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E6893 Big Data Analytics Lecture 8:

Big Data Visualization — I

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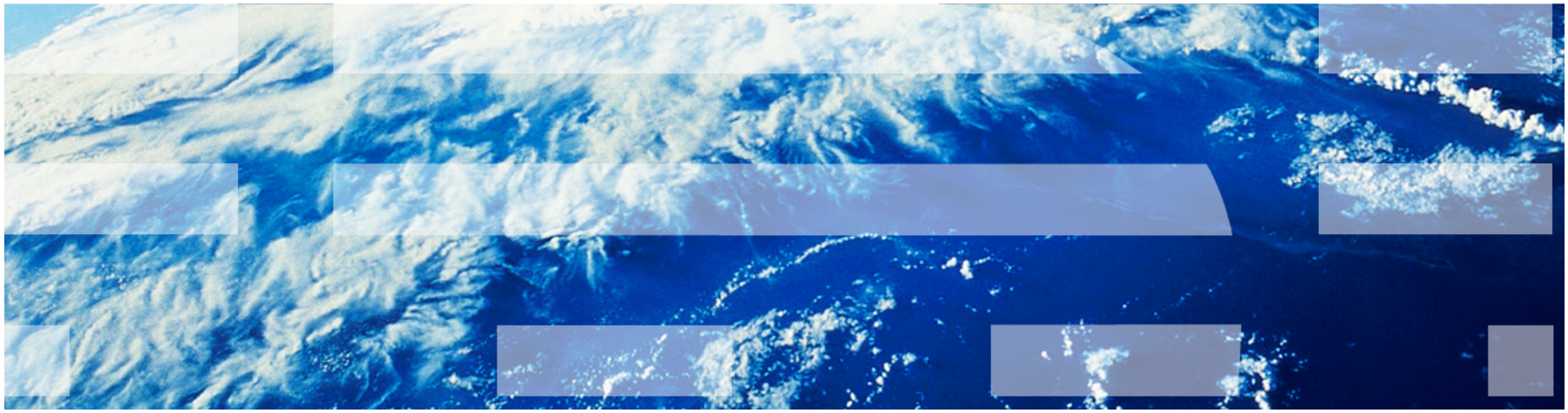


October 25th, 2019

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

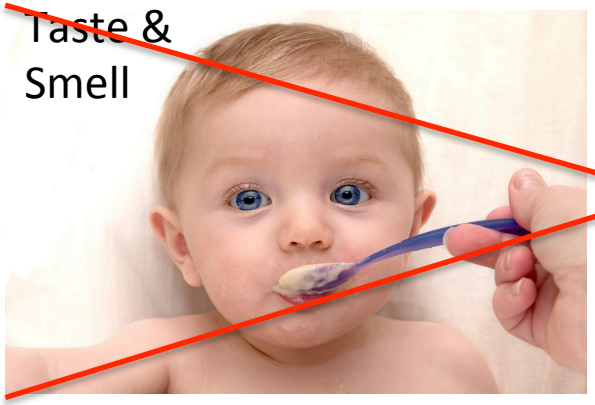
What is visualization?

How can we acquire information?

Do they effective ?

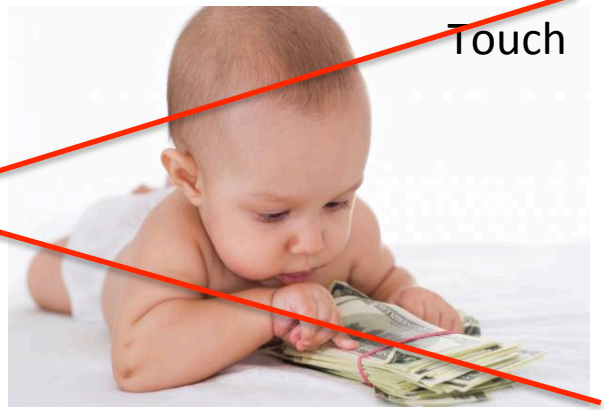
Chemical Signal

Taste & Smell



Physical Signal

Touch



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

Can not be estimated by information theory

Do they effective ?

Sound Signal

Listen

Bandwidth: **about 0.1 KB / s**

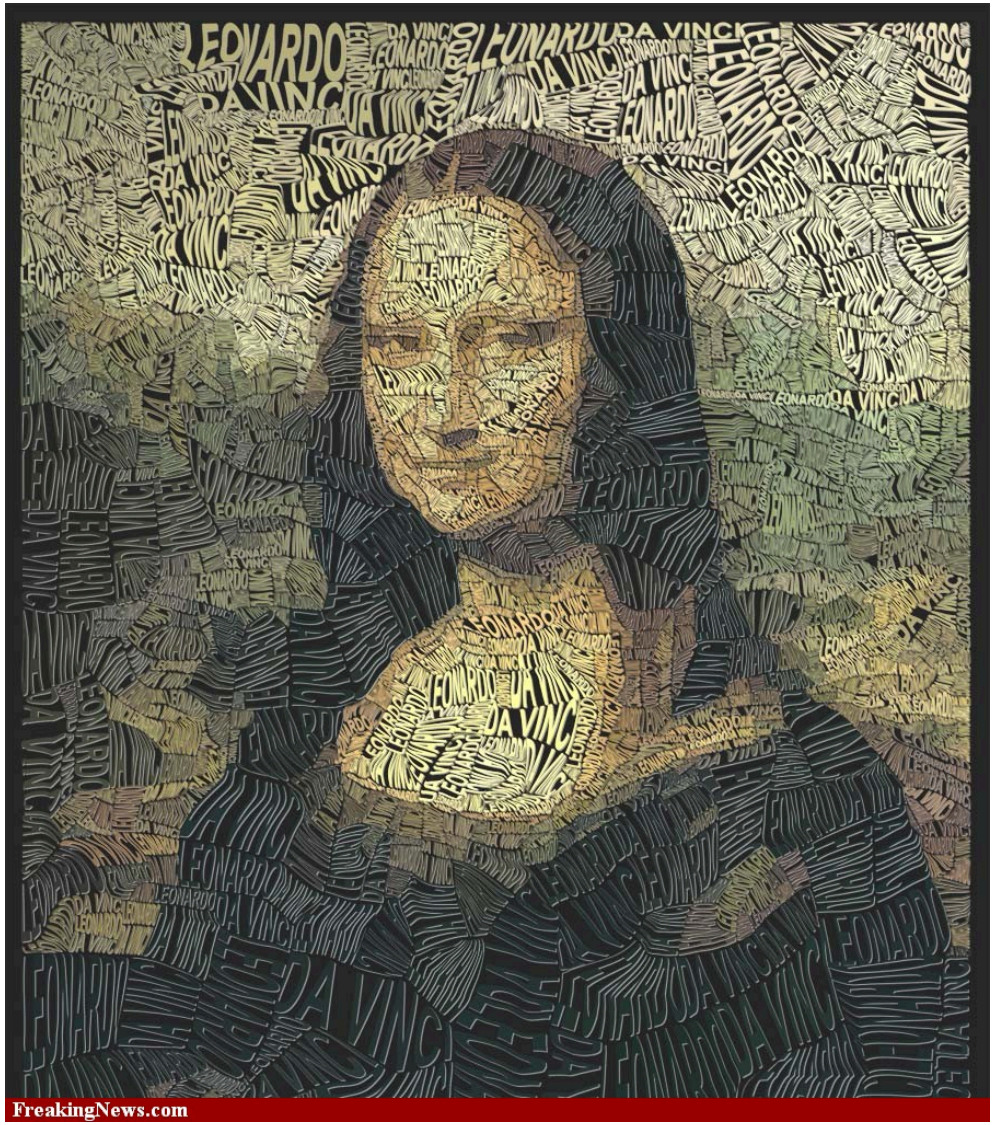
Electronic / Light Signal

Look

> 100 MB/s

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

A picture worth 1000 Words

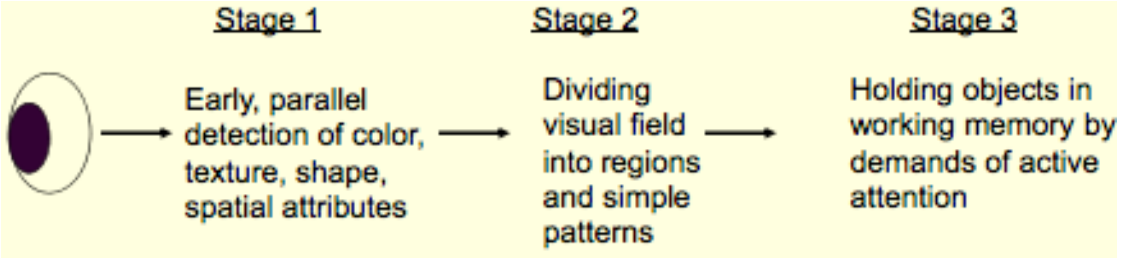


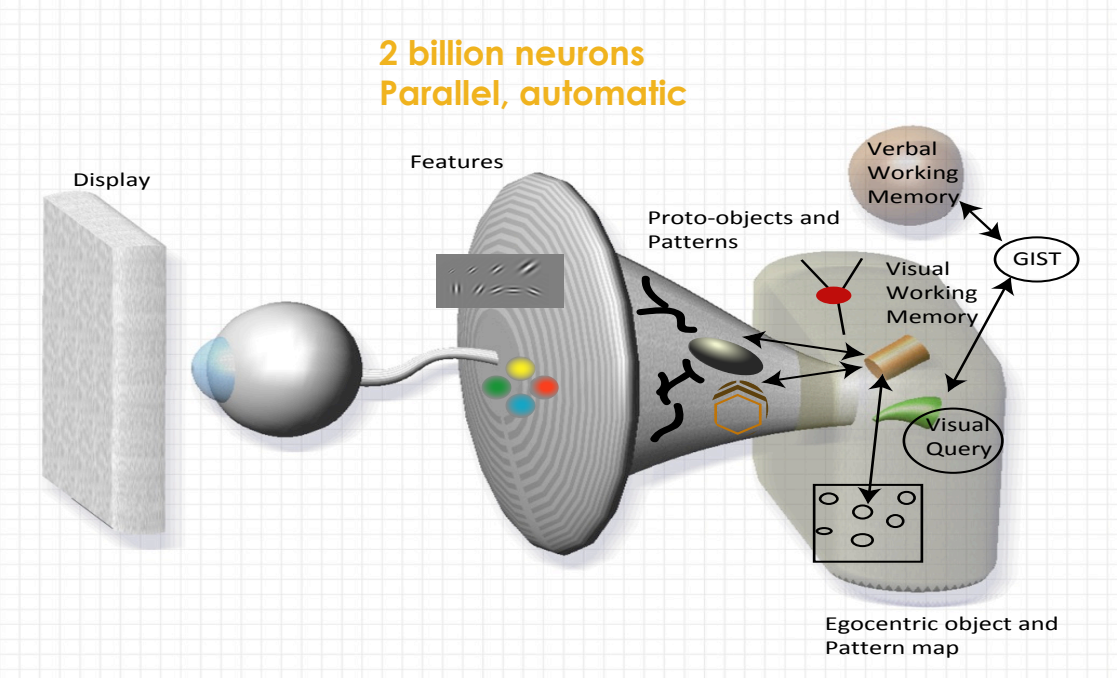
Why efficient ?

The Visual Thinking Pipeline

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

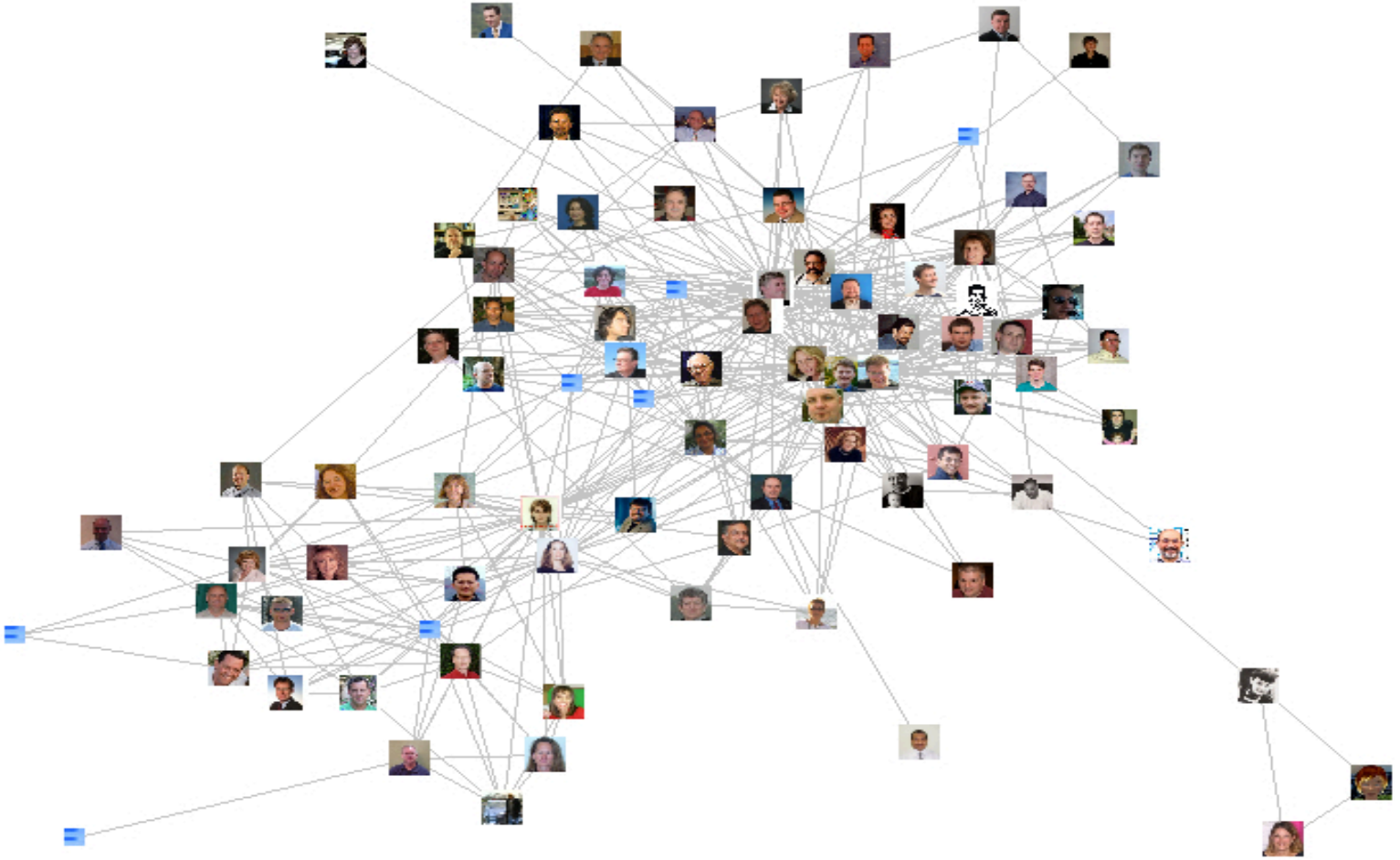
Sequential Goal-Oriented Processing





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

Example

Visualization is used for help reasoning and decision making

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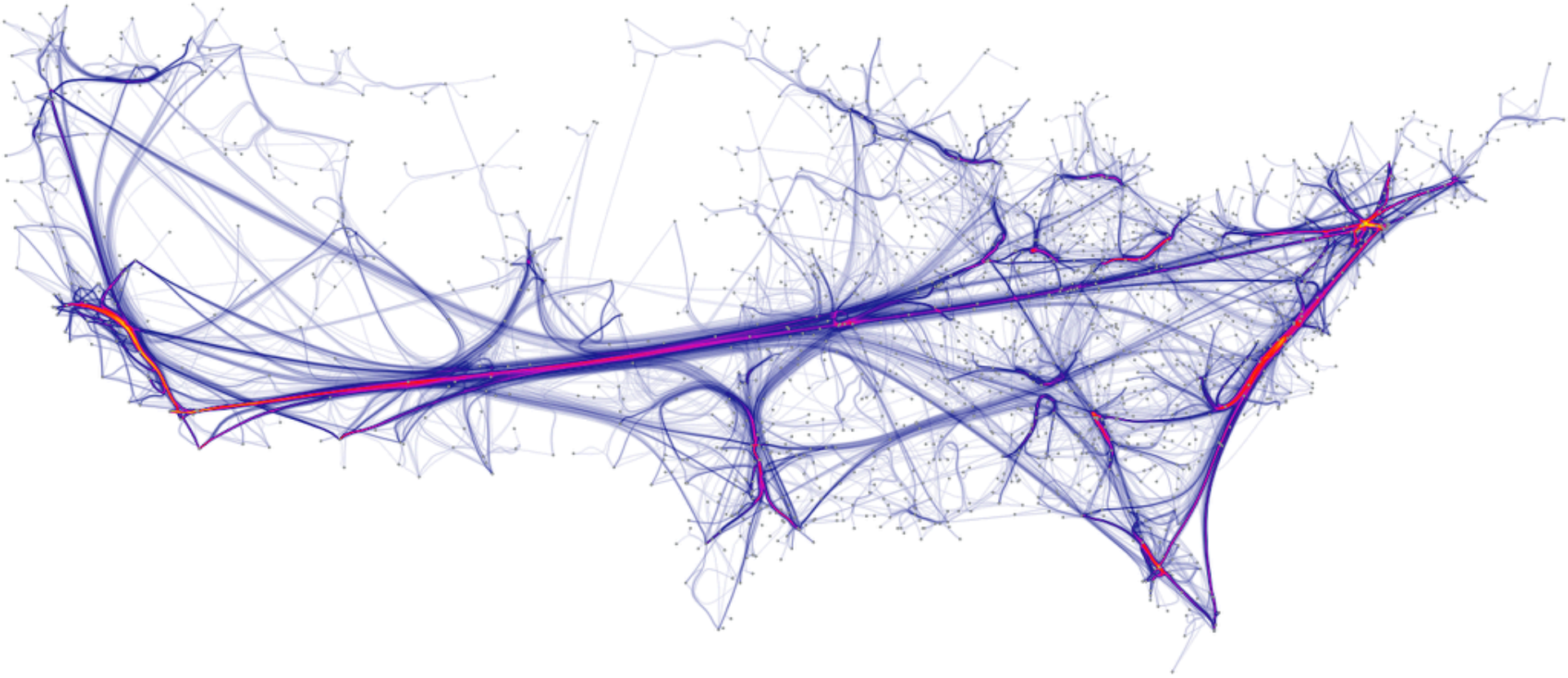
Summarization of Airlines in United States



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

Why do we create visualization?

