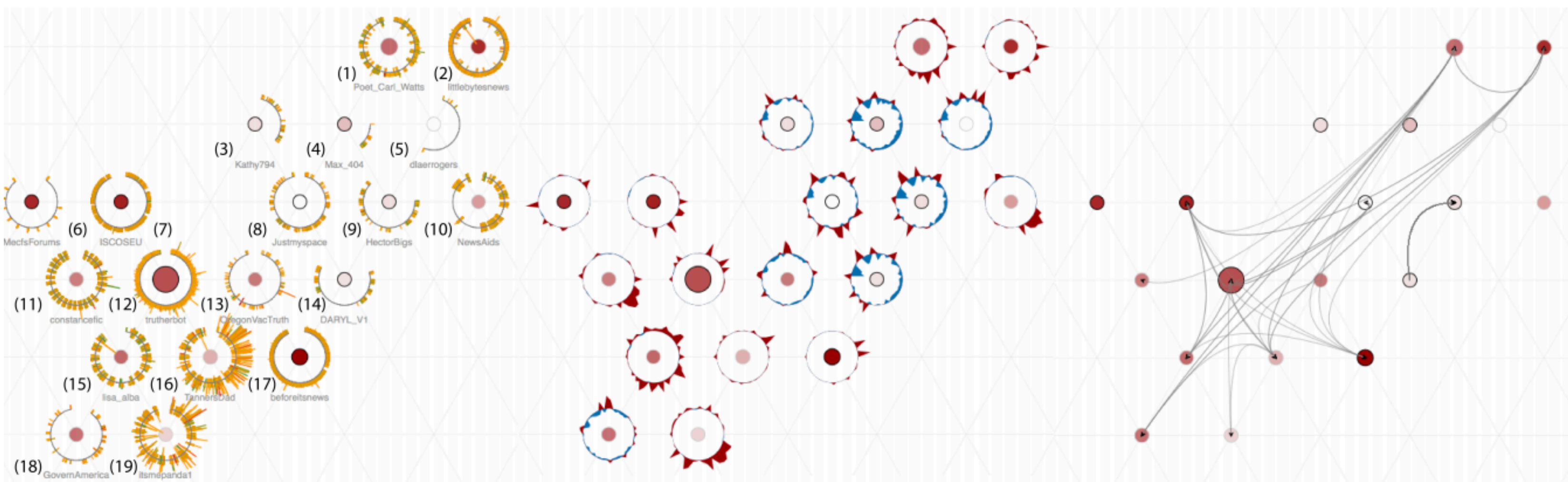
Visual Analysis



Analysis + Visualisation + Interaction

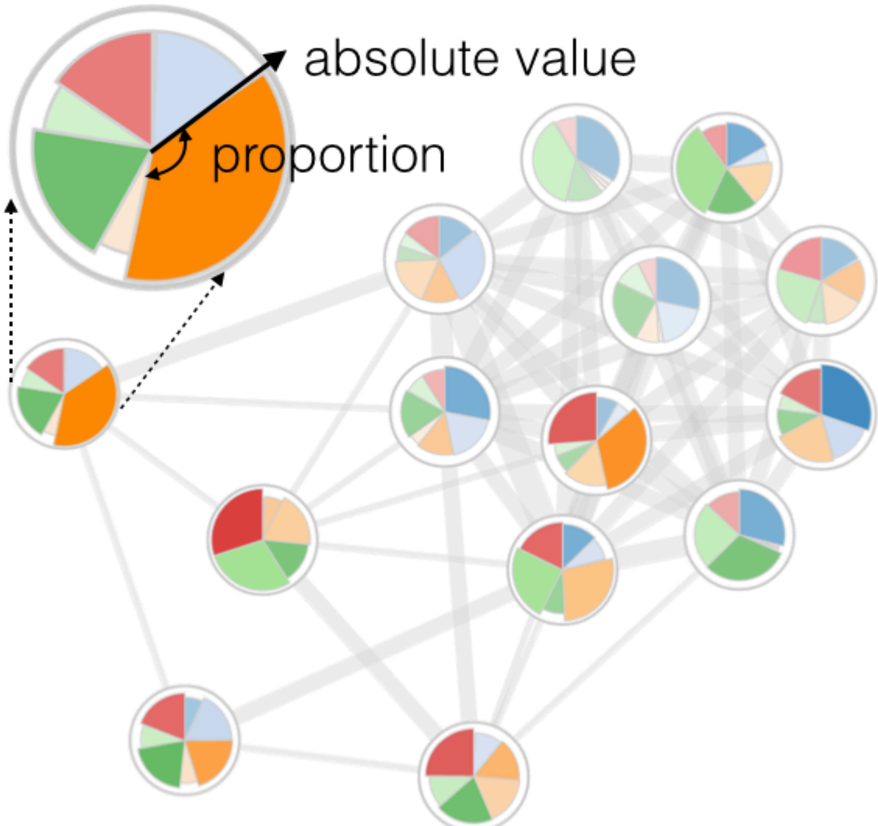
COLUMBIA UNIVERSITY

Example 3: Detect Anomalous Users in Twitter



TargetVue: Visual Analysis of Anomalous User Behaviors in Online Communication Systems, IEEE Transactions on Visualisation and Computer Graphics (VAST'15)

Example 4: Visualizing Large Graphs