Counting the number of 3s in the following Text:

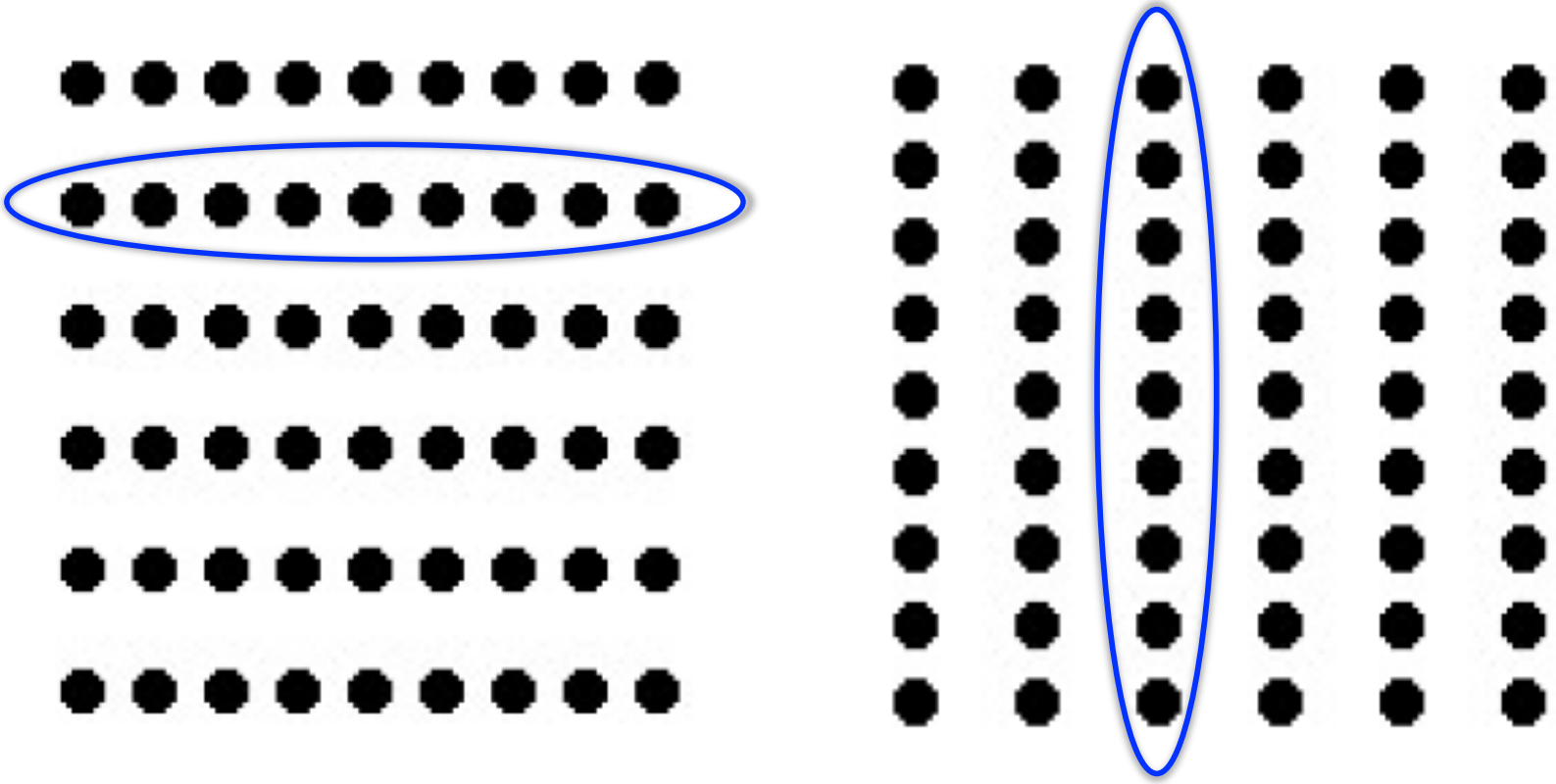
12356932348704529734670378937043679709102539

Counting the number of 3s in the following Text:

12356932348704529734670378937043679709102539

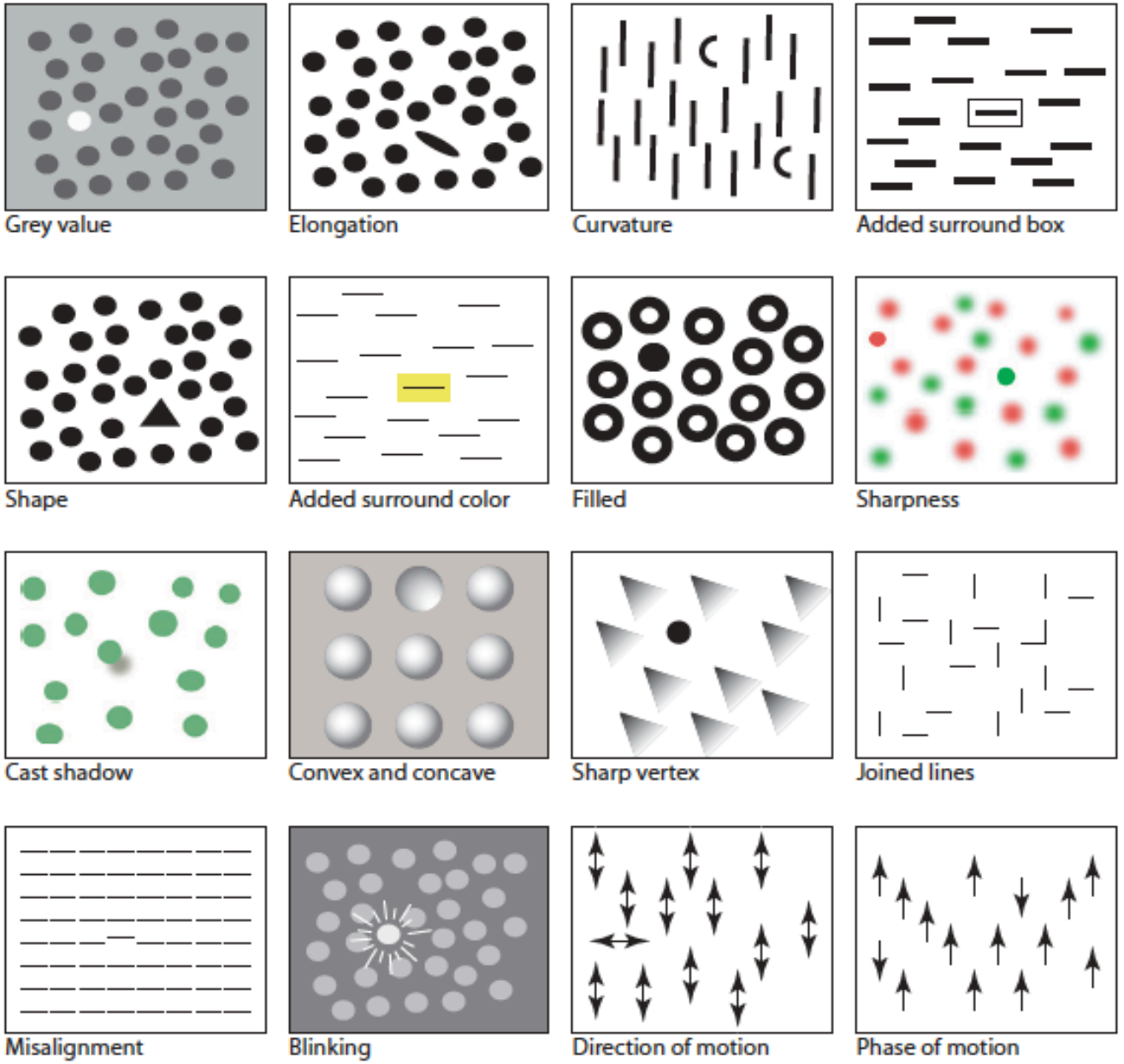
Find Patterns

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



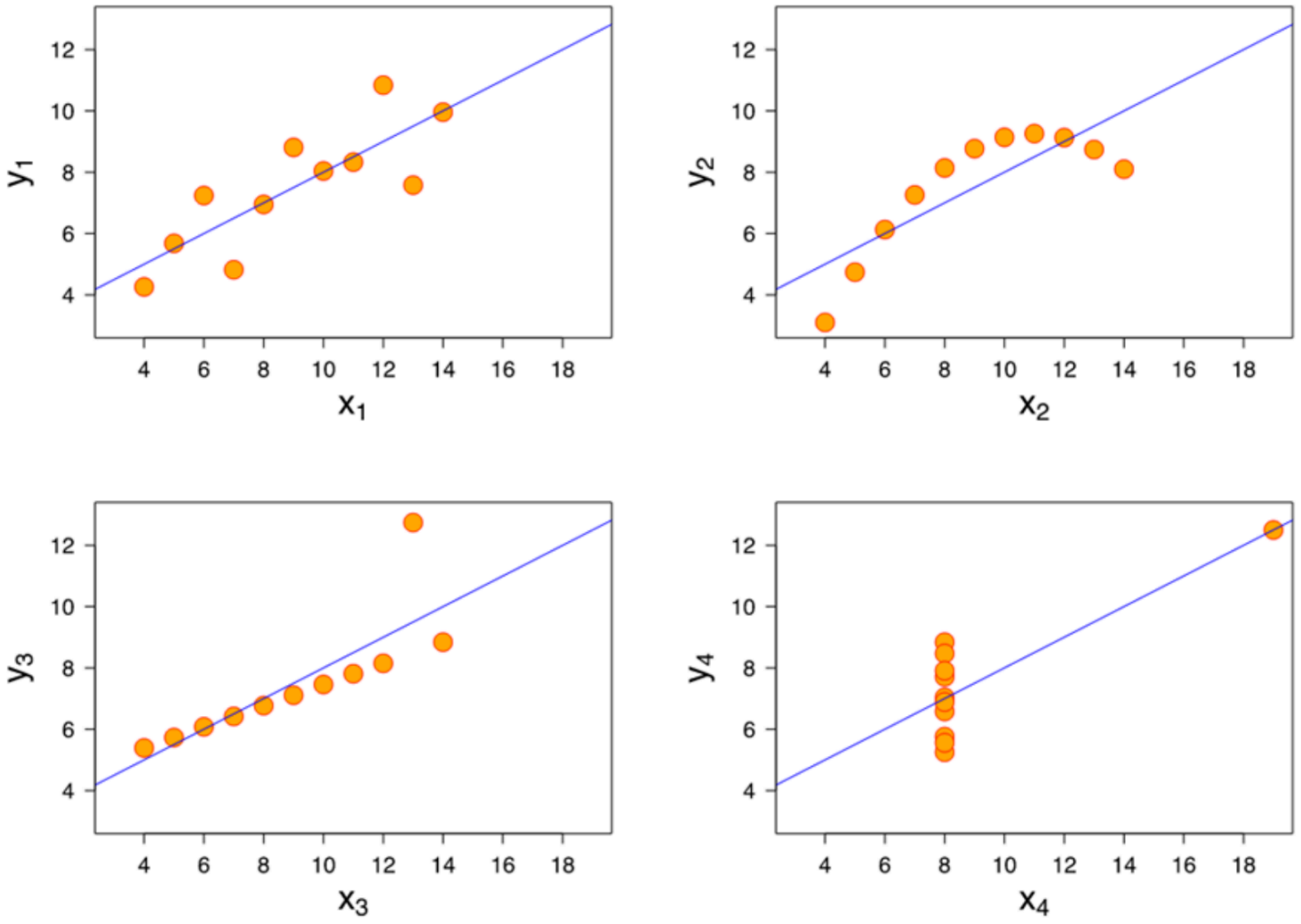
不同突出
内容的方法

color is poweful,
but how about
color blind people?

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 ?

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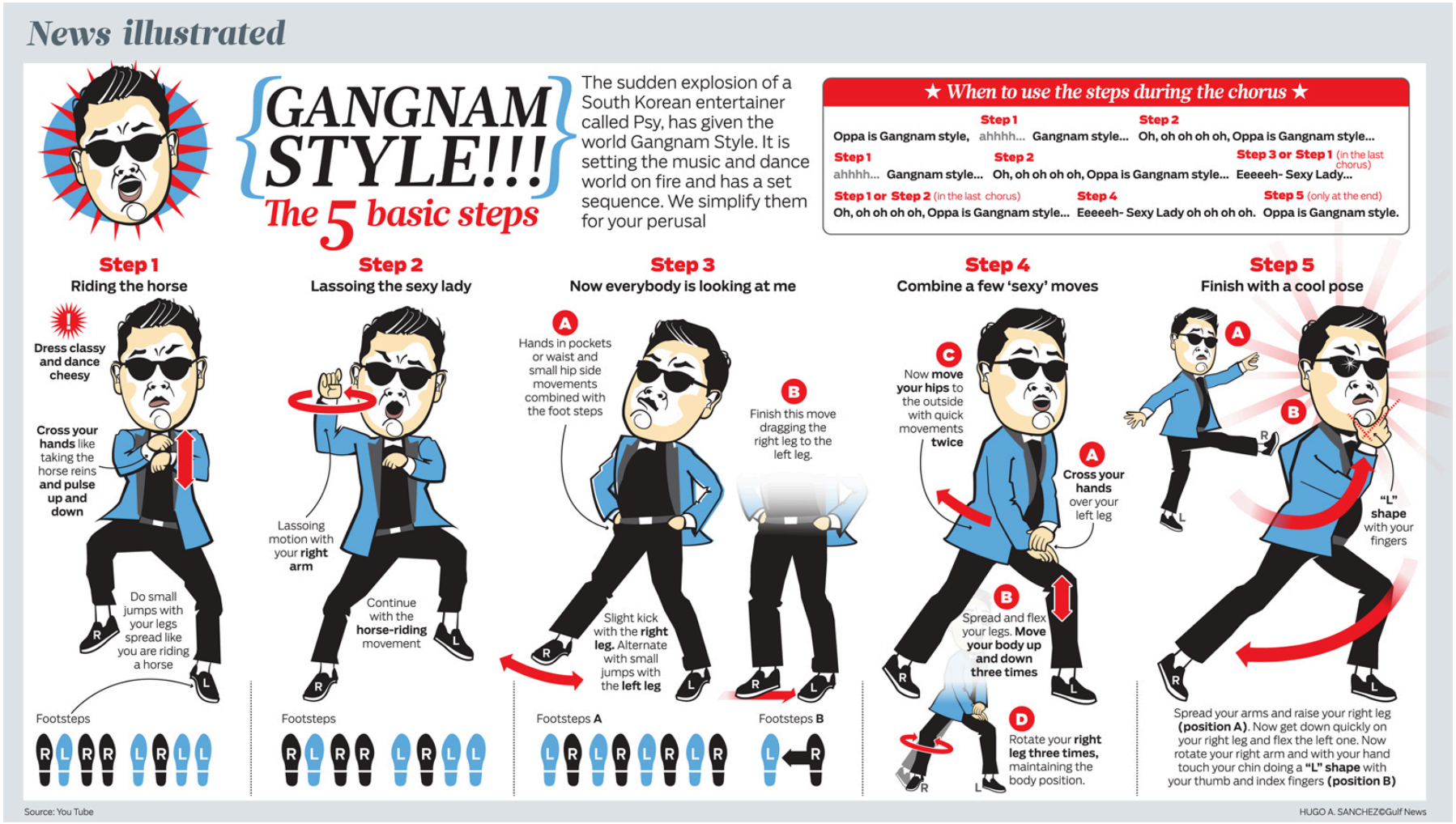
A picture is worth a thousand words



A better communication method

Some other reasons

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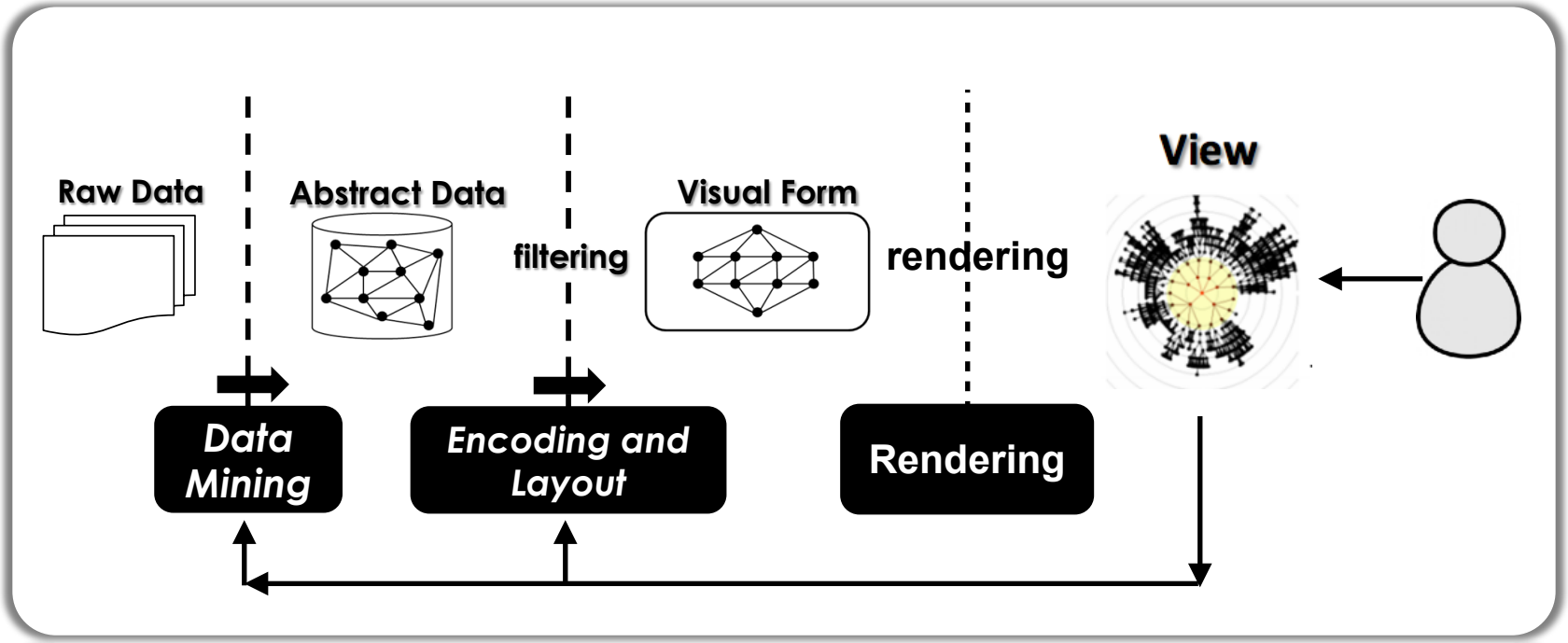
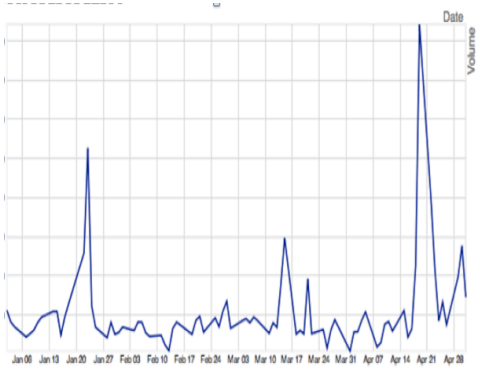
See data in context
Find patterns
Telling a story
Attract attentions
Communicate information with others
Summarization and interpretation
Graphical calculation
Expend memory
Inspire people

Existing Visualisation Techniques

Visualization & Visual Analysis Reference Model



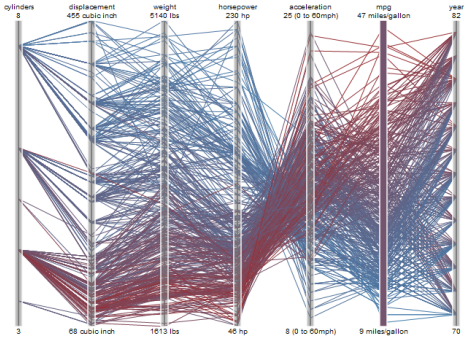
Taxonomy by data types



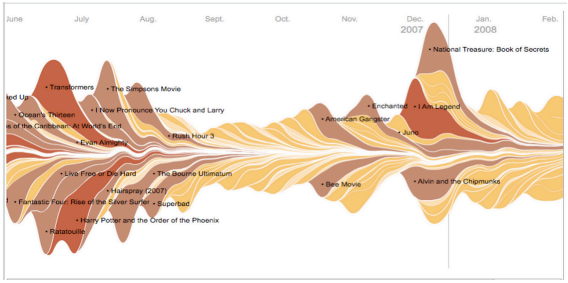
1D

2D

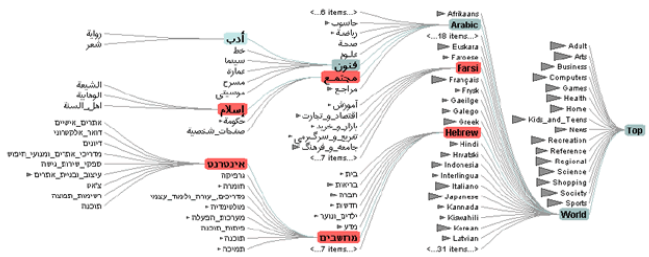
3D



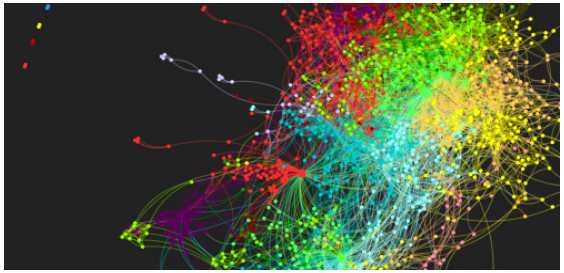
Multi-D



Temporal

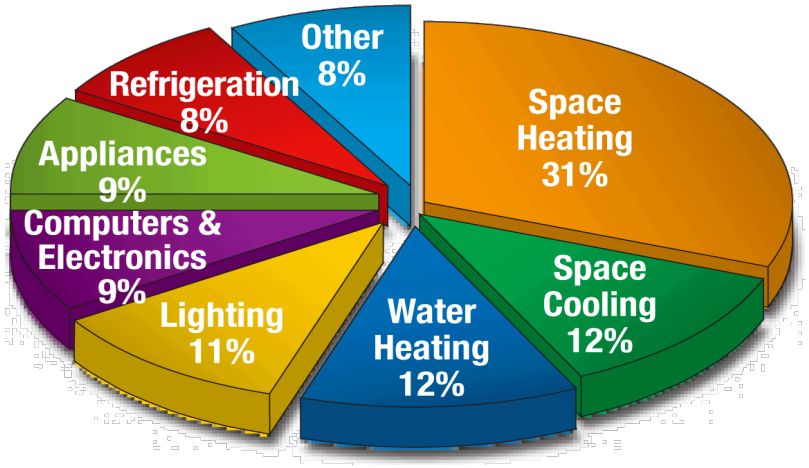


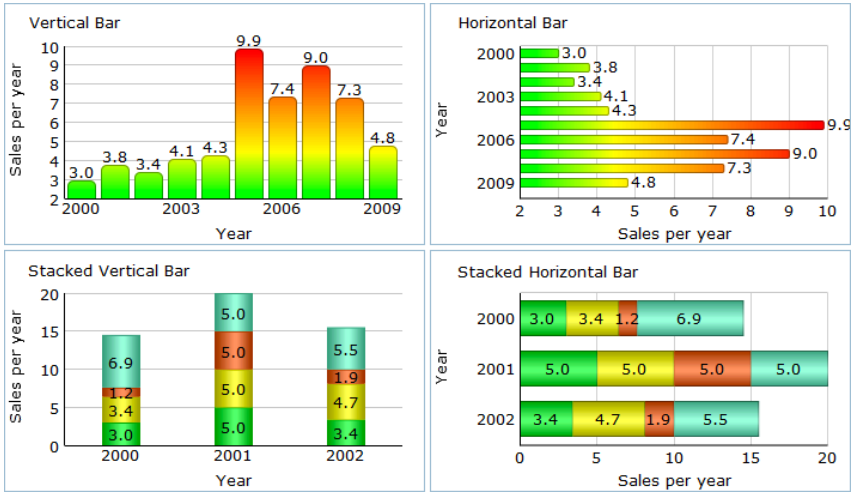
Tree

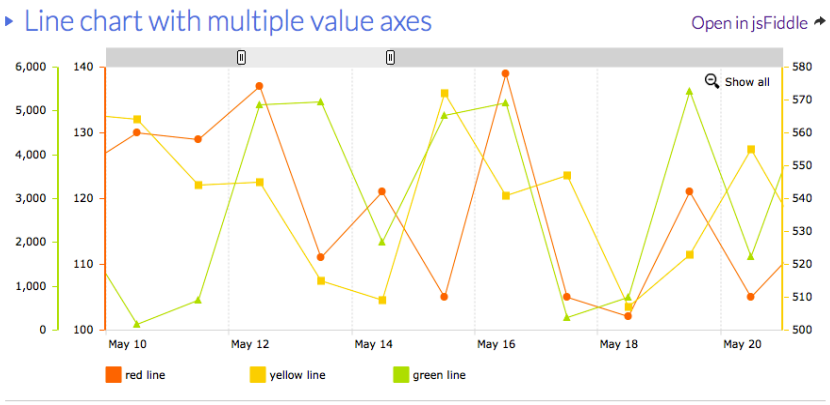


Graph

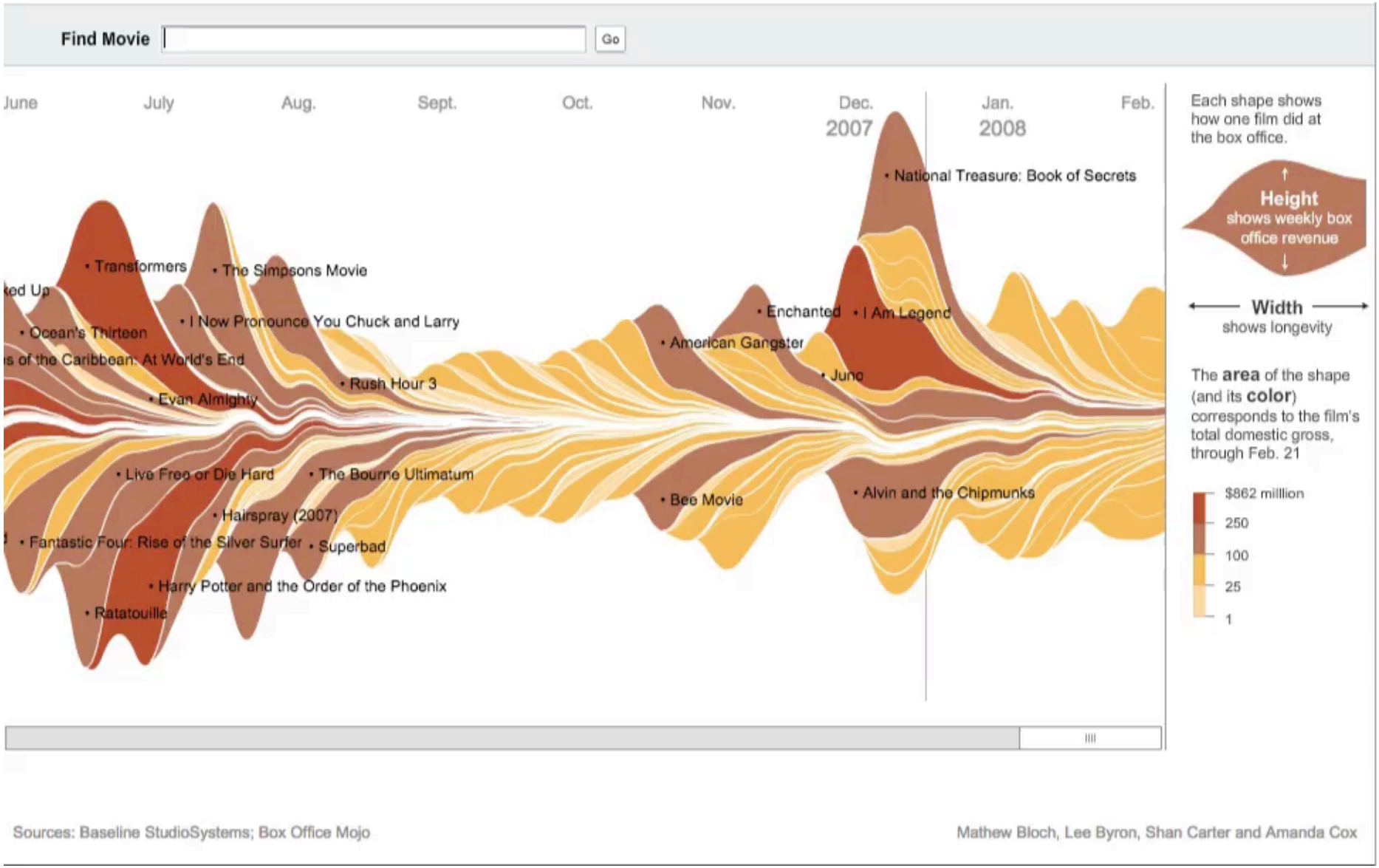
Examples: Visualizing 1D Numerical Data







Example : Visualizing 1D Ordinal Data

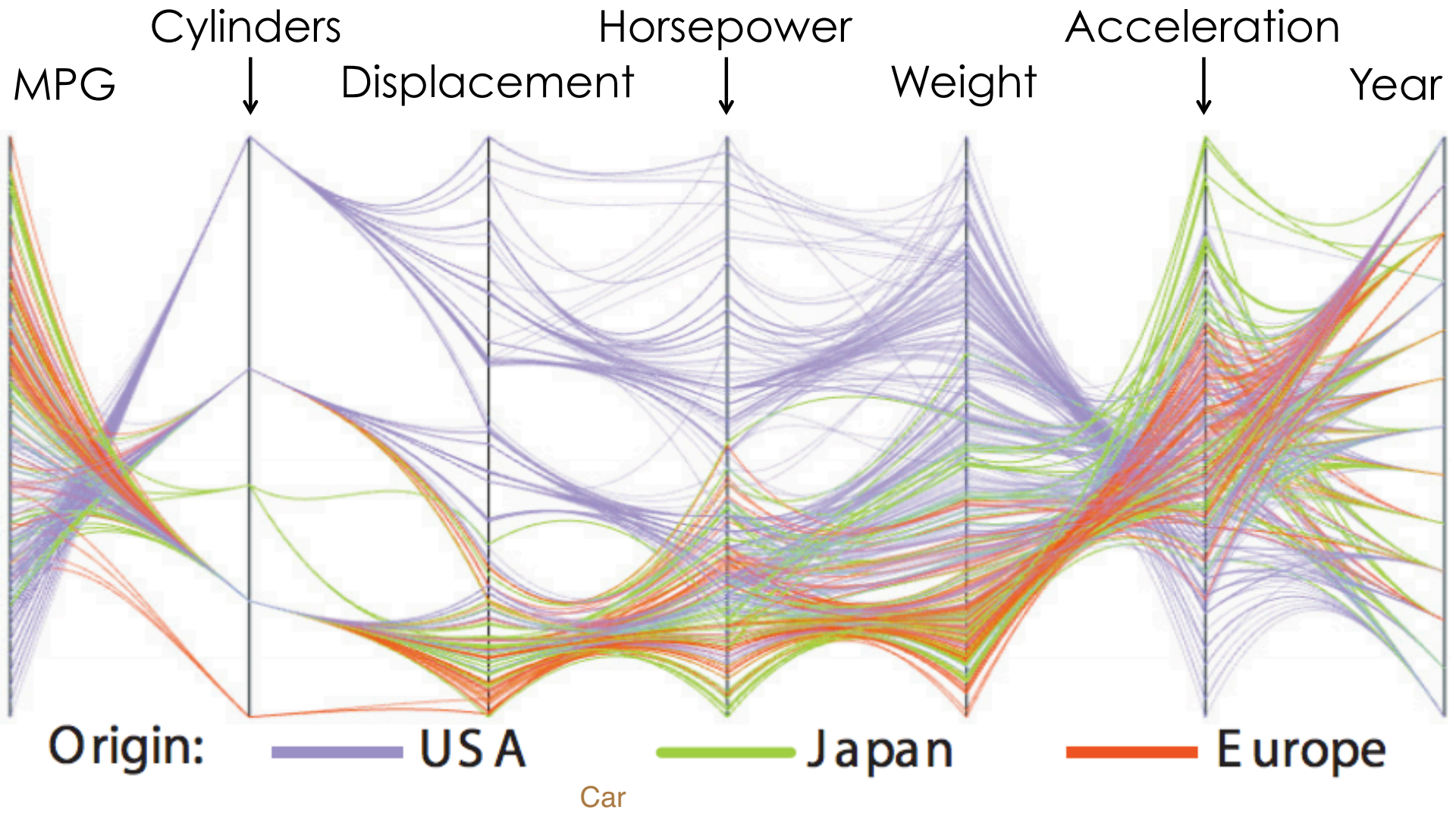


http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html

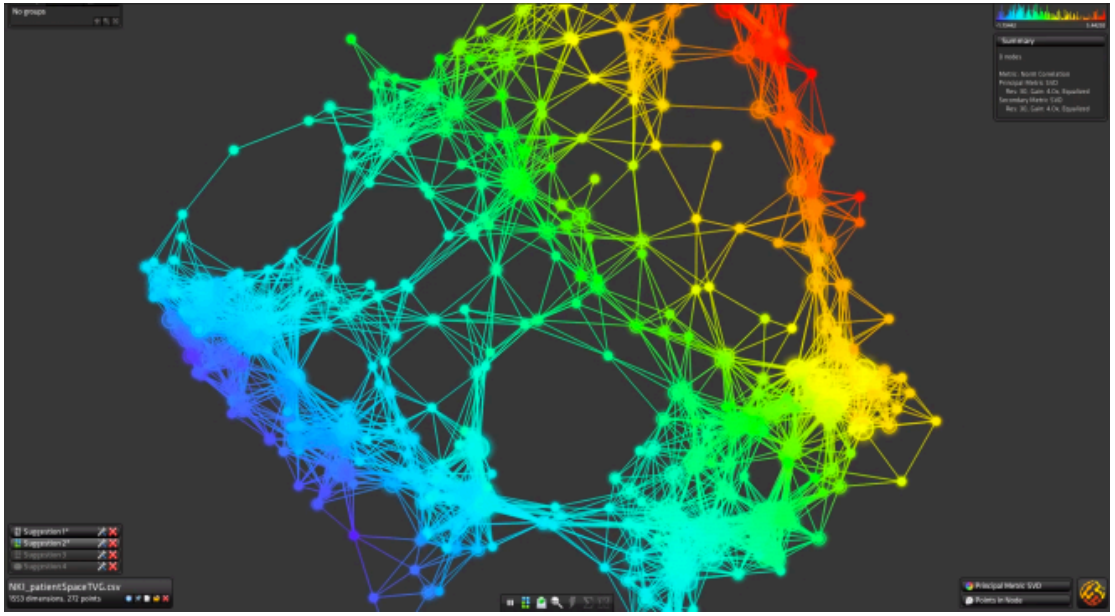
Examples: 2D Data

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

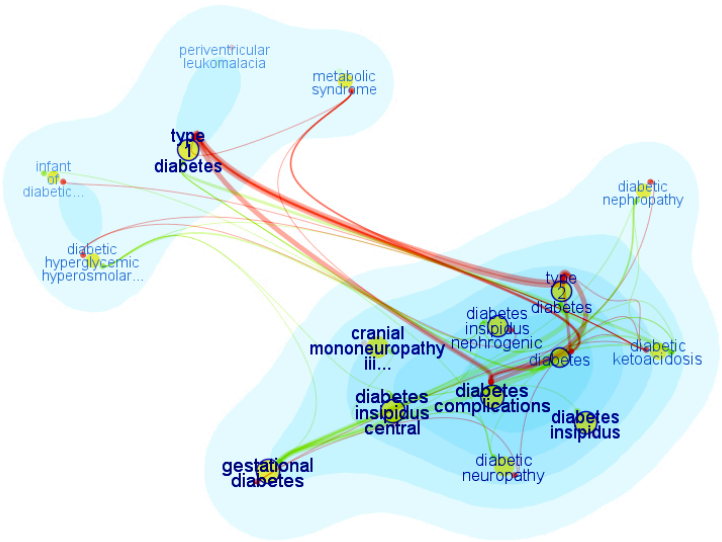
Example：Multi-Dimensional Data

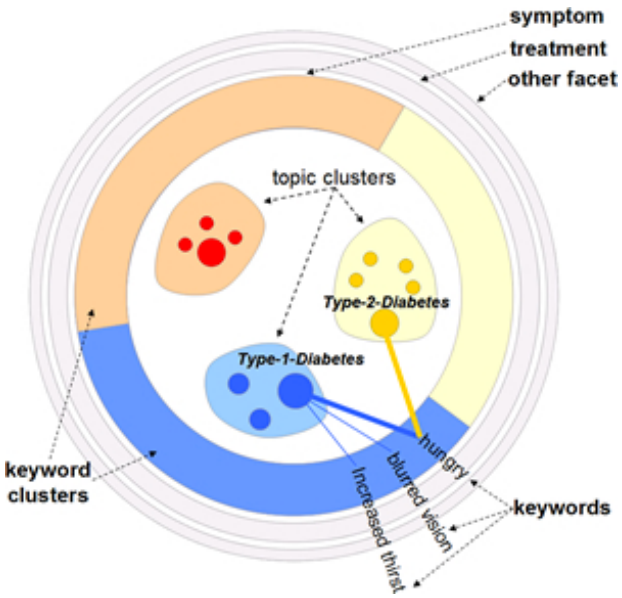


Examples: Visualizing Structured Data

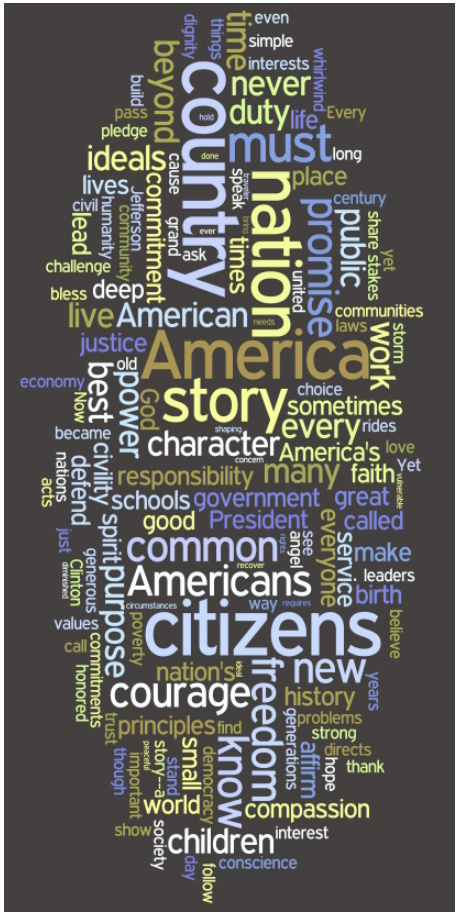


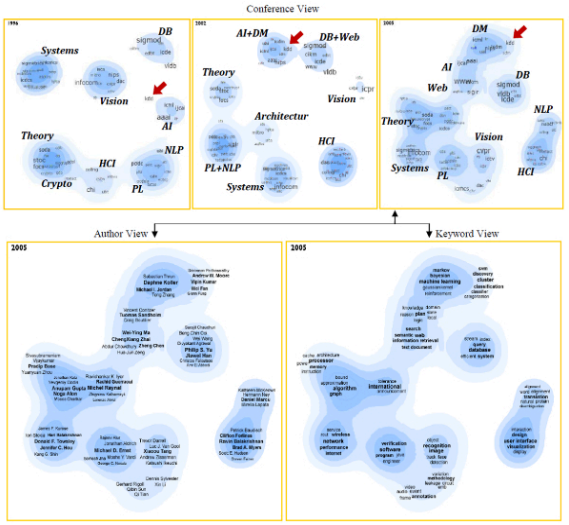
Examples: Visualizing Unstructured Data

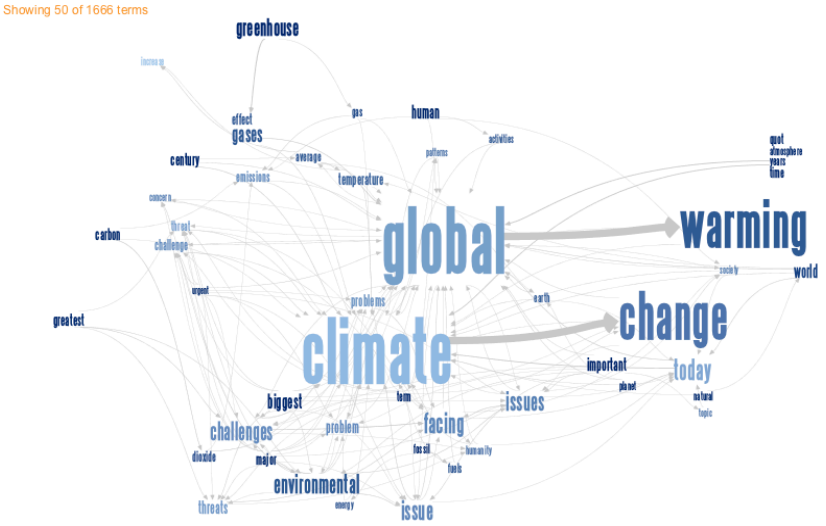




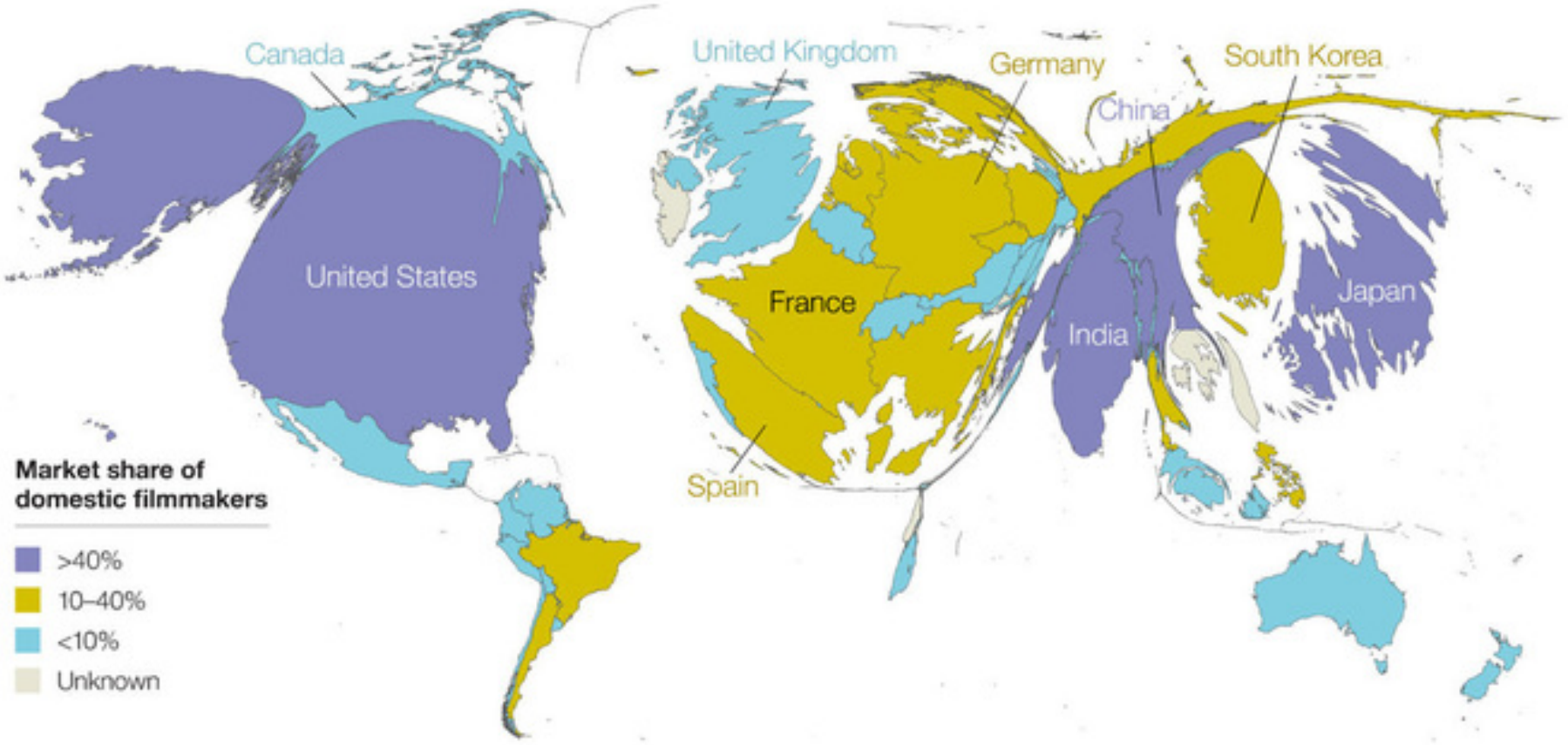
Visualization of Text Documents



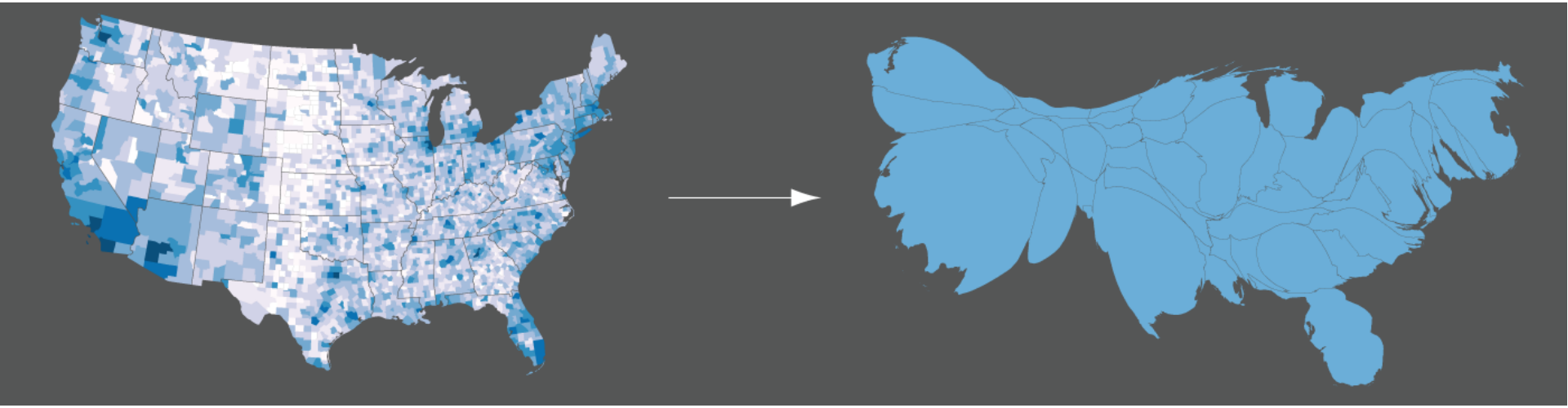


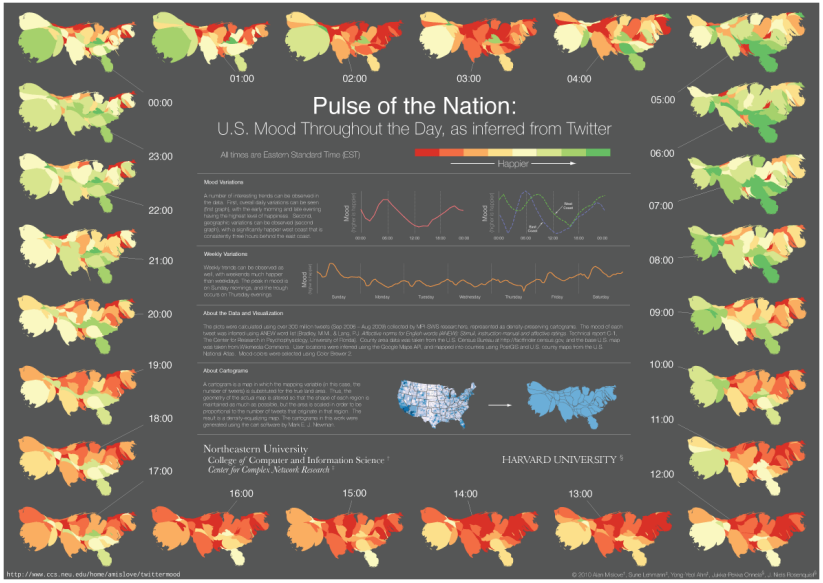


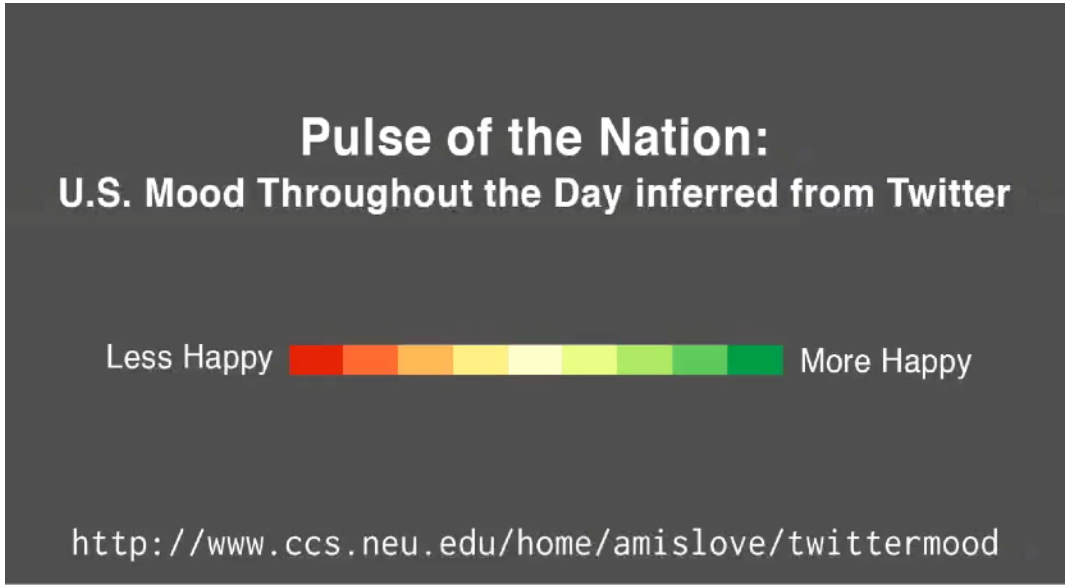