g-Miner: Interactive Visual Group Mining on Multivariate Graphs, ACM CHI 2015

Reading Assignment:

Visualization Viewpoints

Editor:
Theresa-Marie Rhyne

The Top 10 Challenges in Extreme-Scale Visual Analytics

Pak Chung Wong
Pacific Northwest National Laboratory

Han-Wei Shen
Ohio State University

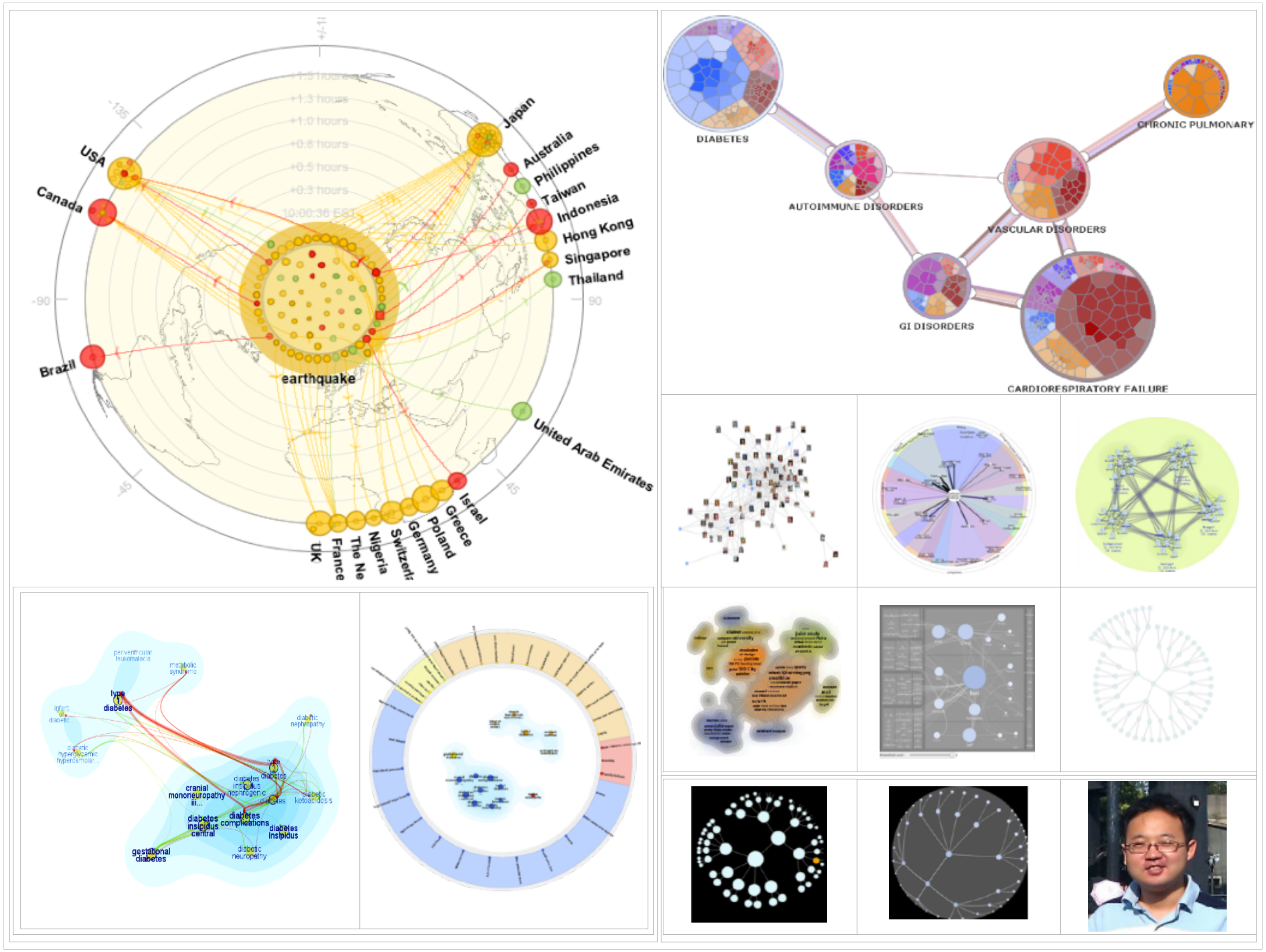
Christopher R. Johnson
University of Utah