Examples: Geospatial



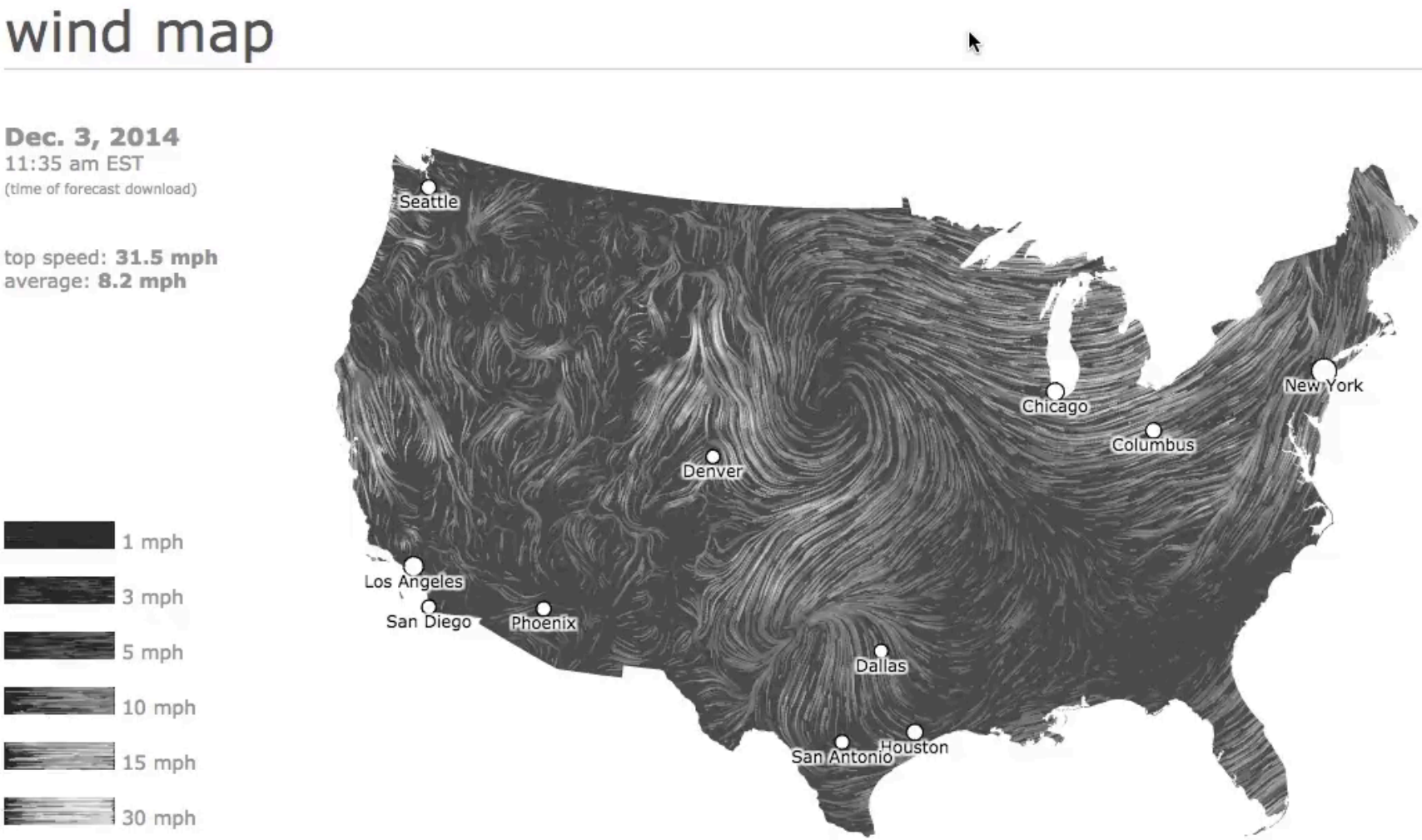
Examples: Visualizing Spatial Temporal Data





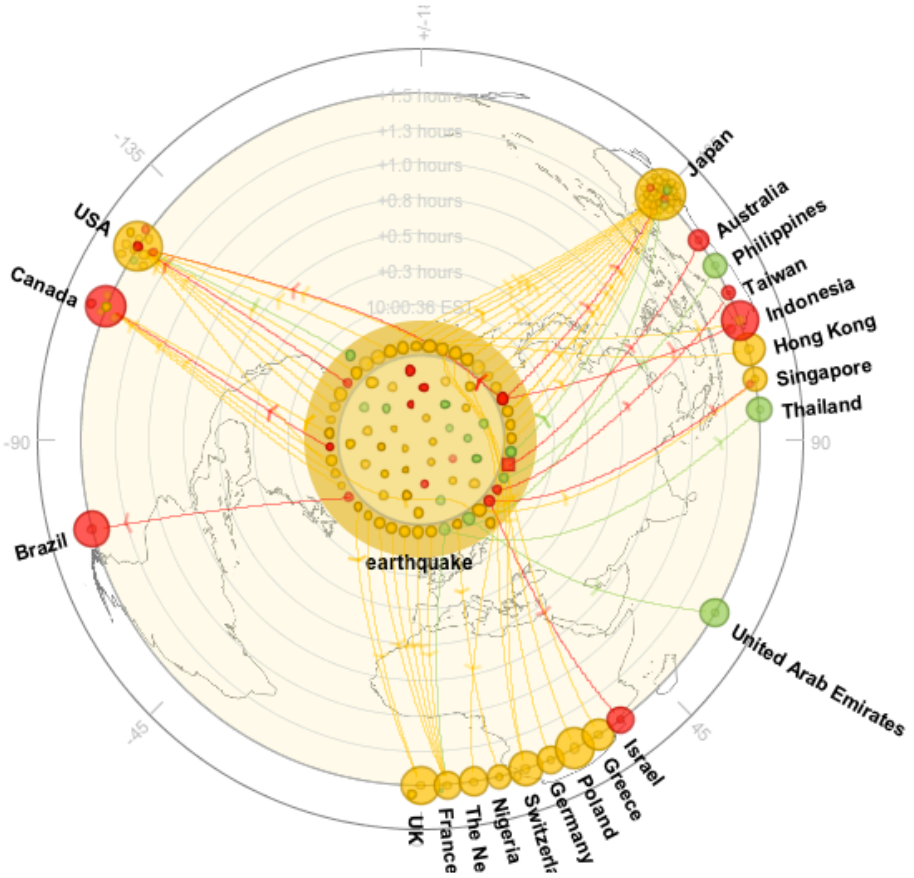


Examples: Visualizing Spatial Temporal Data



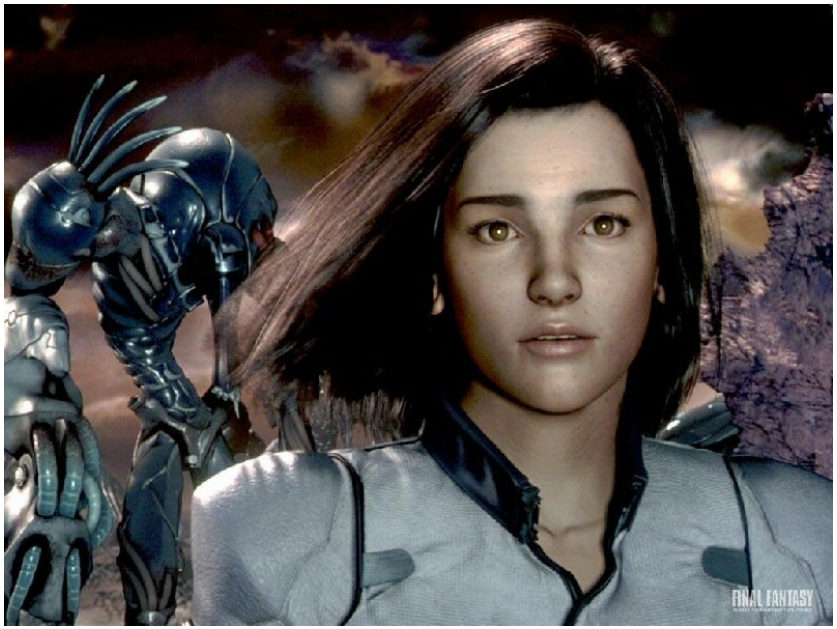
http://hint.fm/wind/

Visualization is not just a beautiful picture

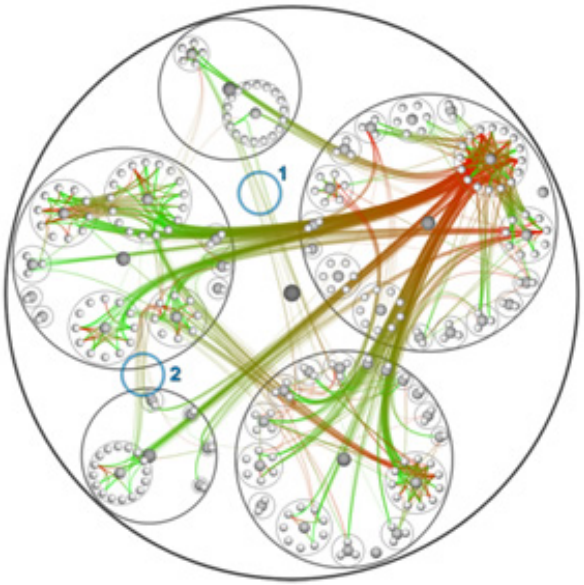


The purpose of visualization is to reveal the insight of the data

InfoVis vs Computer Graphics

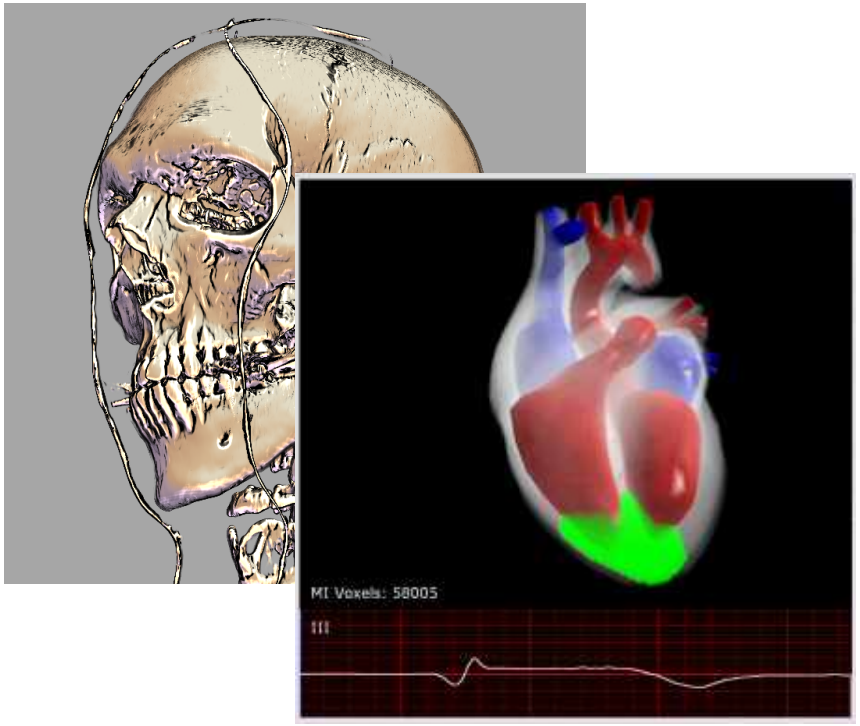


Realism

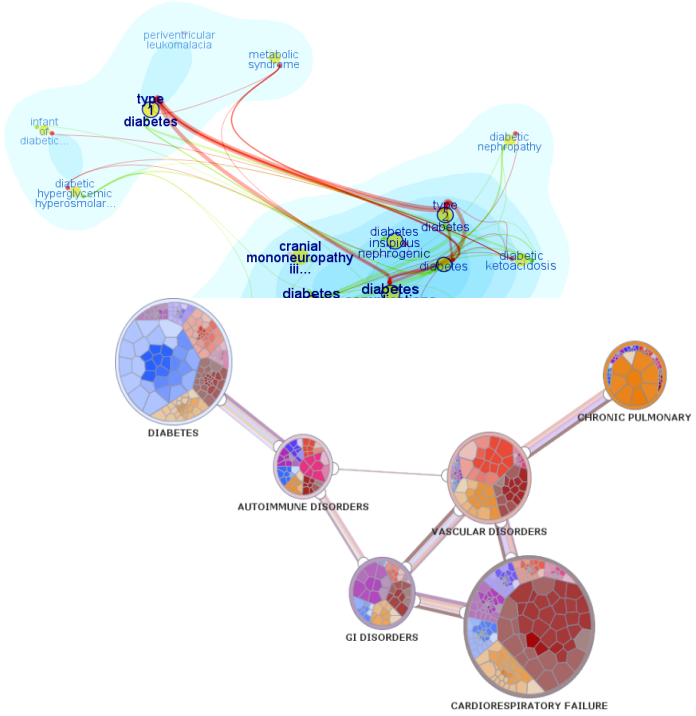


Information

InfoVis v.s. Scientific Visualization



Physical Data



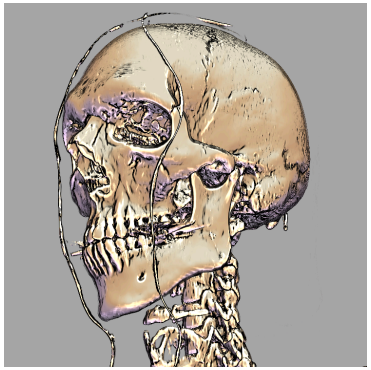
Artificial Data

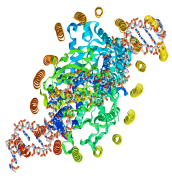
Three Sub-areas

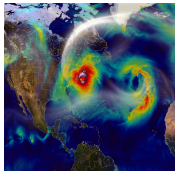
Scientific Visualization (SCIVIS)

Information Visualization (InfoVis)

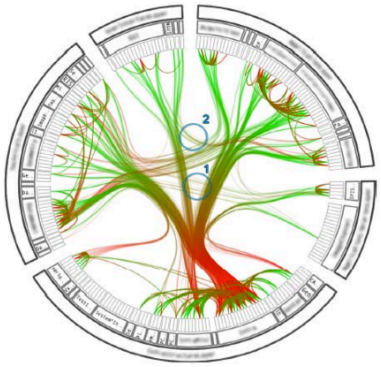
Visual Analysis (VA)

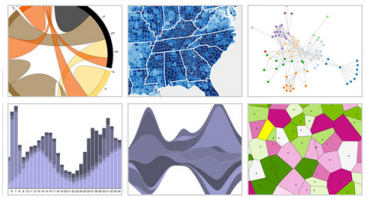






Physical Data





Abstract Data

InfoVis
Data Mining
Machine Learning

Traditional — Research Trend — Modern Technique

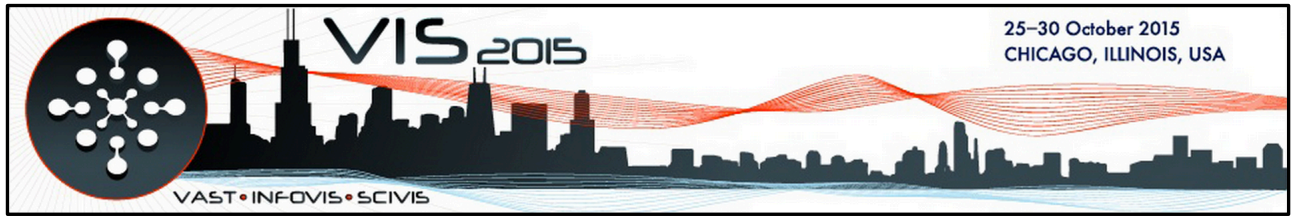
Major Conferences and Journals

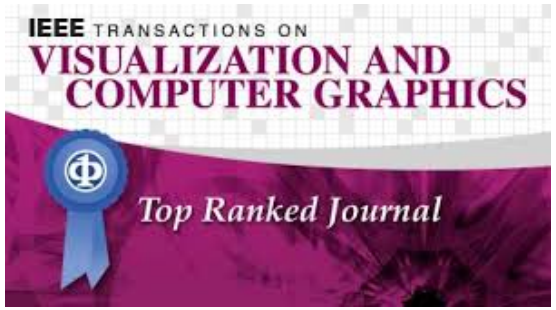
Scientific Visualization (SCIVIS)

Information Visualization (InfoVis)

Visual Analysis (VA)

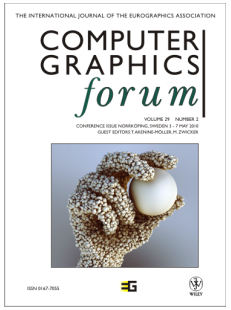
VisWeek: IEEE SCIVIS, INFOVIS, VAST





IEEE Transaction on Visualization and Computer Graphics

>



Computer Graphics Forum

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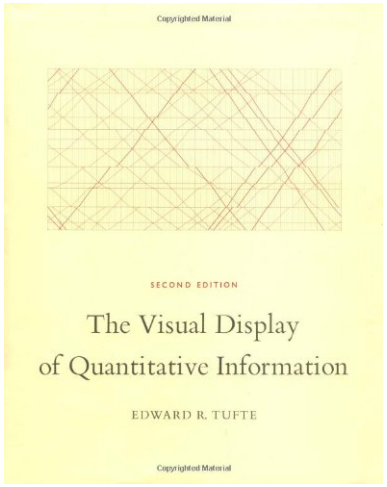
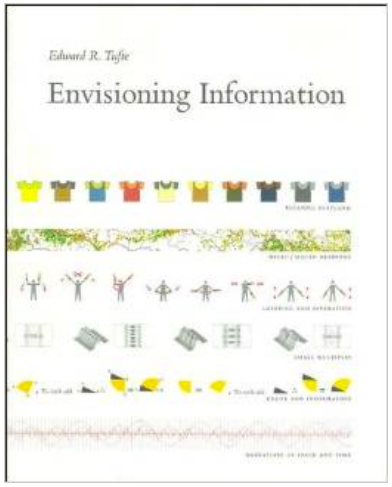
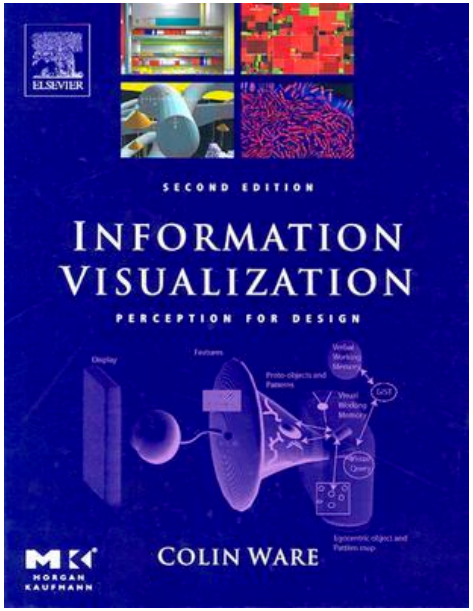
IEEE Computer Graphics and Application

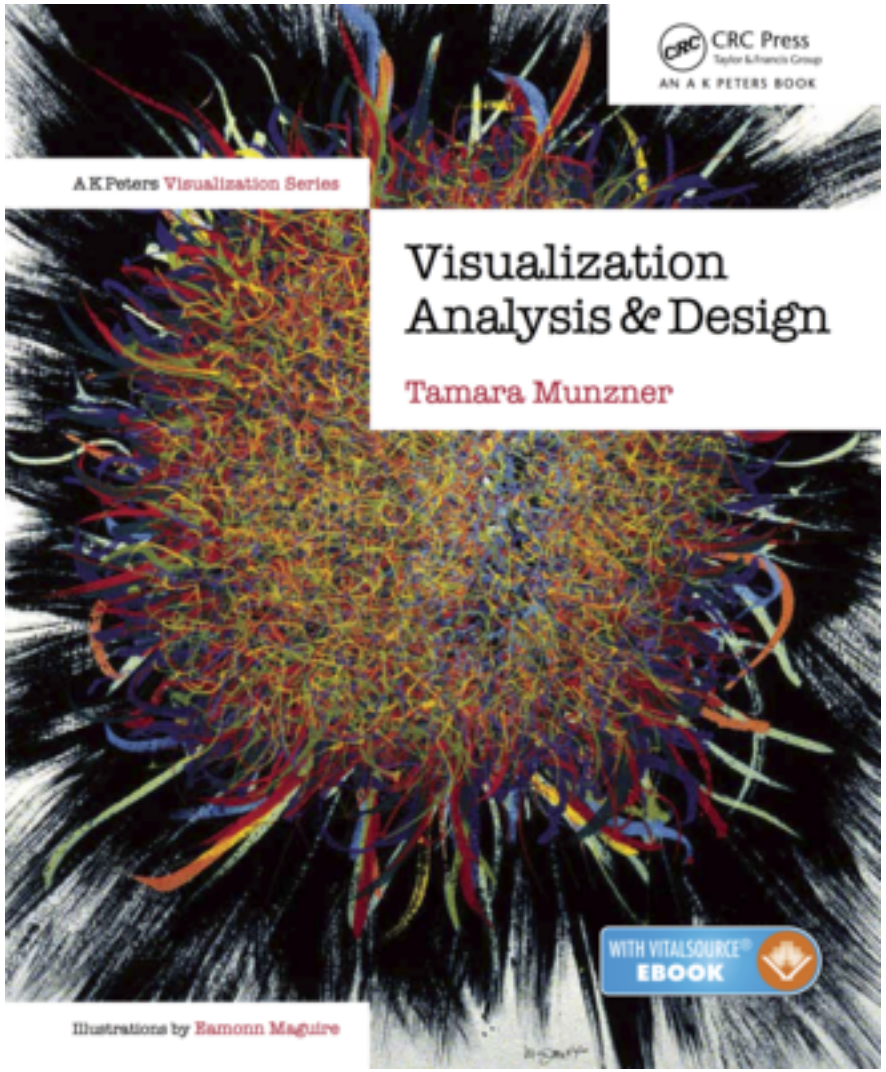
36

Recommended Books







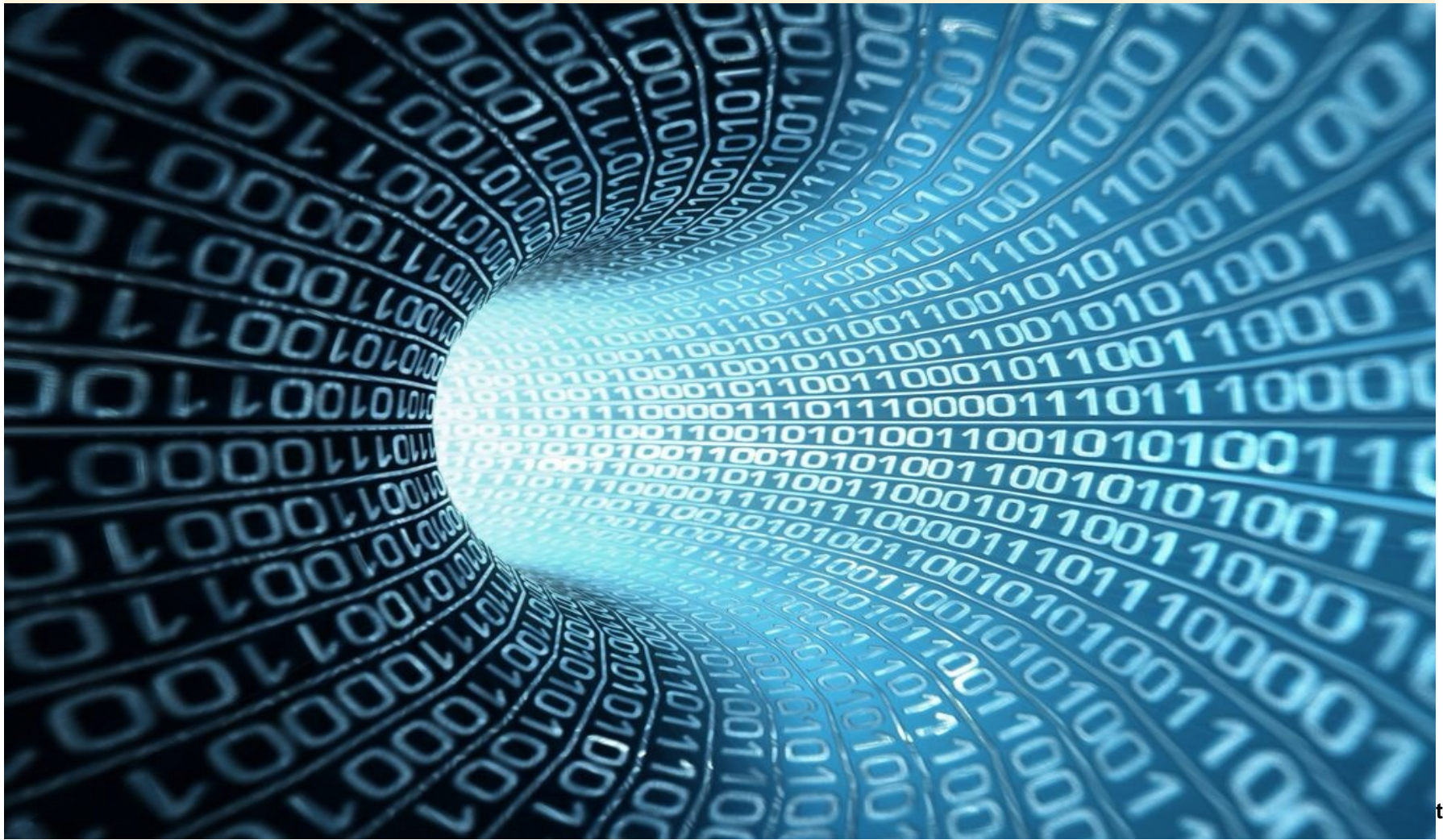


Recommend Must-Learn

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

Part II: Visualising Big Data

Are you ready to *Big Data?*



340 million tweets a day!

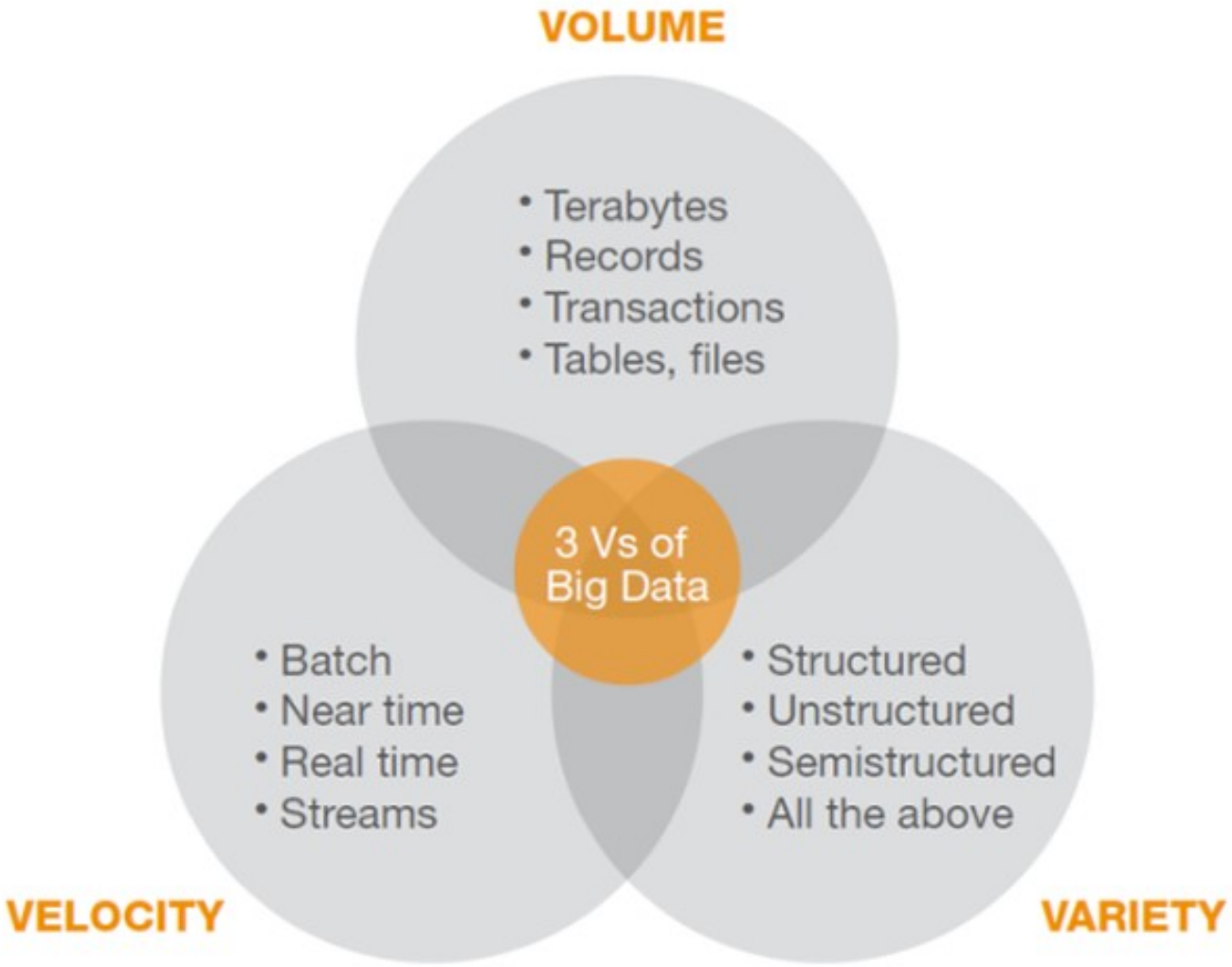
4 billion messages a day!

Information Overload

difficult caused by too much information

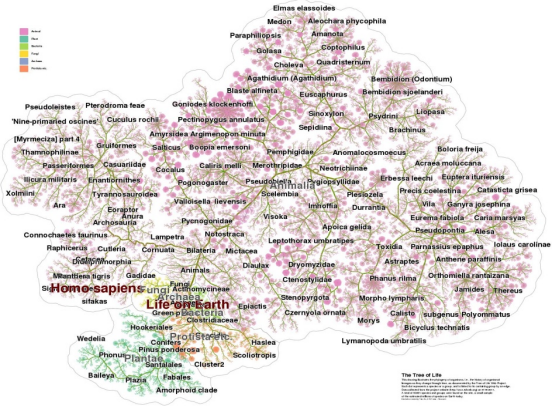
How can we acquire useful information from the overwhelming data

3Vs of Big Data



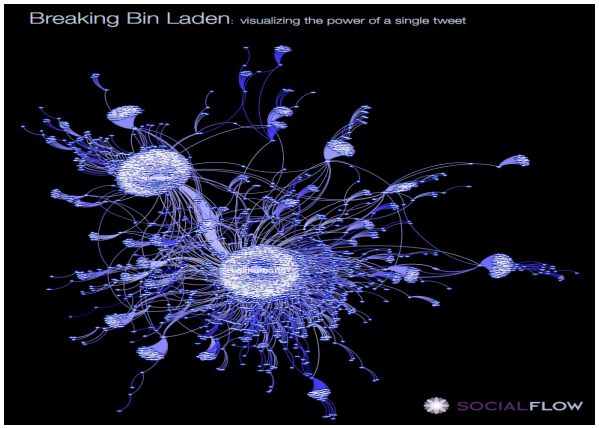
Big Data Visualization

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

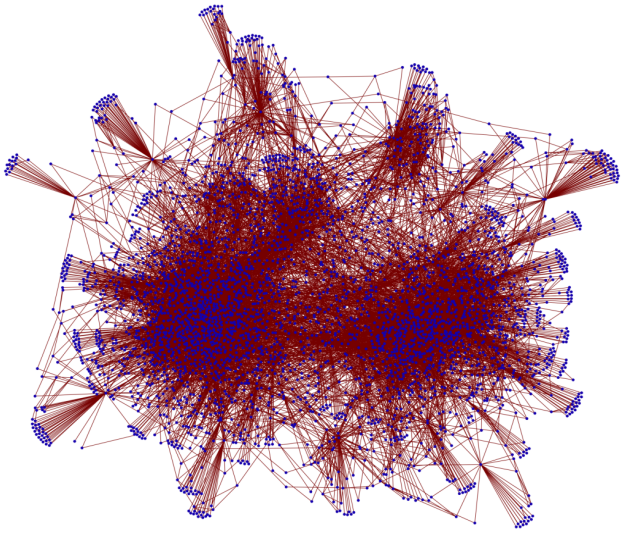
500 million users

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?

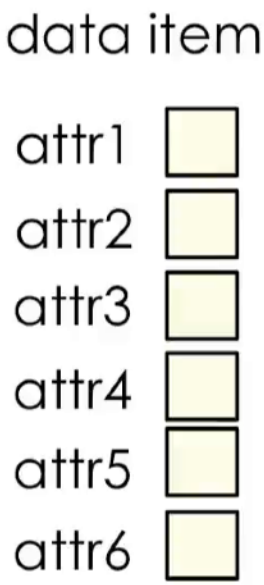
Performance issues

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

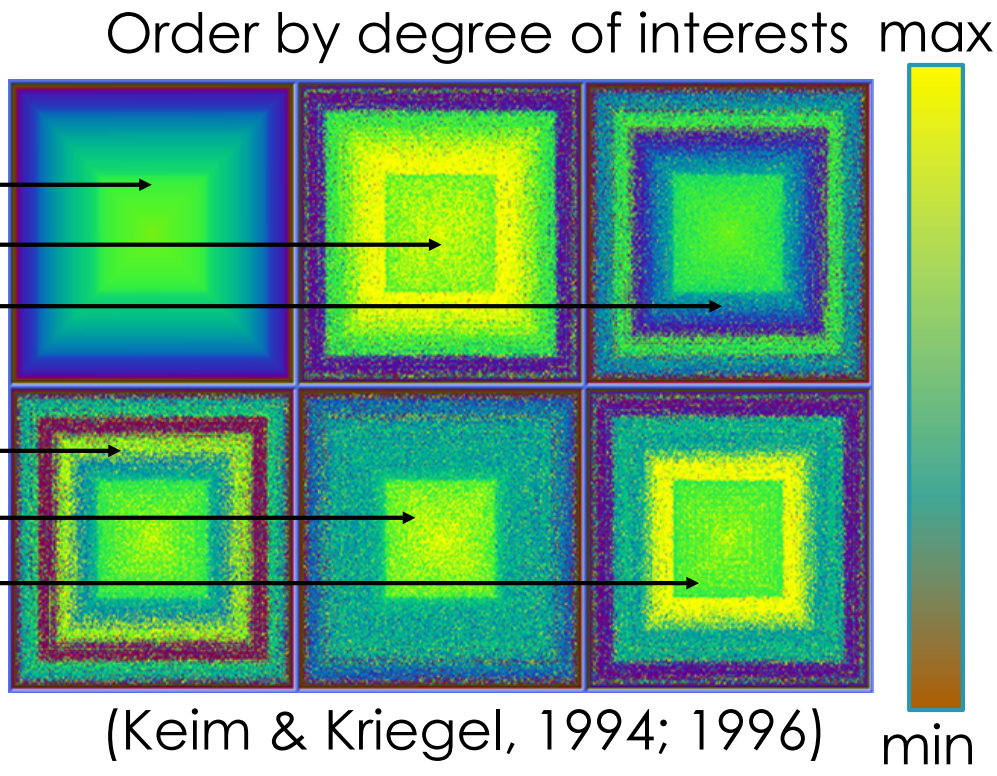


- A multidimensional data item contains 6 attributes

Technique(1) : Pixel Oriented Visualization

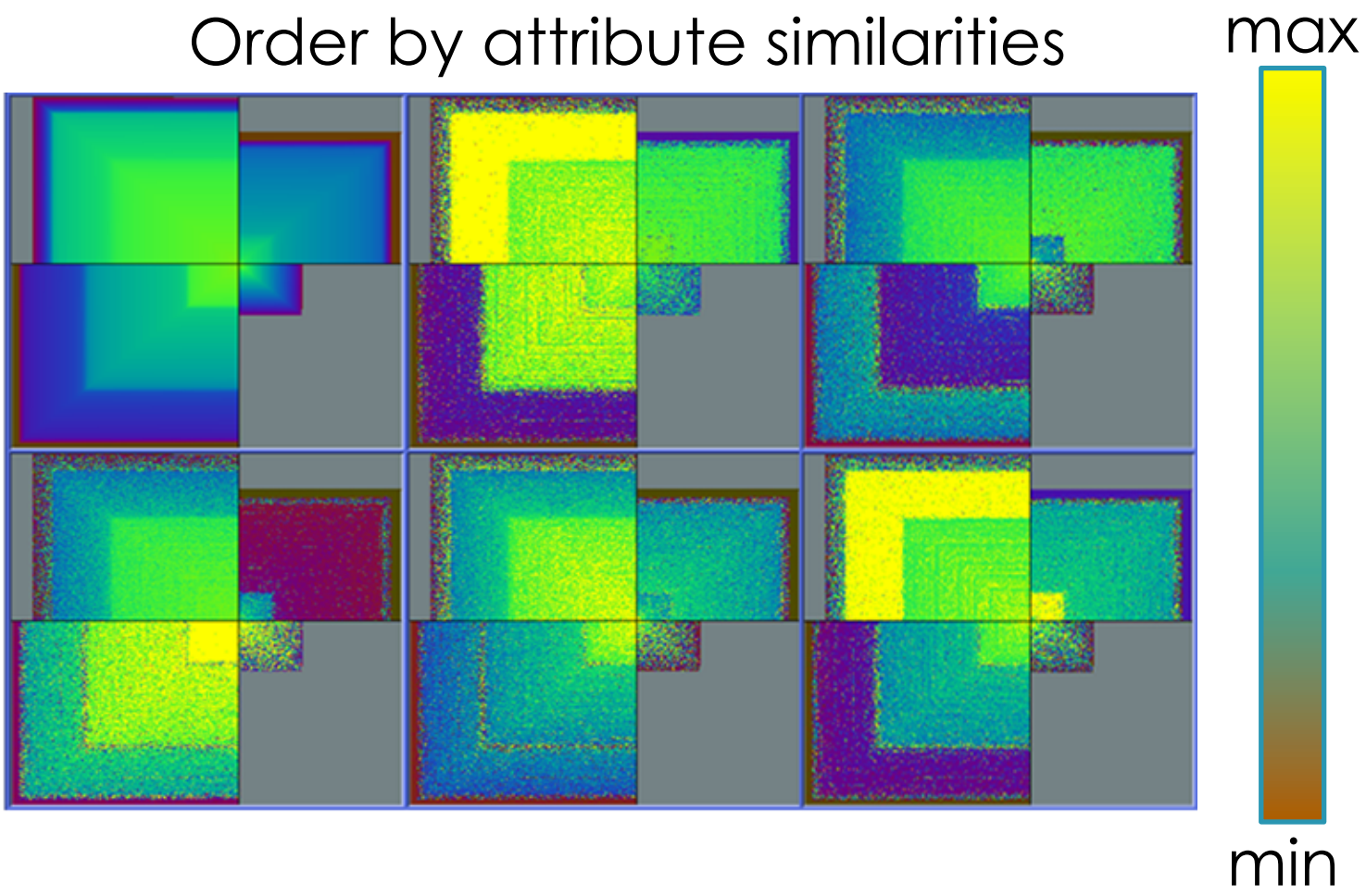
Database visualization (10,000 items, 6 dimensions)