Chaomei Chen
Drexel University

Robert B. Ross
Argonne National Laboratory

Wong, P. C., Shen, H. W., Johnson, C. R., Chen, C., & Ross, R. B. (2012). The top 10 challenges in extreme-scale visual analytics. IEEE computer graphics and applications, 32(4), 63.

Thank You!



Thanks to Dr. Nan Cao http://nancao.org

Final Project Proposal Scoring

Proposal — preparing about 5 pages (each item 1/5 of the proposal score):

- Goal — novel? challenging?
- Data — 3Vs? New dataset? Existing dataset?
- Methods — planning of methodologies and algorithms? Feasible?
- System — an overview of system. What will be implemented?
- Schedule — what to achieve by what time, and by whom?

Final Project Report Scoring

- **Title, Author(s)**
- **Abstract**: Briefly describe your problem, approach, and key results.
- **Introduction (5%)**: Describe and define the problem you are working on. Why is it important? Include an overview of your methods and results.
- **Related Work (5%)**: Discuss published works or approaches that are related to your project. What's the benefit or drawback of the previous works? What kind of problems have they solved? How is your approach similar or different from others?
- **Data (10%)**: Describe the data you are working with for your project. What type of data is it? Where did it come from? How much data are you working with? Did you have to do any preprocessing, filtering, feature engineering, or other special treatment to use this data in your project?
- **Methods (25%)**: Discuss your approach for solving the problems that you set up in the introduction. Why is your approach the right thing to do? Did you consider alternative approaches? Have your tried some methods that didn't work out? It may be helpful to include figures, diagrams, or tables to describe your method or compare it with other methods.
- **Experiments (20%)**: Discuss the experiments that you performed to demonstrate your approach solves the problem. The experiments will vary depending on the project, but you might compare with previously methods, determine the impact of the components of your system, experiment with different hyper-parameters, architectures, or algorithms, use visualization techniques to gain insight of how your model works, etc. Graphs, tables, and figures are highly recommended to be included to illustrate your experimental results.
- **System Overview (25%)**: Describe the software architecture and tech stacks of your application. Discuss potential bottlenecks and improvements that could be made. Mention the software packages that you used. Mention how to use your application. You could provide screenshots to your application.
- **Conclusion (5%):** Summarize your key results. What have you learned? What problems have you discovered and solved? Suggest ideas for future extensions or new applications.
- **Writing / Formatting (5%)** Is your paper clearly written and nicely formatted?