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	353.37	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



Techniques (1): Pixel Oriented Visualization

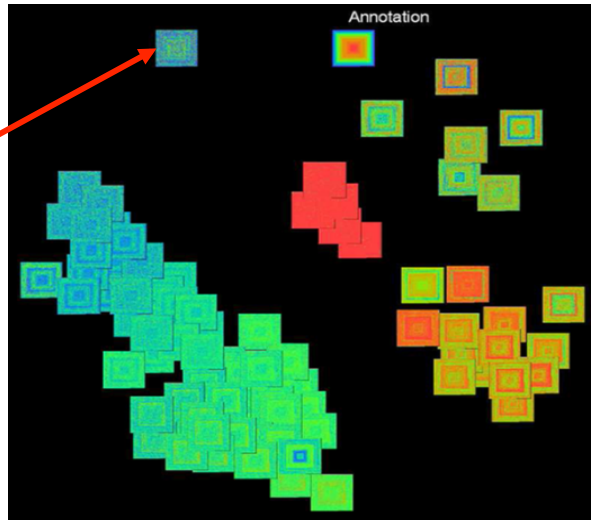
Database Visualization (10,000 items, 6 dimensions)



Different Ways for splitting the display region

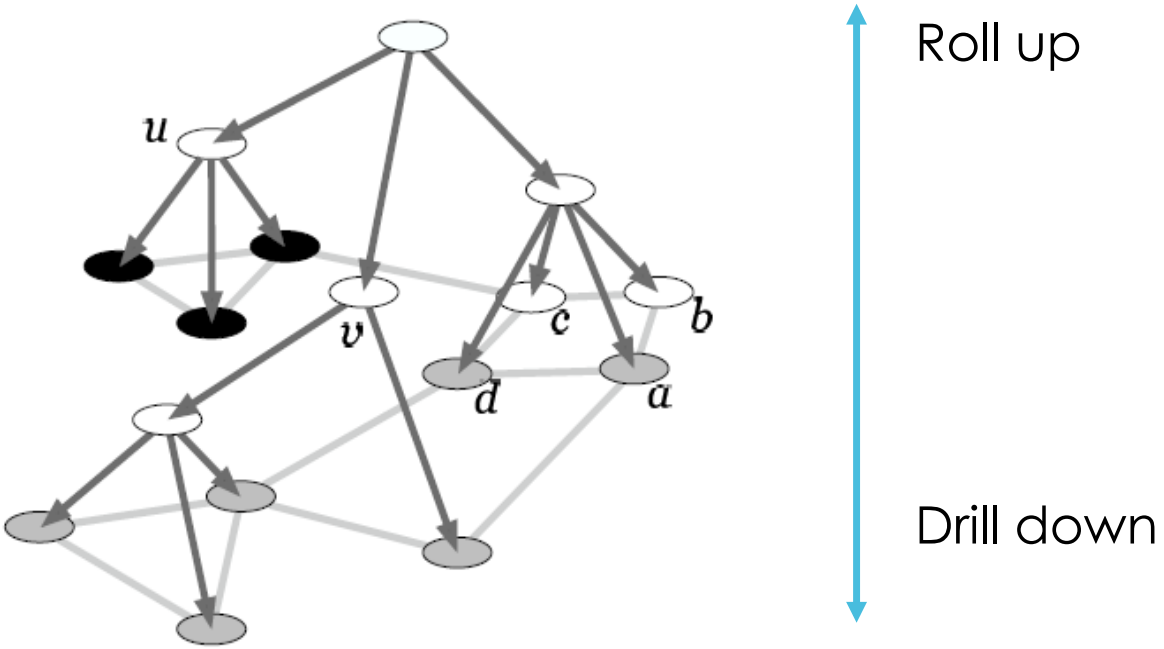
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
1958	-99.99	-99.99	315.7	317.45	317.5	317.26	315.86	314.93	313.2	312.44	313.33	314.6	-99.99
1959	315.62	316.38	316.71	317.72	318.29	318.16	316.54	314.8	313.84	313.26	314.8	315.58	315.98
1960	316.43	316.97	317.58	319.02	320.03	319.59	318.18	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
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	341.13
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	385.02	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.



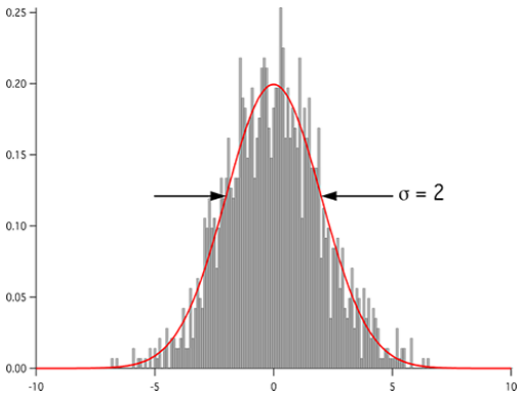
(Yang et al., 2006)

Techniques (2): Aggregation & Level of Details (LOD)

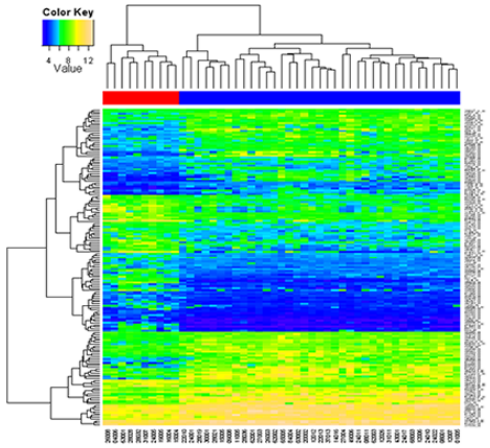


Building a tree for aggregating data items in either a bottom-up or top-down approach

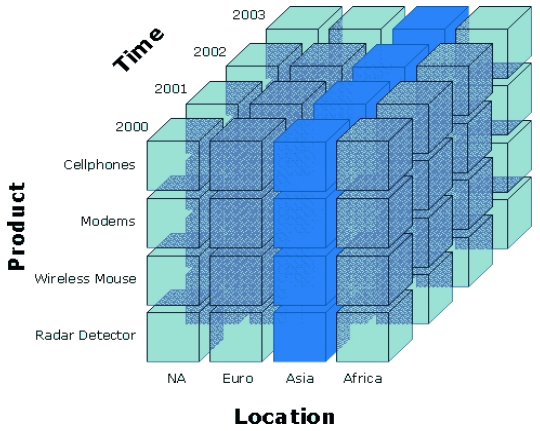
Technique (2) : Aggregation & LOD



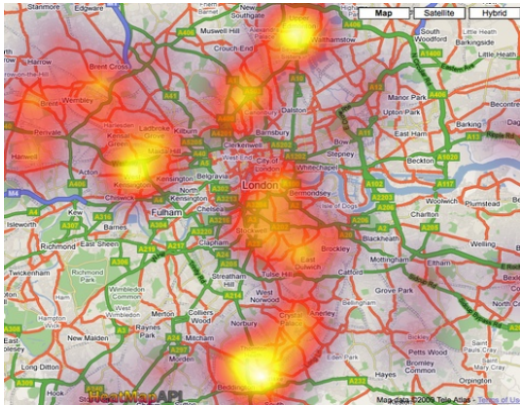
Histogram (Pearson, 1895)



Heatmap
(Wilkinson & Friendly, 2009)



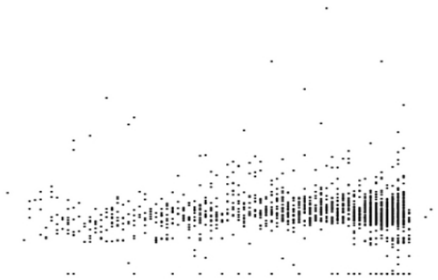
InfoCube
(Stolte et al., 2003)

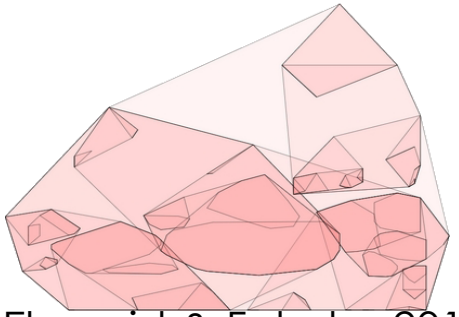


(Lin et al., 2010)

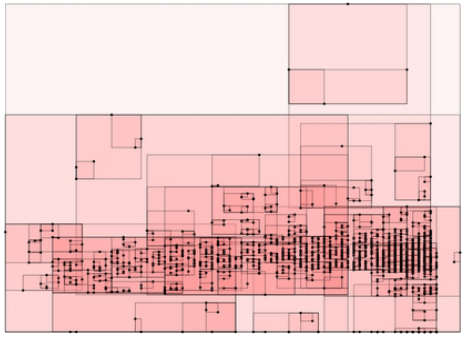
Techniques (2) : Aggregation

Scatter Plots



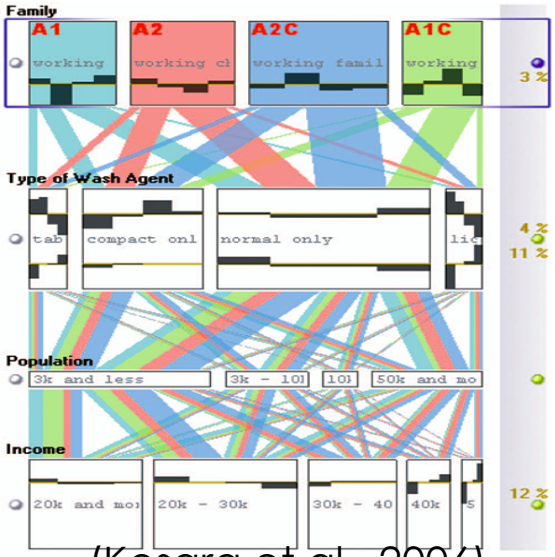


(Elmqvist & Fekete, 2010)

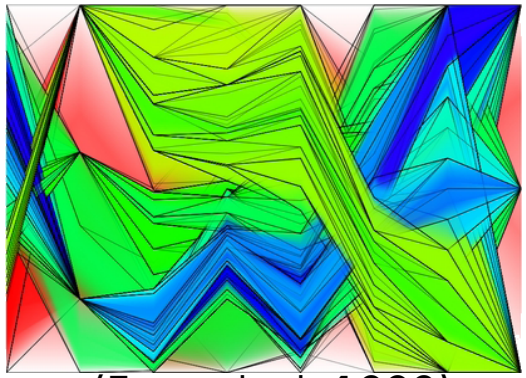


(Yang et al., 2003b)

Parallel Coordinates

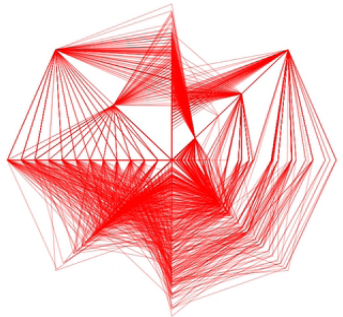


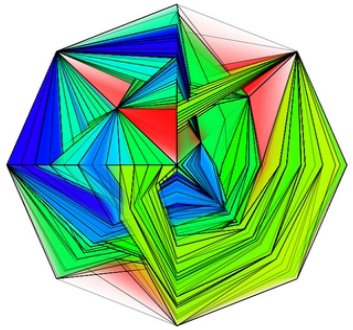
(Kosara et al., 2006)

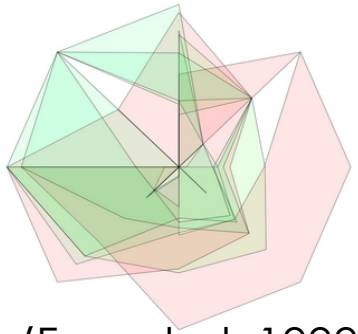


(Fua et al. 1999)

Star Plots

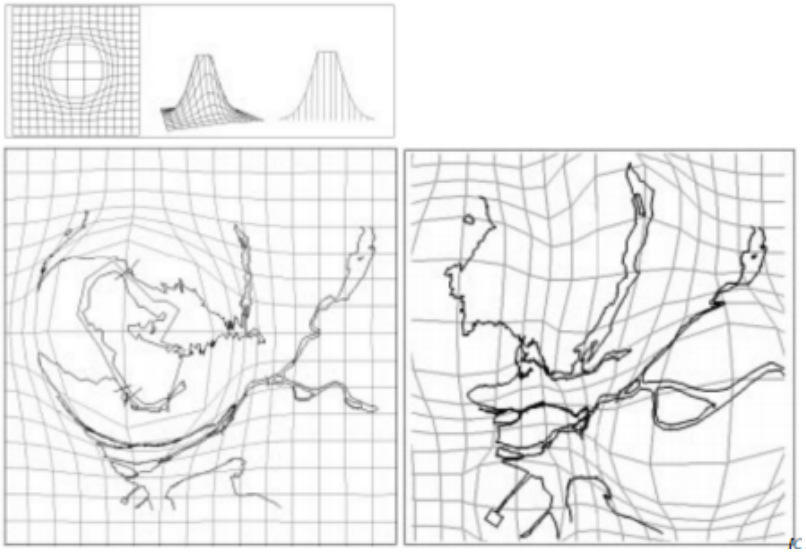


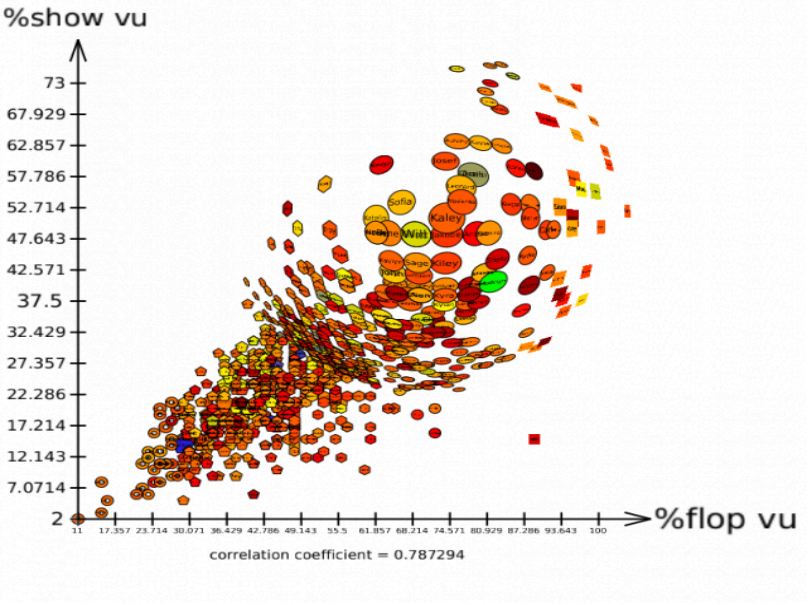


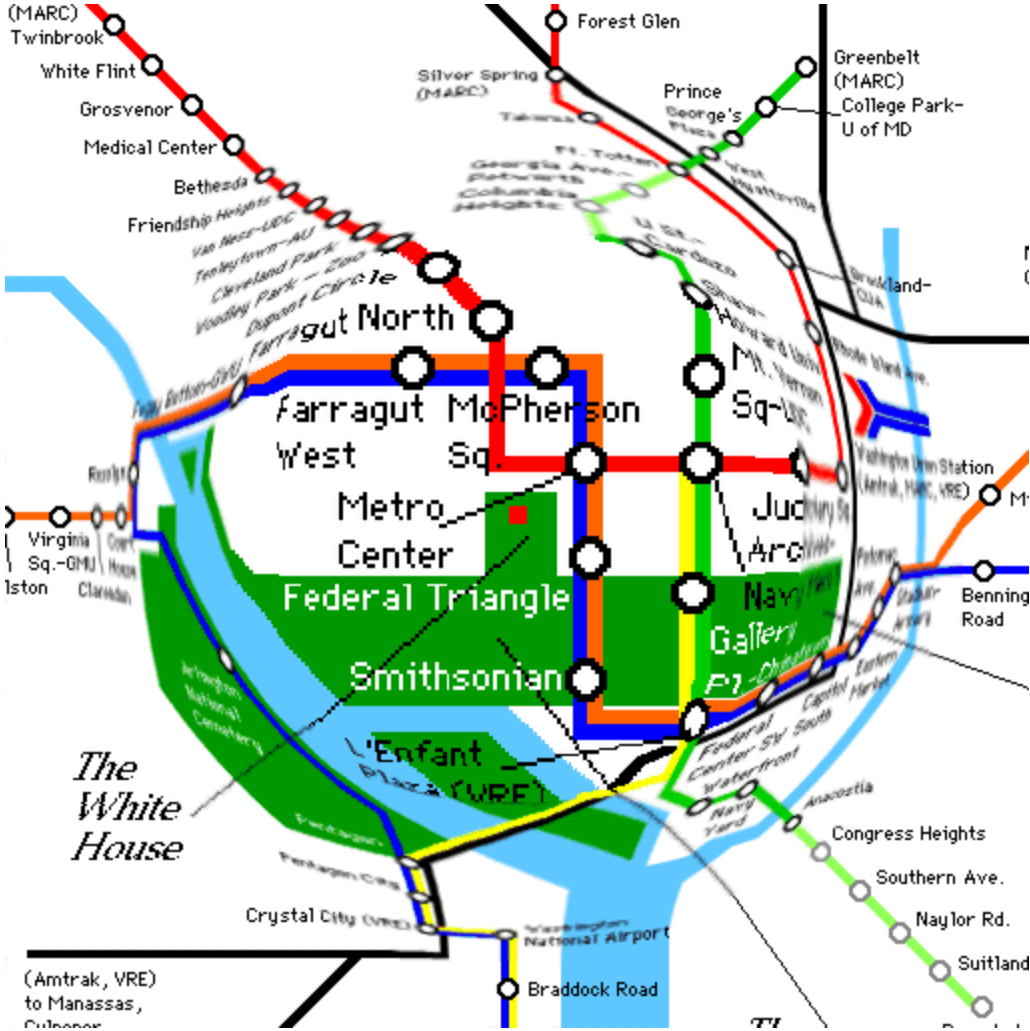


(Fua et al. 1999)

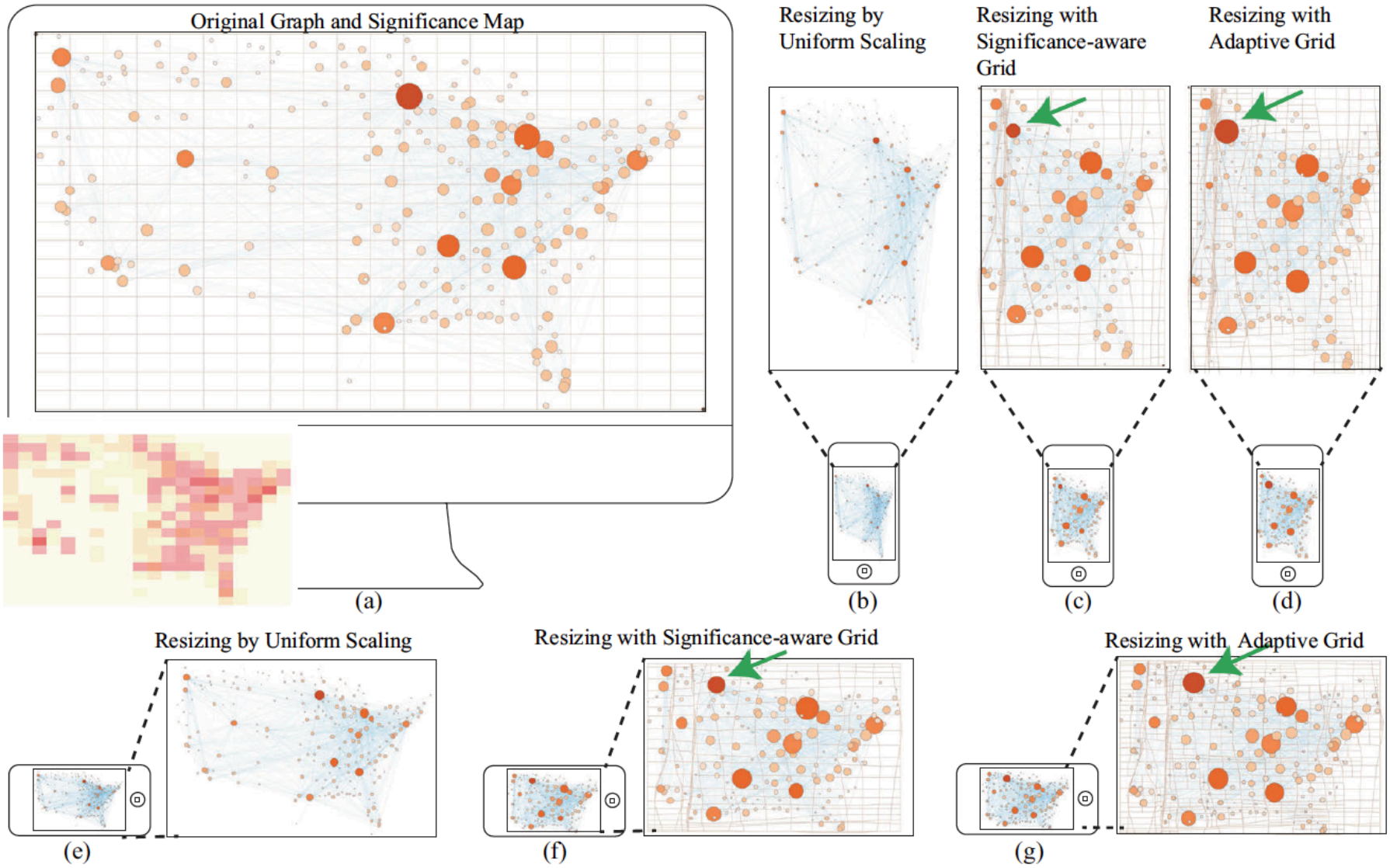
Technique (3) : Distortion



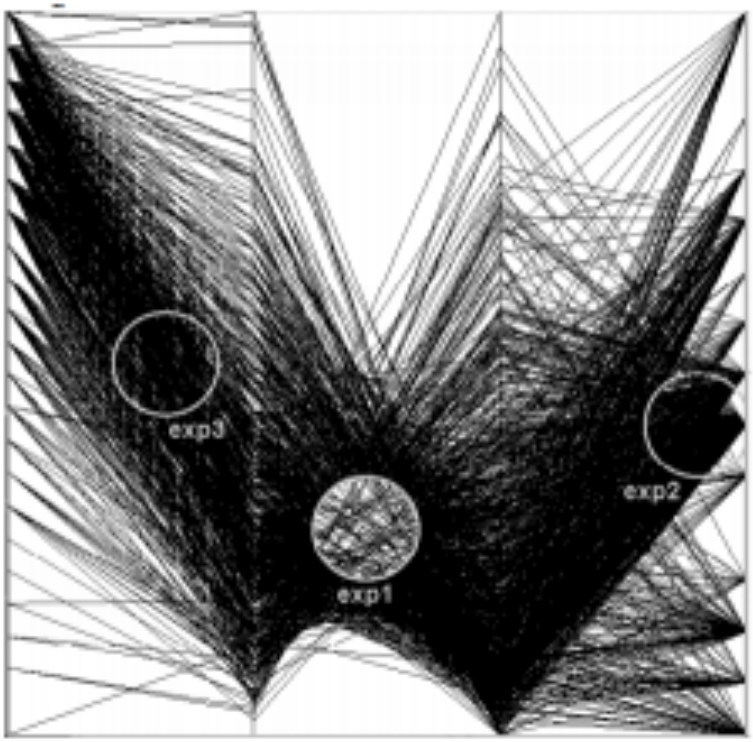




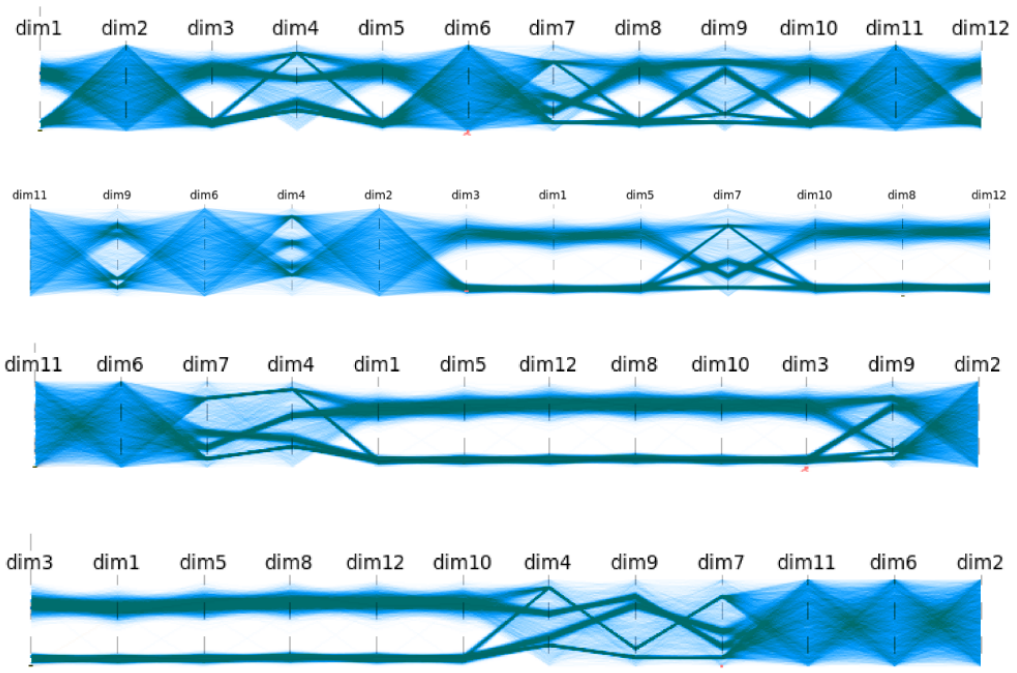
Techniques (3) : Distortion



Technique (4) : Clutter Reduction



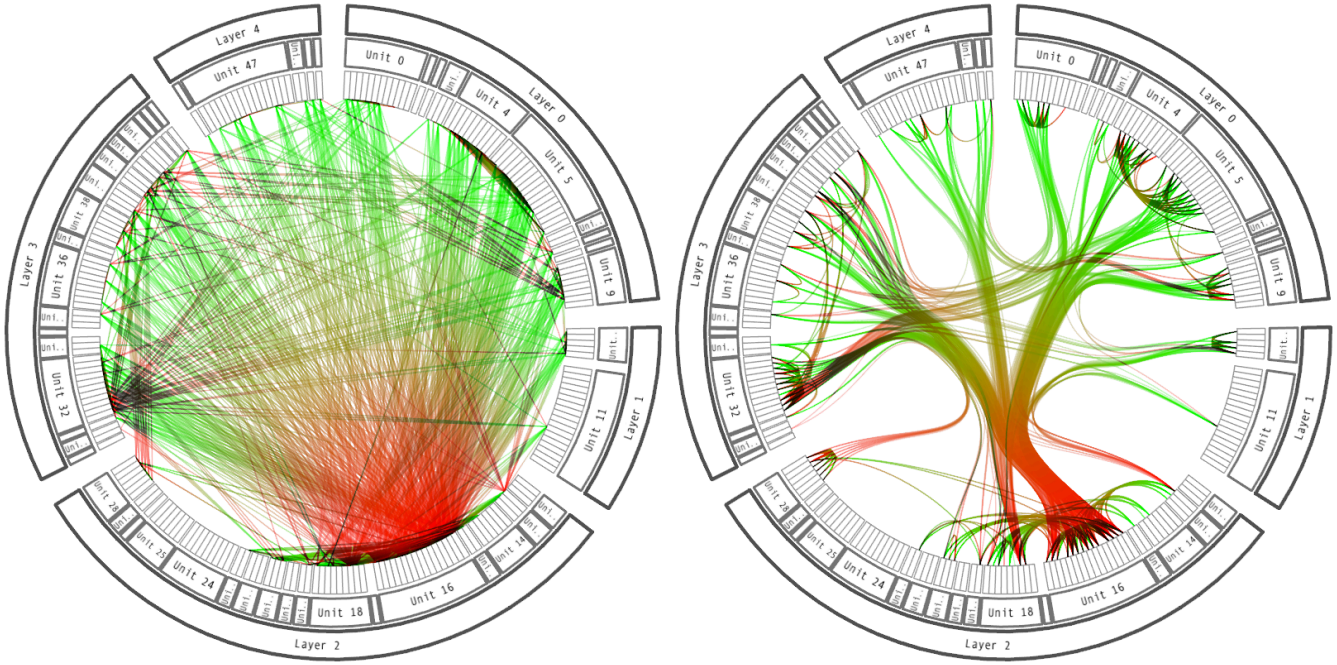
Sampling



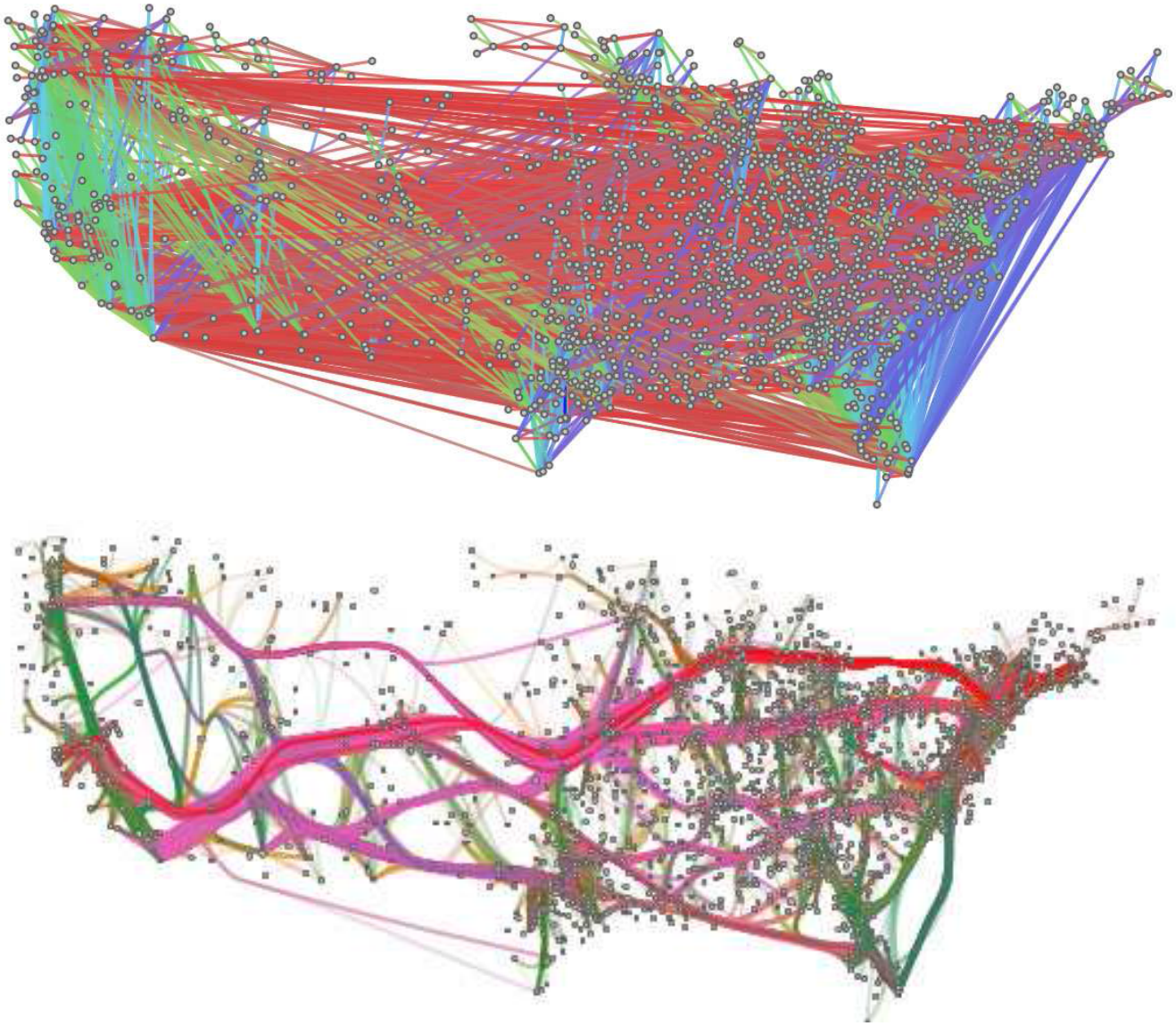
Reordering

Technique (4): Clutter Reduction

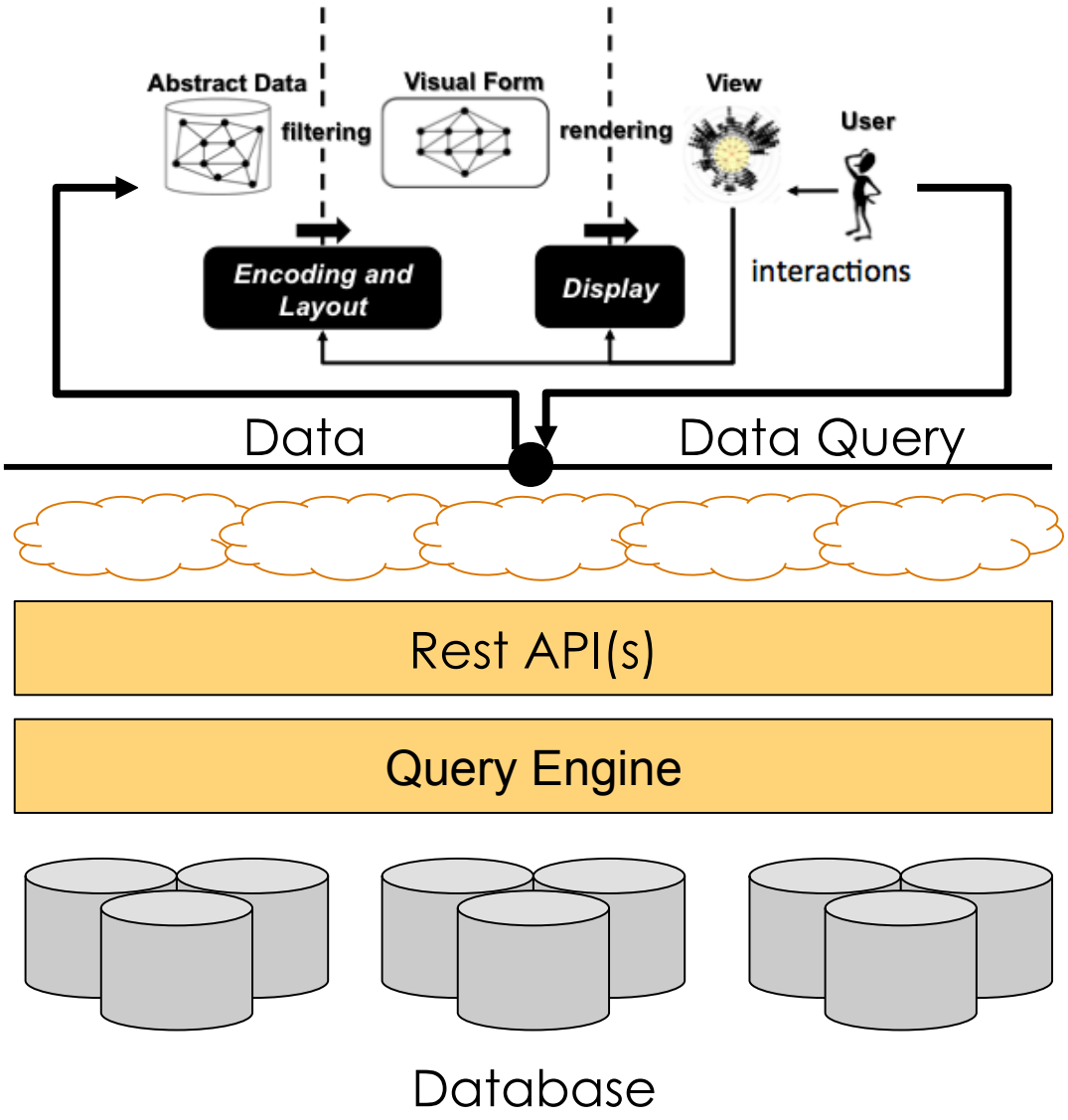
Edge Bundling



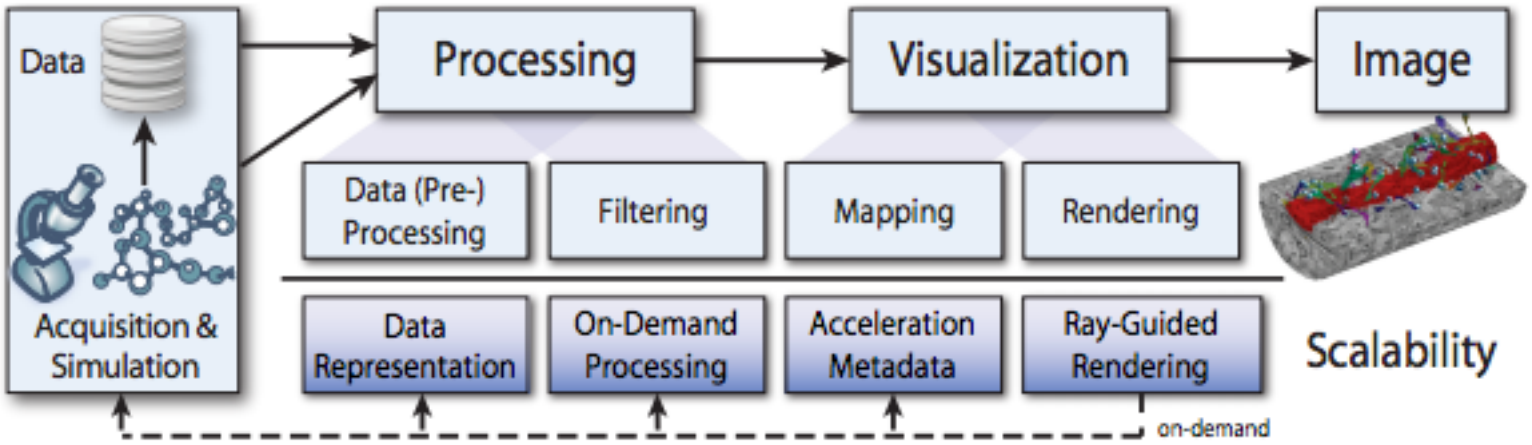
Technique (4): Clutter Reduction



Technique (4): Query based Visualization



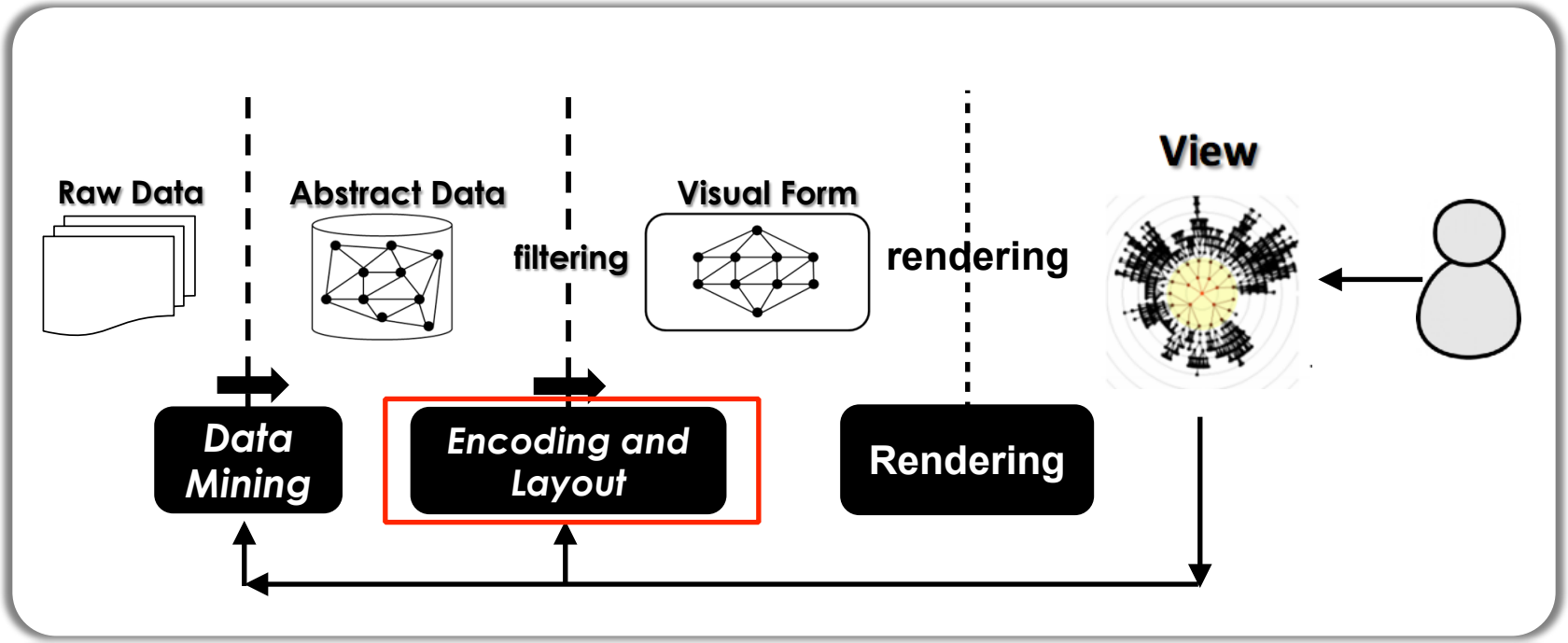
Technique (5): Parallel Computing via GPU or GUGPU



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

Part III :
How can we visualize big data ?

Visualization & Visual Analysis Reference Model



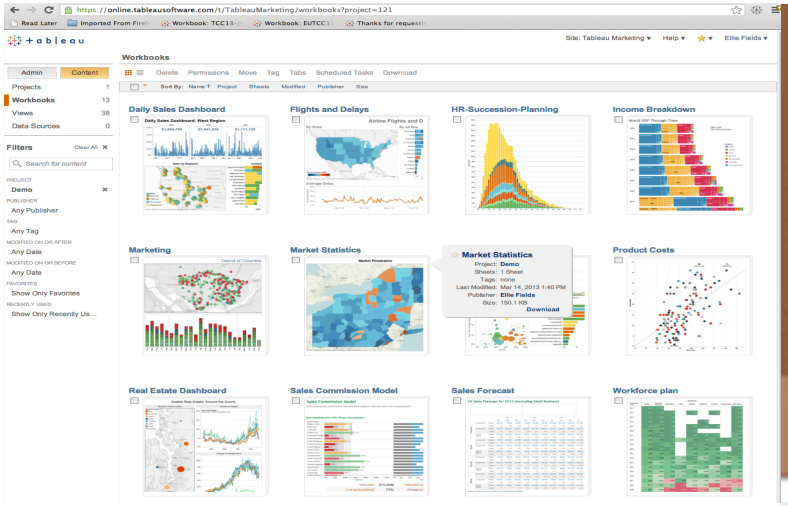
Encoding : Visual Design

Technique : Layout Algorithm

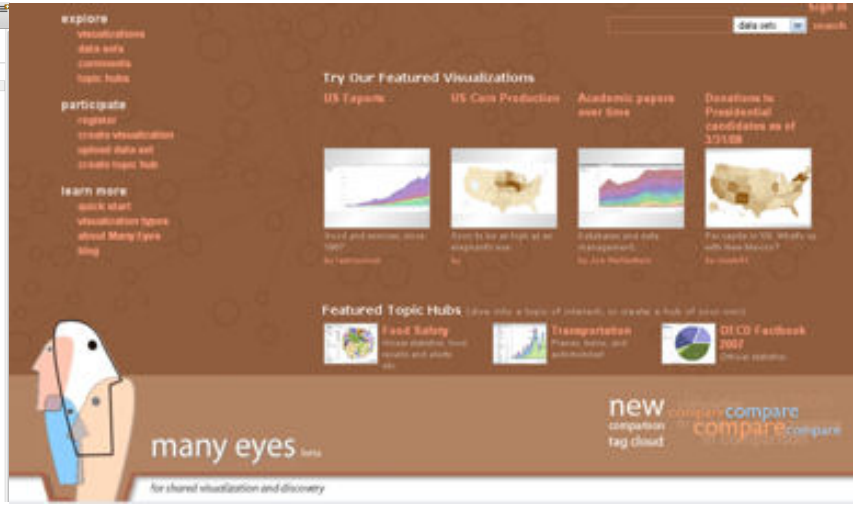
Using existing tools are easy

D3.js

Data-Driven Documents



Tableau



ManyEyes

Columbia University

Python:

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

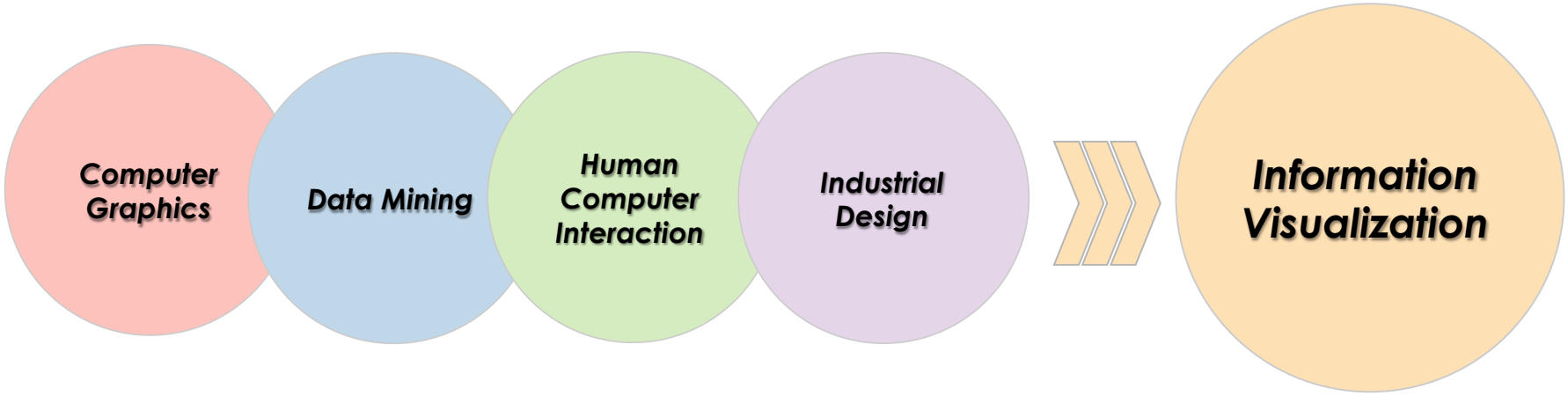
JavaScript:

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

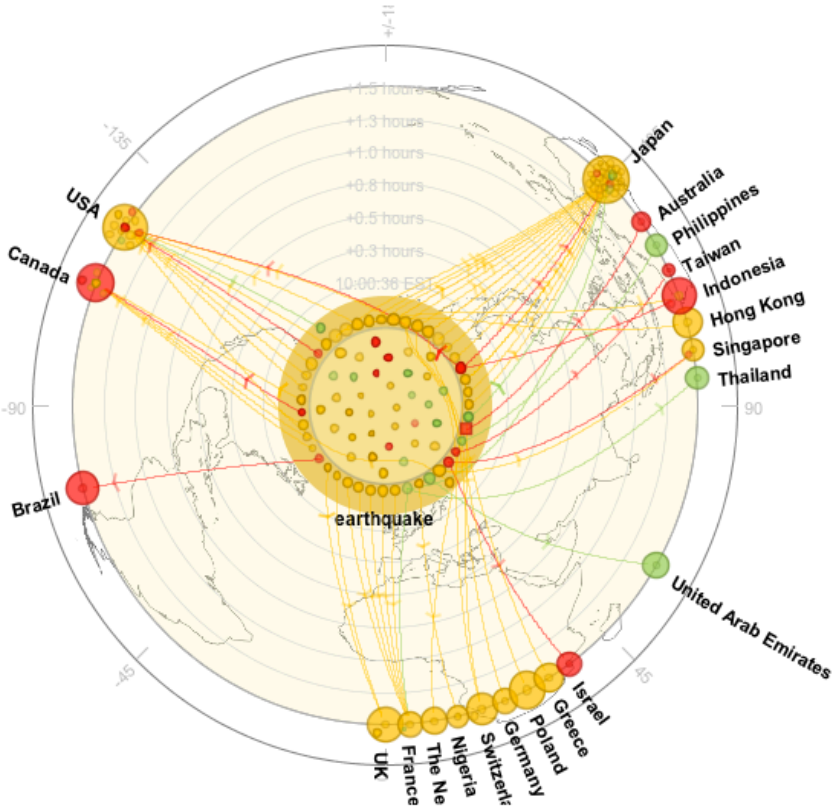
Java:

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

Developing new ones require knowledge from different areas

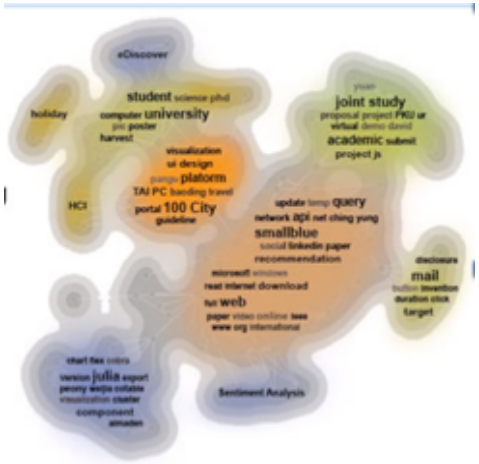


Example 1: Visualising Streaming Data



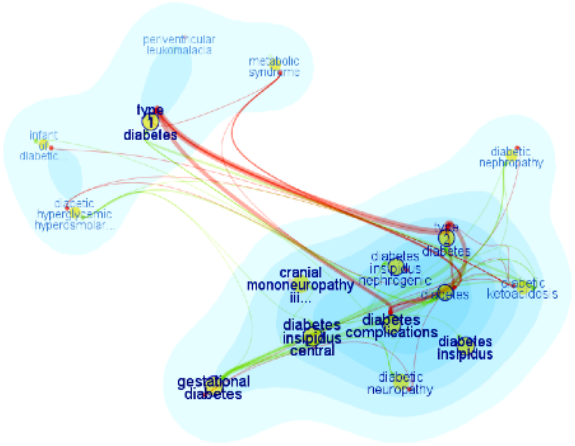
Whisper: Tracing the Spatiotemporal Process of Information Diffusion in Real Time
IEEE InfoVis 2012

Example 2: Visualizing Large Text Corpus



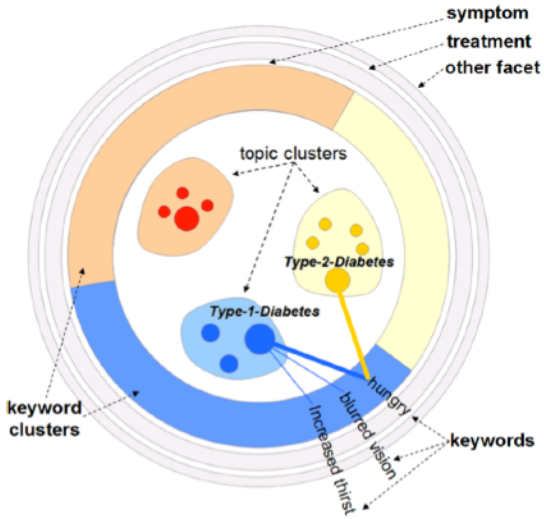
ContexTour
SDM 2010

Visualizing Heterogeneous Clusters



FacetAtlas
TVCG (InfoVis 2010)

Visualizing Multi-relational Clusters



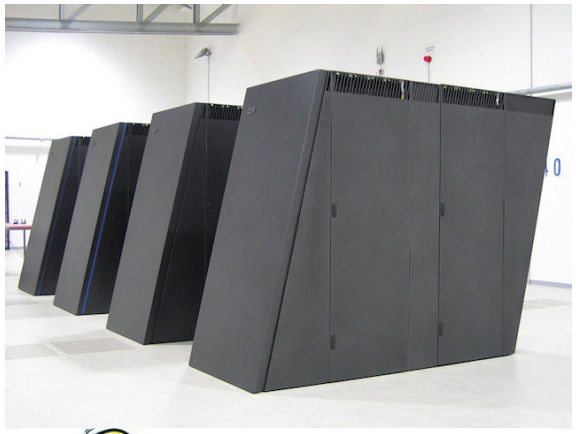
SolarMap
ICDM 2011

Cluster Interpretation

Part IV : Visual Analysis of Big Data

Visual Analysis v.s. Data Mining

Computational Power



hadoop

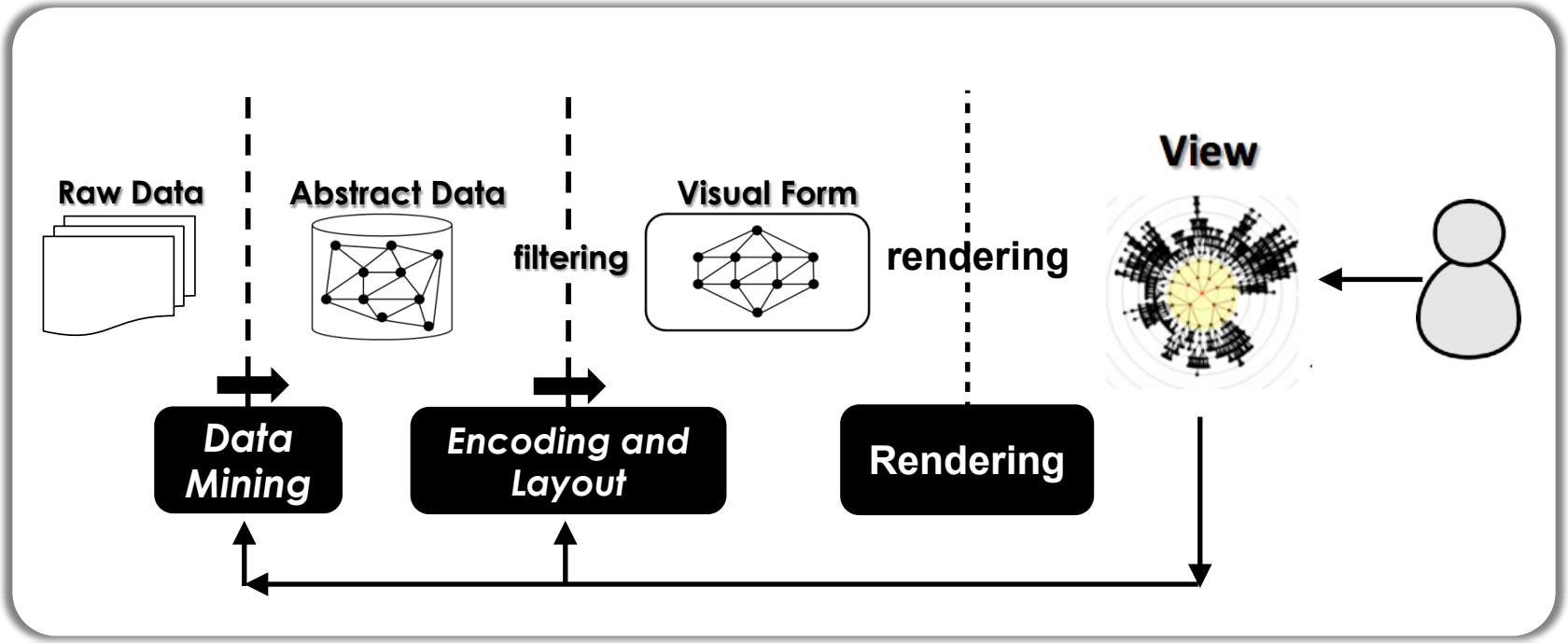
Data Mining

+

Human Intellegence

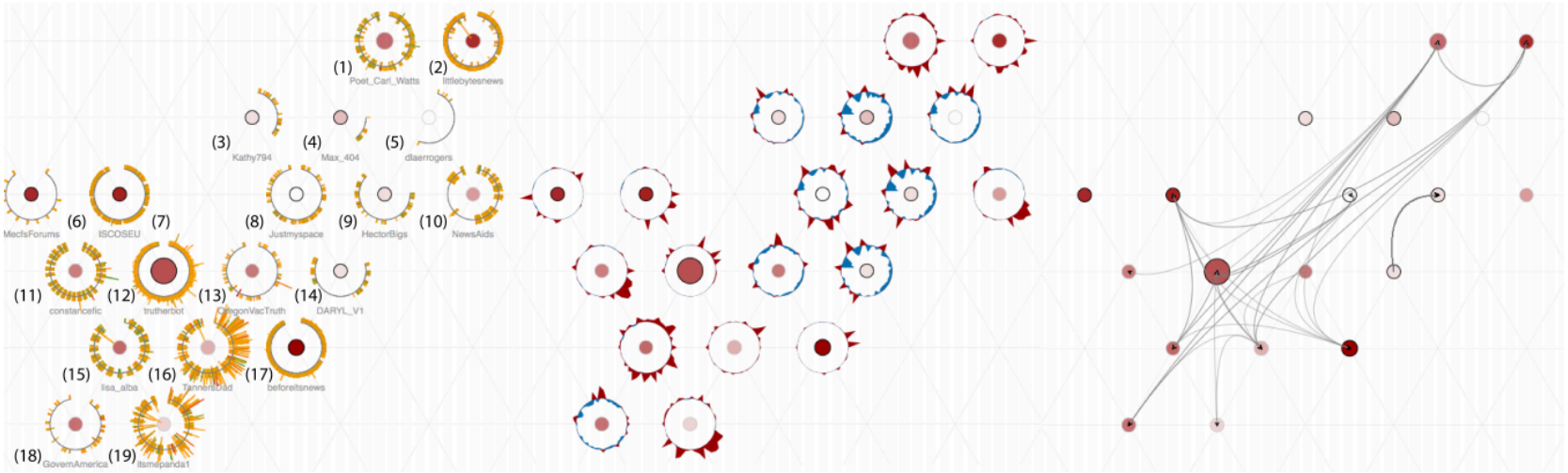
Visual Analysis

Visualization & Visual Analysis Reference Model



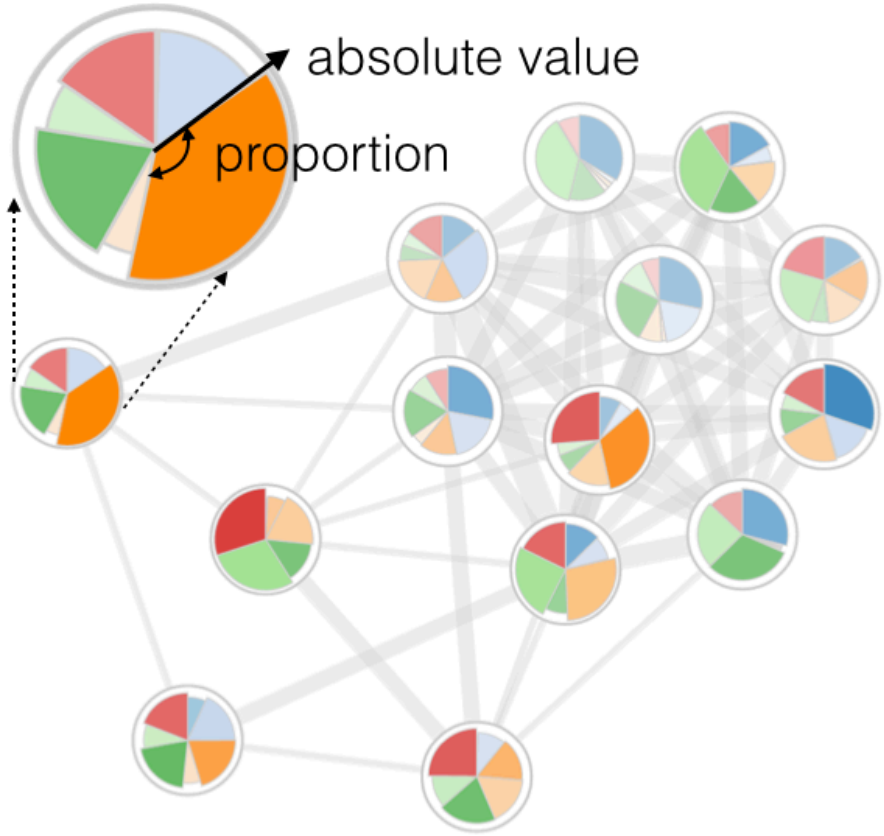
Analysis + Visualisation + Interaction

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:

The Top 10 Challenges in Extreme-Scale Visual Analytics

Pak Chung Wong
Pacific Northwest National Laboratory

Han-Wei Shen
Ohio State University

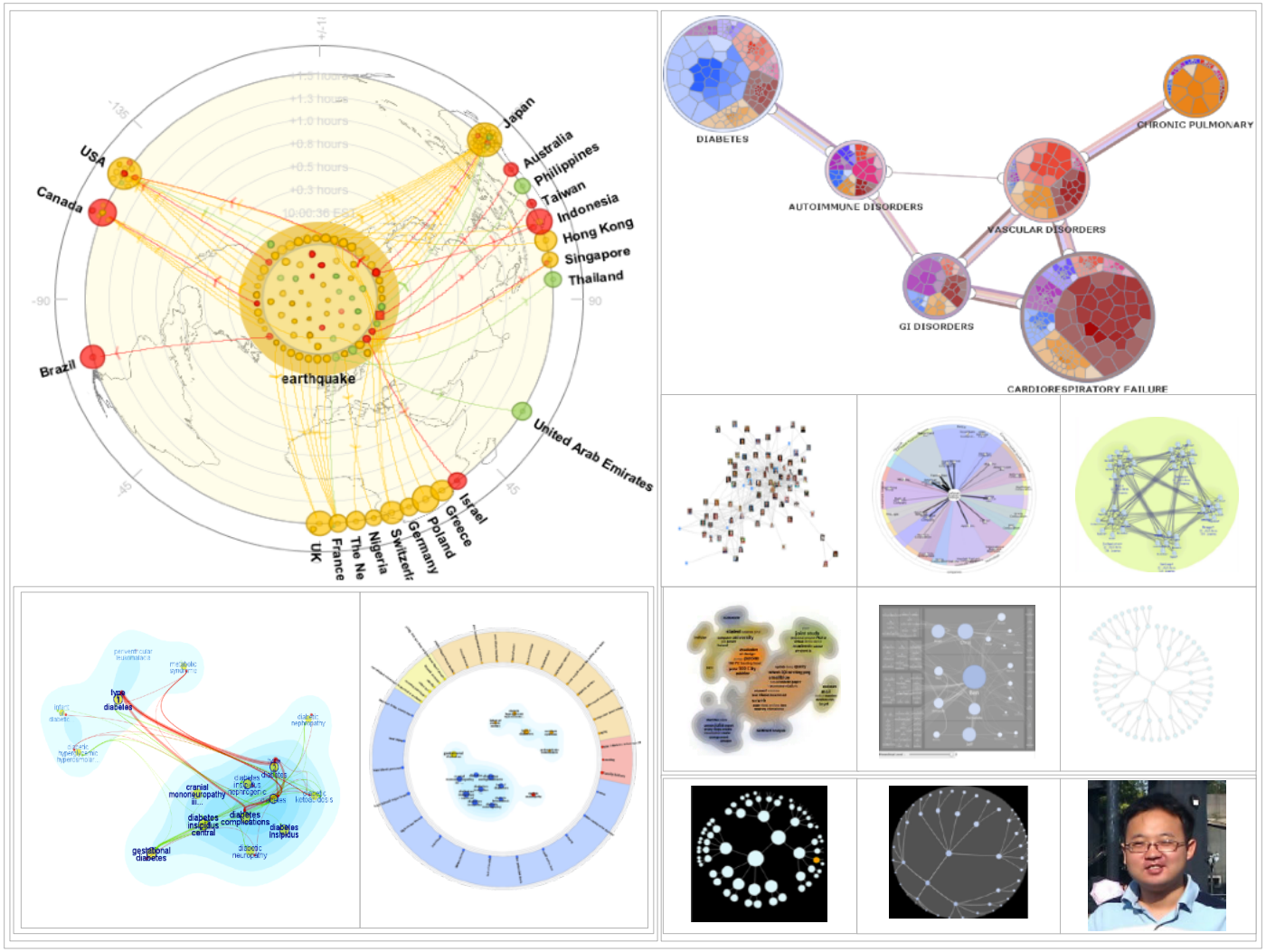
Christopher R. Johnson
University of Utah

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

Homework #4 (Due 11/15/2019, 5pm)

Please see the assignment slides